GE Power Management

745

TRANSFORMER MANAGEMENT RELAY™

INSTRUCTION MANUAL

Firmware Revision: 250.000

Manual P/N: 1601-0070-B2 (GEK-106292)

814768AF.CDR

GE Power Management

215 Anderson Avenue, Markham, Ontario

Canada L6E 1B3

Tel: (905) 294-6222   Fax: (905) 294-8512

Internet: http://www.GEindustrial.com/pm

Manufactured under an ISO9001 Registered system.

These instructions do not purport to cover all details or variations in equipment nor provide for every possible contingency to be met in connection with installation, operation, or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to the General Electric Company.

To the extent required the products described herein meet applicable ANSI, IEEE, and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

TABLE OF CONTENTS

1. PRODUCT OVERVIEW

1.1 INTRODUCTION
1.1.1 DESCRIPTION 1-1
1.1.2 SUMMARY OF PROTECTION FEATURES 1-2
1.1.3 ORDER CODES 1-4

1.2 TECHNICAL SPECIFICATIONS
1.2.1 APPLICABILITY 1-5
1.2.2 INPUTS 1-5
1.2.3 PROTECTION ELEMENTS 1-6
1.2.4 OUTPUTS 1-9

2. GETTING STARTED

2.1 USING THE FRONT PANEL DISPLAY
2.1.1 MANEUVERING 2-1

2.2 CHANGING SETPOINTS
2.2.1 DESCRIPTION 2-3
2.2.2 INSTALLING THE SETPOINT ACCESS JUMPER 2-3
2.2.3 NUMERICAL SETPOINTS 2-3
2.2.4 ENUMERATION SETPOINTS 2-4
2.2.5 TEXT SETPOINTS 2-5

2.3 SECURITY
2.3.1 INSTALLATION 2-6
2.3.2 PASSCODE SECURITY SETUP 2-6
a CHANGING THE PASSCODE 2-6
b DISABLING/ENABLING PASSCODE SECURITY 2-7

3. INSTALLATION

3.1 DRAWOUT CASE
3.1.1 CASE DESCRIPTION 3-1
3.1.2 PANEL CUTOUT 3-1
3.1.3 CASE MOUNTING 3-2
3.1.4 UNIT WITHDRAWAL AND INSERTION 3-2
a RELAY WITHDRAWAL 3-2
b RELAY INSERTION 3-3
c DRAWOUT SEAL 3-3

3.2 TYPICAL WIRING
3.2.1 DESCRIPTION 3-4
3.2.2 REAR TERMINAL LAYOUT 3-4
3.2.3 REAR TERMINAL ASSIGNMENTS 3-5
3.2.4 TYPICAL WIRING DIAGRAMS 3-6
3.2.5 PHASE SEQUENCE AND TRANSFORMER POLARITY 3-8
3.2.6 AC CURRENT TRANSFORMER INPUTS 3-8
3.2.7 AC VOLTAGE INPUT 3-8
3.2.8 CONTROL POWER 3-9
3.2.9 LOGIC INPUTS 3-9
3.2.10 ANALOG INPUT 3-10
3.2.11 TAP POSITION INPUT 3-10
3.2.12 RTD DRIVER/SENSOR 3-10
3.2.13 OUTPUT RELAYS 3-11
3.2.14 SOLID STATE TRIP OUTPUT 3-11
3.2.15 ANALOG OUTPUTS 3-11
3.2.16 RS485 / RS422 COMMUNICATION PORTS 3-12
3.2.17 RS232 FRONT PANEL PROGRAM PORT 3-13
3.2.18 IRIG-B 3-14

3.2.19 DIELECTRIC STRENGTH TESTING 3-14

4. FRONT PANEL OPERATION

4.1 FRONT PANEL

4.1.1 DESCRIPTION 4-1

4.2 DISPLAY, INDICATORS, AND FRONT PORT

4.2.1 DISPLAY 4-2
4.2.2 LEDS 4-2
4.2.3 STATUS INDICATORS 4-2
a IN SERVICE 4-2
b SELF-TEST ERROR 4-2
c TEST MODE 4-2
d DIFFERENTIAL BLOCKED 4-3
e LOCAL 4-3
f MESSAGE 4-3
4.2.4 SYSTEM STATUS INDICATORS 4-3
a TRANSFORMER DE-ENERGIZED 4-3
b TRANSFORMER OVERLOAD 4-3
c LOAD-LIMIT REDUCED 4-3
d SETPOINT GROUP 1 4-3
e SETPOINT GROUP 2 4-3
f SETPOINT GROUP 3 4-3
g SETPOINT GROUP 4 4-3
4.2.5 CONDITION INDICATORS 4-4
a TRIP 4-4
b ALARM 4-4
c PICKUP 4-4
d PHASE A (B/C) 4-4
e GROUND 4-4
4.2.6 PROGRAM PORT 4-4

4.3 KEYPAD

4.3.1 SETPOINT KEY 4-5
4.3.2 ACTUAL KEY 4-5
4.3.3 ESCAPE KEY 4-5
4.3.4 ENTER KEY 4-5
4.3.5 MESSAGE UP/DOWN KEY 4-5
4.3.6 VALUE UP/DOWN KEY 4-5
4.3.7 NUMBER KEYS 4-6
4.3.8 HELP KEY 4-6
4.3.9 RESET KEY 4-6
4.3.10 NEXT KEY 4-6

5. SETPOINTS

5.1 OVERVIEW

5.1.1 SETPOINT GROUPS 5-1
5.1.2 SETPOINT ENTRY 5-2
5.1.3 SETPOINT WRITE ACCESS 5-2

5.2 AUTO-CONFIGURATION

5.2.1 DESCRIPTION 5-3
5.2.2 A TYPICAL POWER TRANSFORMER 5-3
5.2.3 DYNAMIC CT RATIO MISMATCH CORRECTION 5-3
a PROBLEM 1:USE OF STANDARD CT RATIOS 5-3
b PROBLEM 2: ONLOAD TAP CHANGER 5-4
5.2.4 PHASE SHIFTS ON THREE-PHASE TRANSFORMERS 5-6
5.2.5 PHASE ANGLE CORRECTION 5-8
5.2.6 ZERO-SEQUENCE COMPONENT REMOVAL 5-9

5.2.7 TRANSFORMER TYPES TABLE 5-10
5.2.8 TABLE OF PHASE SHIFTS 5-23

5.3 S1 745 SETUP

5.3.1 DESCRIPTION 5-24
5.3.2 PASSCODE 5-24
5.3.3 PREFERENCES 5-25
5.3.4 COMMUNICATIONS 5-26
5.3.5 DNP COMMUNICATIONS 5-27
5.3.6 RESETTING 5-28
5.3.7 CLOCK 5-28
5.3.8 DEFAULT MESSAGES 5-29
a ADDING DEFAULT MESSAGES 5-29
b REMOVING DEFAULT MESSAGES 5-29
5.3.9 SCRATCHPAD 5-30
5.3.10 INSTALLATION 5-30
5.3.11 745 OPTIONS 5-31
5.3.12 UPGRADE OPTIONS 5-32

5.4 S2 SYSTEM SETUP

5.4.1 DESCRIPTION 5-33
5.4.2 TRANSFORMER 5-33
5.4.3 WINDING 1 (2/3) 5-35
5.4.4 ONLOAD TAP CHANGER 5-36
5.4.5 HARMONICS 5-37
5.4.6 FLEXCURVES 5-37
5.4.7 VOLTAGE INPUT 5-38
5.4.8 AMBIENT TEMPERATURE 5-39
5.4.9 ANALOG INPUT 5-40
5.4.10 DEMAND METERING 5-41
5.4.11 ANALOG OUTPUTS 5-42

5.5 SETPOINTS S3 LOGIC INPUTS

5.5.1 DESCRIPTION 5-43
5.5.2 LOGIC INPUTS 5-43
5.5.3 VIRTUAL INPUTS 5-44

5.6 S4 ELEMENTS

5.6.1 DESCRIPTION 5-45
5.6.2 INTRODUCTION TO ELEMENTS 5-45
5.6.3 SETPOINT GROUP 5-46
5.6.4 DIFFERENTIAL 5-46
a PERCENT DIFFERENTIAL 5-46
b HARMONIC INHIBIT 5-49
c ENERGIZATION INHIBIT 5-49
d ENERGIZATION SENSING 5-50
e 5TH HARMONIC INHIBIT 5-51
5.6.5 INSTANTANEOUS DIFFERENTIAL 5-52
5.6.6 PHASE OVERCURRENT 5-52
a WINDING 1 (2/3) PHASE TIME OVERCURRENT 5-52
b WINDING 1 (2/3) PHASE INSTANTANEOUS OVERCURRENT 1 5-54
c WINDING 1 (2/3) PHASE INSTANTANEOUS OVERCURRENT 2 5-54
5.6.7 NEUTRAL OVERCURRENT 5-55
a WINDING 1 (2/3) NEUTRAL TIME OVERCURRENT 5-55
b WINDING 1 (2/3) NEUTRAL INSTANTANEOUS OVERCURRENT 1 5-56
c WINDING 1 (2/3) NEUTRAL INSTANTANEOUS OVERCURRENT 2 5-56
5.6.8 GROUND OVERCURRENT 5-57
a WINDING 1 (2/3) GROUND TIME OVERCURRENT 5-57
b WINDING 1 (2/3) GROUND INSTANTANEOUS OVERCURRENT 1 5-58
c WINDING 1 (2/3) GROUND INSTANTANEOUS OVERCURRENT 2 5-58
5.6.9 RESTRICTED GROUND (DIFFERENTIAL GROUND) 5-59
a WINDING 1 (2/3) RESTRICTED GROUND FAULT 5-59

b RESTRICTED GROUND FAULT SETTINGS EXAMPLE 5-61
c SETPOINTS 5-62
5.6.10 NEGATIVE SEQUENCE OVERCURRENT 5-63
a WINDING 1 (2/3) NEGATIVE SEQUENCE TIME OVERCURRENT 5-63
b WINDING 1 (2/3) NEG. SEQ. INSTANTANEOUS OVERCURRENT 5-64
5.6.11 FREQUENCY 5-65
a UNDERFREQUENCY 1 (2) 5-65
b FREQUENCY DECAY 5-66
c OVERFREQUENCY 5-67
5.6.12 OVEREXCITATION 5-68
a 5TH HARMONIC LEVEL 5-68
b VOLTS-PER-HERTZ 1 (2) 5-69
5.6.13 HARMONICS 5-70
a WINDING 1 (2/3) THD LEVEL 5-70
b WINDING 1 (2/3) HARMONIC DERATING 5-71
5.6.14 INSULATION AGING / LOSS OF LIFE FEATURE 5-72
a DESCRIPTION 5-72
b HOTTEST-SPOT LIMIT 5-72
c INSULATION AGING SETPOINTS 5-73
5.6.15 AGING FACTOR LIMIT 5-74
5.6.16 LOSS OF LIFE LIMIT 5-75
5.6.17 ANALOG INPUT 5-76
a ANALOG LEVEL 1 (2) 5-76
5.6.18 CURRENT DEMAND 5-77
5.6.19 TRANSFORMER OVERLOAD 5-78
5.6.20 TAP CHANGER FAILURE 5-79

5.7 S5 OUTPUTS

5.7.1 DESCRIPTION 5-80
5.7.2 INTRODUCTION TO FLEXLOGIC™ 5-80
5.7.3 FLEXLOGIC™ RULES 5-82
5.7.4 OUTPUT RELAYS 5-84
5.7.5 TRACE MEMORY 5-85
5.7.6 VIRTUAL OUTPUTS 5-85
5.7.7 TIMERS 5-86

5.8 S6 TESTING

5.8.1 DESCRIPTION 5-87
5.8.2 OUTPUT RELAYS 5-87
5.8.3 ANALOG OUTPUTS 5-87
5.8.4 SIMULATION 5-88
5.8.5 PREFAULT VALUES 5-89
5.8.6 FAULT VALUES 5-90
5.8.7 FACTORY SERVICE 5-90

5.9 TIME OVERCURRENT CURVES

5.9.1 NOTE 5-91
5.9.2 ANSI CURVES 5-91
5.9.3 DEFINITE TIME CURVE 5-93
5.9.4 IEC CURVES 5-93
5.9.5 IAC CURVES 5-95

5.10 INVERSE VOLTS-PER-HERTZ CURVES

5.10.1 INVERSE CURVE 1 5-97
5.10.2 INVERSE CURVE 2 5-98
5.10.3 INVERSE CURVE 3 5-99

6. ACTUAL VALUES

6.1 OVERVIEW

6.1.1 DESCRIPTION 6-1

6.1.2 ACTUAL VALUES ORGANIZATION 6-1

6.2 A1 STATUS

6.2.1 DESCRIPTION 6-2
6.2.2 DATE AND TIME 6-2
6.2.3 LOGIC INPUTS 6-2
6.2.4 VIRTUAL INPUTS 6-2
6.2.5 OUTPUT RELAYS 6-3
6.2.6 VIRTUAL OUTPUTS 6-3
6.2.7 SELF-TEST ERRORS 6-3

6.3 A2 METERING

6.3.1 DESCRIPTION 6-4
6.3.2 CURRENT 6-4
a WINDING 1/2/3 CURRENTS 6-4
b POSITIVE SEQUENCE CURRENTS 6-5
c NEGATIVE SEQUENCE CURRENTS 6-5
d ZERO SEQUENCE CURRENTS 6-5
e DIFFERENTIAL CURRENT 6-6
f RESTRAINT CURRENT 6-6
g GROUND DIFFERENTIAL CURRENT 6-6
6.3.3 HARMONIC CONTENT 6-7
a HARMONIC SUB-COMPONENTS 6-7
b TOTAL HARMONIC DISTORTION (THD) 6-7
c HARMONIC DERATING FACTOR 6-8
6.3.4 FREQUENCY 6-8
6.3.5 TAP CHANGER 6-8
6.3.6 VOLTAGE 6-9
6.3.7 DEMAND 6-9
a DEMAND DATA CLEAR 6-9
b CURRENT DEMAND 6-10
6.3.8 AMBIENT TEMPERATURE 6-10
6.3.9 LOSS OF LIFE 6-10
6.3.10 ANALOG INPUT 6-11
6.3.11 POWER 6-11
6.3.12 ENERGY 6-12
a ENERGY DATA CLEAR 6-12
b W1/W2/W3 ENERGY 6-12

6.4 A3 EVENT RECORDER

6.4.1 DESCRIPTION 6-13
6.4.2 EVENT DATA RESET 6-13
6.4.3 EVENT RECORDS 6-13

6.5 A4 PRODUCT INFO

6.5.1 DESCRIPTION 6-17
6.5.2 TECHNICAL SUPPORT 6-17
6.5.3 REVISION CODES 6-17
6.5.4 CALIBRATION 6-18

6.6 TARGET MESSAGES

6.6.1 DESCRIPTION 6-19

6.7 SELF-TEST ERRORS

6.7.1 DESCRIPTION 6-21
6.7.2 MAJOR SELF-TEST ERRORS 6-21
6.7.3 MINOR SELF-TEST ERRORS 6-21

6.8 FLASH MESSAGES

6.8.1 DESCRIPTION 6-23

7. SCHEME LOGIC

7.1 INTRODUCTION

7.1.1 DESCRIPTION 7-1
7.1.2 SETPOINTS 7-1
7.1.3 MEASUREMENT UNITS 7-1
7.1.4 TIME DELAYS 7-1
7.1.5 LED INDICATORS 7-1
7.1.6 LOGIC 7-1

7.2 BLOCK DIAGRAMS

7.2.1 DIFFERENTIAL SCHEME LOGIC 7-2
7.2.2 OVERCURRENT SCHEME LOGIC 7-8
7.2.3 FREQUENCY LOGIC 7-20

8. COMMUNICATIONS

8.1 OVERVIEW

8.1.1 PROTOCOLS 8-1
8.1.2 PHYSICAL LAYER 8-1

8.2 MODBUS PROTOCOL

8.2.1 DESCRIPTION 8-2
8.2.2 GE POWER MANAGEMENT MODBUS PROTOCOL 8-2
8.2.3 ELECTRICAL INTERFACE 8-2
8.2.4 DATA FRAME FORMAT AND RATE 8-2
8.2.5 DATA PACKET FORMAT 8-3
8.2.6 CRC-16 ALGORITHM 8-4
8.2.7 MESSAGE TIMING 8-4
8.2.8 SUPPORTED FUNCTION CODES 8-5
8.2.9 FUNCTION CODE 03H/04H: READ ACTUAL VALUES/SETPOINTS 8-6
8.2.10 FUNCTION CODE 05H: EXECUTE OPERATION 8-7
8.2.11 FUNCTION CODE 06H: STORE SINGLE SETPOINT 8-8
8.2.12 FUNCTION CODE 10H: STORE MULTIPLE SETPOINTS 8-9
8.2.13 EXCEPTION RESPONSES 8-10
8.2.14 READING THE EVENT RECORDER 8-11
8.2.15 READING TRACE MEMORY 8-11
8.2.16 ACCESSING DATA VIA THE USER MAP 8-12
8.2.17 FUNCTION CODE SUBSTITUTIONS 8-15
a FUNCTION CODE 03H AND 04 SUBSTITUTIONS 8-15
b FUNCTION CODE 05H SUBSTITUTION 8-15
c FUNCTION CODE 06H SUBSTITUTION 8-16
8.2.18 MEMORY MAP ORGANIZATION 8-16

8.3 MODBUS MEMORY MAP

8.3.1 745 MEMORY MAP 8-17
8.3.2 MEMORY MAP DATA FORMATS 8-74

8.4 DNP COMMUNICATIONS

8.4.1 DEVICE PROFILE DOCUMENT 8-92
8.4.2 IMPLEMENATION TABLE 8-94

8.5 POINT LISTS

8.5.1 POINT LIST TABLES 8-96

9. 745 PC SOFTWARE

9.1 OVERVIEW

9.1.1 DESCRIPTION 9-1
9.1.2 HARDWARE & SOFTWARE REQUIREMENTS 9-2
9.1.3 MENU SUMMARY 9-2

9.1.4 TOOLBAR 9-3
9.1.5 HARDWARE CONFIGURATION 9-3

9.2 INSTALLATION & CONFIGURATION

9.2.1 745PC INSTALLATION 9-5
9.2.2 STARTUP & COMMUNICATIONS CONFIGURATION 9-6

9.3 USING 745PC

9.3.1 SAVING SETPOINTS TO A FILE 9-7
9.3.2 745 FIRMWARE UPGRADES 9-8
9.3.3 LOADING SETPOINTS FROM A FILE 9-9
9.3.4 ENTERING SETPOINTS 9-9
9.3.5 VIEWING ACTUAL VALUES 9-11

10. COMMISSIONING

10.1 GENERAL

10.1.1 INTRODUCTION 10-1
10.1.2 TESTING PHILOSOPHY 10-1
10.1.3 SAFETY PRECAUTIONS 10-2
10.1.4 CONVENTIONS 10-2

10.2 TEST EQUIPMENT

10.2.1 TEST SETUP 10-3

10.3 GENERAL PRELIMINARY WORK

10.3.1 DESCRIPTION 10-4
10.3.2 DIELECTRIC STRENGTH TESTING 10-5

10.4 LOGIC INPUTS & OUTPUT RELAYS

10.4.1 LOGIC INPUTS 10-6
a PROCEDURE 10-6
10.4.2 OUTPUT RELAYS 10-7
a PROCUDURE: 10-7

10.5 DISPLAY, METERING, COMMUNICATIONS, ANALOG OUTPUTS

10.5.1 DESCRIPTION 10-8
10.5.2 CURRENT INPUTS 10-8
10.5.3 VOLTAGE INPUT 10-9
10.5.4 TRANSFORMER-TYPE SELECTION 10-9
a AUTOMATIC TRANSFORMATION PERFORMED IN THE 745 10-9
b EFFECTS OF ZERO-SEQUENCE COMPONENT REMOVAL 10-10
10.5.5 AMBIENT TEMPERATURE INPUT 10-11
a BASIC CALIBRATION OF RTD INPUT 10-11
b DETAILED CALIBRATION OF RTD INPUT 10-11
c AMBIENT TEMPERATURE BY MONTHLY AVERAGES 10-12
10.5.6 ANALOG OUTPUTS 10-13
10.5.7 TAP POSITION 10-13

10.6 PROTECTION SCHEMES

10.6.1 WARNING 10-14
10.6.2 HARMONIC RESTRAINED PERCENT DIFFERENTIAL 10-14
a MINIMUM PICKUP 10-14
b VERIFICATION OF LOCAL RESET MODE 10-15
c VERIFICATION OF REMOTE RESET MODE 10-15
d VERIFICATION OF SOLID STATE OUTPUT 10-15
e BASIC OPERATING TIME 10-16
f SLOPE MEASUREMENTS 10-16
g SLOPE KNEEPOINT 10-17
h 2nd HARMONIC RESTRAINT 10-18
i 5th HARMONIC RESTRAINT 10-18
j ENERGIZATION DETECTION SCHEME 10-19

k TARGET, OUTPUT CONTACT, & DISPLAY OPERATION 10-20
l BLOCKING FROM LOGIC INPUTS 10-20
10.6.3 INSTANTANEOUS DIFFERENTIAL PROTECTION 10-20
a MINIMUM PICKUP 10-20
b OPERATING TIME 10-20
c TARGET, OUTPUT CONTACT, & DISPLAY OPERATION 10-21
d BLOCKING FROM LOGIC INPUTS 10-21
10.6.4 PHASE TIME OVERCURRENT 10-21
a WINDING #1 ELEMENTS... 10-21
b PICKUP LEVEL 10-22
c OPERATING TIME 10-22
d RESET TIME 10-22
e PHASE B AND C ELEMENTS.. 10-22
f WINDING #2 AND #3 ELEMENTS.. 10-23
10.6.5 PHASE INSTANTANEOUS OVERCURRENT 1 10-23
a WINDING #1 ELEMENTS... 10-23
b PICKUP LEVEL 10-23
c OPERATING TIME 10-23
d PHASE B AND C ELEMENTS.. 10-23
e WINDING #2 AND #3 ELEMENTS.. 10-24
10.6.6 PHASE INSTANTANEOUS OVERCURRENT 2 10-24
10.6.7 NEUTRAL TIME OVERCURRENT... 10-24
a WINDING #1 ELEMENT 10-24
b PICKUP LEVEL 10-24
c OPERATING TIME 10-25
d RESET TIME 10-25
e WINDING #2 OR WINDING #3 ELEMENTS 10-25
10.6.8 NEUTRAL INSTANTANEOUS OVERCURRENT 1 10-26
a WINDING #1 ELEMENT 10-26
b PICKUP LEVEL 10-26
c OPERATING TIME 10-26
d WINDING 2 AND 3 ELEMENTS... 10-26
10.6.9 NEUTRAL INSTANTANEOUS OVERCURRENT 2 10-27
10.6.10 GROUND TIME OVERCURRENT.. 10-27
a WINDING 1 ELEMENT 10-27
b PICKUP LEVEL 10-27
c OPERATING TIME 10-28
d RESET TIME 10-28
e WINDING 2 OR 3 ELEMENTS 10-28
10.6.11 GROUND INSTANTANEOUS OVERCURRENT 1............................... 10-28
a WINDING 1 ELEMENT 10-28
b PICKUP LEVEL 10-29
c OPERATING TIME 10-29
d WINDING 2 OR ELEMENT... 10-29
10.6.12 GROUND INSTANTANEOUS OVERCURRENT 2............................... 10-29
10.6.13 RESTRICTED GROUND FAULT.. 10-30
a WINDING #1 ELEMENT 10-30
b PICKUP LEVEL 10-30
c OPERATING TIME 10-31
d SLOPE... 10-31
e WINDING 2 OR 3 ELEMENTS 10-31
10.6.14 NEGATIVE SEQUENCE TIME OVERCURRENT 10-31
a WINDING #1 ELEMENT 10-31
b PICKUP LEVEL 10-32
c OPERATING TIME 10-32
d RESET TIME 10-33
e WINDINGS 2 AND 3 ELEMENTS... 10-33
10.6.15 NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT 10-33
a WINDING 1 ELEMENT 10-33
b PICKUP LEVEL 10-33
c OPERATING TIME 10-34
d WINDING 2 AND 3 ELEMENTS... 10-34
10.6.16 FREQUENCY ELEMENTS... 10-34

10.6.17 UNDERFREQUENCY 1 10-35
a PRELIMINARIES 10-35
b VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED) 10-35
c CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED) 10-36
10.6.18 UNDERFREQUENCY 2 10-37
10.6.19 OVERFREQUENCY 10-37
a PRELIMINARIES 10-37
b VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED) 10-37
c CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED) 10-38
10.6.20 FREQUENCY DECAY RATE 1 10-39
a PRELIMINARIES 10-39
b VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED) 10-39
c CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED) 10-40
d FREQUENCY DECAY RATE 2, 3, & 4 10-40
10.6.21 VOLTS-PER-HZ 1(2) 10-41
10.6.22 5TH HARMONIC SCHEME 10-41
10.6.23 INSULATION AGING 10-42
a PRELIMINARIES 10-42
b HOTTEST SPOT LIMIT 10-42
c AGING FACTOR LIMIT 10-42
d LOSS-OF-LIFE LIMIT 10-42
10.6.24 TAP MONITOR FAILURE 10-42

10.7 AUXILIARY PROTECTION/MONITORING FUNCTIONS

10.7.1 THD LEVEL SCHEME 10-43
a MINIMUM PICKUP 10-43
b OPERATING TIME 10-43
c MINIMUM OPERATING CURRENT 10-43
d OTHER THD ELEMENTS 10-43
10.7.2 HARMONIC DERATING FUNCTION 10-44
a OPERATING LEVEL 10-44
b OPERATING TIME 10-44
10.7.3 TRANSFORMER OVERLOAD 10-45
a OPERATING LEVEL 10-45
b OPERATING TIME 10-45

10.8 PLACING RELAY INTO SERVICE

10.8.1 DESCRIPTION 10-46

11. SETPOINT TABLES

11.1 COMMISSIONING SUMMARY

11.1.1 S1 745 SETUP 11-1
11.1.2 S2 SYSTEM SETUP 11-2
11.1.3 FLEXCURVES 11-4
11.1.4 S3 LOGIC INPUTS 11-5
11.1.5 S4 ELEMENTS 11-6
11.1.6 S5 OUTPUTS 11-18

A. FIGURES AND TABLES

A.1 FIGURES AND TABLES

A.1.1 LIST OF FIGURES A-1
A.1.2 LIST OF TABLES A-2

B. EU DECLARATION OF CONFORMITY

B.1 EU DECLARATION OF CONFORMITY

C. WARRANTY

C.1 WARRANTY INFORMATION

C.1.1 WARRANTY C-1

1.1.1 DESCRIPTION

The 745 is a high speed, multi-processor based, 3-phase, two or three winding, Transformer Management Relay™ intended for the primary protection and management of small, medium and large power transformers.

The 745 combines Percent Differential, Overcurrent, Frequency and Overexcitation protection elements along with monitoring of individual harmonics, and THD in one economical package.

The relay provides a variety of adaptive relaying features:

- Adaptive Harmonic Restraint which addresses the problem of false tripping during inrush
- Adaptive Time Overcurrent Elements which will adjust their pickup settings based on the calculated transformer capability when supplying load currents with high harmonic content
- Multiple Setpoint Groups which allow the user to enter and dynamically select from up to four groups of relay settings to address the protection requirements of different power system configurations
- Dynamic CT Ratio Mismatch Correction which monitors the on-load tap position and automatically corrects for CT ratio mismatch
- FlexLogic™ which allows PLC style equations based on logic inputs & protection elements to be assigned to any of the 745 outputs.

The 745 also includes a powerful testing and simulation feature. This allows the protection engineer the ability to test the relay operation based on captured or computer generated waveform data which can be converted to a digitized format and downloaded into the 745’s simulation buffer for “playback”.

The 745 also provides its own Waveform Capture function which will record waveform data for fault, inrush or alarm conditions.

The Auto-Configuration function eliminates the need for any special CT connections by having all CTs connected in wye.

1.1.2 SUMMARY OF PROTECTION FEATURES

SYMBOL	COMMON PROTECTION ELEMENT
59/81-1	Volts-Per-Hertz 1
59/81-2	Volts-Per-Hertz 2
81U-1	Underfrequency 1
81U-2	Underfrequency 2
81U-R1	Frequency Decay Rate 1
81U-R2	Frequency Decay Rate 2
81U-R3	Frequency Decay Rate 3
81U-R4	Frequency Decay Rate 4
81-H5	5th Harmonic Level
81O	Overfrequency
87	Differential (Percent)
50/87	Instantaneous Differential
AN-1	Analog Input Level 1
AN-2	Analog Input Level 2
	Insulation Aging – Aging Factor – Hottest Spot Limit – Total Accumulated Life
	Tap Changer Monitor

SYMBOL	WINDING 2 PROTECTION ELEMENT
250/46	Negative Sequence Instantaneous O/C
251/46	Negative Sequence Time O/C
250P1	Phase Instantaneous O/C 1
250P2	Phase Instantaneous O/C 2
250N1	Neutral ($3I_0$) Instantaneous O/C 1
250N2	Neutral ($3I_0$) Instantaneous O/C 2
250G1	Ground Instantaneous O/C 1
250G2	Ground Instantaneous O/C 2
251P	Phase Time O/C
251N	Neutral ($3I_0$) Time O/C
251G	Ground Time O/C
287TG	Ground Differential (Restricted Ground Fault)
2THD	Total Harmonic Distortion Level
2AD	Current Demand

SYMBOL	WINDING 1 PROTECTION ELEMENT
150/46	Negative Sequence Instantaneous O/C
151/46	Negative Sequence Time O/c
150P1	Phase Instantaneous O/C 1
150P2	Phase Instantaneous O/C 2
150N1	Neutral ($3I_0$) Instantaneous O/C 1
150N2	Neutral ($3I_0$) Instantaneous O/C 2
150G1	Ground Instantaneous O/C 1
150G2	Ground Instantaneous O/C 2
151P	Phase Time O/C
151N	Neutral ($3I_0$) Time O/C
151G	Ground Time O/C
187TG	Ground Differential (Restricted Ground Fault)
1THD	Total Harmonic Distortion Level
1AD	Current Demand

SYMBOL	WINDING 3 PROTECTION ELEMENT
350/46	Negative Sequence Instantaneous O/C
351/46	Negative Sequence Time O/c
350P1	Phase Instantaneous O/C 1
350P2	Phase Instantaneous O/C 2
350N1	Neutral ($3I_0$) Instantaneous O/C 1
350N2	Neutral ($3I_0$) Instantaneous O/C 2
351P	Phase Time O/C
351N	Neutral ($3I_0$) Time O/C
351G	Ground Time O/C
387TG	Ground Differential (Restricted Ground Fault)
3THD	Total Harmonic Distortion Level
3AD	Current Demand

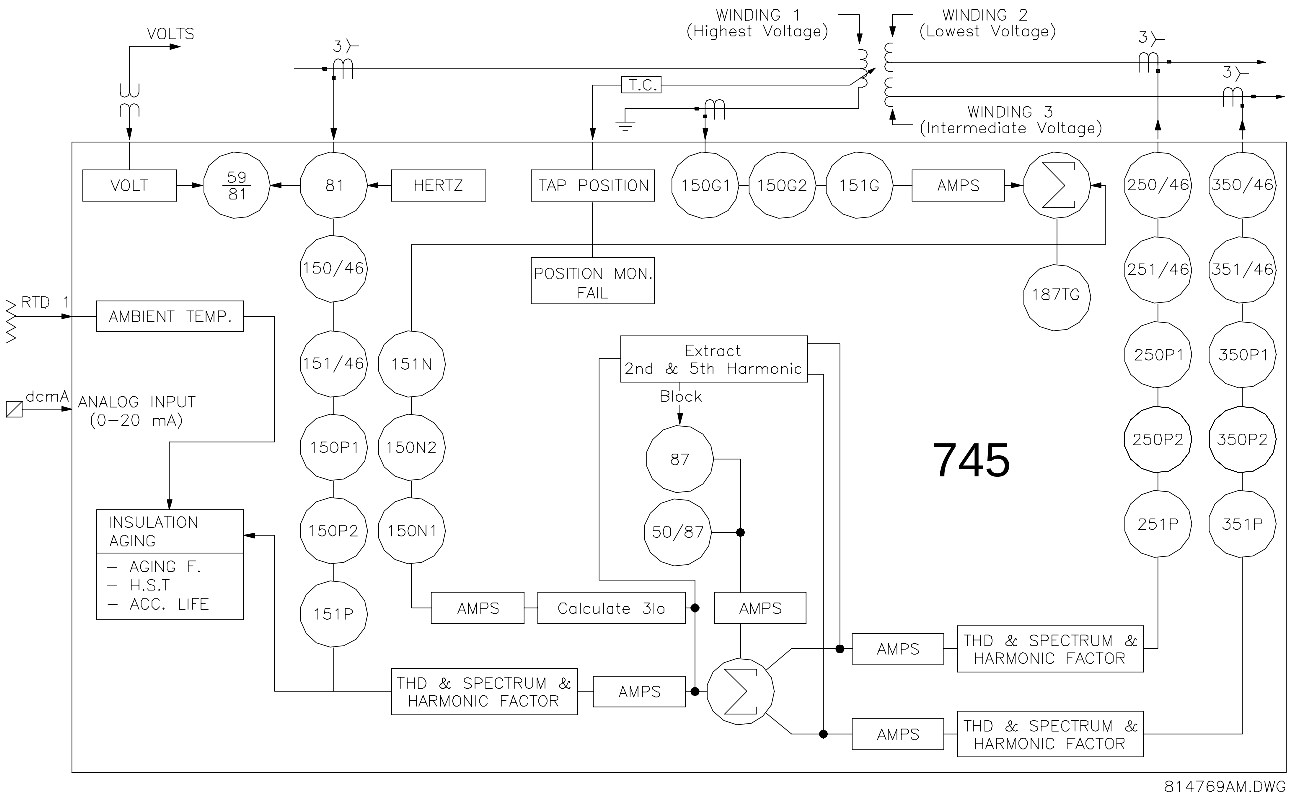


Figure 1–1: SINGLE LINE DIAGRAM

1.1.3 ORDER CODES

745 W2 P5 G5 LO A L R

745 TRANSFORMER MANAGEMENT RELAY®

WINDINGS PER PHASE

W2 = 2 WINDING
W3 = 3 WINDING

PHASE CURRENT INPUT RATINGS

	WINDING 1	WINDING 2	WINDING 3
P1 =	1 A	1 A	(1 A)
P5 =	5 A	5 A	(5 A)
P15 =	1 A	5 A	—
P51 =	5 A	1 A	—
P115 =	1 A	1 A	5 A
P151 =	1 A	5 A	1 A
P155 =	1 A	5 A	5 A
P511 =	5 A	1 A	1 A
P515 =	5 A	1 A	5 A
P551 =	5 A	5 A	1 A

GROUND CURRENT INPUT RATINGS

	WINDING 1/2	WINDING 2/3
G1 =	1 A	1 A
G5 =	5 A	5 A
G15 =	1 A	5 A
G51 =	5 A	1 A

CONTROL POWER

LO = 24-60 Vdc
20-48 Vac @ 48-62 Hz
HI = 90-300 Vdc
70-265 Vac @ 48-62 Hz

OPTIONS

A = ANALOG INPUT/OUTPUTS
L = LOSS OF LIFE
R = RESTRICTED GROUND FAULT

745ORDER.CDR

Figure 1–2: 745 ORDER CODES

1.2.1 APPLICABILITY

Transformers:	2 Winding or 3 Winding
Frequency:	50 or 60 Hz nominal (frequency tracking allows operation from 2 to 65 Hz)

1.2.2 INPUTS

CONTROL POWER (POWER SUPPLY)

Options:	LO/HI (specified when ordering)	
LO Range:	DC = 20 to 60 V; AC = 20 to 48 V @ 48 to 62 Hz	
HI Range:	DC = 90 to 300 V; AC = 70 to 265 V @ 48 to 62 Hz	
Power:	30 VA nominal, 40 VA maximum	
Fuse (not accessible):	Hi-Volt:	Current rating: 3.15 A Type: 5 × 20 mm Slow-Blow Littelfuse, High Breaking Capacity Model #: 2153.15
	Low-Volt:	Current rating: 3.15 A Type: 5 × 20 mm Slow-Blow Littelfuse, High Breaking Capacity Model #: 2153.15

PHASE CURRENT INPUT

Source CT:	1 to 50000 A primary / 1 or 5 A secondary
Relay Input:	1 A or 5 A (specified when ordering)
Burden:	Less than 0.2 VA at rated load per phase
Conversion Range:	0.02 to 46 × CT
Accuracy:	at < 4 x CT: ± 0.25% of 4 × CT (± 0.01 × CT) at ≥ 4 x CT: ± 0.5% of 46 × CT (± 0.2 × CT)
Overload Withstand:	1 second at 80 times rated current 2 seconds at 40 times rated current continuous at 3 times rated current

GROUND CURRENT INPUT

Source CT:	1 to 50000 A primary / 1 or 5 A secondary
Relay Input:	1 A or 5 A (specified when ordering)
Burden:	Less than 0.2 VA at rated load
Conversion Range:	0.02 to 46 × CT
Accuracy:	at < 4 × CT: ± 0.25% of 4 x CT (± 0.01 × CT) at ≥ 4 × CT: ± 0.5% of 46 x CT (± 0.2 × CT)
Overload Withstand:	1 second at 80 times rated current 2 seconds at 40 times rated current continuous at 3 times rated current

VOLTAGE INPUTS

Source VT:	2 to 600 kV / 60 to 120 V
Source VT Ratio:	1 to 5000 in steps of 1
Relay Input:	60 V to 120 V phase-neutral
Burden:	Less than 0.025 VA at 120 V
Max. Continuous:	273 V
Accuracy:	± 1% of 2 × VT (± 0.02 × VT)

LOGIC INPUTS (16)

Dry Contacts:	1000 Ω maximum ON resistance (32 V DC at 2 mA provided by 745)
Wet Contacts:	Inputs 1 to 16: 30 to 300 V DC at 1.5 mA

ANALOG INPUT

Type:	DC mA
Ranges:	0-1 mA, 0-5 mA, 0-10 mA, 0-20 mA, or 4-20 mA (programmable)
Input Impedance:	375 Ω ± 10%
Conversion Range:	0 to 21 mA
Accuracy:	± 1% of full scale (based on input range)

TAP POSITION

Type:	resistance (ohms)
Range:	0 to 500 Ω or 0.5 to 5.0 kΩ
Bias Current:	1 mA or 10 mA (based on input range)
Accuracy:	± 1% of full scale (based on input range)

RTD

Type:	3 wire
RTD Type	100 Ω Platinum (DIN.43760) 100 Ω Nickel 120 Ω Nickel

IRIG-B INPUT

Amplitude-Modulated:	1.0 to 10 V pk-pk
DC Shift:	TTL
Input Impedance	70 to 100 kΩ

1.2.3 PROTECTION ELEMENTS

PERCENT DIFFERENTIAL PROTECTION

Operating Current Pickup:	0.05 to 1.00 in steps of 0.01 x CT	
Dropout Level:	97 to 98% of Pickup	
SLOPE-1 Range:	15% to 100% in steps of 1	
SLOPE-2 Range:	50% to 200% in steps of 1	
KP (SLOPE-1 Kneepoint):	1.0 to 20.0 in steps of 0.1 x CT	
Harmonic Restraint:	0.1% to 65.0% in steps of 0.1	
Operate Time:	Solid State Output:	Pickup < 1 x CT: 42 to 52 ms 1 x CT < Pickup < 1.1 × kneepoint: 34 to 44 ms Pickup > 1.1 × kneepoint: 26 to 36 ms
	Relay Outputs 2-5:	Pickup < 1 x CT: 46 to 56 ms 1 x CT < Pickup < 1.1 × kneepoint: 38 to 48 ms Pickup > 1.1 × kneepoint: 30 to 40 ms

INSTANTANEOUS DIFFERENTIAL OVERCURRENT

Pickup Level:	3.00 to 20.00 in steps of 0.01 x CT	
Dropout Level:	97 to 98% of Pickup	
Level Accuracy:	Per current input	
Operate Time:	Solid State Output:	at 1.2 x pickup: 22 to 30 ms at 2.0 x pickup: 18 to 26 ms at 4.0 x pickup:11 to 19 ms
	Relay Outputs 2-5:	at 1.2 x pickup: 28 to 36 ms at 2.0 x pickup: 24 to 32 ms at 4.0 x pickup: 17 to 25 ms

PHASE / NEUTRAL / GROUND / NEGATIVE SEQUENCE TIME OVERCURRENT

Pickup Level:	0.05 to 20.00 in steps of 0.01 x CT
Dropout Level:	97 to 98% of Pickup
Curve Shape:	ANSI Extremely/Very/Moderately/Normally Inverse; Definite Time (0.1 s base curve); IEC Curve A/B/C and Short; FlexCurve™ A/B/C (programmable curves); IAC Extreme/Very/Inverse/Short
Curve Multiplier Time Dial:	0.5 to 30 for ANSI, IAC & FlexCurves™ in steps of 0.1 s; 0.05 to 100.00 for IEC curves in steps of 0.01
Reset Type:	Instantaneous or Linear
Level Accuracy:	Per current input
Timing Accuracy:	at ≥ 1.03 × pickup: ± 3% of trip time or ± 20 ms (whichever is greater)

PHASE / NEUTRAL / GROUND / NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT

Pickup Level:	0.05 to 20.00 in steps of 0.01 × CT
Dropout Level:	97 to 98% of Pickup
Time Delay:	0 to 60000 in steps of 1 ms
Level Accuracy:	Per current input
Operate Time:	Solid State Output: at 1.2 × pickup: 22 to 30 ms at 2.0 × pickup: 18 to 26 ms at 4.0 × pickup: 11 to 19 ms Relay Outputs 2-5: at 1.2 × pickup: 28 to 36 ms at 2.0 × pickup: 24 to 32 ms at 4.0 × pickup: 17 to 25 ms

UNDERFREQUENCY (2 ELEMENTS)

Operating Current Pickup:	0.05 to 1.00 in steps of 0.01 × CT
Operating Voltage Pickup	0.10 to 0.99 in steps of 0.01 × VT
Pickup Level:	45.00 to 59.99 in steps of 0.01 Hz
Dropout Level:	Pickup + 0.03 Hz
Time Delay:	0.00 to 600.00 s in steps of 0.01 s
Signal Source:	Winding 1 phase A current / voltage
Level Accuracy:	±0.02 Hz
Operate Time:	Solid State Output: at 3% beyond pickup: 120 to 150 ms Relay Outputs 2 to 5: at 3% beyond pickup: 125 to 155 ms (delay set at 0.0 sec.)

FREQUENCY RATE OF CHANGE (4 ELEMENTS)

Operating Current Pickup:	0.05 to 1.00 in steps of 0.01 × CT
Operating Voltage Pickup	0.10 to 0.99 in steps of 0.01 × VT
Pickup Level:	45.00 to 59.99 in steps of 0.01 Hz
Dropout Level:	Pickup + 0.03 Hz
Rate 1/2/3/4:	0.1 to 5.0 in steps of 0.1 Hz/sec.
Dropout Level:	Pickup + 0.07 Hz/sec.
Signal Source:	Winding 1 phase A current / voltage
Level Accuracy:	±0.02 Hz
Operate Time:	The operate time of the frequency trend element is variable and is dependent on the decay rate setting and the supervision frequency level.

OVERFREQUENCY (1 ELEMENT)

Operating Current Pickup:	0.05 to 1.00 in steps of 0.01 × CT
Operating Voltage Pickup	0.10 to 0.99 in steps of 0.01 × VT
Pickup Level:	50.01 to 65.00 in steps of 0.01 Hz
Dropout Level:	Pickup – 0.03 Hz
Time Delay:	0.00 to 600.00 s in steps of 0.01 s
Signal Source:	Winding 1 phase A current / voltage
Level Accuracy:	±0.02 Hz
Operate Time:	Solid State Output: at 3% beyond pickup: 120 to 150 ms Relay Outputs 2-5: at 3% beyond pickup: 125 to 155 ms (delay set to 0.0 s)

OVEREXCITATION ON VOLTS/HERTZ (2 ELEMENTS)

Operating Voltage Pickup:	0.10 to 0.99 in steps of 0.01 × VT
Pickup Level:	1.00 to 4.00 in steps of 0.01 V/Hz
Curve Shape:	Definite Time (0.1 sec. base curve); IEC Curve A/B/C
Time Delay:	0.00 to 600.00 s in steps of 0.01 s
Reset Delay:	0.0 to 6000.0 s in steps of 0.1 s
Signal Source:	Voltage
Range:	10 to 65 Hz
Level Accuracy:	±0.02 V/Hz
Operate Time:	Solid State Output: at 1.10 × pickup: 165 to 195 ms Relay Outputs 2-5: at 1.10 × pickup: 170 to 200 ms (delay set to 0.0 s)

OVEREXCITATION ON 5TH HARMONIC LEVEL

Operating Current Pickup:	0.03 to 1.00 in steps of 0.01 × CT
Pickup Level:	0.1 to 99.9 in steps of 0.1%
Dropout:	95% of pickup
Time Delay:	0 to 60000 s in steps of 1 s
Signal Source:	All phase currents
Operate Time:	Solid State Output: at 1.10 × pickup: 20 to 120 ms Relay Outputs 2-5: at 1.10 × pickup: 25 to 125 ms (delay set at 0.0 s)

INSULATION AGING: HOTTEST-SPOT LIMIT

Pickup Level:	50 to 300 in steps of 1°C
Delay:	0 to 60000 in steps of 1 min.

INSULATION AGING: AGING FACTOR LIMIT

Pickup Level:	1.1 to 10.0 in steps of 0.1
Delay:	0 to 60000 in steps of 1 min.

INSULATION AGING: LOSS OF LIFE LIMIT

Pickup Level:	0 to 20000 in steps of 1 x 10 h

1.2.4 OUTPUTS

Analog Outputs (7)

Output Range: 0-1 mA, 0-5 mA, 0-10 mA, 0-20 mA, or 4-20 mA

Maximum Load: 0-1 mA: 10 kΩ
4-20 mA: 600 Ω

Isolation: Fully isolated

Accuracy: ± 1% of full scale

Solid State Output

Maximum Ratings: Make & Carry 15 A at 250 V DC for 500 ms

Output Relays

Configuration: 2-5 TRIP: Form A (breaker trip rated)
6-8 AUXILIARY: Form C
9 SELF-TEST: Form C

Contact Material: silver alloy

Max Ratings: 300 V AC, 250 V DC, 15 A, 1500 VA

RELAYS: 2-5 TRIP					
VOLTAGE		MAKE/CARRY CONTINUOUS	MAKE/ CARRY 0.2s	BREAK	MAX LOAD
DC Resistive	30 V DC	20 A	40 A	10 A	300 W
	125 V DC	20 A	40 A	0.8 A	300 W
	250 V DC	20 A	40 A	0.4 A	300 W
DC Inductive L/R = 40 ms	30 V DC	20 A	40 A	5 A	150 W
	125 V DC	20 A	40 A	0.3 A	150 W
	250 V DC	20 A	40 A	0.2 A	150 W
AC Resistive	120 V AC	20 A	80 A	20 A	5000 VA
	240 V AC	20 A	80 A	20 A	5000 VA
AC Inductive PF = 0.4	120 V AC	20 A	80 A	8 A	5000 VA
	240 V AC	20 A	80 A	7 A	5000 VA

RELAYS: 6-8 AUXILIARY, 9 SELF-TEST					
VOLTAGE		MAKE/CARRY CONTINUOUS	MAKE/ CARRY 0.2s	BREAK	MAX LOAD
DC Resistive	30 V DC	10 A	30 A	10 A	300 W
	125 V DC	10 A	30 A	0.5 A	62.5 W
	250 V DC	10 A	30 A	0.3 A	75 W
DC Inductive L/R = 40 ms	30 V DC	10 A	30 A	5 A	150 W
	125 V DC	10 A	30 A	0.25 A	31.3 W
	250 V DC	10 A	30 A	0.15 A	37.5 W
AC Resistive	120 V AC	10 A	30 A	10 A	2770 VA
	240 V AC	10 A	30 A	10 A	2770 VA
AC Inductive PF = 0.4	120 V AC	10 A	30 A	4 A	480 VA
	240 V AC	10 A	30 A	3 A	750 VA

COMMUNICATIONS

All Ports: 300 to 19200 baud, programmable parity, Modbus RTU protocol, DNP

CLOCK

Resolution: 1 ms

Accuracy with IRIG-B: ±1 ms
without IRIG-B: ±1 minute/month

Backup Battery Life: 10 years continuous use

HARMONICS

Individual Range: 0.00 to 99.9%
Accuracy: ±1% of Full Scale @ 0.5 x CT

THD Range: 0.00 to 99.9%
Accuracy: ±1% of Full Scale @ 0.5 x CT

OPERATING ENVIRONMENT

Operating Temperature Range: –40°C to +60°C

Ambient Storage Temperature: –40°C to +80°C

Humidity: up to 90% non-condensing

Altitude: 2000 m

Pollution degree: II

CASE

Fully drawout unit (automatic CT shorts); Seal provision; Dust tight door; Panel or 19" rack mount

Weight (case & relay):	18 lbs., 6 oz.
IP class:	X0

PRODUCTION TESTS

Thermal:	Operational test at ambient then increasing to 60 °C
Dielectric Strength:	Per IEC 255-5 and ANSI/IEEE C37.90 On CT inputs, VT inputs, Control Power inputs, Switch inputs, and Relay outputs (2 kV for 1 second)

TYPE WITHSTAND TESTS

Fast Transient:	per ANSI/IEEE C37.90.1 (5 kV) per IEC 255-22-4 (4 kV)
Insulation Resistance:	per IEC 255-5 (500 V DC, 2000 MΩ)
Dielectric Strength:	per IEC 255-5 and ANSI/IEEE C37.90 (2 kV at 60 Hz for 1 minute)
Surge Immunity:	per EN 61000-4-5 (common mode 4 kV, differential modes 2 kV) per ANSI/IEEE C37.90.1, IEC 255-22-1, and Ontario Hydro A-28M-82
Voltage Dips:	per IEC 1000-4-1 (0%, 40%)
Electrostatic Discharge:	per IEC 255-22-2 (8/15 kV)
Power Frequency/ Magnetic Field Immunity:	per EN 61000-4-8
Damp Heat (Cyclic Humidity)	per IEC 68-2-30 (6 days)
Temperature Cycle:	–40°C, +60°C
Mechanical Stress	2 g
Make and Carry Rating	30 A
Current Withstand:	per ANSI/IEEE C37.90 (40 × rated A for 2 seconds, 80 × rated A for 1 second)
RFI Radiated Immunity:	per IEC 255-22-3 (160 MHz, 460 MHz) per EN 61000-4-3 (10 V/m)
RFI Conducted Immunity:	per EN 61000-4-6 (10 V)
RFI Conducted/Radiated Emission:	per EN 55011 / CISPR 11 FCC Part 15

APPROVALS

CSA:	CSA approved
CE:	Conforms to IEC 1010-1 / EN 50082-2
UL:	UL approved
ISO:	Manufactured under ISO9001 registered program

NOTE

It is recommended that all 745 relays be powered up at least once per year to avoid deterioration of electrolytic capacitors in the power supply.

Specifications subject to change without notice.

2.1.1 MANEUVERING

The following procedure describes how to maneuver through the 745 setpoints and actual values.

```
▌▌SETPOINTS HAVE NOT
▌▌BEEN PROGRAMMED!
```

When powered on successfully, the SELF-TEST ERROR and MESSAGE indicators will be on with this message on the display. It indicates that the 745 is in the Not Programmed state and safeguards against the installation of a relay whose setpoints have not been entered. This message will remain until the relay is explicitly put in the Programmed state.

```
▌▌ACTUAL VALUES
▌▌A1 STATUS
```

Press any front panel key once and the header for the first actual values page appears. This page contains system and relay status information. Repeatedly press the ACTUAL key to display the 2nd, 3rd, and 4th actual values page headers. Press the ACTUAL key once more to return to the 1st actual values page header. There are 4 actual values pages in all, numbered from A1 (the 'A' prefix indicating that it is an actual values page) to A4. Actual values page headers, as with setpoint page headers, have double scroll bars on the left side of the message.

```
▌▌SETPOINTS
▌▌S1 745 SETUP
```

Press the SETPOINT key and the header for the first page of setpoints appears. This page contains setpoints to configure the 745 relay.

```
▌▌SETPOINTS
▌▌S2 SYSTEM SETUP
```

Press the SETPOINT key to move to the next setpoints page. This page contains setpoints for entering the characteristics of the power transformer being protected. Repeatedly press the SETPOINT key to display the 3rd, 4th, 5th and 6th page headers and then back to the first setpoints page header. As you have discovered, there are 6 setpoint pages in all, numbered from S1 (the 'S' prefix indicating that it is a setpoint page) to S6.

```
▌PASSCODE
▌[ENTER] for more
```

From the page one header of setpoints, press the MESSAGE ▼ key once to display the first sub-header. Setpoints under this sub-header are related to passcode security. Note that the lower line of every sub-header message reads [ENTER] for more and that there is a single scroll bar on the left side.

```
▌END OF PAGE S1
▌
```

Press the MESSAGE ▼ key repeatedly and display the remaining sub-header messages in this page. The last message appears as shown.

```
▌PREFERENCES
▌[ENTER] for more
```

By pressing the MESSAGE ▲ key repeatedly, move to the second sub-header message. Setpoints under this sub-header message allow the user to specify keypad and display operation preferences.

```
BEEPER:
Enabled
```

Press ESCAPE to display the first setpoint under the preferences sub-header. All setpoint and actual value messages have two parts. The first part (BEEPER:), is displayed in uppercase and followed by a colon. This is the name or description of the data. The second part (Enabled), either starts with an uppercase character followed by lowercase characters or is a number followed by units. This second part is the present value of the data.

```
DEFAULT MESSAGE
INTENSITY:25%
```

To view the remaining setpoints associated with the preferences sub-header, repeatedly press the MESSAGE ▼ key. The last message appears as shown.

Let us review how we got to this last message.

1. First, we started at the setpoints page header **S1 745 SETUP**.
2. We then moved to the second sub-header message under page S1, which is **PREFERENCES**, and we pressed the ENTER key.
3. We then moved to the last message in this group.

A path can be used as a means of specifying where a message is located in the 745 relay. For this last message, the path would be **S1 745 SETUP** / **PREFERENCES** / **DEFAULT MESSAGE INTENSITY**. For the purposes of this manual, we will refer to messages in this manner. Press the ESCAPE key to return to the preferences sub-header message. Pressing the ESCAPE key from any of the messages under a sub-header will return the display to that sub-header message. From a sub-header message, the repeated pressing of MESSAGE ▲ moves the display through the list of sub-header messages to the page header. As an alternative, you could press the SETPOINT key and move directly to the next page.

2.2.1 DESCRIPTION

There are several different classes of setpoints, distinguished by the way their values are displayed and edited. This section describes how to edit the values used by all setpoint classes.

2.2.2 INSTALLING THE SETPOINT ACCESS JUMPER

Hardware and passcode security features are designed to provide protection against unauthorized setpoint changes. Since we will be programming new setpoints using the front panel keys, a hardware jumper must be installed across the setpoint access terminals (D9 and D10) on the back of the relay case. A keyswitch may also be used across these terminals to enable setpoint access. Attempts to enter a new setpoint via the front panel without this connection will be unsuccessful.

2.2.3 NUMERICAL SETPOINTS

Each numerical setpoint has its own minimum, maximum, and increment value associated with it. These parameters define what values are acceptable for a setpoint.

```
NOMINAL VT SECONDARY
VOLTAGE: 120.0 V
```

Select the **S2 SYSTEM SETUP / VOLTAGE INPUT / NOMINAL VT SECONDARY VOLTAGE** setpoint message

```
▌MINIMUM: 60.0
▌MAXIMUM: 120.0
```

```
▌IN STEPS OF:
▌0.1
```

```
▌PRESS (0)-(9) OR
▌VALUE
```

```
▌▌PRESS [ENTER] TO
▌▌STORE NEW VALUE
```

```
▌END OF PAGE S1
▌
```

Press HELP. The following context sensitive flash messages will sequentially appear for several seconds each. For the case of a numerical setpoint message, the HELP key displays the minimum, maximum, and step value.

Two methods of editing and storing a numerical setpoint value are available.

1. **0** *to* **9** *and the decimal key:* The relay numeric keypad works the same as that of any electronic calculator. A number is entered one digit at a time. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the ESCAPE key, before the ENTER key, returns the original value to the display.
2. VALUE ▲ *and* VALUE ▼*:* The VALUE ▲ key increments the displayed value, by the step value, up to the maximum value allowed. While at the maximum value, pressing the VALUE ▲ key again will allow setpoint selection to continue from the minimum value. The VALUE ▼ key decrements the displayed value, by the step value, down to the minimum value. Again, continuing to press the VALUE ▼ key while at the minimum value will continue setpoint selection from the maximum value.

```
NOMINAL VT SECONDARY
VOLTAGE
```

As an example, let's set the nominal VT secondary voltage setpoint to 69.3 V. Press the appropriate numeric keys in the sequence '**6 9 . 3**'. The display message will change as the digits are being entered.

```
▌▌NEW SETPOINT
▌▌HAS BEEN STORED
```

Editing changes are not registered until the ENTER key is pressed. Press the ENTER key to store the new value in memory. This flash message momentarily appears to confirmation the storing process. If 69.28 were entered, the value is automatically rounded to 69.3, since the step value for this setpoint is 0.1.

2.2.4 ENUMERATION SETPOINTS

Enumeration setpoints have data values which are part of a set, whose members are explicitly defined by a name. A set is comprised of two or more members.

```
PHASE SEQUENCE
ABC
```

Move to message **S2 SYSTEM SETUP / TRANSFORMER / PHASE SEQUENCE**.

```
▌▌PRESS [VALUE⇳] TO
▌▌MAKE SELECTION
```

Press the HELP key and the following context sensitive flash messages will sequentially appear for several seconds each. For the case of an enumeration setpoint message, the HELP key displays the number of selections in the enumeration.

```
▌▌PRESS [ENTER] TO
▌▌STORE NEW VALUE
```

```
▌▌FOR FURTHER HELP
▌▌REFER TO MANUAL
```

Enumeration type values are changed using the VALUE ▲ and VALUE ▼ keys. The VALUE ▲ key displays the next selection while the VALUE ▼ key displays the previous selection.

```
INPUT 1 FUNCTION:
ENABLED
```

As an example we may need to set the phase sequence to ACB. Press VALUE ▲ or VALUE ▼ until the proper selection is displayed.

```
▌▌NEW SETPOINT
▌▌HAS BEEN STORED
```

Editing changes are not registered until ENTER is pressed. Pressing ENTER stores the new value in memory. This flash message momentarily appears to confirm the storing process.

2.2.5 TEXT SETPOINTS

Text setpoints have data values which are fixed in length, but user defined in character. They may be comprised of upper case letters, lower case letters, numerals, and a selection of special characters.

```
OUTPUT 3 NAME:
Trip 2
```

Move to the **S5 OUTPUTS \ OUTPUT RELAYS \ OUTPUT RELAY 3 \ OUTPUT 3 NAME** setpoints message. The name of the OUTPUT 3 relay is going to be changed in this section.

```
▌▌PRESS [ENTER] TO
▌▌BEGIN TEXT EDIT
```

```
▌▌PRESS [VALUE⇕] TO
▌▌CHANGE CHARACTER
```

```
▌▌PRESS [ENTER] TO
▌▌STORE CHARACTER
```

```
▌▌AND ADVANCE TO
▌▌NEXT POSITION
```

```
▌▌FOR FURTHER HELP
▌▌REFER TO MANUAL
```

Press the [HELP] key and the following context sensitive flash messages will sequentially appear for several seconds each. For the case of a text setpoint message, the [HELP] key displays how to edit and store a new value.

The editing and storing of a text value is accomplished with the use of the [ENTER], [VALUE ▲], [VALUE ▼], and [ESCAPE] keys.

```
OUTPUT 2 NAME:
Trip 2
```

```
OUTPUT 3 NAME:
INST DIFF TRIP
```

The text entered here should be more descriptive to this output relay. For this example let us rename output relay as INST DIFF TRIP. Press the [ENTER] key and a solid cursor (▮) will appear in the first character position.

Press [VALUE ▲] or [VALUE ▼] key until the character 'I' is displayed in the first position. Now press the [ENTER] key to store the character and advance the cursor to the next position. Change the second character to a 'N' by again pressing the [VALUE ▲] or [VALUE ▼] key. Store this change by pressing the [ENTER] key again. Continue entering characters in this way until all the characters in INST DIFF TRIP are entered. Note that a space is selected like a character. If a character is entered incorrectly, press the [ENTER] key repeatedly until the cursor returns to the position of the error. Re-enter the character as required. Once complete, press the [ESCAPE] key to remove the solid cursor and view the result.

2.3.1 INSTALLATION

Note that the relay is defaulted to the Setpoints Not Programmed state before it leaves the factory. This safeguards against the installation of a relay whose setpoints have not been entered. In addition, a relay in the Not Programmed state blocks signaling of any output relay, and turns off the IN SERVICE indicator.

2

```
745 SETPOINTS:
Not Programmed
```

Move to the **S1 745 SETUP \ INSTALLATION \ 745 SETPOINTS** message. To put the relay in the Programmed state, press the VALUE ▲ or VALUE ▼ key once and press ENTER. Enter Yes for the ARE YOU SURE? message. The front panel IN SERVICE indicator will now turn on.

2.3.2 PASSCODE SECURITY SETUP

To guarantee that the relay settings cannot be tampered with, the user may setup the passcode security feature.

a) CHANGING THE PASSCODE

```
SETPOINT ACCESS:
Read & Write
```

Move to the **S1 745 SETUP \ PASSCODE \ SETPOINT ACCESS** message. This message cannot be edited directly. It simply indicates whether passcode security is enabled (**SETPOINT ACCESS:** Read Only), or passcode security is disabled (**SETPOINT ACCESS:** Read & Write). Each relay is shipped from the factory with setpoint access allowed. The passcode is also defaulted to '0', which disables the passcode security feature entirely.

```
CHANGE PASSCODE?
No
```

Press the MESSAGE ▼ key once.

```
CHANGE PASSCODE?
Yes
```

Press the VALUE ▲ or VALUE ▼ key once.

```
PLEASE ENTER CURRENT
PASSCODE:
```

Press the ENTER key to begin the procedure of changing the passcode. The displayed message will change as shown. The current passcode is '0', so press the '0' numeric key. The relay will acknowledge the key press by displaying 'z'.

```
PLEASE ENTER A NEW
PASSCODE:
```

Press the ENTER key.

```
PLEASE ENTER A NEW
PASSCODE:▌▌▌
```

For this example change the passcode to '123'. Press the appropriate numeric keys in the '1 2 3' sequence. The message will change as the digits are entered, with the end result being as shown.

```
PLEASE RE-ENTER NEW
PASSCODE:
```

Press the ENTER key to store the new passcode and a confirmation message appears. As a safety measure, the relay requires you to enter a new passcode twice. This ensures the passcode has been entered correctly.

```
NEW PASSCODE
HAS BEEN STORED
```

After pressing the appropriate numeric keys in the sequence '1 2 3', press ENTER. This flash message appears momentarily on the display and confirms the new passcode is stored in memory.

```
CHANGE PASSCODE?
No
```

After a few seconds, the original display returns.

```
ALLOW ACCESS TO
SETPOINTS? No
```

Press the MESSAGE ▲ key. As soon as a non-zero passcode is entered, setpoint access will automatically become restricted.

b) DISABLING/ENABLING PASSCODE SECURITY

Suppose at some time in the future you want to alter a setpoint. In order to do this, you must first disable passcode security, make the setpoint change, and then re-enable the passcode security.

ALLOW ACCESS TO SETPOINTS? No	Move to message **S1 745 SETUP \ PASSCODE \ ALLOW ACCESS TO SETPOINTS?**. It is from here that we will disable passcode security. Please note that this message is hidden, when the passcode security feature is disabled by entering a passcode of '0'.
PLEASE ENTER CURRENT PASSCODE:	Press the VALUE ▲ or VALUE ▼ key once to select Yes and press ENTER. The displayed message will change as shown.
▌▌SETPOINT ACCESS ▌▌IS NOW ALLOWED	Enter the current passcode and press the ENTER key. This flash message indicates that the keyed in value was accepted and that passcode security is now disabled.
RESTRICT ACCESS TO SETPOINTS? No	This message will appear after a few seconds. Now that setpoint access is enabled, the ALLOW ACCESS TO SETPOINTS? message has been replaced by the RESTRICT ACCESS TO SETPOINTS message. The relay's setpoints can now be altered and stored. If no front panel keys are pressed for longer than 30 minutes, setpoint access will automatically become restricted again.
PLEASE ENTER CURRENT PASSCODE:	To disable setpoint access, immediately after setpoint editing, move back to message **S1 745 SETUP \ PASSCODE \ RESTRICT ACCESS TO SETPOINTS?** and enter Yes. Key the current passcode into the shown message.
▌▌SETPOINT ACCESS ▌▌IS NOW RESTRICTED	Press the ENTER key and this message will flash on the display. It indicates that passcode security is now enabled.
ALLOW ACCESS TO SETPOINTS? No	After a few seconds, the original display returns.

3.1.1 CASE DESCRIPTION

The 745 is packaged in the standard SR series arrangement, which consists of a drawout relay and a companion case. The case provides mechanical protection for the drawout portion, and is used to make permanent electrical connections to external equipment. Where required, case connectors are fitted with mechanisms, such as automatic CT shorting, to allow the safe removal of the relay from an energized panel. There are no electronic components in the case.

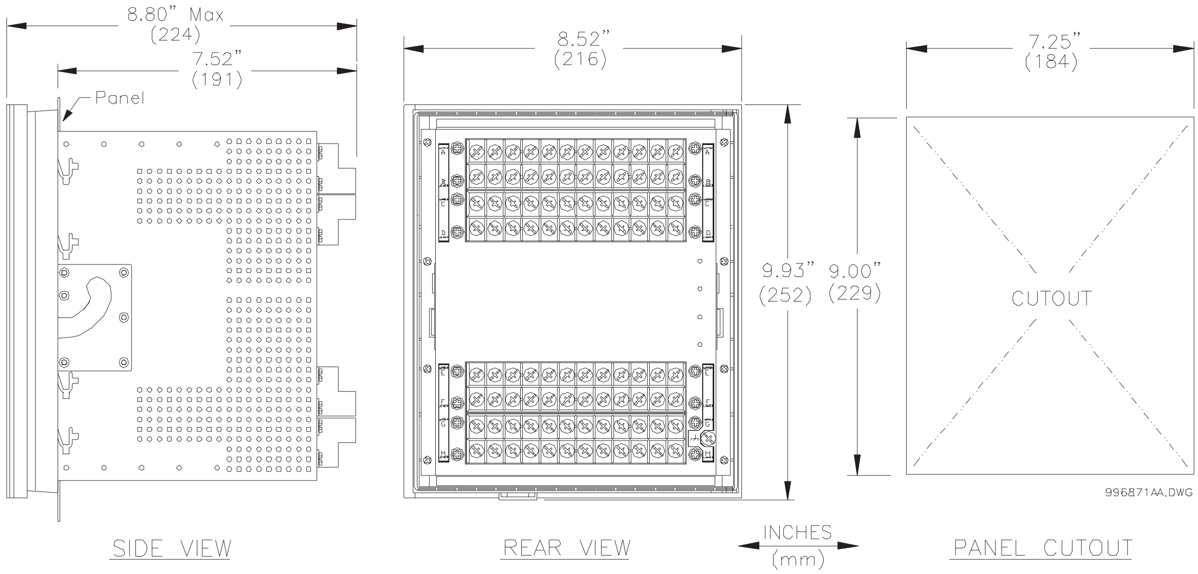


Figure 3–1: CASE DIMENSIONS

3.1.2 PANEL CUTOUT

A 745 can be mounted alone or adjacent to another SR series unit on a standard 19" rack panel. Panel cutout dimensions for both conditions are as shown. When planning the location of your panel cutout, ensure provision is made for the front door to swing open without interference to or from adjacent equipment.

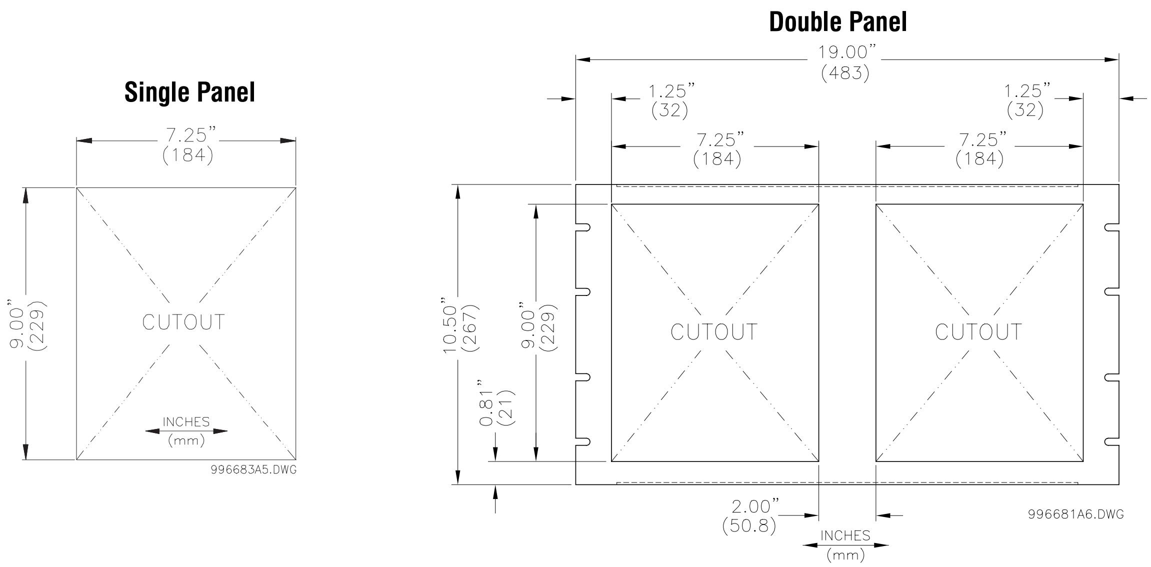


Figure 3–2: SINGLE AND DOUBLE SR RELAY PANEL CUTOUT

3.1.3 CASE MOUNTING

Before mounting the SR unit in the supporting panel, remove the relay portion from its case, as described in the next section. From the front of the panel, slide the empty case into the cutout. To ensure the front bezel sits flush with the panel, apply pressure to the bezel's front while bending the retaining tabs 90°. These tabs are located on the sides and bottom of the case and appear as shown in the illustration. After bending all tabs, the case will be securely mounted so that its relay can be inserted. The SR unit is now ready for panel wiring.

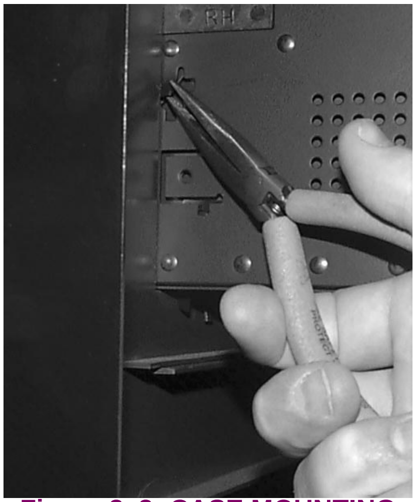


Figure 3–3: CASE MOUNTING

3.1.4 UNIT WITHDRAWAL AND INSERTION

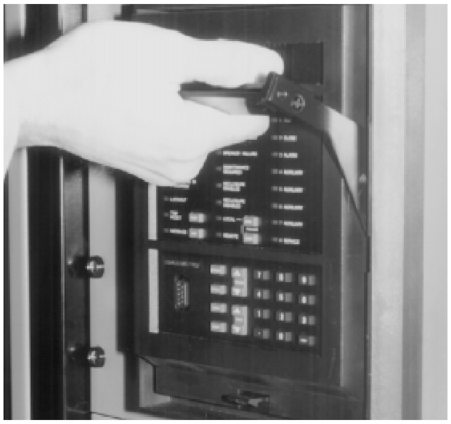
CAUTION

TURN OFF CONTROL POWER BEFORE DRAWING OUT OR RE-INSERTING THE RELAY TO PREVENT MALOPERATION!

a) RELAY WITHDRAWAL

1. Open the door by pulling from the center of its right side. It will rotate to the left about its hinges.
2. Press upward on the locking latch, which is located below the handle, and hold in its raised position. The tip of a small screwdriver may prove helpful in this operation.
3. With the latch raised, pull the center of the handle outward. Once disengaged, continue rotating the handle up to the stop position.

Press Latch Up and Pull Handle



Rotate Handle to Stop Position

4. The locking mechanism releases when the stop position is reached. The relay now slides out of the case when pulled from its handle. To free the relay, it may be necessary to adjust the handle position slightly.

Figure 3–4: SLIDING RELAY OUT OF CASE

b) RELAY INSERTION

Any 745 can be installed in any 745 case, but cannot be inserted into the case of another product in the SR series. For instance, you cannot place an 745 relay into a 735 case.

CAUTION **If an attempt is made to install a relay into a non-matching case, the case configuration pin will prevent full insertion. Applying a strong force in this instance will result in damage to the relay and case.**

Even though a relay may be inserted into a case, one should make sure the model number on the left side of the relay matches the requirements of the installation.

1. With the relay's handle raised, align and slide both rolling guide pins into the case guide slots. Each rolling guide pin is found near the hinges of the relay's handle.
2. Once fully inserted, grasp the handle from its center and rotate it down from the raised position towards the bottom of the relay.
3. As the handle is fully inserted, the latch will be heard to click, locking the handle in the final position. The unit is mechanically held in the case by the handle's rolling pins, which cannot be fully lowered to the locked position until the electrical connections are completely mated.

c) DRAWOUT SEAL

To prevent unauthorized removal of the drawout relay, a wire lead seal can be installed through the slot in the middle of the locking latch. The relay cannot be removed from the case with this seal in place. Even though a passcode or setpoint access jumper can be used to prevent entry of setpoints and still allow monitoring of actual values, access to the front panel controls may still need to be restricted. As such, a separate seal can be installed on the outside of the door to prevent it from being opened.

Figure 3–5: DRAWOUT SEAL

3.2.1 DESCRIPTION

Due to the many features built into the 745 relay, a broad range of applications are available to the user. As such, it is not possible to present connections for all possible schemes. The information in this section will cover the important aspects of interconnections, in the general areas of instrument transformer inputs, other inputs, outputs, communications and grounding.

3.2.2 REAR TERMINAL LAYOUT

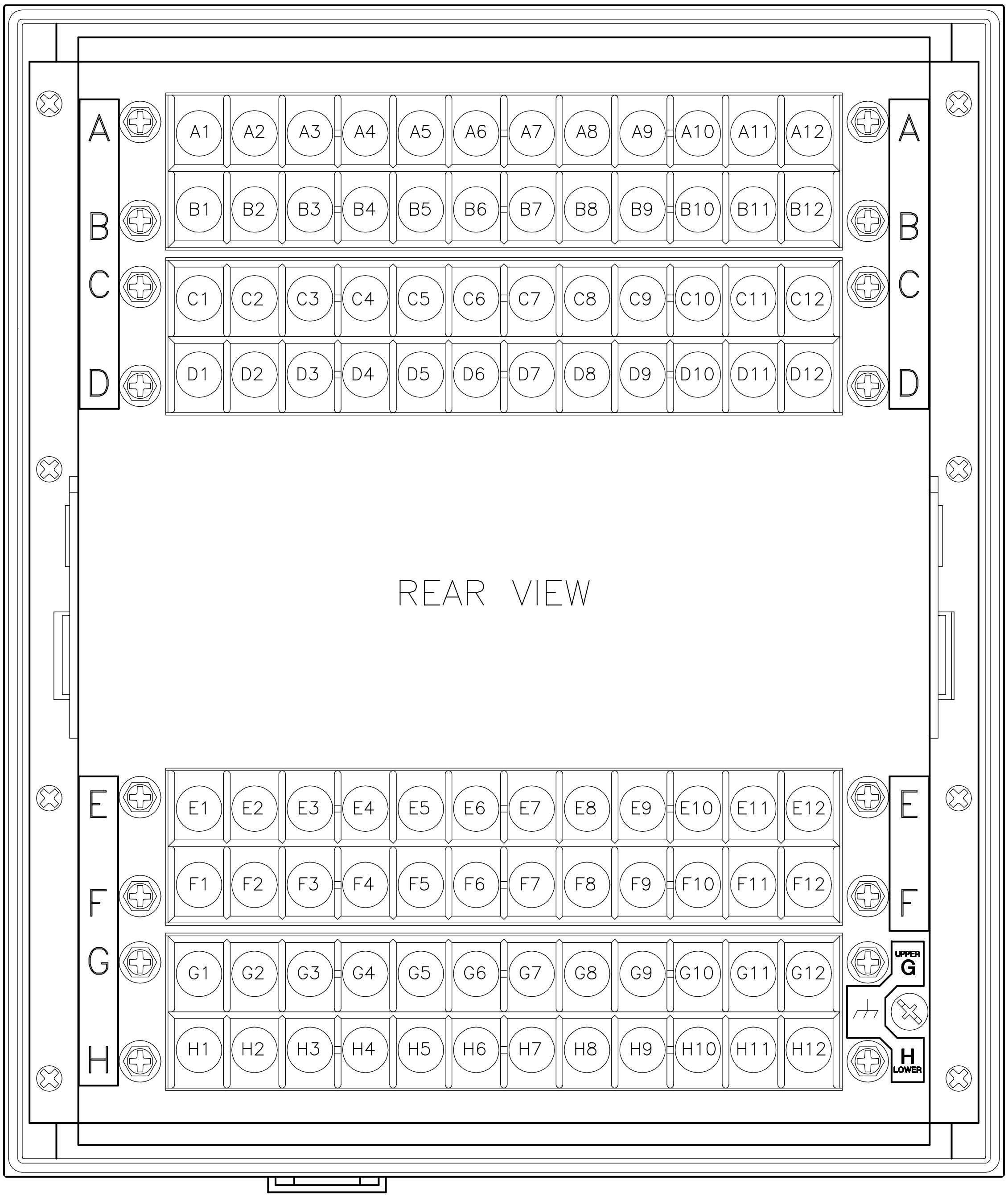


Figure 3–6: REAR TERMINAL LAYOUT

3.2.3 REAR TERMINAL ASSIGNMENTS

ANALOG INTERFACE		OUTPUTS & GROUND CT N2	
A1	ANALOG INPUT +	E1	OUTPUT 1 - SOLID STATE TRIP (+)
A2	ANALOG INPUT –	E2	OUTPUT 2 - TRIP RELAY (N/O)
A3	TAP POSITION (+)	E3	OUTPUT 3 - TRIP RELAY (N/O)
A4	TAP POSITION (–)	E4	OUTPUT 4 - TRIP RELAY (N/O)
A5	ANALOG OUTPUT (Common)	E5	OUTPUT 5 - TRIP RELAY (N/O)
A6	ANALOG OUTPUT 1 (+)	E6	OUTPUT 6 - AUXILIARY RELAY (N/O)
A7	ANALOG OUTPUT 2 (+)	E7	OUTPUT 6 - AUXILIARY RELAY (N/C)
A8	ANALOG OUTPUT 3 (+)	E8	OUTPUT 7 - AUXILIARY RELAY (N/O)
A9	ANALOG OUTPUT 4 (+)	E9	OUTPUT 8 - AUXILIARY RELAY (N/O)
A10	ANALOG OUTPUT 5 (+)	E10	OUTPUT 8 - AUXILIARY RELAY (N/C)
A11	ANALOG OUTPUT 6 (+)	E11	OUTPUT 9 - SERVICE RELAY (Common)
A12	ANALOG OUTPUT 7 (+)	E12	GROUND - WINDING 2/3 CT
COMMUNICATIONS & RTD INPUTS		**OUTPUTS & GROUND CT N2**	
B1	COMPUTER RS485 (+) / RS422 (Rx +)	F1	OUTPUT 1 - SOLID STATE TRIP (–)
B2	COMPUTER RS485 (–) / RS422 (Rx –)	F2	OUTPUT 2 - TRIP RELAY (Common)
B3	COMPUTER RS485 (Com) / RS422 (Com)	F3	OUTPUT 3 - TRIP RELAY (Common)
B4	RS422 (Tx +)	F4	OUTPUT 4 - TRIP RELAY (Common)
B5	RS422 (Tx –)	F5	OUTPUT 5 - TRIP RELAY (Common)
B6	EXTERNAL RS485 (+)	F6	OUTPUT 6 - AUXILIARY RELAY (Common)
B7	EXTERNAL RS485 (–)	F7	OUTPUT 7 - AUXILIARY RELAY (N/O)
B8	IRIG-B +	F8	OUTPUT 7 - AUXILIARY RELAY (N/C)
B9	IRIG-B –	F9	OUTPUT 8 - AUXILIARY RELAY (Common)
B10	RTD 1 HOT	F10	OUTPUT 9 - SERVICE RELAY (N/O)
B11	RTD 1 COMPENSATION	F11	OUTPUT 9 - SERVICE RELAY (N/C)
B12	RTD 1 RETURN	F12	GROUND - WINDING 2/3 CT ■
LOGIC INPUTS 9-16 & VT INPUT		**CT INPUTS & 745 GROUNDING**	
C1	LOGIC INPUT 9 (+)	G1	PHASE A - WINDING 1 CT
C2	LOGIC INPUT 10 (+)	G2	PHASE B - WINDING 1 CT
C3	LOGIC INPUT 11 (+)	G3	PHASE C - WINDING 1 CT
C4	LOGIC INPUT 12 (+)	G4	PHASE A - WINDING 2 CT
C5	LOGIC INPUT 13 (+)	G5	PHASE B - WINDING 2 CT
C6	LOGIC INPUT 14 (+)	G6	PHASE C - WINDING 2 CT
C7	LOGIC INPUT 15 (+)	G7	PHASE A - WINDING 3 CT
C8	LOGIC INPUT 16 (+)	G8	PHASE B - WINDING 3 CT
C9	RESERVED	G9	PHASE C - WINDING 3 CT
C10	RESERVED	G10	GROUND - WINDING 1/2 CT
C11	VT INPUT ■	G11	745 FILTER GROUND
C12	VT INPUT	G12	745 SAFETY GROUND
LOGIC INPUTS 1-8 & DEDICATED INPUTS		**CT and VT INPUTS / POWER**	
D1	LOGIC INPUT 1 (+)	H1	PHASE A - WINDING 1 CT ■
D2	LOGIC INPUT 2 (+)	H2	PHASE B - WINDING 1 CT ■
D3	LOGIC INPUT 3 (+)	H3	PHASE C - WINDING 1 CT ■
D4	LOGIC INPUT 4 (+)	H4	PHASE A - WINDING 2 CT ■
D5	LOGIC INPUT 5 (+)	H5	PHASE B - WINDING 2 CT ■
D6	LOGIC INPUT 6 (+)	H6	PHASE C - WINDING 2 CT ■
D7	LOGIC INPUT 7 (+)	H7	PHASE A - WINDING 3 CT ■
D8	LOGIC INPUT 8 (+)	H8	PHASE B - WINDING 3 CT ■
D9	SETPOINT ACCESS (+)	H9	PHASE C - WINDING 3 CT ■
D10	SETPOINT ACCESS (–)	H10	GROUND - WINDING 1/2 CT ■
D11	LOGIC POWER OUT (+)	H11	CONTROL POWER (–)
D12	LOGIC POWER OUT (–)	H12	CONTROL POWER (+)

■ indicates high side of CT and VT terminals

3.2.4 TYPICAL WIRING DIAGRAMS

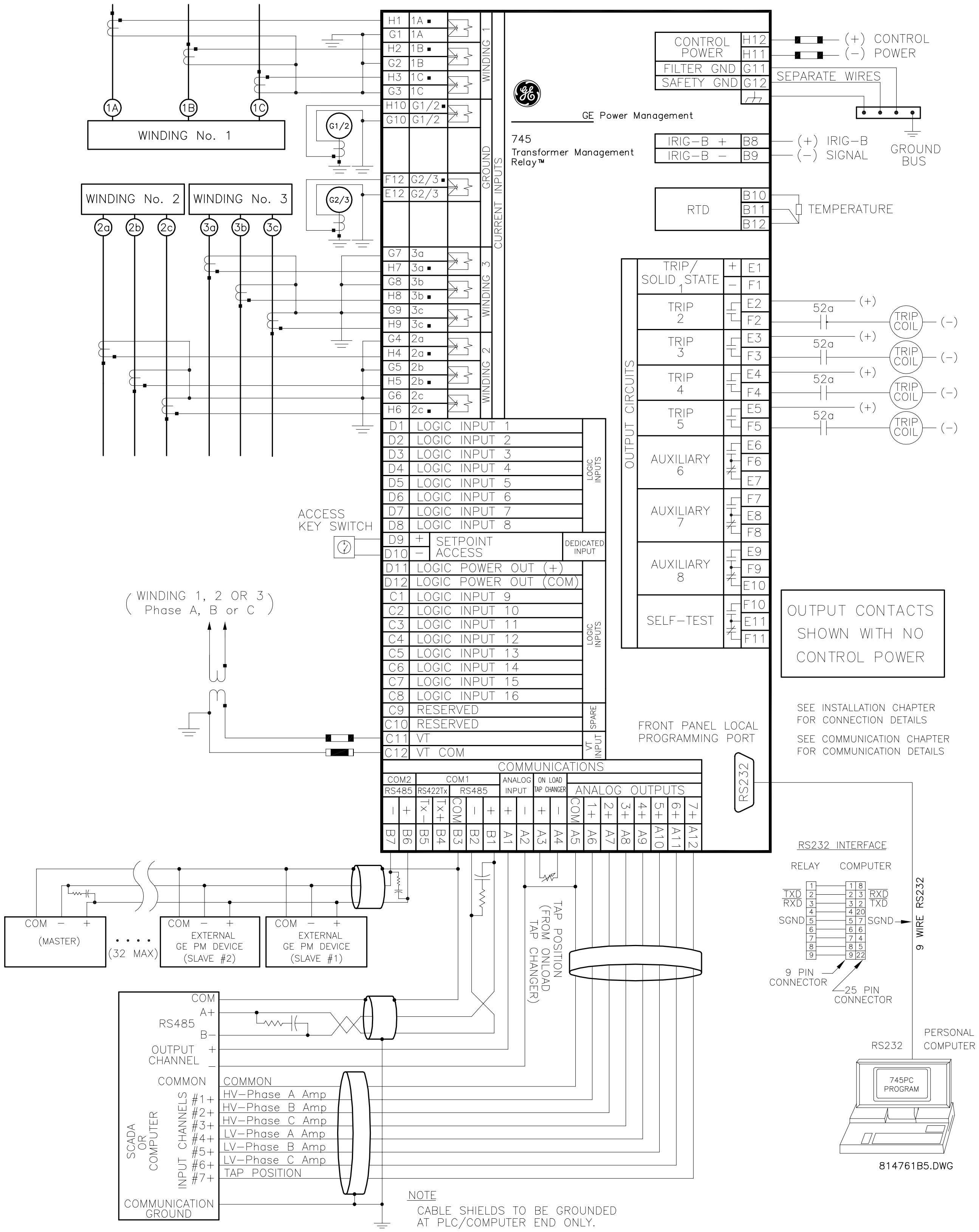


Figure 3–7: TYPICAL WIRING DIAGRAM

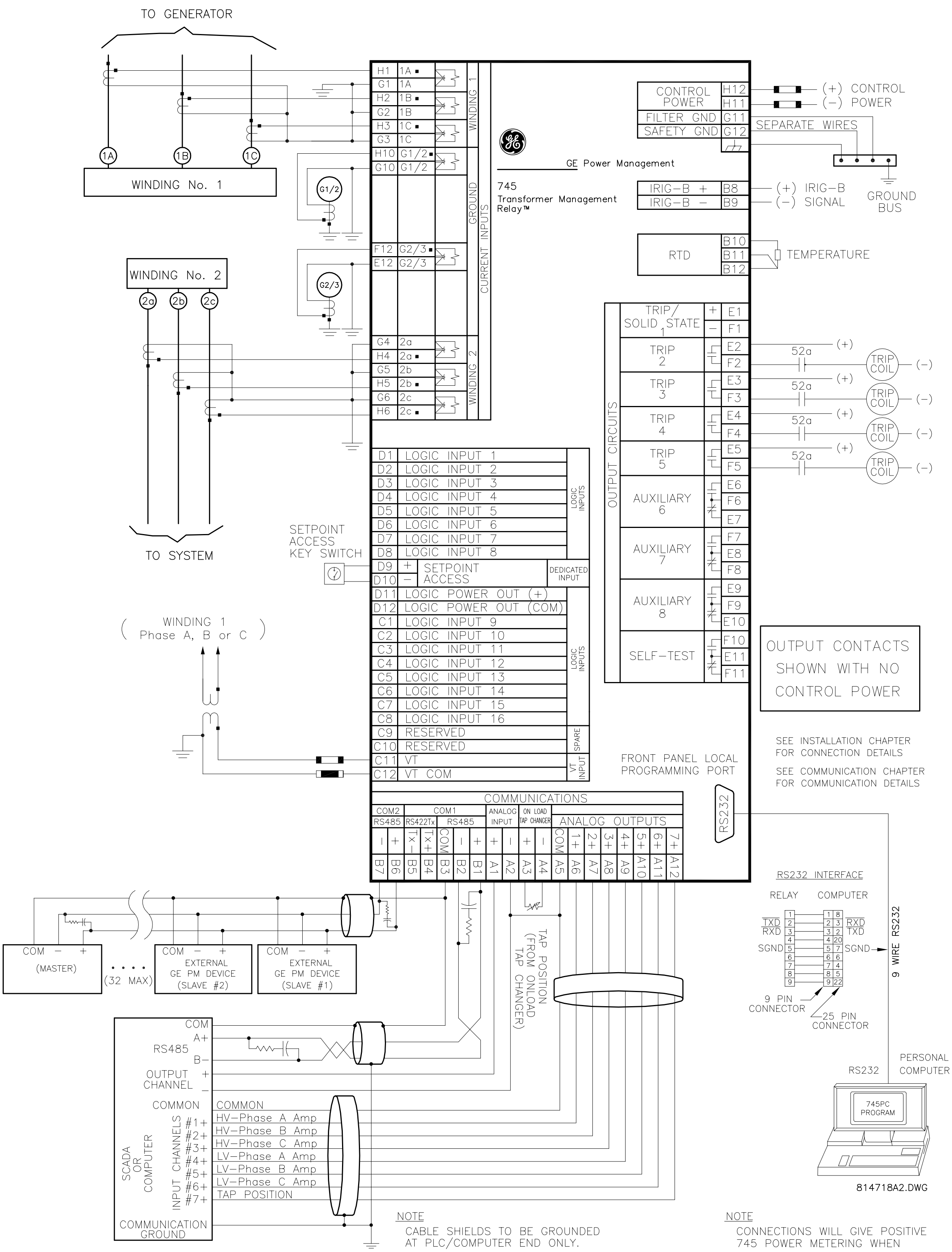


Figure 3–8: TYPICAL WIRING DIAGRAM FOR GENERATOR STEP-UP

3.2.5 PHASE SEQUENCE AND TRANSFORMER POLARITY

For the correct operation of many relay features, the phase sequence and instrument transformer polarities shown on the typical wiring diagram must be followed. Note the markings shown with all instrument transformer connections. When the connections adhere to this drawing, the relay will operate properly.

3.2.6 AC CURRENT TRANSFORMER INPUTS

The 745 has eight or eleven channels for AC current inputs, each with an isolating transformer and an automatic shorting mechanism that acts when the relay is withdrawn from its case. There are no internal ground connections on the current inputs. Current transformers with 1 to 50 000 A primaries may be used.

CAUTION

Verify that the relay's nominal current of 1 A or 5 A matches the secondary rating of the connected CTs. Unmatched CTs may result in equipment damage or inadequate protection.

The exact placement of a zero-sequence CT so that ground fault current will be detected is shown below. Twisted pair cabling on the zero-sequence CT is recommended.

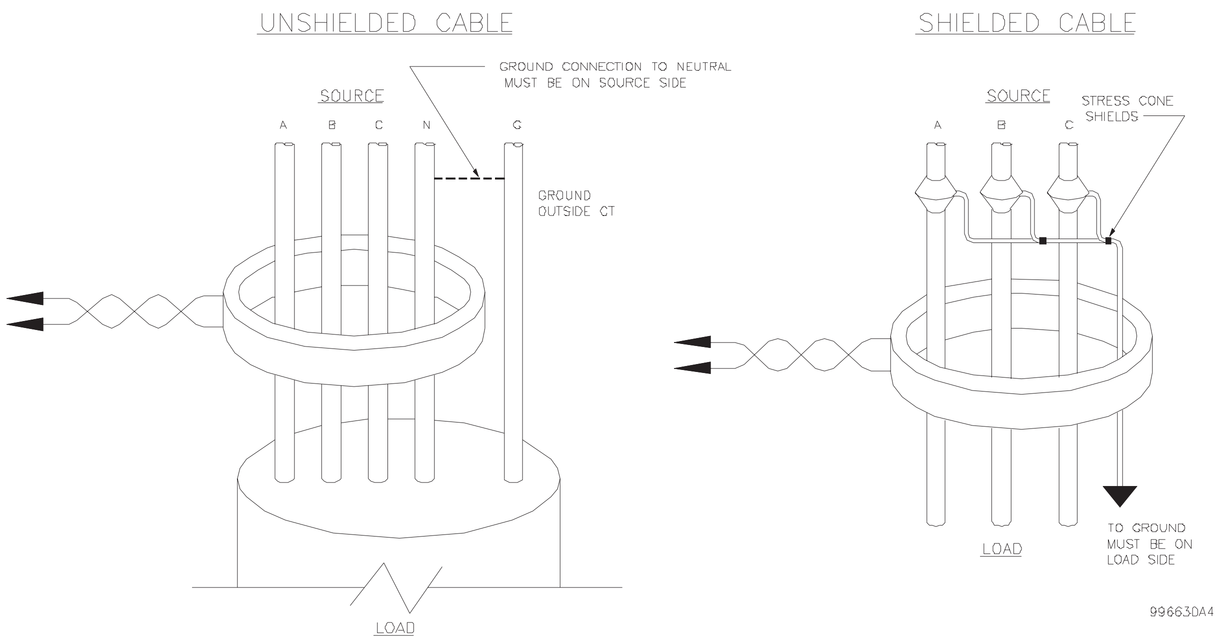


Figure 3–9: ZERO-SEQUENCE (CORE BALANCE) CT INSTALLATION

NOTE

IMPORTANT: The relay will correctly measure up to 46 times the current input nominal rating. Time overcurrent curves become horizontal lines for currents above the 46 × CT rating.

3.2.7 AC VOLTAGE INPUT

The 745 has one voltage divider type input for AC voltages. There are no internal fuses or ground connections. Voltage transformers up to a maximum 5000:1 ratio may be used. The nominal secondary voltage must be in the 60 to 120 V range.

3.2.8 CONTROL POWER

WARNING

Control power supplied to the relay must match the installed power supply range. If the applied voltage does not match, damage to the unit may occur.

The label found on the left side of the relay specifies its order code or model number. The installed power supply operating range will be one of the following.

LO: 25 to 60 V DC or 20 to 48 V AC
HI: 88 to 300 V DC or 70 to 265 V AC

Ensure the applied control voltage matches the requirements of the relay's switching power supply. For example, the HI power supply will work with any DC voltage from 88 to 300 V, or any AC voltage from 70 to 265 V. The internal fuse may blow if the applied voltage exceeds this range.

3

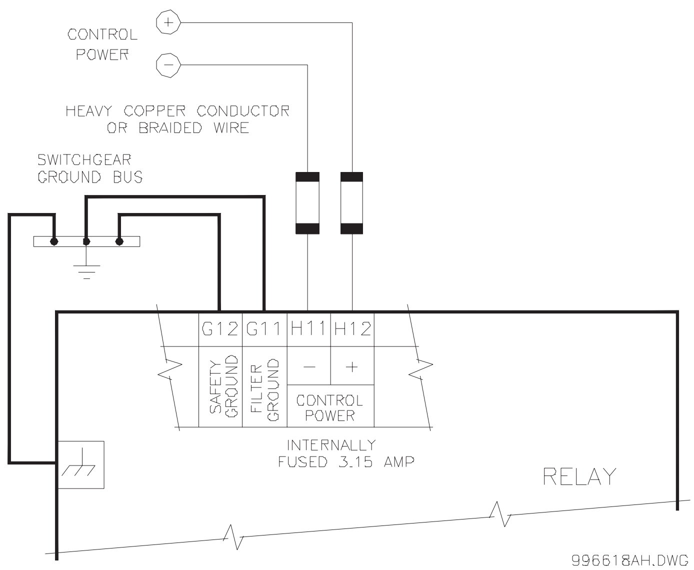


Figure 3–10: CONTROL POWER CONNECTION

3.2.9 LOGIC INPUTS

CAUTION

Correct polarity must be observed for all logic input connections or equipment damage may result.

External contacts can be connected to the 16 logic inputs. As shown, these contacts can be either dry or wet. It is also possible to use a combination of both contact types.

A dry contact has one side connected to terminal D11. This is the +32 V DC voltage rail. The other side of the dry contact is connected to the required logic input terminal. When a dry contact closes, a current of 2.2 mA will flow through the associated circuit.

A wet contact has one side connected to the positive terminal of an external DC power supply. The other side of this contact is connected to the required logic input terminal. In addition, the negative side of the external source must be connected to the relay DC NEGATIVE rail at terminal D12. The maximum external source voltage for this arrangement is 300 V DC.

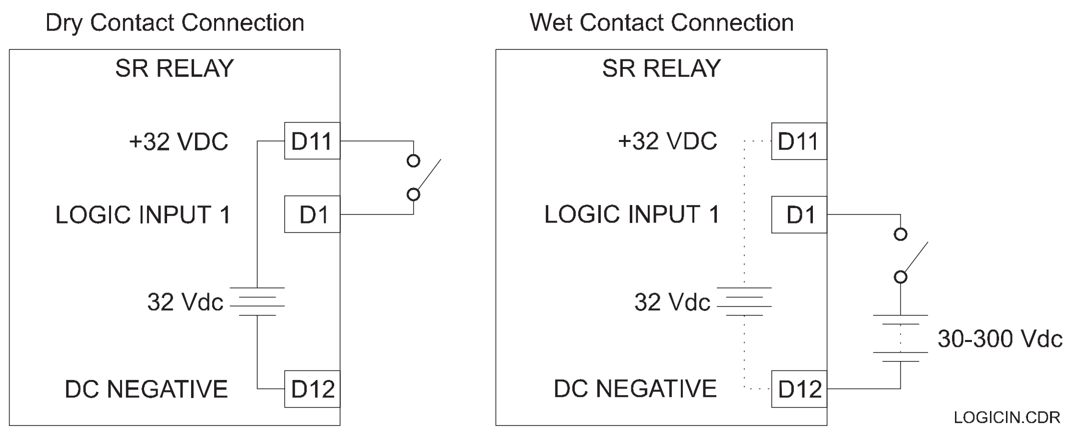


Figure 3–11: DRY AND WET CONTACT CONNECTIONS

3.2.10 ANALOG INPUT

Terminals A1 (+) and A2 (–) are provided for the input of a current signal, from one of the following: 0-1 mA, 0-5 mA, 0-20 mA, or 4-20 mA transducer outputs. This current signal can represent any external quantity, such as temperature, current or voltage. Be sure to observe polarity markings for correct operation. Both terminals are clamped to within 36 volts of ground with surge protection. As such, common mode voltages should not exceed this limit. Shielded wire, with only one end of the shield grounded, is recommended to minimize noise effects. The A2 (–) terminal must be connected to the A5 (ANALOG OUTPUT COM) terminal at the 745.

3.2.11 TAP POSITION INPUT

Terminals A3 (+) and A4 (-) are provided to monitor the position of an Onload Tap Changer from a stepped-resistance position indicator device. Terminal A3 is connected internally to a 4.3 mA current source. This current is used to measure the value of the external resistance. The 745 uses the measured resistance value to calculate the Tap Position.

3.2.12 RTD DRIVER/SENSOR

Terminals B10 (RTD HOT), B11 (RTD COMP) and B12 (RTD RET) provide for the connection of various types of RTD devices. This connection may be made using two or three wires to the RTD. Terminal B10 is connected internally to a 5 mA current source for energizing the RTD. Terminal B11 is connected internally to a 5 mA current source for the purpose of cancelling out the resistance of the wires connecting the RTD to the 745. Terminal B12 is the return path for the two current sources.

In the three-wire connection scheme, the connection from terminal B11 to B12 is made at the RTD. The three-wire connection scheme compensates for the resistance of the wiring between the 745 and the RTD.

In the two-wire connection scheme, the connection from terminal B11 to B12 is made at the terminal block on the rear of the 745. This connection must not be omitted. The two-wire connection scheme does not compensate for the resistance of the wiring between the 745 and the RTD.

3.2.13 OUTPUT RELAYS

Eight output relays are provided with the 745. Output Relays 2 through 5 have Form A contacts while Output Relays 6 to 8 and the SELF-TEST relay have Form C contacts. Since Output Relays 2 to 5 are intended for operating a breaker trip coil, the Form A contacts have higher current ratings than the Form C contacts. Note that the operating mode of the SELF-TEST relay is fixed, while the other relays can be programmed by the user via the FlexLogic™ feature.

3.2.14 SOLID STATE TRIP OUTPUT

A high-speed solid state (SCR) output is also provided. This output is intended for applications where it is necessary to key a communications channel.

3.2.15 ANALOG OUTPUTS

The 745 provides 7 analog output channels whose full scale range can be set to one of the following ranges.

0 to 1 mA; 0 to 5 mA; 0 to 10 mA; 0 to 20 mA; 4 to 20 mA

Each analog output channel can be programmed to represent one of the parameters measured by the relay. For details, see the setpoints chapter.

As shown in the typical wiring diagram, the analog output signals originate from terminals A6 to A12 and share A5 as a common return. Output signals are internally isolated and allow connection to devices which sit at a different ground potential. Each analog output terminal is clamped to within 36 V of ground. To minimize the effects of noise, external connections should be made with shielded cable and only one end of the shield should be grounded.

If a voltage output is required, a burden resistor must be connected at the input of the external measuring device. Ignoring the input impedance, $R_{LOAD} = V_{FULL\ SCALE} / I_{MAX}$.

- If a 5 V full scale output is required with a 0 to 1 mA output channel, R_{LOAD} = 5V / 0.001A = 5 KΩ.
- For a 0 to 5 mA channel this resistor would be 1 KΩ.
- For a 0 to 10 mA channel, this resistor would be 500 Ω.
- For a 4 to 20 mA channel this resistor would be 250 Ω.

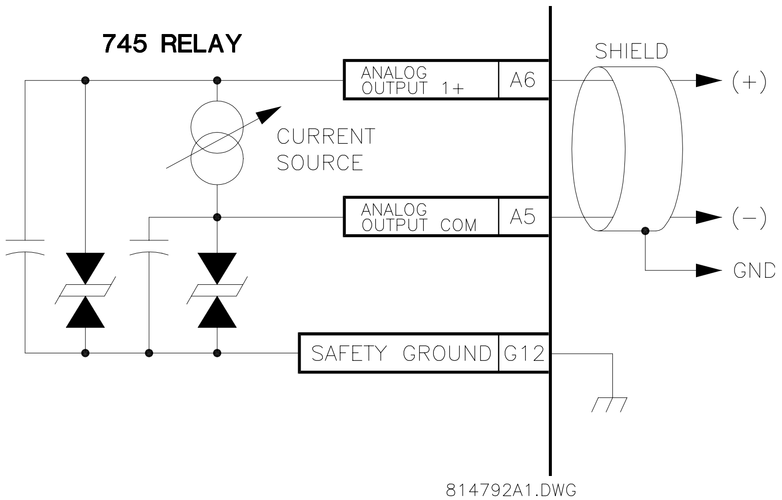


Figure 3–12: ANALOG OUTPUT CONNECTION

3.2.16 RS485 / RS422 COMMUNICATION PORTS

The 745 provides the user with two rear communication ports which may be used simultaneously. Both implement a subset of the AEG Modicon Modbus protocol as outlined in Chapter 8: COMMUNICATIONS.

The first port, COM1, can be used in the two wire RS485 mode or the four wire RS422 mode, but will not operate in both modes at the same time. In the RS485 mode, data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. These wires should be connected to the terminals marked RS485. The RS422 mode uses the COM1 terminals designated as RS485 for receive lines, and the COM1 terminals designated as RS422 for transmit lines. The second port, COM2, is intended for the two wire RS485 mode only. Through the use of these ports, continuous monitoring and control from a remote computer, SCADA system or PLC is possible.

3

To minimize errors from noise, the use of shielded twisted-pair wire is recommended. Correct polarity should also be observed. For instance, the relays must be connected with all B1 terminals (labeled COM1 RS485+) connected together, and all B2 terminals (labeled COM1 RS485–) connected together. Terminal B3 (labeled COM1 RS485 COM) should be connected to the common wire inside the shield. To avoid loop currents, the shield should be grounded at one point only. Each relay should also be daisy-chained to the next in the link. A maximum of 32 relays can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to include more than 32 relays on a single channel. Star or stub connections should be avoided entirely.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally provided at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

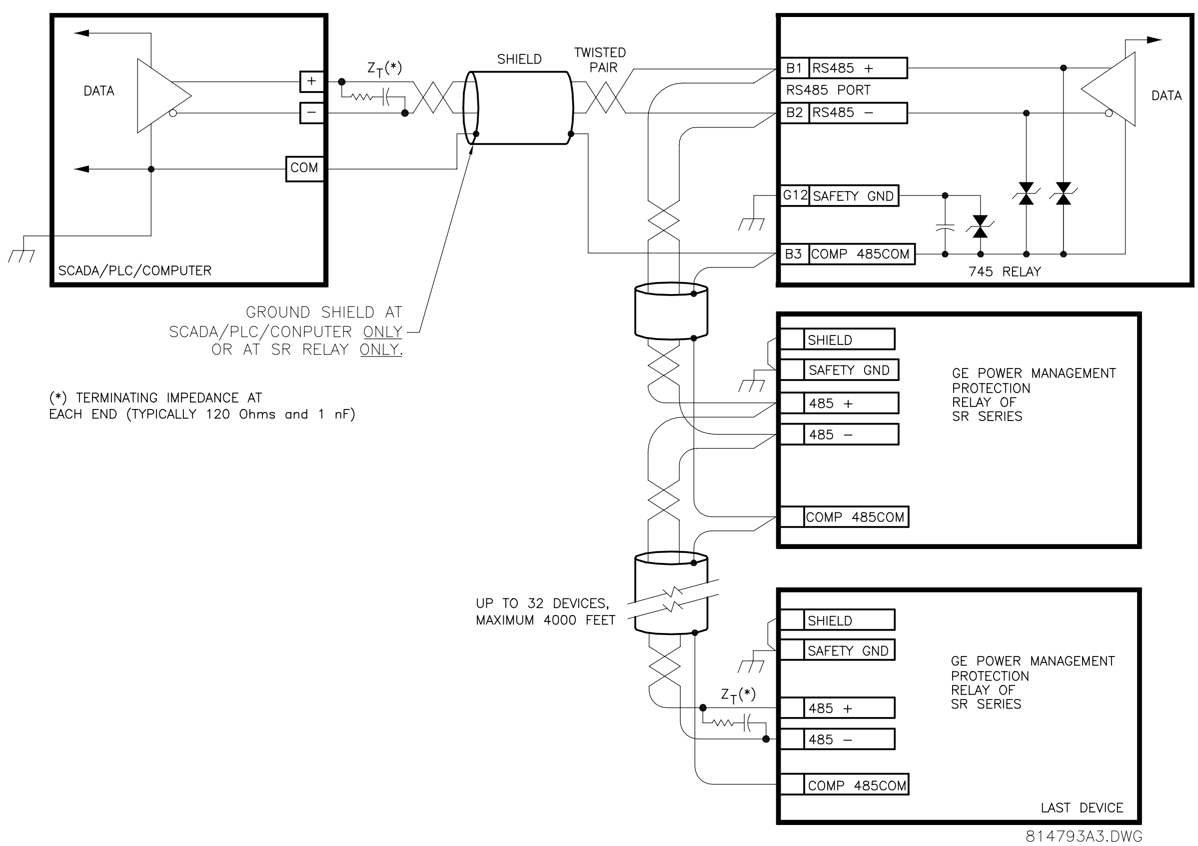


Figure 3–13: RS485 CONNECTION

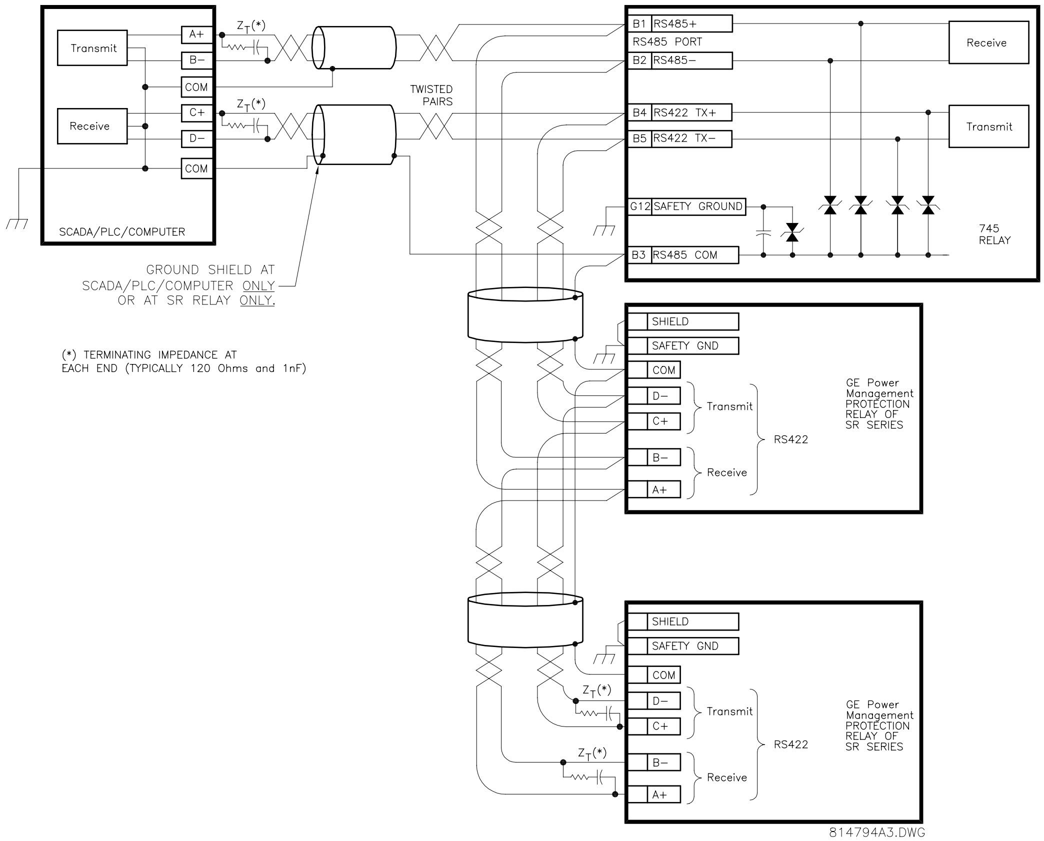


Figure 3–14: RS422 CONNECTION

3.2.17 RS232 FRONT PANEL PROGRAM PORT

A 9 pin RS232C serial port is located on the front panel for programming through a PC. This port uses the same Modbus protocol as the two rear ports. The 745PC software required to use this interface is included with the relay. Cabling for the RS232 port is shown below for both 9 pin and 25 pin connectors.

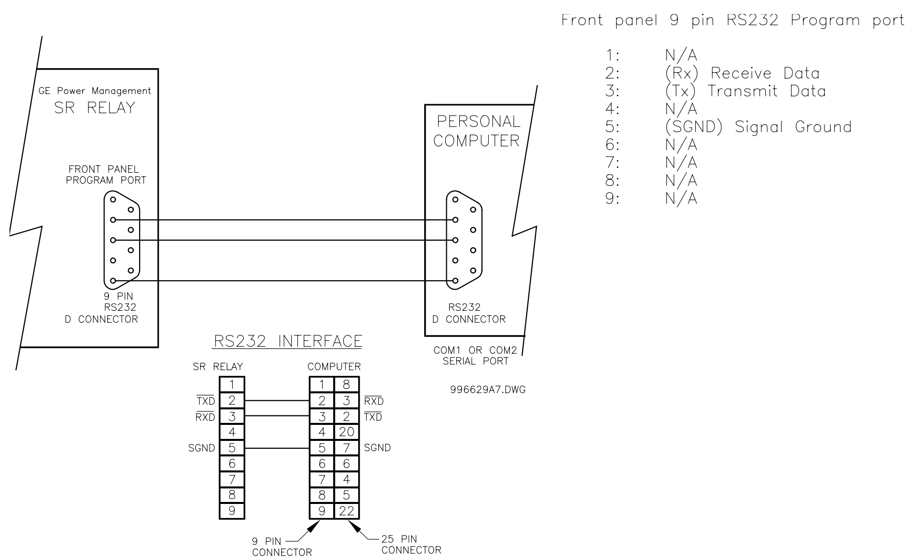


Figure 3–15: RS232 CONNECTION

3.2.18 IRIG-B

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within 1 millisecond. The IRIG time code formats are serial, width-modulated codes which can be either DC level shifted or amplitude modulated (AM). Third party equipment is available for generating the IRIG-B signal; this equipment may use a GPS satellite system to obtain the time reference so that devices at different geographic locations can also be synchronized.

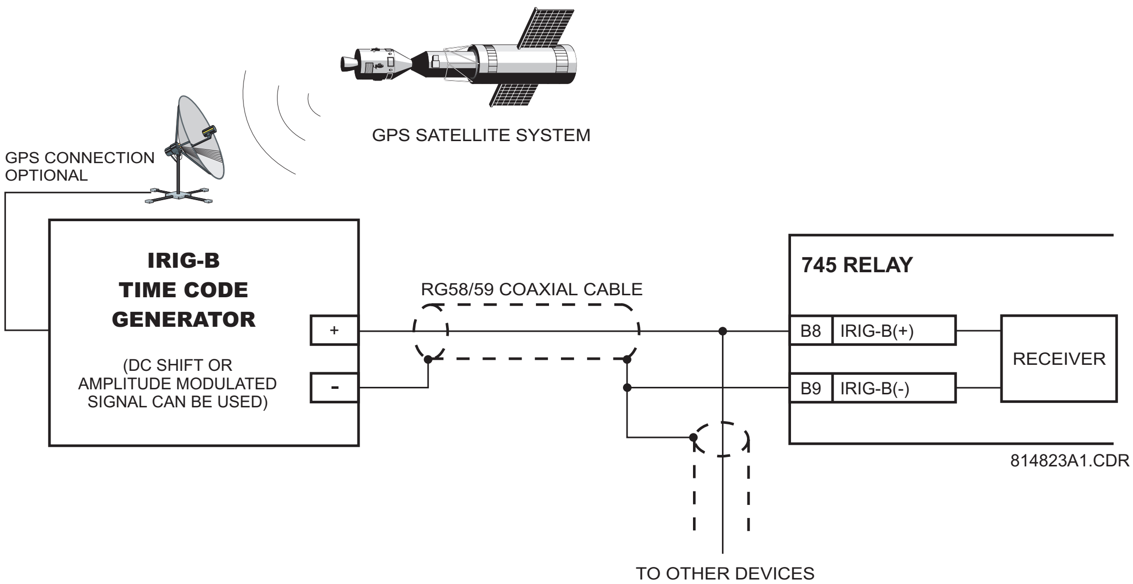


Figure 3–16: IRIG-B FUNCTION

3.2.19 DIELECTRIC STRENGTH TESTING

Dielectric strength test was performed on the 745 relay at the manufacturer. It is not necessary to perform this test again at the customer site. However, if you wish to perform this test, follow instructions outlined in Section 10.3.2: DIELECTRIC STRENGTH TESTING on page 10–5.

NOTE

No special ventilation requirements need to be observed during the installation of the unit. The unit does not have to be cleaned.

WARNING

Hazard may result if the product is not used for its intended purpose.

4.1.1 DESCRIPTION

The front panel provides a local operator interface with a vacuum fluorescent display, LED status indicators, control keys, and program port. The display and status indicators update alarm and status information automatically. The control keys are used to select the appropriate message for entering setpoints or displaying measured values. The RS232 program port is also provided for connection with a computer running the 745PC software.

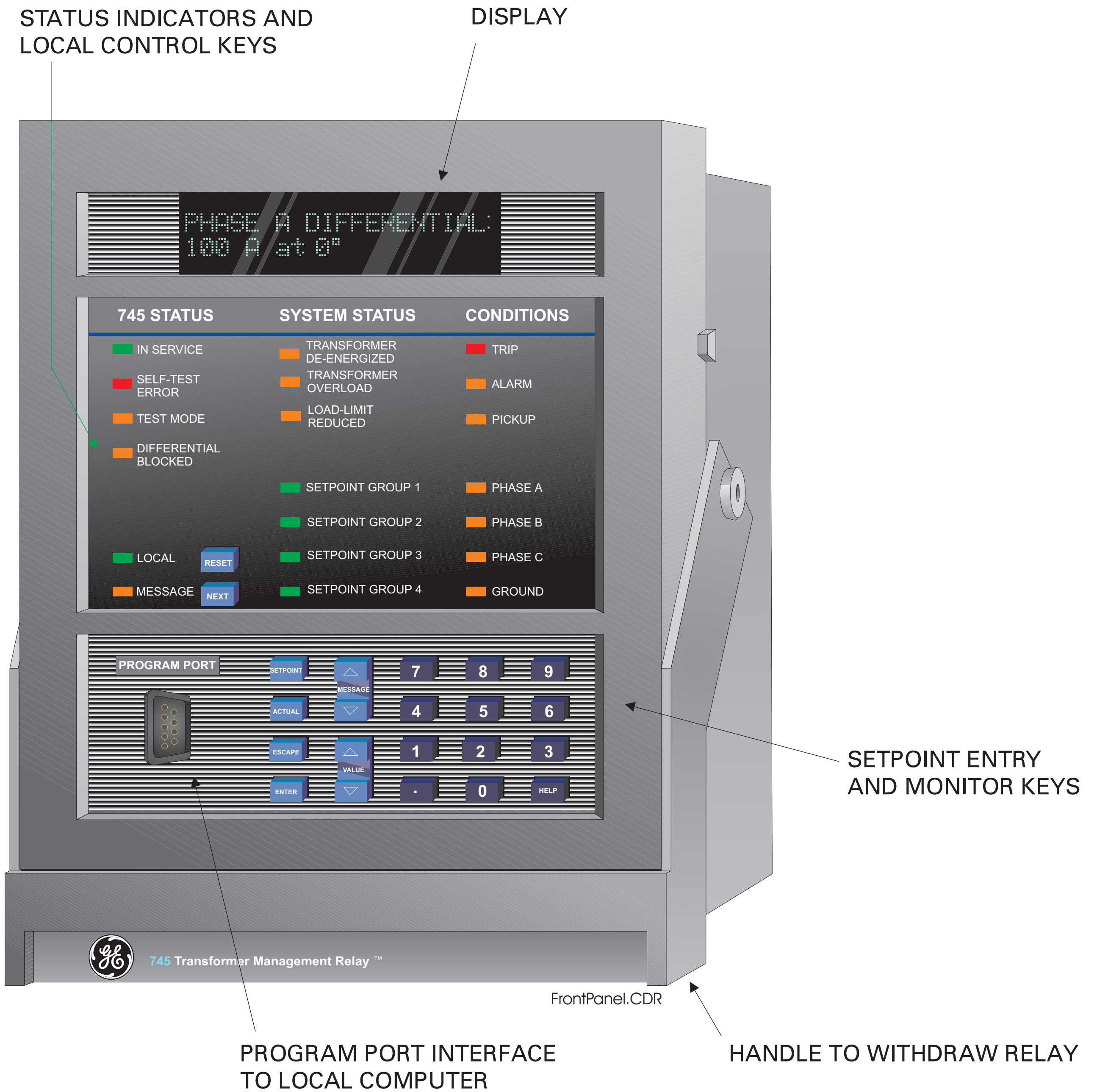


Figure 4–1: 745 FRONT PANEL

4.2.1 DISPLAY

All messages are displayed in English on the 40-character vacuum fluorescent display, which is visible under varied lighting conditions. When the keypad and display are not actively being used, the screen sequentially displays up to 30 user-selected default messages providing system information. These messages appear after a time of inactivity that is programmable by the user. Pressing any key after default messages have appeared will return the display to the last message displayed before the default messages appeared. Trip and alarm condition messages automatically override default messages. All display pixels are illuminated briefly during power up self-testing, and can be energized by pressing NEXT when no trips or alarms are active.

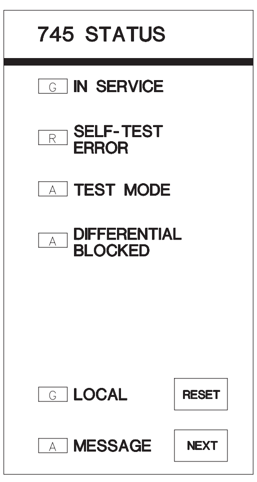
4.2.2 LEDS

Front panel indicators are grouped in three columns: RELAY STATUS, which provides information about the state of the 745; SYSTEM STATUS, which provides information about the state of the transformer and the power system; and CONDITIONS, which provides details about abnormal conditions that have been detected. The color of each indicator conveys information about its importance:

GREEN (G)	indicates a general condition
AMBER (A)	indicates an alert condition
RED (R)	indicates a serious alarm or warning

All indicators can be tested by pressing NEXT while no conditions are active.

4.2.3 STATUS INDICATORS



a) IN SERVICE

The IN SERVICE indicator is on when relay protection is operational.

The indicator is on only if all of the following conditions are met:

- **S1 745 SETUP / INSTALLATION / 745 SETPOINTS:** Programmed
- **S6 TESTING / OUTPUT RELAYS / FORCE OUTPUT RELAYS FUNCTION:** Disabled
- **S6 TESTING / SIMULATION / SIMULATION SETUP / SIMULATION FUNCTION:** Disabled
- No self-test errors which have an effect on protection have been detected
- code programming mode is inactive
- factory service mode is disabled

b) SELF-TEST ERROR

The SELF-TEST ERROR indicator is on when any of the self-diagnostic tests, performed either at power-on or in the background during normal operation, has detected a problem with the relay.

c) TEST MODE

The TEST MODE indicator is on when any of the 745 testing features has been enabled.

The indicator is on if any of the following conditions are met:

- **S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT RELAYS FUNCTION:** Enabled
- **S6 TESTING/ANALOG OUTPUTS/FORCE ANALOG OUTPUTS FUNCTION:** Enabled
- **S6 TESTING/SIMULATION/SIMULATION SETUP/SIMULATION FUNCTION:** Prefault Mode / Fault Mode / Playback Mode
- factory service mode is enabled

d) DIFFERENTIAL BLOCKED

The DIFFERENTIAL BLOCKED indicator is on when the restrained differential protection feature is enabled but is being blocked from operating by any of the harmonic restraint features.

The indicator is on if the following condition is met:

- **S4 ELEMENTS / DIFFERENTIAL / HARMONIC RESTRAINT** is blocking any phase (see scheme logic)

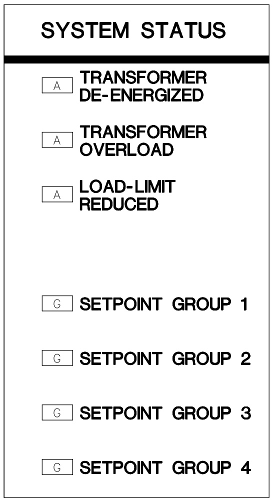
e) LOCAL

The LOCAL indicator is on when the 745 is in local mode, i.e. the front panel RESET key is operational.

f) MESSAGE

The MESSAGE indicator is on when any element has picked up, operated, or is now in a latched state waiting to be reset. With this indicator on, the front panel display is sequentially displaying information about each element that has detected an abnormal condition.

4.2.4 SYSTEM STATUS INDICATORS



814766A9.DWG

a) TRANSFORMER DE-ENERGIZED

The TRANSFORMER DE-ENERGIZED indicator is on when the energization inhibit feature has detected that the transformer is de-energized.

The indicator is on if the **S4 ELEMENTS/DIFFERENTIAL/ENERGIZATN INHIBIT** feature is detecting the transformer as de-energized

b) TRANSFORMER OVERLOAD

The TRANSFORMER OVERLOAD indicator is on when **S4 ELEMENTS/XFORMER OVERLOAD** has operated.

c) LOAD-LIMIT REDUCED

The LOAD-LIMIT REDUCED indicator is on when the adaptive harmonic factor correction feature is detecting enough harmonic content to reduce the load rating of the transformer. The indicator is on if **S2 SYSTEM SETUP/HARMONIC DERATING/HARMONIC DERATING ESTIMATION** is Enabled and the harmonic derating function is below 0.96.

d) SETPOINT GROUP 1

The SETPOINT GROUP 1 indicator is on when the active setpoint group is 1. This indicator flashes when this setpoint group is being edited.

e) SETPOINT GROUP 2

The SETPOINT GROUP 2 indicator is on when the active setpoint group is 2. This indicator flashes when this setpoint group is being edited.

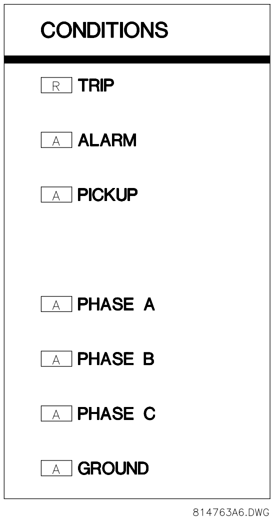
f) SETPOINT GROUP 3

The SETPOINT GROUP 3 indicator is on when the active setpoint group is 3. This indicator flashes when this setpoint group is being edited.

g) SETPOINT GROUP 4

The SETPOINT GROUP 4 indicator is on when the active setpoint group is 4. This indicator flashes when this setpoint group is being edited.

4.2.5 CONDITION INDICATORS



a) TRIP

The TRIP indicator is on when any output relay selected to be of the Trip type has operated.

b) ALARM

The ALARM indicator is on when any output relay selected to be of the Alarm type has operated.

c) PICKUP

The PICKUP indicator is on when any element has picked up. With this indicator on, the front panel display is sequentially displaying information about each element that has picked up.

d) PHASE A (B/C)

The PHASE A (B/C) indicator is on when phase A (B/C) is involved in the condition detected by any element that has picked up, operated, or is now in a latched state waiting to be reset.

e) GROUND

The GROUND indicator is on when ground is involved in the condition detected by any element that has picked up, operated, or is now in a latched state waiting to be reset.

4.2.6 PROGRAM PORT

Use the front panel program port for RS232 communications with the 745. As described in Section 3.2.17: RS232 FRONT PANEL PROGRAM PORT on page 3–13, all that is required is a connection between the relay and a computer running the 745PC software. For continuous monitoring of multiple relays, either the COM1 RS485/RS422 port or the COM2 RS485 port should be used.

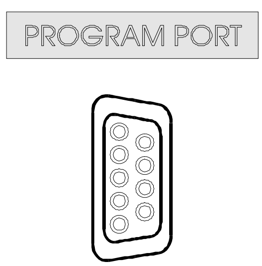


Figure 4–2: PROGRAM PORT

4.3.1 SETPOINT KEY

Setpoints are arranged into groups of related messages called setpoint pages. Each time SETPOINT is pressed, the display advances to the first message of the next setpoints page. Pressing SETPOINT while in the middle of a setpoints page advances the display to the beginning of the next setpoint page. Pressing SETPOINT while in the middle of an actual values page returns the display to the last setpoint message viewed. If the display has timed out to the default messages, pressing SETPOINT returns the display to the last viewed setpoint message. The MESSAGE ▲ / MESSAGE ▼ keys move between messages within a page.

4.3.2 ACTUAL KEY

Measured values and collected data messages are arranged into groups of related messages called actual values pages. Each time ACTUAL is pressed, the display advances to the first message of the next actual values page. Pressing ACTUAL while in the middle of an actual values page advances the display to the beginning of the next page. Pressing ACTUAL while in the middle of a setpoints page returns the display to the last actual values message viewed. If the display has timed out to the default messages, pressing ACTUAL returns the display to the last viewed actual values message. The MESSAGE ▲ / MESSAGE ▼ keys move between messages within a page.

4.3.3 ESCAPE KEY

The ESCAPE key is context-sensitive. The response depends on the message displayed and the relay status. If a value is edited incorrectly during programming, pressing ESCAPE before pressing ENTER restores the original setpoint value. In other situations, ESCAPE moves the display to the next higher header message. This continues until the current sub-header is reached.

4.3.4 ENTER KEY

The context-sensitive ENTER key response depends on the displayed message and the relay status. While displaying a sub-header whose lower line reads [ENTER] for more, press ENTER to enter the group of messages associated with the upper line. After editing setpoints numerically or with VALUE ▲ / VALUE ▼, press ENTER to store a new value in memory. Setpoint access must be allowed for this operation to succeed. The current message can also be made a default message by pressing the key sequence: **[.]** ENTER ENTER

4.3.5 MESSAGE UP/DOWN KEY

The MESSAGE ▲ / MESSAGE ▼ keys move through messages within a page. MESSAGE ▲ scrolls upward through a list of messages while MESSAGE ▼ scrolls downward through the list.

4.3.6 VALUE UP/DOWN KEY

Setpoint values are entered using VALUE ▲ / VALUE ▼ or the numeric keys. It is generally easier to enter numeric values using the number keys and multiple choice selections with VALUE ▲ / VALUE ▼. When a setpoint calls for a yes/no response, pressing VALUE ▲ or VALUE ▼ toggles the value between yes and no. For multiple choice selections, pressing VALUE ▲ or VALUE ▼ displays the next choice. For numeric setpoints, pressing VALUE ▲ increases the value by its step increment. When the maximum value is reached, setpoint selection continues from the minimum value. Each time VALUE ▼ is pressed, the value decreases by its step increment. When the minimum value is reached, setpoint selection continues from the maximum value. Press and hold the value keys down to rapidly change values.

4.3.7 NUMBER KEYS

Number keys are used for direct entry of numeric setpoint values. Thus, enter 27.3 as 2, 7, ., 3. Each key toggles the display between the corresponding number and a hyphen.

4.3.8 HELP KEY

Press HELP to display a sequence of context-sensitive help messages that automatically advance every few seconds. After the last message is displayed, the screen returns to the originally displayed message. Press HELP during the sequence to immediately display the next message. Any other key returns to the normally displayed message.

4.3.9 RESET KEY

This key is operational when the 745 is in local mode. In local mode, RESET puts all latched relays to the non-operated state and clears latched targets if initiating conditions are no longer present.

4.3.10 NEXT KEY

If a target becomes active, a diagnostic message overrides the displayed message and the MESSAGE indicator flashes. If there is more than one target active, NEXT scrolls through the messages. Pressing any other key returns to the normally displayed messages. While viewing the normally displayed messages, the MESSAGE indicator continues to flash if any diagnostic message is active. To return to the diagnostic messages from the normally displayed messages, press the NEXT key.

Note that diagnostic messages for self-resetting targets disappear with the condition, but diagnostic messages for latched targets remain until they are cleared. When no targets are active, NEXT illuminates all front panel indicators for approximately 5 seconds.

5.1.1 SETPOINT GROUPS

The 745 relay has a considerable number of programmable settings (setpoints) which makes it extremely flexible. The setpoints have been grouped into a number of pages as shown below. If using the 745PC software and not connected to a relay, you may have to select the **File > Properties** menu item and set the correct options for your relay.

```
▌▌SETPOINTS
▌▌S1 745 SETUP
```

- Passcode
- Preferences (beeper, flash and default messages)
- Communications (address, COM1 and COM2 parity / hardware type / baud rate)
- Resetting
- Clock
- Default Messages
- Scratch Pad
- Installation
- Upgrade options

```
▌▌SETPOINTS
▌▌S2 SYSTEM SETUP
```

- Transformer
- Windings 1, 2, and 3
- Onload Tap Changer
- Harmonics
- FlexCurves
- Voltage Input
- Ambient Temperature
- Analog Input
- Demand Metering
- Analog Outputs

```
▌▌SETPOINTS
▌▌S3 LOGIC INPUTS
```

- Logic Inputs 1 to 16
- Virtual Inputs 1 to 16

```
▌▌SETPOINTS
▌▌S4 ELEMENTS
```

- Setpoint Group (active group and edit group)
- Differential (percent differential; harmonic, energization, & 5th harmonic inhibits)
- Instantaneous Differential
- Phase Overcurrent (time and instantaneous for all windings)
- Neutral Overcurrent (time and instantaneous for all windings)
- Ground Overcurrent (time and instantaneous for all WYE windings)
- Restricted Ground Fault (time and instantaneous for all windings)
- Negative Sequence (time and instantaneous for all windings)
- Frequency (underfrequency, frequency decay, and overfrequency)
- Overexcitation (5th harmonic level and volts-per-hertz)
- Harmonics (for all windings)
- Insulation aging
- Analog Input
- Current Demand (for all windings)
- Transformer Overload
- Tap changer failure

```
▌▌SETPOINTS
▌▌S5 OUTPUTS
```

- Output Relays
- Trace Memory Triggering
- Virtual Outputs
- Timers

```
▌▌SETPOINTS
▌▌S6 TESTING
```

- Output Relays (Forcing)
- Analog Outputs (Forcing)
- Simulation
- Factory Service

5

5.1.2 SETPOINT ENTRY

Prior to commissioning the 745 relay, setpoints defining transformer characteristics, inputs, output relays, and protection settings must be entered, via one of the following methods:

- Front panel, using the keypad and display.
- Front RS232 or rear terminal RS485/RS422 communication ports, and a portable computer running the 745PC software or a SCADA system running user-written software.

Any of these methods can be used to enter the same information. A computer, however, makes entry much easier. Files can be stored and downloaded for fast, error free entry when a computer is used. Settings files can be prepared and stored on disk without the need to connect to a relay.

All setpoint messages are illustrated and described in blocks throughout this chapter. *The 745 relay leaves the factory with setpoints programmed to default values, and it is these values that are shown in all the setpoint message illustrations.* Some of these factory default values can be left unchanged.

There are many 745 setpoints that must be entered for the relay to function correctly. In order to safeguard against installation when these setpoints have not been entered, the 745 does not allow signaling of any output relay. In addition, the IN SERVICE indicator is off and the SELF-TEST ERROR indicator on until the setpoint **S1 745 SETUP/INSTALLATION/745 SETPOINTS** is set to Programmed. This setpoint is defaulted to Not Programmed when the relay leaves the factory. The following diagnostic message appears until the 745 is put in the programmed state:

5

```
SETPOINTS HAVE NOT
BEEN PROGRAMMED
```

Messages may vary somewhat from those illustrated because of installed options. Also, some messages associated with disabled features (or optional features which have not been ordered) are hidden. *These messages are shown with a shaded message box.*

- **KEYPAD ENTRY**: See Section 2.1: USING THE FRONT PANEL DISPLAY on page 2–1 for details on maneuvering through the messages, viewing actual values, and changing setpoints.
- **COMPUTER ENTRY**: Setpoint values are grouped together on a screen in the 745PC software. The data is organized in a system of menus. See the Chapter 9: 745PC SOFTWARE for details.
- **SCADA ENTRY**: Details of the complete communication protocol for reading and writing setpoints are given in Chapters 8 and 9. A programmable SCADA system connected to the RS485/RS422 terminals can make use of communication commands for remote setpoint programming, monitoring, and control.

5.1.3 SETPOINT WRITE ACCESS

The 745 design incorporates hardware and passcode security features to provide protection against unauthorized setpoint changes.

A hardware jumper must be installed across the setpoint access terminals on the back of the relay to program new setpoints using the front panel keys. When setpoint programming is via a computer connected to the communication ports, no setpoint access jumper is required.

Passcode protection may also be enabled. When enabled, the 745 requests a numeric passcode before any setpoint can be entered. As an additional safety measure, a minor self-test error is generated when the passcode is entered incorrectly three times in a row.

5.2.1 DESCRIPTION

For transformer differential protection, it is necessary to correct the magnitude and phase relationships of the CT secondary currents for each winding, in order to obtain near zero differential currents under normal operating conditions. Traditionally, this has been accomplished using interposing CTs or tapped relay windings and compensating CT connections at the transformer.

The 745 simplifies CT configuration issues by having all CTs connected Wye (polarity markings pointing away from the transformer). All phase angle and magnitude corrections, as well as zero-sequence current compensation, are performed automatically based upon user entered setpoints.

This section describes the process of auto-configuration by means of a specific example, showing how CT ratios, transformer voltage ratios, and the transformer phase shifts are used to generate correction factors. These correction factors are applied to the current signals to obtain extremely accurate differential currents.

5.2.2 A TYPICAL POWER TRANSFORMER

Consider a WYE-DELTA power transformer with the following data:

Connection:	Y/d30° (i.e. DELTA winding phases lag corresponding WYE winding phases by 30°)
Winding 1:	100/133/166 MVA, 220 kV nominal, 500/1 CT ratio
Winding 2:	100/133/166 MVA, 69 kV nominal, 1500/1 CT ratio onload tap changer: 61 to 77 kV in 0.5 kV steps (33 tap positions)
Aux. Cooling:	two stages of forced air

5.2.3 DYNAMIC CT RATIO MISMATCH CORRECTION

a) PROBLEM 1:USE OF STANDARD CT RATIOS

- Standard CT ratios: CT_2 / CT_1=V_1 / V_2
- Tapped relay windings / interposing CTs (inaccurate/expensive)

Solution:

- WxNom Voltage, Wx rated Load, Wx CT primary setpoints
- Automatic correction for mismatch: $(CT_2 \times V_2) / (CT_1 \times V_1) < 16$

Example:

Even ignoring the onload tap changer, the 1500/1 CT on Winding 2 does not perfectly match the 500/1 CT on Winding 1. A perfectly matched Winding 2 CT ratio (at nominal Winding 2 voltage) is calculated as follows:

$$CT_2 \text{ (ideal)} = CT_1 \times \frac{V_1}{V_2} = \frac{500}{1} \times \frac{220 \text{ kV}}{69 \text{ kV}} = \frac{1594.2}{1}$$

where CT_1 = Winding 1 CT ratio
V_1 = Winding 1 nominal voltage
CT_2 = Winding 2 CT ratio
V_2 = Winding 2 nominal voltage

Thus, for any load, the Winding 2 CT secondary current is higher (per unit) than the Winding 1 CT secondary current. The mismatch factor is 1594.2 / 1500 = 1.063.

745 Solution:

The transformer type is entered as the setpoint **S2 SYSTEM SETUP/TRANSFORMER/TRANSFORMER TYPE**. The 745 calculates and automatically corrects for CT mismatch to a maximum mismatch factor of 16. The following information is entered as setpoints:

Under **S2 SYSTEM SETUP / WINDING 1:**

```
WINDING 1 NOM Φ-Φ
VOLTAGE: 220.0 kV
```

```
WINDING 1 RATED
LOAD: 100 MVA
```

```
WINDING 1 PHASE CT
PRIMARY: 500:1 A
```

Under **S2 / SYSTEM SETUP / WINDING 2:**

```
WINDING 2 NOM Φ-Φ
VOLTAGE: 69.0 kV
```

```
WINDING 2 RATED
LOAD: 100 MVA
```

```
WINDING 2 PHASE CT
PRIMARY: 1500:1 A
```

For a 3-winding transformer, the setpoints under **S2 SYSTEM SETUP/WINDING 3** must also be set.

b) PROBLEM 2: ONLOAD TAP CHANGER

- Onload tap changer
- Variable voltage ratio
- $CT_2 / CT_1 = V_1 / V_2$
- Lower sensitivity on differential element

5

Solution:

- Tap position monitoring

$V_2 = V_{min} + (n - 1)V_{incr}$

Example:

The onload tap changer changes the Winding 2 voltage, resulting in an even greater CT mismatch. A perfectly matched Winding 2 CT ratio (based on the tap changer position) is calculated as follows:

$$CT_2\ (\text{ideal}) = CT_1 \times \frac{V_1}{V_{2(\min)} + V_{2(\text{tap})}(n-1)} = \frac{500}{1} \times \frac{220}{61 + 0.5(n-1)}$$

where n = current tap changer position
$V_{2(\min)}$ = Winding 2 minimum voltage (at n = 1)
$V_{2(\text{tap})}$ = Winding 2 voltage increment per tap

Thus, with the tap changer at position 33, the Winding 2 CT ratio must be 1428.6 / 1 to be perfectly matched. In this case, the mismatch factor is 1428.6 / 1500 = 0.952.

745 Solution:

The 745 allows monitoring of the tap changer position via the tap position input. With this input, the 745 dynamically adjusts the CT ratio mismatch factor based on the actual transformer voltage ratio set by the tap changer.

Tap changers are operated by means of a motor drive unit mounted on the outside of the transformer tank. The motor drive is placed in a protective housing containing all devices necessary for operation, including a tap position indication circuit. This indication circuit has a terminal for each tap with a fixed resistive increment per tap. A cam from the drive shaft that provides local tap position indication also controls a wiper terminal in the indication circuit, as illustrated below.

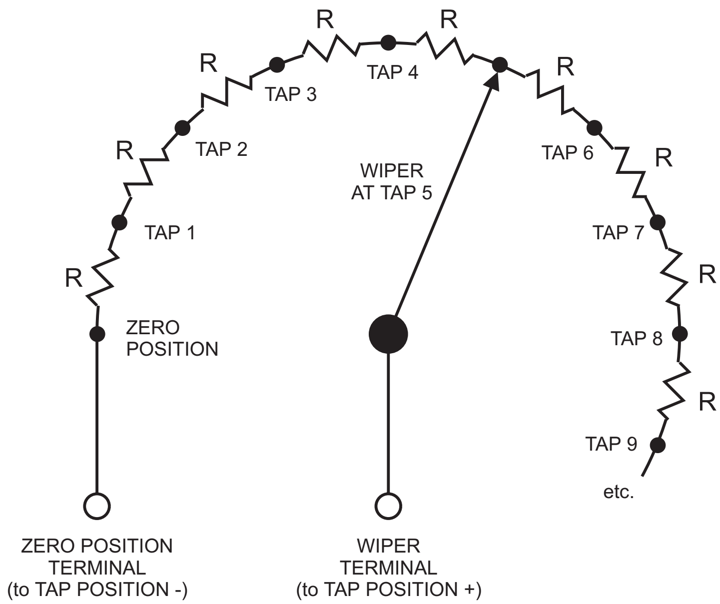


Figure 5–1: TAP POSITION INPUT

The “zero position” terminal and the “wiper” terminal of the tap position circuit are connected to the positive and negative 745 tap position terminals. Polarity is not consequential. The following setpoints configure the 745 to determine tap position.

Under **S2 SYSTEM SETUP** / **ONLOAD TAP CHANGER**:

```
WINDING WITH TAP
CHANGER: Winding 2
```

```
NUMBER OF TAP
POSITIONS: 33
```

```
MINIMUM TAP POSITION
VOLTAGE: 61.0 kV
```

```
VOLTAGE INCREMENT
PER TAP: 0.50 kV
```

```
RESISTANCE INCREMENT
PER TAP: 33 Ω
```

Maximum value resistance on top tap is 5 KΩ

5

5.2.4 PHASE SHIFTS ON THREE-PHASE TRANSFORMERS

Power transformers that are built in accordance with ANSI and IEC standards are required to identify winding terminals and phase relationships among the windings of the transformer.

ANSI standard C.37.12.70 requires that the labels of the terminals include the characters 1, 2, and 3 to represent the names of the individual phases. The phase relationship among the windings must be shown as a phasor diagram on the nameplate, with the winding terminals clearly labeled. This standard specifically states that the phase relationships are established for a condition where the source phase sequence of 1-2-3 is connected to transformer windings labeled 1, 2 and 3 respectively.

IEC standard 60076-1 (1993) states that the terminal markings of the three phases follow national practice. The phase relationship among the windings is shown as a specified notation on the nameplate, and there may be a phasor diagram. In this standard the arbitrary labeling of the windings is shown as I, II, and III. This standard specifically states that the phase relationships are established for a condition where a source phase sequence of I - II - III is connected to transformer windings labeled I, II and III respectively.

The source phase sequence must be stated when describing the winding phase relationships since these relationships change when the phase sequence changes. The example below shows why this happens, using a transformer described in IEC nomenclature as "Yd1" or in GE Power Management nomenclature as "Y/d30."

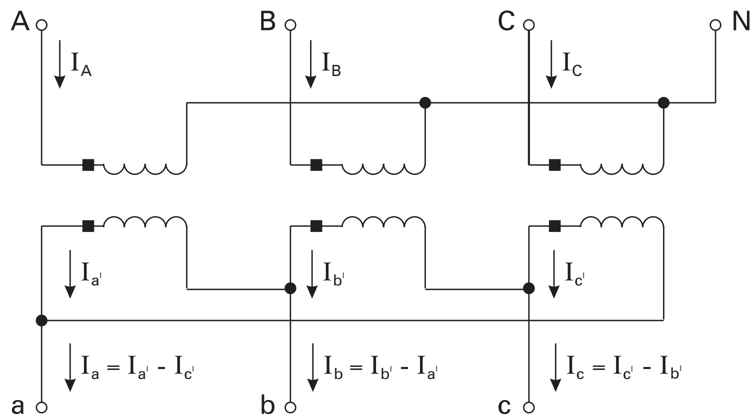


Figure 5–2: EXAMPLE TRANSFORMER

The above figure shows the physical connections within the transformer that produce a phase angle in the delta winding that lags the respective wye winding by 30°. The winding currents are also identified. Note that the total current out of the delta winding is described by an equation. Now assume that a source, with a sequence of ABC, is connected to transformer terminals ABC, respectively. The currents that would be present for a balanced load are shown below.

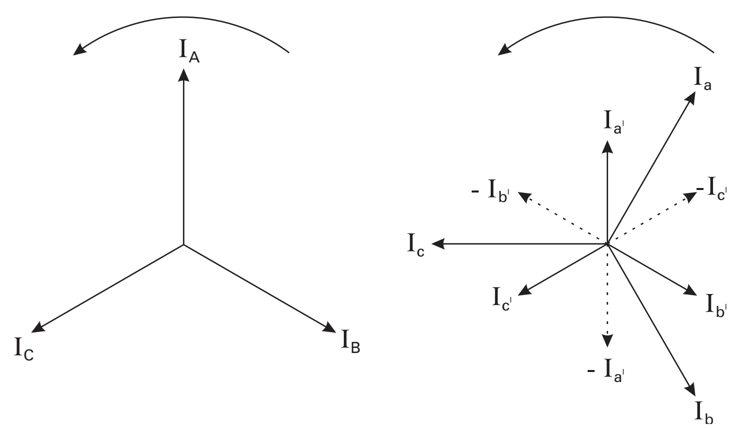


Figure 5–3: PHASORS FOR ABC SEQUENCE

Note that the Delta winding currents lag the Wye winding currents by 30°, which is in agreement with the transformer nameplate.

Now assume that a source, with a sequence of ACB is connected to transformer terminals A, C, B respectively. The currents that would be present for a balanced load are shown below:

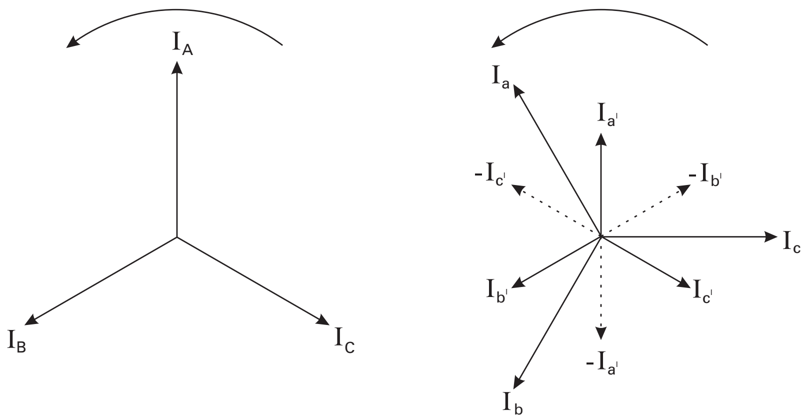


Figure 5–4: PHASORS FOR ACB SEQUENCE

Note that the Delta winding currents leads the Wye winding currents by 30°, (which is a type Yd11 in IEC nomenclature and a type Y/d330 in GE Power Management nomenclature) which is in disagreement with the transformer nameplate. This is because the physical connections and hence the equations used to calculate current for the delta winding have not changed. The transformer nameplate phase relationship information is only correct for a stated phase sequence.

It may be suggested that for the ACB sequence the phase relationship can be returned to that shown on the transformer nameplate by connecting source phases A, B and C to transformer terminals A, C, and B respectively. This will restore the nameplate phase shifts but will cause incorrect identification of phases B and C within the relay, and is therefore not recommended.

All information presented in this manual is based on connecting the relay phase A, B and C terminals to the power system phases A, B and C respectively. The transformer types and phase relationships presented are for a system phase sequence of ABC, in accordance with the standards for power transformers. Users with a system phase sequence of ACB must determine the transformer type for this sequence.

5.2.5 PHASE ANGLE CORRECTION

The following diagram shows the internal connections of the Y/d30° transformer of our example:

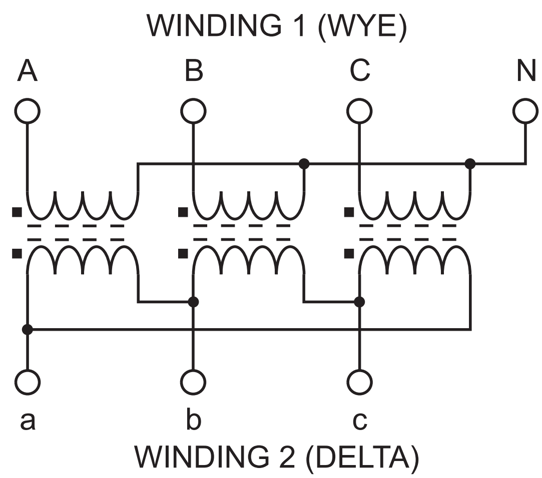


Figure 5–5: WYE / DELTA (30° LAG) TRANSFORMER

Under balanced conditions, the Winding 2 phase current phasors lag the corresponding phase current phasors of Winding 1 by 30°. With CTs connected in a Wye arrangement (polarity markings pointing away from the transformer), the corresponding phase currents cannot be summed directly to obtain a zero differential current, since corresponding phasors will NOT be 180° out-of-phase.

Traditionally, this problem is solved by connecting the CTs on the WYE side of the transformer (Winding 1) in a Delta arrangement. This compensates for the phase angle lag introduced in the Delta side (Winding 2).

The 745 performs this phase angle correction internally based on the following setpoint. Under **S2 SYSTEM SETUP/TRANSFORMER**, set:

```
TRANSFORMER TYPE:
Y/d30°
```

The 745 supports over 100 two and three-winding transformer types. Table 5–1: TRANSFORMER TYPES on page 5–10 provides the following information about each transformer type:

transformer type notation as it appears on the display

winding connection (wye, delta, or zig-zag) and ground CT assignment

angle by which a winding lags Winding 1

diagrams showing the phase relationship of voltage phasors, where ↑ (the arrow head) indicates the reference phase

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d30°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°

phase angle correction (or phase shift) that is performed internally to calculate differential currents

As shown in the ‘Y/d30°’ entry of the table of transformer types, the phase angle correction (or phase shift) introduces 30° lag in Winding 1. This lag is described in Table 5–2: PHASE SHIFTS on page 5–23. This table provides the following information about each phase shift type:

the phase shift as it appears in the table of transformer types

the phasors before the phase shift is applied (A/B/C)

the phasors after the phase shift is applies (a/b/c/)

the equations used to achieve the phase shift (A/B/C → a/b/c)

PHASE SHIFT	INPUT PHASORS	OUTPUT PHASORS	PHASOR TRANSFORMATION
30° lag			a = (A – C) / √3 b = (B – A) / √3 c = (C – B) / √3

5.2.6 ZERO-SEQUENCE COMPONENT REMOVAL

1. If zero-sequence current can flow into and out of one transformer winding (e.g. a grounded Wye or zig-zag winding) but not the other winding (e.g. a Delta winding), external ground faults will cause the differential element to operate incorrectly. Traditionally, this problem is solved by Delta connecting the CTs on the Wye side of a Wye/Delta transformer so that the currents coming to the relay are both phase corrected and void of zero-sequence current. Because the 745 software mimics the CT Delta connection, the zero-sequence current is automatically removed from all Wye or zig-zag winding currents of transformers having at least one delta winding.
2. External ground faults also cause maloperation of the differential element for transformers having an in-zone grounding bank on the Delta side (and the Wye connected CTs on the same side). Traditionally, this problem is solved by inserting a zero-sequence current trap in the CT circuitry. The 745 automatically removes zero-sequence current from all Delta winding currents when calculating differential current. Where there is no source of zero-sequence current (e.g. Delta windings not having a grounding bank), the 745 effectively removes nothing.
3. Autotransformers have an internal tertiary winding to provide a path for third-harmonic currents and control transient overvoltages. Also, many two-winding Wye/Wye transformers have a three-legged core construction that forces zero-sequence flux into the transformer tank, creating an inherent Delta circuit. In both these cases, there is zero-sequence impedance between the primary and secondary windings. The 745 removes zero-sequence current from all windings of Wye/Wye and Wye/Wye/Wye transformers to prevent possible relay maloperations resulting from these two conditions.

5.2.7 TRANSFORMER TYPES TABLE

Table 5–1: TRANSFORMER TYPES (Sheet 1 of 26)

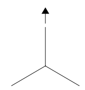
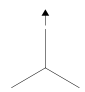
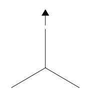
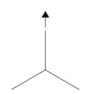
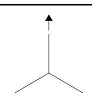
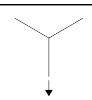
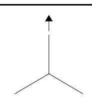
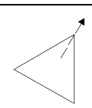
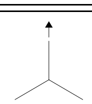
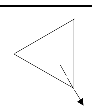
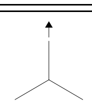
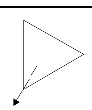
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
2W External Correction	1	WYE (gnd 1/2)		0°
	2	WYE (gnd 2/3) 0°		0°
Y/y0°	1	WYE (gnd 1/2)		0°
	2	WYE (gnd 2/3) 0°		0°
Y/y180°	1	WYE (gnd 1/2)		180° lag
	2	WYE (gnd 2/3) 180° lag		0°
Y/d30°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
Y/d150°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
Y/d210°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 2 of 26)

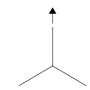
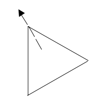
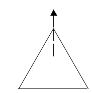
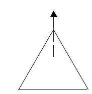
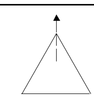
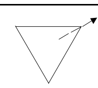
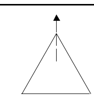
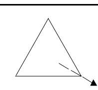
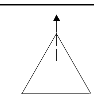
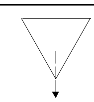
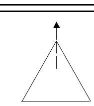
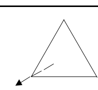
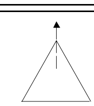
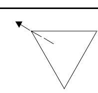
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d330°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
D/d0°	1	DELTA		0°
	2	DELTA 0°		0°
D/d60°	1	DELTA		60° lag
	2	DELTA 60° lag		0°
D/d120°	1	DELTA		120° lag
	2	DELTA 120° lag		0°
D/d180°	1	DELTA		180° lag
	2	DELTA 180° lag		0°
D/d240°	1	DELTA		240° lag
	2	DELTA 240° lag		0°
D/d300°	1	DELTA		300° lag
	2	DELTA 300° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 3 of 26)

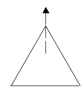
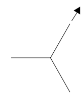
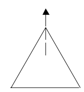
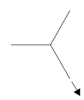
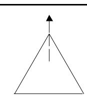
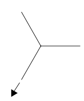
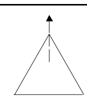
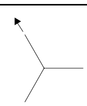
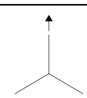
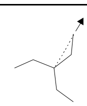
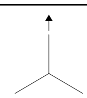
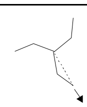
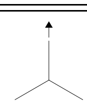
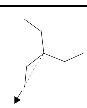
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y30°	1	DELTA		0°
	2	WYE (gnd 1/2) 30° lag		330° lag
D/y150°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
D/y210°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
D/y330°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
Y/z30°	1	WYE (gnd 1/2)		30° lag
	2	ZIG-ZAG (gnd 2/3) 30° lag		0°
Y/z150°	1	WYE (gnd 1/2)		150° lag
	2	ZIG-ZAG (gnd 2/3) 150° lag		0°
Y/z210°	1	WYE (gnd 1/2)		210° lag
	2	ZIG-ZAG (gnd 2/3) 210° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 4 of 26)

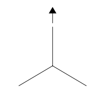
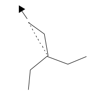
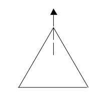
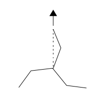
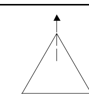
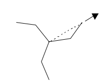
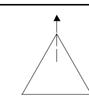
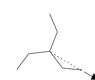
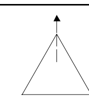
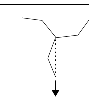
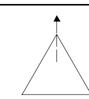
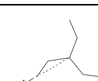
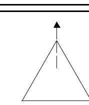
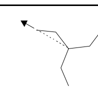
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/z330°	1	WYE (gnd 1/2)		330° lag
	2	ZIG-ZAG (gnd 2/3) 330° lag		0°
D/z0°	1	DELTA		0°
	2	ZIG-ZAG (gnd 1/2) 0° lag		0°
D/z60°	1	DELTA		60° lag
	2	ZIG-ZAG (gnd 1/2) 60° lag		0°
D/z120°	1	DELTA		120° lag
	2	ZIG-ZAG (gnd 1/2) 120° lag		0°
D/z180°	1	DELTA		180° lag
	2	ZIG-ZAG (gnd 1/2) 180° lag		0°
D/z240°	1	DELTA		240° lag
	2	ZIG-ZAG (gnd 1/2) 240° lag		0°
D/z300°	1	DELTA		300° lag
	2	ZIG-ZAG (gnd 1/2) 300° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 5 of 26)

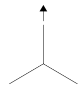
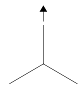
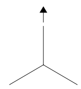
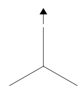
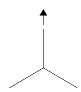
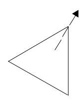
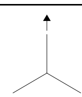
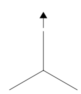
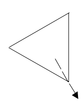
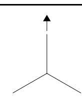
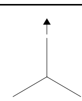
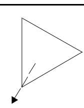
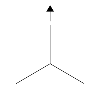
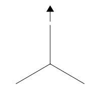
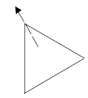
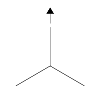
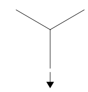
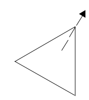
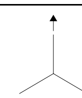
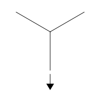
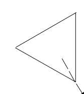
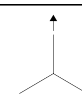
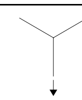
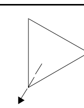
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
3W External Correction	1	WYE (gnd 1/2)		0°
	2	WYE (gnd 2/3) 0°		0°
	3	WYE 0°		0°
Y/y0°/d30°	1	WYE (gnd 1/2)		30° lag
	2	WYE (gnd 2/3) 0°		30° lag
	3	DELTA 30° lag		0°
Y/y0°/d150°	1	WYE (gnd 1/2)		150° lag
	2	WYE (gnd 2/3) 0°		150° lag
	3	DELTA 150° lag		0°
Y/y0°/d210°	1	WYE (gnd 1/2)		210° lag
	2	WYE (gnd 2/3) 0°		210° lag
	3	DELTA 210° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 6 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/y0°/d330°	1	WYE (gnd 1/2)		330° lag
	2	WYE (gnd 2/3) 0°		330° lag
	3	DELTA 330° lag		0°
Y/y180°/d30°	1	WYE (gnd 1/2)		30° lag
	2	WYE (gnd 2/3) 180° lag		210° lag
	3	DELTA 30° lag		0°
Y/y180°/ d150°	1	WYE (gnd 1/2)		150° lag
	2	WYE (gnd 2/3) 180° lag		330° lag
	3	DELTA 150° lag		0°
Y/y180°/ d210°	1	WYE (gnd 1/2)		210° lag
	2	WYE (gnd 2/3) 180° lag		30° lag
	3	DELTA 210° lag		0°

5

Table 5–1: TRANSFORMER TYPES (Sheet 7 of 26)

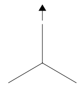
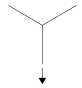
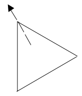
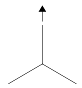
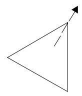
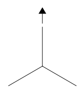
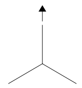
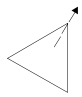
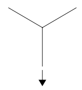
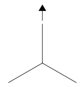
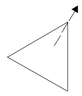
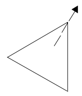
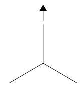
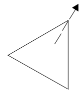
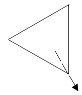
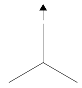
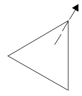
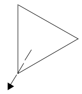
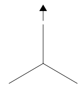
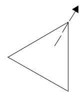
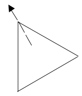
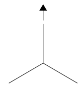
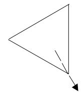
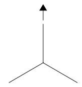
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/y180°/ d330°	1	WYE (gnd 1/2)		330° lag
	2	WYE (gnd 2/3) 180° lag		150° lag
	3	DELTA 330° lag		0°
Y/d30°/y0°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	WYE (gnd 2/3) 0°		30° lag
Y/d30°/y180°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	WYE (gnd 2/3) 180° lag		210° lag
Y/d30°/d30°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	DELTA 30° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 8 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d30°/d150°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	DELTA 150° lag		240° lag
Y/d30°/d210°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	DELTA 210° lag		180° lag
Y/d30°/d330°	1	WYE (gnd 1/2)		30° lag
	2	DELTA 30° lag		0°
	3	DELTA 330° lag		60° lag
Y/d150°/y0°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	WYE (gnd 2/3) 0°		150° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 9 of 26)

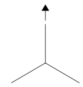
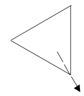
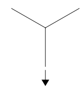
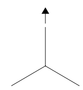
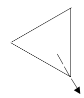
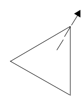
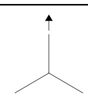
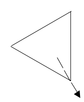
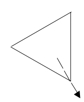
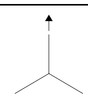
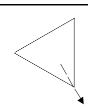
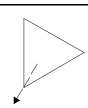
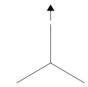
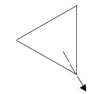
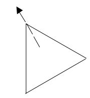
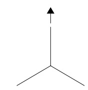
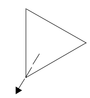
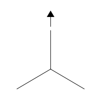
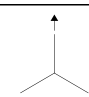
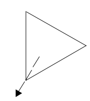
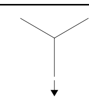
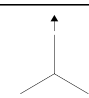
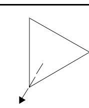
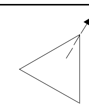
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d150°/ y180°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	WYE (gnd 2/3) 180° lag		330° lag
Y/d150°/d30°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	DELTA 30° lag		120° lag
Y/d150°/ d150°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	DELTA 150° lag		0°
Y/d150°/ d210°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	DELTA 210° lag		300° lag

Table 5–1: TRANSFORMER TYPES (Sheet 10 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d150°/ d330°	1	WYE (gnd 1/2)		150° lag
	2	DELTA 150° lag		0°
	3	DELTA 330° lag		180° lag
Y/d210°/y0°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	WYE (gnd 2/3) 0°		210° lag
Y/d210°/ y180°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	WYE (gnd 2/3) 180° lag		30° lag
Y/d210°/d30°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	DELTA 30° lag		180° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 11 of 26)

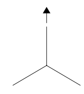
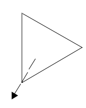
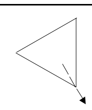
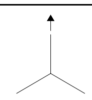
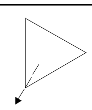
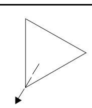
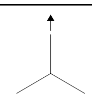
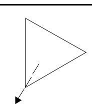
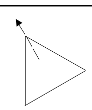
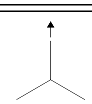
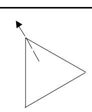
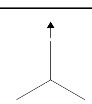
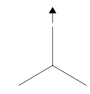
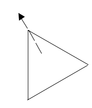
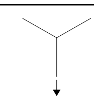
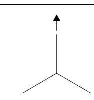
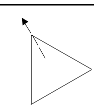
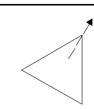
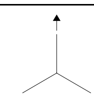
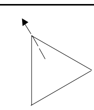
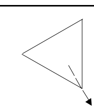
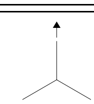
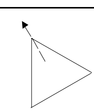
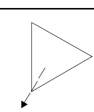
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d210°/ d150°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	DELTA 150° lag		60° lag
Y/d210°/ d210°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	DELTA 210° lag		0°
Y/d210°/ d330°	1	WYE (gnd 1/2)		210° lag
	2	DELTA 210° lag		0°
	3	DELTA 330° lag		240° lag
Y/d330°/y0°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	WYE (gnd 2/3) 0°		330° lag

Table 5–1: TRANSFORMER TYPES (Sheet 12 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d330°/ y180°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	WYE (gnd 2/3) 180° lag		150° lag
Y/d330°/d30°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	DELTA 30° lag		300° lag
Y/d330°/ d150°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	DELTA 150° lag		180° lag
Y/d330°/ d210°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	DELTA 210° lag		120° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 13 of 26)

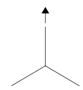
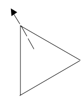
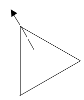
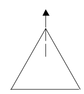
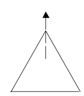
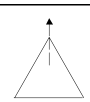
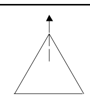
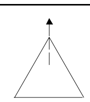
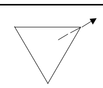
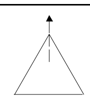
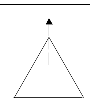
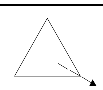
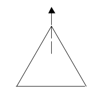
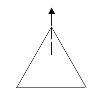
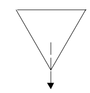
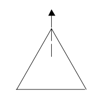
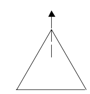
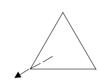
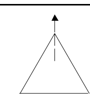
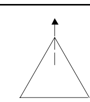
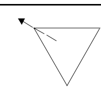
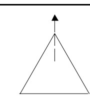
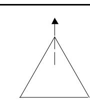
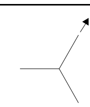
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/d330°/ d330°	1	WYE (gnd 1/2)		330° lag
	2	DELTA 330° lag		0°
	3	DELTA 330° lag		0°
D/d0°/d0°	1	DELTA		0°
	2	DELTA 0°		0°
	3	DELTA 0°		0°
D/d0°/d60°	1	DELTA		60° lag
	2	DELTA 0°		60° lag
	3	DELTA 60° lag		0°
D/d0°/d120°	1	DELTA		120° lag
	2	DELTA 0°		120° lag
	3	DELTA 120° lag		0°

Table 5–1: TRANSFORMER TYPES (Sheet 14 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d0°/d180°	1	DELTA		180° lag
	2	DELTA 0°		180° lag
	3	DELTA 180° lag		0°
D/d0°/d240°	1	DELTA		240° lag
	2	DELTA 0°		240° lag
	3	DELTA 240° lag		0°
D/d0°/d300°	1	DELTA		300° lag
	2	DELTA 0°		300° lag
	3	DELTA 300° lag		0°
D/d0°/y30°	1	DELTA		0°
	2	DELTA 0°		0°
	3	WYE (gnd 2/3) 30° lag		330° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 15 of 26)

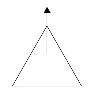
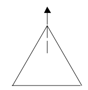
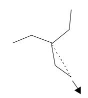
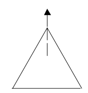
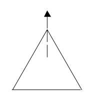
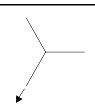
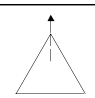
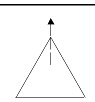
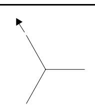
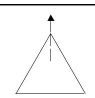
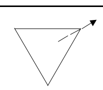
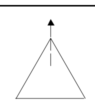
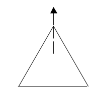
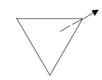
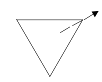
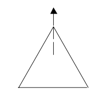
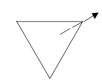
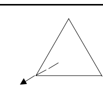
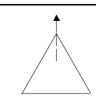
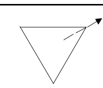
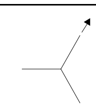
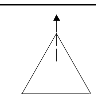
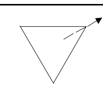
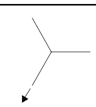
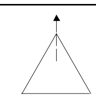
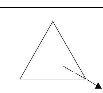
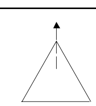
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d0°/y150°	1	DELTA		0°
	2	DELTA 0°		0°
	3	WYE (gnd 2/3) 150° lag		210° lag
D/d0°/y210°	1	DELTA		0°
	2	DELTA 0°		0°
	3	WYE (gnd 2/3) 210° lag		150° lag
D/d0°/y330°	1	DELTA		0°
	2	DELTA 0°		0°
	3	WYE (gnd 2/3) 330° lag		30° lag
D/d60°/d0°	1	DELTA		60° lag
	2	DELTA 60° lag		0°
	3	DELTA 0°		60° lag

Table 5–1: TRANSFORMER TYPES (Sheet 16 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d60°/d60°	1	DELTA		60° lag
	2	DELTA 60° lag		0°
	3	DELTA 60° lag		0°
D/d60°/d240°	1	DELTA		240° lag
	2	DELTA 60° lag		180° lag
	3	DELTA 240° lag		0°
D/d60°/y30°	1	DELTA		0°
	2	DELTA 60° lag		300° lag
	3	WYE (gnd 2/3) 30° lag		330° lag
D/d60°/y210°	1	DELTA		0°
	2	DELTA 60° lag		300° lag
	3	WYE (gnd 2/3) 210° lag		150° lag
D/d120°/d0°	1	DELTA		120° lag
	2	DELTA 120° lag		0°
	3	DELTA 0°		120° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 17 of 26)

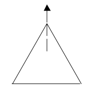
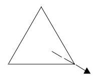
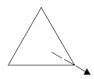
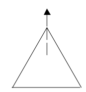
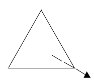
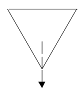
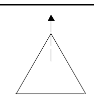
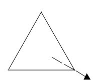
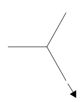
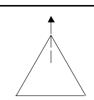
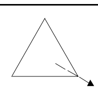
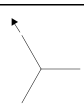
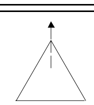
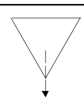
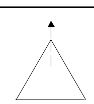
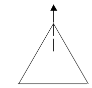
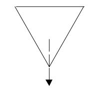
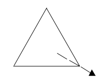
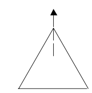
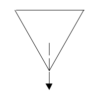
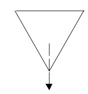
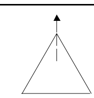
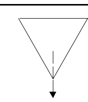
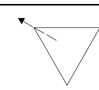
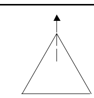
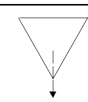
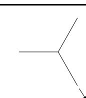
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d120°/ d120°	1	DELTA		120° lag
	2	DELTA 120° lag		0°
	3	DELTA 120° lag		0°
D/d120°/ d180°	1	DELTA		120° lag
	2	DELTA 120° lag		0°
	3	DELTA 180° lag		300° lag
D/d120°/ y150°	1	DELTA		0°
	2	DELTA 120° lag		240° lag
	3	WYE (gnd 2/3) 150° lag		210° lag
D/d120°/ y330°	1	DELTA		0°
	2	DELTA 120° lag		240° lag
	3	WYE (gnd 2/3) 330° lag		30° lag
D/d180°/d0°	1	DELTA		180° lag
	2	DELTA 180° lag		0°
	3	DELTA 0°		180° lag

Table 5–1: TRANSFORMER TYPES (Sheet 18 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d180°/ d120°	1	DELTA		120° lag
	2	DELTA 180° lag		300° lag
	3	DELTA 120° lag		0°
D/d180°/ d180°	1	DELTA		0°
	2	DELTA 180° lag		180° lag
	3	DELTA 180° lag		180° lag
D/d180°/ d300°	1	DELTA		300° lag
	2	DELTA 180° lag		120° lag
	3	DELTA 300° lag		0°
D/d180°/ y150°	1	DELTA		0°
	2	DELTA 180° lag		180° lag
	3	WYE (gnd 2/3) 150° lag		210° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 19 of 26)

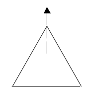
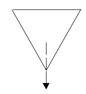
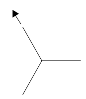
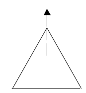
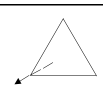
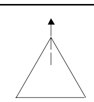
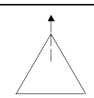
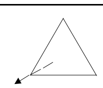
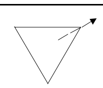
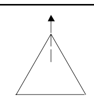
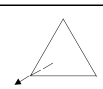
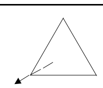
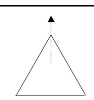
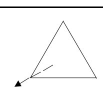
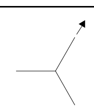
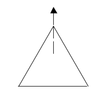
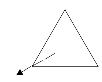
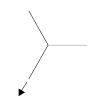
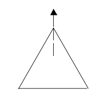
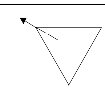
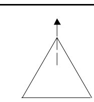
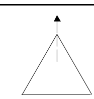
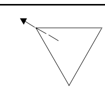
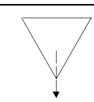
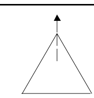
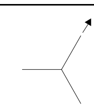
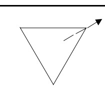
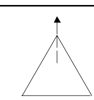
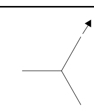
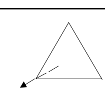
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d180°/y330°	1	DELTA		0°
	2	DELTA 180° lag		180° lag
	3	WYE (gnd 2/3) 330° lag		30° lag
D/d240°/d0°	1	DELTA		240° lag
	2	DELTA 240° lag		0°
	3	DELTA 0°		240° lag
D/d240°/d60°	1	DELTA		240° lag
	2	DELTA 240° lag		0°
	3	DELTA 60° lag		180° lag
D/d240°/d240°	1	DELTA		240° lag
	2	DELTA 240° lag		0°
	3	DELTA 240° lag		0°
D/d240°/y30°	1	DELTA		0°
	2	DELTA 240° lag		120° lag
	3	WYE (gnd 2/3) 30° lag		330° lag

Table 5–1: TRANSFORMER TYPES (Sheet 20 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/d240°/y210°	1	DELTA		0°
	2	DELTA 240° lag		120° lag
	3	WYE (gnd 2/3) 210° lag		150° lag
D/d300°/d0°	1	DELTA		300° lag
	2	DELTA 300° lag		0°
	3	DELTA 0°		300° lag
D/d300°/d180°	1	DELTA		300° lag
	2	DELTA 300° lag		0°
	3	DELTA 180° lag		120° lag
D/y30°/d60°	1	DELTA		0°
	2	WYE (gnd 1/2) 30° lag		330° lag
	3	DELTA 60° lag		300° lag
D/y30°/d240°	1	DELTA		0°
	2	WYE (gnd 1/2) 30° lag		330° lag
	3	DELTA 240° lag		120° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 21 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y30°/y30°	1	DELTA		0°
	2	WYE (gnd 1/2) 30° lag		330° lag
	3	WYE (gnd 2/3) 30° lag		330° lag
D/y30°/y210°	1	DELTA		0°
	2	WYE (gnd 1/2) 30° lag		330° lag
	3	WYE (gnd 2/3) 210° lag		150° lag
D/y150°/d0°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	DELTA 0°		0°
D/y150°/d120°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	DELTA 120° lag		240° lag

Table 5–1: TRANSFORMER TYPES (Sheet 22 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y150°/d180°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	DELTA 180° lag		180° lag
D/y150°/d300°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	DELTA 300° lag		60° lag
D/y150°/y150°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	WYE (gnd 2/3) 150° lag		210° lag
D/y150°/y330°	1	DELTA		0°
	2	WYE (gnd 1/2) 150° lag		210° lag
	3	WYE (gnd 2/3) 330° lag		30° lag

Table 5–1: TRANSFORMER TYPES (Sheet 23 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y210°/d0°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
	3	DELTA 0°		0°
D/y210°/d60°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
	3	DELTA 60° lag		300° lag
D/y210°/ d240°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
	3	DELTA 240° lag		120° lag
D/y210°/y30°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
	3	WYE (gnd 2/3) 30° lag		330° lag

Table 5–1: TRANSFORMER TYPES (Sheet 24 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y210°/ y210°	1	DELTA		0°
	2	WYE (gnd 1/2) 210° lag		150° lag
	3	WYE (gnd 2/3) 210° lag		150° lag
D/y330°/d0°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	DELTA 0°		0°
D/y330°/ d120°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	DELTA 120° lag		240° lag
D/y330°/ d180°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	DELTA 180° lag		180° lag

5

Table 5–1: TRANSFORMER TYPES (Sheet 25 of 26)

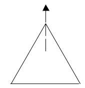
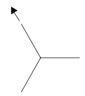
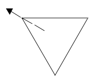
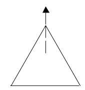
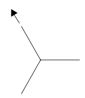
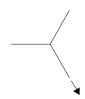
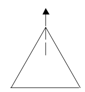
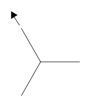
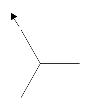
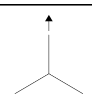
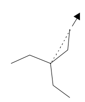
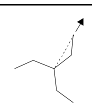
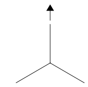
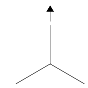
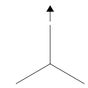
TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
D/y330°/ d300°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	DELTA 300° lag		60° lag
D/y330°/ y150°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	WYE (gnd 2/3) 150° lag		210° lag
D/y330°/ y330°	1	DELTA		0°
	2	WYE (gnd 1/2) 330° lag		30° lag
	3	WYE (gnd 2/3) 330° lag		30° lag
Y/z30°/z30°	1	WYE		30° lag
	2	ZIG-ZAG (gnd 1/2) 30° lag		0°
	3	ZIG-ZAG (gnd 2/3) 30° lag		0°

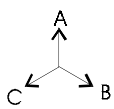
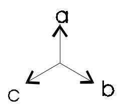
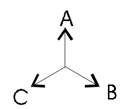
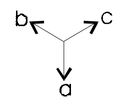
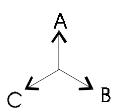
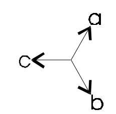
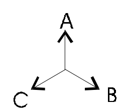
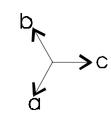
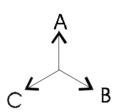
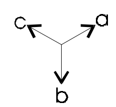
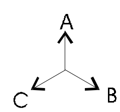
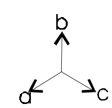
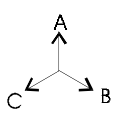
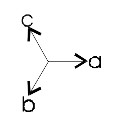
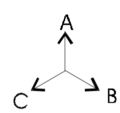
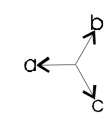
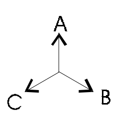
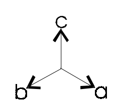
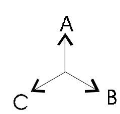
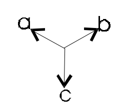
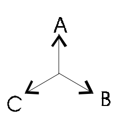
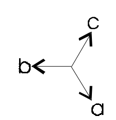
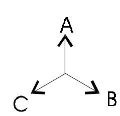
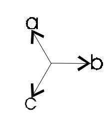
Table 5–1: TRANSFORMER TYPES (Sheet 26 of 26)

TRANSFORMER TYPE	WDG #	CONNECTION	VOLTAGE PHASORS	PHASE SHIFT
Y/y0°/y0°	1	WYE		0°
	2	WYE (gnd 1/2) 0°		0°
	3	WYE (gnd 2/3) 0°		0°

5.2.8 TABLE OF PHASE SHIFTS

This table provides additional information about the Phase Shift column in Table 5–1: TRANSFORMER TYPES on page 5–10 and represents an assumed ABC phasor rotation. For transformers connected to a system with a phasor rotation of ACB, interchange all B (b) and C (c) designations.

Table 5–2: PHASE SHIFTS

PHASE SHIFT	INPUT PHASORS	OUTPUT PHASORS	PHASOR TRANSFORMATION	PHASE SHIFT	INPUT PHASORS	OUTPUT PHASORS	PHASOR TRANSFORMATION
0°			a = A b = B c = C	180° lag			a = –A b = –B c = –C
30° lag			a = (A – C) / √3 b = (B – A) / √3 c = (C – B) / √3	210° lag			a = (C – A) / √3 b = (A – B) / √3 c = (B – C) / √3
60° lag			a = –C b = –A c = –B	240° lag			a = C b = A c = B
90° lag			a = (B – C) / √3 b = (C – A) / √3 c = (A – B) / √3	270° lag			a = (C – B) / √3 b = (A – C) / √3 c = (B – A) / √3
120° lag			a = B b = C c = A	300° lag			a = –B b = –C c = –A
150° lag			a = (B – A) / √3 b = (C – B) / √3 c = (A – C) / √3	330° lag			a = (A – B) / √3 b = (B – C) / √3 c = (C – A) / √3

5

5.3.1 DESCRIPTION

Settings to configure the relay are entered on this page. This includes passcode security, user preferences, the RS485/RS422 communication port, the internal time and date, default messages, and various commands.

```
▌▌ SETPOINTS
▌▌ S1 745 SETUP
```

This message indicates the start of the **S1 745 SETUP** setpoints page. Press MESSAGE ▼ to view the contents of this page or SETPOINT to go to the next page.

5.3.2 PASSCODE

After installing the setpoint access jumper, a passcode must be entered (if the passcode security feature is enabled) before setpoints can be changed. When the 745 is shipped from the factory, the passcode is defaulted to 0. When the passcode is 0, the passcode security feature is disabled and only the setpoint access jumper is required for changing setpoints from the front panel. Passcode entry is also required when programming setpoints from any of the serial communication ports.

```
▌ PASSCODE
▌ [ENTER] for more
```

This message indicates the start of the **PASSCODE** section. To continue with these setpoints press ENTER or press MESSAGE ▼ to go to the next section.

```
SETPOINT ACCESS:
Read & Write
```

Range: Cannot be edited

This message cannot be edited directly. It indicates whether passcode protection is enabled (Read Only) or disabled (Read & Write).

```
RESTRICT SETPOINT
WRITE ACCESS? No
```

Range: No / Yes

This message is only displayed when setpoint write access is allowed and the current passcode is not 0. Select Yes and follow directions to restrict write access. This message is replaced by **ALLOW SETPOINT WRITE ACCESS?** when write access is restricted.

```
ALLOW SETPOINT
WRITE ACCESS? No
```

Range: No / Yes

This message is only displayed when setpoint write access is restricted. New setpoints cannot be entered in this state. To gain write access, select Yes and follow directions to enter the previously programmed passcode. If the passcode is correctly entered, new setpoint entry is allowed. If there is no keypress within 30 minutes, setpoint write access is automatically restricted. As an additional safety measure, the following minor self-test error is generated when the passcode is entered incorrectly three times in a row:

SELF-TEST ERROR: ACCESS DENIED

```
CHANGE PASSCODE?
No
```

Range: No / Yes

Select Yes and follow directions to change the current passcode. Changing the passcode to the factory default of 0 disables the passcode security feature.

```
ENCRYPTED PASSCODE:
AIKFBAIK
```

Factory default passcode: 0

If the programmed passcode is unknown, consult the factory service department with the encrypted passcode. The passcode can be determined using a deciphering program.

5.3.3 PREFERENCES

Some relay characteristics can be modified to accommodate the user preferences. This section allows for the definition of such characteristics.

```
▌ PREFERENCES
▌ [ENTER] for more
```

This message indicates the start of the **PREFERENCES** section. To continue with these setpoints press ENTER or press MESSAGE ▼ to go to the next section.

```
BEEPER:
Enabled
```

Range: Disabled / Enabled

When enabled, a beeper sounds in response to any front panel key pressed.

```
FLASH MESSAGE TIME:
 4.0 s
```

Range: 0.5 to 10.0 s in steps of 0.5 s

Flash messages are status, warning, error, or information messages displayed for several seconds, in response to certain key presses during setpoint programming. The time these messages remain on the display, overriding the normal messages, can be changed to accommodate different user reading rates.

```
DEFAULT MESSAGE
TIMEOUT: 300 s
```

Range: 10 to 900 s in steps of 1 s

After this period of time of no activity on the keys, the 745 automatically begins to display the programmed set of default messages programmed in **S1 745 SETUP/DEFAULT MESSAGES**.

```
DEFAULT MESSAGE
INTENSITY: 25%
```

Range: 0 to 100% in steps of 25%

To extend the life of the phosphor in the vacuum fluorescent display, the brightness of the display can be attenuated when default messages are being displayed. When interacting with the display using the front panel keys, the display will always operate at full brightness. One of five settings can be selected for attenuation of default messages: 100% (maximum), 75%, 50%, 25%, or 0% (minimum).

5

5.3.4 COMMUNICATIONS

Up to 32 relays can be daisy-chained and connected to a computer or a programmable controller, using either the two wire RS485 or the four wire RS422 serial communication port at the rear of the 745. Before using communications, each relay must be programmed with a unique address and a common baud rate.

▌ COMMUNICATIONS ▌ [ENTER] for more	This message indicates the start of the **COMMUNICATIONS** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.
SLAVE ADDRESS: 254	*Range: 1 to 254 (steps of 1)* Enter a unique address, from 1 to 254, for this particular relay on both COM1 and COM2 serial communication links. This setpoint cannot be changed via the communication ports. Although addresses need not be sequential, no two relays can have the same address. Generally each relay added to the link will use the next higher address, starting from address 1. No address is required to use the front panel program port since only one relay can be connected at one time.
COM1 BAUD RATE: 19200 Baud	*Range: 300 / 1200 / 2400 / 4800 / 9600 / 19200* Select the baud rate for COM1, the RS485/RS422 communication port. This setpoint cannot be changed via the communication ports. All relays on the communication link, and the computer connecting them, must run at the same baud rate. The fastest response is obtained at 19200 baud.
COM1 PARITY: None	*Range: None / Even / Odd* The data frame is fixed at 1 start, 8 data, and 1 stop bit. If required, a parity bit is programmable. This setpoint cannot be changed via the communication ports. The parity of the transmitted signal must match the parity displayed in this setpoint.
COM1 HARDWARE: RS485	*Range: RS485 / RS422* If the two-wire RS485 hardware configuration is required for the COM1 serial communication port, select RS485. This setpoint cannot be changed via the communication ports. If the four wire RS422 hardware configuration is required, select RS422.
COM2 BAUD RATE: 19200 Baud	*Range: 300 / 1200 / 2400 / 4800 / 9600 / 19200* Select the baud rate for the COM2 port. This setpoint cannot be changed via the communication ports.
COM2 PARITY: None	*Range: None / Even / Odd* Select the parity type for the COM2 port. This setpoint cannot be changed via the communication ports.
FRONT BAUD RATE: 19200 Baud	*Range: 300 / 1200 / 2400 / 4800 / 9600 / 19200* Select the baud rate for the front panel port. This setpoint cannot be changed via the communication ports.
FRONT PARITY: None	*Range: None / Even / Odd* Select the parity type for the front panel port. This setpoint cannot be changed via the communication ports.

5

5.3.5 DNP COMMUNICATIONS

```
▌ DNP
▌ [ENTER] for more
```

This message indicates the start of the **DNP COMMUNICATION** page. To continue with these setpoints press ENTER, or press MESSAGE ▲ to go back to the PORT SETUP section.

```
DNP PORT:
None
```

Range: None / Com1 / Com2 / Front

Select the communication port that you will use for DNP.

```
DNP POINT MAPPING:
Enabled
```

Range: Enabled / Disabled

When enabled, the 120 User Map Values are included in the DNP Object 30 point list. For more information, refer to Section 8.4: DNP COMMUNICATIONS.

```
TRANSMISSION DELAY:
0 ms
```

Range: 0 to 65000 (Steps of 1)

Select the minimum time from when a DNP request is received and a response issued. A value of zero causes the response to be issued as quickly as possible.

```
DATA LINK CONFIRM
MODE: Never
```

Range: Never / Always / Sometimes

Select the data link confirmation mode desired for responses sent by the 745. When Sometimes is selected, data link confirmation is only requested when the response contains more than one frame.

```
DATA LINK CONFIRM
TIMOUT: 1000 ms
```

Range: 1 to 65000 (Steps of 1)

Select a desired timeout. If no confirmation response is received within this time, the 745 will resend the frame if retries are still available.

```
DATA LINK CONFIRM
RETRIES: 3
```

Range: 0 to 100 (Steps of 1)

Select the maximum number of retries that will be issued for a given data link frame.

```
SELECT/OPERATE ARM
TIMEOUT: 10000 ms
```

Range: 1 to 65000 (Steps of 1)

Select the duration of the select / operate arm timer.

```
WRITE TIME INTERVAL:
0 min.
```

Range: 0 to 65000 (Steps of 1)

Select the time that must elapse before the 745 will set the "need time" internal indication (IIN). After the time is written by a DNP master, the IIN will be set again after this time elapses. A value of zero disables this feature.

```
COLD RESTART
INHIBIT: Disabled
```

Range: Enabled / Disabled

When disabled, a cold restart request from a DNP master will cause the 745 to be reset. Enabling this setpoint will cause the cold restart request to initialize only the DNP sub-module.

WARNING

When "Disabled" is selected, a cold restart request will cause loss of protection until the 745 reset completes.

5.3.6 RESETTING

The reset function performs the following actions: all latched relays are set to the non-operated state and latched target messages are cleared, if the initiating conditions are no longer present. Resetting can be performed in any of the following ways: via RESET on the front panel while the 745 is in local mode (i.e. the LOCAL indicator is on); via a logic input; via any of the communication ports. The following setpoints allowing configuring some of the features associated with resetting.

```
▌ RESETTING
▌ [ENTER] for more
```

This message indicates the start of the **RESETTING** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
LOCAL RESET
BLOCK: Disabled
```

Range: Disabled / Logic Inpt 1 (2-16) / Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

The 745 is defaulted to the local mode. As a result, the front panel (local) RESET key is normally operational. Select any logic input, virtual input, output relay, or virtual output which, when asserted or operated, will block local mode, and hence the operation of the front panel RESET.

```
REMOTE RESET
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, will (remotely) cause a reset command.

5

5.3.7 CLOCK

The 745 includes a battery-backed internal clock that runs even when control power is lost. Battery power is used only when the 745 is not powered. The battery is rated to last for at least 10 years continuous use. The clock is accurate to within 1 minute per month. An IRIG-B signal may be connected to the 745 to synchronize the clock to a known time base and to other relays. The clock performs time and date stamping for various relay features, such as event and last trip data recording. Without an IRIG-B signal, the current time and date must be entered in a new relay for any time and date displayed. If not entered, all message references to time or date will display Unavailable. With an IRIG-B signal, only the current year needs to be entered.

```
▌ CLOCK
▌ [ENTER] for more
```

This message indicates the start of the **CLOCK** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
DATE (MM/DD/YYYY):
 01/01/1996
```

Range: Month = 1 to 12, Day = 1 to 31, Year = 1990 to 2089

Enter the current date, using two digits for the month, two digits for the day, and four digits for the year. For example, April 30, 1996 would be entered as 04 30 1996. If entered from the front panel, the new date will take effect at the moment of pressing the ENTER key.

```
TIME (HH:MM:SS):
00:00:00
```

Range: Hour = 0 to 23, Minute = 0 to 59, Second = 0 to 59

Enter the current time by using two digits for the hour in 24 hour time, two digits for the minutes, and two digits for the seconds. The new time takes effect at the moment of pressing the ENTER key. For example, 3:05 PM is entered as 15 05 00, with the ENTER key pressed at exactly 3:05 PM.

```
IRIG-B SIGNAL TYPE:
None
```

Range: None / DC Shift / Amplitude Modulated

Select the type of IRIG-B signal being used for clock synchronization. Select 'None' if no IRIG-B signal is to be used.

5.3.8 DEFAULT MESSAGES

Under normal conditions, if no front panel keys have been pressed for longer than the time specified in **S1 745 SETUP/PREFERENCES/DEFAULT MESSAGE TIMEOUT**, the screen begins to sequentially display up to 30 user-selected default messages. In addition, up to 5 user programmable text messages can be assigned as default messages. For example, the relay could be set to sequentially display a text message identifying the transformer, the system status, the measured current in each phase, and the harmonic inhibit level. Currently selected default messages are viewed under **S1 745 SETUP/DEFAULT MESSAGES**. The first message in this section states the number of messages currently selected. The messages that follow are copies of the default messages in the sequence they will be displayed.

▌ DEFAULT MESSAGES ▌ [ENTER] for more	This message indicates the start of the **DEFAULT MESSAGES** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.
1 MESSAGES SELECTED 29 REMAIN UNASSIGNED	*Range: cannot be edited*
▌▌ 745 Transformer ▌▌ Management Relay	Press **[.]** ENTER ENTER at any message to select as a default message.

a) ADDING DEFAULT MESSAGES

Default messages can be added to the end of the default message list, as follows:

1. Allow access to setpoints by installing the setpoint access jumper and entering the correct passcode.
2. Select the setpoint or actual value message to be entered as a default message, so that it is displayed. If user text is required, go into **S1 745 SETUP/SCRATCHPAD** and edit the text for default.
3. Press the decimal key followed by ENTER while the message is displayed. The screen will display **PRESS [ENTER] TO ADD AS DEFAULT**. Press ENTER again while this message is being displayed. The message is now added to the default message list.

b) REMOVING DEFAULT MESSAGES

Default messages can be removed from the default message list, as follows:

1. Allow access to setpoints by installing the setpoint access jumper and entering the correct passcode.
2. Select the message under the section **S1 745 SETUP/DEFAULT MESSAGES** to remove from the default message list.
3. Press the decimal key followed by ENTER. The screen displays **PRESS [ENTER] TO REMOVE MESSAGE**. Press ENTER while this message is being displayed. The message is now removed from the default message list and the messages that follow are moved up to fill the gap.

5

5.3.9 SCRATCHPAD

Up to 5 message screens can be programmed and selected as default messages. These messages can be used to provide identification information about the system or instructions to operators. User text messages can be entered as follows:

```
▌ SCRATCHPAD
▌ [ENTER] for more
```

Use these setpoints to enter up to 5 user programmable messages to be displayed with the list of default messages. To continue setting the user messages press the ENTER key, or press the MESSAGE ▼ key to go to the next section.

```
Text 1
```

Range: 40 alphanumeric characters

Press ENTER to begin editing scratchpad message 1 (2-5). The text may be changed from Text 1 one character at a time, using VALUE ▲/VALUE ▼. Press the ENTER key to store the edit and advance to the next character position. This message may then be stored as a default message.

5.3.10 INSTALLATION

```
▌ INSTALLATION
▌ [ENTER] for more
```

This message indicates the start of the **INSTALLATION** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
745 SETPOINTS:
Not Programmed
```

Range: Not Programmed / Programmed

In order to safeguard against the installation of a relay whose setpoints have not been entered, the 745 will not allow signaling of any output relay, will have the IN SERVICE indicator off and the SELF-TEST ERROR indicator on, until the 745 is set to Programmed. The setpoint is defaulted to Not Programmed when the relay leaves the factory. The following self-test error message is displayed automatically until the 745 is put into the programmed state:

```
▌ SETPOINTS HAVE NOT
▌ BEEN PROGRAMMED
```

5.3.11 745 OPTIONS

Some of the options supported by the 745 may be added while the relay is in the field. These include the Analog I/O, Loss Of Life and Restricted Ground Fault options.

Should this be desired, contact the factory with the following information:

- The 745 order code (found under **A4 PRODUCT INFO/REVISION CODES/INSTALLED OPTIONS**).
- The 745 serial number (found under **A4 PRODUCT INFO/REVISION CODES/SERIAL NUMBER**).
- The new option(s) that are to be added.

The factory will supply a passcode that may be used to add the new options to the 745. Before entering the passcode and performing the upgrade, it is important to set the **ENABLE** setpoints correctly (see below). Any options that are currently supported by the 745 as well as any options that are to be added should have the corresponding **ENABLE** setpoint set to Yes. All others must be set to No.

For example, if the 745 currently supports only the Analog I/O option and the Loss Of Life option is to be added, then the **ENABLE ANALOG I/O?** setpoint and the **ENABLE LOSS OF LIFE?** setpoint must be set to Yes. The **ENABLE RESTRICTED GROUND FAULT?** setpoint must be set to No.

▌ UPGRADE UPTIONS ▌ [ENTER] for more	This message indicates the start of the **UPGRADE OPTIONS** section. To continue with these setpoints press ENTER, or press MESSAGE ▲ to go to the previous section.
ENABLE ANALOG I/O? Yes	*Range: Yes / No*
ENABLE LOSS OF LIFE? Yes	*Range: Yes / No*
ENABLE RESTRICTED GROUND FAULT? Yes	*Range: Yes / No*
ENTER PASSCODE:	Enter passcode supplied by the manufacturer.
UPGRADE OPTIONS? Yes	*Range: Yes / No*

5

5.3.12 UPGRADE OPTIONS

Display	Description
▌ UPGRADE OPTIONS ▌ [ENTER] for more	This message indicates the start of the **UPGRADE OPTIONS** section. To continue with these setpoints press ENTER, or press MESSAGE ▲ to go to the previous section.
ENABLE ANALOG I/O? No	*Range: No / Yes* Select Yes if the upgrade options set supports the Analog I/O feature, otherwise select No. The default value for this setpoint reflects the current state of the option.
ENABLE LOSS OF LIFE? No	*Range: No / Yes* Select Yes if the upgrade options set supports the Loss Of Life feature and select No otherwise. The default value for this setpoint reflects the current state of the option.
ENABLE RESTRICTED GROUND FAULT? No	*Range: No / Yes* Select Yes if the upgrade options set supports the Restricted Ground Fault feature and select No otherwise. The default value for this setpoint reflects the current state of the option.
ENTER PASSCODE:	*Range: 16 hexadecimal characters [0 to 9 and A to F]* Press ENTER to begin entering the factory-supplied upgrade passcode. This setpoint has a textual format, thus it is edited in the same manner as, for example, the setpoints under **S1 745 SETUP/SCRATCHPAD**.
UPGRADE UPTIONS? No	*Range: No / Yes* When all of the above setpoints are properly programmed, select Yes and press ENTER to prompt the 745 to upgrade its options. A flash message appears indicating the results of the upgrade. A successful upgrade may be verified by examining the installed options display under **A4 PRODUCT INFO/ REVISION CODES/INSTALLED OPTIONS**.

5

5.4.1 DESCRIPTION

This group of setpoints is critical for the protection features to operate correctly. When the relay is ordered, the phase and ground CT inputs must be specified as either 5 A or 1 A. The characteristics of the equipment installed on the system are entered on this page. This includes information on the transformer type, CTs, VT, ambient temperature sensor, onload tap changer, demand metering, analog outputs and analog input.

```
▌▌ SETPOINTS
▌▌ S2 SYSTEM SETUP
```

This message indicates the start of setpoints page **S2 SYSTEM SETUP**. Press MESSAGE ▼ to view the contents of this page, or SETPOINT to go on to the next page.

5.4.2 TRANSFORMER

In order to provide accurate and effective transformer protection, the parameters of both the transformer and the system configuration must be supplied to the 745 relay.

```
▌ TRANSFORMER
▌ [ENTER] for more
```

This message indicates the start of the **TRANSFORMER** section. To continue with these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section.

```
NOMINAL FREQUENCY:
60 Hz
```

Range: 60 Hz / 50 Hz

Enter the nominal frequency of the power system. This setpoint is used to determine the sampling rate in the absence of a measurable frequency. Frequency is measured from the VT input when available. If the VT input is not available, current from phase A of Winding 1 is used.

```
FREQUENCY TRACKING:
Enabled
```

Range: Enabled / Disabled

In situations where the AC signals contain significant amount of sub-harmonic components, it may be necessary to disable frequency tracking.

```
PHASE SEQUENCE:
ABC
```

Range: ABC / ACB

Enter the phase sequence of the power system. Systems with an ACB phase sequence require special considerations. See Section 5.2.4: PHASE SHIFTS ON THREE-PHASE TRANSFORMERS on page 5–6 for details.

```
TRANSFORMER TYPE:
Y/d30°
```

Range: See Table 5–1: TRANSFORMER TYPES on page 5–10.

Enter the transformer connection from the table of transformer types. Phase correction and zero-sequence removal are performed automatically as required.

WARNING

If **TRANSFORMER TYPE** is entered as 2W or 3W EXTERNAL CORRECTION with a DELTA/WYE power transformer, the **WINDING 1/2/3 PHASE CT PRIMARY** setting values must be divided by $\sqrt{3}$ on the DELTA current transformer side to compensate the current magnitude. With this correction, the 745 will properly compare line to neutral currents on all sides of the power transformer.

For example, for a 2-Winding DELTA/WYE power transformer with

- WYE connected current transformers on the DELTA side of the power transformer (25000:5 ratio)
- DELTA connected current transformers on the WYE side of the power transformer (4000:5 ratio)

Set: **TRANSFORMER TYPE** = 2W External Connection
WINDING 1 PHASE CT PRIMARY = 25000:5
WINDING 2 PHASE CT PRIMARY = $(4000/\sqrt{3})$:5 or 2309:5

```
LOAD LOSS AT RATED
LOAD: 1250 kW
```

Range: 0 to 20000 in steps of 1
(Auto-ranging; see Table 5–3: LOW VOLTAGE WINDING RATING)

Enter the load loss at rated load. This value is used for calculation of harmonic derating factor, and in the Insulating Aging function.

```
LOW VOLTAGE WINDING
RATING: Above 5 kV
```

Range: Above 5 kV / 1 kV to 5 kV / Below 1 kV

Enter the low voltage winding rating. This selection affects the setpoint ranges of **WINDING (1,2,3) NOM Ø-Ø VOLTAGE**, **WINDING (1,2,3) RATED LOAD**, **MINIMUM TAP POSITION VOLTAGE** and **VOLTAGE INCREMENT PER TAP** shown in Table 5–3: LOW VOLTAGE WINDING RATING below.

```
RATED WINDING TEMP
RISE: 65°C (oil)
```

Range: 65ºC (oil) / 55ºC (oil) / 150ºC (dry) / 115ºC (dry) / 80ºC (dry)

This setting determines the type of insulation, for use in the computation of Insulation Aging.

```
NO LOAD LOSS:
125.0 kW
```

Range: 0.1 to 2000.0 in steps of 0.1
(Auto-ranging; see Table 5–3: LOW VOLTAGE WINDING RATING)

From the transformer data. It is required for Insulation Aging calculations.

```
TYPE OF COOLING:
OA
```

Range: FA / OA / Directed FOA / FOW / Non-Directed FOA/FOW

From Transformer data, required for Insulation Aging calculations.

```
RATED TOP OIL RISE
OVER AMBIENT: 10°C
```

Range: 1 to 200 (steps of 1)

Required for Insulation Aging calculations

5

```
XFMR THRML CAPACITY:
1.00 kwh/°C
```

Range: 0.00 to 200.00 (steps of 0.01)

Required for Insulation Aging calculations. Obtain from transformer manufacturer

```
WINDING TIME CONST:
2.00 min.
```

Range: 0.25 to 15.00 (steps of 0.01)

Required for Insulation Aging calculations

```
SET ACCUMULATED LOSS
OF LIFE: 0 x 10h
```

Range: 0 to 20000 (steps of 1)

Required for Insulation Aging calculations. Set equal to the estimated accumulated loss of life.

Table 5–3: LOW VOLTAGE WINDING RATING

DESCRIPTION	LOW VOLTAGE WINDING RATING		
	ABOVE 5 kV	1 kV to 5 kV	BELOW 1 kV
WINDING *x* NOM ϕ-ϕ VOLTAGE:	0.1 to 2000.0 in steps of 0.1 kV	0.01 to 200.00 in steps of 0.01 kV	0.001 to 20.000 in steps of 0.001 kV
WINDING *x* RATED LOAD	0.1 to 2000.0 in steps of 0.1 MVA	0.01 to 200.00 in steps of 0.01 MVA	0.001 to 20.000 in steps of 0.001 MVA
MINIMUM TAP POSITION VOLTAGE	0.1 to 2000.0 in steps of 0.1 kV	0.01 to 200.00 in steps of 0.01 kV	0.001 to 20.000 in steps of 0.001 kV
VOLTAGE INCREMENT PER TAP	0.01 to 20.00 in steps of 0.01 kV	0.001 to 2.000 in steps of 0.001 kV	0.0001 to 0.2000 in steps of 0.0001 kV
Load Loss at Rated Load	1 to 20000 in steps of 0.1 KW	0.1 to 2000.0 in steps of 0.01 KW	0.01 to 200.00 in steps of 0.001 KW
No load Loss	0.1 to 2000.0 in steps of 1 KW	0.01 to 200.00 in steps of 0.1 KW	0.001 to 20.000 in steps of 0.01 KW

5.4.3 WINDING 1 (2/3)

These sections describe the characteristics of each transformer winding and the CTs connected to them.

```
▌ WINDING 1
▌ [ENTER] for more
```

This message indicates the start of the **WINDING 1 (2/3)** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
WINDING 1 NOM ø-ø
VOLTAGE: 220.0 kV
```

Range: Above 5 kV - 0.1 to 2000.0 (steps of 0.1),
1 kV to 5 kV - 0.01 to 200.00 (steps of 0.01),
Below 1 kV - 0.001 to 20.000 (steps of 0.001)

Enter the nominal phase-to-phase voltage rating of Winding 1 (2/3) of the transformer. The range for this setpoint is affected by the setting made at **S2 SYSTEM SETUP/TRANSFORMER/LOW VOLTAGE WINDING RATING**.

```
WINDING 1 RATED
LOAD:    100.0 MVA
```

Range: Above 5 kV - 0.1 to 2000.0 (steps of 0.1),
1 kV to 5 kV - 0.01 to 200.00 (steps of 0.01),
Below 1 kV - 0.001 to 20.000 (steps of 0.001)

Enter the self-cooled load rating for Winding 1 (2/3) of the transformer. The range for this setpoint is affected by the setting made at **S2 SYSTEM SETUP/TRANSFORMER/LOW VOLTAGE WINDING RATING**.

```
WINDING 1 PHASE CT
PRIMARY:   500:5 A
```

Range: 1 to 50000 (steps of 1)

Enter the phase CT primary current rating of the current transformers connected to Winding 1 (2/3). The CT secondary current rating must match the relay phase current input rating indicated.

```
WINDING 1 GROUND CT
PRIMARY:   500:5 A
```

Range: 1 to 50000 (steps of 1)

Enter the ground CT primary current rating of the current transformers connected in the Winding 1 (2/3) neutral to ground path. The CT secondary current rating must match the relay ground current input rating indicated. This message will only appear if the transformer type setpoint shows that Winding 1 (2/3) is a wye-connected winding.

```
WINDING 1 SERIES 3ø
RESISTANCE: 10.700 O
```

Range: 0.001 to 50.000 (steps of 0.001)

Enter the series three-phase resistance of the winding (i.e. the sum of the resistance of each of the three phases for the winding). This value is normally only available from the transformer manufacturer's test report, and is used in the 745 for calculation of harmonic derating factor.

NOTE

The above setpoint options are also available for the second and third winding. W3 setpoints are only visible if the unit has the appropriate hardware and if the selected transformer type is 3-winding.

5

5.4.4 ONLOAD TAP CHANGER

This section contains the settings to configure the tap position input. The 745 accepts a resistive input from the tap changer control circuitry, which is used in the 745 to dynamically correct for CT ratio mismatch based on the dynamically changing voltage ratio of the transformer. Thus, the percent differential function of the device can be set for greater sensitivity. See the auto-configuration section of this chapter for more details on the tap position input.

```
▌ ONLOAD TAP CHANGER
▌ [ENTER] for more
```

This message indicates the start of the **ONLOAD TAP CHANGER** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
WINDING WITH TAP
CHANGER: None
```

Range: None / Winding 1 / Winding 2 / Winding 3

Enter the winding with the tap changer. Enter 'None' for a transformer with no onload tap changer, or to disable this feature.

```
NUMBER OF TAP
POSITIONS: 33
```

Range: 2 to 50 (steps of 1)

Enter the number of tap changer positions.

```
MINIMUM TAP POSITION
VOLTAGE:   61.0 kV
```

Range:	*above 5 kV:*	*0.1 to 2000.0 (steps of 0.1)*
	1 kV to 5 kV:	*0.01 to 200.00 (steps of 0.01)*
	below 1 kV:	*0.001 to 20.000 (steps of 0.001)*

Enter the voltage at the lowest tap position. The range is affected by the **S2 SYSTEM SETUP/TRANSFORMER/LOW VOLTAGE WINDING RATING** setpoint.

5

```
VOLTAGE INCREMENT
PER TAP: 0.50 kV
```

Range:	*above 5 kV*	*0.1 to 2000.0 (steps of 0.1)*
	1 kV to 5 kV	*0.01 to 200.00 (steps of 0.01)*
	below 1 kV	*0.001 to 20.000 (steps of 0.001)*

Enter the voltage increment for each tap. The range is affected by the **S2 SYSTEM SETUP/TRANSFORMER/LOW VOLTAGE WINDING RATING** setpoint.

```
RESISTANCE INCREMENT
PER TAP: 33 Ω
```

Range: 10 to 500 (steps of 1)

Enter the resistance increment that the 745 will see for each tap increment. Maximum value resistance on top tap is 5 KΩ

5.4.5 HARMONICS

The 745 calculates the individual harmonics in each of the phase current inputs up to the 21st harmonic. With this information, it calculates an estimate of the effect of non-sinusoidal load currents on the transformer rated full load current. These calculations are based on ANSI/IEEE guide C57.110-1986, and require information that is often only available from the transformer manufacturer's test report, including the three-phase resistance of each winding and the load loss at rated load. The harmonic derating factor will only be valid if this information has been entered correctly.

The 745 also calculates the total harmonic distortion of the phase current input signals. The band of frequencies over which this calculation is made can be changed to be more selective than the default 2nd to 21st harmonics.

▌ HARMONICS ▌ [ENTER] for more	This message indicates the start of the **HARMONICS** section. To continue with this setpoint press ENTER, or press MESSAGE ▼ to go to the next section.
HARMONIC DERATING ESTIMATION: Disabled	*Range: Disabled / Enabled* Enter Enabled to enable the harmonic derating factor calculations.
THD MINIMUM HARMONIC NUMBER: 2nd	*Range: 2nd / 3rd / ... / 21st* Enter the minimum harmonic number of the frequency band over which total harmonic distortion is calculated.
THD MAXIMUM HARMONIC NUMBER: 21st	*Range: 2nd / 3rd / ... / 21st* Enter the maximum harmonic number of the frequency band over which total harmonic distortion is calculated.

5

5.4.6 FLEXCURVES

Three programmed custom FlexCurves can be stored in the 745 as FlexCurve A, FlexCurve B and FlexCurve C. This allows the user to save special curves for specific applications and then select them as required for time overcurrent element curves. The custom FlexCurve has setpoints for entering the times-to-trip at various levels of pickup. The levels are as follows: 1.03, 1.05, 1.1 to 6.0 in steps of 0.1, and 6.5 to 20.0 in steps of 0.5.

▌ FLEXCURVES ▌ [ENTER] for more	This message indicates the start of the **FLEXCURVES** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.
▌ FLEXCURVE A ▌ [ENTER] for more	This message indicates the start of the **FLEXCURVE A (B/C)** section. To continue with these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section. Note that the messages for curve B and curve C are similar to the following message shown for curve A.
CURVE A TRIP TIME AT 1.03 x PU: 0 ms	*Range: 0 to 65000 (steps of 1)* Enter the trip time for 1.03 times the pickup level for curve A (B/C). The messages that follow sequentially, correspond to the trip times for the various pickup levels as indicated above.

5.4.7 VOLTAGE INPUT

The 745 provides a voltage input for the purposes of energization detection (for the ENERGIZATION INHIBIT feature of the percent differential element), overexcitation protection (the VOLTS-PER-HERTZ 1 and 2 functions), and frequency protection (the UNDERFREQUENCY, the FREQUENCY DECAY and the OVERFREQUENCY functions). Note that the frequency elements will use Winding 1, phase A current input if voltage is not available.

```
▌ VOLTAGE INPUT
▌ [ENTER] for more
```

This message indicates the start of the **VOLTAGE INPUT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
VOLTAGE SENSING:
Disabled
```

Range: Disabled / Enabled

Enter Enabled when connecting a voltage transformer to this input.

```
VOLTAGE INPUT
PARAMETER: W1 Van
```

Range: W1 Van / W1 Vbn / W1 Vcn / W1 Vab / W1 Vbc / W1 Vca / W2 Van / W2 Vbn / W2 Vcn / W2 Vab / W2 Vbc / W2 Vca / W3 Van / W3 Vbn / W3 Vcn / W3 Vab / W3 Vbc / W3 Vca

Enter the winding and phase of the voltage connected to the voltage input.

```
NOMINAL VT SECONDARY
VOLTAGE: 120.0 V
```

Range: 60.0 to 120.0 (steps of 0.1)

Enter the nominal secondary voltage (in volts) of the voltage transformer.

```
VT RATIO:
1000:1
```

Range: 1 to 5000 (steps of 1)

Enter the ratio of the voltage transformer.

5.4.8 AMBIENT TEMPERATURE

The 745 provides an RTD input for monitoring the ambient temperature. The three RTD types which may be used are 100 Ω platinum, 120 Ω nickel, and 100 Ω nickel, the characteristics of which are as follows:

Table 5–4: RTD RESISTANCE VS. TEMPERATURE

Temperature (° Celsius)	100 Ω Platinum (DIN 43760)	120 Ω Nickel	100 Ω Nickel
–50	80.31	86.17	71.81
–40	84.27	92.76	77.30
–30	88.22	99.41	82.84
–20	92.16	106.15	88.45
–10	96.09	113.00	94.17
0	100.00	120.00	100.00
10	103.90	127.17	105.97
20	107.79	134.52	112.10
30	111.67	142.06	118.38
40	115.54	149.79	124.82
50	119.39	157.74	131.45
60	123.24	165.90	138.25
70	127.07	174.25	145.20
80	130.89	182.84	152.37
90	134.70	191.64	159.70
100	138.50	200.64	167.20
110	142.29	209.85	174.87
120	146.06	219.29	182.75
130	149.82	228.96	190.80
140	153.58	238.85	199.04
150	157.32	248.95	207.45
160	161.04	259.30	216.08
170	164.76	269.91	224.92
180	168.47	280.77	233.97
190	172.46	291.96	243.30
200	175.84	303.46	252.88
210	179.51	315.31	262.76
220	183.17	327.54	272.94
230	186.82	340.14	283.45
240	190.45	353.14	294.28
250	194.08	366.53	305.44

```
▌ AMBIENT TEMP
▌ [ENTER] for more
```

This message indicates the start of the **AMBIENT TEMP** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
AMBIENT TEMPERATURE
SENSING: Disabled
```

Range: Disabled / Enabled

Enter Enabled to use an RTD to monitor ambient temperature.

```
AMBIENT RTD TYPE:
100 Ω Platinum
```

Range: 100 Ω Platinum / 120 Ω Nickel / 100 Ω Nickel / By Monthly Average

Enter the RTD sensor type being used.

```
AVERAGE AMBIENT TEMP
FOR JANUARY:    20°C
```

Range: –50ºC to 125ºC (steps)

This message is displayed only when the **AMBIENT RTD TYPE** is set for By Monthly Average. Ambient temperature is used in the calculation of Insulation Aging and must be enabled for the function to operate.

NOTE

There is a display for each month similar to the box above.

5.4.9 ANALOG INPUT

The 745 provides a general purpose DC current input for use in monitoring any external parameter. Any standard transducer output may be connected to the analog input for monitoring.

```
▌ ANALOG INPUT
▌ [ENTER] for more
```

This message indicates the start of the **ANALOG INPUT** section. To continue these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
ANALOG INPUT NAME:
ANALOG INPUT
```

Range: 18 alphanumeric characters

Press ENTER to begin editing the name of the analog input. The text may be changed from ANALOG INPUT one character at a time, using the VALUE ▲/ VALUE ▼ keys. Press the ENTER key to store the edit and advance to the next character position. This name will appear in the actual value message **A2 METERING/ANALOG INPUT**.

```
ANALOG INPUT UNITS:
µA
```

Range: 6 alphanumeric characters

Enter the units of the quantity being read by editing the text as described above. The 6 characters entered will be displayed instead of Units wherever the analog input units are displayed.

```
ANALOG INPUT RANGE:
0-1 mA
```

Range: 0-1 mA / 0-5 mA / 4-20 mA / 0-20 mA

Select the current output range of the transducer that is connected to the analog input.


```
ANALOG INPUT MINIMUM
VALUE: 0 µA
```

Range: 0 to 65000 (steps of 1)

Enter the value of the quantity measured which corresponds to the minimum output value of the transducer.

```
ANALOG INPUT MAXIMUM
VALUE:    1000 µA
```

Range: 0 to 65000 (steps of 1)

Enter the value of the quantity measured which corresponds to the maximum output value of the transducer.

5.4.10 DEMAND METERING

This section assigns the demand setpoints for monitoring current demand on all three phases of each windings. Current demand on the 745 is performed one of three ways: Thermal, Rolling Demand or Block Interval.

```
▌ DEMAND METERING
▌ [ENTER] for more
```

This message indicates the start of the **DEMAND METERING** section. To continue press ENTER or press MESSAGE ▼ to go to the next section.

```
CURRENT DEMAND METER
TYPE: Thermal
```

Range: Thermal, Block Interval, Rolling Demand (see table below).

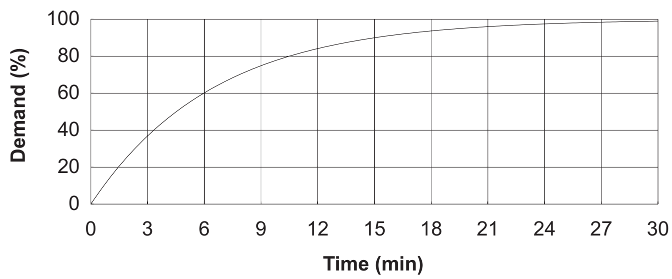
Select the method to be used for the current demand metering.

THERMAL

Select 'Thermal' to emulate the action of an analog peak-recording thermal demand meter. The 745 measures the current on each phase every second, and assumes the circuit quantity remains at this value until updated by the next measurement. It calculates the "thermal demand equivalent" based on the following equation:

$$d(t) = D(1 - e^{-kt})$$

where d = demand after applying input for time t (in minutes)
D = input quantity (constant)
k = 2.3 / thermal 90% response time



The graph above shows the thermal response characteristic for a thermal 90% response time of 15 minutes. A setpoint establishes the time to reach 90% of a steady-state value, just as the response time of an analog instrument (a steady-state value applied for twice the response time will indicate 99% of the value).

BLOCK INTERVAL

Select 'Block Interval' to calculate a linear average of the current over the programmed demand TIME INTERVAL, starting daily at 00:00:00 (i.e. 12 am). The 1440 minutes per day is divided into the number of blocks as set by the programmed time interval. Each new value of demand becomes available at the end of each time interval.

ROLLING DEMAND

Select 'Rolling Demand' to calculate a linear average of the current over the programmed demand **TIME INTERVAL** (in the same way as Block Interval). The value is updated every minute and indicates the demand over the time interval just preceding the time of update.

```
THERMAL 90% RESPONSE
TIME: 15 min.
```

Range: 5 min. / 10 min. / 15 min. / 20 min. / 30 min. / 60 min.

This message is displayed only when the **CURRENT DEMAND METER TYPE** is set for Thermal. Enter the time required for a steady-state current to indicate 90% of actual value.

```
TIME INTERVAL:
20 min.
```

Range: 5 min. / 10 min. / 15 min. / 20 min. / 30 min. / 60 min.

This message is displayed only when the **CURRENT DEMAND METER TYPE** is set for Block Interval or Rolling Demand. Enter the time period over which the current demand calculation is performed.

5

5.4.11 ANALOG OUTPUTS

There are seven analog outputs on the 745 relay which are selected to provide a full-scale output range of one of 0-1 mA, 0-5 mA, 4-20 mA, 0-20 mA or 0-10 mA. Each channel can be programmed to monitor any measured parameter. This sub-section is only displayed with the option installed.

```
▌ ANALOG OUTPUTS
▌ [ENTER] for more
```

This message indicates the start of the **ANALOG OUTPUTS** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
▌ ANALOG OUTPUT 1
▌ [ENTER] for more
```

This message indicates the start of the analog output 1 (2-7) setpoints of the analog outputs. To continue with these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section.

```
ANALOG OUTPUT 1
FUNCTION: Disabled
```

Range: Disabled / Enabled

This message enables or disables the analog output 1 (2-7) feature. When disabled, 0 mA will appear at the corresponding terminal.

```
ANALOG OUTPUT 1
VALUE: W1 ∅A Current
```

Range: see below

Select the measured parameter to be represented by the mA DC current level of analog output 1 (2-7).

W1 (2/3) fA (B/C) Current	Select to monitor the RMS value (at fundamental frequency) of the winding 1 (2/3) phase A (B/C) current input.
W1 (2/3) Loading	Select to monitor the winding 1 (2/3) load as a percentage of the rated load for that winding.
W1 (2/3) fA (B/C) THD	Select to monitor the total harmonic distortion in the winding 1 (2/3) phase A (B/C) current input.
W1 (2/3) Derating	Select to monitor the harmonic derating factor (i.e. the derated transformer capability while supplying non-sinusoidal load currents) in winding 1 (2/3).
Frequency	Select to monitor the system frequency.
Tap Position	Select to monitor the onload tap changer position.
Voltage	Select to monitor the system voltage as measured from the voltage input.
W1 (2/3) fA (B/C) Demand	Select to monitor the current demand value of the winding 1 (2/3) phase A (B/C) current input.
Analog Input	Select to monitor the general purpose analog input current.
Max Event W1 (2/3) Ia (b/c/g)	Select to monitor the maximum captured RMS value (at fundamental frequency) of the winding 1 (2/3) phase A (phase B / phase C / ground) current input for all events since the last time the event recorder was cleared.

```
ANALOG OUTPUT 1
RANGE: 4-20 mA
```

Range: 0-1 mA / 0-5 mA / 4-20 mA / 0-20 mA / 0-10 mA

Select the full-scale range of output current for analog output 1 (2-7).

```
ANALOG OUTPUT 1
MIN: 0 A
```

Range: matches the range of the selected measured parameter.

Enter the value of the selected parameter which corresponds to the minimum output current of analog output 1 (2-7).

```
ANALOG OUTPUT 1
MAX: 1000 A
```

Range: matches the range of the associated actual value

Enter the value of the selected parameter which corresponds to the maximum output current of analog output 1 (2-7).

5.5.1 DESCRIPTION

The 745 has two types of digital inputs: *Logic Inputs* have physical terminals for connecting to external contacts. *Virtual Inputs*, on the other hand, although providing the same function as logic inputs, have no physical external connections: a setpoint defines the state of each in terms of “ON” or “OFF”.

There are 16 of each of logic inputs and virtual inputs. The state (‘asserted’ or ‘not asserted’) of each logic or virtual input can be used to cause any of a variety of predefined logic functions, such as protection element blocking, energization detection, etc. In addition, any logic or virtual input can be used as an input in FlexLogic™ equations to implement custom schemes.

```
▌▌ SETPOINTS
▌▌ S3 LOGIC INPUTS
```

This message indicates the start of setpoints page **S3 LOGIC INPUTS**. Press MESSAGE ▼ to view the contents of this page or SETPOINT to go to the next page.

5.5.2 LOGIC INPUTS

```
▌ LOGIC INPUTS
▌ [ENTER] for more
```

This message indicates the start of the **LOGIC INPUTS** section. To continue these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section.

```
▌ LOGIC INPUT 1
▌ [ENTER] for more
```

This message indicates the start of the logic input 1 (2-16) setpoints. To continue with these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section.

```
INPUT 1 FUNCTION
Disabled
```

Range: Disabled / Enabled

Select ‘Enabled’ if this logic input is to be used. Selecting Disabled will never allow this logic input to achieve the ‘Asserted’ (or signaling) state.

```
INPUT 1 TARGET:
Self-Reset
```

Range: None / Latched / Self-Reset

Chose None to inhibit the display of the target message when the input is asserted. Thus an input whose “target type” is None will never disable the LED self-test feature because cannot generate a displayable target message.

```
INPUT 1 NAME:
Logic Input 1
```

Range: 18 alphanumeric characters

Press ENTER to begin editing the name of the logic input. The text may be changed from Logic Input 1 one character at a time, using VALUE ▲/VALUE ▼. Press ENTER to store the edit and advance to the next character position.

```
INPUT 1 ASSERTED
STATE: Closed
```

Range: Open / Closed

Select Closed as the input asserted state when connected to a normally open contact (where the signaling state is closed). Select Open when connected to a normally closed contact (where the signaling state is open).

5

5.5.3 VIRTUAL INPUTS

The Virtual Inputs setpoints are listed below:

```
▌ VIRTUAL INPUTS
▌ [ENTER] for more
```

This message indicates the start of the **VIRTUAL INPUTS** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
▌ VIRTUAL INPUT 1
▌ [ENTER] for more
```

This message indicates the start of the virtual input 1 (2-16) setpoints. To continue with these setpoints, press ENTER key, or press MESSAGE ▼ to go to the next section.

```
INPUT 1 FUNCTION
Disabled
```

Range: Disabled / Enabled

Select Enabled if this logic input is to be used. Selecting Disabled will never allow this logic input to achieve the 'Asserted' (or signaling) state.

```
INPUT 1 TARGET:
Self-Reset
```

Range: None / Latched / Self-Reset

Select None to inhibit the display of the target message when the input is asserted. Thus an input whose "target type" is None will never disable the LED self-test feature because can not generate a displayable target message.

```
INPUT 1 NAME:
Virtual Input 1
```

Range: 18 alphanumeric characters

Press ENTER to begin editing the name of the virtual input. The text may be changed from Virtual Input 1 one character at a time, using the VALUE ▲/ VALUE ▼ keys. Press ENTER to store the edit and advance to the next character position.

```
INPUT 1 PROGRAMMED
STATE: Not Asserted
```

Range: Not Asserted / Asserted

Select Asserted to place the virtual input in the signaling state. Select Not Asserted to place the virtual input in the non-signaling state.

5.6.1 DESCRIPTION

Protection and monitoring elements are configured in this page. This includes: complete differential protection; phase, neutral, ground, negative sequence overcurrent protection; restricted ground fault (differential ground) protection; under, over, and rate-of-change of frequency; overexcitation; harmonic monitoring; analog input monitoring; current demand monitoring; and transformer overload monitoring.

```
▌▌ SETPOINTS
▌▌ S4 ELEMENTS
```

This message indicates the start of setpoints page **S4 ELEMENTS**. Press MESSAGE ▼ to view the contents of this page, or SETPOINT to go to the next page.

5.6.2 INTRODUCTION TO ELEMENTS

Each element is comprised of a number of setpoints, some of which are common to all elements. These common setpoints are described below, avoiding repeated descriptions throughout this section:

```
<NAME OF ELEMENT>
FUNCTION: Enabled
```

Range: Disabled / Enabled

Select Enabled to enable the element. For critical protection elements, this setpoint will normally be set to Enabled except for test purposes. For elements which are not to be used, this setpoint should be set to Disabled.

```
<NAME OF ELEMENT>
TARGET: Latched
```

Range: Self-reset / Latched / None

Target messages (accessed by the NEXT key) indicate which elements have picked up or operated. Select Latched to keep the element target message in the queue of target messages, even after the condition which caused the element to operate has been cleared, until a reset command is issued. Select Self-reset to automatically remove the target message from the queue of messages after the condition has been cleared. Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature because can not generate a displayable target message.

```
<NAME OF ELEMENT>
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) / Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

Select any logic input, virtual input, output relay, or virtual output which, when asserted or operated, will block the element from operating. Selecting a logic input or virtual input allows the element to be blocked based on a decision external to the 745. Selecting an output relay or virtual output allows the element to be blocked based on conditions detected by the 745 and the combination of logic programmed in the associated FlexLogic™ equation.

5.6.3 SETPOINT GROUP

Each protection and monitoring element setpoint (programmed in **S4 ELEMENTS**) has four copies, and these settings are organized in four setpoint groups. Only one group of settings are active in the protection scheme at a time. The active group can be selected using the **ACTIVE SETPOINT GROUP** setpoint or using a logic input. The setpoints in any group can be viewed or edited using the **EDIT SETPOINT GROUP** setpoint.

```
▌ SETPOINT GROUP
▌ [ENTER] for more
```

This message indicates the start of the **SETPOINT GROUP** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
ACTIVE SETPOINT
GROUP: Group 1
```

Range: Group 1 / Group 2 / Group 3 / Group 4

Select the number of the **SETPOINT GROUP** whose settings are to be active in the protection scheme. This selection will be overridden if a higher number setpoint group is activated using logic inputs.

```
EDIT SETPOINT
GROUP: Active Group
```

Range: Group 1 / Group 2 / Group 3 / Group 4 / Active Group

Select the number of the **SETPOINT GROUP** whose settings are to be viewed and/or edited via the front panel keypad or any of the communication ports. Selecting Active Group selects the currently active setpoint group for editing.

```
GROUP 2 ACTIVATE
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, will (remotely) select **SETPOINT GROUP 2 (3-4)** to be the active group. This selection will be overridden if a higher number setpoint group is activated using the **ACTIVE SETPOINT GROUP** setpoint or another logic input.

5

5.6.4 DIFFERENTIAL

This section contains the settings to configure the percent differential element, including all associated harmonic inhibit features. The 745 provides three independent harmonic inhibit features: **HARMONIC INHIBIT**, which implements an inhibit scheme based on 2^{nd} or 2^{nd} + 5^{th} harmonic which is 'in-circuit' at all times; **ENERGIZATION INHIBIT**, which allows changing the characteristics of the inhibit scheme during energization to improve reliability; and **5TH HARMONIC INHIBIT**, which implements an inhibit scheme based on 5^{th} harmonic only, allowing inhibiting the percent differential during intentional overexcitation of the system.

```
▌ DIFFERENTIAL
▌ [ENTER] for more
```

This message indicates the start of the **DIFFERENTIAL** section. To continue these setpoints, press ENTER, or press MESSAGE ▼ to go to the next section.

a) PERCENT DIFFERENTIAL

This section contains the settings to configure the percent differential element. The main purpose of the percent-slope characteristic of the differential element is to prevent maloperation because of unbalances between CTs during external faults. These unbalances arise as a result of the following factors:

- CT ratio mismatch (not a factor, since the 745 automatically corrects for this mismatch)
- Onload tap changers which result in dynamically changing CT mismatch
- CT accuracy errors
- CT saturation

The basic operating principle of the percent differential element can be described by the following diagram and its associated equations:

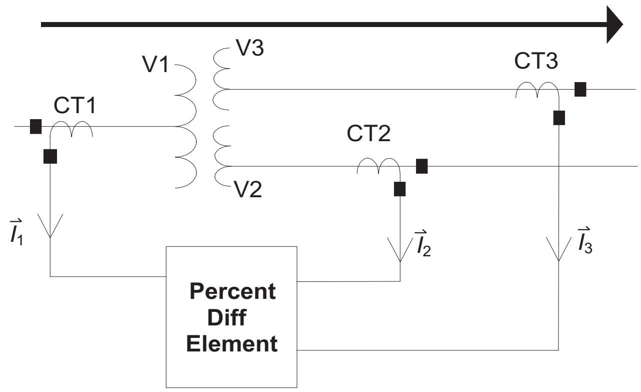


Figure 5–6: PERCENT DIFFERENTIAL OPERATING PRINCIPLE

NOTE

Restraint current calculations have been changed from *average* to *maximum* to provide better security during external faults.

Basic Operating Principle (3-winding):

$$I_r = I_{restraint} = \max(|\vec{I}_1|, |\vec{I}_2|, |\vec{I}_3|)$$

$$I_d = I_{differential} = |\vec{I}_1 + \vec{I}_2 + \vec{I}_3|$$

$$\%slope = \frac{I_d}{I_r} \times 100\%$$

Basic Operating Principle (2-winding):

$$I_r = I_{restraint} = \max(|\vec{I}_1|, |\vec{I}_2|)$$

$$I_d = I_{differential} = |\vec{I}_1 + \vec{I}_2|$$

$$\%slope = \frac{I_d}{I_r} \times 100\%$$

where $I_{restraint}$ = per-phase **maximum** of the currents after phase, ratio, and zero-sequence correction
$I_{differential}$ = per-phase **vector sum** of currents after phase, ratio, and zero-sequence correction

NOTE

In the above equations, the 180° phase shift due to the wiring connections is taken into account, hence the + sign to obtain the differential current.

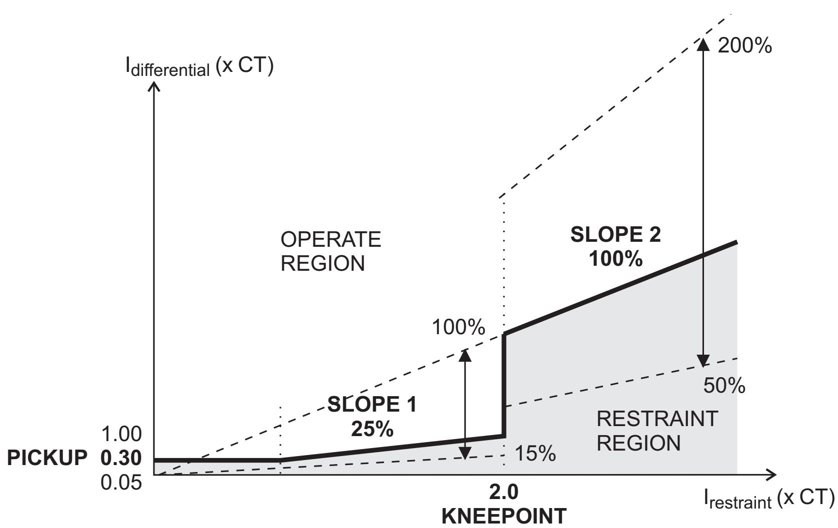


Figure 5–7: PERCENT DIFFERENTIAL – DUAL SLOPE CHARACTERISTIC

The percent differential setpoints are shown below:

```
▌ PERCENT DIFFERENTL
▌ [ENTER] for more
```

This message indicates the start of the **PERCENT DIFFERENTIAL** section. To continue with these setpoints press [ENTER], or press [MESSAGE ▼] to go to the next section.

```
PERCENT DIFFERENTIAL
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
PERCENT DIFFERENTIAL
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
PERCENT DIFFERENTIAL
PICKUP: 0.30 x CT
```

Range: 0.05 to 1.00 (steps of 0.01)

Enter the minimum differential current required for operation. This setting is chosen based on the amount of differential current that might be seen under normal operating conditions.

```
PERCENT DIFFERENTIAL
SLOPE 1: 25%
```

Range: 15 to 100 (steps of 1)

Enter the slope 1 percentage (of differential current to restraint current) for the dual-slope percent differential element. The slope 1 setting is applicable for restraint currents of zero to the kneepoint, and defines the ratio of differential to restraint current above which the element will operate. This slope is set to ensure sensitivity to internal faults at normal operating current levels. The criteria for setting this slope are: (1) to allow for mismatch when operating at the limit of the transformer’s onload tap-changer range; (2) to accommodate for CT errors.

```
PERCENT DIFFERENTIAL
KNEEPOINT: 2.0 x CT
```

Range: 1.0 to 20.0 (steps of 0.1)

Enter the kneepoint for the dual-slope percent differential element. This is the transition point between slopes 1 and 2, in terms of restraint current, in units of relay nominal current. Set the kneepoint just above the maximum operating current level of the transformer between the maximum forced-cooled rated current and the maximum emergency overload current level.

```
PERCENT DIFFERENTIAL
SLOPE 2: 95%
```

Range: 50 to 200 (steps of 1)

Enter the slope 2 percentage (of differential current to restraint current) for the dual-slope percent differential element. This setting is applicable for restraint currents above the kneepoint and is set to ensure stability under heavy through fault conditions which could lead to high differential currents as a result of CT saturation.

NOTE

Since $I_{restraint} = \max(|I_1|, |I_2|, |I_3|)$, it is not guaranteed that the differential current is always greater than 100% of the restraint current. Because of this enhancement, the **PERCENT DIFFERENTIAL SLOPE 2** settings may cause slow operation (in rare cases no operation) in the following situations:

1. **PERCENT DIFFERENTIAL SLOPE 2** is set above 100%.
2. The source is connected to one winding only.

Therefore, the **PERCENT DIFFERENTIAL SLOPE 2** value cannot be greater than 100%. To increase dependability, the slope 2 settings should be less than 98%

```
PERCENT DIFFERENTIAL
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

b) HARMONIC INHIBIT

This section contains the settings of the percent differential harmonic inhibit feature. This the percent differential element in a particular phase if the 2nd harmonic of the same phase exceeds the **HARMONIC INHIBIT LEVEL** setpoint. With harmonic inhibit parameters set to 2nd+5th, the RMS sum of the 2nd and 5th harmonic components is compared against the level setting. With harmonic averaging enabled, all three phases are inhibited if the three-phase average of the harmonics exceeds the level setting.

```
▌ HARMONIC INHIBIT
▌ [ENTER] for more
```

This message indicates the start of the **HARMONIC INHIBIT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
HARMONIC INHIBIT
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
HARMONIC INHIBIT
PARAMETERS: 2nd
```

Range: 2nd / 2nd + 5th

Select 2nd to compare only the 2nd harmonic current against the **HARMONIC INHIBIT LEVEL**. Select 2nd+5th to use the RMS sum of the 2nd & 5th harmonic components. For most transformers, the 2nd harmonic current alone will exceed 20% during energization and the 2nd setting is sufficient to inhibit the differential element for inrush current.

```
HARMONIC AVERAGING:
Disabled
```

Range: Disabled / Enabled

Select Enabled to use the three-phase average of the harmonic current against the harmonic inhibit setting. For most applications, enabling harmonic averaging is not recommended.

```
HARMONIC INHIBIT
LEVEL: 20.0% ƒo
```

Range: 0.1 to 65.0 (steps of 0.1)

Enter the level of harmonic current (2nd or 2nd+5th) above which the percent differential element will be inhibited from operating. For most applications, this level should be set to 20%.

c) ENERGIZATION INHIBIT

Over and above the standard harmonic inhibit feature programmed above, the 745 contains a harmonic inhibit feature which is in service only during energization and/or sympathetic inrush.

De-energization and energization of the transformer is detected by any of the following three methods:

1. With energization sensing by current enabled, all currents dropping below the minimum energization current indicates de-energization; any current exceeding the minimum energization current indicates energization. This method is the least reliable method of detecting energization, since an energized and unloaded transformer will be detected as being de-energized if this method is used alone.
2. With energization sensing by voltage enabled, the voltage dropping below the minimum energization voltage indicates de-energization; any *current* exceeding the minimum energization current indicates energization.
3. With 'b' auxiliary contacts from all switching devices (which can be used to energize the transformer) connected in series to a logic input and assigned to the **BREAKERS ARE OPEN** setpoint, the contacts closed indicates de-energization; any current exceeding the minimum energization current indicates energization.

Energization inhibit settings are put in service upon detection of de-energization. Upon energization, the energization inhibit duration timer is initiated and the settings are removed from service when the time delay elapses.

The energization inhibit feature may also be put in service during sympathetic inrush. The onset of sympathetic inrush is detected via a close command to the parallel transformer switching device connected to a logic input, assigned to the **PARALL XFMR BRKR CLS** setpoint. The energization inhibit settings are put in service when the contact closes. Upon the removal of the signal, the energization inhibit duration timer is initiated and the settings are removed from service when the time delay elapses.

In a “breaker-and-a-half scheme”, where current can be present in the CTs without being present in the transformer winding, it may be necessary to use the Parallel transformer Breaker Close contact to initiate Energization Inhibit.

```
▌ ENERGIZATN INHIBIT
▌ [ENTER] for more
```

This message indicates the start of the **ENERGIZATION INHIBIT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
ENERGIZATION INHIBIT
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
ENERGIZATION INHIBIT
PARAMETERS: 2nd
```

Range: 2nd / 2nd + 5th

Select 2nd to compare the 2nd harmonic current against **HARMONIC INHIBIT LEVEL**. Select 2nd+5th to use the RMS sum of the 2nd and 5th harmonics.

```
HARMONIC AVERAGING:
Enabled
```

Range: Disabled / Enabled

Select Enabled to use the three-phase average of the harmonic current against the harmonic inhibit setting.

5

```
ENERGIZATION INHIBIT
LEVEL: 20.0% ƒo
```

Range: 0.1 to 65.0 (steps of 0.1)

Enter the level of harmonic current (2nd or 2nd + 5th) above which the percent differential element is inhibited from operating. This setting will often need to be set significantly lower than the **HARMONIC INHIBIT LEVEL**, especially when used with the Parallel Xfmr BkrCls logic input function for sympathetic inrush.

```
ENERGIZATION INHIBIT
DURATION:   0.10 s
```

Range: 0.05 to 600.00 (steps of 0.01)

Enter the time delay from the moment of energization (or the end of the parallel breaker close command) before the energization inhibit feature is removed from service.

d) ENERGIZATION SENSING

This section contains the settings for the Energization Sensing element. Energization sensing allows for the measurement of de-energization by current and voltage.

```
▌ ENERGIZATION SENSING
▌ [ENTER] for more
```

This message indicates the start of the **ENERGIZATION SENSING** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
ENERGIZATION SENSING
BY CURRENT: Enabled
```

Range: Disabled / Enabled

Select Enabled to detect de-energization by the level of all currents dropping below the minimum energization current.

```
MINIMUM ENERGIZATION
CURRENT: 0.10 x CT
```

Range: 0.10 to 0.50 (steps of 0.01)

Enter the level of current below which the transformer is considered de-energized (energization sensing by current enabled), and above which the transformer is considered energized (any energization sensing enabled).

```
ENERGIZATION SENSING
BY VOLTAGE: Disabled
```

Range: Disabled / Enabled

Select Enabled to detect de-energization by the level of the voltage dropping below the minimum energization voltage. This setpoint is displayed only if voltage sensing is enabled under **S2 SYSTEM SETUP/VOLTAGE INPUT**.

```
MINIMUM ENERGIZATION
VOLTAGE: 0.85 X VT
```

Range: 0.50 to 0.99 (steps of 0.01)

Enter the voltage level below which the transformer is considered de-energized (when **ENERGIZATION SENSING BY VOLTAGE** is Enabled). Displayed only if **S2 SYSTEM SETUP/VOLTAGE INPUT/VOLTAGE SENSING** is Enabled.

```
BREAKERS ARE OPEN
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, will indicate to the 745 that the transformer is de-energized. The selected logic input should be connected to the auxiliary contacts of the transformer breaker or disconnect switch.

```
PARALL XFMR BRKR CLS
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, will indicate to the 745 the onset of sympathetic inrush. The selected logic input should be connected to the close command going to the parallel transformer switching device.

e) 5TH HARMONIC INHIBIT

This section contains the settings of the 5^{th} harmonic inhibit feature of the percent differential element, which allows inhibiting the percent differential during intentional overexcitation of the system. This feature inhibits the percent differential element in a particular phase if the 5^{th} harmonic of the same phase exceeds the harmonic inhibit level setting. With harmonic averaging enabled, all three phases are inhibited if the three-phase average of the 5^{th} harmonic exceeds the level setting.

5

```
▌ 5th HARM INHIBIT
▌ [ENTER] for more
```

This message indicates the start of the **5TH HARMONIC INHIBIT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
5th HARMONIC INHIBIT
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
HARMONIC AVERAGING:
Disabled
```

Range: Disabled / Enabled

Select ‘Enabled’ to use the three-phase average of the 5th harmonic current against the harmonic inhibit setting.

```
5th HARMONIC INHIBIT
LEVEL: 10.0% ƒo
```

Range: 0.1 to 65.0 (steps of 0.1)

Enter the level of 5th harmonic current above which the percent differential element will be inhibited from operating.

5.6.5 INSTANTANEOUS DIFFERENTIAL

This section contains the settings to configure the (unrestrained) instantaneous differential element, for protection under high magnitude internal faults.

```
▌ INST DIFFERENTIAL
▌ [ENTER] for more
```

This message indicates the start of the **INSTANTANEOUS DIFFERENTIAL** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
INST DIFFERENTIAL
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
INST DIFFERENTIAL
TARGET: Latched
```

Range: Self-reset / Latched / None

Select "None" to inhibit the display of the target message when the element operates. Thus an element whose "target type" is "None" never disables the LED self-test feature since it cannot generate a displayable target message.

```
INST DIFFERENTIAL
PICKUP: 8.00 x CT
```

Range: 3.00 to 20.00 (steps of 0.01)

Enter the level of differential current (in units of relay nominal current) above which the instantaneous differential element will pickup and operate.

```
INST DIFFERENTIAL
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

5.6.6 PHASE OVERCURRENT

This section contains settings to configure the phase overcurrent elements. Included are phase time overcurrents and two levels of phase instantaneous overcurrent for each phase of each winding.

```
▌ PHASE OC
▌ [ENTER] for more
```

This message indicates the start of the **PHASE OVERCURRENT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

a) WINDING 1 (2/3) PHASE TIME OVERCURRENT

```
▌ W1 PHASE TIME OC
▌ [ENTER] for more
```

This message indicates the start of the **PHASE TIME OVERCURRENT** section for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 PHASE TIME OC
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
W1 PHASE TIME OC
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
W1 PHASE TIME OC
PICKUP: 1.20 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the phase current level (in units of relay nominal current) above which the W1 (2/3) phase time overcurrent element will pickup and start timing.

```
W1 PHASE TIME OC
SHAPE: Ext Inverse
```

Range: Ext Inverse / Very Inverse / Norm Inverse / Mod Inverse / Definite Time / IEC Curve A / IEC Curve B / IEC Curve C / IEC Short Inv / IAC Ext Inv / IAC Very Inv / IAC Inverse / IAC Short Inv / FlexCurve A / FlexCurve B / FlexCurve C

Select the time overcurrent curve shape to be used for the W1 (2/3) phase time overcurrent element. Section 5.9: TIME OVERCURRENT CURVES on page 5–91 describes the time overcurrent curve shapes.

```
W1 PHASE TIME OC
MULTIPLIER: 1.00
```

Range: 0.00 to 100.00 (steps of 0.01)

Enter the multiplier constant by which the selected time overcurrent curve shape (the base curve) is to be shifted in time.

```
W1 PHASE TIME OC
RESET: Linear
```

Range: Instantaneous / Linear

Select Linear reset to coordinate with electromechanical time overcurrent relays, in which the reset characteristic (when the current falls below the reset threshold before tripping) is proportional to ratio of “energy” accumulated to that required to trip. Select Instantaneous reset to coordinate with relays, such as most static units, with instantaneous reset characteristics.

```
W1 PHASE TIME OC
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

```
W1 HARMONIC DERATING
CORRECTION: Disabled
```

Range: Disabled / Enabled

Select Enabled to enable automatic harmonic derating correction of the W1 (2/3) phase time overcurrent curve. The 745 calculates the derated transformer capability when supplying non-sinusoidal load currents (as per ANSI / IEEE C57.110-1986) and, when this feature is enabled, automatically shifts the phase time overcurrent curve pickup in order to maintain the required protection margin with respect to the transformer thermal damage curve, as illustrated below.

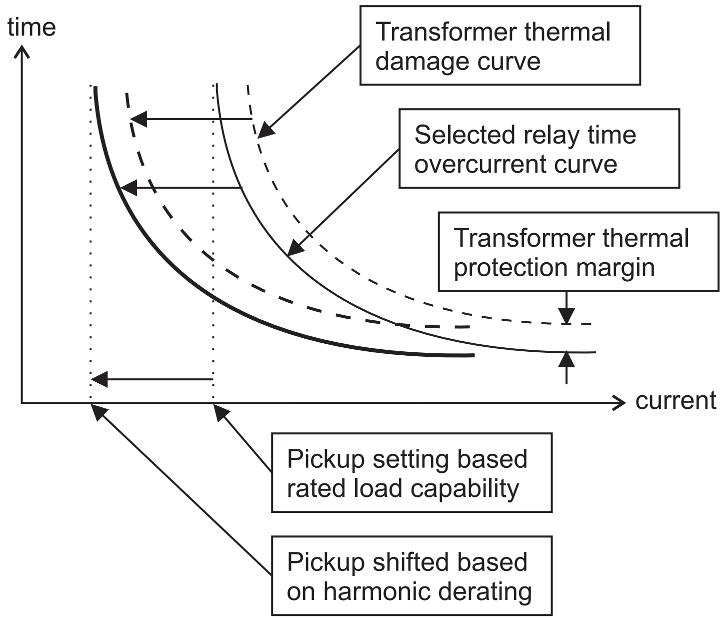


Figure 5–8: HARMONIC DERATING CORRECTION

5

b) WINDING 1 (2/3) PHASE INSTANTANEOUS OVERCURRENT 1

```
▌ W1 PHASE INST OC 1
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the first level of **PHASE INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 PHASE INST OC 1
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
W1 PHASE INST OC 1
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature because can not generate a displayable target message.

```
W1 PHASE INST OC 1
PICKUP: 10.00 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of phase current (in units of relay nominal current) above which the W1 (2/3) phase instantaneous overcurrent 1 element will pickup and start the delay timer.

```
W1 PHASE INST OC 1
DELAY:     0 ms
```

Range: 0 to 60000 (steps of 1)

Enter the time that the phase current must remain above the pickup level before the element operates.

```
W1 PHASE INST OC 1
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

c) WINDING 1 (2/3) PHASE INSTANTANEOUS OVERCURRENT 2

```
▌ W1 PHASE INST OC 2
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the second level of **PHASE INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

NOTE

The messages that follow are identical to those described for PHASE INSTANTANEOUS OVERCURRENT 1 above.

5.6.7 NEUTRAL OVERCURRENT

In the 745, "neutral" refers to residual current ($3I_0$), which is calculated internally as the vector sum of the three phases. This section contains the settings to configure the neutral overcurrent elements. Included are neutral time overcurrents for each winding, and two levels of neutral instantaneous overcurrent for each winding.

```
▌ NEUTRAL OC
▌ [ENTER] for more
```

This message indicates the start of the **NEUTRAL OVERCURRENT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

a) WINDING 1 (2/3) NEUTRAL TIME OVERCURRENT

```
▌ W1 NTRL TIME OC
▌ [ENTER] for more
```

This message indicates the start of the **NEUTRAL TIME OVERCURRENT** section for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 NEUTRAL TIME OC
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
W1 NEUTRAL TIME OC
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None will never disable the LED self-test feature because can not generate a displayable target message.

```
W1 NEUTRAL TIME OC
PICKUP: 0.85 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of neutral current (in units of relay nominal current) above which the W1 (2/3) neutral time overcurrent element will pickup and start timing.

```
W1 NEUTRAL TIME OC
SHAPE: Ext Inverse
```

Range: Ext Inverse / Very Inverse / Norm Inverse / Mod Inverse / Definite Time / IEC Curve A / IEC Curve B / IEC Curve C / IEC Short Inv / IAC Ext Inv / IAC Very Inv / IAC Inverse / IAC Short Inv / FlexCurve A / FlexCurve B / FlexCurve C

Select the time overcurrent curve shape to be used for the W1 (2/3) neutral time overcurrent element. Section 5.9: TIME OVERCURRENT CURVES on page 5–91 describes the time overcurrent curve shapes.

```
W1 NEUTRAL TIME OC
MULTIPLIER: 1.00
```

Range: 0.00 to 100.00 (steps of 0.01)

Enter the multiplier constant by which the selected time overcurrent curve shape (the base curve) is to be shifted in time.

```
W1 NEUTRAL TIME OC
RESET: Linear
```

Range: Instantaneous / Linear

Select Linear reset to coordinate with electromechanical time overcurrent relays, in which the reset characteristic (when the current falls below the reset threshold before tripping) is proportional to ratio of "energy" accumulated to that required to trip. Select Instantaneous reset to coordinate with relays, such as most static units, with instantaneous reset characteristics.

```
W1 NEUTRAL TIME OC
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

b) WINDING 1 (2/3) NEUTRAL INSTANTANEOUS OVERCURRENT 1

```
▌ W1 NTRL INST OC 1
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the first level of **NEUTRAL INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 NEUTRAL INST OC 1
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
W1 NEUTRAL INST OC 1
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None will never disable the LED self-test feature because can not generate a displayable target message.

```
W1 NEUTRAL INST OC 1
PICKUP: 10.00 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of neutral current (in units of relay nominal current) above which the W1 (2/3) neutral instantaneous overcurrent 1 element will pickup and start the delay timer.

```
W1 NEUTRAL INST OC 1
DELAY:      0 ms
```

Range: 0 to 60000 (steps of 1)

Enter the time that the neutral current must remain above the pickup level before the element operates.

```
W1 NEUTRAL INST OC 1
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

c) WINDING 1 (2/3) NEUTRAL INSTANTANEOUS OVERCURRENT 2

```
▌ W1 NTRL INST OC 2
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the second level of **NEUTRAL INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

NOTE

The messages that follow are identical to those described for NEUTRAL INSTANTANEOUS OVERCURRENT 1.

5.6.8 GROUND OVERCURRENT

In the 745, "ground" refers to the current measured in a CT in the connection between the transformer neutral and ground. The 745 has two ground inputs which are automatically assigned to wye or zig-zag connected windings, based on the transformer type selected. As a result, only those ground overcurrent settings whose winding is assigned a ground input are displayed and enabled. This section contains the settings to configure the ground overcurrent elements. Included are ground time overcurrents for each (wye or zig-zag) winding, and two levels of ground instantaneous overcurrent for each (wye or zig-zag) winding.

```
▌ GROUND OC
▌ [ENTER] for more
```

This message indicates the start of the **GROUND OVERCURRENT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

a) WINDING 1 (2/3) GROUND TIME OVERCURRENT

```
▌ W1 GND TIME OC
▌ [ENTER] for more
```

Here is the start of the **GROUND TIME OVERCURRENT** section for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 GROUND TIME OC
FUNCTION: Enabled
```

Range: Disabled / Enabled

```
W1 GROUND TIME OC
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
W1 GROUND TIME OC
PICKUP: 0.85 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of ground current (in units of relay nominal current) above which the W1 (2/3) ground time overcurrent element will pickup and start timing.

```
W1 GROUND TIME OC
SHAPE: Ext Inverse
```

Range: Ext Inverse / Very Inverse / Norm Inverse / Mod Inverse / Definite Time / IEC Curve A / IEC Curve B / IEC Curve C / IEC Short Inv / IAC Ext Inv / IAC Very Inv / IAC Inverse / IAC Short Inv / FlexCurve A / FlexCurve B / FlexCurve C

Select the time overcurrent curve shape to be used for the W1 (2/3) ground time overcurrent element. Section 5.9: TIME OVERCURRENT CURVES on page 5–91 describes the time overcurrent curve shapes.

```
W1 GROUND TIME OC
MULTIPLIER: 1.00
```

Range: 0.00 to 100.00 (steps of 0.01)

Enter the multiplier constant by which the selected time overcurrent curve shape (the base curve) is to be shifted in time.

```
W1 GROUND TIME OC
RESET: Linear
```

Range: Instantaneous / Linear

Select Linear reset to coordinate with electromechanical time overcurrent relays, in which the reset characteristic (when the current falls below the reset threshold before tripping) is proportional to ratio of energy accumulated to that required to trip. Select Instantaneous reset to coordinate with relays, such as most static units, with instantaneous reset characteristics.

```
W1 GROUND TIME OC
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

b) WINDING 1 (2/3) GROUND INSTANTANEOUS OVERCURRENT 1

```
▌ W1 GND INST OC 1
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the first level of **GROUND INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 GROUND INST OC 1
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
W1 GROUND INST OC 1
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None will never disable the LED self-test feature because can not generate a displayable target message.

```
W1 GROUND INST OC 1
PICKUP: 10.00 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of ground current (in units of relay nominal current) above which the W1 (2/3) ground instantaneous overcurrent 1 element will pickup and start the delay timer.

```
W1 GROUND INST OC 1
DELAY:     0 ms
```

Range: 0 to 60000 (steps of 1)

Enter the time that the ground current must remain above the pickup level before the element operates.


```
W1 GROUND INST OC 1
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

c) WINDING 1 (2/3) GROUND INSTANTANEOUS OVERCURRENT 2

```
▌ W1 GND INST OC 2
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the second level of **GROUND INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

NOTE

The messages that follow are identical to those described for GROUND INSTANTANEOUS OVERCURRENT 1.

5.6.9 RESTRICTED GROUND (DIFFERENTIAL GROUND)

```
▌ RESTRICTED GROUND
▌ [ENTER] for more
```

This message indicates the start of the **RESTRICTED GROUND** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

a) WINDING 1 (2/3) RESTRICTED GROUND FAULT

This section contains the settings to configure the restricted ground fault elements.

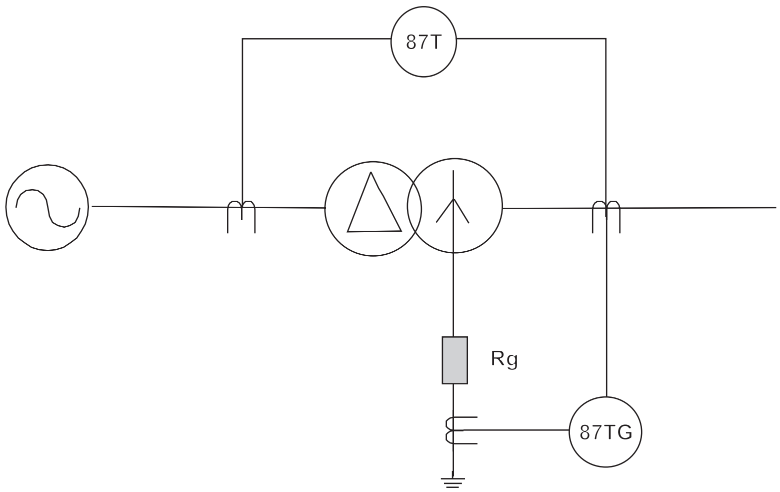


Figure 5–9: RESTRICTED EARTH GROUND FAULT PROTECTION

Restricted Ground Fault protection is often applied to transformers having impedance grounded wye windings. It is intended to provide sensitive ground fault detection for low magnitude fault currents which would not be detected by the percent differential element.

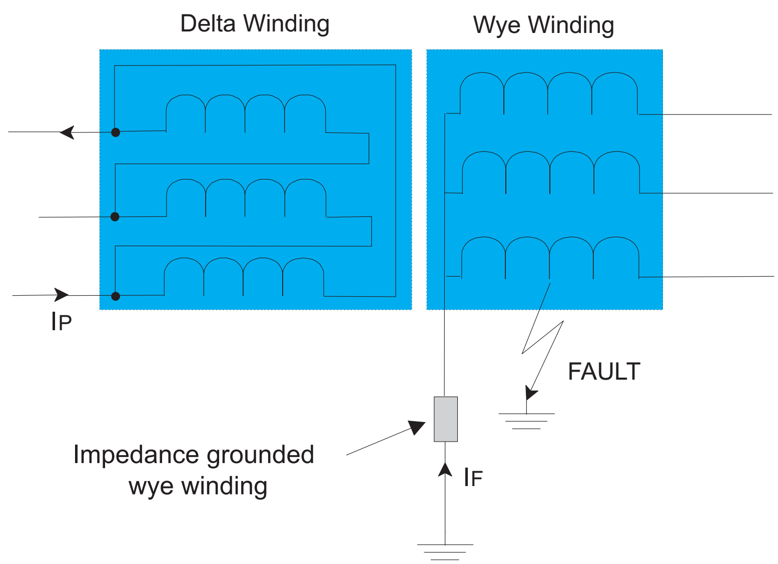


Figure 5–10: RESISTANCE GROUNDED WYE WINDING

An internal ground fault on an impedance grounded wye winding (see Figure 5–10: RESISTANCE GROUNDED WYE WINDING above) produces a fault current (I_F) dependent on the value of the ground impedance and the position of the fault on the winding with respect to the neutral point. The resultant primary current (I_P) will be negligible for faults on the lower 30% of the winding since the fault voltage will not be the system voltage but the result of the transformation ratio between the primary windings and the percentage of shorted turns on the secondary. Therefore, the resultant differential currents could be below the slope threshold of the percent differential element and thus the fault could go undetected. The graph below shows the relationship between the primary (I_P) and fault (I_F) currents as a function of the distance of the fault point from the neutral and Figure 5–12: RGF AND PERCENT DIFFERENTIAL ZONES OF PROTECTION outlines the zones of effective protection along the winding for an impedance grounded wye.

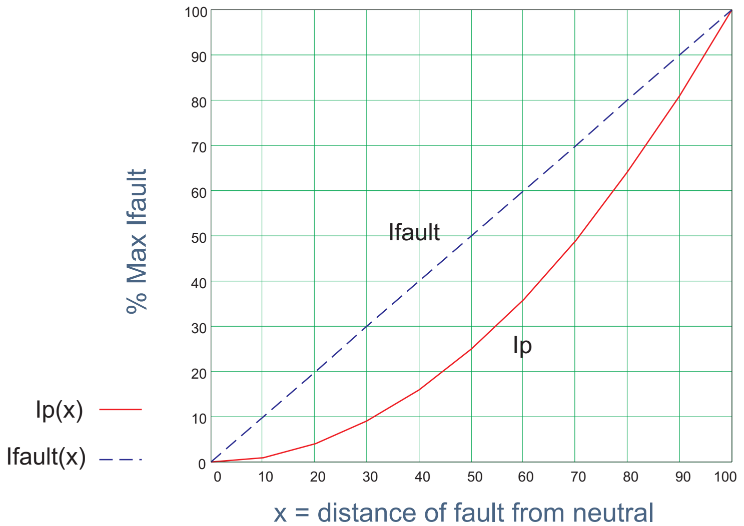


Figure 5–11: FAULT CURRENTS VS. FAULT POINT FROM NEUTRAL

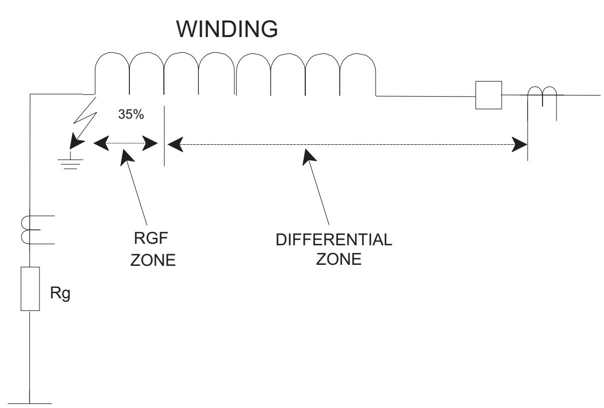


Figure 5–12: RGF AND PERCENT DIFFERENTIAL ZONES OF PROTECTION

The 745 implementation of RGF (Figure 5–13: RESTRICTED GROUND FAULT IMPLEMENTATION) is a low impedance current differential scheme where "spill" current due to CT tolerances is handled via load bias similar to the percent differential. The 745 calculates the vectorial difference of the residual and ground currents (i.e. $3I_0 - I_g$) and divides this by the maximum line current (I_{max}) to produce a percent slope value. The slope setting allows the user to determine the sensitivity of the element based on the class and quality of the CTs used. Typically no more than 4% overall error due to CT "spill" is assumed for protection class CTs at nominal load.

The issue of maloperation due to heavy external faults resulting in CT saturation is handled by a programmable timer. The timer provides the necessary delay required for the external fault to be cleared by the appropriate external protection with the added benefit that if the RGF element remains picked up after the timer expires the 745 will operate and clear the fault. This approach provides backup protection. Since the RGF element is targeted at detecting low magnitude internal winding fault currents, the time delay for internal faults is of little consequence since sensitivity and security are the critical parameters.

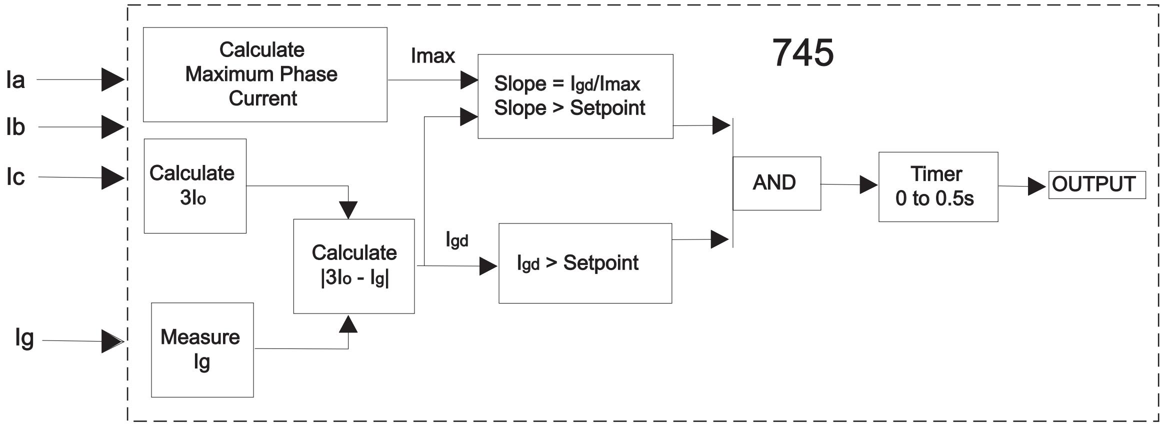


Figure 5–13: RESTRICTED GROUND FAULT IMPLEMENTATION

b) RESTRICTED GROUND FAULT SETTINGS EXAMPLE

Consider a transformer with the following specifications:

10 MVA, 33 kV to 11 kV, 10% Impedance, Delta/Wye30
Rg = 6.3 ohms
CT Ratio = 600 / 1 Amp
Rated Load Current = I_{rated} = 10 MVA / (√3 x 11 kV) = 525 Amps
Maximum Phase-to-Ground Fault Current = $I_{gf(max)}$ = 11 kV / (√ 3 x 6.3) = 1000 Amps

For a winding fault point at 5% distance from the neutral:

$$I_{fault} = 0.05 \times I_{gf(max)} = 0.05 \times 1000 \text{ A} = 50 \text{ A}$$

From Figure 5–11: FAULT CURRENTS VS. FAULT POINT FROM NEUTRAL on page 5–60, we see that the I_p increase due to the fault is negligible and therefore $3I_o = 0$ (approx.)

Therefore: maximum phase current = $I_{max} = I_{rated}$ = 525 A (approx.), and

$$I_{gd} = |3I_0 - I_g| = \left|0 - \frac{I_{fault}}{\text{CT Ratio}}\right| = \left|0 - \frac{50\text{ A}}{600}\right| = 0.08 \times \text{CT} = \text{Pickup Setting}$$

$$\text{Slope} = \frac{I_{gd}}{I_{max}} = \frac{50\text{ A}}{525\text{ A}} = 9.5\% \quad \text{(select Slope Setting = 9\%)}$$

Time Delay: dependent on downstream protection coordination (100 ms typical)

c) SETPOINTS

The Winding 1 Restricted Ground Fault setpoints are shown below:

▌ W1 RESTD GND FAULT ▌ [ENTER] for more	Here is the start of the **RESTRICTED GROUND FAULT** section for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.
W1 RESTD GND FAULT FUNCTION: Disabled	*Range: Disabled / Enabled*
W1 RESTD GND FAULT TARGET: Latched	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature because can not generate a displayable target message.
W1 RESTD GND FAULT PICKUP: 0.08 x CT	*Range: 0.05 to 20.00 (steps of 0.01)* Enter the minimum level of ground differential current (in units of relay nominal current) for the W1 (2/3) restricted ground fault element.
W1 RESTD GND FAULT SLOPE: 10%	*Range: 0 to 100 (steps of 1)* Enter a slope percentage (of ground differential current to maximum line current).
W1 RESTD GND FAULT DELAY: 0.10 s	*Range: 0.00 to 600.00 (steps of 0.01)* Enter the time that the W1 (2/3) restricted ground fault element must remain picked up before the element operates.
W1 RESTD GND FAULT BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

5.6.10 NEGATIVE SEQUENCE OVERCURRENT

This section contains the settings to configure the negative sequence overcurrent elements. Included are negative sequence time overcurrents for each winding, and negative sequence instantaneous overcurrents for each winding.

```
▌ NEG SEQ OC
▌ [ENTER] for more
```

This message indicates the start of the **NEGATIVE SEQUENCE OVERCURRENT** section. To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

a) WINDING 1 (2/3) NEGATIVE SEQUENCE TIME OVERCURRENT

```
▌ W1 NEG SEQ TIME OC
▌ [ENTER] for more
```

This message indicates the start of the **NEGATIVE SEQUENCE TIME OVERCURRENT** section for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 NEG SEQ TIME OC
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
W1 NEG SEQ TIME OC
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
W1 NEG SEQ TIME OC
PICKUP: 0.25 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of negative sequence current (in units of relay nominal current) above which the W1 (2/3) negative sequence time overcurrent element will pickup and start timing.

```
W1 NEG SEQ TIME OC
SHAPE: Ext Inverse
```

Range: Ext Inverse / Very Inverse / Norm Inverse / Mod Inverse / Definite Time / IEC Curve A / IEC Curve B / IEC Curve C / IEC Short Inv / IAC Ext Inv / IAC Very Inv / IAC Inverse / IAC Short Inv / FlexCurve A / FlexCurve B / FlexCurve C

Select the time overcurrent curve shape to be used for the W1 (2/3) negative sequence time overcurrent element. Section 5.9: TIME OVERCURRENT CURVES on page 5–91 describes the time overcurrent curve shapes.

```
W1 NEG SEQ TIME OC
MULTIPLIER: 1.00
```

Range: 0.00 to 100.00 (steps of 0.01)

Enter the multiplier constant by which the selected time overcurrent curve shape (the base curve) is to be shifted in time.

```
W1 NEG SEQ TIME OC
RESET: Linear
```

Range: Instantaneous / Linear

Select Linear reset to coordinate with electromechanical time overcurrent relays, in which the reset characteristic (when the current falls below the reset threshold before tripping) is proportional to ratio of “energy” accumulated to that required to trip. Select Instantaneous reset to coordinate with relays, such as most static units, with instantaneous reset characteristics.

```
W1 NEG SEQ TIME OC
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

b) WINDING 1 (2/3) NEG. SEQ. INSTANTANEOUS OVERCURRENT

```
▌ W1 NEG SEQ INST OC
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the **NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT** protection for Winding 1 (2/3). To continue with these setpoints press ENTER, or press MESSAGE ▼ to go to the next section.

```
W1 NEG SEQ INST OC
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
W1 NEG SEQ INST OC
TARGET: Latched
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature because can not generate a displayable target message.

```
W1 NEG SEQ INST OC
PICKUP: 10.00 x CT
```

Range: 0.05 to 20.00 (steps of 0.01)

Enter the level of negative sequence current (in units of relay nominal current) above which the W1 (2/3) negative sequence instantaneous overcurrent element will pickup and start the delay timer.

```
W1 NEG SEQ INST OC
DELAY: 0 ms
```

Range: 0 to 60000 (steps of 1)

Enter the time that the negative sequence current must remain above the pickup level before the element operates.

5

```
W1 NEG SEQ INST OC
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5.6.11 FREQUENCY

The 745 can be used as the primary detecting relay in automatic load shedding schemes based on underfrequency. This need arises if, during a system disturbance, an area becomes electrically isolated from the main system and suffers generation deficiency due to loss of either transmission or generation facilities. If reserve generation is not available in the area, conditions of low system frequency occur that may lead to a complete collapse. The 745 provides a means of automatically disconnecting sufficient load to restore an acceptable balance between load and generation.

The 745 uses both frequency and frequency rate-of-change as the basis for its operating criteria. These values are measured based on the voltage input or, if voltage is disabled, the Winding 1 phase A current input. The relay has two underfrequency and four rate-of-change levels. Thus, four or more separate blocks of load can be shed, according to the severity of the disturbance.

In addition to these elements, the 745 has an overfrequency element. A significant overfrequency condition, likely caused by a breaker opening and disconnecting load from a particular generation location, can be detected and used to quickly ramp the turbine speed back to normal. If this is not done, the overspeed can lead to a turbine trip, which would then subsequently require a turbine start up before restoring the system. If the turbine speed can be controlled successfully, system restoration can be much quicker. The overfrequency element of the 745 can be used for this purpose at a generating location.

NOTE

WE STRONGLY RECOMMEND THE USE OF EITHER THE VOLTAGE OR CURRENT OR BOTH SIGNAL FOR SUPERVISION. IF NO SUPERVISING CONDITIONS ARE ENABLED, THE ELEMENT *COULD PRODUCE UNDESIRABLE OPERATION!*

```
▌ FREQUENCY
▌ [ENTER] for more
```

This message indicates the start of the **FREQUENCY** section. To continue these setpoints press ENTER or press MESSAGE ▼ to go to the next section.

a) UNDERFREQUENCY 1 (2)

```
▌ UNDERFREQUENCY 1
▌ [ENTER] for more
```

This message indicates the start of the **UNDERFREQUENCY** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
UNDERFREQUENCY 1
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
UNDERFREQUENCY 1
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
CURRENT SENSING:
Enabled
```

Range: Disabled / Enabled

```
MINIMUM OPERATING
CURRENT: 0.20 x CT
```

Range: 0.20 to 1.00 (steps of 0.01)

Enter the minimum value of winding 1 phase A current (in units of relay nominal current) required to allow the underfrequency element to operate.

```
MINIMUM OPERATING
VOLTAGE: 0.50 x VT
```

Range: 0.10 to 0.99 (steps of 0.01)

Enter the minimum value of voltage (in units of relay nominal voltage) required to allow the underfrequency element to operate.

```
UNDERFREQUENCY 1
PICKUP: 59.00 Hz
```

Range: 45.00 to 59.99 (steps of 0.01)

Enter the frequency (in Hz) below which the Underfrequency 1 element will pickup and start the delay timer.

UNDERFREQUENCY 1 DELAY: 1.00 s	*Range: 0.00 to 600.00 (steps of 0.05)* Enter the time the frequency must remain below the pickup level before the element operates.
UNDERFREQUENCY 1 BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

b) FREQUENCY DECAY

▌ FREQUENCY DECAY ▌ [ENTER] for more	This message indicates the start of the **FREQUENCY DECAY** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
FREQUENCY DECAY FUNCTION: Disabled	*Range: Disabled / Enabled*
FREQUENCY DECAY TARGET: Latched	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.
CURRENT SENSING: Enabled	*Range: Disabled / Enabled*
MINIMUM OPERATING CURRENT: 0.20 x CT	*Range: 0.20 to 1.00 (steps of 0.01)* Enter the minimum value of Winding 1 phase A current (in units of relay nominal current) required to allow the frequency decay element to operate.
MINIMUM OPERATING VOLTAGE: 0.50 x VT	*Range: 0.10 to 0.99 (steps of 0.01)* Enter the minimum value of voltage (in units of relay nominal voltage) required to allow the underfrequency element to operate.
FREQUENCY DECAY THRESHOLD: 59.50 Hz	*Range: 45.00 to 59.99 (steps of 0.01)* Enter the frequency (in Hz) below which the four frequency rate-of-change levels of the frequency decay element will be allowed to operate.
FREQUENCY DECAY DELAY: 0.00 s	*Range: 0.00 to 600.00 (steps of 0.01)*
FREQUENCY DECAY RATE 1: 0.4 Hz/s	*Range: 0.1 to 5.0 (steps of 0.1)* Enter the rate of frequency decay beyond which the rate 1 element operates.
FREQUENCY DECAY RATE 2: 1.0 Hz/s	*Range: 0.1 to 5.0 (steps of 0.1)* Enter the rate of frequency decay beyond which the rate 2 element operates.
FREQUENCY DECAY RATE 3: 2.0 Hz/s	*Range: 0.1 to 5.0 (steps of 0.1)* Enter the rate of frequency decay beyond which the rate 3 element operates.
FREQUENCY DECAY RATE 4: 4.0 Hz/s	*Range: 0.1 to 5.0 (steps of 0.1)* Enter the rate of frequency decay beyond which the rate 4 element operates.
FREQUENCY DECAY BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

c) OVERFREQUENCY

▌ OVERFREQUENCY ▌ [ENTER] for more	This message indicates the start of the **OVERFREQUENCY** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
OVERFREQUENCY FUNCTION: Disabled	*Range: Disabled / Enabled*
OVERFREQUENCY TARGET: Latched	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None will never disable the LED self-test feature because it cannot generate a displayable target message.
CURRENT SENSING: Enabled	*Range: Disabled / Enabled*
MINIMUM OPERATING CURRENT: 0.20 x CT	*Range: 0.20 to 1.00 (steps of 0.01)* Enter the minimum value of Winding 1 phase A current (in units of relay nominal current) required to allow the overfrequency element to operate.
MINIMUM OPERATING VOLTAGE: 0.50 x VT	*Range: 0.10 to 0.99 (steps of 0.01)* Enter the minimum value of voltage (in units of relay nominal voltage) required to allow the underfrequency element to operate.
OVERFREQUENCY PICKUP: 60.50 Hz	*Range: 50.01 to 65.00 (steps of 0.01)* Enter the frequency (in Hz) above which the overfrequency element will pickup and start the delay timer.
OVERFREQUENCY DELAY: 5.00 s	*Range: 0.00 to 600.00 (steps of 0.05)* Enter the time that the frequency must remain above the pickup level before the element operates.
OVERFREQUENCY BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

5.6.12 OVEREXCITATION

A transformer is designed to operate at or below a maximum magnetic flux density in the transformer core. Above this design limit the eddy currents in the core and nearby conductive components cause overheating which within a very short time may cause severe damage. The magnetic flux in the core is proportional to the voltage applied to the winding divided by the impedance of the winding. The flux in the core increases with either increasing voltage or decreasing frequency. During startup or shutdown of generator-connected transformers, or following a load rejection, the transformer may experience an excessive ratio of volts to hertz, that is, become overexcited.

When a transformer core is overexcited, the core is operating in a non-linear magnetic region, and creates harmonic components in the exciting current. A significant amount of current at the 5th harmonic is characteristic of overexcitation.

This section contains the settings to configure the overexcitation monitoring elements. Included are a 5th harmonic level, and two volts-per-hertz elements, each with a pickup level and a time delay.

▌ OVEREXCITATION ▌ [ENTER] for more	This message indicates the start of the **OVEREXCITATION** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

a) 5TH HARMONIC LEVEL

▌ 5th HARMONIC LEVEL ▌ [ENTER] for more	This message indicates the start of the section describing the characteristics of **5TH HARMONIC LEVEL**. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
5th HARMONIC LEVEL FUNCTION: Disabled	*Range: Disabled / Enabled*
5th HARMONIC LEVEL TARGET: Self-reset	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature because can not generate a displayable target message.
MINIMUM OPERATING CURRENT: 0.10 x CT	*Range: 0.03 to 1.00 (steps of 0.01)* Enter the minimum value of current (in units of relay nominal current) required to allow the 5th harmonic level element to operate.
5th HARMONIC LEVEL PICKUP: 10.0% fo	*Range: 0.1 to 99.9 (steps of 0.1)* Enter the 5th harmonic current (in $\%f_0$) above which the 5th harmonic level element will pickup and start the delay timer.
5th HARMONIC LEVEL DELAY: 10 s	*Range: 0 to 60000 (steps of 1)* Enter the time that the 5th harmonic current must remain above the pickup level before the element operates.
5th HARMONIC LEVEL BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

b) VOLTS-PER-HERTZ 1 (2)

```
▌ VOLTS-PER-HERTZ 1
▌ [ENTER] for more
```

This message indicates the start of the section describing the characteristics of the **VOLTS-PER-HERTZ 1(2)** element. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
VOLTS-PER-HERTZ 1
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
VOLTS-PER-HERTZ 1
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None will never disable the LED self-test feature because can not generate a displayable target message.

```
MINIMUM OPERATING
VOLTAGE: 0.10 x VT
```

Range: 0.10 to 0.99 (steps of 0.01)

Enter the minimum value of voltage (in terms of nominal VT secondary voltage) required to allow the volts-per-hertz 1 element to operate.

```
VOLTS-PER-HERTZ 1
PICKUP: 2.36 V/Hz
```

Range: 1.00 to 4.00 (steps of 0.01)

Enter the volts-per-hertz value (in V/Hz) above which the volts-per-hertz 1 element will pickup and start the delay timer.

```
VOLTS-PER-HERTZ 1
SHAPE: Definite Time
```

Range: Definite Time / Inv Curve 1 / Inv Curve 2 / Inv Curve 3

Select the curve shape to be used for the volts-per-hertz 1 (2) element. A description of inverse volts-per-hertz curve shapes can be found at the end of this chapter.

```
VOLTS-PER-HERTZ 1
DELAY:   2.00 s
```

Range: 0.00 to 600.00 (steps of 0.01)

Enter the time that the volts-per-hertz value must remain above the pickup level before the element operates.

```
VOLTS-PER-HERTZ 1
RESET:      0.0 s
```

Range: 0.0 to 6000.0 (steps of 0.01)

Enter the time that the volts-per-hertz value must remain below the pickup level before the element resets.

```
VOLTS-PER-HERTZ 1
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

5.6.13 HARMONICS

This section contains the settings to configure the total harmonic distortion monitoring elements. Included are a THD level element for each winding and each phase.

```
▌ HARMONICS
▌ [ENTER] for more
```

This message indicates the start of the **THD LEVEL** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

a) WINDING 1 (2/3) THD LEVEL

```
▌ W1 THD LEVEL
▌ [ENTER] for more
```

This message indicates the start of the **W1 (2/3) THD** level section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
W1 THD LEVEL
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
W1 THD LEVEL
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
MINIMUM OPERATING
CURRENT: 0.10 x CT
```

Range: 0.03 to 1.00 (steps of 0.01)

Enter the minimum value of current (in units of relay nominal current) required to allow the THD level element to operate.

```
W1 THD LEVEL
PICKUP: 50.0% fo
```

Range: 0.1 to 50.0 (steps of 0.1)

Enter the total harmonic distortion (in $\% f_0$) above which the **W1 (2/3) THD** level will pickup and start the delay timer.

```
W1 THD LEVEL
DELAY: 10 s
```

Range: 0 to 60000 (steps of 1)

Enter the time that the total harmonic distortion must remain above the pickup level before the element operates.

```
W1 THD LEVEL
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

b) WINDING 1 (2/3) HARMONIC DERATING

```
▌ W1 HARM DERATING
▌ [ENTER] for more
```

This message indicates the start of the **W1 (2/3) HARMONIC DERATING** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
W1 HARMONIC DERATING
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
W1 HARMONIC DERATING
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature since it cannot generate a displayable target message.

```
MINIMUM OPERATING
CURRENT: 0.10 x CT
```

Range: 0.03 to 1.00 (steps of 0.01)

Enter the minimum value of current (in units of relay nominal current) required to allow the Harmonic Derating element to operate.

```
W1 HARMONIC DERATING
PICKUP: 0.90
```

Range: 0.01 to 0.98 (steps of 0.1)

Enter the harmonic derating below which the W1 (2/3) harmonic derating will pickup and start the delay timer.

```
W1 HARMONIC DERATING
DELAY: 10 s
```

Range: 0 to 60000 (steps of 1)

Enter the time that the harmonic derating must remain below the pickup level before the element operates.

```
W1 HARMONIC DERATING
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5.6.14 INSULATION AGING / LOSS OF LIFE FEATURE

a) DESCRIPTION

The 745 Insulation Aging/Loss of Life feature is based on the computational methods presented in IEEE standards C57.91–1995, *IEEE Guide for Loading Mineral-Oil-Immersed Transformers*, and C57.96–1989, *IEEE Guide for Loading Dry-Type Distribution and Power Transformers*. These standards present a method of computing the top oil temperature, the hottest spot inside the transformer, the aging factor, and the total accumulated loss of life. The computations are based on the loading of the transformer, the ambient temperature, and the transformer data entered. The computations assume that the transformer cooling system is fully operational and able to maintain transformer temperatures within the specified limits under normal load conditions.

The computation results are a guide only. The transformer industry has not yet been able to define, with any degree of precision, the exact end of life of a transformer. Many transformers are still in service today, though they have long surpassed their theoretical end of life, some of them by a factor of three of four times.

Three protection elements are provided as part of the Loss of Life feature. The first element monitors the hottest-spot temperature. The second element monitors the aging factor and the third monitors the total accumulated loss of life. Each element produces an output when the monitored quantity exceeds a set limit.

The Insulation Aging/Loss of Life feature is a field-upgradeable feature. For the feature (and associated elements) to operate correctly, it must first be enabled under the factory settings using the passcode provided at purchase. If the feature was ordered when the relay was purchased, then it is already enabled. Note that setting this feature using the 745PC software requires that it be enabled the under **File > Properties > Loss of Life** menu. If the computer is communicating with a relay with the feature installed, it is automatically detected.

5

For the computations to be performed correctly, it is necessary to enter the transformer data under **S2 SYSTEM SETUP/TRANSFORMER**. The transformer load is taken from the winding experiencing the greatest loading. All transformer and winding setpoints must be correct or the computations will be meaningless.

The preferred approach for ambient temperature is to use an RTD connected to the 745. If this is not feasible, average values for each month of the year can be entered as settings, under **S2 SYSTEM SETUP/AMBIENT TEMPERATURE/AMBIENT RTD TYPE** and selecting By Monthly Average.

b) HOTTEST-SPOT LIMIT

The Hottest-Spot Limit element provides a means of detecting an abnormal hot spot inside the transformer. The element operates on the computed hottest-spot value. *The Hottest-spot temperature will revert to 0°C for 1 minute if the power supply to the relay is interrupted.* The necessary settings required for this element to perform correctly are entered under:

S4 ELEMENTS/INSULATION AGING/HOTTEST-SPOT LIMIT

c) INSULATION AGING SETPOINTS

```
▌ INSULATION AGING
▌ [ENTER] for more
```

This message indicates the start of the **INSULATION AGING** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
▌ HOTTEST-SPOT LIMIT
▌ [ENTER] for more
```

This message indicates the start of the **HOTTEST-SPOT LIMIT** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
HOTTEST-SPOT LIMIT
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
HOTTEST-SPOT LIMIT
TARGET: Self-Reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
HOTTEST-SPOT LIMIT
PICKUP: 150°C
```

Range: 50 to 300 (steps of 1)

Enter the Hottest-spot temperature required for operation of the element. This setting should be a few degrees above the maximum permissible hottest-spot temperature under emergency loading condition and maximum ambient temperature.

```
HOTTEST-SPOT LIMIT
DELAY: 10 min.
```

Range: 0 to 60,000, steps of 1 minute

Enter a time delay above which the hottest-spot temperature must remain before the element operates.

```
HOTTEST-SPOT LIMIT
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

5.6.15 AGING FACTOR LIMIT

The Aging Factor Limit element provides a means of detecting when a transformer is aging faster than would normally be acceptable. The element operates on the computed aging factor, which in turn is derived from the computed hottest-spot value. *The aging factor value will revert to zero if the power supply to the relay is interrupted*. The necessary settings required for this element to perform correctly are entered under:

SETPOINTS/S4 ELEMENTS/INSULATION AGING/AGING FACTOR LIMIT

▌ AGING FACTOR LIMIT ▌ [ENTER] for more	This message indicates the start of the **AGING FACTOR LIMIT** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
AGING FACTOR LIMIT FUNCTION: Disabled	*Range: Disabled / Enabled*
AGING FACTOR LIMIT TARGET: Self-Reset	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None never disables the LED self-test feature since it cannot generate a displayable target message.
AGING FACTOR LIMIT PICKUP: 2.0	*Range: 1.1 to 10 (steps of 0.1)* Enter the Aging Factor required for operation of the element. This setting should be above the maximum permissible aging factor under emergency loading condition and maximum ambient temperature.
AGING FACTOR LIMIT DELAY: 10 min.	*Range: 0 to 60,000, steps of 1 minute* Enter a time delay above which the Aging Factor must remain before the element operates.
AGING FACTOR LIMIT BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

5

5.6.16 LOSS OF LIFE LIMIT

The Loss of Life Limit element computes the total expended life of the transformer, based on the aging factor and the actual in-service time of the transformer. For example, if the aging factor is a steady 1.5 over a time period of 10 hours, the transformer will have aged for an equivalent $1.5 \times 10 = 15$ hours. The cumulative total number of hours expended is retained in the relay even when control power is lost. The initial Loss of Life value, when a relay is first placed in service, can be programmed under the transformer settings. The element operates on the cumulative total value, with no time delay. The output of this element should be used as an alarm only, as users may wish to leave the transformer in service beyond the theoretical expended life. The necessary settings required for this element to perform correctly are entered under:

SETPOINTS/S4 ELEMENTS/INSULATION AGING/LOSS OF LIFE LIMIT

▌ LOSS OF LIFE LIMIT ▌ [ENTER] for more	This message indicates the start of the **LOSS OF LIFE LIMIT** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
LOSS OF LIFE LIMIT FUNCTION: Disabled	*Range: Disabled / Enabled*
LOSS OF LIFE LIMIT TARGET: Self-Reset	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. An element whose “target type” is None never disables the LED self-test feature because it cannot generate a displayable target message.
LOSS OF LIFE LIMIT PICKUP: 16000 x 10h	*Range 0 to 20,000 (steps of 1), providing for a maximum of 200,000 hrs.* Enter the expended life, in hours, required for operation of the element. This setting should be above the total life of the transformer, in hours. As an example, for a 15-year transformer, the total number of hours would be $13140 \times 10 = 131400$.
LOSS OF LIFE LIMIT BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

NOTE

The actual values are only displayed if the Loss of Life option is installed and the ambient temperature is enabled.

5

5.6.17 ANALOG INPUT

The 745 has the ability to monitor any external quantity, such as bus voltage, battery voltage, etc., via a general purpose auxiliary current input called the analog input. Any one of the standard transducer output ranges 0-1 mA, 0-5 mA, 4-20 mA, or 0-20 mA can be connected to the analog input terminals. The analog input is configured in **S2 SYSTEM SETUP** / **ANALOG INPUT** and the actual values displayed in **A2 METERING** / **ANALOG INPUT**.

This section contains the settings to configure the analog input monitoring elements. Included are two analog input levels, each with a programmable pickup threshold and time delay.

```
▌ ANALOG INPUT
▌ [ENTER] for more
```

This message indicates the start of the **ANALOG INPUT** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

a) ANALOG LEVEL 1 (2)

```
▌ ANALOG LEVEL 1
▌ [ENTER] for more
```

This message indicates the start of the **ANALOG LEVEL 1(2)** sub-section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
ANALOG INPUT LEVEL 1
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
ANALOG INPUT LEVEL 1
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None will never disable the LED self-test feature because can not generate a displayable target message.

```
ANALOG INPUT LEVEL 1
PICKUP: 10 uA
```

Range: 1 to 65000 (steps of 1)

Enter the analog input value (in the units programmed) above which the analog input level 1 element will pickup and start the delay timer.

```
ANALOG INPUT LEVEL 1
DELAY: 50 s
```

Range: 0 to 60000 (steps of 1)

Enter the time that the analog input value must remain above the pickup level before the element operates.

```
ANALOG INPUT LEVEL 1
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

5

5.6.18 CURRENT DEMAND

This section contains the settings to configure the current demand monitoring elements. Included are a current demand level for each winding and each phase.

▌ CURRENT DEMAND ▌ [ENTER] for more	This message indicates the start of the **CURRENT DEMAND** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
▌ W1 CURRENT DEMAND ▌ [ENTER] for more	This message indicates the start of the **W1 (2/3) CURRENT DEMAND** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
W1 CURRENT DEMAND FUNCTION: Disabled	*Range: Disabled / Enabled*
W1 CURRENT DEMAND TARGET: Self-reset	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. An element whose “target type” is None never disables the LED self-test feature because it cannot generate a displayable target message.
W1 CURRENT DEMAND PICKUP: 100 A	*Range: 0 to 65000 (steps of 1 autoranging)* Enter the current demand above which the W1 (2/3) current demand element will pickup and operate.
W1 CURRENT DEMAND BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

5.6.19 TRANSFORMER OVERLOAD

This section contains the settings to configure the transformer overload monitoring element.

```
▌ XFORMER OVERLOAD
▌ [ENTER] for more
```

This message indicates the start of the **TRANSFORMER OVERLOAD** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
TRANSFORMER OVERLOAD
FUNCTION: Disabled
```

Range: Disabled / Enabled

```
TRANSFORMER OVERLOAD
TARGET: Self-reset
```

Range: Self-reset / Latched / None

Select None to inhibit the display of the target message when the element operates. Thus an element whose "target type" is None never disables the LED self-test feature since it cannot generate a displayable target message.

```
TRANSFORMER OVERLOAD
PICKUP: 208% rated
```

Range: 50 to 300 (steps of 1)

Enter the transformer loading (in terms of the percent of rated load) above which the transformer overload element will pickup and start the delay timer.

```
TRANSFORMER OVERLOAD
DELAY: 10 s
```

Range: 0 to 60000 (steps of 1)

Enter the time that the transformer loading must remain above the pickup level before the element operates.

```
TRANSFORMER OVERLOAD
BLOCK: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)

```
XFMR OVERTEMP ALARM
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input that, when asserted, indicates the transformer cooling system has failed and an over-temperature condition exists. The logic input should be connected to the transformer winding temperature alarm contacts.

5.6.20 TAP CHANGER FAILURE

The Tap Changer Failure element monitors the resistance seen by the tap changer monitoring circuit. Should the resistance be greater than 150% of the resistance at the maximum tap, per the settings of the Tap Changer Monitoring feature, this element will produce an output signal. This signal can be used as an alarm or as a signal to change Setpoint Group. A change in the Setpoint Group would be programmed through the FlexLogic. This approach would be useful if very sensitive settings had been used in the normal in-service Setpoint group for the Harmonic Restrained Differential element, assuming that the tap changer position was used to compensate the input current magnitude.

▌ TAP CHANGER FAILURE ▌ [ENTER] for more	This message indicates the start of the **TAP CHANGER FAILURE** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.
TAP CHANGER FAILURE FUNCTION: Disabled	*Range: Disabled / Enabled*
TAP CHANGER FAILURE TARGET: Self-reset	*Range: Self-reset / Latched / None* Select None to inhibit the display of the target message when the element operates. Thus an element whose “target type” is None never disables the LED self-test feature since it cannot generate a displayable target message.
TAP CHANGER FAILURE DELAY: 5.00 s	*Range: 0 to 600.00 (steps of 0.01)*
TAP CHANGER FAILURE BLOCK: Disabled	*Range: Disabled / Logc Inpt 1 (2-16) /Virt Inpt 1 (2-16) / Output Rly 1 (2-8) / SelfTest Rly / Virt Outpt 1 (2-5)*

5

5.7.1 DESCRIPTION

The **S5 OUTPUTS** page contains the settings to configure all outputs.

```
▌▌ SETPOINTS
▌▌ S5 OUTPUTS
```

This message indicates the start of setpoints page **S5 OUTPUTS**. Press MESSAGE ▼ to view the contents or SETPOINT to go on to the next page.

The 745 has nine digital outputs (one solid-state, four trip rated form A contacts, and four auxiliary form C contacts) which are fully programmable using FlexLogic™ equations. FlexLogic™ is a highly flexible and easy-to-use equation format which allows any combination of protection and monitoring elements, logic inputs, outputs, and timers to be assigned to any output, using multiple input AND, OR, NAND, NOR, XOR, and NOT Boolean logic gates. Each digital output can have an equation of up to 20 parameters. Five “virtual outputs” are also available, each having an equation containing up to 10 parameters, whose output can be used as a parameter in any other equation.

In addition to these outputs, the conditions to trigger a waveform capture (trace memory) is also programmable using FlexLogic™. A 10 parameter equation is provided for this purpose.

5.7.2 INTRODUCTION TO FLEXLOGIC™

5

A FlexLogic™ equation defines the combination of inputs and logic gates to operate an output. Each output has its own equation, an equation being a linear array of parameters. Evaluation of an equation results in either a 1 (= ON, i.e. operate the output), or 0 (= OFF, i.e. do not operate the output).

The table below provides information about FlexLogic™ equations for all outputs in the 745:

Table 5–5: FLEXLOGIC™ OUTPUT TYPES

NAME	TYPE	NUMBER OF EQUATION PARAMETERS	EVALUATION RATE
Output Relay 1	solid-state	20	every 1/2 cycle*
Output Relay 2 Output Relay 3 Output Relay 4 Output Relay 5	trip-rated form A contacts	20 each	every 1/2 cycle*
Output Relay 6 Output Relay 7 Output Relay 8	form C contacts	20 each	every 100 ms
Self-Test Relay	form C contacts dedicated for self-test (not programmable)	---	every 100 ms
Trace Trigger	waveform capture trigger	10	every 1/2 cycle*
Virtual Output 1 Virtual Output 2 Virtual Output 3 Virtual Output 4 Virtual Output 5	internal register (for use in other equations)	10 each	every 1/2 cycle*

* cycle refers to the power system cycle as detected by the frequency circuitry of the 745.

As mentioned above, the parameters of an equation can contain either INPUTS or GATES.

Table 5–6: FLEXLOGIC™ INPUT TYPES

INPUTS	INPUT IS “1” (= ON) IF...
element* pickup	the pickup setting of the element is exceeded
element* operate	the pickup setting of the element is exceeded for the programmed time delay
logic inputs 1 to 16	the logic input contact is asserted
virtual inputs 1 to 16	the virtual input is asserted
output relays 1 to 8	the output relay operates (i.e. evaluation of the FlexLogic™ equation results in a ‘1’)
virtual outputs 1 to 5	the virtual output operates (i.e. evaluation of the FlexLogic™ equation results in a ‘1’)
timers 1 to 10	the timer runs to completion (i.e. the ‘start’ condition is met for the programmed time delay)

* element refers to any protection or monitoring element programmed under page **S4 ELEMENTS**

Table 5–7: FLEXLOGIC™ GATES

GATES	NUMBER OF INPUTS	OUPUT IS “1” (= ON) IF...
NOT	1	input is ‘0’
OR	2 to 19 (for 20 parameter equations) 2 to 9 (for 10 parameter equations)	any input is ‘1’
AND	2 to 19 (for 20 parameter equations) 2 to 9 (for 10 parameter equations)	all inputs are ‘1’
NOR	2 to 19 (for 20 parameter equations) 2 to 9 (for 10 parameter equations)	all inputs are ‘0’
NAND	2 to 19 (for 20 parameter equations) 2 to 9 (for 10 parameter equations)	any input is ‘0’
XOR	2 to 19 (for 20 parameter equations) 2 to 9 (for 10 parameter equations)	odd number of inputs are ‘1’

Inputs and gates are combined into a FlexLogic™ equation. The sequence of entries in the linear array of parameters follows the general rules listed in the following section.

5.7.3 FLEXLOGIC™ RULES

1. INPUTS TO A GATE ALWAYS PRECEDE THE GATE IN THE EQUATION.
2. GATES HAVE ONLY ONE OUTPUT.
3. THE OUTPUT OF A GATE CAN BE THE INPUT TO ANOTHER GATE. Therefore, according to rule 1, the former gate will precede the latter gate in the equation.)
4. ANY INPUT CAN BE USED MORE THAN ONCE IN AN EQUATION.
5. THE OUTPUT OF AN EQUATION CAN BE USED AS AN INPUT TO ANY EQUATION (INCLUDING FEEDBACK TO ITSELF).
6. IF ALL PARAMETERS OF AN EQUATION ARE NOT USED, THE 'END' PARAMETER MUST FOLLOW THE LAST PARAMETER USED.

As an example, assume that the following logic is required to operate Output Relay 2:

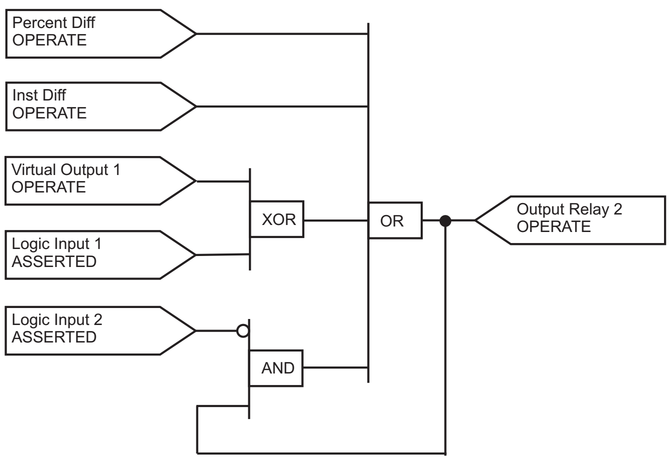


Figure 5–14: FLEXLOGIC™ EXAMPLE

Based on the rules given above, the Output Relay 2 FlexLogic™ equation is shown above. On the left is a stack of boxes showing the FlexLogic™ messages for Output Relay 2. On the right of the stack of boxes is an illustration of how the equation is interpreted.

In this example, the inputs of the 4-input OR gate are Percent Diff OP, Inst Diff OP, the output of the XOR gate, and the output of the AND gate. The inputs of the 2-input AND gate are the output of the NOT gate, and Output Relay 2. The input to the NOT gate is Logic Input 2. The inputs to the 2-input XOR gate are Virtual Output 1 and Logic Input 1. For all these gates, the inputs precede the gate itself.

This ordering of parameters of an equation, where the gate (or "operator") follows the input (or "value") is commonly referred to as "Postfix" or "Reverse Polish" notation.

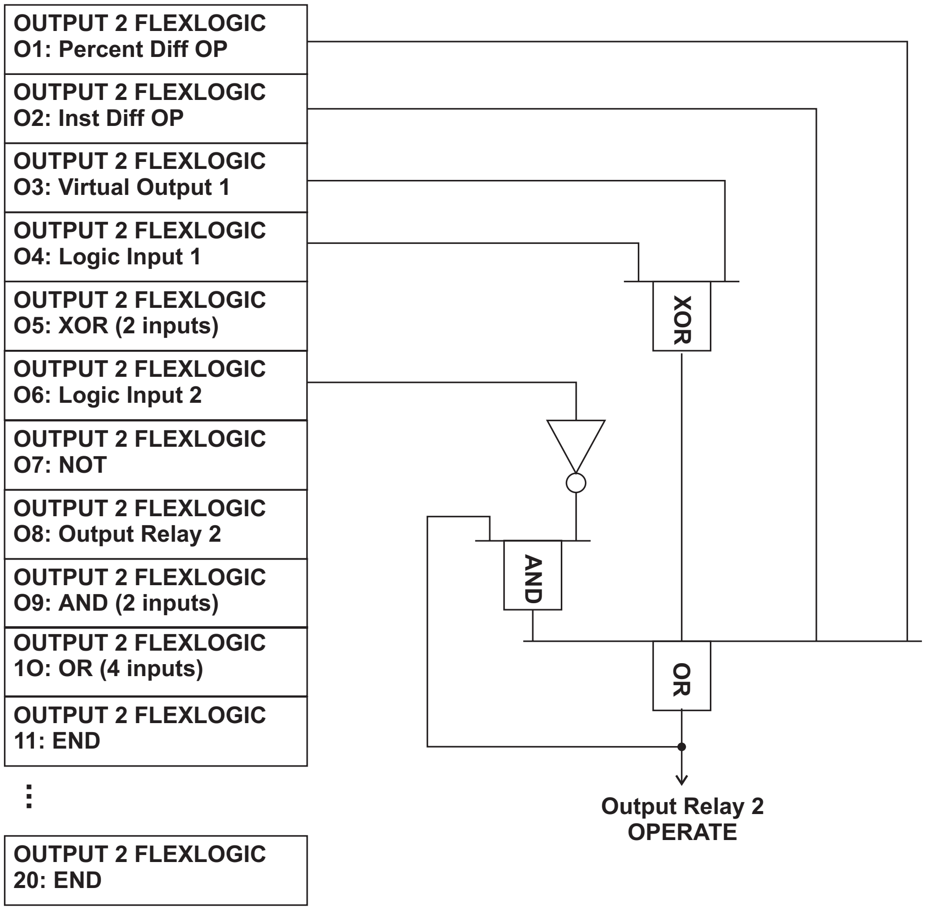


Figure 5–15: FLEXLOGIC EXAMPLE IMPLEMENTED

Any equation entered in the 745 that does not make logical sense according to the notation described here, will be flagged as a self-test error. The following message will be displayed until the error is corrected:

```
▌ SELF-TEST ERROR:
▌ Flexlogic Eqn
```

5.7.4 OUTPUT RELAYS

This section contains the settings (including the FlexLogic™ equation) to configure output relays 1 to 8.

```
▌ OUTPUT RELAYS
▌ [ENTER] for more
```

This message indicates the start of the **OUTPUT RELAYS** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
▌ OUTPUT RELAY 1
▌ [ENTER] for more
```

This message indicates the start of the **OUTPUT RELAY 1 (2-8)** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
OUTPUT 1 NAME:
Solid State Trip
```

Range: 18 alphanumeric characters

Press ENTER edit the name of the output. The text may be changed from Solid State Trip one character at a time, using the VALUE ▲/VALUE ▼: keys. Press ENTER to store the edit and advance to the next character position.

```
OUTPUT 1 OPERATION:
Self-resetting
```

Range: Self-resetting / Latched

Select Latched to maintain the Output 1 (2-8) contacts in the energized state, even after the condition that caused the contacts to operate is cleared, until a reset command is issued (or automatically after one week). Select Self-reset to automatically de-energize the contacts after the condition is cleared.

The solid state output (Output 1) remains closed until externally reset by a momentary interruption of current, unless wired in parallel with an electromechanical relay (Outputs 2-8) in which case it turns off when the relay operates.

5

```
OUTPUT 1 TYPE:
Trip
```

Range: Trip / Alarm / Control

Select Trip to turn the TRIP indicator on or Alarm to turn the ALARM indicator on when this output operates. Otherwise, select Control.

Note that the TRIP indicator remains on until a reset command is issued (or automatically after one week). The ALARM indicator turns off automatically when the output is no longer operated.

```
OUTPUT 1 FLEXLOGIC
01: Percent Diff OP
```

Range: any FlexLogic™ input or gate

The 20 messages shown in the table below are the parameters of the FlexLogic™ equation for Output 1 (2-8) as described in the introduction to FlexLogic™.

Table 5–8: OUTPUT RELAY DEFAULT FLEXLOGIC

FLEXLOGIC GATE	OUTPUT RELAY NUMBER					
	1 to 3	4	5	6	7	8
01	Percent Diff OP	Volts/Hertz 1 OP	W1 THD Level OP	Underfreq 1 OP	Underfreq 2 OP	Freq Decay 3 OP
02	Inst Diff OP	Volts/Hertz 2 OP	W2 THD Level OP	Freq Decay R1 OP	Freq Decay R2 OP	END
03	Any W1 OC OP	OR (2 inputs)	Xfmr Overload OP	OR (2 inputs)	OR (2 inputs)	END
04	Any W2 OC OP	END	5th HarmLevel OP	END	END	END
05	OR (4 inputs)	END	OR (4 inputs)	END	END	END
06 to 20	END	END	END	END	END	END

5.7.5 TRACE MEMORY

Trace memory is the oscillography feature of the 745. All system inputs are synchronously digitized at a sampling rate of 64 times a power cycle. Upon occurrence of a user-defined trigger condition, the 16 cycles of oscillographic waveforms are captured into trace memory. The trigger condition is defined by a FlexLogic™ equation, and the number of pre-trigger cycles of data captured is programmable.

This section contains the settings (including the FlexLogic™ equation) to configure trace memory triggering.

```
▌ TRACE MEMORY
▌ [ENTER] for more
```

This message indicates the start of the **TRACE MEMORY** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
NO. OF PRE-TRIGGER
CYCLES: 12 cycles
```

Range: 1 to 15 (steps of 1)

Enter the number of cycles of data, of the 16 cycles of waveform data to be captured, that are to be pre-trigger information.

```
TRACE TRIG FLEXLOGIC
01: Any Element PKP
```

Range: any FlexLogic™ input or gate

The following 10 messages are the parameters of the FlexLogic™ equation for trace memory triggering as described in the introduction to FlexLogic™.

The Trace Memory default Flexlogic is as follows:

TRACE TRIG FLEXLOGIC: **01: Any Element PKP**
02 to 12: END

5.7.6 VIRTUAL OUTPUTS

Virtual outputs are FlexLogic™ equations whose output (or result) can be used as inputs to other equations. The 745 has 5 virtual outputs. One application of these outputs may be to contain a block of logic that is repeated for more than one output.

This section contains the FlexLogic™ equations to configure virtual outputs 1 to 5.

```
▌ VIRTUAL OUTPUTS
▌ [ENTER] for more
```

This message indicates the start of the **VIRTUAL OUTPUTS** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

VIRTUAL OUTPUT 1 (2-5)

```
▌ VIRTUAL OUTPUT 1
▌ [ENTER] for more
```

This message indicates the start of the VIRTUAL OUTPUT 1 (2-5) section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
VIRTUAL 1 FLEXLOGIC
01: END
```

Range: any FlexLogic™ input or gate

The following 10 messages are the parameters of the FlexLogic™ equation for virtual output 1 (2-5) as described in the introduction to FlexLogic™.

5

5.7.7 TIMERS

Protection and monitoring elements already have their own programmable delay timers, where they are required. For additional flexibility, 10 independent timers are available for implementing custom schemes where timers are not available. For example, a pickup delay timer may be required on a logic input; or, a single delay timer may be required on the output of a block of logic.

This section contains the settings to configure timers 1 to 10.

```
▌ TIMERS
▌ [ENTER] for more
```

This message indicates the start of the **TIMERS** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

TIMER 1 (2-10)

```
▌ TIMER 1
▌ [ENTER] for more
```

This message indicates the start of the **TIMER 1 (2-10)** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
TIMER 1 START:
END
```

Range: any FlexLogic input.

Select the FlexLogic entry which, when operated or asserted, will start timer 1 (2-10).

```
TIMER 1 PICKUP
DELAY: 0.00 s
```

Range: 0.00 to 600.00 (steps of 0.01)

Enter the delay time during which the start condition for timer 1 (2-10) must remain operated or asserted, before the timer will operate.

```
TIMER 1 DROPOUT
DELAY: 0.00 s
```

Range: 0.00 to 600.00 (steps of 0.01)

Enter the delay time after which the start condition for timer 1 (2-10) must remain not operated or not asserted, before the timer will stop operating.

5.8.1 DESCRIPTION

The 745 provides various diagnostic tools to verify the relay functionality. The normal function of all output contacts can be overridden and forced to be energized or de-energized. Analog outputs may be forced to any level of their output range. The simulation feature allows system parameters (magnitudes and angles) to be entered as setpoints and made to generate fault conditions without the necessity of any system connections. In addition, 16 cycles of sampled current/voltage waveform data (in IEEE Comtrade file format) can be loaded and “played back” to test the response of the 745 under any (previously recorded) system disturbance.

```
■■ SETPOINTS
■■ S6 TESTING
```

This message indicates the start of setpoints page **S6 TESTING**. Press MESSAGE ▼ to view the contents or SETPOINT to go on to the next page.

5.8.2 OUTPUT RELAYS

The 745 has the ability to override the normal function of all outputs, forcing each to energize and de-energize for testing. Enabling this feature turns the IN SERVICE indicator off and the TEST MODE indicator on.

```
■ OUTPUT RELAYS
■ [ENTER] for more
```

This message indicates the start of the **OUTPUT RELAYS** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
FORCE OUTPUT RELAYS
FUNCTION: Disabled
```

Range: Disabled / Enabled

Select Enabled to enable the output relay testing feature and override normal output relay operation. This setpoint is defaulted to Disabled at power on.

```
FORCE OUTPUT 1:
De-energized
```

Range: De-energized / Energized

Select Energized to force Output 1 (2-8) to the energized state. Select De-energized to force Output 1 (2-8) to the de-energized state. This setpoint is only operational while the output relay testing feature is enabled.

```
FORCE SELF-TEST RLY:
De-energized
```

Range: De-energized / Energized

Select Energized to force the self-test relay to the energized state and De-energized to force to the de-energized state. This setpoint is only operational while the output relay testing feature is enabled.

5.8.3 ANALOG OUTPUTS

The 745 has the ability to override the normal function of analog transducer outputs, forcing each to any level of its output range. Enabling this feature turns the TEST MODE indicator on and de-energize the self-test relay.

```
■ ANALOG OUTPUTS
■ [ENTER] for more
```

This message indicates the start of the **ANALOG OUTPUTS** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
FORCE ANALOG OUTPUTS
FUNCTION: Disabled
```

Range: Disabled / Enabled

Select Enabled to enable the analog output testing and override the analog output normal operation. This setpoint defaults to Disabled at power on.

```
FORCE ANALOG OUT 1:
   0%
```

Range: 0 to 100 (steps of 1)

Enter the percentage of the DC mA output range of Analog Output 1 (2–7). For example, if the analog output range has been programmed to 4-20 mA, entering 100% outputs 20 mA, 0% outputs 4 mA, and 50% outputs 12 mA. This setpoint is only operational if analog output testing is enabled.

5.8.4 SIMULATION

The simulation feature allows testing of the functionality of the relay in response to programmed conditions, without the need of external AC voltage and current inputs. System parameters such as currents and voltages, phase angles and system frequency are entered as setpoints. When placed in simulation mode, the relay suspends reading actual AC inputs and generates samples to represent the programmed phasors. These samples are used in all calculations and protection logic. Enabling this feature will turn off the IN SERVICE indicator, turn on the TEST MODE indicator, and de-energize the self-test relay.

CAUTION

WHEN IN SIMULATION MODE, PROTECTION FEATURES DO NOT OPERATE BASED ON ACTUAL SYSTEM INPUTS. IF SIMULATION MODE IS USED FOR FIELD TESTING ON EQUIPMENT, OTHER MEANS OF PROTECTION MUST BE PROVIDED BY THE OPERATOR.

```
▌ SIMULATION
▌ [ENTER] for more
```

This message indicates the start of the **SIMULATION** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

SIMULATION SETUP:

```
▌ SIMULATION SETUP
▌ [ENTER] for more
```

This message indicates the start of the **SIMULATION SETUP** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
SIMULATION FUNCTION:
Disabled
```

Range: Disabled / Prefault Mode / Fault Mode / Playback Mode

Select the simulation mode required. Select Disabled to return the 745 to normal operation. See Table 5–9: SIMULATION MODES on page 5–89 for details on the simulation function modes.

```
BLOCK OPERATION OF
OUTPUTS: 12345678
```

Range: any combination of outputs 1 to 8

Select the output relays which must be blocked from operating while in simulation mode.

An operator can use the simulation feature to provide a complete functional test of the protection features, except for the measurement of external input values. As this feature may be used for on site testing, provision is made (with this setpoint) to block the operation of output relays during this testing, to prevent the operation of other equipment. Note that the default setting blocks the operation of all output relays.

```
START FAULT MODE
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, initiates Fault Mode simulation. This signal has an effect only if the 745 is initially in Prefault Mode.

```
START PLAYBACK MODE
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1 (2-16)

Select any logic input which, when asserted, initiates Playback Mode simulation. This signal has an effect only if the 745 is initially in Prefault Mode.

Table 5–9: SIMULATION MODES

MODE	DESCRIPTION
Prefault Mode	Select Prefault Mode to simulate the normal operating condition of a transformer. In this mode, the normal inputs are replaced with sample values generated based on the programmed prefault values. Phase currents are balanced (i.e. equal in magnitude and 120° apart), and the phase lag between windings is that which would result under normal conditions for the transformer type selected. The magnitude of phase currents for each winding are set to the values programmed in **S6 TESTING/SIMULATION/PREFAULT VALUES/W1 (2/3) PHASE ABC CURRENT MAGNITUDE**. The magnitude of the voltage is set to the value programmed in **S6 TESTING/SIMULATION/PREFAULT VALUES/VOLTAGE INPUT MAGNITUDE**. The frequency is set to the value programmed in **S2 SYSTEM SETUP/TRANSFORMER/NOMINAL FREQUENCY**.
Fault Mode	Select Fault Mode to simulate the faulted operating condition of a transformer. In this mode, the normal inputs are replaced with sample values generated based on the programmed fault values. The magnitude and angle of each phase current and ground current of the available windings, the magnitude and angle of the voltage input, and system frequency are set to the values programmed under **S6 TESTING/SIMULATION/FAULT VALUES**. A logic input, programmed to the Simulate Fault function, can be used to trigger the transition from the Prefault Mode to the Fault Mode, allowing the measurement of element operating times.
Playback Mode	Select Playback Mode to play back a sampled waveform data file which has been pre-loaded into the relay. In this mode, the normal inputs are replaced with 16-cycles of waveform samples downloaded into the 745 by the 745PC program (from an oscillographic data file in the IEEE "Comtrade" file format). A logic input, programmed to the Simulate Playback function, can be used to trigger the transition from the Prefault Mode to the Playback Mode, allowing the measurement of element operating times.

5.8.5 PREFAULT VALUES

This section contains the settings to configure prefault mode simulation.

```
▌ PREFAULT VALUES
▌ [ENTER] for more
```

This message indicates the start of the **PREFAULT VALUES** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
W1 PHASE ABC CURRENT
MAGNITUDE: 1.0 x CT
```

Range: 0.0 to 40.0 (steps of 0.1)

Enter the winding 1 (2/3) phase current magnitude (in terms of the winding full load current) while in Prefault Mode.

```
VOLTAGE INPUT
MAGNITUDE: 1.0 x VT
```

Range: 0.0 to 2.0 (steps of 0.1)

Enter the voltage magnitude (in terms of the nominal VT secondary voltage) while in Prefault Mode.

5.8.6 FAULT VALUES

This section contains the settings to configure fault mode simulation.

```
▌ FAULT VALUES
▌ [ENTER] for more
```

This message indicates the start of the **FAULT VALUES** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
W1 PHASE A CURRENT
MAGNITUDE: 1.0 x CT
```

Range: 0.0 to 40.0 (steps of 0.1)

Enter the Winding 1 (2/3) phase A (B/C) current magnitude (in terms of the winding full load current) while in Fault Mode.

```
W1 PHASE A CURRENT
ANGLE: 0°
```

Range: 0 to 359 (steps of 1)

Enter the Winding 1 (2/3) phase A (B/C) current angle (with respect to the Winding 1 phase A current phasor) while in Fault Mode. Note that the Winding 1 phase A current angle cannot be edited and is used as a reference for the other phase angles.

```
W1 GROUND CURRENT
MAGNITUDE: 0.0 x CT
```

Range: 0.0 to 40.0 (steps of 0.1)

Enter the Winding 1 (2/3) ground current magnitude (in terms of the winding FLC) while in Fault Mode. Note that ground refers to the measured CT current in the connection between transformer neutral and ground. As such, this message only appears for wye or zig-zag connected windings.

5

```
W1 GROUND CURRENT
ANGLE:   0° Lag
```

Range: 0 to 359 (steps of 0.1)

Enter the Winding 1 (2/3) ground current angle (with respect to the Winding 1 phase A current phasor). This message only appears for wye or zig-zag connected windings.

```
VOLTAGE INPUT
MAGNITUDE: 1.0 x VT
```

Range: 0.0 to 2.0 (steps of 0.1)

Enter the voltage magnitude (in terms of the nominal VT secondary voltage) while in Prefault Mode.

```
VOLTAGE INPUT
ANGLE:   0° Lag
```

Range: 0 to 359 (steps of 1)

Enter the voltage angle (with respect to the winding 1 phase A current phasor) while in Fault Mode.

```
FREQUENCY:
60.00 Hz
```

Range: 45.00 to 60.00 (steps of 0.01)

Enter the system frequency (in Hz) while in Fault Mode.

5.8.7 FACTORY SERVICE

This section contains settings intended for factory use only, for calibration, testing, and diagnostics. The messages can only be accessed by entering a factory service passcode in the first message.

```
▌ FACTORY SERVICE
▌ [ENTER] for more
```

This message indicates the start of the **FACTORY SERVICE** section. To continue these setpoints press ENTER or press MESSAGE ▼ for the next section.

```
ENTER FACTORY
PASSCODE:
```

(Restricted Access For Factory Personnel Only)

5.9.1 NOTE

NOTE

Graphs of time-current curves on 11”x17” log-log graph paper are available upon request.

5.9.2 ANSI CURVES

The ANSI time overcurrent curve shapes conform to industry standard curves and fit into the ANSI C37.90 curve classifications for extremely, very, normally, and moderately inverse. The 745 ANSI curves are derived from the following formula:

$$T = \begin{cases} M \times \left[A + \dfrac{B}{1.03 - C} + \dfrac{D}{(1.03 - C)^2} + \dfrac{E}{(1.03 - C)^3} \right], & \text{for } 1 \le \dfrac{I}{I_{pkp}} < 1.03 \\ M \times \left[A + \dfrac{B}{I/I_{pkp} - C} + \dfrac{D}{(I/I_{pkp} - C)^2} + \dfrac{E}{(I/I_{pkp} - C)^3} \right], & \text{for } 1.03 \le \dfrac{I}{I_{pkp}} < 20.0 \\ M \times \left[A + \dfrac{B}{20.0 - C} + \dfrac{D}{(20.0 - C)^2} + \dfrac{E}{(20.0 - C)^3} \right], & \text{for } \dfrac{I}{I_{pkp}} \ge 20.0 \end{cases}$$

where:
T = Operate Time (seconds)
M = Multiplier setpoint
I = Input Current
I_{pkp} = Pickup Current setpoint
A, B, C, D, E = Constants

Table 5–10: ANSI CURVE CONSTANTS

ANSI CURVE SHAPE	CONSTANTS				
	A	B	C	D	E
EXTREMELY INVERSE	0.0399	0.2294	0.5000	3.0094	0.7222
VERY INVERSE	0.0615	0.7989	0.3400	–0.2840	4.0505
NORMALLY INVERSE	0.0274	2.2614	0.3000	–4.1899	9.1272
MODERATELY INVERSE	0.1735	0.6791	0.8000	–0.0800	0.1271

Table 5–11: ANSI CURVE TRIP TIMES (IN SECONDS)

MULTIPLIER M	CURRENT I / I_{pkp}									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
ANSI EXTREMELY INVERSE										
0.5	2.000	0.872	0.330	0.184	0.124	0.093	0.075	0.063	0.055	0.049
1.0	4.001	1.744	0.659	0.368	0.247	0.185	0.149	0.126	0.110	0.098
2.0	8.002	3.489	1.319	0.736	0.495	0.371	0.298	0.251	0.219	0.196
4.0	16.004	6.977	2.638	1.472	0.990	0.742	0.596	0.503	0.439	0.393
6.0	24.005	10.466	3.956	2.208	1.484	1.113	0.894	0.754	0.658	0.589
8.0	32.007	13.955	5.275	2.944	1.979	1.483	1.192	1.006	0.878	0.786
10.0	40.009	17.443	6.594	3.680	2.474	1.854	1.491	1.257	1.097	0.982
ANSI VERY INVERSE										
0.5	1.567	0.663	0.268	0.171	0.130	0.108	0.094	0.085	0.078	0.073
1.0	3.134	1.325	0.537	0.341	0.260	0.216	0.189	0.170	0.156	0.146
2.0	6.268	2.650	1.074	0.682	0.520	0.432	0.378	0.340	0.312	0.291
4.0	12.537	5.301	2.148	1.365	1.040	0.864	0.755	0.680	0.625	0.583
6.0	18.805	7.951	3.221	2.047	1.559	1.297	1.133	1.020	0.937	0.874
8.0	25.073	10.602	4.295	2.730	2.079	1.729	1.510	1.360	1.250	1.165
10.0	31.341	13.252	5.369	3.412	2.599	2.161	1.888	1.700	1.562	1.457
ANSI NORMALLY INVERSE										
0.5	2.142	0.883	0.377	0.256	0.203	0.172	0.151	0.135	0.123	0.113
1.0	4.284	1.766	0.754	0.513	0.407	0.344	0.302	0.270	0.246	0.226
2.0	8.568	3.531	1.508	1.025	0.814	0.689	0.604	0.541	0.492	0.452
4.0	17.137	7.062	3.016	2.051	1.627	1.378	1.208	1.082	0.983	0.904
6.0	25.705	10.594	4.524	3.076	2.441	2.067	1.812	1.622	1.475	1.356
8.0	34.274	14.125	6.031	4.102	3.254	2.756	2.415	2.163	1.967	1.808
10.0	42.842	17.656	7.539	5.127	4.068	3.445	3.019	2.704	2.458	2.260
ANSI MODERATELY INVERSE										
0.5	0.675	0.379	0.239	0.191	0.166	0.151	0.141	0.133	0.128	0.123
1.0	1.351	0.757	0.478	0.382	0.332	0.302	0.281	0.267	0.255	0.247
2.0	2.702	1.515	0.955	0.764	0.665	0.604	0.563	0.533	0.511	0.493
4.0	5.404	3.030	1.910	1.527	1.329	1.208	1.126	1.066	1.021	0.986
6.0	8.106	4.544	2.866	2.291	1.994	1.812	1.689	1.600	1.532	1.479
8.0	10.807	6.059	3.821	3.054	2.659	2.416	2.252	2.133	2.043	1.972
10.0	13.509	7.574	4.776	3.818	3.324	3.020	2.815	2.666	2.554	2.465

5.9.3 DEFINITE TIME CURVE

The Definite Time curve shape causes a trip as soon as the pickup level is exceeded for a specified period of time. The base Definite Time curve has a delay of 0.1 seconds. The curve multiplier makes this delay adjustable from 0.000 to 10.000 seconds in steps of 0.001 seconds.

5.9.4 IEC CURVES

For European applications, the relay offers the four standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, IEC Curve C, and Short Inverse. The formula for these curves is:

$$T = \begin{cases} M \times \left[\dfrac{K}{(1.03)^E - 1}\right], & 1 \le \dfrac{I}{I_{pkp}} < 1.03 \\ M \times \left[\dfrac{K}{(I/I_{pkp})^E - 1}\right], & 1.03 \le \dfrac{I}{I_{pkp}} < 20.0 \\ M \times \left[\dfrac{K}{(20.0)^E - 1}\right], & \dfrac{I}{I_{pkp}} \ge 20.0 \end{cases}$$

where: T = Operate Time (seconds)
M = Multiplier Setpoint
I = Input Current
I_{pkp} = Pickup Current Setpoint
K, E = Constants

Table 5–12: IEC CURVE CONSTANTS

IEC (BS) CURVE SHAPE	CONSTANTS	
	K	E
IEC CURVE A (BS142)	0.140	0.020
IEC CURVE B (BS142)	13.500	1.000
IEC CURVE C (BS142)	80.000	2.000
IEC SHORT INVERSE	0.050	0.040

5

Table 5–13: IEC CURVE TRIP TIMES

MULTIPLIER *M*	CURRENT I / I_{pkp}									
	1.5	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
IEC CURVE A										
0.05	0.860	0.501	0.315	0.249	0.214	0.192	0.176	0.165	0.156	0.149
0.10	1.719	1.003	0.630	0.498	0.428	0.384	0.353	0.330	0.312	0.297
0.20	3.439	2.006	1.260	0.996	0.856	0.767	0.706	0.659	0.623	0.594
0.40	6.878	4.012	2.521	1.992	1.712	1.535	1.411	1.319	1.247	1.188
0.60	10.317	6.017	3.781	2.988	2.568	2.302	2.117	1.978	1.870	1.782
0.80	13.755	8.023	5.042	3.984	3.424	3.070	2.822	2.637	2.493	2.376
1.00	17.194	10.029	6.302	4.980	4.280	3.837	3.528	3.297	3.116	2.971
IEC CURVE B										
0.05	1.350	0.675	0.338	0.225	0.169	0.135	0.113	0.096	0.084	0.075
0.10	2.700	1.350	0.675	0.450	0.338	0.270	0.225	0.193	0.169	0.150
0.20	5.400	2.700	1.350	0.900	0.675	0.540	0.450	0.386	0.338	0.300
0.40	10.800	5.400	2.700	1.800	1.350	1.080	0.900	0.771	0.675	0.600
0.60	16.200	8.100	4.050	2.700	2.025	1.620	1.350	1.157	1.013	0.900
0.80	21.600	10.800	5.400	3.600	2.700	2.160	1.800	1.543	1.350	1.200
1.00	27.000	13.500	6.750	4.500	3.375	2.700	2.250	1.929	1.688	1.500
IEC CURVE C										
0.05	3.200	1.333	0.500	0.267	0.167	0.114	0.083	0.063	0.050	0.040
0.10	6.400	2.667	1.000	0.533	0.333	0.229	0.167	0.127	0.100	0.081
0.20	12.800	5.333	2.000	1.067	0.667	0.457	0.333	0.254	0.200	0.162
0.40	25.600	10.667	4.000	2.133	1.333	0.914	0.667	0.508	0.400	0.323
0.60	38.400	16.000	6.000	3.200	2.000	1.371	1.000	0.762	0.600	0.485
0.80	51.200	21.333	8.000	4.267	2.667	1.829	1.333	1.016	0.800	0.646
1.00	64.000	26.667	10.000	5.333	3.333	2.286	1.667	1.270	1.000	0.808
IEC SHORT TIME										
0.05	0.153	0.089	0.056	0.044	0.038	0.034	0.031	0.029	0.027	0.026
0.10	0.306	0.178	0.111	0.088	0.075	0.067	0.062	0.058	0.054	0.052
0.20	0.612	0.356	0.223	0.175	0.150	0.135	0.124	0.115	0.109	0.104
0.40	1.223	0.711	0.445	0.351	0.301	0.269	0.247	0.231	0.218	0.207
0.60	1.835	1.067	0.668	0.526	0.451	0.404	0.371	0.346	0.327	0.311
0.80	2.446	1.423	0.890	0.702	0.602	0.538	0.494	0.461	0.435	0.415
1.00	3.058	1.778	1.113	0.877	0.752	0.673	0.618	0.576	0.544	0.518

5.9.5 IAC CURVES

The curves for the General Electric type IAC relay family are derived from the formula:

$$T = \begin{cases} M \times \left[A + \dfrac{B}{1.03 - C} + \dfrac{D}{(1.03 - C)^2} + \dfrac{E}{(1.03 - C)^3} \right], & \text{for } 1 \le \dfrac{I}{I_{pkp}} < 1.03 \\ M \times \left[A + \dfrac{B}{I/I_{pkp} - C} + \dfrac{D}{(I/I_{pkp} - C)^2} + \dfrac{E}{(I/I_{pkp} - C)^3} \right], & \text{for } 1.03 \le \dfrac{I}{I_{pkp}} < 20.0 \\ M \times \left[A + \dfrac{B}{20.0 - C} + \dfrac{D}{(20.0 - C)^2} + \dfrac{E}{(20.0 - C)^3} \right], & \text{for } \dfrac{I}{I_{pkp}} \ge 20.0 \end{cases}$$

where: T = Operate Time (seconds)
M = Multiplier Setpoint
I = Input Current
I_{pkp} = Pickup Current Setpoint
A, B, C, D, E = Constants

Table 5–14: IAC CURVE CONSTANTS

IAC CURVE SHAPE	CONSTANTS				
	A	B	C	D	E
IAC EXTREME INVERSE	0.0040	0.6379	0.6200	1.7872	0.2461
IAC VERY INVERSE	0.0900	0.7955	0.1000	–1.2885	7.9586
IAC INVERSE	0.2078	0.8630	0.8000	–0.4180	0.1947
IAC SHORT INVERSE	0.0428	0.0609	0.6200	–0.0010	0.0221

Table 5–15: IAC CURVE TRIP TIMES

MULTIPLIER *M*	CURRENT I / I_{pkp}									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IAC EXTREMELY INVERSE										
0.5	1.699	0.749	0.303	0.178	0.123	0.093	0.074	0.062	0.053	0.046
1.0	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093
2.0	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185
4.0	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370
6.0	20.387	8.990	3.635	2.133	1.474	1.115	0.893	0.743	0.636	0.556
8.0	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741
10.0	33.979	14.983	6.058	3.555	2.457	1.859	1.488	1.239	1.060	0.926
IAC VERY INVERSE										
0.5	1.451	0.656	0.269	0.172	0.133	0.113	0.101	0.093	0.087	0.083
1.0	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165
2.0	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331
4.0	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662
6.0	17.407	7.872	3.225	2.061	1.598	1.359	1.215	1.117	1.046	0.992
8.0	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323
10.0	29.012	13.121	5.374	3.434	2.663	2.266	2.025	1.862	1.744	1.654
IAC NORMALLY INVERSE										
0.5	0.578	0.375	0.266	0.221	0.196	0.180	0.168	0.160	0.154	0.148
1.0	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297
2.0	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594
4.0	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188
6.0	6.931	4.496	3.192	2.656	2.353	2.158	2.022	1.921	1.843	1.781
8.0	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375
10.0	11.552	7.494	5.320	4.426	3.922	3.597	3.369	3.201	3.072	2.969
IAC SHORT INVERSE										
0.5	0.072	0.047	0.035	0.031	0.028	0.027	0.026	0.026	0.025	0.025
1.0	0.143	0.095	0.070	0.061	0.057	0.054	0.052	0.051	0.050	0.049
2.0	0.286	0.190	0.140	0.123	0.114	0.108	0.105	0.102	0.100	0.099
4.0	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197
6.0	0.859	0.569	0.419	0.368	0.341	0.325	0.314	0.307	0.301	0.296
8.0	1.145	0.759	0.559	0.490	0.455	0.434	0.419	0.409	0.401	0.394
10.0	1.431	0.948	0.699	0.613	0.569	0.542	0.524	0.511	0.501	0.493

5.10.1 INVERSE CURVE 1

The curve for the inverse curve 1 shape is derived from the formula:

$$T = \frac{D}{\left(\frac{V/F}{\text{Pickup}}\right)^2 - 1} \quad \text{when } \frac{V}{F} > \text{Pickup}$$

where T = operate time (seconds)
D = delay setpoint (seconds)
V = fundamental RMS value of voltage (V)
F = frequency of voltage signal (Hz)
Pickup = volts-per-hertz pickup setpoint (V/Hz)

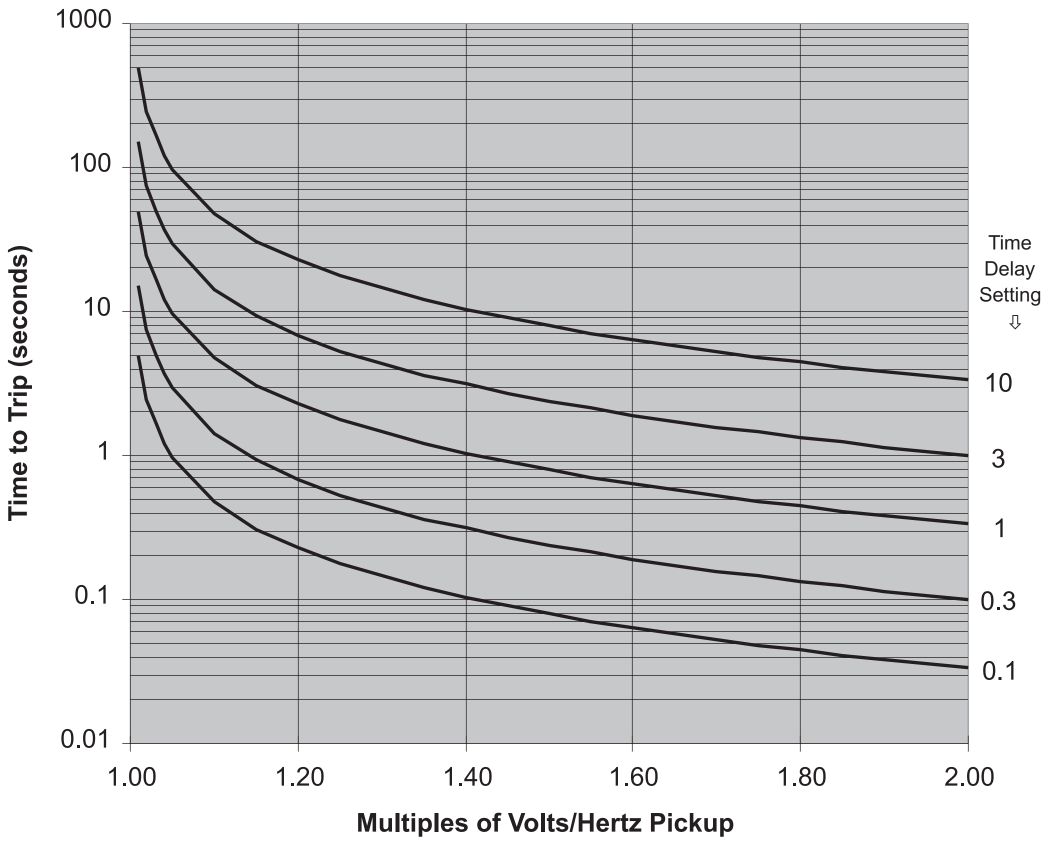


Figure 5–16: INVERSE CURVE 1

5.10.2 INVERSE CURVE 2

The curve for the inverse curve 2 shape is derived from the formula:

$$T = \frac{D}{\frac{V/F}{\text{Pickup}} - 1} \quad \text{when } \frac{V}{F} > \text{Pickup}$$

where T = operate time (seconds)
D = delay setpoint (seconds)
V = fundamental RMS value of voltage (V)
F = frequency of voltage signal (Hz)
Pickup = volts-per-hertz pickup setpoint (V/Hz)

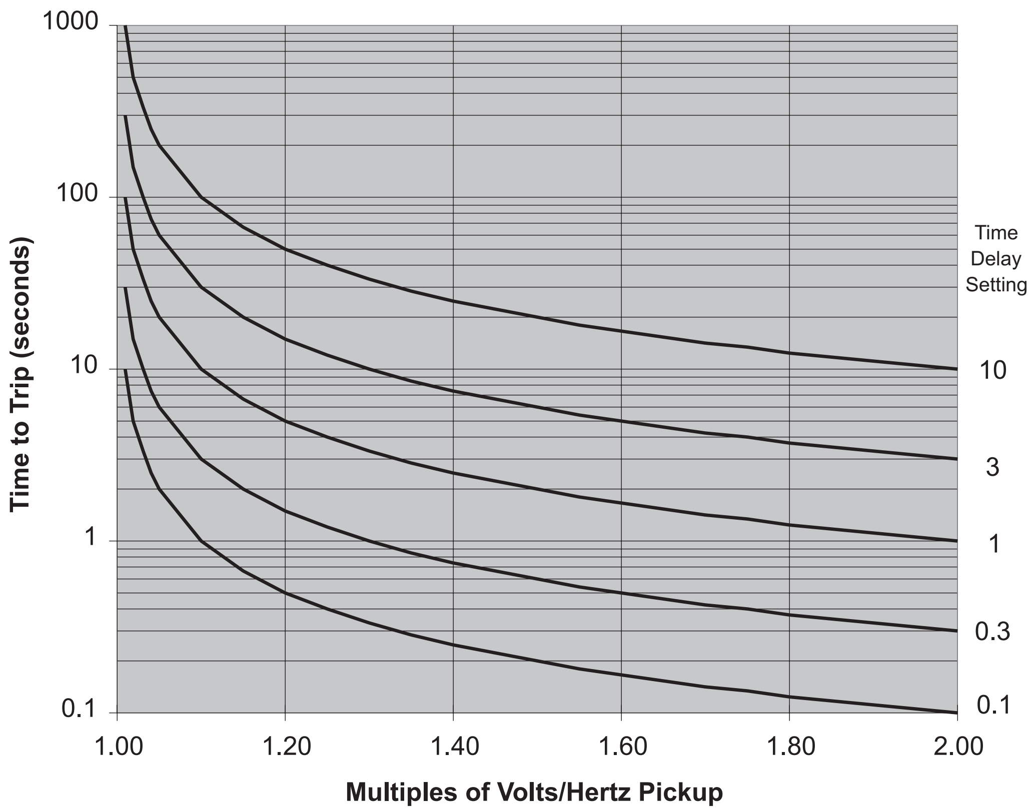


Figure 5–17: INVERSE CURVE 2

5.10.3 INVERSE CURVE 3

The curve for the inverse curve 3 shape is derived from the formula:

$$T = \frac{D}{\left(\frac{V/F}{\text{Pickup}}\right)^{0.5} - 1} \quad \text{when } \frac{V}{F} > \text{Pickup}$$

where T = operate time (seconds)
D = delay setpoint (seconds)
V = fundamental RMS value of voltage (V)
F = frequency of voltage signal (Hz)
Pickup = volts-per-hertz pickup setpoint (V/Hz)

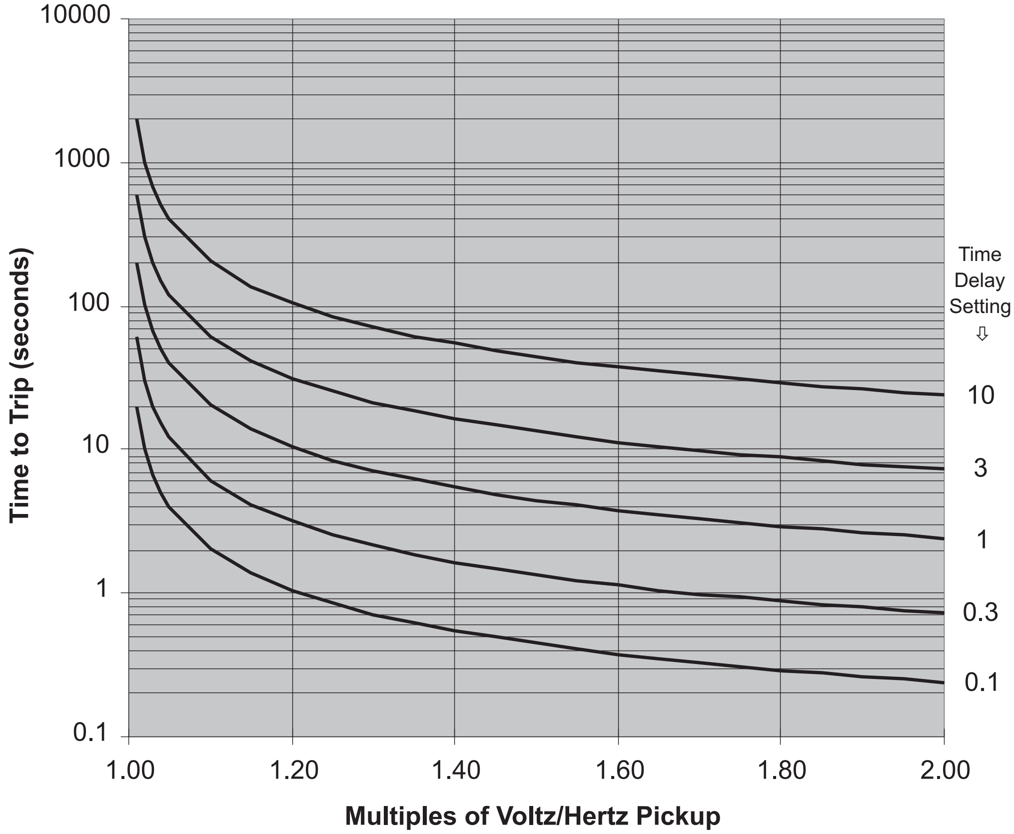


Figure 5–18: INVERSE CURVE 3

6.1.1 DESCRIPTION

Measured values, event records and product information are actual values. Actual values may be accessed via any of the following methods:

- Front panel, using the keys and display.
- Front program port, and a portable computer running the 745PC software supplied with the relay.
- Rear RS485/RS422 COM 1 port or RS485 COM 2 port with any system running user written software.

Any of these methods can be used to view the same information. A computer, however, makes viewing much more convenient, since more than one piece of information can be viewed at the same time.

Actual value messages are organized into logical groups, or pages, for easy reference. All actual value messages are illustrated and described in blocks throughout this chapter. A reference of all messages is also provided at the end of the chapter. All values shown in these message illustrations assume that no inputs (besides control power) are connected to the 745.

Some messages appear on the following pages with a gray background. This indicates that the message may not appear depending upon the configuration of the relay (as selected by setpoints) or the options installed in the relay during manufacture. For example, no display associated with Winding 3 will ever appear if the relay is not configured for three-winding operation.

6.1.2 ACTUAL VALUES ORGANIZATION

```
▌▌ACTUAL VALUES
▌▌A1 STATUS
```

- Current Date and Time
- Logic Inputs
- Virtual Inputs
- Output Relays
- Virtual Outputs
- Self-Test Errors

```
▌▌ACTUAL VALUES
▌▌A2 METERING
```

- Currents (Phase, Neutral, Ground, Positive, Negative, and Zero Sequence, Differential, Restraint, Ground Differential)
- Harmonic Content (2nd to 21st, THD, Harmonic Derating)
- System Frequency and Frequency Decay Rate
- Tap Changer
- Voltage and Volts-Per-Hertz
- Current Demand
- Ambient Temperature
- Loss of Life
- Analog Input
- Power
- Energy

```
▌▌ACTUAL VALUES
▌▌A3 EVENT RECORDER
```

- 128 events

```
▌▌ACTUAL VALUES
▌▌A4 PRODUCT INFO
```

- Technical Support
- Revision Codes
- Calibration Dates

6.2.1 DESCRIPTION

```
▌▌ACTUAL VALUES
▌▌A1 STATUS
```

This is the header of Actual Values page A1 STATUS. To view these actual values press MESSAGE ▼ or press ACTUAL to go to the next page header.

Some status information is displayed by the front panel indicators. More status details can be viewed from the first page of actual values. This information includes date and time, logic input status and output relay status.

6.2.2 DATE AND TIME

```
▌DATE AND TIME
▌[ENTER] for more
```

This message indicates the start of the Date and Time actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
CURRENT DATE:
Jan 01 2001
```

The current date is displayed in this message.

```
CURRENT TIME:
00:00:00
```

The current time is displayed in this message.

6.2.3 LOGIC INPUTS

```
▌LOGIC INPUTS
▌[ENTER] for more
```

This message indicates the start of the Logic Inputs actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
LOGIC INPUT 1
STATE: Not Asserted
```

This message displays the state of logic input #1. Similar messages appear sequentially for logic inputs 2 through 16.

```
SETPOINT ACCESS
STATE: Open
```

This message displays the state of the setpoint access jumper. Setpoints cannot be changed from the front panel when the state is opened.

6

6.2.4 VIRTUAL INPUTS

```
▌ VIRTUAL INPUTS
▌ [ENTER] for more
```

This message indicates the start of the Virtual Inputs actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
VIRTUAL INPUT 1
STATE: Not Asserted
```

This message displays the state of virtual input #1. Similar messages appear sequentially for Virtual inputs 2 through 16.

6.2.5 OUTPUT RELAYS

```
▌ OUTPUT RELAYS
▌ [ENTER] for more
```

This message indicates the start of the Output Relays actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
OUTPUT RELAY 1
STATE: De-energized
```

This message displays the state of output relay #1. Similar messages appear sequentially for output relays 2 through 8.

```
SELF-TEST RELAY
STATE: Energized
```

This message displays the state of the self-test relay.

6.2.6 VIRTUAL OUTPUTS

```
▌ VIRTUAL OUTPUTS
▌ [ENTER] for more
```

This message indicates the start of the Virtual Outputs actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
VIRTUAL OUTPUT 1
STATE: De-energized
```

This message displays the state of virtual output #1. Similar messages appear sequentially for virtual outputs 2 through 5.

6.2.7 SELF-TEST ERRORS

```
▌ SELF-TEST ERRORS
▌ [ENTER] for more
```

This message indicates the start of the Self-Test Errors actual values. To view these actual values press ENTER. Pressing MESSAGE ▼ proceeds to the ending of page S1.

```
FLEXLOGIC EQN ERROR:
None
```

This message displays the source of the error occurring in the FlexLogic™ equation.

```
BAD SETTINGS ERROR:
None
```

This message displays the cause of a bad setting made within the setting of the setpoints.

6

6.3.1 DESCRIPTION

```
▌▌ ACTUAL VALUES
▌▌ A2 METERING
```

This is the header of Actual Values page A2 METERING. To view these actual values press MESSAGE ▼ or press ACTUAL to go to the next page header.

The 745 measures all winding currents and their harmonic components as well as system frequency and voltage, tap changer position, ambient temperature and an auxiliary analog input channel. From these, derived values including neutral, sequence components, differential and restraint currents, THD, harmonic derating factors and current demand are calculated. These processed values are both displayed and used to perform the required protection and monitoring functions.

6.3.2 CURRENT

For each monitored winding, the fundamental frequency magnitude and phase angle of phase A, B, C and ground currents are recalculated every half-cycle for use in differential and overcurrent protection. From these values, neutral, positive, negative and zero-sequence as well as differential, restraint and ground differential currents are calculated. These are displayed and updated approximately twice a second for readability.

```
▌ CURRENT
▌ [ENTER] for more
```

This message indicates the start of the Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

a) WINDING 1/2/3 CURRENTS

```
▌ W1 CURRENT
▌ [ENTER] for more
```

This message indicates the start of the Winding 1 Current actual values (Windings 2 and 3 are similar). To view these actual values press ENTER or press MESSAGE ▼ for the next section.

6

The following Actual Values messages are repeated for Windings 1, 2 and 3.

```
W1 PHASE A CURRENT:
 0A at   0°Lag
```

The fundamental frequency current magnitude and phase for Winding 1 (2/3), phase A is shown. The current angle for Winding 1, phase A is always set to zero as this angle is used as a reference for all other currents, both measured and derived.

```
W1 PHASE B CURRENT:
 0A at   0°Lag
```

This message displays the fundamental frequency current magnitude and phase for Winding 1 (2/3), phase B.

```
W1 PHASE C CURRENT:
 0A at   0°Lag
```

The fundamental frequency current magnitude and phase for Winding 1 (2/3), phase C is displayed.

```
W1 NEUTRAL CURRENT:
 0A at   0°Lag
```

This Winding displays the fundamental frequency current magnitude and phase for winding 1 (2/3), neutral.

```
W1 GROUND CURRENT:
 0A at   0°Lag
```

This message displays the fundamental frequency current magnitude and phase for Winding 1 (2/3), ground current input, if used.

```
WINDING 1 LOADING:
 0% of rated load
```

This message displays what percentage of its maximum specified load Winding 1 (2/3) is currently carrying.

```
W1 AVERAGE PHASE
CURRENT:   0 A
```

The average phase current value in the corresponding winding is displayed.

b) POSITIVE SEQUENCE CURRENTS

NOTE

All sequence component phase angles are referenced to Winding 1 phase A current.

```
▌ POSITIVE SEQUENCE
▌ [ENTER] for more
```

This message indicates the start of the Positive Sequence Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
W1 POS SEQ CURRENT:
 0A at   0°Lag
```

This message displays the positive sequence current magnitude and phase for Winding 1.

```
W2 POS SEQ CURRENT:
 0A at   0°Lag
```

This message displays the positive sequence current magnitude and phase for Winding 2.

```
W3 POS SEQ CURRENT:
 0A at   0°Lag
```

This message displays the positive sequence current magnitude and phase for Winding 3.

c) NEGATIVE SEQUENCE CURRENTS

```
▌ NEGATIVE SEQUENCE
▌ [ENTER] for more
```

This message indicates the start of the Negative Sequence Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
W1 NEG SEQ CURRENT:
 0A at   0°Lag
```

This message displays the negative sequence current magnitude and phase for Winding 1.

```
W2 NEG SEQ CURRENT:
 0A at   0°Lag
```

This message displays the negative sequence current magnitude and phase for Winding 2.

```
W3 NEG SEQ CURRENT:
 0A at   0°Lag
```

This message displays the negative sequence current magnitude and phase for Winding 3.

d) ZERO SEQUENCE CURRENTS

```
▌ ZERO SEQUENCE
▌ [ENTER] for more
```

This message indicates the start of the Zero Sequence Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
W1 ZERO SEQ CURRENT:
 0A at   0°Lag
```

This message displays the zero sequence current magnitude and phase for Winding 1.

```
W2 ZERO SEQ CURRENT:
 0A at   0°Lag
```

This message displays the zero sequence current magnitude and phase for Winding 2.

```
W3 ZERO SEQ CURRENT:
 0A at   0°Lag
```

This message displays the zero sequence current magnitude and phase for Winding 3.

e) DIFFERENTIAL CURRENT

The differential current phase angles are referenced to Winding 1 phase A current.

▌ DIFFERENTIAL ▌ [ENTER] for more	This message indicates the start of the Differential Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
PHASE A DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current magnitude for phase A.
PHASE A DIFFERENTIAL ANGLE: 0°Lag	This message displays the differential current angle for phase A.
PHASE B DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current magnitude for phase B.
PHASE B DIFFERENTIAL ANGLE: 0°Lag	This message displays the differential current angle for phase B.
PHASE C DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current magnitude for phase C.
PHASE C DIFFERENTIAL ANGLE: 0°Lag	This message displays the differential current angle for phase C.

f) RESTRAINT CURRENT

6

▌ RESTRAINT ▌ [ENTER] for more	This message indicates the start of the Restraint Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
PHASE A RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current magnitude for phase A.
PHASE B RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current magnitude for phase B.
PHASE C RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current magnitude for phase C.

g) GROUND DIFFERENTIAL CURRENT

▌ GND DIFFERENTIAL ▌ [ENTER] for more	This message indicates the Ground Differential Current actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
W1 GND DIFFERENTIAL CURRENT: 0.000 x CT	This message displays the ground differential current magnitude for Winding #1.
W2 GND DIFFERENTIAL CURRENT: 0.000 x CT	This message displays the ground differential current magnitude for Winding #2.
W3 GND DIFFERENTIAL CURRENT: 0.000 x CT	This message displays the ground differential current magnitude for Winding #3.

6.3.3 HARMONIC CONTENT

The 745 can determine the harmonic components of every current that it measures. This allows it to calculate total harmonic distortion (THD) as well as a harmonic derating factor that can be used to adjust phase time overcurrent protection to account for additional internal energy dissipation that arises from the presence of harmonic currents.

```
▌ HARMONIC CONTENT
▌ [ENTER] for more
```

This message indicates the start of the Harmonic Content actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

a) HARMONIC SUB-COMPONENTS

The 745 is capable of measuring harmonic components up to a frequency of 21 times the nominal system frequency. An actual value is calculated for each phase of each monitored winding.

The example below shows what is displayed in a typical case for harmonic components (in this case the second harmonic). Similar displays exist for all harmonics up to the 21st.

```
▌ 2nd HARMONIC
▌ [ENTER] for more
```

This message indicates the start of the Second Harmonic actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next sequential harmonic section.

```
W1 (% ƒo) H2a: 0.0
H2b: 0.0 H2c: 0.0
```

The second harmonic magnitude for each phase current of Winding 1 is displayed. Values are expressed as a percentage of the magnitude of the corresponding fundamental frequency component.

```
W2 (% ƒo) H2a: 0.0
H2b: 0.0 H2c: 0.0
```

The second harmonic magnitude for each phase current of Winding 2 is displayed. Values are expressed as a percentage of the magnitude of the corresponding fundamental frequency component.

```
W3 (% ƒo) H2a: 0.0
H2b: 0.0 H2c: 0.0
```

The second harmonic magnitude for each phase current of Winding 3 is displayed. Values are expressed as a percentage of the magnitude of the corresponding fundamental frequency component.

6

b) TOTAL HARMONIC DISTORTION (THD)

THD is calculated and displayed. Every THD value is calculated as the ratio of the RMS value of the sum of the squared individual harmonic amplitudes to the rms value of the fundamental frequency. The calculations are based on IEEE standard 519-1986

```
▌ THD
▌ [ENTER] for more
```

This message indicates the start of the THD actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

The following Actual Value messages are repeated for Windings 1, 2, and 3.

```
W1 THDa (2nd-21st):
0.0% fo
```

This message displays the THD for Winding 1 phase A current, expressed as a percentage of the fundamental frequency component. The numbers in parentheses indicate the programmed frequency band (in terms of harmonic number) over which THD is being calculated.

```
W1 THDb (2nd-21st):
0.0% fo
```

This message displays the THD for Winding 1 phase B current, expressed as a percentage of the fundamental frequency component.

```
W1 THDc (2nd-21st):
0.0% fo
```

This message displays the THD for Winding 1 phase C current, expressed as a percentage of the fundamental frequency component.

c) HARMONIC DERATING FACTOR

The Harmonic Derating Factor for each of the windings shows the effect of nonsinusoidal load currents on power transformer's rated full load current. The calculations are based on ANSI/IEEE standard C57.110-1986.

```
▌ HARMONIC DERATING
▌ [ENTER] for more
```

This message indicates the start of the Harmonic Derating Factor actual values of page A2. To view these actual values press ENTER; press ESCAPE key to return to the Harmonic Content sub-heading or press ACTUAL to go to the next section.

```
W1 HARMONIC DERATING
FACTOR: 1.00
```

This message displays the harmonic derating factor for Winding 1.

```
W2 HARMONIC DERATING
FACTOR: 1.00
```

This message displays the harmonic derating factor for Winding 2.

```
W3 HARMONIC DERATING
FACTOR: 1.00
```

This message displays the harmonic derating factor for Winding 3.

6.3.4 FREQUENCY

```
▌ FREQUENCY
▌ [ENTER] for more
```

This message indicates the start of the Frequency actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
SYSTEM FREQUENCY:
 0.00 Hz
```

This message displays the system frequency. Frequency is calculated from the voltage input provided that the voltage sensing is enabled and the injected voltage is above 50% of VT. If these criteria are not satisfied, then the system frequency is determined from Winding 1 phase A current provided that it is above 0.05 × CT. If frequency still cannot be calculated, 0.00 is displayed, though the sampling rate is then set for the nominal frequency set under **S2 SYSTEM SETUP / TRANSFORMER**.

```
FREQUENCY DECAY
RATE: 0.00 Hz/s
```

This message displays the frequency decay rate. This actual value can only be calculated if system frequency can be calculated.

6.3.5 TAP CHANGER

```
▌ TAP CHANGER
▌ [ENTER] for more
```

This message indicates the start of the Tap Changer actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
TAP CHANGER
POSITION: n/a
```

This message displays the actual tap position. If tap position sensing is disabled, n/a will be displayed.

6.3.6 VOLTAGE

```
▌ VOLTAGE
▌ [ENTER] for more
```

This message indicates the start of the Voltage actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
SYSTEM LINE-TO-LINE
VOLTAGE: 0.00 kV
```

This message displays the system's line-to-line voltage. For phase-to-neutral input voltages, this display is converted to its line-to-line equivalent.

```
VOLTS-PER-HERTZ:
0.00 V/Hz
```

This message displays the calculated volts-per-hertz.

```
LINE-NTRL VOLTAGE:
 0.00 kV at   0°Lag
```

This message displays the line-to-neutral phase voltage magnitude and angle.

6.3.7 DEMAND

The 745 measures current demand on each phase of each monitored winding. These parameters can be monitored to reduce supplier demand penalties or for statistical metering purposes. Demand is calculated based on the measurement type in **S2 SYSTEM SETUP/DEMAND METERING**. For each quantity, the 745 displays the demand over the most recent demand time interval, the maximum demand since the last date that the demand data was reset, and the time and date stamp of this maximum value.

```
▌ DEMAND
▌ [ENTER] for more
```

This message indicates the start of the Demand actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

a) DEMAND DATA CLEAR

```
▌ DEMAND DATA CLEAR
▌ [ENTER] for more
```

This message indicates the start of the Demand Data Clear actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
CLEAR MAX DEMAND
DATA? No
```

Enter Yes to clear all maximum demand data.

```
DATE OF LAST CLEAR:
Jan 01 1996
```

This message displays the last date that the demand data was cleared. If the date has never been programmed, this message will display Jan 01 1996.

```
TIME OF LAST CLEAR:
00:00:00.000
```

This message displays the last time that the demand data was cleared.

b) CURRENT DEMAND

The following Actual Values messages are repeated for Windings 1, 2 and 3.

▌ W1 CURRENT DEMAND ▌ [ENTER] for more	This message indicates the start of the Winding 1 (2/3) Current Demand actual values. To view these actual values press ENTER or press MESSAGE ▼ to scroll to the current demand values for the next winding.
W1 PHASE A CURRENT DEMAND: 0A	This message displays the Winding 1 (2/3) phase A current demand.
W1 PHASE B CURRENT DEMAND: 0A	This message displays the Winding 1 (2/3) phase B current demand.
W1 PHASE C CURRENT DEMAND: 0A	This message displays the Winding 1 (2/3) phase C current demand.
MAXIMUM W1 DEMAND: 0A in phase A	This message displays the maximum Winding 1 (2/3) current demand and the phase in which it occurred since the demand data was last reset.
MAXIMUM W1 DEMAND DATE: Jan 01 1996	This message displays the date when the maximum Winding 1 (2/3) current demand was detected. If the date has never been programmed, this message will display Jan 01 1996
MAXIMUM W1 DEMAND TIME: 00:00:00.000	This message displays the time when the maximum Winding 1 (2/3) current demand was detected.

6.3.8 AMBIENT TEMPERATURE

6

Ambient temperature is monitored via an RTD connected to the 745.

▌ AMBIENT TEMP ▌ [ENTER] for more	This message indicates the start of the Ambient Temperature actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
AMBIENT TEMPERATURE 0 °C	This message displays the measured ambient temperature.

6.3.9 LOSS OF LIFE

▌ LOSS OF LIFE ▌ [ENTER] for more	This message indicates the start of the LOSS OF LIFE actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
HOTTEST-SPOT WINDING TEMPERATURE: 1°C	This is the computed hottest-spot temperature, based on the ambient temperature and the highest-load winding current.
INSULATION AGING FACTOR: 0.0	The insulation aging factor is computed from the hottest-spot temperature.
TOTAL ACCUM LOSS OF LIFE: 0.00 hours	Total equivalent service hours of the transformer.

6.3.10 ANALOG INPUT

The 745 provides the ability to monitor any external quantity via an auxiliary current input called the ANALOG INPUT.

```
▌ ANALOG INPUT
▌ [ENTER] for more
```

This message indicates the start of the Analog Input actual values. To view these actual values press ENTER or press MESSAGE ▼ for the end of page A2.

```
ANALOG INPUT:
    0 µA
```

This message displays the scaled value of the analog input, as defined by the setpoints noted above. In this message, the name programmed in **S2 SYSTEM SETUP/ANALOG INPUT/ANALOG INPUT NAME** is displayed instead of ANALOG INPUT (the factory default), and the units programmed in **S2 SYSTEM SETUP/ANALOG INPUT/ANALOG INPUT UNITS** are displayed instead of µA (which is the factory default).

6.3.11 POWER

The 745 calculates and displays real, reactive, and apparent power as well as the power factor for all of the available windings providing that the voltage sensing is enabled. Power flowing into the power transformer is designated as source power and power flowing out of the transformer is designated as load power.

```
▌ POWER
▌ [ENTER] for more
```

This message indicates the start of the Power actual values. To view these actual values press ENTER or press MESSAGE ▼ for the end of page A2.

The following Actual Values messages are repeated for Windings 1, 2 and 3.

```
▌ W1 POWER
▌ [ENTER] for more
```

This message indicates the start of the Power actual values. To view these actual values press ENTER or press MESSAGE ▼ for the end of page A2.

```
W1 REAL POWER:
      0 MW
```

This message displays the total 3 phase real power (in MW) for winding 1(2/3) as source or load.

```
W1 REACTIVE POWER:
      0 Mvar
```

This message displays the total 3 phase reactive power (in Mvar) for winding 1(2/3) as source or load.

```
W1 APPARENT POWER:
      0 MVA
```

This message displays the total 3 phase apparent power (in MVA) for winding 1(2/3).

```
W1 POWER FACTOR:
0.00
```

This message displays the total 3 phase power factor (as lead or lag) for winding 1(2/3).

6.3.12 ENERGY

The 745 calculates and displays watthours and varhours for source currents and load currents for all of the available windings providing that the voltage sensing is enabled.

```
▌ ENERGY
▌ [ENTER] for more
```

This message indicates the start of the Energy actual values. To view these actual values press ENTER or press MESSAGE ▼ for the end of page A2.

a) ENERGY DATA CLEAR

```
▌ ENERGY DATA CLEAR
▌ [ENTER] for more
```

This message indicates the start of the Energy Data Clear actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
CLEAR ENERGY
DATA? No
```

Enter Yes to clear all energy data.

```
DATE OF LAST CLEAR:
Jan 01 1996
```

This message displays the last date that the energy data was cleared. If the date has never been programmed, this message will display Jan 01 1996.

```
TIME OF LAST CLEAR:
00:00:00
```

This message displays the last time that the energy data was cleared.

b) W1/W2/W3 ENERGY

The following Actual Values messages are repeated for Windings 1, 2 and 3.

```
▌ W1 ENERGY
▌ [ENTER] for more
```

This message indicates the start of the Energy actual values. To view these actual values press ENTER or press MESSAGE ▼ for the end of page A2.

```
W1 SOURCE WATTHOURS:
            0 MWh
```

This message displays the source watthours (in MWh) for Winding 1(2/3).

```
W1 LOAD WATTHOURS:
            0 MWh
```

This message displays the load watthours (in MWh) for Winding 1(2/3).

```
W1 SOURCE VARHOURS:
            0 Mvarh
```

This message displays the source varhours (in Mvarh) for Winding 1(2/3).

```
W1 LOAD VARHOURS:
            0 Mvarh
```

This message displays the load varhours (in Mvarh) for Winding 1(2/3).

6.4.1 DESCRIPTION

```
▌▌ ACTUAL VALUES
▌▌ A3 EVENT RECORDER
```

This is the header of Actual Values page A3 EVENT RECORDER. To view these actual values press MESSAGE ▼ or press ACTUAL to go to the next page header.

The 745 relay contains an event recording feature which runs continuously, capturing and storing the conditions present at the moment of occurrence of the last 128 events, as well as the time and date of each event.

6.4.2 EVENT DATA RESET

```
▌ EVENT DATA CLEAR
▌ [ENTER] for more
```

This message indicates the start of the Event Data Clear actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next section.

```
CLEAR EVENT RECORDER
DATA? No
```

Enter Yes to clear all event recorder data.

```
CLEAR EVENT RECORDER
SIGNAL: Disabled
```

Range: Disabled / Logc Inpt 1(2-16)

Assign a logic input to be used for remote clearing of the event recorder.

```
DATE OF LAST CLEAR:
Jan 01 1996
```

This message displays the date that the event recorder was last cleared. If the date has never been programmed, this message will display Jan 01 1996.

```
TIME OF LAST CLEAR:
00:00:00.000
```

This message displays the time that the event recorder was last cleared.

```
NO. OF EVENTS SINCE
LAST CLEAR: 0
```

This message displays the number of time an event has occurred since the last clearing of the event recorder.

6

6.4.3 EVENT RECORDS

The header message for each event contains two pieces of information: the event number (higher numbers denote more recent events) and the event date. If the event record is clear or if the date has never been programmed, Unavailable is displayed instead of a date. No more than 128 events are stored at the same time.

```
▌ E001: Unavailable
▌ [ENTER] for more
```

This message indicates the start of the Event #001 actual values. To view these actual values press ENTER or press MESSAGE ▼ for the next sequential event record. After the oldest event is displayed, pressing MESSAGE ▼ goes to the end of page A3. The date that the event occurred is displayed as part of the message.

```
EVENT DATE:
Jan 01 2001
```

This message displays the date that the event occurred. If the date has never been programmed, this message will display Unavailable.

```
EVENT TIME:
00:00:00:000
```

This message displays the time that the event occurred. If the time has never been programmed, this message will display Unavailable.

```
EVENT CAUSE: On
Control Power
```

This message displays two pieces of information: the phases which are involved in the event (if applicable), and the cause of the event, which may be any of those listed in Table 6–1: TYPES/CAUSES OF EVENTS below

W1 PHASE A CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase A of winding 1 at the moment of the event.
W1 PHASE B CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase B of winding 1 at the moment of the event.
W1 PHASE C CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase C of winding 1 at the moment of the event.
W1 GROUND CURRENT 0 A at 0° Lag	This message displays the ground current magnitude and phase angle for winding 1 at the moment of the event.
W1 (% *f*o) H2a: 0.0 H2b: 0.0 H2c: 0.0	This message displays the magnitude of the second harmonic current for each phase of winding 1 at the moment of the event.
W1 (% *f*o) H5a: 0.0 H5b: 0.0 H5c: 0.0	This message displays the magnitude of the fifth harmonic current for each phase of winding 1 at the moment of the event.
W2 PHASE A CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase A of winding 2 at the moment of the event.
W2 PHASE B CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase B of winding 2 at the moment of the event.
W2 PHASE C CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase C of winding 2 at the moment of the event.
W2 GROUND CURRENT 0 A at 0° Lag	This message displays the ground current magnitude and phase angle for winding 2 at the moment of the event.
W2 (% *f*o) H2a: 0.0 H2b: 0.0 H2c: 0.0	This message displays the magnitude of the second harmonic current for each phase of winding 2 at the moment of the event.
W2 (% *f*o) H5a: 0.0 H5b: 0.0 H5c: 0.0	This message displays the magnitude of the fifth harmonic current for each phase of winding 2 at the moment of the event.
W3 PHASE A CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase A of winding 3 at the moment of the event.
W3 PHASE B CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase B of winding 3 at the moment of the event.
W3 PHASE C CURRENT 0 A at 0° Lag	This message displays the phase current magnitude and phase angle for phase C of winding 3 at the moment of the event.
W3 GROUND CURRENT 0 A at 0° Lag	This message displays the ground current magnitude and phase angle for winding 3 at the moment of the event.
W3 (% *f*o) H2a: 0.0 H2b: 0.0 H2c: 0.0	This message displays the magnitude of the second harmonic current for each phase of winding 3 at the moment of the event.

W3 (% fo) H5a: 0.0 H5b: 0.0 H5c: 0.0	This message displays the magnitude of the fifth harmonic current for each phase of winding 3 at the moment of the event.
PHASE A DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current for phase A at the moment of the event.
PHASE B DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current for phase B at the moment of the event.
PHASE C DIFFERENTIAL CURRENT: 0.00 x CT	This message displays the differential current for phase C at the moment of the event.
PHASE A RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current for phase A at the moment of the event.
PHASE B RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current for phase B at the moment of the event.
PHASE C RESTRAINT CURRENT: 0.00 x CT	This message displays the restraint current for phase C at the moment of the event.
SYSTEM FREQUENCY: 0.00 Hz	This message displays the system frequency at the moment of the event.
FREQUENCY DECAY RATE: 0.00 Hz/s	This message displays the frequency decay rate at the moment of the event.
TAP CHANGER POSITION: n/a	This message displays the tap changer position at the moment of the event.
VOLTS-PER-HERTZ: 0.00 V/Hz	This message displays the volts-per-hertz at the moment of the event.
AMBIENT TEMPERATURE: 0°C	This message displays the ambient temperature at the moment of the event.
ANALOG INPUT: 0 μA	This message displays the measured analog input at the moment of the event.

Table 6–1: TYPES/CAUSES OF EVENTS

PICKUP / OPERATE / DROPOUT			
Percent Differential	Inst Differential	W1 Phase Time OC	W2 Phase Time OC
W3 Phase Time OC	W1 Phase Inst OC 1	W2 Phase Inst OC 1	W3 Phase Inst OC 1
W1 Phase Inst OC 2	W2 Phase Inst OC 2	W3 Phase Inst OC 2	W1 Neutral Time OC
W2 Neutral Time OC	W3 Neutral Time OC	W1 Neutral Inst OC 1	W2 Neutral Inst OC 1
W3 Neutral Inst OC 1	W1 Neutral Inst OC 2	W2 Neutral Inst OC 2	W3 Neutral Inst OC 2
W1 Ground Time OC	W2 Ground Time OC	W3 Ground Time OC	W1 Ground Inst OC 1
W2 Ground Inst OC 1	W3 Ground Inst OC 1	W1 Ground Inst OC 2	W2 Ground Inst OC 2
W3 Ground Inst OC 2	W1 Restd Gnd Fault	W2 Restd Gnd Fault	W3 Restd Gnd Fault
W1 Neg Seq Time OC	W2 Neg Seq Time OC	W3 Neg Seq Time OC	W1 Neg Seq Inst OC
W2 Neg Seq Inst OC	W3 Neg Seq Inst OC	Underfrequency 1	Underfrequency 2
Frequency Decay 1	Frequency Decay 2	Frequency Decay 3	Frequency Decay 4
Overfrequency	5th Harmonic Level	Volts-Per-Hertz 1	Volts-Per-Hertz 2
W1 THD Level	W2 THD Level	W3 THD Level	W1 Harmonic Derating
W2 Harmonic Derating	W3 Harmonic Derating	Analog Level 1	Analog Level 2
W1 Current Demand	W2 Current Demand	W3 Current Demand	Transformer Overload
ON/OFF			
Logic Input 1	Logic Input 2	Logic Input 3	Logic Input 4
Logic Input 5	Logic Input 6	Logic Input 7	Logic Input 8
Logic Input 9	Logic Input 10	Logic Input 11	Logic Input 12
Logic Input 13	Logic Input 14	Logic Input 15	Logic Input 16
Virtual Input 1	Virtual Input 2	Virtual Input 3	Virtual Input 4
Virtual Input 5	Virtual Input 6	Virtual Input 7	Virtual Input 8
Virtual Input 9	Virtual Input 10	Virtual Input 11	Virtual Input 12
Virtual Input 13	Virtual Input 14	Virtual Input 15	Virtual Input 16
Output Relay 1	Output Relay 2	Output Relay 3	Output Relay 4
Output Relay 5	Output Relay 6	Output Relay 7	Output Relay 8
Self-Test Relay	Virtual Output 1	Virtual Output 2	Virtual Output 3
Virtual Output 4	Virtual Output 5	Setpoint Group 1	Setpoint Group 2
Setpoint Group 3	Setpoint Group 4	Test Mode	Simulation Disabled
Simulation Prefault	Simulation Fault	Simulation Playback	Logic Input Reset
Front Panel Reset	Comm Port Reset	Manual Trace Trigger	Auto Trace Trigger
Control Power	Aging factor Limit	Ambient Temperature	Tap Changer failure
ERROR!			
Logic Input Power	Analog Output Power	Unit Not Calibrated	EEPROM Memory
Real-Time Clock	Battery	Emulation Software	Int. Temperature
Flexlogic Equation	DSP Processor	Bad Xfmr Settings	IRIG-B Signal
Setpt Access Denied	Ambnt temperature		

Note: The recorded event displayed for Logic inputs, Virtual Inputs, and Relay outputs will show the programmed name of the input/output.

6.5.1 DESCRIPTION

▌▌ ACTUAL VALUES ▌▌ A4 PRODUCT INFO

This is the header of Actual Values page A4 PRODUCT INFO. To view these actual values press MESSAGE ▼ or press ACTUAL to cycle back to the A1 header.

This page of actual values contains information specifying the product. This information, which includes hardware and software revision codes and calibration dates, is for GE Power Management service personnel.

6.5.2 TECHNICAL SUPPORT

Display	Description
▌ TECHNICAL SUPPORT ▌ [ENTER] for more	This message indicates the start of the Revision Codes actual value. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
GE Power Management 215 Anderson Avenue	This message displays the manufacturer's address.
Markham, Ontario, Canada, L6E 1B3	This message displays the manufacturer's address.
Tel: (905) 294-6222 Fax: (905) 201-2098	This message displays the manufacturer's telephone and fax number
Internet Address: www.ge.com/indsys/pm	This message displays the manufacturer's Internet address

6.5.3 REVISION CODES

6

Display	Description
▌ REVISION CODES ▌ [ENTER] for more	This message indicates the start of the Revision Codes actual value. To view these actual values press ENTER or press MESSAGE ▼ for the next section.
▌▌ 745 Transformer ▌▌ Management Relay	This message displays the product name.
HARDWARE REVISION: D	This message displays the hardware revision of the relay.
SOFTWARE REVISION: 240	This message displays the software revision of the relay.
BOOTWARE REVISION: 120	This message displays the revision number of the boot software.
VERSION NUMBER: 000	This message displays the version number of the relay, indicating any special modification number.
INSTALLED OPTIONS: W3-P1-G1-LO-ALR	This message displays the order code of the relay and, consequently, the installed options.

Display	Description
SERIAL NUMBER: D33xxxxx	The product serial number is an eight digit alphanumeric value.
MANUFACTURE DATE: Jan 01 2001	This message display the date the relay was manufactured.

6.5.4 CALIBRATION

Display	Description
▌ CALIBRATION ▌ [ENTER] for more	This message indicates the start of the Calibration actual values. To view these actual values press ENTER or press MESSAGE ▼ to go to the end of page A4.
ORIGINAL CALIBRATION DATE: Jan 01 2001	This message displays the date the relay was first calibrated.
LAST CALIBRATION DATE: Jan 01 2001	This message displays the date the relay was most recently calibrated.

6

6.6.1 DESCRIPTION

Target messages are displayed when any protection, monitoring or self-test target is activated. The messages contain information about the type of the active target(s), and are displayed in a queue that is independent of both the setpoint and actual value message structures.

When any target is active, the MESSAGE indicator will light, and the first message in the queue is displayed automatically. The target message queue may be scrolled through by pressing NEXT.

If no key is pressed, the next target message in the queue will be displayed after a delay of four seconds. This process repeats, continuously cycling through the queue of target messages.

As long as there is at least one message in the queue, the MESSAGE indicator will remain lit. Pressing any key other than NEXT will return the display to the setpoint or actual value message that was previously displayed. The NEXT key may be pressed any time the MESSAGE indicator is lit, to redisplay the target message queue.

If NEXT is pressed when no target messages are in the queue, all front-panel LEDs will light and the flash message

```
NO ACTIVE TARGETS
(TESTING LEDS)
```

will appear. A typical active target message looks like this,

```
LATCHED: a
Percent Differentl
```

and consists of three components which are arranged thus:

```
<STATUS>: <PHASE>
<CAUSE>
```

<STATUS> will be one of PICKUP, OPERATE or LATCHED.

- **PICKUP:** Indicates that the fault condition that is required to activate the protection element has been detected by the 745 but has not persisted for a sufficiently long time to cause the relay to activate its protection function.
- **OPERATE**: Indicates that the protection element has been activated.
- **LATCHED**: Indicates that the protection element is (or was) activated. This display will remain even if the conditions that caused the element to activate are removed.
- **<PHASE>** are the phase(s) that are associated with the element (where applicable).

Messages for LATCHED targets remain in the queue until the relay is reset. Messages for PICKUP and OPERATE targets remain in the queue as long as the condition causing the target to be active is present.

In addition, messages for LATCHED targets will automatically be deleted if an entire week passes without any changes to the state of the target messages but the conditions that caused the LATCHED messages to be displayed originally are no longer present.

The bottom line of the display (i.e., <CAUSE>) will be the name of the element that has been activated. Following are the elements available on the 745 (and which may appear in an active target display).

Table 6–2: 745 PROTECTION ELEMENTS

Percent Differentl	Inst Differential	W1 Phase Time OC	W2 Phase Time OC
W3 Phase Time OC	W1 Phase Inst OC 1	W2 Phase Inst OC 1	W3 Phase Inst OC 1
W1 Phase Inst OC 2	W2 Phase Inst OC 2	W3 Phase Inst OC 2	W1 Ntrl Time OC
W2 Ntrl Time OC	W3 Ntrl Time OC	W1 Ntrl Inst OC 1	W2 Ntrl Inst OC 1
W3 Ntrl Inst OC 1	W1 Ntrl Inst OC 2	W2 Ntrl Inst OC 2	W3 Ntrl Inst OC 2
W1 Gnd Time OC	W2 Gnd Time OC	W3 Gnd Time OC	W1 Gnd Inst OC 1
W2 Gnd Inst OC 1	W3 Gnd Inst OC 1	W1 Gnd Inst OC 2	W2 Gnd Inst OC 2
W3 Gnd Inst OC 2	W1 Rest Gnd Fault	W2 Rest Gnd Fault	W3 Rest Gnd Fault
W1 Neg Seq Time OC	W2 Neg Seq Time OC	W3 Neg Seq Time OC	W1 Neg Seq Inst OC
W2 Neg Seq Inst OC	W3 Neg Seq Inst OC	Underfrequency 1	Underfrequency 2
Freq Decay Rate 1	Freq Decay Rate 2	Freq Decay Rate 3	Freq Decay Rate 4
Overfrequency	5th Harmonic Level	Volts-per-hertz 1	Volts-per-hertz 2
W1 THD Level	W2 THD Level	W3 THD Level	W1 Harmonic Derating
W2 Harmonic Derating	W3 Harmonic Derating	Analog Level 1	Analog Level 2
W1 Current Demand	W2 Current Demand	W3 Current Demand	Xformer Overload
Logic Input 1	Logic Input 2	Logic Input 3	Logic Input 4
Logic Input 5	Logic Input 6	Logic Input 7	Logic Input 8
Logic Input 9	Logic Input 10	Logic Input 11	Logic Input 12
Logic Input 13	Logic Input 14	Logic Input 15	Logic Input 16
Virtual Input 1	Virtual Input 2	Virtual Input 3	Virtual Input 4
Virtual Input 5	Virtual Input 6	Virtual Input 7	Virtual Input 8
Virtual Input 9	Virtual Input 10	Virtual Input 11	Virtual Input 12
Virtual Input 13	Virtual Input 14	Virtual Input 15	Virtual Input 16

The recorded event displayed for Logic inputs and Virtual Inputs will show the programmed name of the input/output. An active target display may also be generated as a result of a self-test error. When this occurs, the target message will look like this:

```
▌ SELF-TEST ERROR:
▌ <ERROR>
```

<ERROR> in the display will be one of the following:

Logic Power Out	Analog Output	Emulation Software
Real-Time Clock	Battery	Bad Xfmr Settings
Flexlogic Eqn	DSP Processor	EEPROM Memory
Access Denied	Not Calibrated	Int Temperature
IRIG-B Signal		

For more detail about these errors, refer to Section 6.7: SELF-TEST ERRORS.

As well, there is an additional message that may appear as a target message. It looks like this:

```
▌ SETPOINTS HAVE NOT
▌ BEEN PROGRAMMED!
```

This message will be placed in the target message queue whenever **S1 745 SETUP/INSTALLATION/745 SETPOINTS** is set to Not Programmed. This serves as a warning that the relay has not been programmed for the installation and is therefore not in the in-service state.

6.7.1 DESCRIPTION

The 745 performs self-diagnostics at initialization (after power-up), and continuously thereafter (in a background task). The tests ensure that every testable unit of the hardware is functioning correctly.

CAUTION

ANY SELF-TEST ERROR INDICATES A SERIOUS PROBLEM REQUIRING SERVICE.

6.7.2 MAJOR SELF-TEST ERRORS

Upon detection of a major self-test error, the 745:

- disables all protection functionality
- turns on the front panel SELF-TEST ERROR indicator
- turns off the front panel IN SERVICE indicator
- de-energizes all output relays, including the SELF-TEST relay
- indicates the failure by inserting an appropriate message in the target message queue
- records the failure in the EVENT RECORDER

6.7.3 MINOR SELF-TEST ERRORS

Upon detection of a minor self-test error, the 745:

- turns on the front panel SELF-TEST ERROR indicator
- de-energizes the SELF-TEST relay
- indicates the failure by inserting an appropriate message in the target message queue
- records the failure in the EVENT RECORDER

All conditions listed in Table 6–3: SELF-TEST ERROR INTERPRETATION cause a target message to be generated.

Table 6–3: SELF-TEST ERROR INTERPRETATION

MESSAGE	SEVERITY	CAUSE
EEPROM Memory	major	This error is caused by detection of corrupted location in the 745 data memory which cannot be self-corrected. Errors that can be automatically corrected are not indicated. Any function of the 745 is susceptible to misoperate from this failure.
Flexlogic Eqn	major	This error is caused when an error in FlexLogic is detected. No feature of the 745 that is controlled by FlexLogic will operate when this failure occurs. Programming correct FlexLogic equations will remove this error.
DSP Processor	major	This error is caused when communications with the internal digital signal processor is lost. Most of the monitoring capability of the 745 (including all measurement of current) will be lost when this failure occurs.
Bad Xfmr Settings	major	This error is caused when the 745 determines that the transformer configuration programmed via setpoints does not correspond to a realistic physical system.
Logic Power Out	minor	This error is caused by failure of the +32 V DC power supply used to power dry contacts of logic inputs. Logic inputs using internal power are affected by this failure. This may be caused by an external connection which shorts this power supply to ground.
Analog Output	minor	This error is caused by failure of the +32 V DC power supply used to power analog outputs. Analog output currents are affected by this failure.
Not Calibrated	minor	This error message appears when the 745 determines that it has not been calibrated. Although the relay is fully functional, the accuracy of measured input values (e.g. currents and line voltage) as well as generated outputs (e.g. analog outputs) is not likely to be within those specified for the relay.
Real-Time Clock	minor	This error is caused when the 745 detects that the real-time clock is not running. Under this condition, the 745 will not be able to maintain the current time and date. This would normally occur if backup battery power for the clock is lost and control power is removed from the 745. Even if control power is restored, the clock will not operate until the time and/or date are programmed via **S1 745 SETUP** / **CLOCK**.
Battery	minor	This error is caused by the loss of battery power to the real-time clock. The ability of the 745 to maintain the current date and time without control power is lost.
Emulation Software	minor	This error is caused by development software being loaded in the relay.
Int Temperature	minor	This error is caused by the detection of unacceptably low (less than –40°C) or high (greater than +85°C) temperatures detected inside the unit
IRIG-B Failure	minor	This error is caused when the IRIG-B signal type selected does not match the format code being injected into the IRIG-B terminals.
Access Denied	minor	This error is caused when the passcode is entered incorrectly three times in a row from either the front panel or any of the communication ports. This error may be removed by entering the correct passcode.
Ambnt temperature	minor	This error is caused when ambient temperature is out of range.(–50 to 250ºC inclusive).

6.8.1 DESCRIPTION

Flash messages are warning, error, or general information messages displayed in response to certain key presses. The length of time these messages remain displayed can be programmed in **S1 745 SETUP/PREFERENCES /FLASH MESSAGE TIME**. The factory default flash message time is 4 seconds.

```
ADJUSTED VALUE
HAS BEEN STORED
```

This flash message is displayed in response to pressing ENTER while on a setpoint message with a numerical value. The edited value had to be adjusted to the nearest multiple of the step value before it was stored.

```
COMMAND IS BEING
EXECUTED
```

This flash message is displayed in response to executing a command at a command message. Entering Yes at a command message will display the message **ARE YOU SURE?**. Entering Yes again will perform the requested command, and display this flash message.

```
DEFAULT MESSAGE
HAS BEEN ADDED
```

This flash message is displayed in response to pressing the decimal key, followed by ENTER twice, on any setpoint or actual value message except those in the subgroup **S1 745 SETUP / DEFAULT MESSAGES**.

```
DEFAULT MESSAGE
HAS BEEN REMOVED
```

This flash message is displayed in response to pressing the decimal key, followed by ENTER twice, on one of the selected default messages in the subgroup **S1 745 SETUP / DEFAULT MESSAGES**.

```
ENTERED PASSCODE
IS INVALID
```

This flash message is displayed in response to an incorrectly entered passcode when attempting to enable or disable setpoint access. It is also displayed when an attempt has been made to upgrade to an option without the correct passcode.

```
ENTRY MISMATCH -
CODE NOT STORED
```

This flash message is displayed while changing the programmed passcode from the command message **S1 745 SETUP/PASSCODE/CHANGE PASSCODE**. If the passcode entered at the prompt PLEASE RE-ENTER NEW PASSCODE is different from the one entered at the prompt PLEASE ENTER A NEW PASSCODE, the 745 will not store the entered passcode, and display this flash message.

```
INPUT FUNCTION IS
ALREADY ASSIGNED
```

This flash message is displayed under certain conditions when attempting to assign logic input functions under **S3 LOGIC INPUTS**. Only the Disabled and To FlexLogic functions can be assigned to more than one logic input. If an attempt is made to assign any another function to a logic input when it is already assigned to another logic input, the assignment will not be made and this message will be displayed.

```
INVALID KEY: MUST
BE IN LOCAL MODE
```

This flash message is displayed in response to pressing RESET while the 745 is in REMOTE mode. The 745 must be put into LOCAL mode in order for this key to be operational.

```
NEW PASSCODE HAS
BEEN STORED
```

This flash message is displayed in response to changing the programmed passcode from the setpoint **S1 745 SETUP/PASSCODE/CHANGE PASSCODE**. The directions to change the passcode were followed correctly, and the new passcode was stored as entered.

```
NEW SETPOINT HAS
BEEN STORED
```

This flash message is displayed in response to pressing ENTER while editing on any setpoint message. The edited value was stored as entered.

```
NO ACTIVE TARGETS
(TESTING LEDS)
```

This flash message is displayed in response to the NEXT key, while the MESSAGE indicator is off. There are no active conditions to display in the target message queue.

6

OUT OF RANGE – VALUE NOT STORED	This flash message is displayed in response to pressing ENTER while on a setpoint message with a numerical value. The edited value was either less than the minimum or greater than the maximum acceptable value for this setpoint and, as a result, was not stored.
PLEASE ENTER A NON-ZERO PASSCODE	This flash message is displayed while changing the passcode from the setpoint **S1 745 SETUP/PASSCODE/CHANGE PASSCODE**. An attempt was made to change the passcode to 0 when it was already 0.
PRESS [ENTER] TO ADD AS DEFAULT	This flash message is displayed for 5 seconds in response to pressing the decimal key followed by ENTER while displaying any setpoint or actual value message except the **S1 745 SETUP/DEFAULT MESSAGES/SELECTED DEFAULTS** setpoints. Pressing ENTER again while this message is displayed adds the setpoint or actual value message to the default list.
PRESS [ENTER] TO BEGIN TEXT EDIT	This flash message is displayed in response to pressing VALUE ▲ or VALUE ▼ while on a setpoint message with a text entry value. The ENTER key must first be pressed to begin editing.
PRESS [ENTER] TO REMOVE MESSAGE	This flash message is displayed for 5 seconds in response to pressing the decimal key followed by ENTER while displaying one of the selected default messages in **S1 745 SETUP/DEFAULT MESSAGES/SELECTED DEFAULTS**. Pressing ENTER again while this message is displayed removes the default message from the list.
PRESSED KEY IS INVALID HERE	This flash message is displayed in response to any pressed key that has no meaning in the current context.
RESETTING LATCHED CONDITIONS	This flash message is displayed in response to pressing RESET when the relay is in local mode. All active targets for which the activating condition is no longer present will be cleared.
SETPOINT ACCESS DENIED (PASSCODE)	This flash message is displayed in response to pressing ENTER while on any setpoint message. Setpoint access is restricted because the programmed passcode has not been entered to allow access.
SETPOINT ACCESS DENIED (SWITCH)	This flash message is displayed in response to pressing ENTER while on any setpoint message. Setpoint access is restricted because the setpoint access terminals have not been connected.
SETPOINT ACCESS IS NOW ALLOWED	This flash message is displayed in response to entering the programmed passcode at the **S1 745 SETUP/PASSCODE/ALLOW SETPOINT WRITE ACCESS** setpoint. The command to allow write access to setpoints has been successfully executed and setpoints can be changed and entered.
SETPOINT ACCESS IS NOW RESTRICTED	This flash message is displayed in response to correctly entering the programmed passcode at **S1 745 SETUP/PASSCODE/RESTRICT SETPOINT WRITE ACCESS?**. The command to restrict access to setpoints has been successfully executed and setpoints cannot be changed.
INVALID SERIAL NUMBER	This flash message is displayed when an attempt is made to upgrade installed options and the 745 detects an invalid serial number.
PASSCODE VALID - OPTIONS ADJUSTED	This flash message is displayed when an attempt to upgrade an option was successful.

6

7.1.1 DESCRIPTION

The 745 instruction manual provides complete descriptions of the operation of each feature in the relay in Chapter 5: SETPOINTS in the form of written descriptions. This chapter provides block diagrams for each feature. These diagrams are sequential logic diagrams illustrating how each setpoint, input parameter, and internal logic is used in a feature to obtain an output.

7.1.2 SETPOINTS

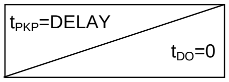
- shown as a block with heading 'SETPOINT'
- the location of setpoints is indicated by the 'Path' heading of the diagram
- the exact wording of the displayed setpoint message identifies the setpoint
- major functional setpoint selections are listed below the name and are incorporated in the logic

7.1.3 MEASUREMENT UNITS

- shown as a block with inset labelled 'RUN'
- the associated pickup or dropout setpoint is shown directly above
- operation of the detector is controlled by logic entering the 'RUN' inset
- relationship between setpoint and input parameter is indicated by simple mathematical symbols: '<' (less than), '>' (greater than), etc.

7.1.4 TIME DELAYS

- shown as a block with the following schematic symbol:



- the delay before pickup is indicated by t_{PKP}, and the delay after dropout is indicated by t_{DO}.
- if the delay before pickup is adjustable, the associated delay setpoint is shown directly above, and the schematic symbol indicates that t_{PKP} = DELAY.

7.1.5 LED INDICATORS

- shown as the following schematic symbol: ⊗
- the exact wording of the front panel label identifies the indicator

7.1.6 LOGIC

- described using basic ‘AND’ gates and 'OR' gates

The remainder of this chapter illustrates the block diagrams for each feature.

7.2.1 DIFFERENTIAL SCHEME LOGIC

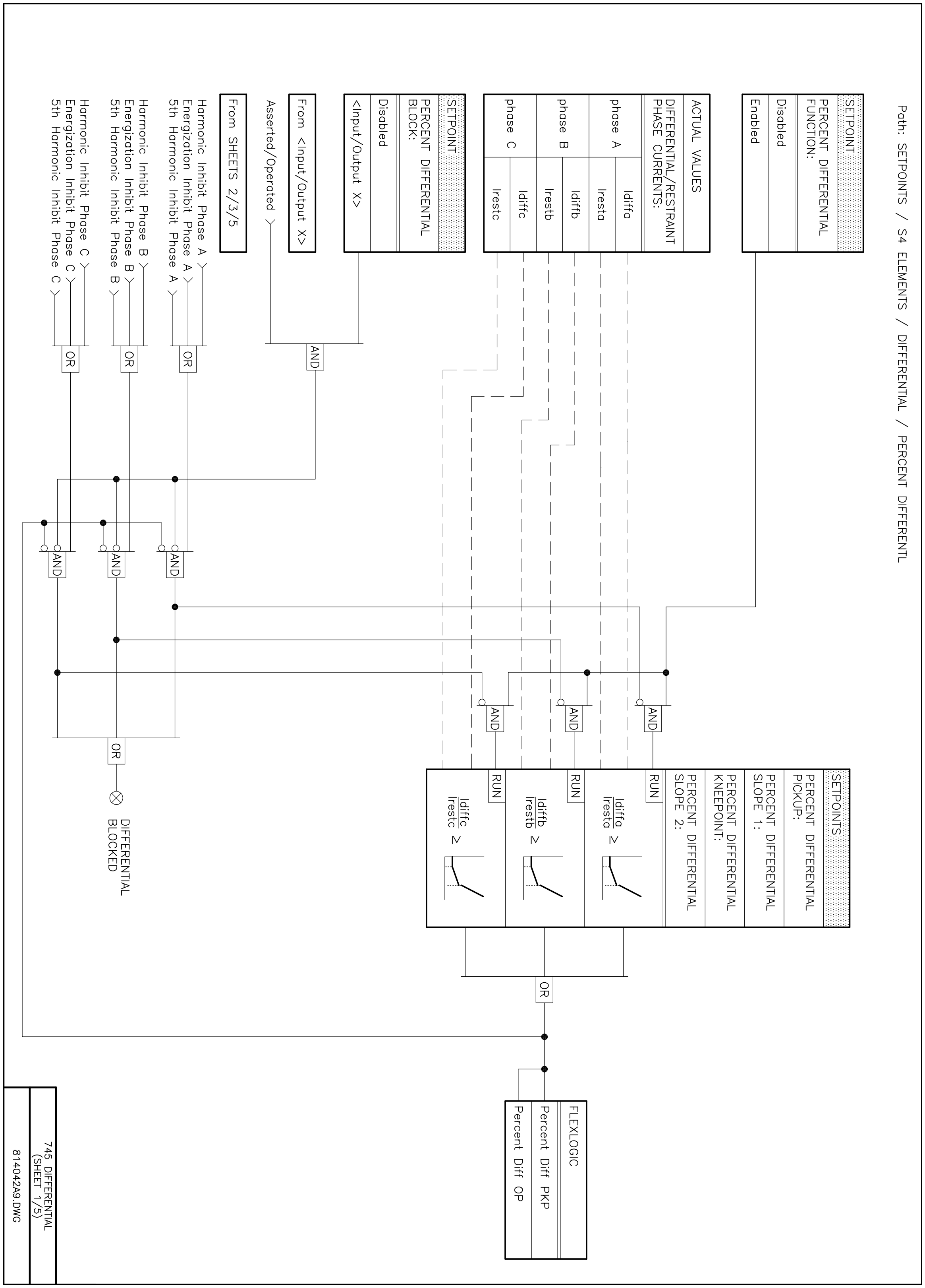


Figure 7–1: DIFFERENTIAL SCHEME LOGIC – PERCENT DIFFERENTIAL

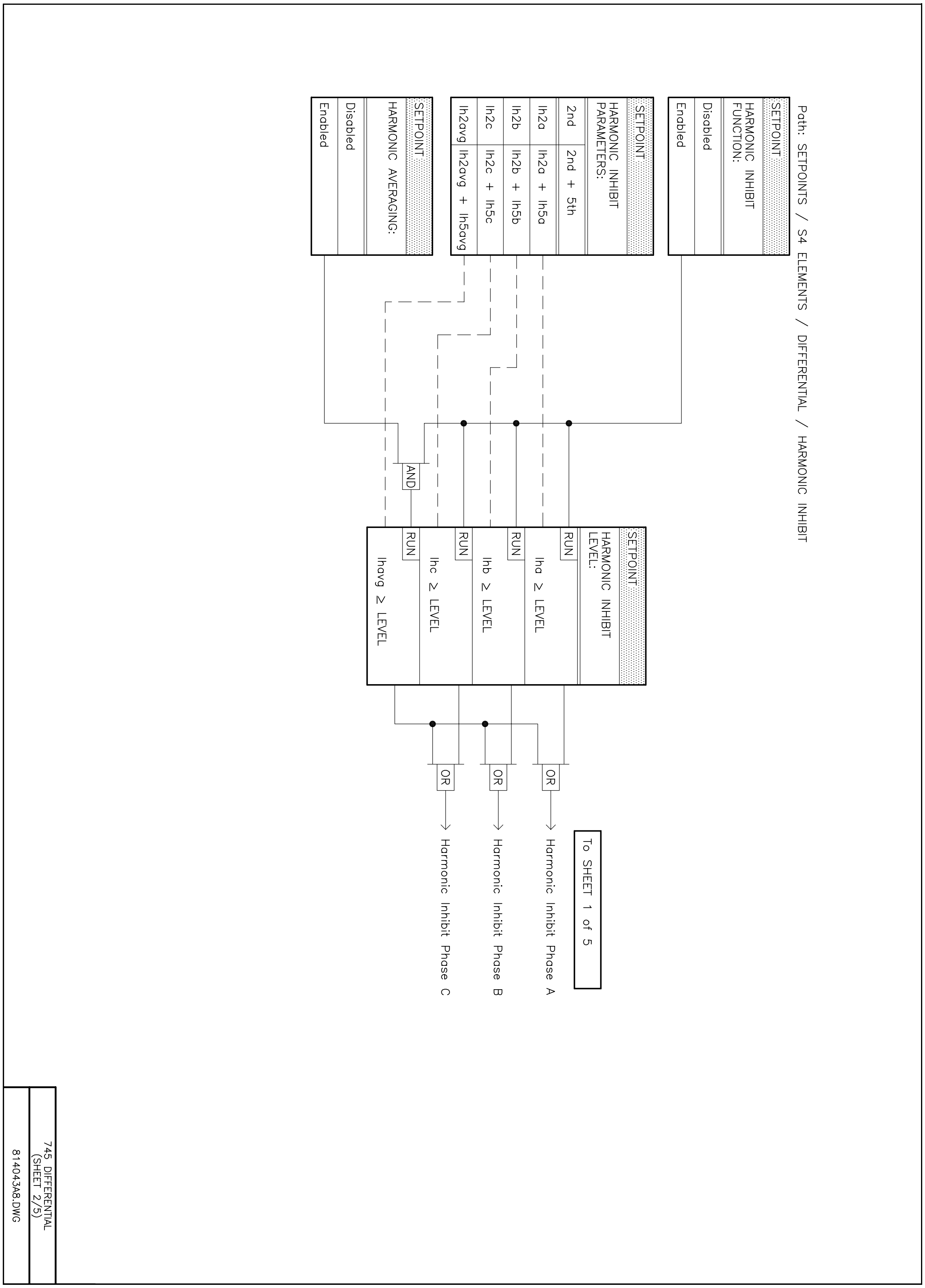


Figure 7–2: DIFFERENTIAL SCHEME LOGIC – 5TH HARMONIC INHIBIT

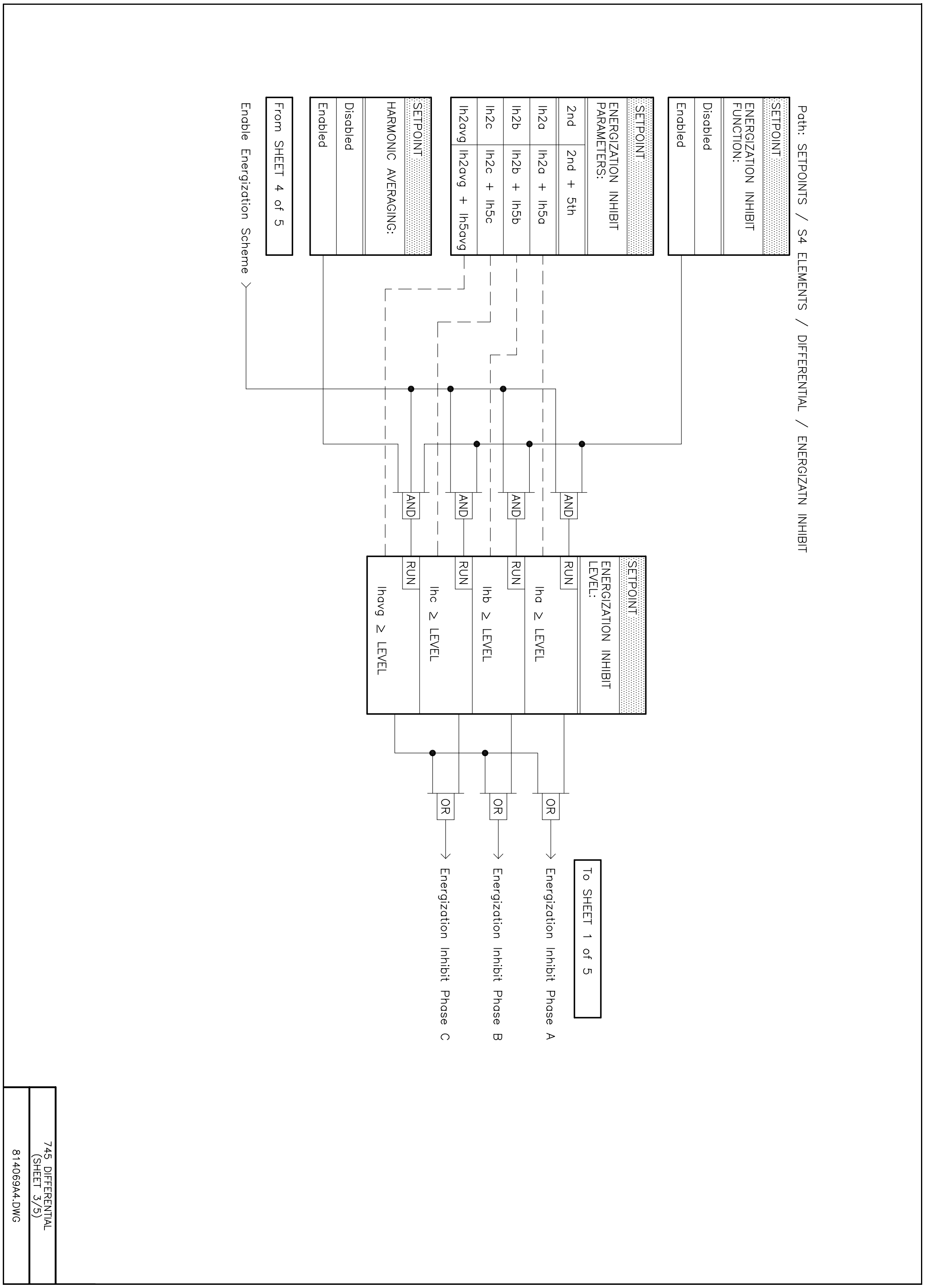


Figure 7–3: DIFFERENTIAL SCHEME LOGIC – ENERGIZATION INHIBIT

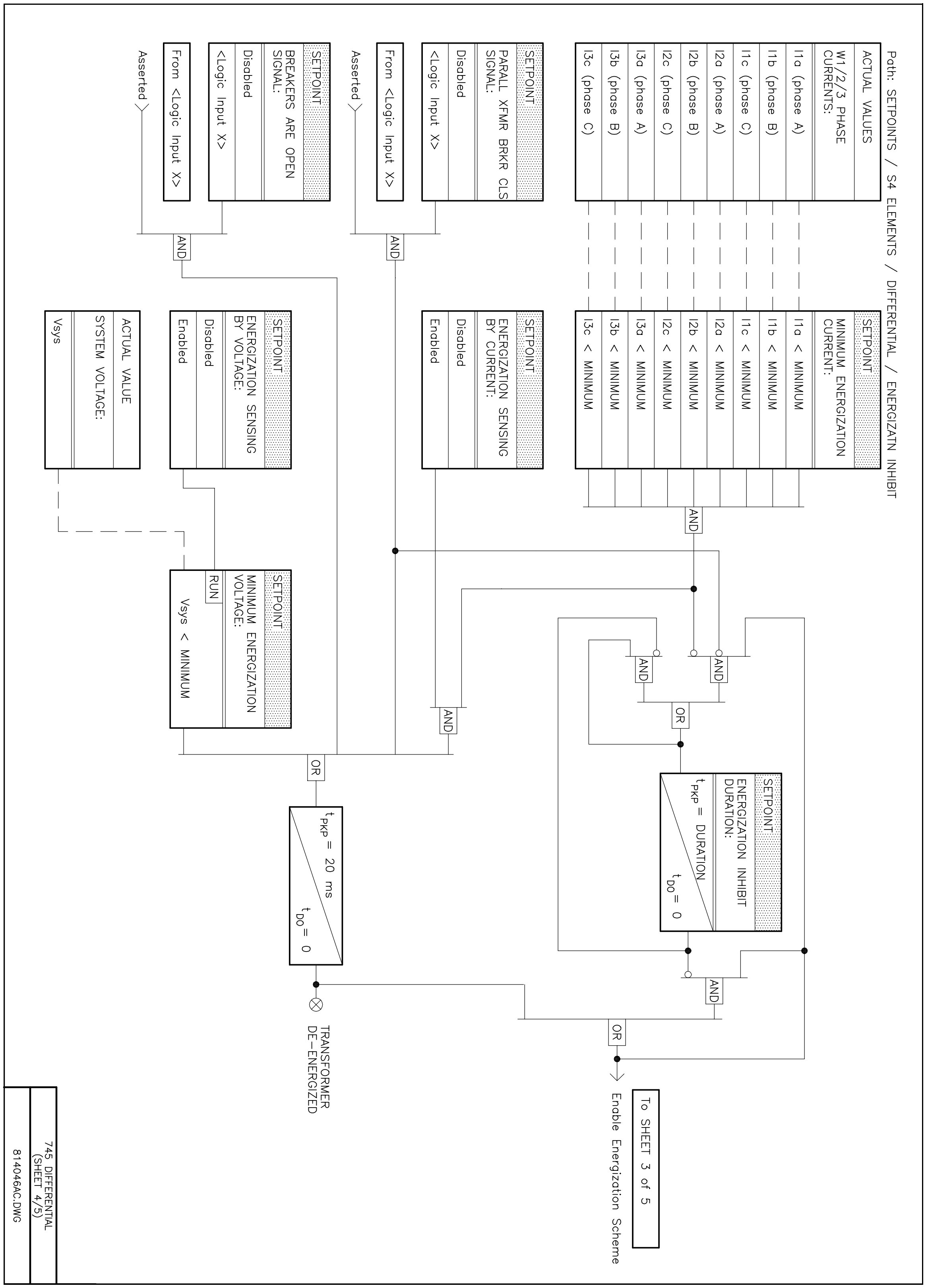


Figure 7–4: DIFFERENTIAL SCHEME LOGIC – ENERGIZATION INHIBIT

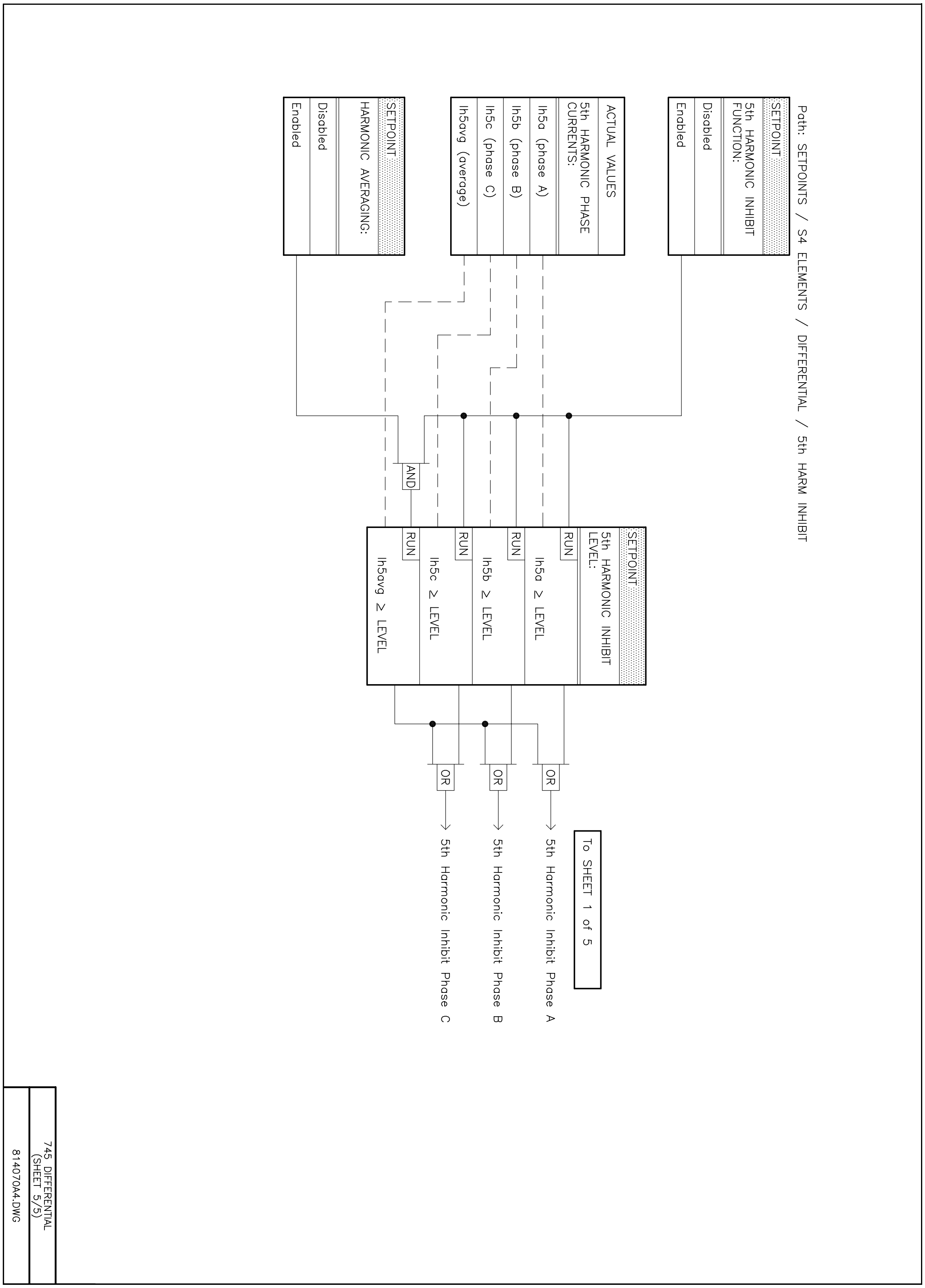


Figure 7–5: DIFFERENTIAL SCHEME LOGIC – 5TH HARMONIC INHIBIT

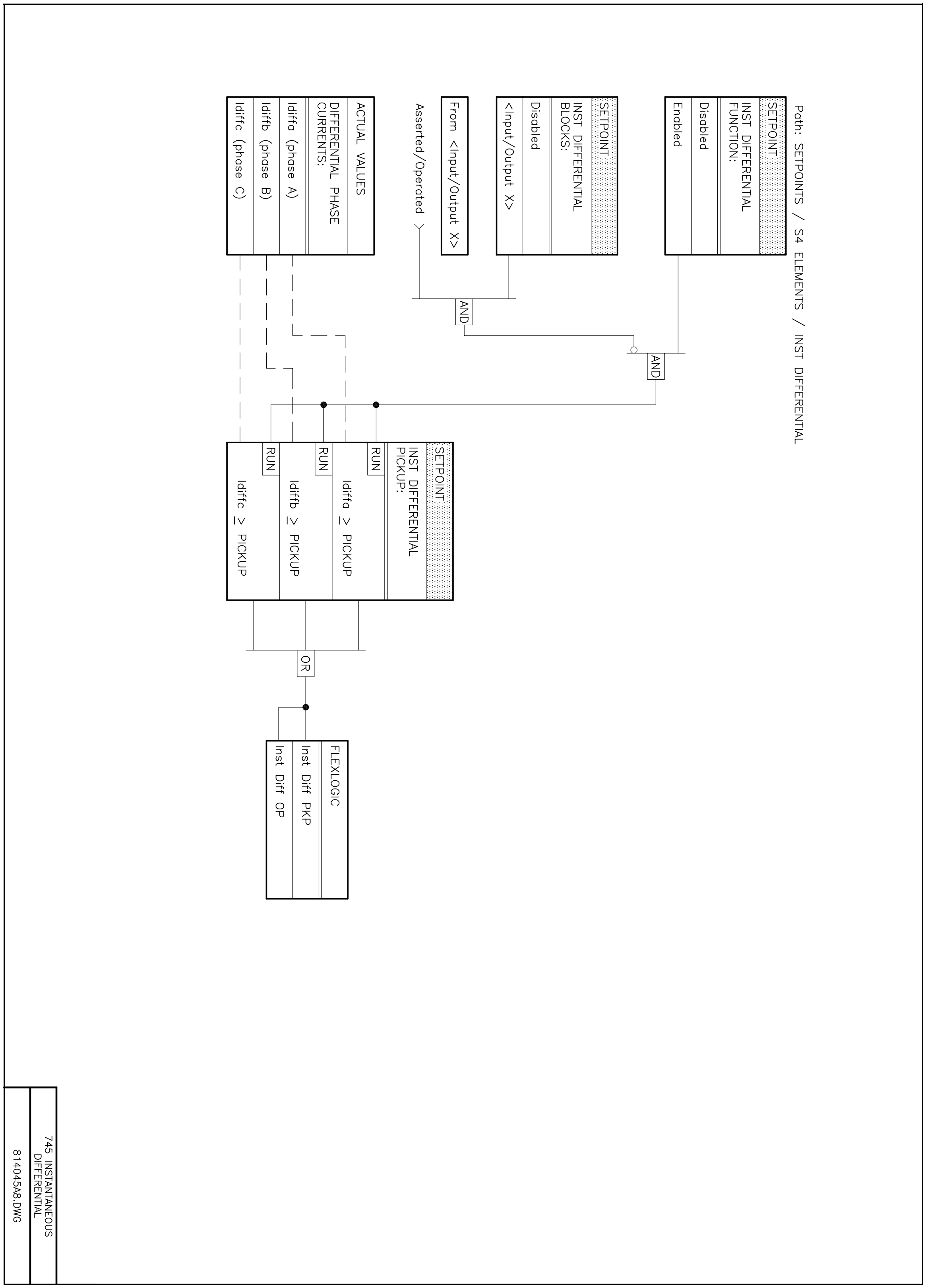


Figure 7–6: INSTANTANEOUS DIFFERENTIAL SCHEME LOGIC

7.2.2 OVERCURRENT SCHEME LOGIC

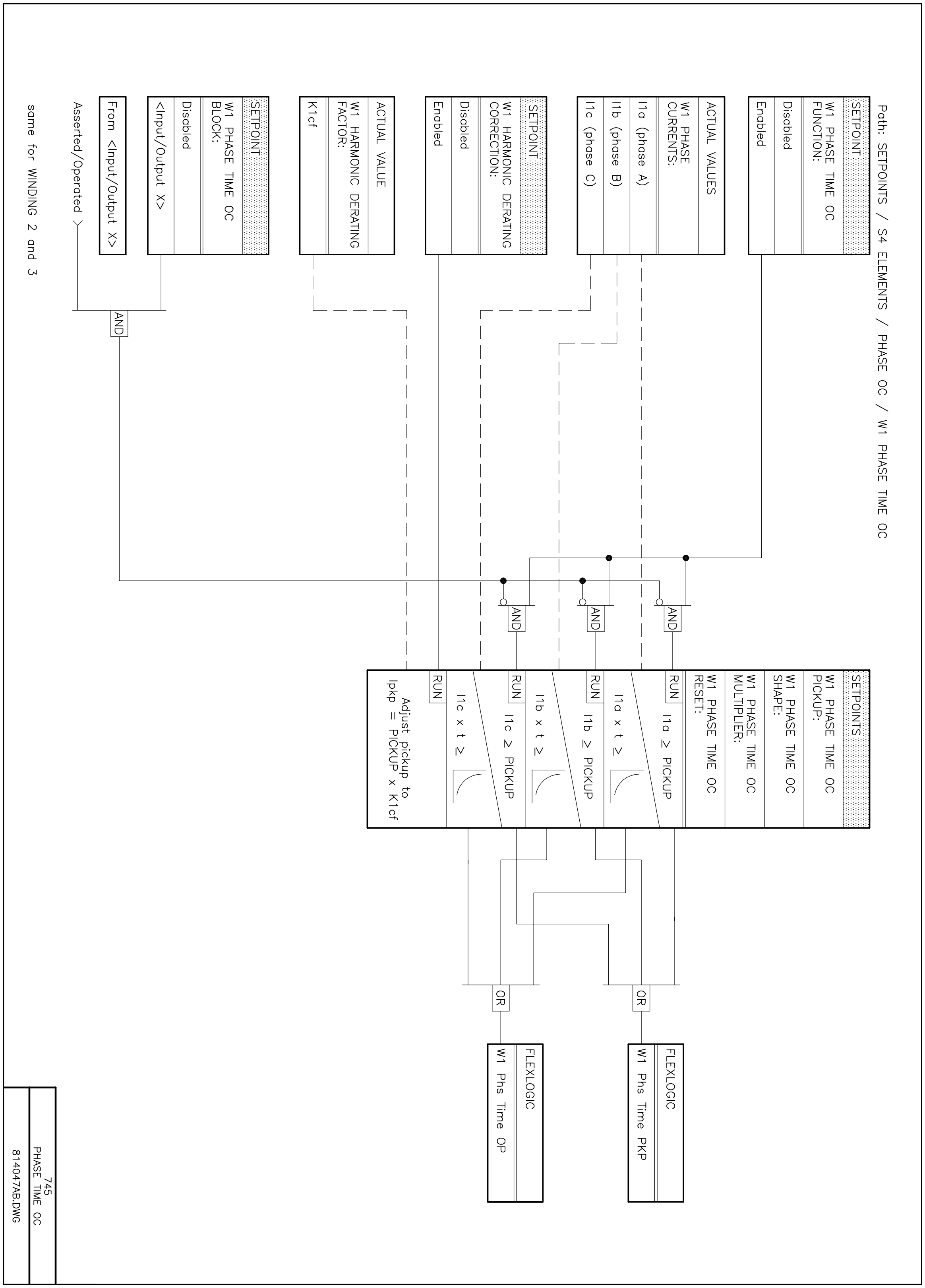


Figure 7–7: PHASE TIME O/C SCHEME LOGIC

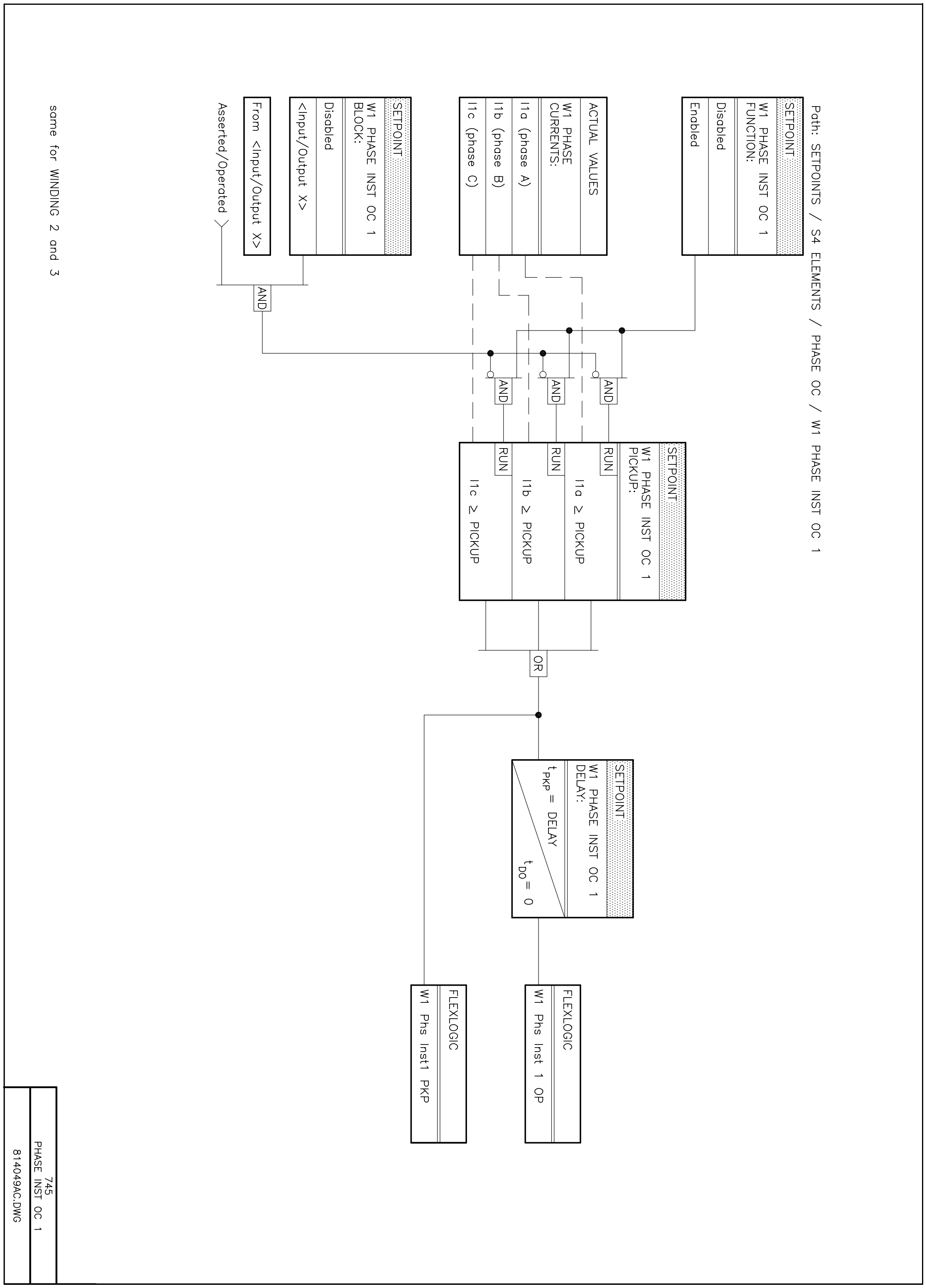


Figure 7–8: PHASE INST O/C 1 SCHEME LOGIC

7

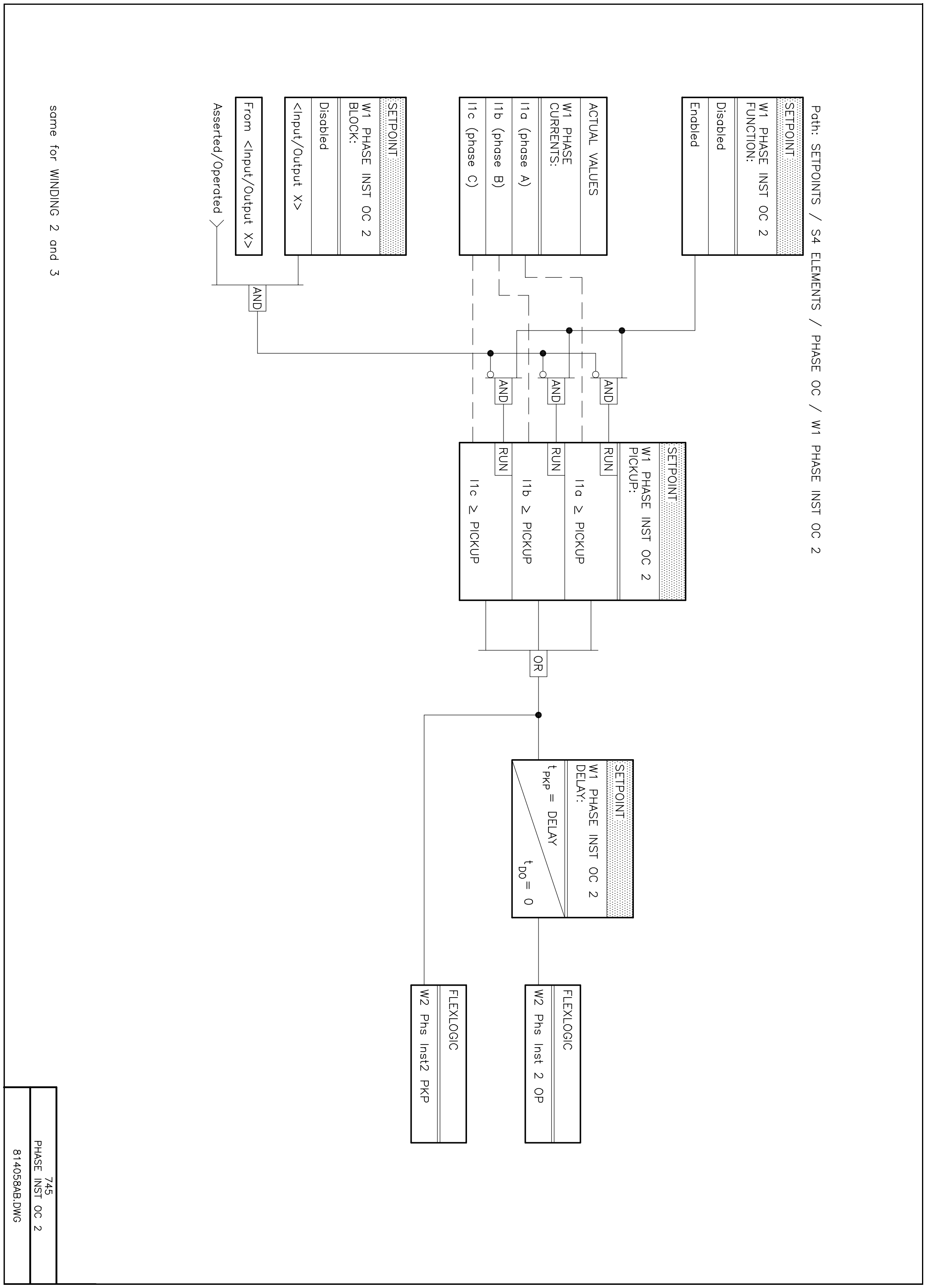


Figure 7–9: PHASE INST O/C 2 SCHEME LOGIC

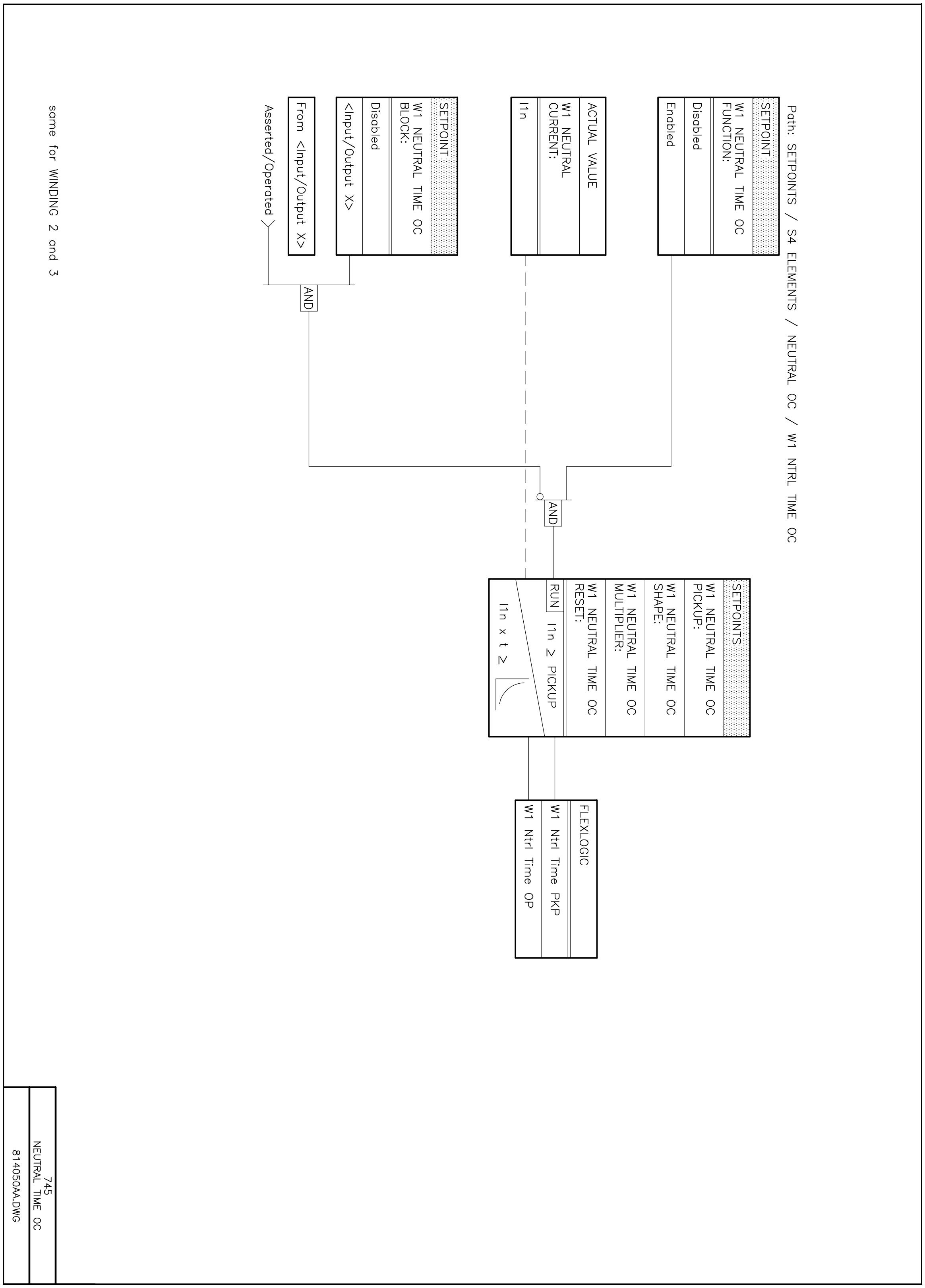


Figure 7–10: NEUTRAL TIME O/C SCHEME LOGIC

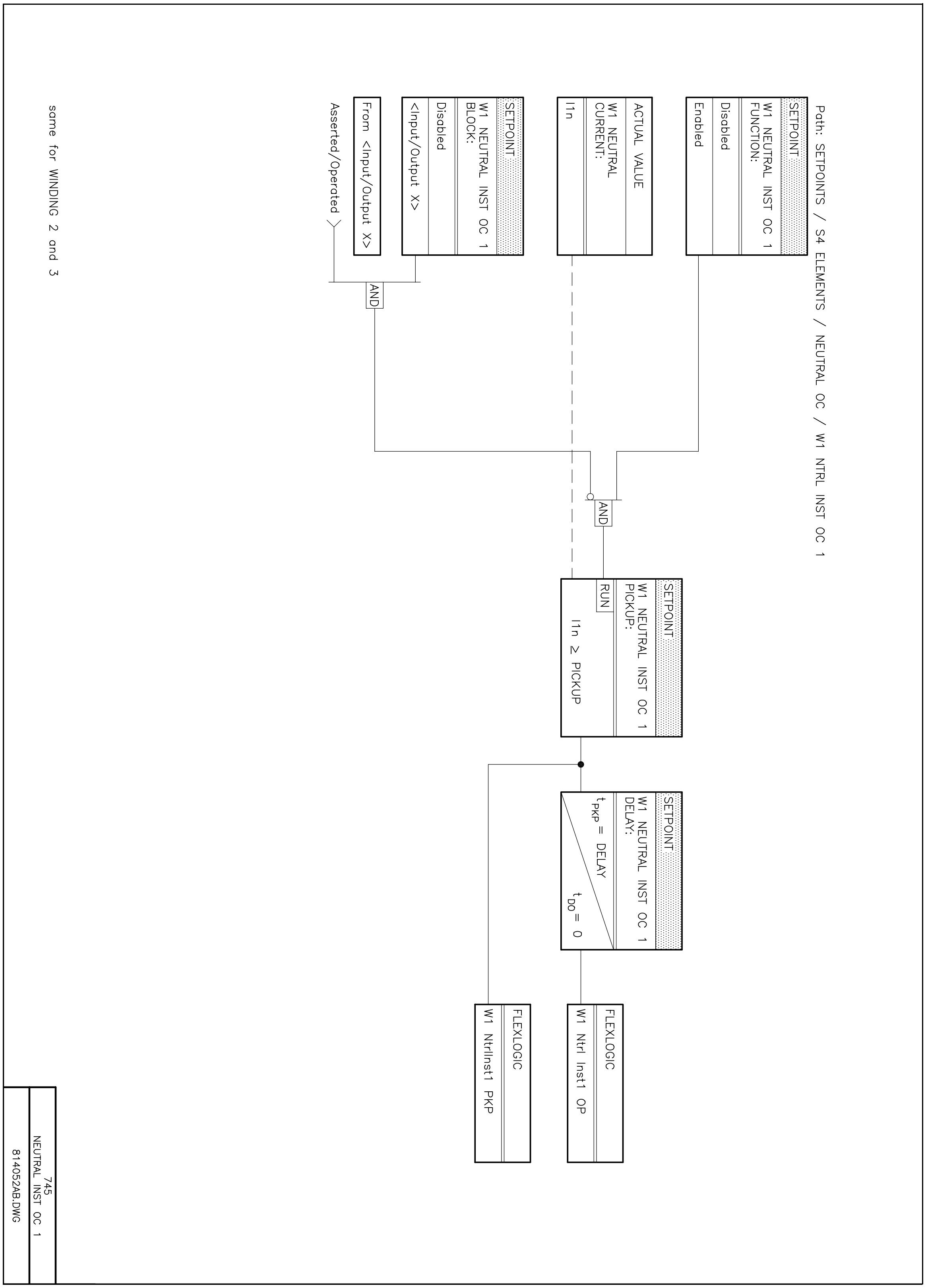


Figure 7–11: NEUTRAL INST O/C 1 SCHEME LOGIC

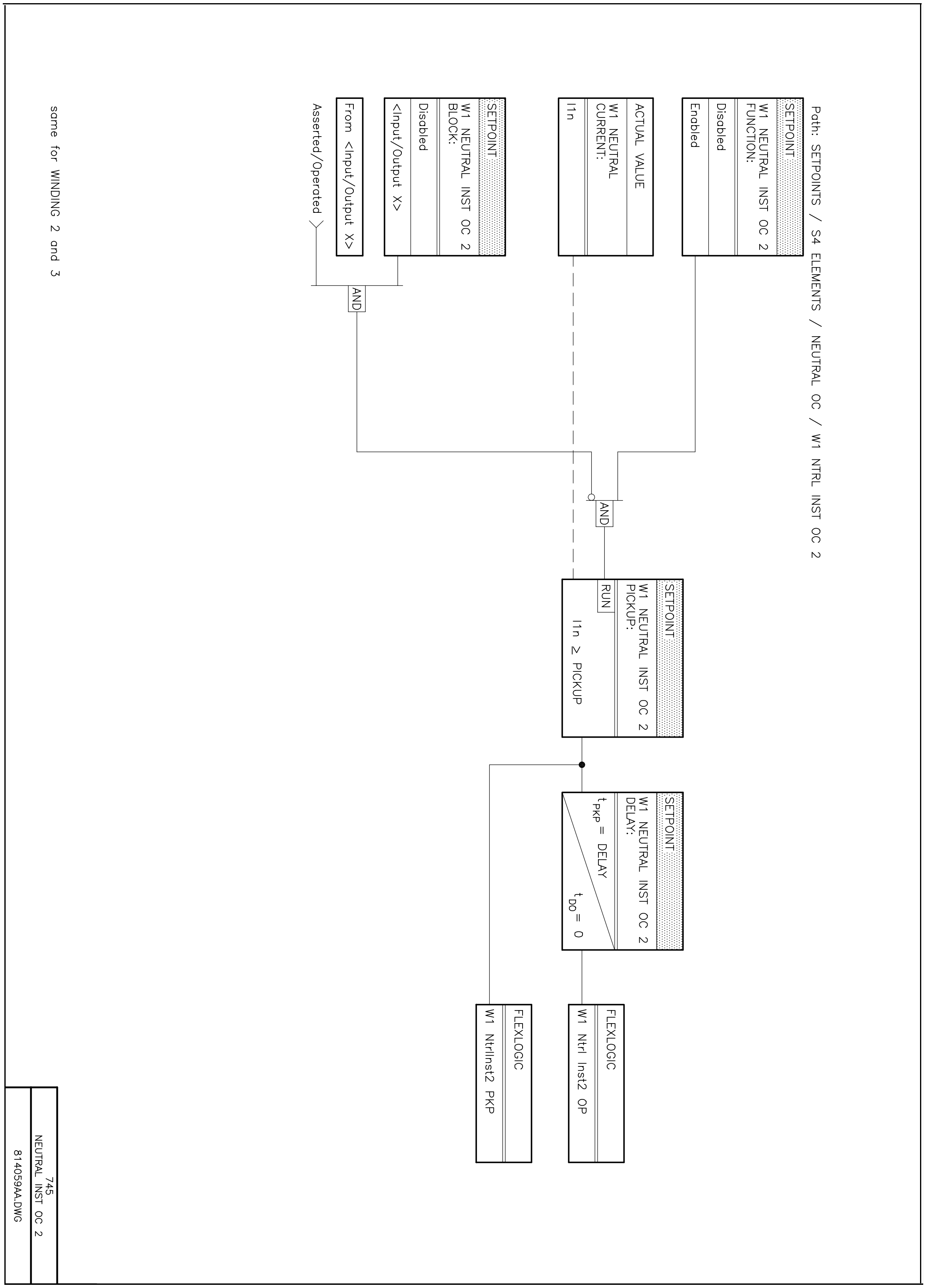


Figure 7–12: NEUTRAL INST O/C 2 SCHEME LOGIC

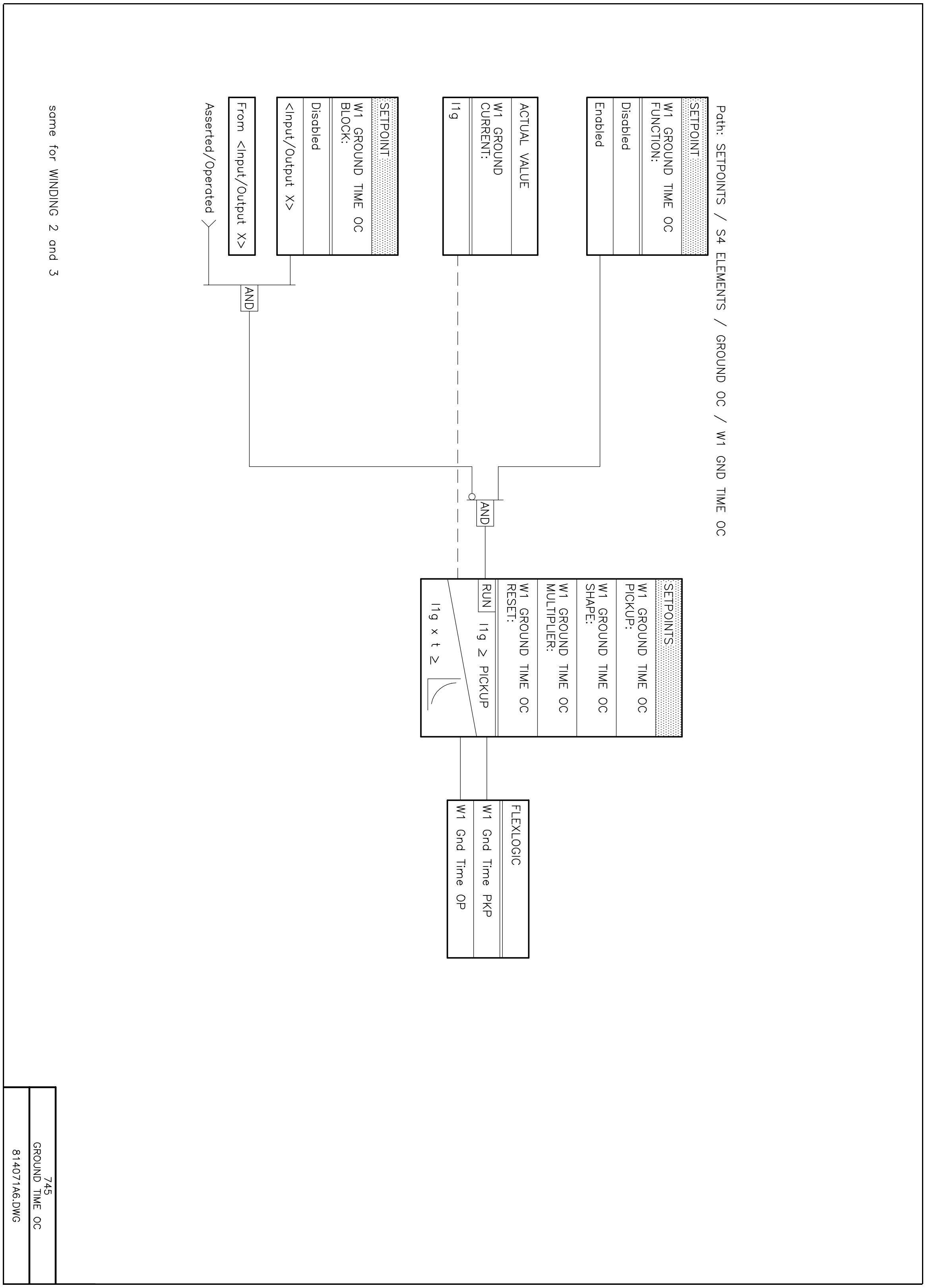


Figure 7–13: GROUND TIME O/C SCHEME LOGIC

7

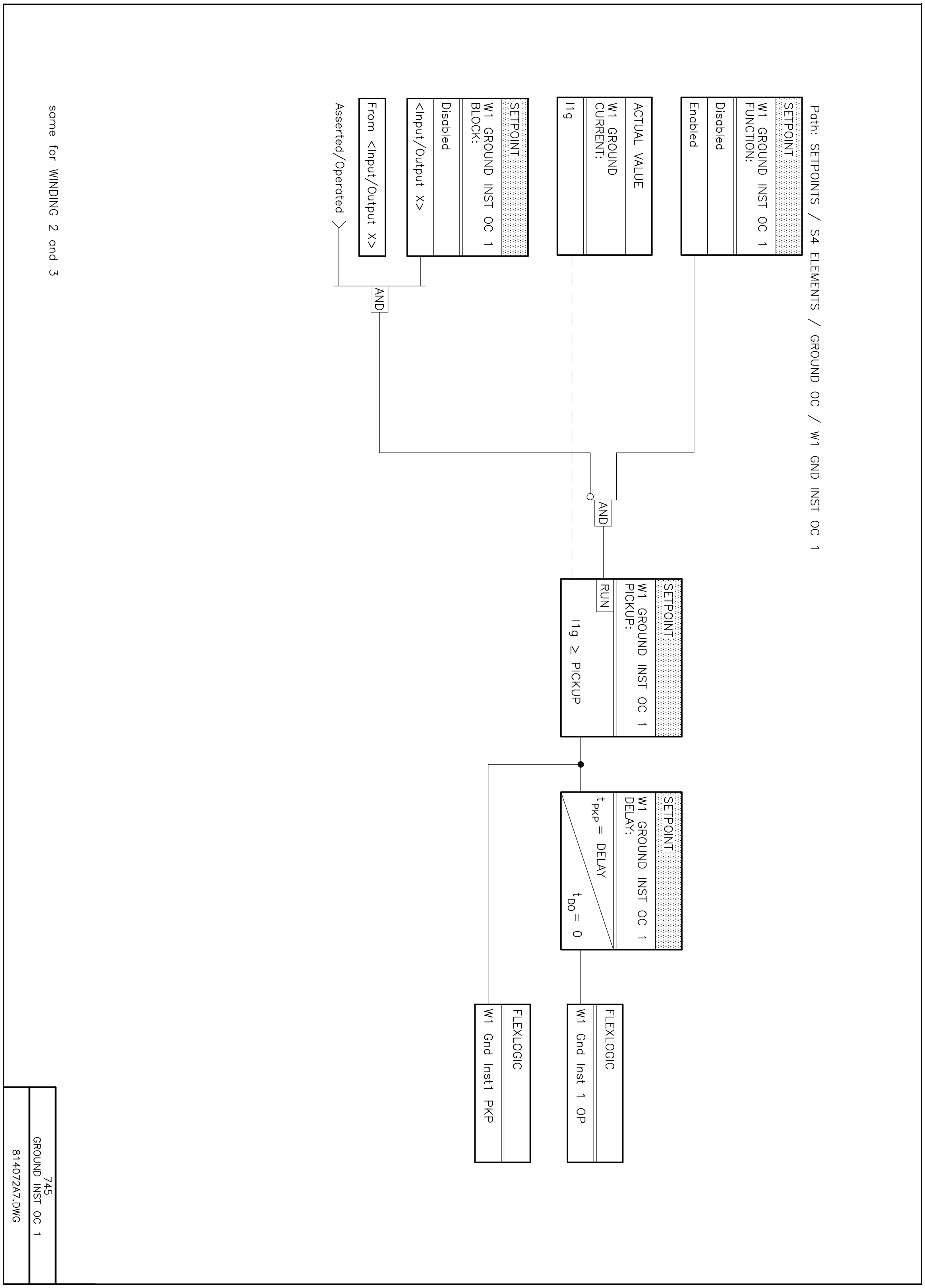


Figure 7–14: GROUND INST O/C 1 SCHEME LOGIC

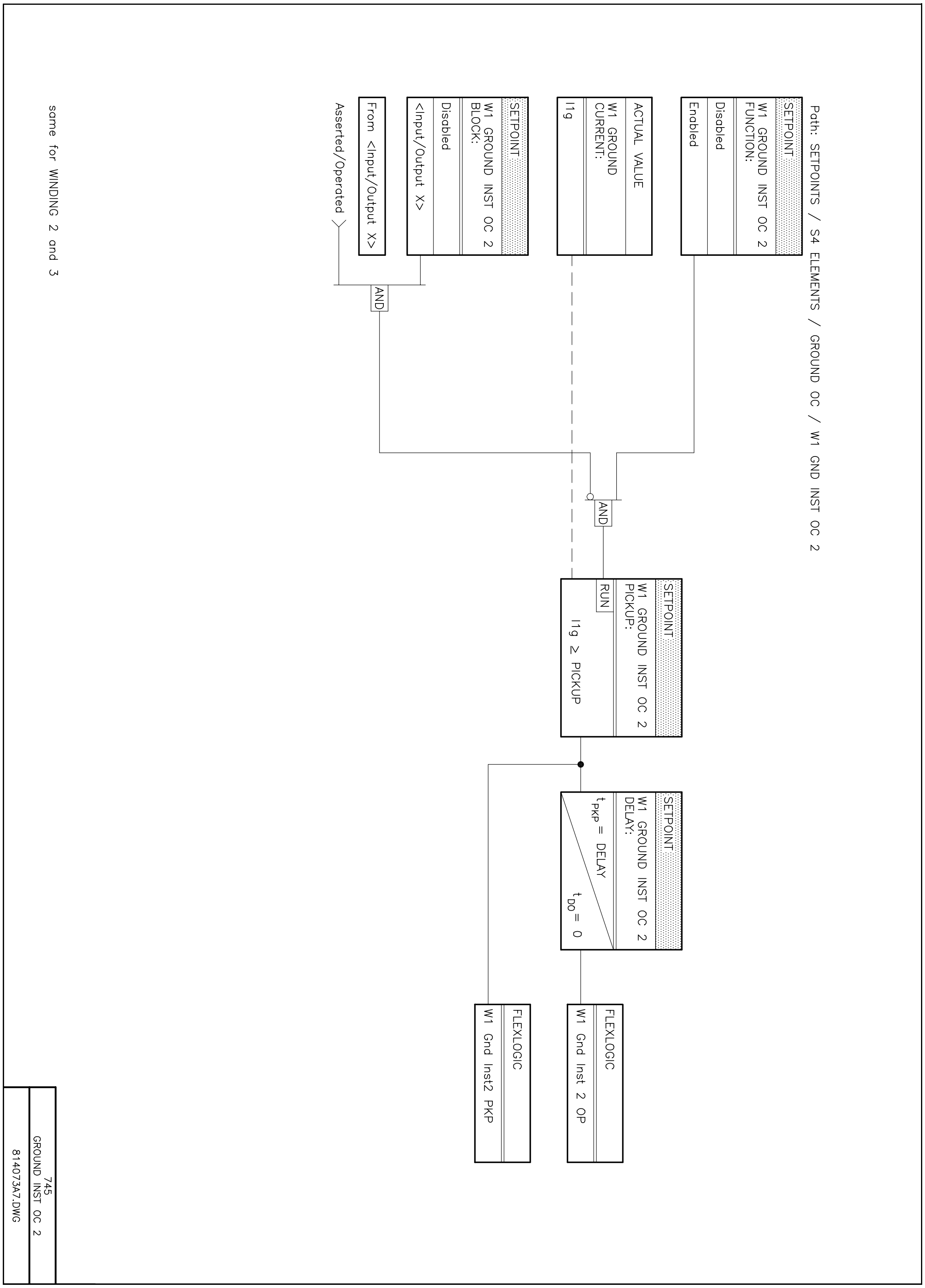


Figure 7–15: GROUND INST O/C 2 SCHEME LOGIC

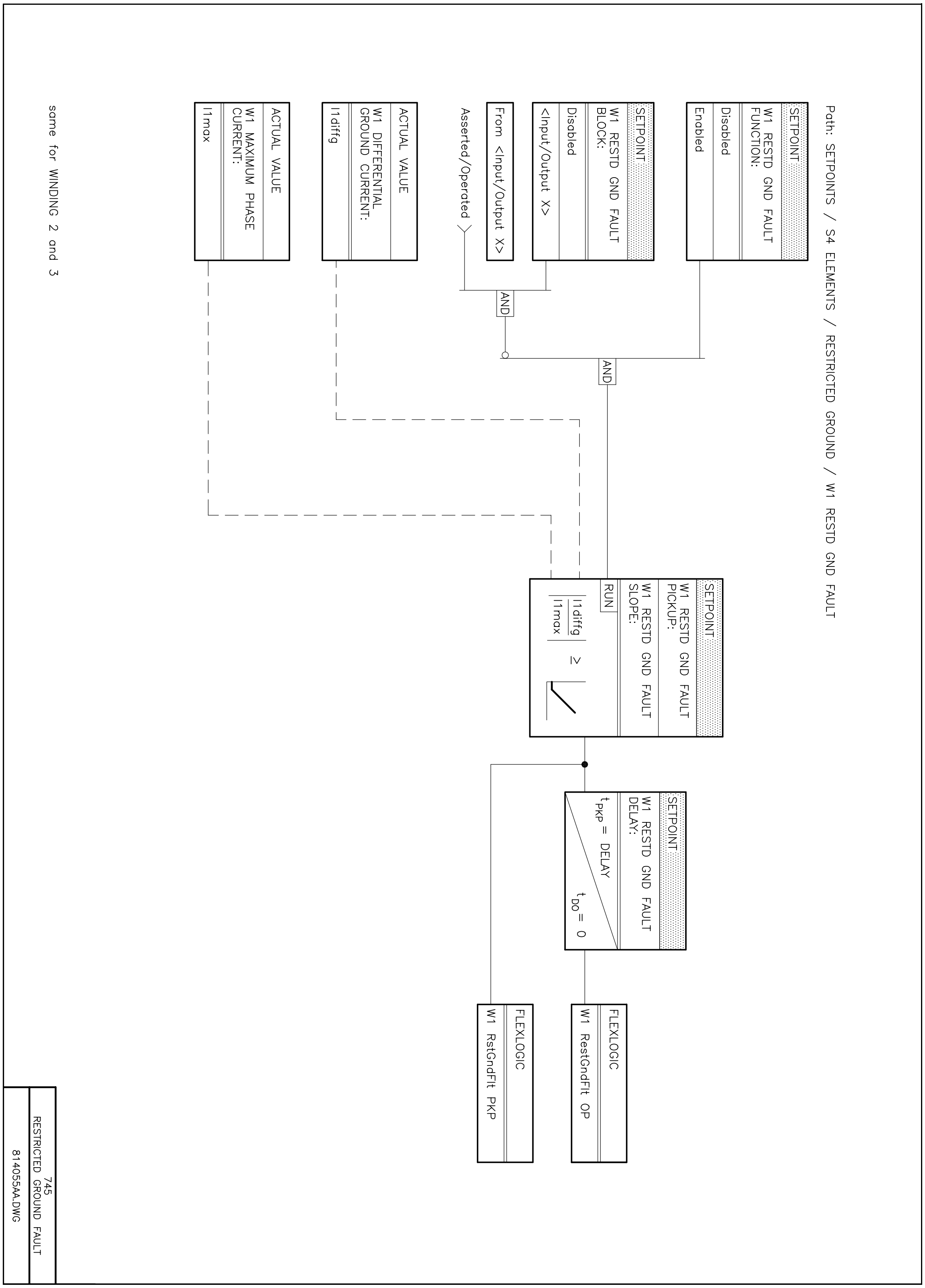


Figure 7–16: RESTRICTED GROUND FAULT SCHEME LOGIC

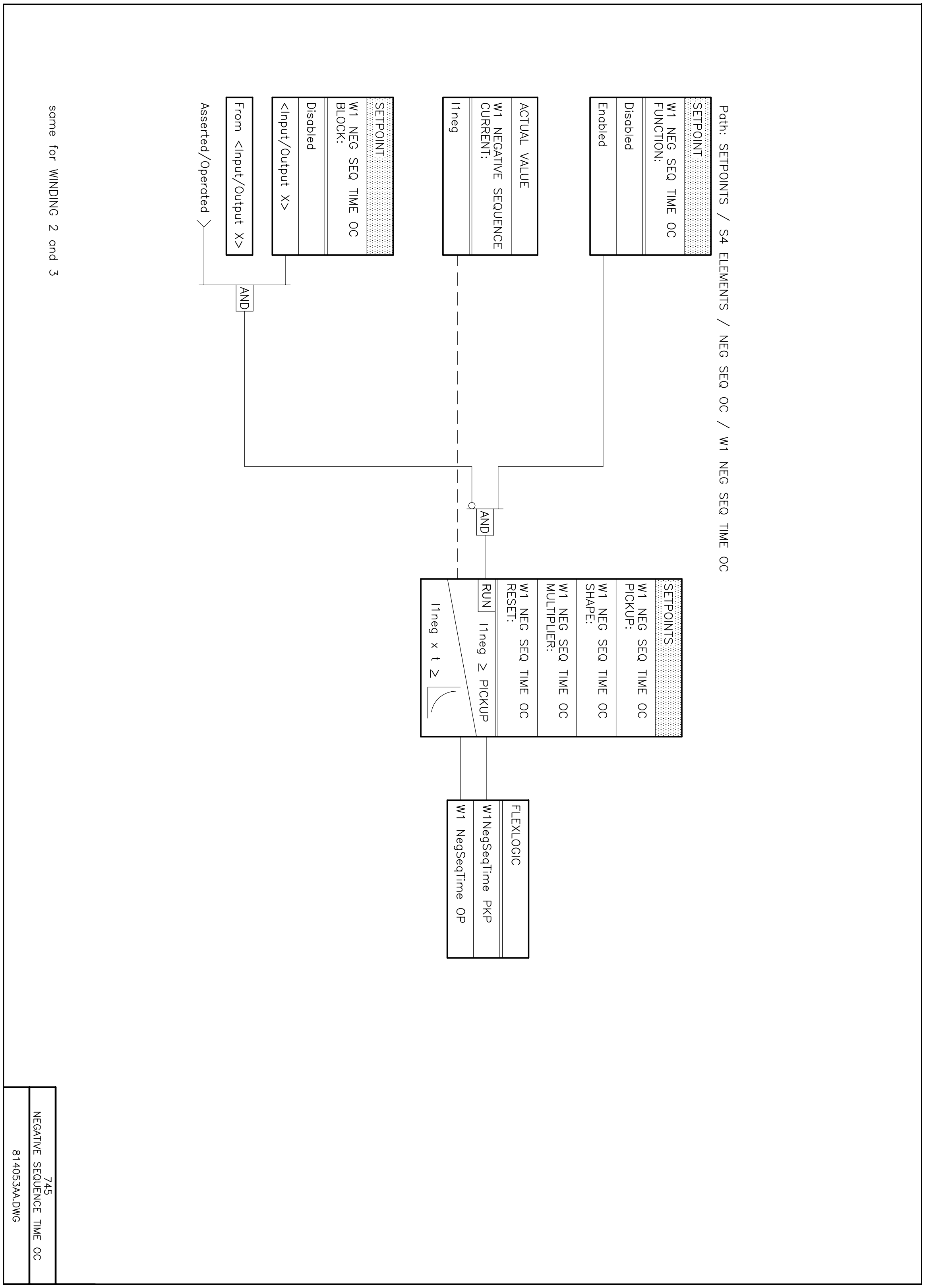


Figure 7–17: NEGATIVE SEQUENCE TIME O/C SCHEME LOGIC

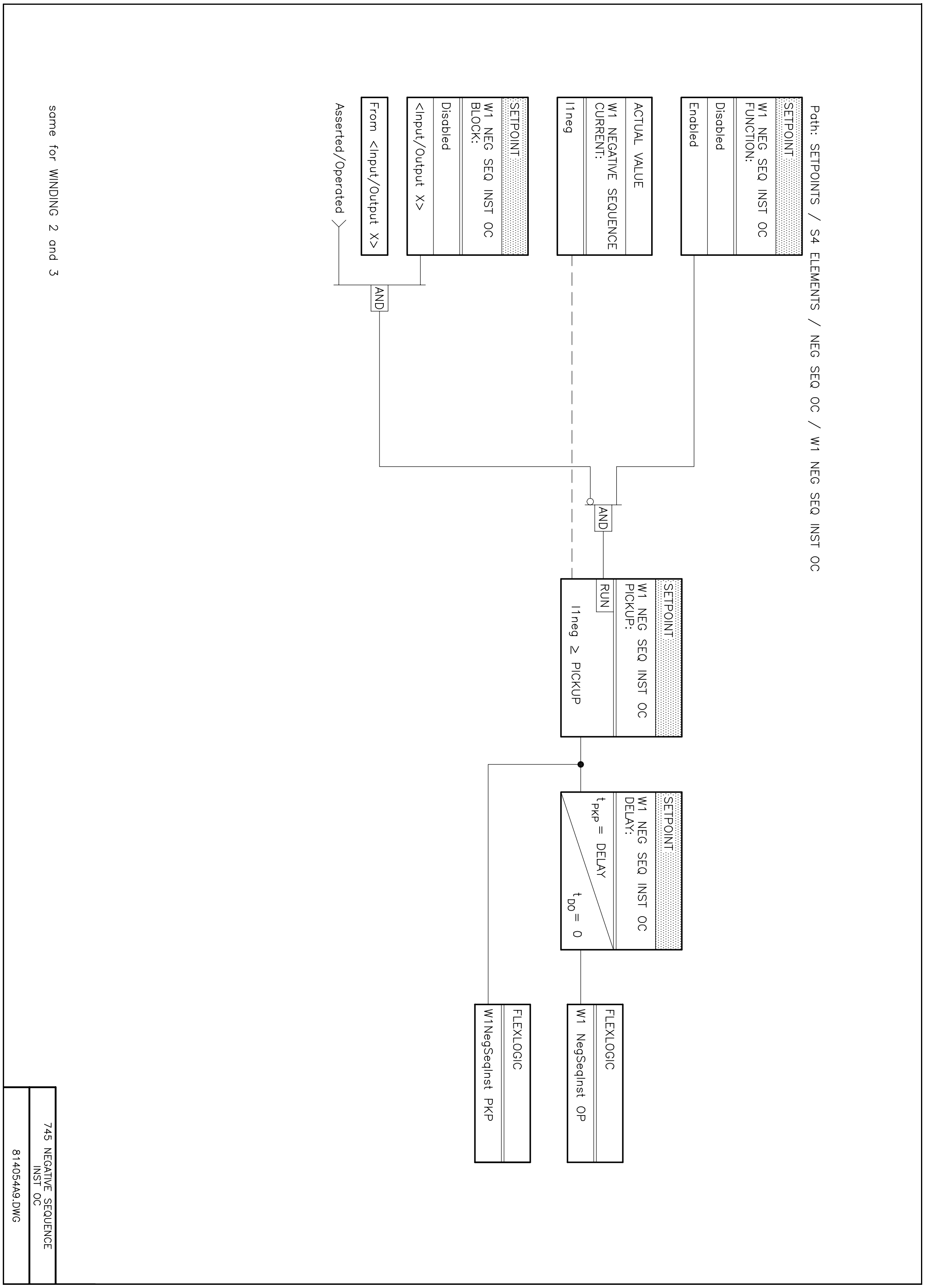


Figure 7–18: NEGATIVE SEQUENCE INST O/C SCHEME LOGIC

7.2.3 FREQUENCY LOGIC

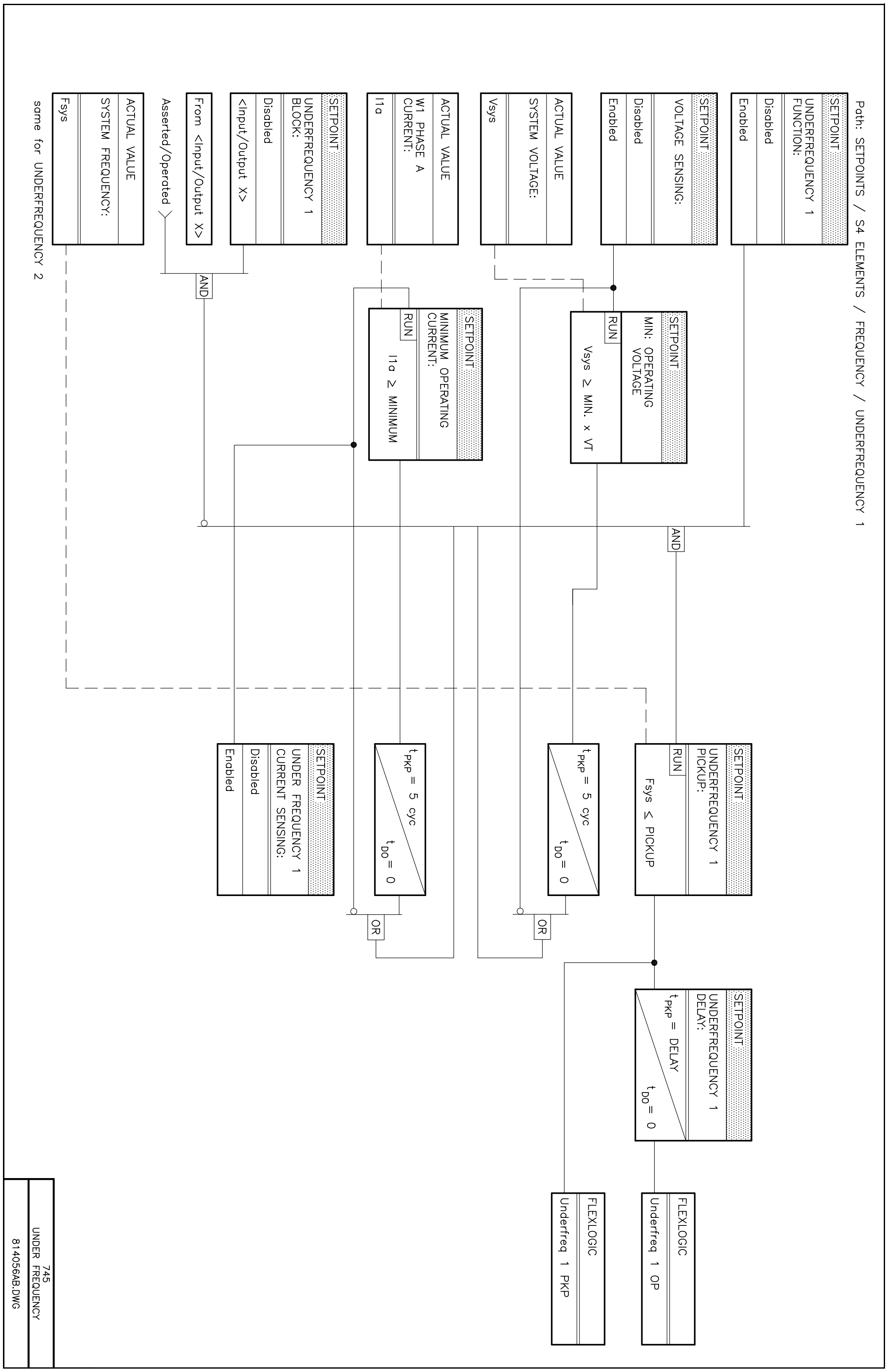


Figure 7–19: UNDERFREQUENCY SCHEME LOGIC

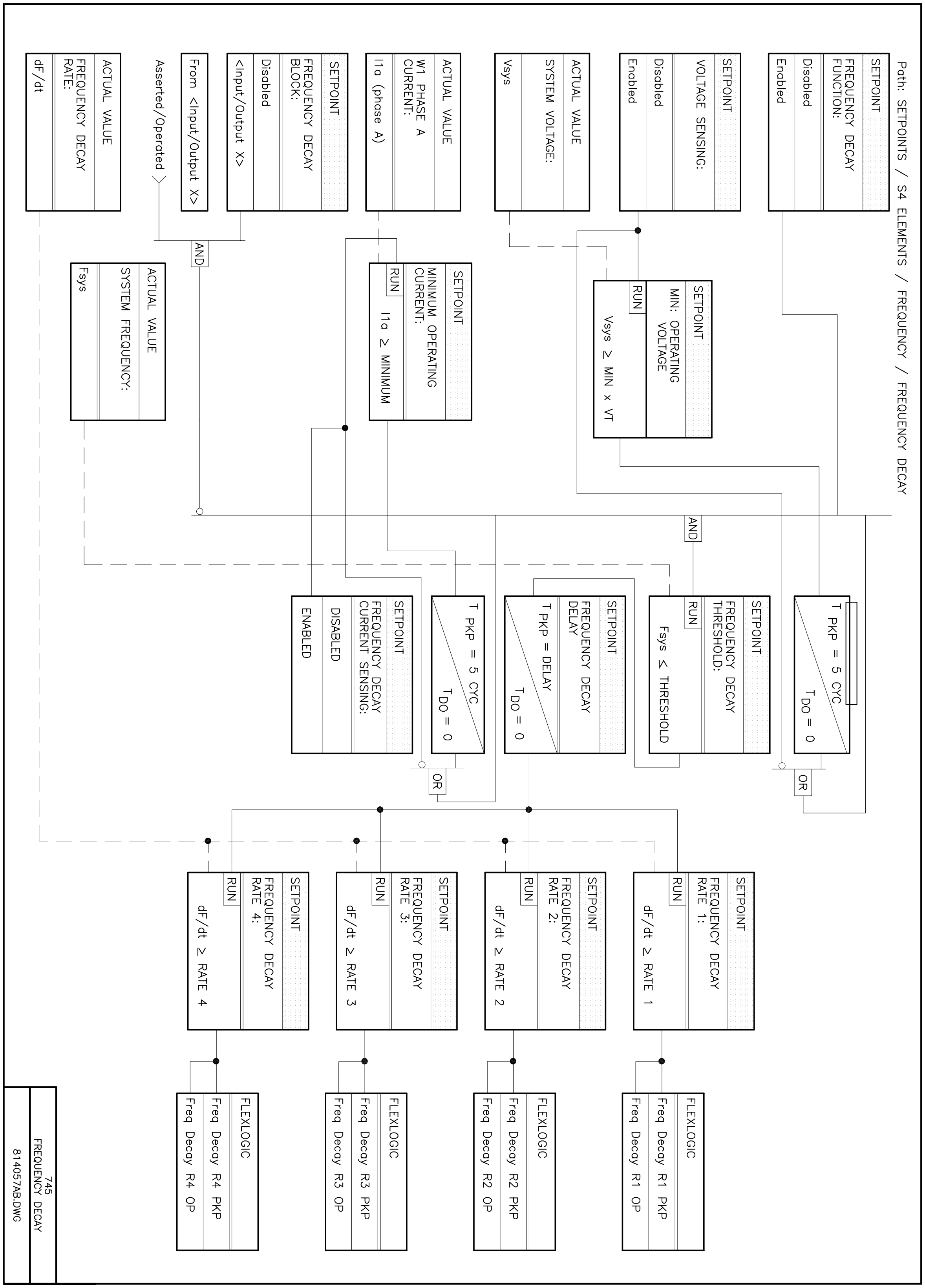


Figure 7–20: FREQUENCY DECAY SCHEME LOGIC

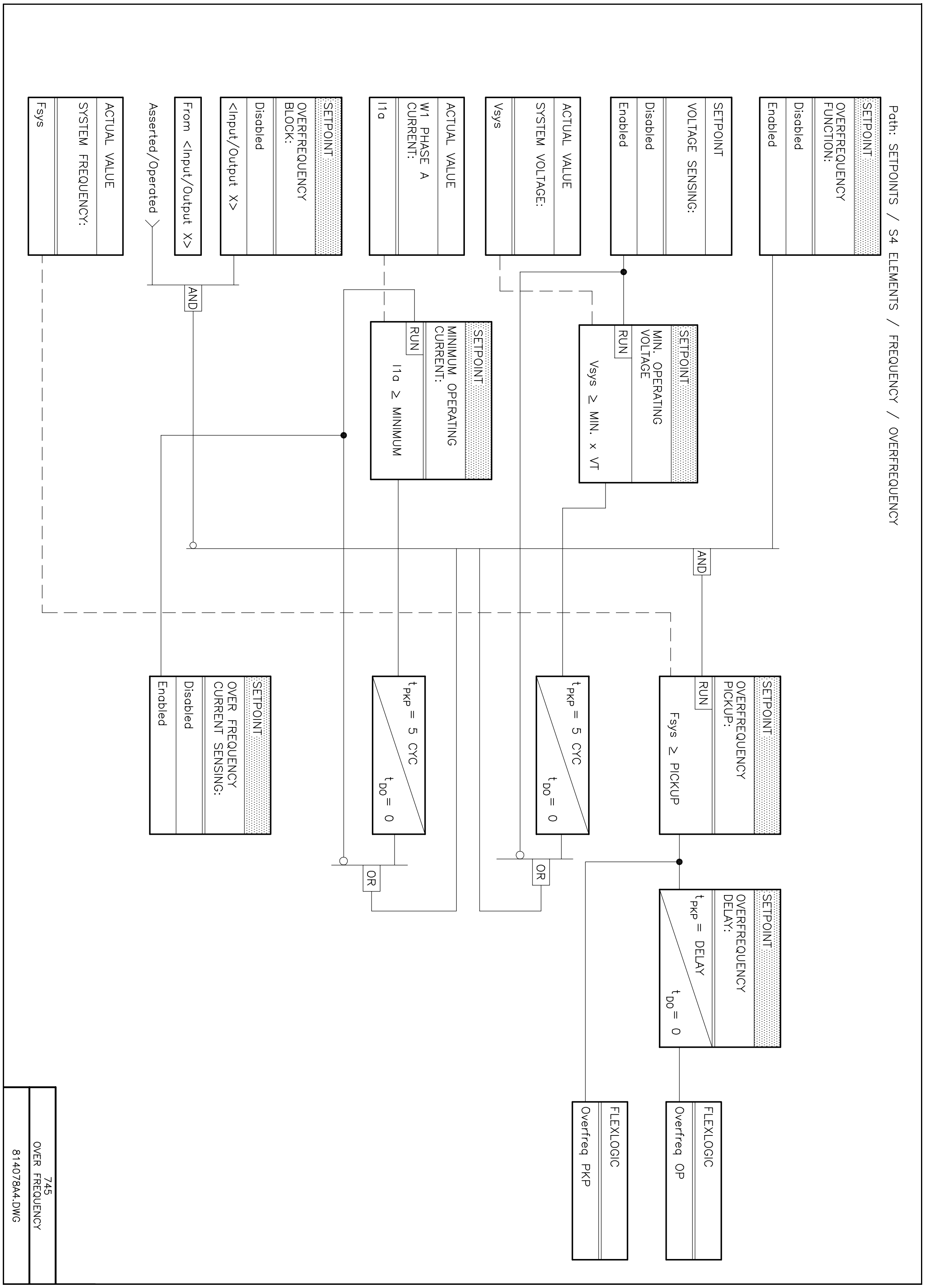


Figure 7–21: OVERFREQUENCY SCHEME LOGIC

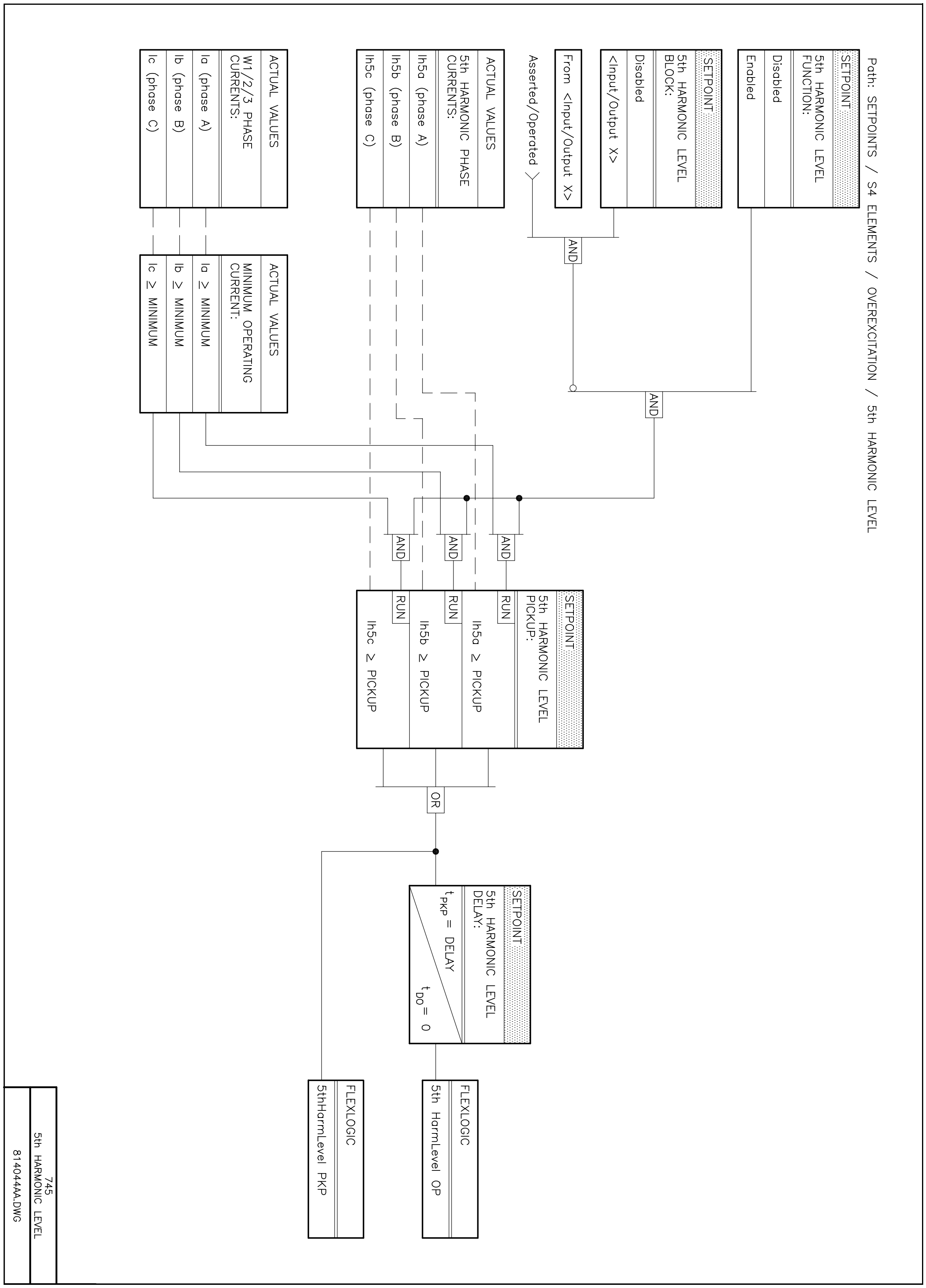


Figure 7–22: 5TH HARMONIC LEVEL SCHEME LOGIC

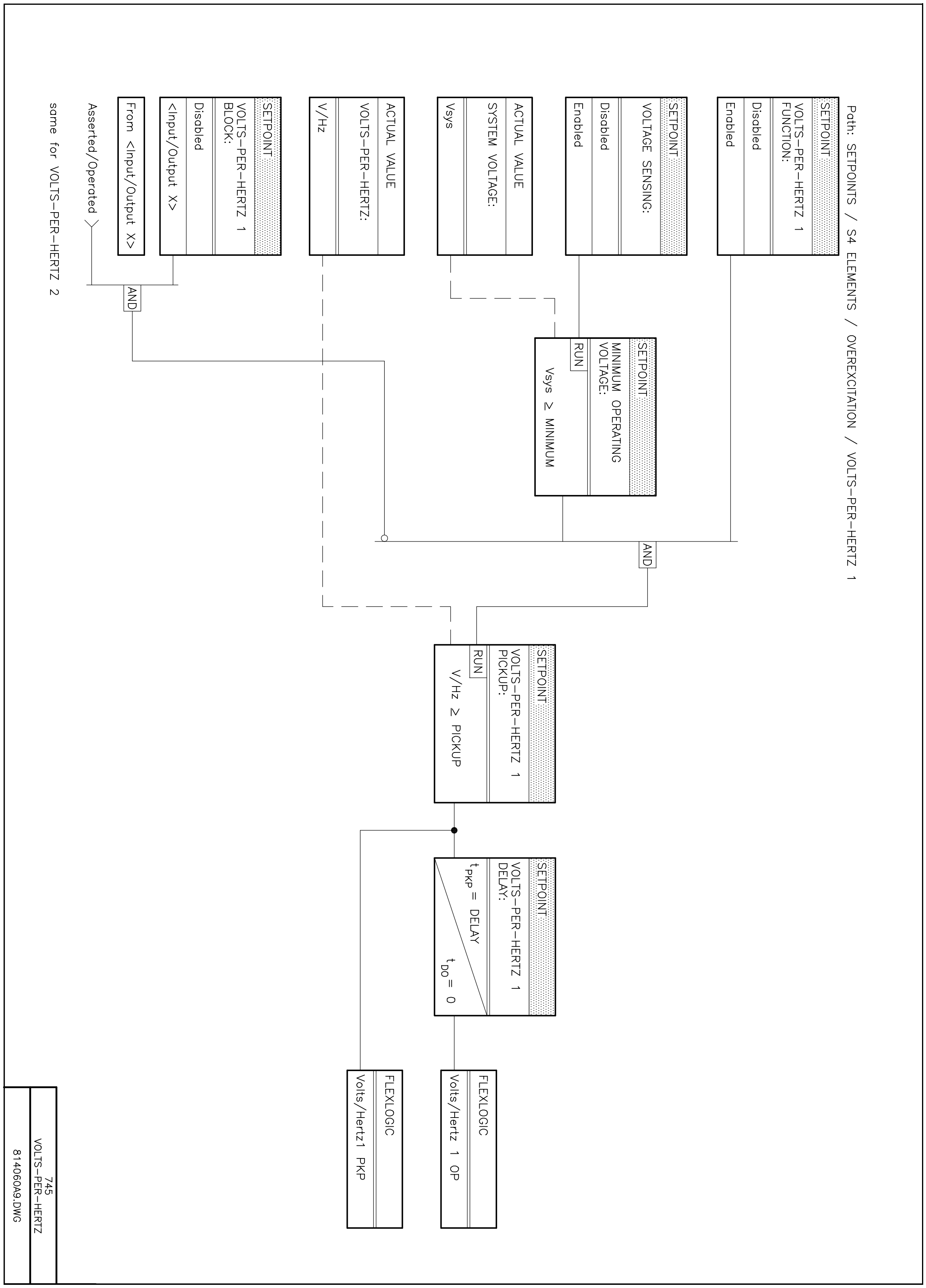


Figure 7–23: VOLTS-PER-HERTZ SCHEME LOGIC

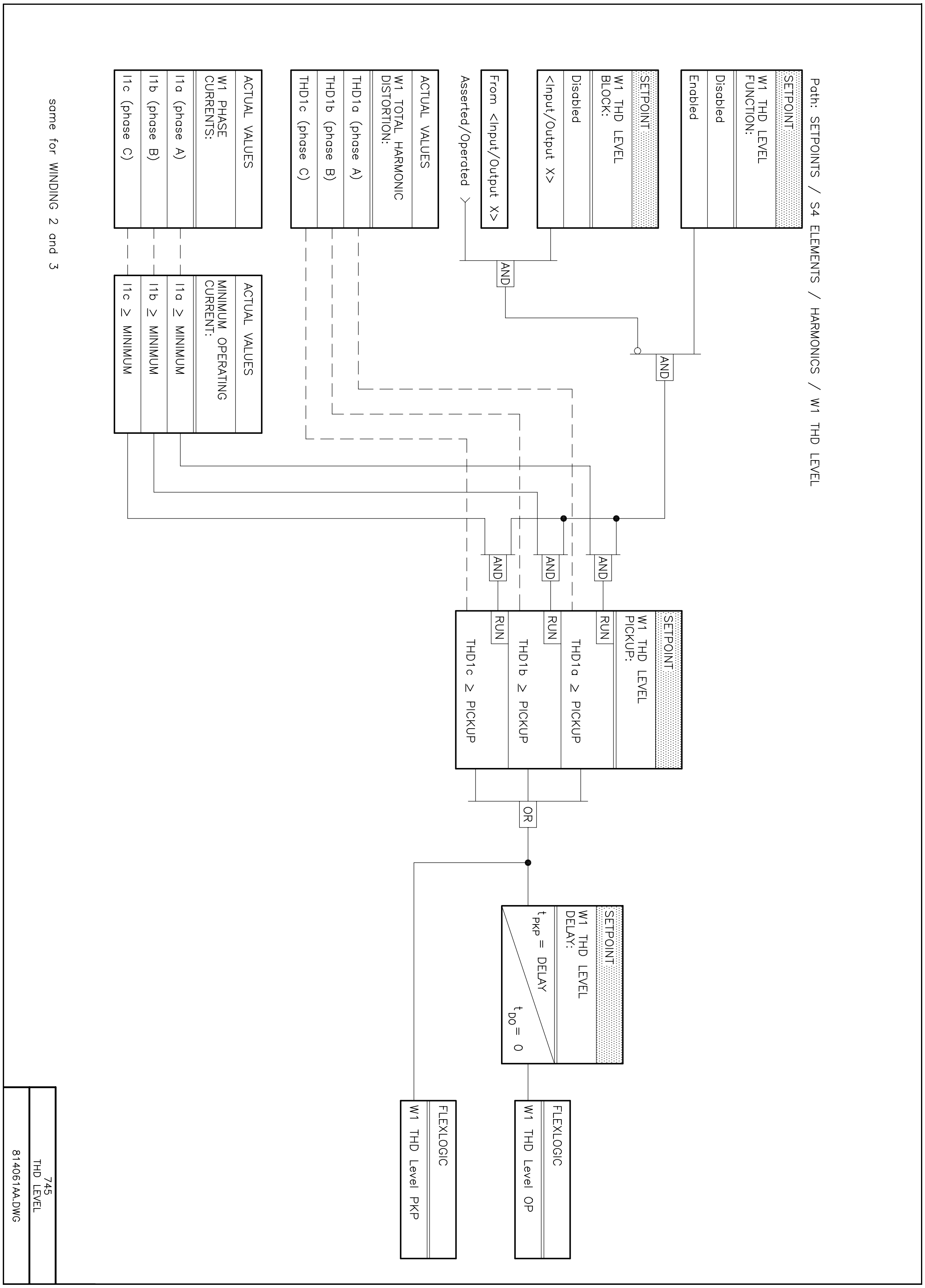


Figure 7–24: THD LEVEL SCHEME LOGIC

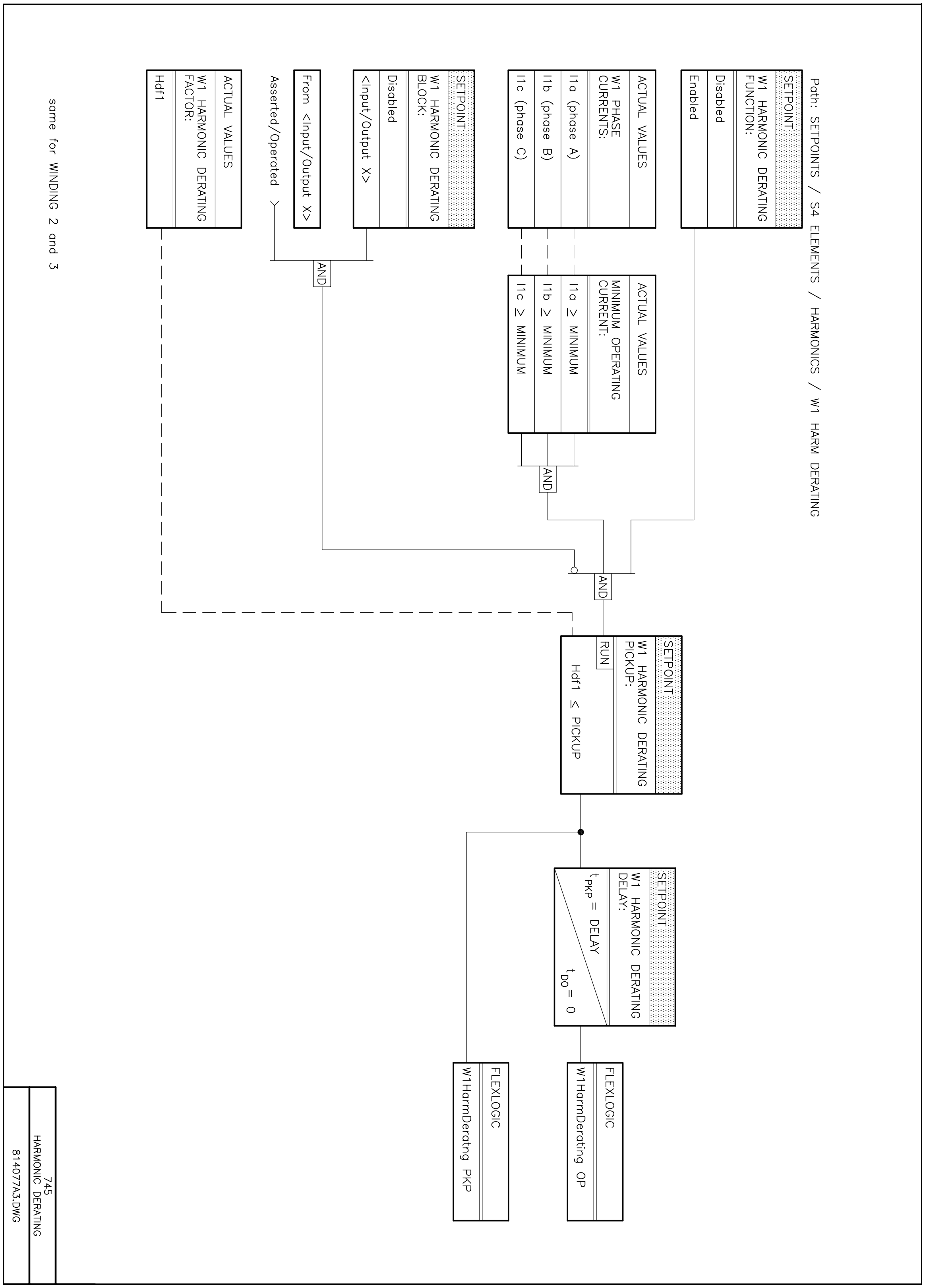


Figure 7–25: HARMONIC DERATING SCHEME LOGIC

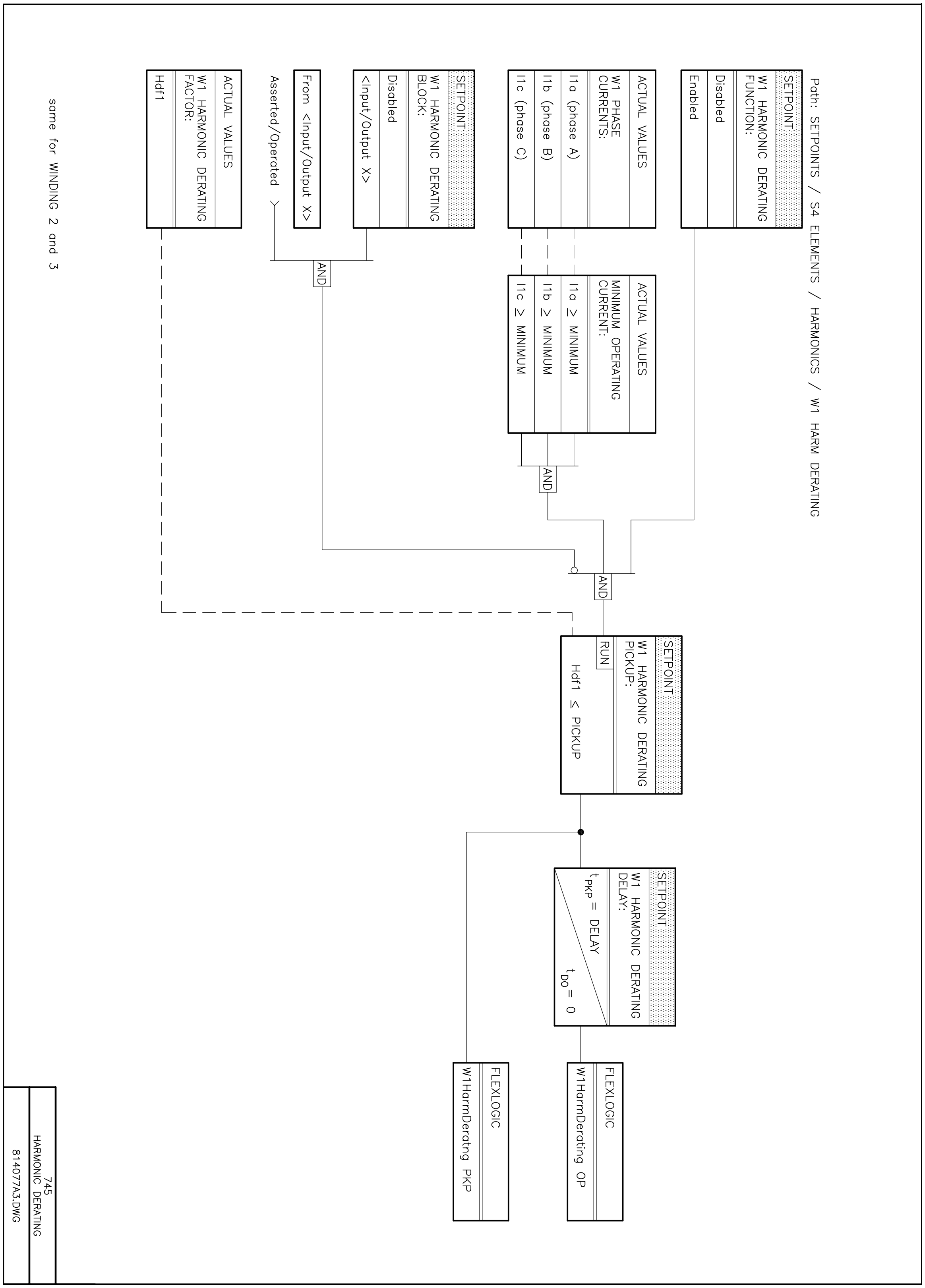


Figure 7–26: ANALOG INPUT SCHEME LOGIC

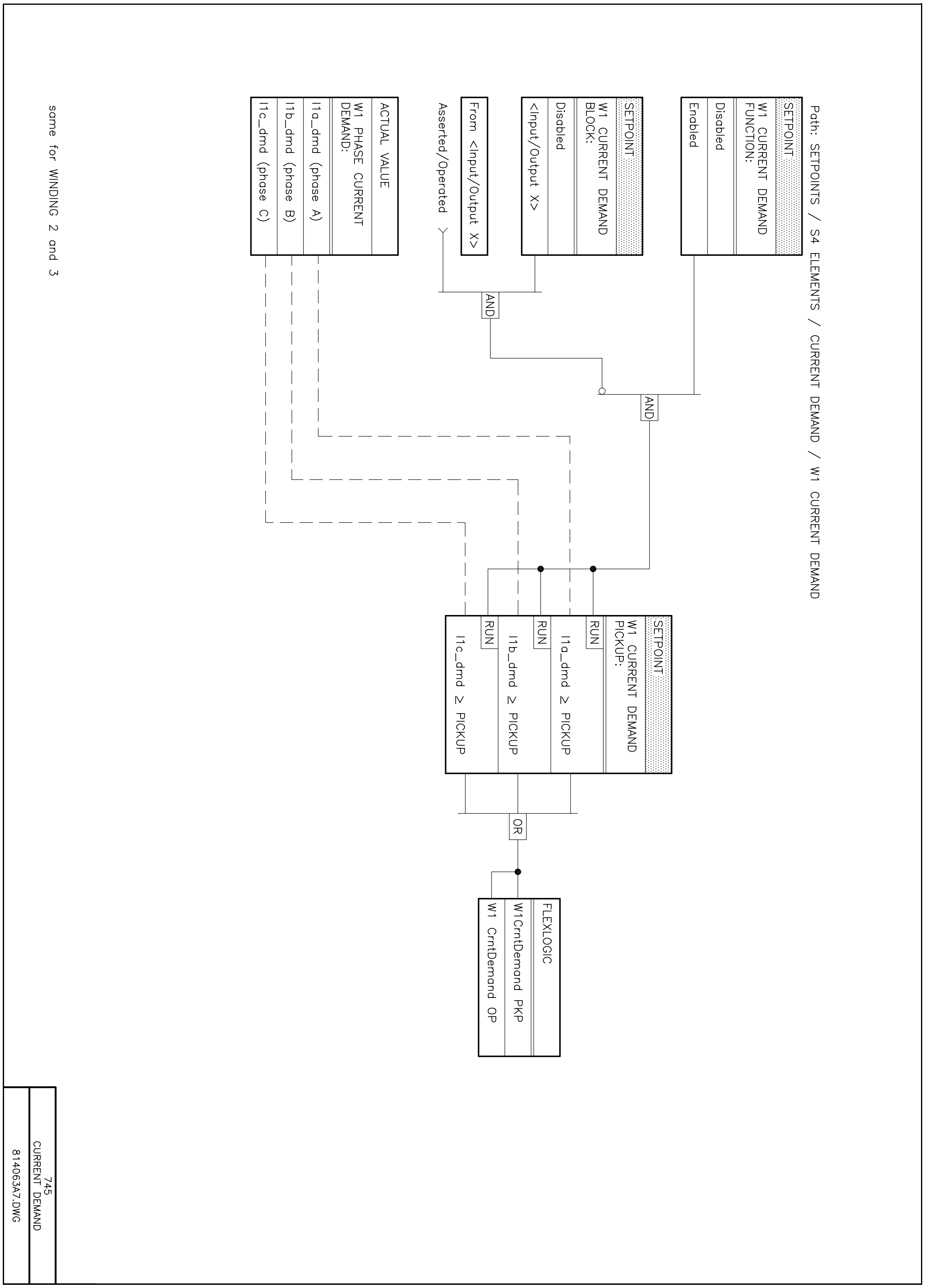


Figure 7–27: CURRENT DEMAND SCHEME LOGIC

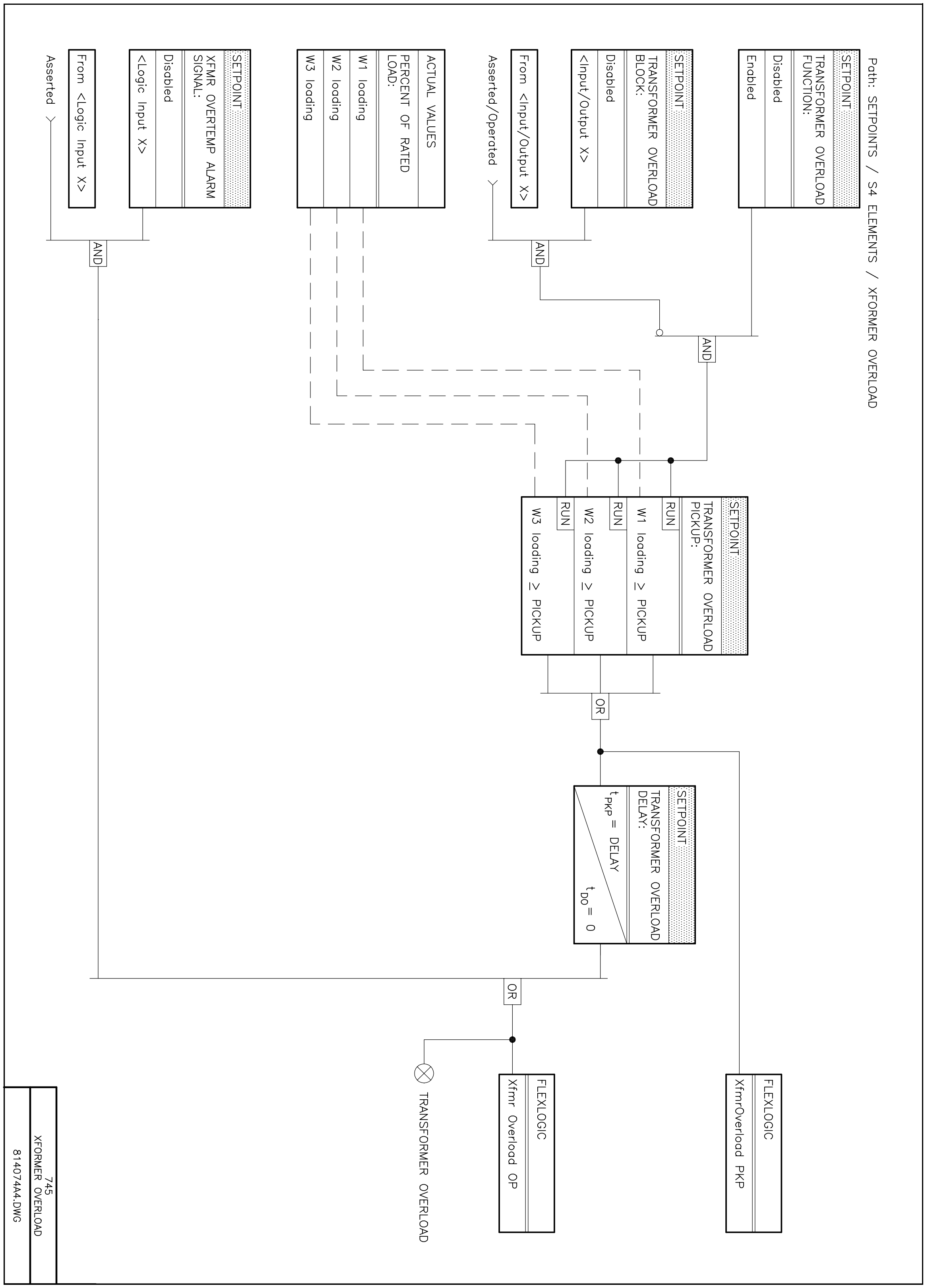


Figure 7–28: TRANSFORMER OVERLOAD

7

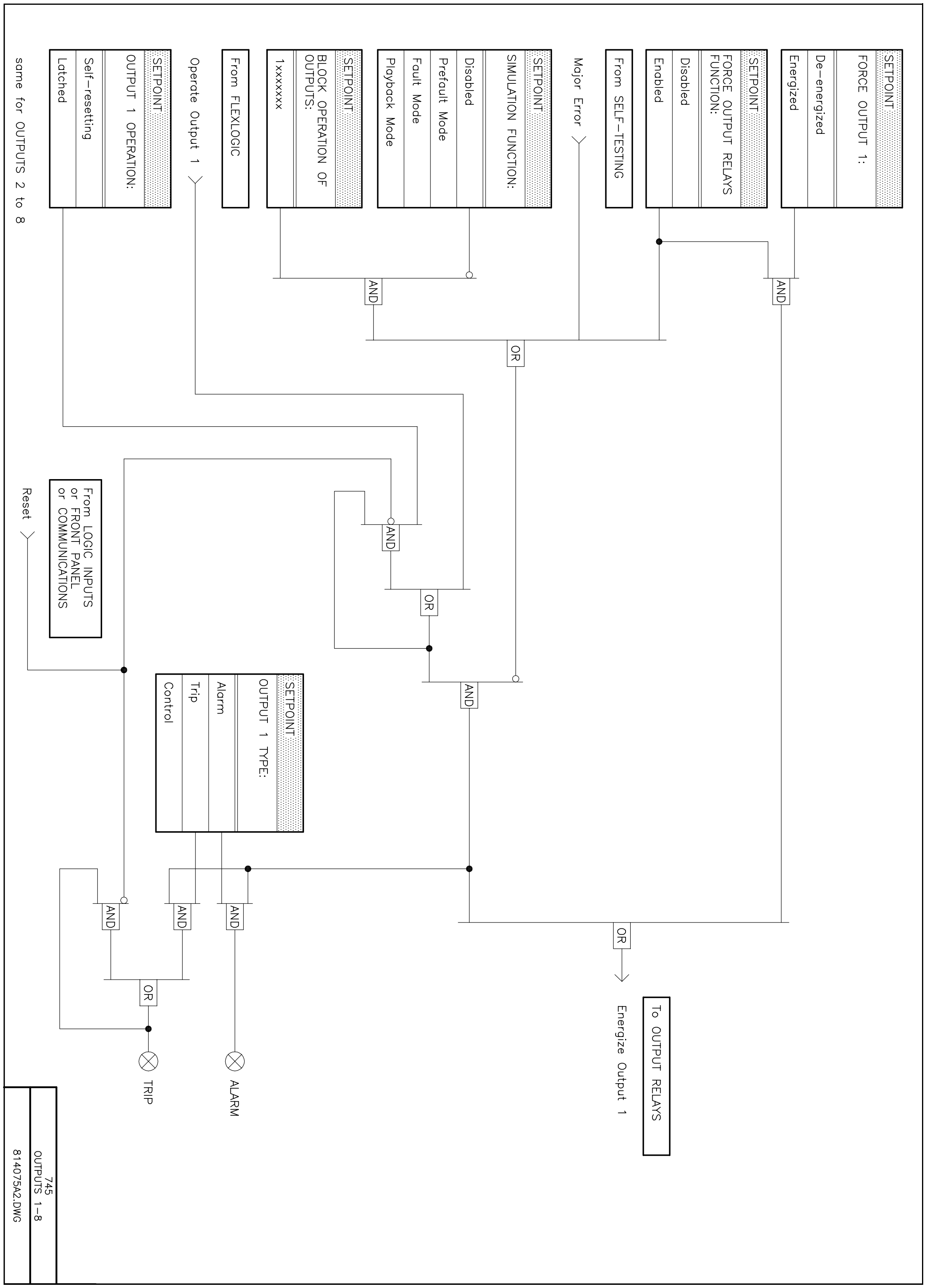


Figure 7–29: OUTPUT RELAYS 1-8

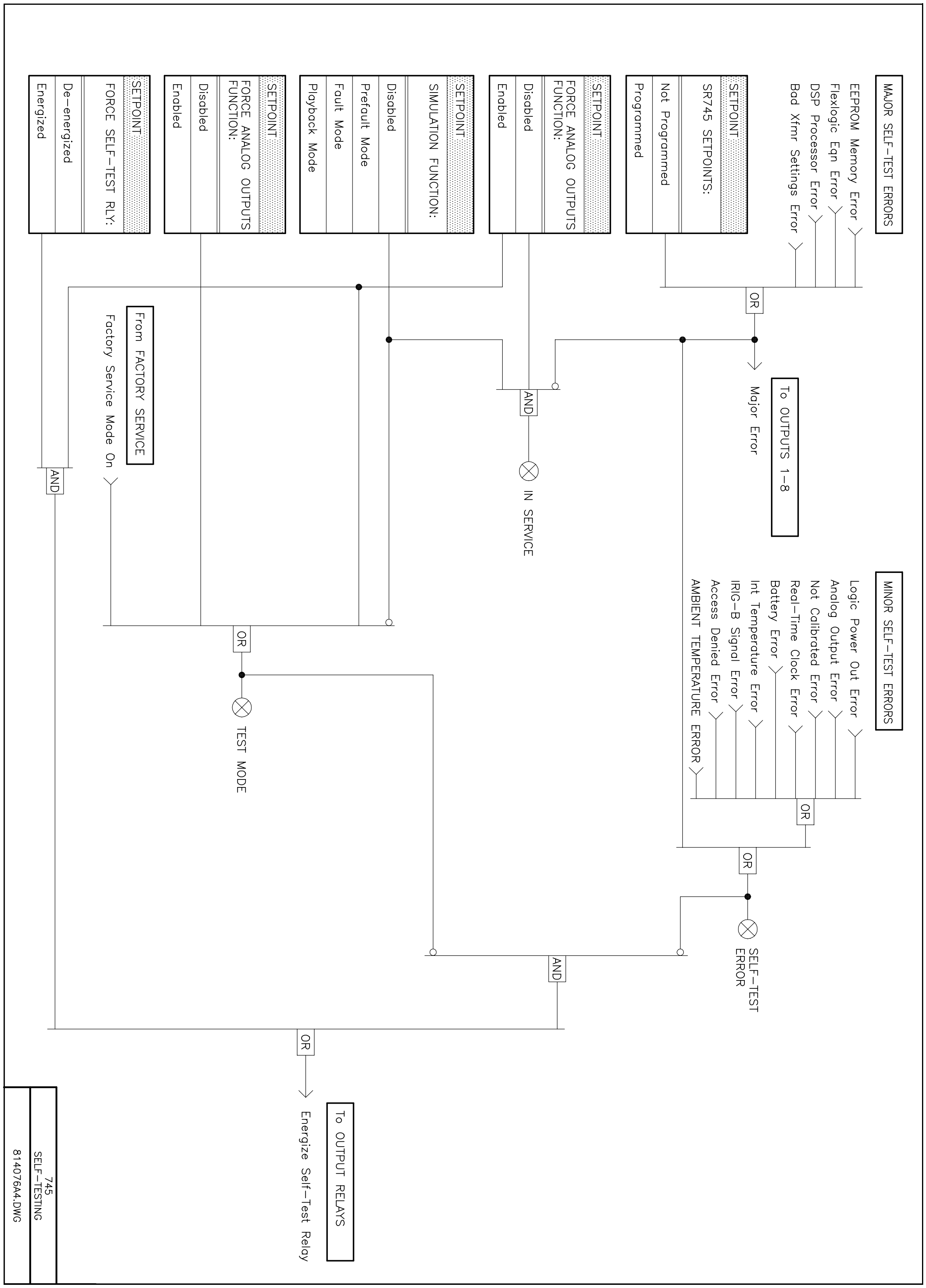


Figure 7–30: SELF-TEST RELAY

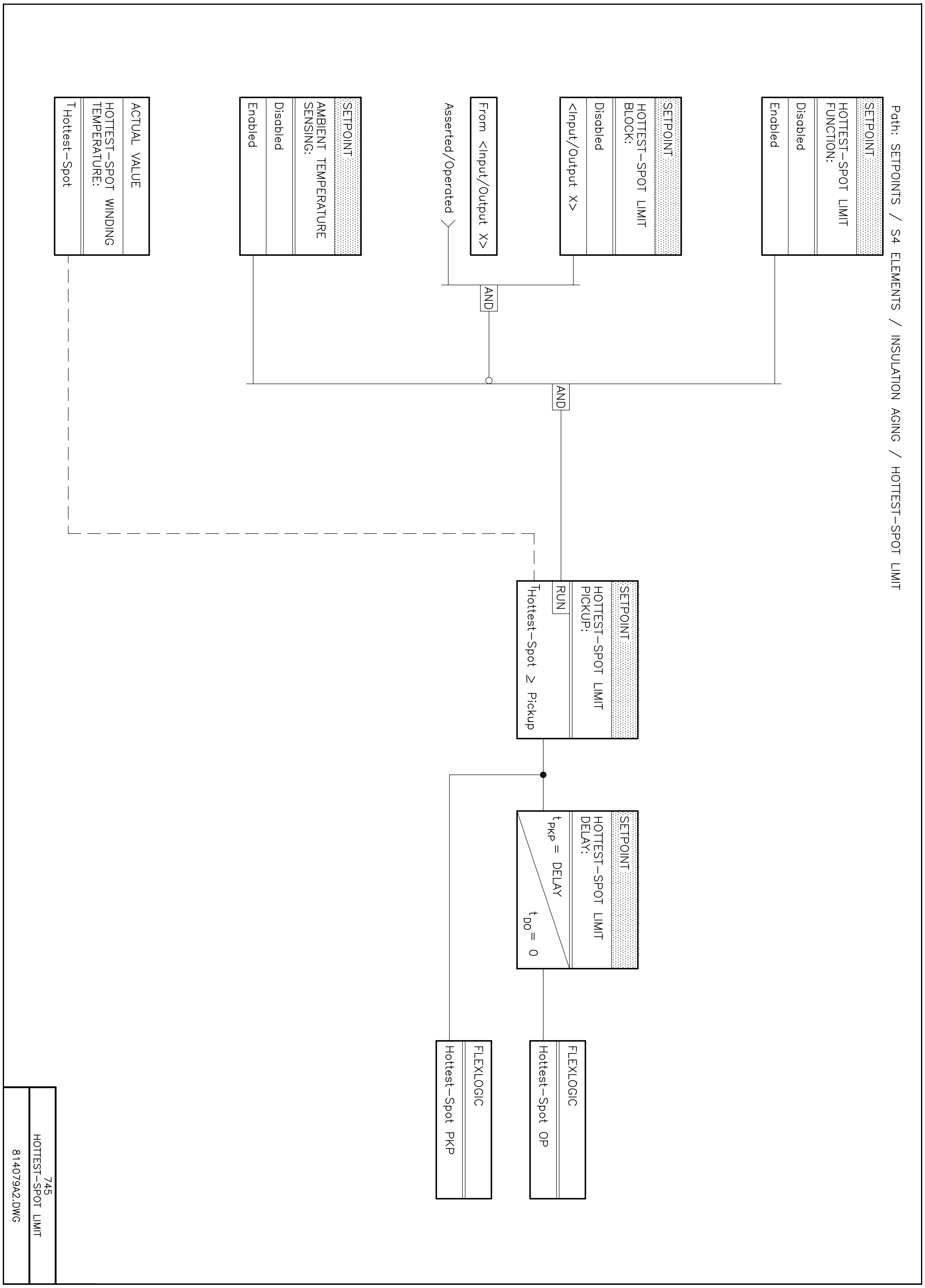


Figure 7–31: HOTTEST-SPOT LIMIT

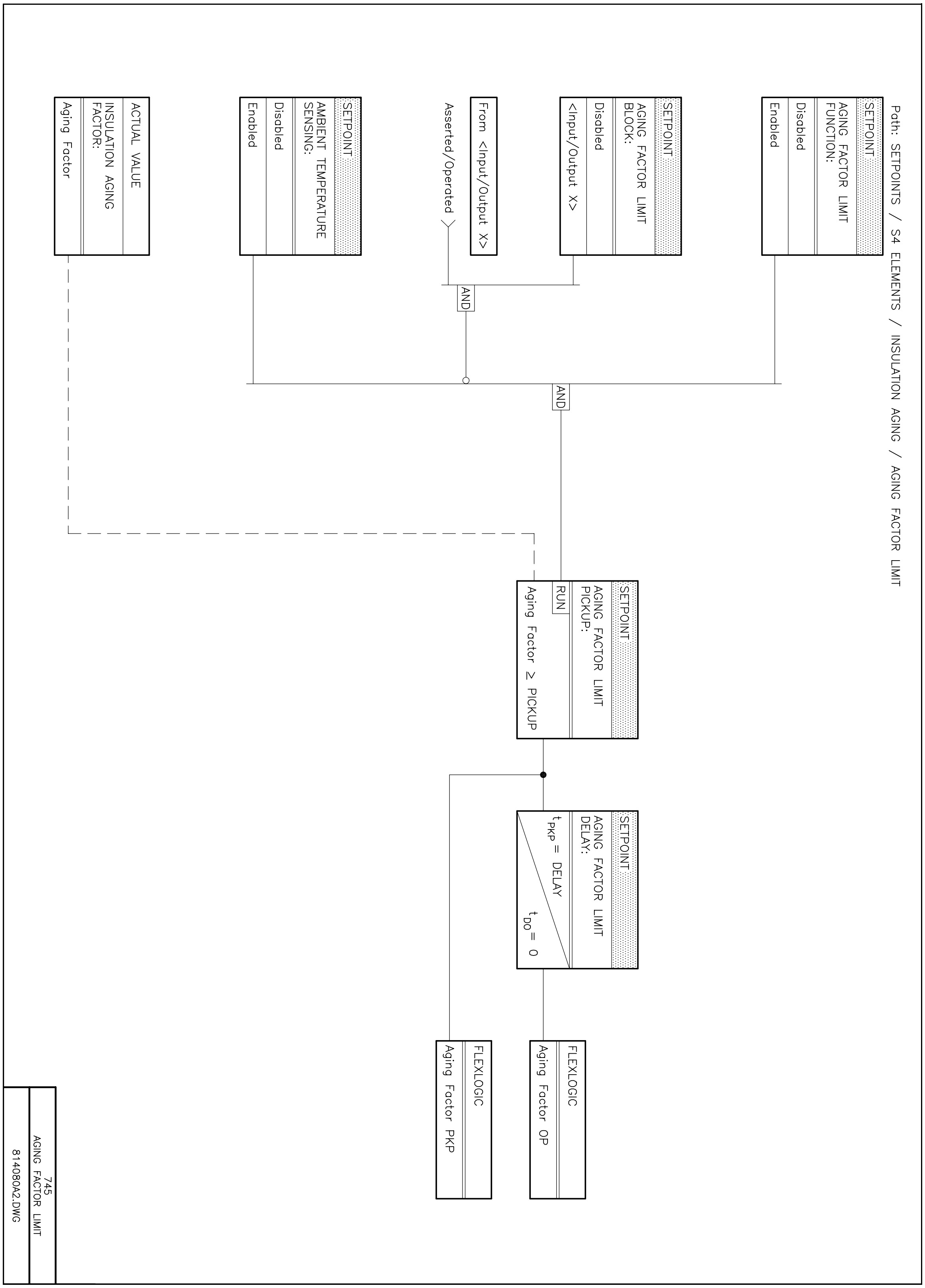


Figure 7–32: AGING FACTOR LIMIT

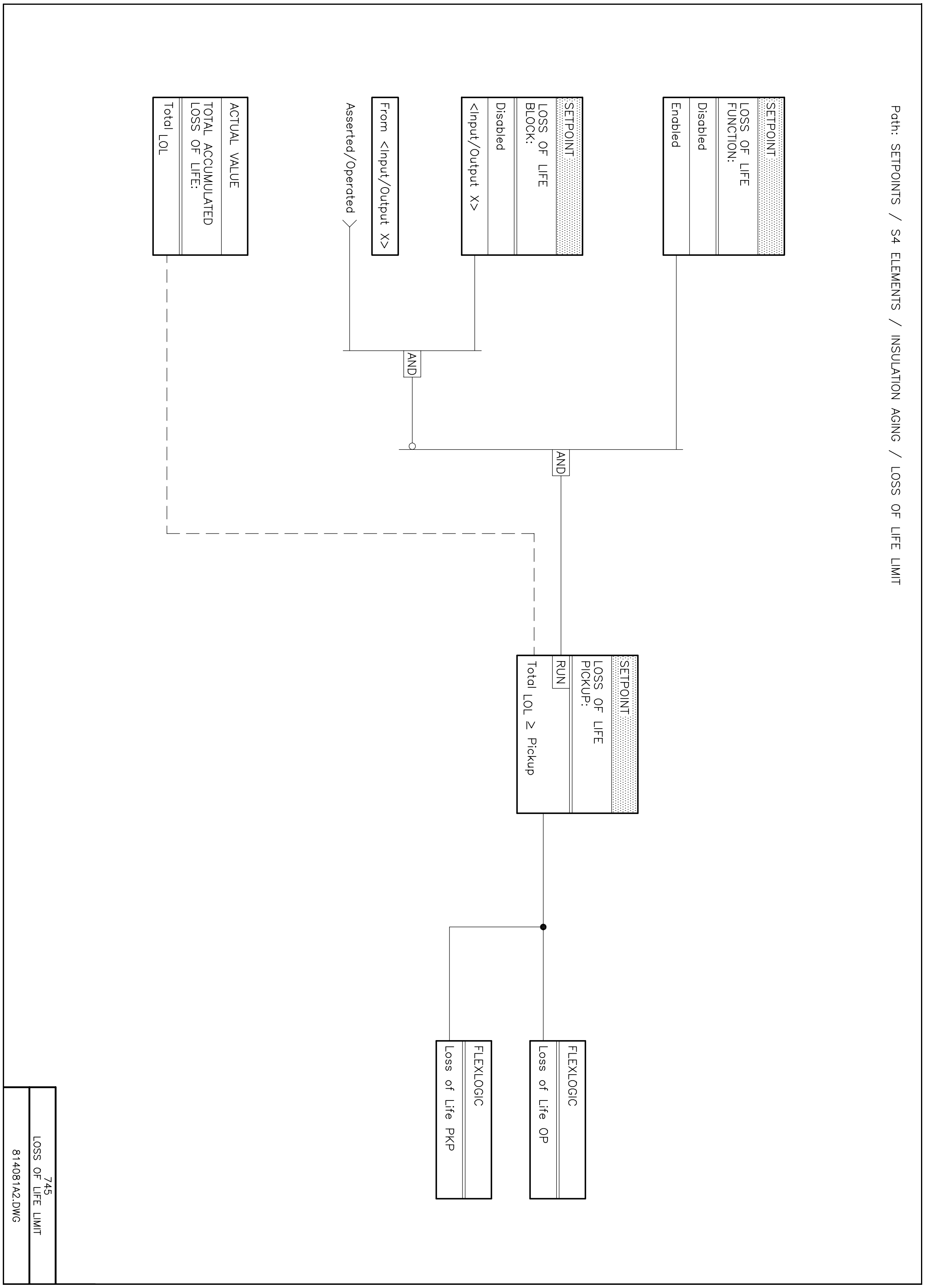


Figure 7–33: LOSS OF LIFE LIMIT

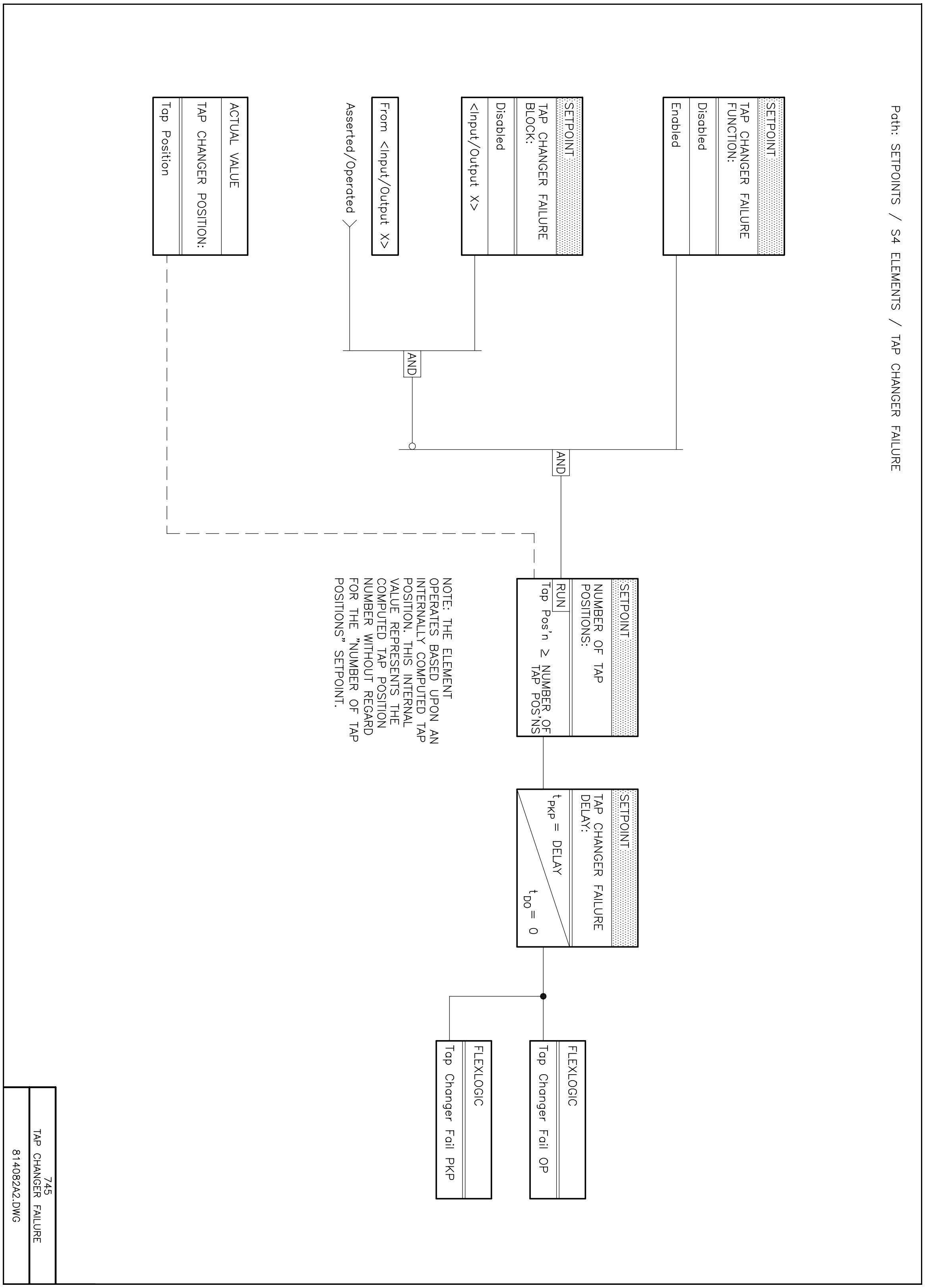


Figure 7–34: TAP CHANGER FAILURE

8.1.1 PROTOCOLS

The GE Power Management 745 Transformer Management relay communicates with other computerized equipment such as programmable logic controllers, personal computers, or plant master computers using either the AEG Modicon Modbus protocol or the Harris Distributed Network Protocol (DNP), Version 3.0. Following are some general notes:

- The 745 relay always act as slave devices meaning that they never initiate communications; they only listen and respond to requests issued by a master computer.
- For Modbus, a subset of the Remote Terminal Unit (RTU) format of the protocol is supported which allows extensive monitoring, programming and control functions using read and write register commands.
- For DNP, the functionality is restricted to monitoring of essential relay data and control of important relay functions. A complete description of the services available via DNP may be found in the Device Profile Document which is included in this chapter.

DNP is a complex protocol. As a consequence, it is not possible within the scope of this manual to provide a description of the protocol's operation in anything approaching the detail required to understand how to use it to communicate with the relay. It is strongly recommended that interested users contact the DNP Users Group at www.dnp.org to obtain further information:

Members of the DNP Users Group are eligible to receive complete descriptions of all aspects of the protocol. The Users Group also operates a website (www.dnp.org) where technical information and support is available.

8.1.2 PHYSICAL LAYER

Both the MODBUS and DNP protocols are hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232, RS422, RS485, fiber optics, etc. The 745 includes a front panel RS232 port and two rear terminal RS485 ports, one of which can also be configured as RS422. Data flow is half duplex in all configurations. See Section 3.2.16: RS485 / RS422 COMMUNICATION PORTS on page 3–12 for details on wiring.

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame. This is important for transmission through modems at high bit rates (11 bit data frames are not supported by many modems at baud rates greater than 300).

The baud rate and parity are independently programmable for each communications port. Baud rates of 300, 1200, 2400, 4800, 9600, and 19200 are available. Even, odd, and no parity are available. See Section 5.3.4: COMMUNICATIONS on page 5–26 for further details.

The master device in any system must know the address of the slave device with which it is to communicate. The 745 will not act on a request from a master if the address in the request does not match the relay's slave address (unless the address is the broadcast address -- see below).

A single setpoint selects the slave address used for all ports with the exception that for the front panel port the relay will accept any address when the Modbus protocol is used. The slave address is otherwise the same regardless of the protocol in use, but note that the broadcast address is 0 for Modbus and 65535 for DNP. The relay recognizes and processes a master request (under conditions that are protocol-specific) if the broadcast address is used but never returns a response.

DNP may be used on, at most, one of the communications ports. Any port(s) not selected to use DNP will communicate using Modbus. Setpoint **S1 RELAY SETUP / COMMUNICATIONS / DNP / DNP PORT** is used to select which port will communicate using DNP.

The maximum time for a 745 relay to return a response to any (non-broadcast) master request never exceeds 1 second.

8.2.1 DESCRIPTION

This section dedicated to discussion of details of the Modbus protocol. As noted above, specifics of DNP are best obtained directly from the DNP Users Group at www.dnp.org. Along with the Device Profile Document, the DNP specification provides sufficient information for a user to develop an interface should DNP wish to be used for communications with the relay.

8.2.2 GE POWER MANAGEMENT MODBUS PROTOCOL

The GE Power Management 745 Transformer Management Relay implements a subset of the AEG Modicon Modbus serial communication standard. Many devices support this protocol directly with a suitable interface card, allowing direct connection of relays. The Modbus protocol is hardware-independent; that is, the physical layer can be any of a variety of standard hardware configurations. This includes RS232, RS422, RS485, fibre optics, etc. The 745 includes a front panel RS232 port and two rear terminal RS485 ports, one of which can be configured as a four-wire RS422 port. Modbus is a single master / multiple slave protocol suitable for a multi-drop configuration as provided by RS485/RS422 hardware. In this configuration up to 32 slaves can be daisy-chained together on a single communication channel.

The GE Power Management 745 is always a Modbus slave. It cannot be programmed as a Modbus master. The Modbus protocol exists in two versions: Remote Terminal Unit (RTU, binary) and ASCII. Only the RTU version is supported by the 745. Monitoring, programming and control functions are possible using read and write register commands.

Additional information on the Modbus protocol can be found on the Modbus website at www.modbus.org.

8.2.3 ELECTRICAL INTERFACE

The hardware or electrical interface is any of the following:

- two-wire RS485 for the rear terminal COM1 and COM2 terminals
- four-wire RS422 for the rear terminal COM1 terminals
- RS232 for the front panel connector

In a two-wire RS485 link, data flow is bi-directional. The four-wire RS422 port uses the RS485 terminal for receive lines, and two other terminals for transmit lines. In the front panel RS232 link there are separate lines for transmission and reception as well as a signal ground wire. In all configurations data flow is half duplex. That is, data is never transmitted and received at the same time.

RS485 and RS422 lines should be connected in a daisy chain configuration (avoid star connections) with terminating resistors and capacitors installed at each end of the link, i.e. at the master end and at the slave farthest from the master. The value of the terminating resistors should be equal to the characteristic impedance of the line. This is approximately 120 Ω for standard 24 AWG twisted pair wire. The value of the capacitors should be 1 nF. Shielded wire should always be used to minimize noise. Polarity is important in RS485 communications. The '+' terminal of every device must be connected together for the system to operate.

8.2.4 DATA FRAME FORMAT AND RATE

One data frame of an asynchronous transmission to or from a GE Power Management 745 consists of 1 start bit, 8 data bits, and 1 stop bit. This produces a 10 bit data frame. The 745 can be configured to include an additional even or odd parity bit if required, producing an 11 bit data frame.

All ports of the GE Power Management 745 support operation at 300, 1200, 2400, 9600, and 19200 baud.

8.2.5 DATA PACKET FORMAT

A complete request/response sequence consists of the following bytes transmitted as separate data frames:

MASTER QUERY MESSAGE:	
SLAVE ADDRESS:	(1 byte)
FUNCTION CODE:	(1 byte)
DATA:	(variable number of bytes depending on FUNCTION CODE)
CRC:	(2 bytes)
SLAVE RESPONSE MESSAGE:	
SLAVE ADDRESS:	(1 byte)
FUNCTION CODE:	(1 byte)
DATA:	(variable number of bytes depending on FUNCTION CODE)
CRC:	(2 bytes)

A message is terminated when no data is received for a period of 3½ character transmission times. Consequently, the transmitting device must not allow gaps between bytes larger than this interval (about 3 ms at 9600 baud).

- **SLAVE ADDRESS**: This is the first byte of every message. This byte represents the user-assigned address of the slave device that is to receive the message sent by the master. Each slave device must be assigned a unique address, and only the addressed slave will respond to a message that starts with its address. In a master query message the SLAVE ADDRESS represents the address of the slave to which the request is being sent. In a slave response message the SLAVE ADDRESS is a confirmation representing the address of the slave that is sending the response. A master query message with a SLAVE ADDRESS of 0 indicates a broadcast command. All slaves on the communication link will take action based on the message, but none will respond to the master. Broadcast mode is only recognized when associated with FUNCTION CODES 05h, 06h, and 10h. For any other function code, a message with broadcast mode slave address 0 will be ignored.
- **FUNCTION CODE**: This is the second byte of every message. Modbus defines function codes of 1 to 127. The GE Power Management 745 implements some of these functions. In a master query message the FUNCTION CODE tells the slave what action to perform. In a slave response message, if the FUNCTION CODE sent from the slave is the same as the FUNCTION CODE sent from the master then the slave performed the function as requested. If the high order bit of the FUNCTION CODE sent from the slave is a 1 (i.e. if the FUNCTION CODE is > 7Fh) then the slave did not perform the function as requested and is sending an error or exception response.
- **DATA**: This will be a variable number of bytes depending on the FUNCTION CODE. This may include actual values, setpoints, or addresses sent by the master to the slave or by the slave to the master.
- **CRC**: This is a two byte error checking code. The RTU version of Modbus includes a two byte CRC-16 (16 bit cyclic redundancy check) with every message. The CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (11000000000000101B). The 16 bit remainder of the division is appended to the end of the message, MSByte first. The resulting message including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred. If a GE Power Management Modbus slave device receives a message in which an error is indicated by the CRC-16 calculation, the slave device will not respond to the message. A CRC-16 error indicates that one or more bytes of the message were received incorrectly and thus the entire message should be ignored in order to avoid the slave device performing any incorrect operation. The CRC-16 calculation is an industry standard method used for error detection.

8.2.6 CRC-16 ALGORITHM

Once the following algorithm is completed, the working register "A" will contain the CRC value to be transmitted. Note that this algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped, since it does not affect the value of the remainder. The following symbols are used in the algorithm:

Symbols:

-->	data transfer
A	16 bit working register
A_{low}	low order byte of A
A_{high}	high order byte of A
CRC	16 bit CRC-16 result
i, j	loop counters
(+)	logical EXCLUSIVE-OR operator
N	total number of data bytes
D_i	i-th data byte (i = 0 to N-1)
G	16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed
shr (x)	right shift operator (the LSbit of x is shifted into a carry flag, a '0' is shifted into the MSbit of x, all other bits are shifted right one location)

Algorithm:

1. FFFF (hex) --> A
2. 0 --> i
3. 0 --> j
4. D_i (+) A_{low} --> A_{low}
5. j + 1 --> j
6. shr (A)
7. Is there a carry? No: go to step 8.
Yes: G (+) A --> A and continue.
8. Is j = 8? No: go to 5.
Yes: continue.
9. i + 1 --> i
10. Is i = N? No: go to 3.
Yes: continue.
11. A --> CRC

NOTE

GE Power Management will provide a C programming language implementation of this algorithm upon request.)

8.2.7 MESSAGE TIMING

Communication message synchronization is maintained by timing constraints. The receiving device must measure the time between the reception of characters. If three and one half character times elapse without a new character or completion of the message, then the communication link must be reset (i.e. all slaves start listening for a new query message from the master). Thus at 1200 baud a delay of greater than 3.5 x 1/1200 x 10 = 29.2 ms will cause the communication link to be reset. At 9600 baud a delay of greater than 3.5 x 1/9600 x 10 = 3.6 ms will cause the communication link to be reset. Most master query messages will be responded to in less than 50 ms.

8.2.8 SUPPORTED FUNCTION CODES

The second byte of every message is the function code. Modbus defines function codes of 01h to 7Fh. The GE Power Management SR Series Modbus protocol supports some of these functions, as summarized below.

Table 8–1: GE POWER MANAGEMENT FUNCTION CODES

FUNCTION CODE		DEFINITION	DESCRIPTION	SUBSTITUTE
HEX	DEC			
03	3	READ ACTUAL VALUES OR SETPOINTS	Read actual value or setpoint registers from one or more consecutive memory map register addresses.	04H
04	4			03H
05	5	EXECUTE OPERATION	Perform 745 specific operations.	10H
06	6	STORE SINGLE SETPOINT	Write a specific value into a single setpoint register.	10H
10	16	STORE MULTIPLE SETPOINTS	Write specific values into one or more consecutive setpoint registers.	---

NOTE

* Since some programmable logic controllers only support function codes 03h (or 04h) and 10h, most of the above Modbus commands can be performed by reading from or writing to special addresses in the 745 memory map using these function codes. See section entitled FUNCTION CODE SUBSTITUTIONS for details.

8.2.9 FUNCTION CODE 03H/04H: READ ACTUAL VALUES/SETPOINTS

Modbus implementation:	*Read Holding Registers*
GE Power Management implementation:	*Read Actual Values or Setpoints*

Since some PLC implementations of Modbus only support one of function codes 03h and 04h, the 745 interpretation allows either function code to be used for reading one or more consecutive setpoints or actual values. The data starting address will determine the type of data being read. Function codes 03h and 04h are therefore identical.

The GE Power Management implementation of Modbus views "holding registers" as any setpoint or actual value register in the 745 memory map. Registers are 16 bit (two byte) values transmitted high order byte first. Thus all GE Power Management setpoints and actual values in the memory map are sent as two byte registers. This function code allows the master to read one or more consecutive setpoints or actual values from the addressed slave device.

The maximum number of values that can be read in a single message is 120.

MESSAGE FORMAT AND EXAMPLE:

Request to read 3 register values starting from address 0200 from slave device 11.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	03	read register values
DATA STARTING ADDRESS: high order byte	02	data starting at address 0200
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF REGISTERS: high order byte	00	3 register values = 6 bytes total
NUMBER OF REGISTERS: low order byte	03	
CRC: low order byte	06	
CRC: high order byte	E3	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	03	read register values
BYTE COUNT	06	3 register values = 6 bytes total
DATA #1: high order byte	02	register value in address 0200 = 022B
DATA #1: low order byte	2B	
DATA #2: high order byte	00	register value in address 0201 = 0000
DATA #2: low order byte	00	
DATA #3: high order byte	00	register value in address 0202 = 0064
DATA #3: low order byte	64	
CRC: low order byte	C8	
CRC: high order byte	BA	

8.2.10 FUNCTION CODE 05H: EXECUTE OPERATION

Modbus implementation:	*Force Single Coil*
GE Power Management implementation:	*Execute Operation*

This function code allows the master to perform various operations in the 745. The 2 byte CODE VALUE of FF00h must be sent after the OPERATION CODE for the operation to be performed.

MESSAGE FORMAT AND EXAMPLE:

Request to perform reset operation in slave device 11.

Master Query Message:	Example (hex):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	05	execute operation
OPERATION CODE: high order byte	00	remote reset
OPERATION CODE: low order byte	01	
CODE VALUE: high order byte	FF	perform operation
CODE VALUE: low order byte	00	
CRC: low order byte	DF	
CRC: high order byte	6A	

Field:	Example (hex):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	05	execute operation
OPERATION CODE: high order byte	00	remote reset
OPERATION CODE: low order byte	01	
CODE VALUE: high order byte	FF	perform operation
CODE VALUE: low order byte	00	
CRC: low order byte	DF	
CRC: high order byte	6A	

Table 8–2: SUMMARY OF OPERATION CODES FOR FUNCTION CODE 05H

OPERATION CODE	DEFINITION	DESCRIPTION
0000	NO OPERATION	Does not do anything.
0001	REMOTE RESET	Performs the same function as the front panel RESET key.
0002	TRIGGER TRACE MEMORY	Initiates a waveform capture of trace memory and increments the "Total Number of Trace Triggers" registers.
0003	CLEAR MAXIMUM DEMAND DATA	Performs the same function as the command in message **A2 METERING / DEMAND / DEMAND DATA CLEAR / CLEAR MAXIMUM DEMAND DATA**.
0004	CLEAR EVENT RECORDER DATA	Performs the same function as the command in message **A3 EVENT RECORDER / EVENT DATA CLEAR / CLEAR EVENT RECORDER DATA**.
0005	CLEAR LOSS-OF-LIFE DATA	Performs the same function as the command in message **S1 745 SETUP / INSTALLATION / CLEAR LOSS-OF-LIFE DATA**.
0006	CLEAR TRACE MEMORY	Clears all trace memory buffers and sets the "Total Number of Trace Triggers" register to zero.
0007	CLEAR ENERGY DATA	Performs the same function as the command in message **A2 METERING / ENERGY / ENERGY DATA CLEAR / CLEAR ENERGY**.

8.2.11 FUNCTION CODE 06H: STORE SINGLE SETPOINT

Modbus Implementation:	*Preset Single Register*
GE Power Management Implementation:	*Store Single Setpoint*

This function code allows the master to modify the contents of a single setpoint register in the addressed slave device. The response of the slave device to this function code is an echo of the entire master query message.

MESSAGE FORMAT AND EXAMPLE:

Request slave device 11 to write the value 00C8 at setpoint address 1100.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	06	store single setpoint value
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
DATA: high order byte	00	data for address 1100 = 00C*
DATA: low order byte	C8	
CRC: low order byte	8F	
CRC: high order byte	F0	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	06	store single setpoint value
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
DATA: high order byte	00	data for address 1100 = 00C*
DATA: low order byte	C8	
CRC: low order byte	8F	
CRC: high order byte	F0	

8.2.12 FUNCTION CODE 10H: STORE MULTIPLE SETPOINTS

Modbus Implementation:	*Preset Multiple Registers*
GE Power Management Implementation:	*Store Multiple Setpoints*

This function code allows the master to modify the contents of a one or more consecutive setpoint registers in the addressed slave device. Setpoint registers are 16 bit (two byte) values transmitted high order byte first.

The maximum number of register values (setpoints) that can be stored in a single message is 60.

MESSAGE FORMAT AND EXAMPLE:

Request slave device 11 to write the value 00C8 at setpoint address 1100, and the value 0001 at setpoint address 1101.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF SETPOINTS: high order byte	00	2 setpoint values = 4 bytes total
NUMBER OF SETPOINTS: low order byte	02	
BYTE COUNT	04	4 bytes of data
DATA #1: high order byte	00	data for address 1100 = 00C8
DATA #1: low order byte	C8	
DATA #2: high order byte	00	data for address 1101 = 0001
DATA #2: low order byte	01	
CRC: low order byte	27	
CRC: high order byte	01	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF SETPOINTS: high order byte	00	2 setpoint values = 4 bytes total
NUMBER OF SETPOINTS: low order byte	02	
CRC: low order byte	46	
CRC: high order byte	64	

8.2.13 EXCEPTION RESPONSES

Programming or operation errors happen because of illegal data in a message, hardware or software problems in the slave device, etc. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response message to the master consisting of slave address, function code, error code, and CRC. To indicate that the response is a notification of an error, the high order bit of the function code is set to 1.

Table 8–3: ERROR CODES

ERROR CODE	MODBUS DEFINITION	GE POWER MANAGEMENT IMPLEMENTATION
01	ILLEGAL FUNCTION	The function code of the master query message is not a function code supported by the slave.
02	ILLEGAL DATA ADDRESS	The address referenced in the data field of the master query message is not an address supported by the slave.
03	ILLEGAL DATA VALUE	The value referenced in the data field of the master query message is not allowable in the addressed slave location.
04	FAILURE IN ASSOCIATED DEVICE	An external device connected to the addressed slave device has failed and the data requested cannot be sent. This response will be returned if a GE Power Management device connected to the RS485 external device port of the 745 has failed to respond to the 745.
05*	ACKNOWLEDGE	The addressed slave device has accepted and is processing a long duration command. Poll for status.
06*	BUSY, REJECTED MESSAGE	The message was received without error, but the slave device is engaged in processing a long duration command. Retransmit later, when the slave device may be free.
07*	NAK - NEGATIVE ACKNOWLEDGE	The message was received without error, but the request could not be performed, because this version of the 745 does not have the requested operation available.

NOTE

*** Some implementations of Modbus may not support these exception responses.**

MESSAGE FORMAT AND EXAMPLE:

Request to slave device 11 to perform unsupported function code 39h.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	39	unsupported function code – error
CRC: low order byte	CD	
CRC: high order byte	F2	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	B9	return unsupported fn. code with high-order bit set
ERROR CODE	01	illegal function
CRC: low order byte	93	
CRC: high order byte	95	

8.2.14 READING THE EVENT RECORDER

All Event Recorder data can be read from Modbus registers found in the address range 0800h - 0FFFh.

The 'Total Number of Events Since Last Clear' register at address 0804h is incremented by one every time a new event occurs. The register is cleared to zero when the Event Recorder is cleared. When a new event occurs, the event is assigned an 'event number' which is equal to the incremented value of this register. The newest event will have an event number equal to the Total Number of Events. This register can be used to determine if any new events have occurred by periodically reading the register to see if the value has changed. If the Total Number of Events has increased, then new events have occurred.

Only the data for a single event can be read from the Modbus memory map in a single data packet. The 'Event Record Selector Index' register at address 0805h selects the event number whose data can be read from the memory map. For example, to read the data for event number 123, the value 123 must first be written to this register. All the data for event number 123 can now be read from the 'Event Recorder Data' registers at addresses 0830h to 0866h. Only the last 128 events are actually stored in the relay's memory. Attempting to retrieve data for older events that are not stored will result in a Modbus exception response when writing to the 'Event Record Selector Index'.

The following example illustrates how information can be retrieved from the Event Recorder:

A SCADA system polls the Total Number of Events register once every minute. It now reads a value of 27 from the register when previously the value was 24, which means that three new events have occurred during the last minute. The SCADA system writes a value of 25 to the Event Record Selector Index register. It then reads the data for event number 25 from the Event Recorder Data registers and stores the data to permanent memory for retrieval by an operator. The SCADA system now writes the value 26 to the selector and then reads the data for event number 26. Finally, the SCADA system writes the value 27 to the selector and then reads the data for this event. All the data for the new events has now been retrieved by the SCADA system, so it resumes polling the Total Number of Events register.

8.2.15 READING TRACE MEMORY

All Trace Memory data can be read from Modbus registers found in the address range 4000h - 47FFh.

The 'Total Number of Trace Triggers Since Last Clear' register at address 4004h is incremented by one every time a new trace memory waveform capture is triggered. The register is cleared to zero when the Trace Memory is cleared. When a new trigger occurs, the captured trace memory buffer is assigned a 'trigger number' which is equal to the incremented value of this register. The newest captured buffer will have a trigger number equal to the Total Number of Trace Triggers. This register can be used to determine if any new triggers have occurred by periodically reading the register to see if the value has changed. If the Total Number of Trace Triggers has increased, then new trace memory waveform captures have occurred.

Only the data for a single channel of a single trace memory buffer can be read from the Modbus memory map at a time. The 'Trace Buffer Selector Index' register at address 4005h selects the trace memory buffer, and the 'Trace Channel Selector Index' register at address 4006h selects the trace memory channel, whose waveform data can be read from the memory map. For example, to read the waveform data for the 'Winding 1 Phase C Current' of trace memory buffer 5, the value 5 must be written to the Trace Buffer Selector Index, and the value 2 (as per data format F65) must be written to the Trace Channel Selector Index. All the captured waveform data for buffer 5, channel 'Winding 1 Phase C Current' can now be read from the 'Trace Memory Data' registers at addresses 4010h to 4416h. Only the trace memory buffers for the last 3 trace memory triggers are actually stored in the relay's memory. Attempting to retrieve data for older triggers that are not stored will result in a Modbus exception response when writing to the 'Trace Buffer Selector Index'.

The following example illustrates how information can be retrieved from the Trace Memory:

A SCADA system polls the Total Number of Trace Triggers register once every minute. It now reads a value of 6 from the register when previously the value was 5, which means that one new trigger has occurred during the last minute. The SCADA system writes a value of 6 to the Trace Buffer Selector Index register. It then writes the value of 0 to the Trace Channel Selector Index register, reads the waveform data for Winding 1 Phase A Current of trace buffer 6 from the Trace Memory Data registers and stores the data to permanent memory for retrieval by an operator. The SCADA system now writes the value 1 to the Trace Channel Selector Index and then reads the waveform data for Winding 1 Phase B Current. The SCADA system continues by writing all other channel numbers to the Trace Channel Selector Index, each time reading the waveform data, until all channels for buffer 6 have been read. All the waveform data for the new trace memory trigger has now been retrieved by the SCADA system, so it resumes polling the Total Number of Trace Triggers register.

8.2.16 ACCESSING DATA VIA THE USER MAP

The 745 has a powerful feature, called the User Map, which allows a computer to access up to 120 non-consecutive registers (setpoints or actual values) by using one Modbus read message.

It is often necessary for a master computer to continuously poll various values in each of the connected slave relays. If these values are scattered throughout the memory map, reading them would require numerous transmissions and would labor the communication link. The User Map can be programmed to join any memory map address to one in the block of consecutive User Map locations, so that they can be accessed by reading (and writing to, if joined to setpoints) these consecutive locations.

The User Map feature consists of:

1. User Map Addresses #1 to #120 (located at memory map addresses 0180 to 01F7 hex). These are the setpoints which store the (possibly discontinuous) memory map addresses of the values that are to be accessed.
2. User Map Values #1 to #120 (located at memory map addresses 0100 to 0177 hex). These are the access points of the remapped locations. Reading User Map Value #1 returns the value at the address stored in User Map Address #1, User Map Value #2 the value at User Map Address #2, and so on. Writing to any User Map Value is only possible if the address stored in the corresponding User Map Address is that of a setpoint value.

For an example of how to use the User Map feature, say the master computer is required to continuously read the memory map locations shown in the table below from slave 11. Normally, this would require at least 4 separate master query messages.

Table 8–4: MEMORY MAP LOCATIONS TO BE ACCESSED

ADDRESS	DESCRIPTION	TYPE
0200H	Relay Status	actual value
0210H	W3 Phase Time O/C Flag	actual value
0300H	W1 Phase A 4th Harmonic Content	actual value
0301H	W1 Phase B 4th Harmonic Content	actual value
0302 hex	W1 Phase C 4th Harmonic Content	actual value
2002 hex	Percent Differential Pickup	setpoint

1. First, preload the addresses listed in the first column of the table to in User Map Addresses #1 to #6 (addresses 0180 to 0185 hex).

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte	01	data starting at address 0180
DATA STARTING ADDRESS: low order byte	80	
NUMBER OF SETPOINTS: high order byte	00	6 setpoint values = 12 bytes total
NUMBER OF SETPOINTS: low order byte	06	
BYTE COUNT	0C	12 bytes of data
DATA #1: high order byte	02	0200 → Relay Status
DATA #1: low order byte	00	
DATA #2: high order byte	02	0210 → W3 Phase Time O/C Flag
DATA #2: low order byte	10	
DATA #3: high order byte	03	0300 → W1 Phase A 4th Harmonic Content
DATA #3: low order byte	00	
DATA #4: high order byte	03	0301 → W1 Phase B 4th Harmonic Content
DATA #4: low order byte	01	
DATA #5: high order byte	03	0302 → W1 Phase C 4th Harmonic Content
DATA #5: low order byte	02	
DATA #6: high order byte	20	2002 → Percent Differential Pickup
DATA #6: low order byte	02	
CRC: low order byte	2F	
CRC: high order byte	8A	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte	11	data starting at address 0180
DATA STARTING ADDRESS: low order byte	80	
NUMBER OF SETPOINTS: high order byte	00	6 setpoint values = 12 bytes total
NUMBER OF SETPOINTS: low order byte	06	
CRC: low order byte	42	
CRC: high order byte	8F	

2. Now that the User Map Addresses have been setup, the required memory map locations can be accessed via the User Map Values #1 to #6 (addresses 0100 to 0105 hex). Both actual values and setpoints may be read.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	03	read register values
DATA STARTING ADDRESS: high order byte	01	data starting at address 0100
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF REGISTERS: high order byte	00	6 setpoint values = 12 bytes total
NUMBER OF REGISTERS: low order byte	06	
CRC: low order byte	C6	
CRC: high order byte	A4	

Field:	Example (hex):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	03	read register values
BYTE COUNT	0C	6 registers values = 12 bytes of data
DATA #1: high order byte	82	Relay Status
DATA #1: low order byte	01	
DATA #2: high order byte	00	W3 Phase Time O/C Flag = not operated
DATA #2: low order byte	01	
DATA #3: high order byte	00	W1 Phase A 4th Harmonic Content = 1% f_0
DATA #3: low order byte	01	
DATA #4: high order byte	00	W1 Phase B 4th Harmonic Content = 1% f_0
DATA #4: low order byte	01	
DATA #5: high order byte	00	W1 Phase C 4th Harmonic Content = 1% f_0
DATA #5: low order byte	01	
DATA #6: high order byte	00	Percent Differential Pickup = 0.30 $\times$ I_d
DATA #6: low order byte	1E	
CRC: low order byte	80	
CRC: high order byte	F1	

3. Setpoints may be written via the user map. In the example above, to change the value of Restrained Differential Pickup to 0.20 x CT through the user map, transmit the following Modbus message:

Master Query Message:	Example (hex):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	06	store single setpoint values
DATA STARTING ADDRESS: high order byte	01	data starting at address 0185
DATA STARTING ADDRESS: low order byte	85	
DATA: high order byte	00	0014 = 0.30 $\times$ I_d
DATA: low order byte	14	
CRC: low order byte	9B	
CRC: high order byte	40	

Field:	Example (hex):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	06	store single setpoint values
DATA STARTING ADDRESS: high order byte	01	data starting at address 0185
DATA STARTING ADDRESS: low order byte	85	
DATA: high order byte	00	0014 = 0.30 $\times$ I_d
DATA: low order byte	14	
CRC: low order byte	9B	
CRC: high order byte	40	

8.2.17 FUNCTION CODE SUBSTITUTIONS

Most 745 supported Modbus commands can be performed via function codes 03h (or 04h), and 10h and special memory map addresses.

a) FUNCTION CODE 03H AND 04 SUBSTITUTIONS

Function codes 03h and 04h are interchangeable. Both have identical message formats, and both perform the same action.

b) FUNCTION CODE 05H SUBSTITUTION

Function code 05h (EXECUTE OPERATION) can be performed by writing the command as if it were data in the memory map.

0080h OPERATION CODE

The message format and example is shown below.

Request slave device 11 to reset targets:

Master Query Message:	Example (hex):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoints (substituted for code 05H)
DATA STARTING ADDRESS: high order byte	00	data starting at address 0080
DATA STARTING ADDRESS: low order byte	80	
NUMBER OF SETPOINTS: high order byte	00	1 register values = 2 bytes total
NUMBER OF SETPOINTS: low order byte	01	
BYTE COUNT	02	2 bytes of data
DATA #1: high order byte	00	0001 = operation code 0001H (reset targets)
DATA #1: low order byte	01	
CRC: low order byte	B5	
CRC: high order byte	90	

Field:	Example (hex):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	10	store multiple setpoints
DATA STARTING ADDRESS: high order byte	00	data starting at address 0080
DATA STARTING ADDRESS: low order byte	80	
NUMBER OF SETPOINTS: high order byte	00	1 setpoint values = 2 bytes total
NUMBER OF SETPOINTS: low order byte	01	
CRC: low order byte	02	
CRC: high order byte	31	

c) FUNCTION CODE 06H SUBSTITUTION

Function code 06h (STORE SINGLE SETPOINT) is simply a shorter version of function code 10h (STORE MULTIPLE SETPOINTS). Using function code 10h, such that the NUMBER OF SETPOINTS stored is 1, has the same effect as function code 06h. The message format and example is shown below.

Request slave device 11 to write the single setpoint value 00C8 at setpoint address 1100.

Master Query Message:	**Example (hex):**	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoints (substituted for code 06H)
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF SETPOINTS: high order byte	00	1 setpoint values = 2 bytes total
NUMBER OF SETPOINTS: low order byte	01	
BYTE COUNT	02	2 bytes of data
DATA #1: high order byte	00	data for address 1100 = 00C8
DATA #1: low order byte	C8	
CRC: low order byte	6B	
CRC: high order byte	07	

Field:	**Example (hex):**	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	00	store multiple setpoint values
DATA STARTING ADDRESS: high order byte	11	data starting at address 1100
DATA STARTING ADDRESS: low order byte	00	
NUMBER OF SETPOINTS: high order byte	00	1 setpoint values = 2 bytes total
NUMBER OF SETPOINTS: low order byte	01	
CRC: low order byte	06	
CRC: high order byte	65	

8.2.18 MEMORY MAP ORGANIZATION

Data in the 745 that is accessible via computer communications is grouped into several sections of the memory map as shown in the table below. All memory map locations are two-byte (16-bit) values. The following section lists all memory map locations. Addresses for all locations are in hexadecimal. Consult the range, step, units, and the data format (listed after the memory map) to interpret the register values.

8

Table 8–5: MEMORY MAP ORGANIZATION

MEMORY MAP SECTION	ADDRESS RANGE	DESCRIPTION
Product ID	0000 to 007F	Identification and revision information. Read only.
Commands	0080 to 00FF	Substitute command locations. Read and write.
User Map	0100 to 01FF	User Map Values and Addresses. Read and write.
Actual Values	0200 to 07FF	Read only.
Event Recorder	0800 to 0FFF	Read only (except "Event Record Selector Index").
Common Setpoints	1000 to 1FFF	Read and write.
Setpoint Group 1/2/3/4	2000 to 3FFF	Read and write.
Trace Memory	4000 to 47FF	Read only (except "Trace Buffer Selector Index" and "Trace Channel Selector Index").
Playback Memory	4800 to 4FFF	Read and write.

8.3.1 745 MEMORY MAP

Table 8–6: 745 MEMORY MAP (Sheet 1 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
Product ID (Addresses 0000 to 007F) - Read Only							
PRODUCT ID	0000	GE Product Device Code	---	---	---	F1	33 = 745
	0001	Hardware Revision	---	---	---	F13	4 = D
	0002	Software Revision	---	---	---	F14	200
	0003	Version Number	000 to 999	001	---	F1	000
	0004	Bootware Revision	000 to 999	001	---	F14	120
	0005	Installed Options	---	---	---	F15	---
	0006	Serial Number (4 registers)	---	---	---	F33	"A0000000"
	000A	Manufacture Date (2 registers)	---	---	---	F23	---
	000C	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	001F	Reserved					
Upgrade Options (Addresses 0020 to 002F) - Read / Write							
MODIFY OPTIONS	0020	New Options	---	---	---	F15	---
	0021	Modify Passcode	---	---	---	F33	---
	0022	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	007F	Reserved					
Commands (Addresses 0080 to 00FF) - Read / Write							
COMMANDS	0080	Command Operation Code	---	---	---	F19	---
	0081	Passcode Access (4 registers)	---	---	---	F33	---
	0085	Change Passcode (4 registers)	---	---	---	F33	---
	0089	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	008F	Reserved					
VIRTUAL INPUTS	0090	Virtual Input 1 Programmed State	---	---	---	F43	0
	0091	Virtual Input 2 Programmed State	---	---	---	F43	0
	0092	Virtual Input 3 Programmed State	---	---	---	F43	0
	0093	Virtual Input 4 Programmed State	---	---	---	F43	0
	0094	Virtual Input 5 Programmed State	---	---	---	F43	0
	0095	Virtual Input 6 Programmed State	---	---	---	F43	0
	0096	Virtual Input 7 Programmed State	---	---	---	F43	0
	0097	Virtual Input 8 Programmed State	---	---	---	F43	0
	0098	Virtual Input 9 Programmed State	---	---	---	F43	0
	0099	Virtual Input 10 Programmed State	---	---	---	F43	0
	009A	Virtual Input 11 Programmed State	---	---	---	F43	0
	009B	Virtual Input 12 Programmed State	---	---	---	F43	0

Table 8–6: 745 MEMORY MAP (Sheet 2 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
VIRTUAL INPUTS continued	009C	Virtual Input 13 Programmed State	---	---	---	F43	0
	009D	Virtual Input 14 Programmed State	---	---	---	F43	0
	009E	Virtual Input 15 Programmed State	---	---	---	F43	0
	009F	Virtual Input 16 Programmed State	---	---	---	F43	0
	00A0	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	00EF	Reserved					
TIME/DATE	00F0	Time (2 registers)	---	---	---	F22	---
	00F2	Date (2 registers)	---	---	---	F23	---
	00F4	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	00FF	Reserved					
User Map (Addresses 0100 to 01FF) - Read / Write							
USER MAP VALUES	0100	User Map Value #1	---	---	---	---	---
	0101	User Map Value #2	---	---	---	---	---
	↓	↓	↓	↓	↓	↓	↓
	0177	User Map Value #120	---	---	---	---	---
	0178	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	017F	Reserved					
USER MAP ADDRESSES	0180	User Map Address #1	0000 to FFFF	0001	hex	F1	0000 hex
	0181	User Map Address #2	0000 to FFFF	0001	hex	F1	0000 hex
	↓	↓	↓	↓	↓	↓	↓
	01F7	User Map Address #120	0000 to FFFF	0001	hex	F1	0000 hex
	01F8	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	01FF	Reserved					
Actual Values (Addresses 0200 to 07FF) - Read Only							
SYSTEM STATUS	0200	Relay Status	---	---	---	F20	---
	0201	System Status	---	---	---	F21	---
	0202	Conditions	---	---	---	F35	---
	0203	Operation Status	---	---	---	F44	---
	0204	Logic Input Status	---	---	---	F49	---
	0205	Output Relay Status	---	---	---	F50	---
	0206	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	0207	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 3 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
ELEMENT FLAGS	0208	Any Element Flag	---	---	---	F52	---
	0209	Any Winding 1 Overcurrent Element Flag	---	---	---	F52	---
	020A	Any Winding 2 Overcurrent Element Flag	---	---	---	F52	---
	020B	Any Winding 3 Overcurrent Element Flag	---	---	---	F52	---
	020C	Percent Differential Flag	---	---	---	F52	---
	020D	Inst Differential Flag	---	---	---	F52	---
	020E	Winding 1 Phase Time O/C Flag	---	---	---	F52	---
	020F	Winding 2 Phase Time O/C Flag	---	---	---	F52	---
	0210	Winding 3 Phase Time O/C Flag	---	---	---	F52	---
	0211	Winding 1 Phase Inst O/C 1 Flag	---	---	---	F52	---
	0212	Winding 2 Phase Inst O/C 1 Flag	---	---	---	F52	---
	0213	Winding 3 Phase Inst O/C 1 Flag	---	---	---	F52	---
	0214	Winding 1 Phase Inst O/C 2 Flag	---	---	---	F52	---
	0215	Winding 2 Phase Inst O/C 2 Flag	---	---	---	F52	---
	0216	Winding 3 Phase Inst O/C 2 Flag	---	---	---	F52	---
	0217	Winding 1 Neutral Time O/C Flag	---	---	---	F52	---
	0218	Winding 2 Neutral Time O/C Flag	---	---	---	F52	---
	0219	Winding 3 Neutral Time O/C Flag	---	---	---	F52	---
	021A	Winding 1 Neutral Inst O/C 1 Flag	---	---	---	F52	---
	021B	Winding 2 Neutral Inst O/C 1 Flag	---	---	---	F52	---
	021C	Winding 3 Neutral Inst O/C 1 Flag	---	---	---	F52	---
	021D	Winding 1 Neutral Inst O/C 2 Flag	---	---	---	F52	---
	021E	Winding 2 Neutral Inst O/C 2 Flag	---	---	---	F52	---
	021F	Winding 3 Neutral Inst O/C 2 Flag	---	---	---	F52	---
	0220	Winding 1 Ground Time O/C Flag	---	---	---	F52	---
	0221	Winding 2 Ground Time O/C Flag	---	---	---	F52	---
	0222	Winding 3 Ground Time O/C Flag	---	---	---	F52	---
	0223	Winding 1 Ground Inst O/C 1 Flag	---	---	---	F52	---
	0224	Winding 2 Ground Inst O/C 1 Flag	---	---	---	F52	---
	0225	Winding 3 Ground Inst O/C 1 Flag	---	---	---	F52	---
	0226	Winding 1 Ground Inst O/C 2 Flag	---	---	---	F52	---
	0227	Winding 2 Ground Inst O/C 2 Flag	---	---	---	F52	---
	0228	Winding 3 Ground Inst O/C 2 Flag	---	---	---	F52	---
	0229	Winding 1 Restricted Ground Time O/C Flag	---	---	---	F52	---
	022A	Winding 2 Restricted Ground Time O/C Flag	---	---	---	F52	---
	022B	Winding 3 Restricted Ground Time O/C Flag	---	---	---	F52	---
	022C	Winding 1 Restricted Ground Inst O/C Flag	---	---	---	F52	---
	022D	Winding 2 Restricted Ground Inst O/C Flag	---	---	---	F52	---

Table 8–6: 745 MEMORY MAP (Sheet 4 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
ELEMENT FLAGS continued	022E	Winding 3 Restricted Ground Inst O/C Flag	---	---	---	F52	---
	022F	Winding 1 Neg Seq Time O/C Flag	---	---	---	F52	---
	0230	Winding 2 Neg Seq Time O/C Flag	---	---	---	F52	---
	0231	Winding 3 Neg Seq Time O/C Flag	---	---	---	F52	---
	0232	Winding 1 Neg Seq Instantaneous O/C Flag	---	---	---	F52	---
	0233	Winding 2 Neg Seq Instantaneous O/C Flag	---	---	---	F52	---
	0234	Winding 3 Neg Seq Instantaneous O/C Flag	---	---	---	F52	---
	0235	Underfrequency 1 Flag	---	---	---	F52	---
	0236	Underfrequency 2 Flag	---	---	---	F52	---
	0237	Frequency Decay Rate 1 Flag	---	---	---	F52	---
	0238	Frequency Decay Rate 2 Flag	---	---	---	F52	---
	0239	Frequency Decay Rate 3 Flag	---	---	---	F52	---
	023A	Frequency Decay Rate 4 Flag	---	---	---	F52	---
	023B	Overfrequency Flag	---	---	---	F52	---
	023C	5th Harmonic Level Flag	---	---	---	F52	---
	023D	Volts-Per-Hertz 1 Flag	---	---	---	F52	---
	023E	Volts-Per-Hertz 2 Flag	---	---	---	F52	---
	023F	Winding 1 THD Level Flag	---	---	---	F52	---
	0240	Winding 2 THD Level Flag	---	---	---	F52	---
	0241	Winding 3 THD Level Flag	---	---	---	F52	---
	0242	Winding 1 Harmonic Derating Flag	---	---	---	F52	---
	0243	Winding 2 Harmonic Derating Flag	---	---	---	F52	---
	0244	Winding 3 Harmonic Derating Flag	---	---	---	F52	---
	0245	Hottest-Spot Temperature Limit Flag	---	---	---	F52	---
	0246	Loss-Of-Life Limit Flag	---	---	---	F52	---
	0247	Analog Input Level 1 Flag	---	---	---	F52	---
	0248	Analog Input Level 2 Flag	---	---	---	F52	---
	0249	Winding 1 Current Demand Flag	---	---	---	F52	---
	024A	Winding 2 Current Demand Flag	---	---	---	F52	---
	024B	Winding 3 Current Demand Flag	---	---	---	F52	---
	024C	Transformer Overload Flag	---	---	---	F52	---
	024D	Aging Factor Limit Flag	---	---	---	F52	---
	024E	Tap Changer Failure Flag	---	---	---	F52	---
	024F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	025F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 5 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
INPUT / OUTPUT FLAGS	0260	Logic Input Assert Flags	---	---	---	F56	---
	0261	Virtual Input Assert Flags	---	---	---	F56	---
	0262	Output Relay Operate Flags	---	---	---	F57	---
	0263	Virtual Output Operate Flags	---	---	---	F59	---
	0264	Timer Operate Flags	---	---	---	F61	---
	0265	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	027F	Reserved					
WINDING 1 CURRENT	0280	Winding 1 Phase A Current - Magnitude	---	---	A	F78	---
	0281	Winding 1 Phase A Current - Angle	0	---	° Lag	F1	---
	0282	Winding 1 Phase B Current - Magnitude	---	---	A	F78	---
	0283	Winding 1 Phase B Current - Angle	0 to 359	1	° Lag	F1	---
	0284	Winding 1 Phase C Current - Magnitude	---	---	A	F78	---
	0285	Winding 1 Phase C Current - Angle	0 to 359	1	° Lag	F1	---
	0286	Winding 1 Neutral Current - Magnitude	---	---	A	F78	---
	0287	Winding 1 Neutral Current - Angle	0 to 359	1	° Lag	F1	---
	0288	Winding 1 Ground Current - Magnitude	---	---	A	F81	---
	0289	Winding 1 Ground Current - Angle	0 to 359	1	° Lag	F1	---
	028A	Winding 1 Loading	0 to 999	1	% rated	F1	---
	028B	Winding 1 Ave. Phase Current	---	---	A	F78	---
	028C	Reserved					
	028F	Reserved					
WINDING 2 CURRENT	0290	Winding 2 Phase A Current - Magnitude	---	---	A	F79	---
	0291	Winding 2 Phase A Current - Angle	0 to 359	1	° Lag	F1	---
	0292	Winding 2 Phase B Current - Magnitude	---	---	A	F79	---
	0293	Winding 2 Phase B Current - Angle	0 to 359	1	° Lag	F1	---
	0294	Winding 2 Phase C Current - Magnitude	---	---	A	F79	---
	0295	Winding 2 Phase C Current - Angle	0 to 359	1	° Lag	F1	---
	0296	Winding 2 Neutral Current - Magnitude	---	---	A	F79	---
	0297	Winding 2 Neutral Current - Angle	0 to 359	1	° Lag	F1	---
	0298	Winding 2 Ground Current - Magnitude	---	---	A	F82	---
	0299	Winding 2 Ground Current - Angle	0 to 359	1	° Lag	F1	---
	029A	Winding 2 Loading	0 to 999	1	% rated	F1	---
	029B	Winding 2 Ave. Phase Current	---	---	A	F79	---
	029C	Reserved					
	029F	Reserved					

8

Table 8–6: 745 MEMORY MAP (Sheet 6 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 3 CURRENT	02A0	Winding 3 Phase A Current - Magnitude	---	---	A	F80	---
	02A1	Winding 3 Phase A Current - Angle	0 to 359	1	° Lag	F1	---
	02A2	Winding 3 Phase B Current - Magnitude	---	---	A	F80	---
	02A3	Winding 3 Phase B Current - Angle	0 to 359	1	° Lag	F1	---
	02A4	Winding 3 Phase C Current - Magnitude	---	---	A	F80	---
	02A5	Winding 3 Phase C Current - Angle	0 to 359	1	° Lag	F1	---
	02A6	Winding 3 Neutral Current - Magnitude	---	---	A	F80	---
	02A7	Winding 3 Neutral Current - Angle	0 to 359	1	° Lag	F1	---
	02A8	Winding 3 Ground Current - Magnitude	---	---	A	F83	---
	02A9	Winding 3 Ground Current - Angle	0 to 359	1	° Lag	F1	---
	02AA	Winding 3 Loading	0 to 999	1	% rated	F1	---
	02AB	Winding 3 Ave. Phase Current	---	---	A	F80	---
	02AC	Reserved					
	02AF	Reserved					
SEQUENCE CURRENTS	02B0	Winding 1 Positive Sequence Current Magnitude	---	---	A	F78	---
	02B1	Winding 1 Positive Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02B2	Winding 2 Positive Sequence Current Magnitude	---	---	A	F79	---
	02B3	Winding 2 Positive Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02B4	Winding 3 Positive Sequence Current Magnitude	---	---	A	F80	---
	02B5	Winding 3 Positive Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02B6	Winding 1 Negative Sequence Current Magnitude	---	---	A	F78	---
	02B7	Winding 1 Negative Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02B8	Winding 2 Negative Sequence Current Magnitude	---	---	A	F79	---
	02B9	Winding 2 Negative Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02BA	Winding 3 Negative Sequence Current Magnitude	---	---	A	F80	---
	02BB	Winding 3 Negative Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02BC	Winding 1 Zero Sequence Current Magnitude	---	---	A	F78	---
	02BD	Winding 1 Zero Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02BE	Winding 2 Zero Sequence Current Magnitude	---	---	A	F79	---
	02BF	Winding 2 Zero Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02C0	Winding 3 Zero Sequence Current Magnitude	---	---	A	F80	---
	02C1	Winding 3 Zero Sequence Current Angle	0 to 359	1	° Lag	F1	---
	02C2	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	02CF	Reserved					
DIFFERENTIAL CURRENT	02D0	Phase A Differential Current - Magnitude	0.00 to 655.35	0.01	x CT	F3	---
	02D1	Phase A Differential Current - Angle	0 to 359	1	° Lag	F1	---
	02D2	Phase B Differential Current - Magnitude	0.00 to 655.35	0.01	x CT	F3	---

8

Table 8–6: 745 MEMORY MAP (Sheet 7 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
DIFFERENTIAL CURRENT continued	02D3	Phase B Differential Current - Angle	0 to 359	1	° Lag	F1	---
	02D4	Phase C Differential Current - Magnitude	0.00 to 655.35	0.01	x CT	F3	---
	02D5	Phase C Differential Current - Angle	0 to 359	1	° Lag	F1	---
RESTRAINT CURRENT	02D6	Phase A Restraint Current	0.00 to 655.35	0.01	x CT	F3	---
	02D7	Phase B Restraint Current	0.00 to 655.35	0.01	x CT	F3	---
	02D8	Phase C Restraint Current	0.00 to 655.35	0.01	x CT	F3	---
GROUND DIFFERENTIAL CURRENT	02D9	Winding 1 Ground Differential Current	0.000 to 65.535	0.001	x CT	F53	---
	02DA	Winding 2 Ground Differential Current	0.000 to 65.535	0.001	x CT	F53	---
	02DB	Winding 3 Ground Differential Current	0.000 to 65.535	0.001	x CT	F53	---
	02DC	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	02DF	Reserved					
2ND HARMONIC	02E0	Winding 1 Phase A 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E1	Winding 1 Phase B 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E2	Winding 1 Phase C 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E3	Winding 2 Phase A 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E4	Winding 2 Phase B 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E5	Winding 2 Phase C 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E6	Winding 3 Phase A 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E7	Winding 3 Phase B 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E8	Winding 3 Phase C 2nd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02E9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	02EF	Reserved					
3RD HARMONIC	02F0	Winding 1 Phase A 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F1	Winding 1 Phase B 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F2	Winding 1 Phase C 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F3	Winding 2 Phase A 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F4	Winding 2 Phase B 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F5	Winding 2 Phase C 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F6	Winding 3 Phase A 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F7	Winding 3 Phase B 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F8	Winding 3 Phase C 3rd Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	02F9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	02FF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 8 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
4TH HARMONIC	0300	Winding 1 Phase A 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0301	Winding 1 Phase B 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0302	Winding 1 Phase C 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0303	Winding 2 Phase A 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0304	Winding 2 Phase B 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0305	Winding 2 Phase C 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0306	Winding 3 Phase A 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0307	Winding 3 Phase B 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0308	Winding 3 Phase C 4th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0309	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	030F	Reserved					
5TH HARMONIC	0310	Winding 1 Phase A 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0311	Winding 1 Phase B 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0312	Winding 1 Phase C 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0313	Winding 2 Phase A 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0314	Winding 2 Phase B 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0315	Winding 2 Phase C 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0316	Winding 3 Phase A 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0317	Winding 3 Phase B 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0318	Winding 3 Phase C 5th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0319	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	031F	Reserved					
6TH HARMONIC	0320	Winding 1 Phase A 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0321	Winding 1 Phase B 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0322	Winding 1 Phase C 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0323	Winding 2 Phase A 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0324	Winding 2 Phase B 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0325	Winding 2 Phase C 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0326	Winding 3 Phase A 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0327	Winding 3 Phase B 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0328	Winding 3 Phase C 6th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0329	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	032F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 9 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
7TH HARMONIC	0330	Winding 1 Phase A 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0331	Winding 1 Phase B 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0332	Winding 1 Phase C 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0333	Winding 2 Phase A 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0334	Winding 2 Phase B 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0335	Winding 2 Phase C 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0336	Winding 3 Phase A 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0337	Winding 3 Phase B 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0338	Winding 3 Phase C 7th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0339	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	033F	Reserved					
8TH HARMONIC	0340	Winding 1 Phase A 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0341	Winding 1 Phase B 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0342	Winding 1 Phase C 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0343	Winding 2 Phase A 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0344	Winding 2 Phase B 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0345	Winding 2 Phase C 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0346	Winding 3 Phase A 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0347	Winding 3 Phase B 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0348	Winding 3 Phase C 8th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0349	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	034F	Reserved					
9TH HARMONIC	0350	Winding 1 Phase A 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0351	Winding 1 Phase B 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0352	Winding 1 Phase C 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0353	Winding 2 Phase A 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0354	Winding 2 Phase B 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0355	Winding 2 Phase C 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0356	Winding 3 Phase A 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0357	Winding 3 Phase B 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0358	Winding 3 Phase C 9th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0359	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	035F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 10 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
10TH HARMONIC	0360	Winding 1 Phase A 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0361	Winding 1 Phase B 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0362	Winding 1 Phase C 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0363	Winding 2 Phase A 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0364	Winding 2 Phase B 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0365	Winding 2 Phase C 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0366	Winding 3 Phase A 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0367	Winding 3 Phase B 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0368	Winding 3 Phase C 10th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0369	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	036F	Reserved					
11TH HARMONIC	0370	Winding 1 Phase A 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0371	Winding 1 Phase B 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0372	Winding 1 Phase C 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0373	Winding 2 Phase A 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0374	Winding 2 Phase B 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0375	Winding 2 Phase C 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0376	Winding 3 Phase A 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0377	Winding 3 Phase B 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0378	Winding 3 Phase C 11th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0379	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	037F	Reserved					
12TH HARMONIC	0380	Winding 1 Phase A 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0381	Winding 1 Phase B 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0382	Winding 1 Phase C 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0383	Winding 2 Phase A 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0384	Winding 2 Phase B 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0385	Winding 2 Phase C 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0386	Winding 3 Phase A 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0387	Winding 3 Phase B 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0388	Winding 3 Phase C 12th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	0389	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	038F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 11 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
13TH HARMONIC	0390	Winding 1 Phase A 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0391	Winding 1 Phase B 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0392	Winding 1 Phase C 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0393	Winding 2 Phase A 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0394	Winding 2 Phase B 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0395	Winding 2 Phase C 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0396	Winding 3 Phase A 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0397	Winding 3 Phase B 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0398	Winding 3 Phase C 13th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0399	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	039F	Reserved					
14TH HARMONIC	03A0	Winding 1 Phase A 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A1	Winding 1 Phase B 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A2	Winding 1 Phase C 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A3	Winding 2 Phase A 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A4	Winding 2 Phase B 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A5	Winding 2 Phase C 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A6	Winding 3 Phase A 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A7	Winding 3 Phase B 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A8	Winding 3 Phase C 14th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03A9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03AF	Reserved					
15TH HARMONIC	03B0	Winding 1 Phase A 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B1	Winding 1 Phase B 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B2	Winding 1 Phase C 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B3	Winding 2 Phase A 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B4	Winding 2 Phase B 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B5	Winding 2 Phase C 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B6	Winding 3 Phase A 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B7	Winding 3 Phase B 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B8	Winding 3 Phase C 15th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03B9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03BF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 12 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
16TH HARMONIC	03C0	Winding 1 Phase A 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C1	Winding 1 Phase B 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C2	Winding 1 Phase C 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C3	Winding 2 Phase A 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C4	Winding 2 Phase B 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C5	Winding 2 Phase C 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C6	Winding 3 Phase A 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C7	Winding 3 Phase B 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C8	Winding 3 Phase C 16th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03C9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03CF	Reserved					
17TH HARMONIC	03D0	Winding 1 Phase A 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D1	Winding 1 Phase B 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D2	Winding 1 Phase C 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D3	Winding 2 Phase A 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D4	Winding 2 Phase B 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D5	Winding 2 Phase C 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D6	Winding 3 Phase A 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D7	Winding 3 Phase B 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D8	Winding 3 Phase C 17th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03D9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03DF	Reserved					
18TH HARMONIC	03E0	Winding 1 Phase A 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E1	Winding 1 Phase B 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E2	Winding 1 Phase C 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E3	Winding 2 Phase A 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E4	Winding 2 Phase B 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E5	Winding 2 Phase C 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E6	Winding 3 Phase A 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E7	Winding 3 Phase B 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E8	Winding 3 Phase C 18th Harmonic Content	0.0 to 99.9	0.1	% *fo*	F2	---
	03E9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03EF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 13 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
19TH HARMONIC	03F0	Winding 1 Phase A 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F1	Winding 1 Phase B 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F2	Winding 1 Phase C 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F3	Winding 2 Phase A 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F4	Winding 2 Phase B 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F5	Winding 2 Phase C 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F6	Winding 3 Phase A 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F7	Winding 3 Phase B 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F8	Winding 3 Phase C 19th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	03F9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	03FF	Reserved					
20TH HARMONIC	0400	Winding 1 Phase A 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0401	Winding 1 Phase B 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0402	Winding 1 Phase C 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0403	Winding 2 Phase A 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0404	Winding 2 Phase B 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0405	Winding 2 Phase C 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0406	Winding 3 Phase A 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0407	Winding 3 Phase B 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0408	Winding 3 Phase C 20th Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0409	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	040F	Reserved					
21ST HARMONIC	0410	Winding 1 Phase A 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0411	Winding 1 Phase B 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0412	Winding 1 Phase C 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0413	Winding 2 Phase A 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0414	Winding 2 Phase B 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0415	Winding 2 Phase C 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0416	Winding 3 Phase A 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0417	Winding 3 Phase B 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0418	Winding 3 Phase C 21st Harmonic Content	0.0 to 99.9	0.1	% ƒo	F2	---
	0419	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	041F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 14 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
TOTAL HARMONIC DISTORTION	0420	Winding 1 Phase A Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0421	Winding 1 Phase B Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0422	Winding 1 Phase C Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0423	Winding 2 Phase A Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0424	Winding 2 Phase B Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0425	Winding 2 Phase C Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0426	Winding 3 Phase A Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0427	Winding 3 Phase B Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0428	Winding 3 Phase C Total Harmonic Distortion	0.0 to 99.9	0.1	% ƒo	F2	---
	0429	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	042F	Reserved					
HARMONIC DERATING	0430	Winding 1 Harmonic Derating Factor	0.00 to 1.00	0.01	---	F3	---
	0431	Winding 2 Harmonic Derating Factor	0.00 to 1.00	0.01	---	F3	---
	0432	Winding 3 Harmonic Derating Factor	0.00 to 1.00	0.01	---	F3	---
	0433	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	043F	Reserved					
FREQUENCY	0440	System Frequency	0.00 to 99.99	0.01	Hz	F3	---
	0441	Frequency Decay Rate	–9.99 to 9.99	0.01	Hz/s	F6	---
	0442	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	0444	Reserved					
TAP CHANGER	0445	Tap Changer Position	1 to 50	1	---	F1	---
	0446	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	0448	Reserved					
VOLTAGE	0449	System Line-to-Line Voltage	0.00 to 600.00	0.01	kV	F3	---
	044A	Volts-per-Hertz	0.00 to 4.00	0.01	V/Hz	F3	---
	044B	Line-to-Ntrl Voltage - Magnitude	0.00 to 600.00	0.01	kV	F3	---
	044C	Line-to-Ntrl Voltage - Angle	0 to 359	1	° Lag	F1	
	044D	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	044F	Reserved					
CURRENT DEMAND	0450	Demand Data Last Clear Date (2 registers)	---	---	---	F23	---
	0452	Demand Data Last Clear Time (2 registers)	---	---	---	F22	---
	0454	Winding 1 Phase A Current Demand	---	---	A	F78	---
	0455	Winding 1 Phase B Current Demand	---	---	A	F78	---

8

Table 8–6: 745 MEMORY MAP (Sheet 15 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
CURRENT DEMAND continued	0456	Winding 1 Phase C Current Demand	---	---	A	F78	---
	0457	Winding 1 Max Current Demand	---	---	A	F78	0 A
	0458	Winding 1 Max Current Demand Phase	---	---	---	F18	0 = phase A
	0459	Wdg 1 Max Current Demand Date (2 registers)	---	---	---	F23	Jan 01 1996
	045B	Wdg 1 Max Current Demand Time (2 registers)	---	---	---	F22	00:00:00.000
	045D	Winding 2 Phase A Current Demand	---	---	A	F79	---
	045E	Winding 2 Phase B Current Demand	---	---	A	F79	---
	045F	Winding 2 Phase C Current Demand	---	---	A	F79	---
	0460	Winding 2 Max Current Demand	---	---	A	F79	0 A
	0461	Winding 2 Max Current Demand Phase	---	---	---	F18	0 = phase A
	0462	Wdg 2 Max Current Demand Date (2 registers)	---	---	---	F23	Jan 01 1996
	0464	Wdg 2 Max Current Demand Time (2 registers)	---	---	---	F22	00:00:00.000
	0466	Winding 3 Phase A Current Demand	---	---	A	F80	---
	0467	Winding 3 Phase B Current Demand	---	---	A	F80	---
	0468	Winding 3 Phase C Current Demand	---	---	A	F80	---
	0469	Winding 3 Max Current Demand	---	---	A	F80	0 A
	046A	Winding 3 Max Current Demand Phase	---	---	---	F18	0 = phase A
	046B	Wdg 3 Max Current Demand Date (2 registers)	---	---	---	F23	Jan 01 1996
	046D	Wdg 3 Max Current Demand Time (2 registers)	---	---	---	F22	00:00:00.000
	046F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	0477	Reserved					
AMBIENT TEMP	0478	Ambient Temperature	–51 to 251	1	°C	F4	---
	0479	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	047F	Reserved					
LOSS-OF-LIFE	0480	Hottest-spot Winding Temperature	–50 to 300	1	°C	F4	---
	0481	Total Accumulated Loss-of-Life (2 registers)	0 to 200000	1	hours	F7	0 hours
	0483	Aging Factor	0.0 to 2000.0	0.1	-	F2	-
	↓	↓	↓	↓	↓	↓	↓
	0487	Reserved					
ANALOG INPUT	0488	Analog Input	0 to 65000	1	<Units>	F1	---
	0489	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	048F	Reserved					
POWER	0490	W1 Real Power	–32000 to 32000	---	MW	F93	---
	0491	W1 Reactive Power	–32000 to 32000	---	Mvar	F93	---
	0492	W1 Apparent Power	0 to 32000	---	MVA	F93	---

8

Table 8–6: 745 MEMORY MAP (Sheet 16 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
POWER continued	0493	W1 Power Factor	–0.00 to 1.00	0.01	---	F3	---
	0494	W2 Real Power	–32000 to 32000	---	MW	F94	---
	0495	W2 Reactive Power	–32000 to 32000	---	Mvar	F94	---
	0496	W2 Apparent Power	0 to 32000	---	MVA	F94	---
	0497	W2 Power Factor	–0.00 to 1.00	0.01	---	F3	---
	0498	W3 Real Power	–32000 to 32000	---	MW	F95	---
	0499	W3 Reactive Power	–32000 to 32000	---	Mvar	F95	---
	049A	W3 Apparent Power	0 to 32000	---	MVA	F95	---
	049B	W3 Power Factor	–0.00 to 1.00	0.01	---	F3	---
ENERGY	0500	Energy Clear Date	---	---	---	F23	---
	0502	Energy Clear Time	---	---	---	F22	---
	0504	W1 Source Watthours	---	---	MWh	F96	---
	0506	W1 Load Watthours	---	---	MWh	F96	---
	0508	W1 Source Varhours	---	---	Mvarh	F96	---
	050A	W1 Load Varhours	---	---	Mvarh	F96	---
	050C	W2 Source Watthours	---	---	MWh	F97	---
	050E	W2 Load Watthours	---	---	MWh	F97	---
	0510	W2 Source Varhours	---	---	Mvarh	F97	---
	0512	W2 Load Varhours	---	---	Mvarh	F97	---
	0514	W3 Source Watthours	---	---	MWh	F98	---
	0516	W3 Load Watthours	---	---	MWh	F98	---
	0518	W3 Source Varhours	---	---	Mvarh	F98	---
	051A	W3 Load Varhours	---	---	Mvarh	F98	---
	07FF	Reserved					
Event Recorder (Addresses 0800 to 0FFF) - Read Only							
EVENT RECORDER	0800	Event Recorder Last Clear Date (2 registers)	---	---	---	F23	---
	0802	Event Recorder Last Clear Time (2 registers)	---	---	---	F22	---
	0804	Total Number of Events Since Last Clear	0 to 65535	1	---	F1	0
	0805	Event Record Selector Index (XX) [read/write]	1 to 65535	1	---	F1	1 = Event 1
	0806	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	080F	Reserved					
MAXIMUM EVENT CURRENT	0810	Maximum Event Winding 1 Phase A Current	---	---	A	F78	0 A
	0811	Maximum Event Winding 1 Phase B Current	---	---	A	F78	0 A
	0812	Maximum Event Winding 1 Phase C Current	---	---	A	F78	0 A
	0813	Maximum Event Winding 1 Ground Current	---	---	A	F81	0 A
	0814	Maximum Event Winding 2 Phase A Current	---	---	A	F79	0 A
	0815	Maximum Event Winding 2 Phase B Current	---	---	A	F79	0 A

Table 8–6: 745 MEMORY MAP (Sheet 17 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
MAXIMUM EVENT CURRENT continued	0816	Maximum Event Winding 2 Phase C Current	---	---	A	F79	0 A
	0817	Maximum Event Winding 2 Ground Current	---	---	A	F82	0 A
	0818	Maximum Event Winding 3 Phase A Current	---	---	A	F80	0 A
	0819	Maximum Event Winding 3 Phase B Current	---	---	A	F80	0 A
	081A	Maximum Event Winding 3 Phase C Current	---	---	A	F80	0 A
	081B	Maximum Event Winding 3 Ground Current	---	---	A	F83	0 A
	081C	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	082F	Reserved					
EVENT RECORDER DATA	0830	Event XX Date of Event (2 registers)	---	---	---	F23	---
	0832	Event XX Time of Event (2 registers)	---	---	---	F22	---
	0834	Event XX Cause of Event	---	---	---	F24	---
	0835	Event XX Winding 1 Phase A Current Magnitude	---	---	A	F78	0 A
	0836	Event XX Winding 1 Phase A Current Angle	0	---	° Lag	F1	0° Lag
	0837	Event XX Winding 1 Phase B Current Magnitude	---	---	A	F78	0 A
	0838	Event XX Winding 1 Phase B Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0839	Event XX Winding 1 Phase C Current Magnitude	---	---	A	F78	0 A
	083A	Event XX Winding 1 Phase C Current Angle	0 to 359	1	° Lag	F1	0° Lag
	083B	Event XX Winding 1 Ground Current Magnitude	---	---	A	F81	0 A
	083C	Event XX Winding 1 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	083D	Event XX Winding 1 Phase A 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	083E	Event XX Winding 1 Phase B 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	083F	Event XX Winding 1 Phase C 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	0840	Event XX Winding 1 Phase A 5th Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	0841	Event XX Winding 1 Phase B 5th Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	0842	Event XX Winding 1 Phase C 5th Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	0843	Event XX Winding 2 Phase A Current Magnitude	---	---	A	F79	0 A
	0844	Event XX Winding 2 Phase A Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0845	Event XX Winding 2 Phase B Current Magnitude	---	---	A	F79	0 A
	0846	Event XX Winding 2 Phase B Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0847	Event XX Winding 2 Phase C Current Magnitude	---	---	A	F79	0 A
	0848	Event XX Winding 2 Phase C Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0849	Event XX Winding 2 Ground Current Magnitude	---	---	A	F82	0 A
	084A	Event XX Winding 2 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	084B	Event XX Winding 2 Phase A 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	084C	Event XX Winding 2 Phase B 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	084D	Event XX Winding 2 Phase C 2nd Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*
	084E	Event XX Winding 2 Phase A 5th Harmonic	0.0 to 99.9	0.1	% *fo*	F2	0% *fo*

Table 8–6: 745 MEMORY MAP (Sheet 18 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
EVENT RECORDER DATA continued	084F	Event XX Winding 2 Phase B 5th Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	0850	Event XX Winding 2 Phase C 5th Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	0851	Event XX Winding 3 Phase A Current Magnitude	---	---	A	F80	0 A
	0852	Event XX Winding 3 Phase A Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0853	Event XX Winding 3 Phase B Current Magnitude	---	---	A	F80	0 A
	0854	Event XX Winding 3 Phase B Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0855	Event XX Winding 3 Phase C Current Magnitude	---	---	A	F80	0 A
	0856	Event XX Winding 3 Phase C Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0857	Event XX Winding 3 Ground Current Magnitude	---	---	A	F83	0 A
	0858	Event XX Winding 3 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	0859	Event XX Winding 3 Phase A 2nd Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085A	Event XX Winding 3 Phase B 2nd Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085B	Event XX Winding 3 Phase C 2nd Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085C	Event XX Winding 3 Phase A 5th Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085D	Event XX Winding 3 Phase B 5th Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085E	Event XX Winding 3 Phase C 5th Harmonic	0.0 to 99.9	0.1	% ƒo	F2	0% ƒo
	085F	Event XX Phase A Differential Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0860	Event XX Phase B Differential Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0861	Event XX Phase C Differential Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0862	Event XX Phase A Restraint Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0863	Event XX Phase B Restraint Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0864	Event XX Phase C Restraint Current	0.00 to 655.35	0.01	× CT	F3	0.00 × CT
	0865	Event XX System Frequency	0.00 to 99.99	0.01	Hz	F3	0.00 Hz
	0866	Event XX Frequency Decay Rate	–9.99 to 9.99	0.01	Hz/s	F6	0.00 Hz/s
	0867	Event XX Tap Changer Position	1 to 50	1	---	F1	0 = n/a
	0868	Event XX Volts-per-Hertz	0.00 to 4.00	0.01	V/Hz	F3	0.00 V/Hz
	0869	Event XX Ambient Temperature	–51 to 251	1	°C	F4	0 °C
	086A	Event XX Analog Input	0 to 65000	1	<Units>	F1	0 <Units>
	086B	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	0FFF	Reserved					
Common Setpoints (Addresses 1000 to 1FFF) - Read / Write							
745 SETUP	1000	745 Setpoints	---	---	---	F29	0 = Not Prog'd
	1001	Encrypted Passcode (4 registers) [read only]	---	---	---	F33	"AIKFBAIK"
	1005	Beeper	---	---	---	F30	1 = Enabled
	1006	Flash Message Time	0.5 to 10.0	0.5	s	F2	40 = 4.0 s
	1007	Default Message Timeout	10 to 900	1	s	F1	300 s
	1008	Default Message Intensity	0 to 100	25	%	F1	25%

8

Table 8–6: 745 MEMORY MAP (Sheet 19 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
745 SETUP continued	1009	Slave Address	1 to 254	1	---	F1	254
	100A	COM1 Baud Rate	---	---	---	F31	5 = 19200 Bd
	100B	COM1 Parity	---	---	---	F73	0 = None
	100C	COM1 Communication Hardware	---	---	---	F17	0 = RS485
	100D	COM2 Baud Rate	---	---	---	F31	5 = 19200 Bd
	100E	COM2 Parity	---	---	---	F73	0 = None
	100F	Front Port Baud Rate	---	---	---	F31	5 = 19200 Bd
	1010	Front Port Parity	---	---	---	F73	0 = None
	1011	Local Reset Block	---	---	---	F87	0 = Disabled
	1012	Remote Reset Signal	---	---	---	F88	0 = Disabled
	1013	IRIG-B Signal Type	---	---	---	F84	0 = None
	1014	Active Setpoint Group	---	---	---	F60	0 = Group 1
	1015	Edit Setpoint Group	---	---	---	F74	4 = Active Grp
	1016	Setpoint Group 2 Activate Signal	---	---	---	F88	0 = Disabled
	1017	Setpoint Group 3 Activate Signal	---	---	---	F88	0 = Disabled
	1018	Setpoint Group 4 Activate Signal	---	---	---	F88	0 = Disabled
	1019	Clear Event Recorder Signal	---	---	---	F88	0 = Disabled
	101A	DNP port	---	---	---	F99	0=None
	101B	Reserved					
	101F	Reserved					
DEFAULT MESSAGES	1020	No. Of Default Messages Selected [read only]	0 to 30	1	---	F1	1
	1021	Default Message #1 (2 registers)	---	---	---	F32	---
	1023	Default Message #2 (2 registers)	---	---	---	F32	---
	1025	Default Message #3 (2 registers)	---	---	---	F32	---
	1027	Default Message #4 (2 registers)	---	---	---	F32	---
	1029	Default Message #5 (2 registers)	---	---	---	F32	---
	102B	Default Message #6 (2 registers)	---	---	---	F32	---
	102D	Default Message #7 (2 registers)	---	---	---	F32	---
	102F	Default Message #8 (2 registers)	---	---	---	F32	---
	1031	Default Message #9 (2 registers)	---	---	---	F32	---
	1033	Default Message #10 (2 registers)	---	---	---	F32	---
	1035	Default Message #11 (2 registers)	---	---	---	F32	---
	1037	Default Message #12 (2 registers)	---	---	---	F32	---
	1039	Default Message #13 (2 registers)	---	---	---	F32	---
	103B	Default Message #14 (2 registers)	---	---	---	F32	---
	103D	Default Message #15 (2 registers)	---	---	---	F32	---
	103F	Default Message #16 (2 registers)	---	---	---	F32	---
	1041	Default Message #17 (2 registers)	---	---	---	F32	---

Table 8–6: 745 MEMORY MAP (Sheet 20 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
DEFAULT MESSAGES continued	1043	Default Message #18 (2 registers)	---	---	---	F32	---
	1045	Default Message #19 (2 registers)	---	---	---	F32	---
	1047	Default Message #20 (2 registers)	---	---	---	F32	---
	1049	Default Message #21 (2 registers)	---	---	---	F32	---
	104B	Default Message #22 (2 registers)	---	---	---	F32	---
	104D	Default Message #23 (2 registers)	---	---	---	F32	---
	104F	Default Message #24 (2 registers)	---	---	---	F32	---
	1051	Default Message #25 (2 registers)	---	---	---	F32	---
	1053	Default Message #26 (2 registers)	---	---	---	F32	---
	1055	Default Message #27 (2 registers)	---	---	---	F32	---
	1057	Default Message #28 (2 registers)	---	---	---	F32	---
	1059	Default Message #29 (2 registers)	---	---	---	F32	---
	105B	Default Message #30 (2 registers)	---	---	---	F32	---
	105D	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	105F	Reserved					
SCRATCHPAD	1060	Scratchpad Message 1 (20 registers)	---	---	---	F33	"Text 1"
	1074	Scratchpad Message 2 (20 registers)	---	---	---	F33	"Text 2"
	1088	Scratchpad Message 3 (20 registers)	---	---	---	F33	"Text 3"
	109C	Scratchpad Message 4 (20 registers)	---	---	---	F33	"Text 4"
	10B0	Scratchpad Message 5 (20 registers)	---	---	---	F33	"Text 5"
	10C4	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	10CF	Reserved					
DNP	10D0	Port Used For DNP	---	---	---	F99	0 = None
	10D1	Include User Map Points (Point Mapping)	---	---	---	F30	1 = Enabled
	10D2	Transmission Delay	0 to 65000	1	ms	F1	0 ms
	10D3	Data Link Confirmation Mode	---	---	---	F102	0 = Never
	10D4	Data Link Confirmation Timeout	1 to 65000	1	ms	F1	1000 ms
	10D5	Data Link Confirmation Retries	0 to 100	1	---	F1	3
	10D6	Select/Operate Arm Timer Duration	1 to 65000	1	ms	F1	10000 ms
	10D7	Write Time Interval	0 to 65000	1	ms	F1	0 ms
	10D8	Inhibit Cold Restart	---	---	---	F30	0 = Disabled
	10D9	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	10FF	Reserved					
TRANSFORMER	1100	Nominal Frequency	50 to 60	10	Hz	F1	60 Hz
	1101	Phase Sequence	---	---	---	F27	0 = ABC

8

Table 8–6: 745 MEMORY MAP (Sheet 21 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
TRANSFORMER continued	1102	Transformer Type	---	---	---	F28	3 = Y/d30°
	1103	Rated Winding Temperature Rise	---	---	---	F37	1 = 65°C (oil)
	1104	Type of Cooling: Oil Immersed	---	---	---	F39	0 = 0A
	1105	Load Loss at Rated Load (2 registers)	1 to 20000	1	kW	F101	1250 kW
	1107	No-Load Loss	0.1 to 2000	0.1	kW	F90	1250=125.0 kW
	1108	Top Oil Rise Over Ambient (at rated load)	1 to 200	1	°C	F1	10°C
	1109	Transformer Thermal Capacity	0.00 to 200.00	0.01	kWh/°C	F3	100=1.00 kWh/°C
	110A	Winding Time Constant: Oil-Immersed	0.25 to 15.00	0.01	minutes	F3	200 = 2.00 min
	110B	Type of Cooling: Dry	-	-	-	F100	0=sealed self-cooled
	110C	Thermal Time Constant: Dry	0.25 to 15.00	0.01	minutes	F3	200 = 2.00 min
	110D	Set Initial Accumulated Loss of Life	0 to 20000	1	hrs x 10	F1	0 hours
	110E	Frequency Tracking	---	---	---	F30	1 = Enabled
	110F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	111F	Reserved					
WINDING 1	1120	Winding 1 Nominal Phase-to-Phase Voltage	1 to 20000	---	kV	F90	220.0 kV
	1121	Winding 1 Rated Load	1 to 20000	---	MVA	F90	1000 = 100 MVA
	1122	Winding 1 Phase CT Primary	1 to 50000	1	:1 or :5 A	F1	500 A
	1123	Winding 1 Ground CT Primary	1 to 50000	1	:1 or :5 A	F1	500 A
	1124	Winding 1 Series 3-Phase Resistance	0.001 to 50.000	0.001	Ω	F53	10700 = 10.7 Ω
	1125	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	112F	Reserved					
WINDING 2	1130	Winding 2 Nominal Phase-to-Phase Voltage	1 to 20000	---	kV	F90	690 = 69.0 kV
	1131	Winding 2 Rated Load	1 to 20000	---	MVA	F90	1000 = 100 MVA
	1132	Winding 2 Phase CT Primary	1 to 50000	1	:1 or :5 A	F1	1500 A
	1133	Winding 2 Ground CT Primary	1 to 50000	1	:1 or :5 A	F1	1500 A
	1134	Winding 2 Series 3-Phase Resistance	0.001 to 50.000	0.001	Ω	F53	2100 = 2.100 Ω
	1135	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	113F	Reserved					
WINDING 3	1140	Winding 3 Nominal Phase-to-Phase Voltage	1 to 20000	---	kV	F90	690 = 69.0 kV
	1141	Winding 3 Rated Load	1 to 20000	---	MVA	F90	1000 = 100 MVA
	1142	Winding 3 Phase CT Primary	1 to 50000	1	:1 or :5 A	F1	1500 A
	1143	Winding 3 Ground CT Primary	1 to 50000	1	:1 or :5 A	F1	1500 A
	1144	Winding 3 Series 3-Phase Resistance	0.001 to 50.000	0.001	Ω	F53	2100 = 2.100 Ω
	1145	Reserved					
	↓	↓	↓	↓	↓	↓	↓

Table 8–6: 745 MEMORY MAP (Sheet 22 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
	115F	Reserved					
ONLOAD TAP CHANGER	1160	Winding With Tap Changer	---	---	---	F40	0 = None
	1161	Number of Tap Positions	2 to 50	1	---	F1	33
	1162	Minimum Tap Position Voltage	1 to 20000	---	kV	F90	610 = 61.0 kV
	1163	Voltage Increment Per Tap	1 to 2000	---	kV	F91	50 = 0.50 kV
	1164	Resistance Increment Per Tap	10 to 500	1	Ω	F1	33 = 33 Ω
	1165	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1167	Reserved					
HARMONICS	1168	Harmonic Derating Estimation	---	---	---	F30	0 = Disabled
	1169	THD Minimum Harmonic Number	---	---	---	F92	0 = 2nd
	116A	THD Maximum Harmonic Number	---	---	---	F92	19 = 21st
	116B	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	116F	Reserved					
FLEXCURVES	1170	FlexCurve A Delay at 1.03 × PKP	0 to 65000	1	ms	F1	0 ms
	1171	FlexCurve A Delay at 1.05 × PKP	0 to 65000	1	ms	F1	0 ms
	1172	FlexCurve A Delay at 1.10 × PKP	0 to 65000	1	ms	F1	0 ms
	1173	FlexCurve A Delay at 1.20 × PKP	0 to 65000	1	ms	F1	0 ms
	1174	FlexCurve A Delay at 1.30 × PKP	0 to 65000	1	ms	F1	0 ms
	1175	FlexCurve A Delay at 1.40 × PKP	0 to 65000	1	ms	F1	0 ms
	1176	FlexCurve A Delay at 1.50 × PKP	0 to 65000	1	ms	F1	0 ms
	1177	FlexCurve A Delay at 1.60 × PKP	0 to 65000	1	ms	F1	0 ms
	1178	FlexCurve A Delay at 1.70 × PKP	0 to 65000	1	ms	F1	0 ms
	1179	FlexCurve A Delay at 1.80 × PKP	0 to 65000	1	ms	F1	0 ms
	117A	FlexCurve A Delay at 1.90 × PKP	0 to 65000	1	ms	F1	0 ms
	117B	FlexCurve A Delay at 2.00 × PKP	0 to 65000	1	ms	F1	0 ms
	117C	FlexCurve A Delay at 2.10 × PKP	0 to 65000	1	ms	F1	0 ms
	117D	FlexCurve A Delay at 2.20 × PKP	0 to 65000	1	ms	F1	0 ms
	117E	FlexCurve A Delay at 2.30 × PKP	0 to 65000	1	ms	F1	0 ms
	117F	FlexCurve A Delay at 2.40 × PKP	0 to 65000	1	ms	F1	0 ms
	1180	FlexCurve A Delay at 2.50 × PKP	0 to 65000	1	ms	F1	0 ms
	1181	FlexCurve A Delay at 2.60 × PKP	0 to 65000	1	ms	F1	0 ms
	1182	FlexCurve A Delay at 2.70 × PKP	0 to 65000	1	ms	F1	0 ms
	1183	FlexCurve A Delay at 2.80 × PKP	0 to 65000	1	ms	F1	0 ms
	1184	FlexCurve A Delay at 2.90 × PKP	0 to 65000	1	ms	F1	0 ms
	1185	FlexCurve A Delay at 3.00 × PKP	0 to 65000	1	ms	F1	0 ms
	1186	FlexCurve A Delay at 3.10 × PKP	0 to 65000	1	ms	F1	0 ms

Table 8–6: 745 MEMORY MAP (Sheet 23 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
FLEXCURVES continued	1187	FlexCurve A Delay at 3.20 × PKP	0 to 65000	1	ms	F1	0 ms
	1188	FlexCurve A Delay at 3.30 × PKP	0 to 65000	1	ms	F1	0 ms
	1189	FlexCurve A Delay at 3.40 × PKP	0 to 65000	1	ms	F1	0 ms
	118A	FlexCurve A Delay at 3.50 × PKP	0 to 65000	1	ms	F1	0 ms
	118B	FlexCurve A Delay at 3.60 × PKP	0 to 65000	1	ms	F1	0 ms
	118C	FlexCurve A Delay at 3.70 × PKP	0 to 65000	1	ms	F1	0 ms
	118D	FlexCurve A Delay at 3.80 × PKP	0 to 65000	1	ms	F1	0 ms
	118E	FlexCurve A Delay at 3.90 × PKP	0 to 65000	1	ms	F1	0 ms
	118F	FlexCurve A Delay at 4.00 × PKP	0 to 65000	1	ms	F1	0 ms
	1190	FlexCurve A Delay at 4.10 × PKP	0 to 65000	1	ms	F1	0 ms
	1191	FlexCurve A Delay at 4.20 × PKP	0 to 65000	1	ms	F1	0 ms
	1192	FlexCurve A Delay at 4.30 × PKP	0 to 65000	1	ms	F1	0 ms
	1193	FlexCurve A Delay at 4.40 × PKP	0 to 65000	1	ms	F1	0 ms
	1194	FlexCurve A Delay at 4.50 × PKP	0 to 65000	1	ms	F1	0 ms
	1195	FlexCurve A Delay at 4.60 × PKP	0 to 65000	1	ms	F1	0 ms
	1196	FlexCurve A Delay at 4.70 × PKP	0 to 65000	1	ms	F1	0 ms
	1197	FlexCurve A Delay at 4.80 × PKP	0 to 65000	1	ms	F1	0 ms
	1198	FlexCurve A Delay at 4.90 × PKP	0 to 65000	1	ms	F1	0 ms
	1199	FlexCurve A Delay at 5.00 × PKP	0 to 65000	1	ms	F1	0 ms
	119A	FlexCurve A Delay at 5.10 × PKP	0 to 65000	1	ms	F1	0 ms
	119B	FlexCurve A Delay at 5.20 × PKP	0 to 65000	1	ms	F1	0 ms
	119C	FlexCurve A Delay at 5.30 × PKP	0 to 65000	1	ms	F1	0 ms
	119D	FlexCurve A Delay at 5.40 × PKP	0 to 65000	1	ms	F1	0 ms
	119E	FlexCurve A Delay at 5.50 × PKP	0 to 65000	1	ms	F1	0 ms
	119F	FlexCurve A Delay at 5.60 × PKP	0 to 65000	1	ms	F1	0 ms
	11A0	FlexCurve A Delay at 5.70 × PKP	0 to 65000	1	ms	F1	0 ms
	11A1	FlexCurve A Delay at 5.80 × PKP	0 to 65000	1	ms	F1	0 ms
	11A2	FlexCurve A Delay at 5.90 × PKP	0 to 65000	1	ms	F1	0 ms
	11A3	FlexCurve A Delay at 6.00 × PKP	0 to 65000	1	ms	F1	0 ms
	11A4	FlexCurve A Delay at 6.50 × PKP	0 to 65000	1	ms	F1	0 ms
	11A5	FlexCurve A Delay at 7.00 × PKP	0 to 65000	1	ms	F1	0 ms
	11A6	FlexCurve A Delay at 7.50 × PKP	0 to 65000	1	ms	F1	0 ms
	11A7	FlexCurve A Delay at 8.00 × PKP	0 to 65000	1	ms	F1	0 ms
	11A8	FlexCurve A Delay at 8.50 × PKP	0 to 65000	1	ms	F1	0 ms
	11A9	FlexCurve A Delay at 9.00 × PKP	0 to 65000	1	ms	F1	0 ms
	11AA	FlexCurve A Delay at 9.50 × PKP	0 to 65000	1	ms	F1	0 ms
	11AB	FlexCurve A Delay at 10.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11AC	FlexCurve A Delay at 10.5 × PKP	0 to 65000	1	ms	F1	0 ms

Table 8–6: 745 MEMORY MAP (Sheet 24 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
FLEXCURVES continued	11AD	FlexCurve A Delay at 11.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11AE	FlexCurve A Delay at 11.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11AF	FlexCurve A Delay at 12.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11B0	FlexCurve A Delay at 12.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11B1	FlexCurve A Delay at 13.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11B2	FlexCurve A Delay at 13.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11B3	FlexCurve A Delay at 14.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11B4	FlexCurve A Delay at 14.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11B5	FlexCurve A Delay at 15.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11B6	FlexCurve A Delay at 15.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11B7	FlexCurve A Delay at 16.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11B8	FlexCurve A Delay at 16.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11B9	FlexCurve A Delay at 17.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11BA	FlexCurve A Delay at 17.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11BB	FlexCurve A Delay at 18.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11BC	FlexCurve A Delay at 18.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11BD	FlexCurve A Delay at 19.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11BE	FlexCurve A Delay at 19.5 × PKP	0 to 65000	1	ms	F1	0 ms
	11BF	FlexCurve A Delay at 20.0 × PKP	0 to 65000	1	ms	F1	0 ms
	11C0	FlexCurve B (80 registers: see FlexCurve A)	---	---	---	---	---
	1210	FlexCurve C (80 registers: see FlexCurve A)	---	---	---	---	---
	1260	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	126F	Reserved					
VOLTAGE INPUT	1270	Voltage Sensing	---	---	---	F30	0 = Disabled
	1271	Voltage Input Parameter	---	---	---	F63	0 = W1 Van
	1272	Nominal VT Secondary Voltage	60.0 to 120.0	0.1	V	F2	1200 = 120.0 V
	1273	VT Ratio	1 to 5000	1	:1	F1	1000:1
	1274	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	127F	Reserved					
AMBIENT TEMP	1280	Ambient Temperature Sensing	---	---	---	F30	0 = Disabled
	1281	Ambient RTD Type	---	---	---	F41	0 = 100W Pt
	1282	Average Ambient Temperature for January	–50 to 125	1	°C	F4	20°C
	1283	Average Ambient Temperature for February	–50 to 125	1	°C	F4	20°C
	1284	Average Ambient Temperature for March	–50 to 125	1	°C	F4	20°C
	1285	Average Ambient Temperature for April	–50 to 125	1	°C	F4	20°C
	1286	Average Ambient Temperature for May	–50 to 125	1	°C	F4	20°C

8

Table 8–6: 745 MEMORY MAP (Sheet 25 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
AMBIENT TEMP continued	1287	Average Ambient Temperature for June	–50 to 125	1	°C	F4	20°C
	1288	Average Ambient Temperature for July	–50 to 125	1	°C	F4	20°C
	1289	Average Ambient Temperature for August	–50 to 125	1	°C	F4	20°C
	128A	Average Ambient Temperature for September	–50 to 125	1	°C	F4	20°C
	128B	Average Ambient Temperature for October	–50 to 125	1	°C	F4	20°C
	128C	Average Ambient Temperature for November	–50 to 125	1	°C	F4	20°C
	128D	Average Ambient Temperature for December	–50 to 125	1	°C	F4	20°C
	128E	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	128F	Reserved					
ANALOG INPUT	1290	Analog Input Name (9 registers)	---	---	---	F33	ANALOG INPUT
	1299	Analog Input Units (3 registers)	---	---	---	F33	"uA"
	129C	Analog Input Range	---	---	---	F42	0 = 0-1 mA
	129D	Analog Input Minimum Value	0 to 65000	1	<Units>	F1	0 <Units>
	129E	Analog Input Maximum Value	0 to 65000	1	<Units>	F1	1000 <Units>
	129F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	12BF	Reserved					
DEMAND METERING	12C0	Current Demand Meter Type	---	---	---	F58	0 = Thermal
	12C1	Thermal 90% Response Time	---	---	---	F16	2 = 15 min
	12C2	Time Interval	---	---	---	F16	3 = 20 min
	12C3	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	12CF	Reserved					
ANALOG OUTPUTS	12D0	Analog Output 1 Function	---	---	---	F30	0 = Disabled
	12D1	Analog Output 1 Value	---	---	---	F45	0 = W1 øA curr
	12D2	Analog Output 1 Range	---	---	---	F26	2 = 4-20 mA
	12D3	Analog Output 1 Minimum	---	---	---	---	0 A
	12D4	Analog Output 1 Maximum	---	---	---	---	1000 A
	12D5	Analog Output 2 Function	---	---	---	F30	0 = Disabled
	12D6	Analog Output 2 Value	---	---	---	F45	1 = W1 øB curr
	12D7	Analog Output 2 Range	---	---	---	F26	2 = 4-20 mA
	12D8	Analog Output 2 Minimum	---	---	---	---	0 A
	12D9	Analog Output 2 Maximum	---	---	---	---	1000 A
	12DA	Analog Output 3 Function	---	---	---	F30	0 = Disabled
	12DB	Analog Output 3 Value	---	---	---	F45	2 = W1 øC curr
	12DC	Analog Output 3 Range	---	---	---	F26	2 = 4-20 mA
	12DD	Analog Output 3 Minimum	---	---	---	---	0 A

Table 8–6: 745 MEMORY MAP (Sheet 26 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
ANALOG OUTPUTS continued	12DE	Analog Output 3 Maximum	---	---	---	---	1000 A
	12DF	Analog Output 4 Function	---	---	---	F30	0 = Disabled
	12E0	Analog Output 4 Value	---	---	---	F45	9 = W1 loading
	12E1	Analog Output 4 Range	---	---	---	F26	2 = 4-20 mA
	12E2	Analog Output 4 Minimum	---	---	---	---	0%
	12E3	Analog Output 4 Maximum	---	---	---	---	100%
	12E4	Analog Output 5 Function	---	---	---	F30	0 = Disabled
	12E5	Analog Output 5 Value	---	---	---	F45	26 = Voltage
	12E6	Analog Output 5 Range	---	---	---	F26	2 = 4-20 mA
	12E7	Analog Output 5 Minimum	---	---	---	---	0 = 0.00 kV
	12E8	Analog Output 5 Maximum	---	---	---	---	14.40 kV
	12E9	Analog Output 6 Function	---	---	---	F30	0 = Disabled
	12EA	Analog Output 6 Value	---	---	---	F45	24 = frequency
	12EB	Analog Output 6 Range	---	---	---	F26	2 = 4-20 mA
	12EC	Analog Output 6 Minimum	---	---	---	---	5700 = 57.0 Hz
	12ED	Analog Output 6 Maximum	---	---	---	---	6300 = 63.0 Hz
	12EE	Analog Output 7 Function	---	---	---	F30	0 = Disabled
	12EF	Analog Output 7 Value	---	---	---	F45	25 = Tap Pos.
	12F0	Analog Output 7 Range	---	---	---	F26	2 = 4-20 mA
	12F1	Analog Output 7 Minimum	---	---	---	---	1
	12F2	Analog Output 7 Maximum	---	---	---	---	33
	12F3	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	12FF	Reserved					
LOGIC INPUTS	1300	Logic Input 1 Function	---	---	---	F30	0 = Disabled
	1301	Logic Input 1 Name (9 registers)	---	---	---	F33	"Logic Input 1"
	130A	Logic Input 1 Asserted State	---	---	---	F75	1 = Closed
	130B	Logic Input 2 Function	---	---	---	F30	0 = Disabled
	130C	Logic Input 2 Name (9 registers)	---	---	---	F33	"Logic Input 2"
	1315	Logic Input 2 Asserted State	---	---	---	F75	1 = Closed
	1316	Logic Input 3 Function	---	---	---	F30	0 = Disabled
	1317	Logic Input 3 Name (9 registers)	---	---	---	F33	"Logic Input 3"
	1320	Logic Input 3 Asserted State	---	---	---	F75	1 = Closed
	1321	Logic Input 4 Function	---	---	---	F30	0 = Disabled
	1322	Logic Input 4 Name (9 registers)	---	---	---	F33	"Logic Input 4"
	132B	Logic Input 4 Asserted State	---	---	---	F75	1 = Closed
	132C	Logic Input 5 Function	---	---	---	F30	0 = Disabled
	132D	Logic Input 5 Name (9 registers)	---	---	---	F33	"Logic Input 5"

Table 8–6: 745 MEMORY MAP (Sheet 27 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
LOGIC INPUTS continued	1336	Logic Input 5 Asserted State	---	---	---	F75	1 = Closed
	1337	Logic Input 6 Function	---	---	---	F30	0 = Disabled
	1338	Logic Input 6 Name (9 registers)	---	---	---	F33	"Logic Input 6"
	1341	Logic Input 6 Asserted State	---	---	---	F75	1 = Closed
	1342	Logic Input 7 Function	---	---	---	F30	0 = Disabled
	1343	Logic Input 7 Name (9 registers)	---	---	---	F33	"Logic Input 7"
	134C	Logic Input 7 Asserted State	---	---	---	F75	1 = Closed
	134D	Logic Input 8 Function	---	---	---	F30	0 = Disabled
	134E	Logic Input 8 Name (9 registers)	---	---	---	F33	"Logic Input 8"
	1357	Logic Input 8 Asserted State	---	---	---	F75	1 = Closed
	1358	Logic Input 9 Function	---	---	---	F30	0 = Disabled
	1359	Logic Input 9 Name (9 registers)	---	---	---	F33	"Logic Input 9"
	1362	Logic Input 9 Asserted State	---	---	---	F75	1 = Closed
	1363	Logic Input 10 Function	---	---	---	F30	0 = Disabled
	1364	Logic Input 10 Name (9 registers)	---	---	---	F33	"Logic Input 10"
	136D	Logic Input 10 Asserted State	---	---	---	F75	1 = Closed
	136E	Logic Input 11 Function	---	---	---	F30	0 = Disabled
	136F	Logic Input 11 Name (9 registers)	---	---	---	F33	"Logic Input 11"
	1378	Logic Input 11 Asserted State	---	---	---	F75	1 = Closed
	1379	Logic Input 12 Function	---	---	---	F30	0 = Disabled
	137A	Logic Input 12 Name (9 registers)	---	---	---	F33	"Logic Input 12"
	1383	Logic Input 12 Asserted State	---	---	---	F75	1 = Closed
	1384	Logic Input 13 Function	---	---	---	F30	0 = Disabled
	1385	Logic Input 13 Name (9 registers)	---	---	---	F33	"Logic Input 13"
	138E	Logic Input 13 Asserted State	---	---	---	F75	1 = Closed
	138F	Logic Input 14 Function	---	---	---	F30	0 = Disabled
	1390	Logic Input 14 Name (9 registers)	---	---	---	F33	"Logic Input 14"
	1399	Logic Input 14 Asserted State	---	---	---	F75	1 = Closed
	139A	Logic Input 15 Function	---	---	---	F30	0 = Disabled
	139B	Logic Input 15 Name (9 registers)	---	---	---	F33	"Logic Input 15"
	13A4	Logic Input 15 Asserted State	---	---	---	F75	1 = Closed
	13A5	Logic Input 16 Function	---	---	---	F30	0 = Disabled
	13A6	Logic Input 16 Name (9 registers)	---	---	---	F33	"Logic Input 16"
	13AF	Logic Input 16 Asserted State	---	---	---	F75	1 = Closed
	13B0	Logic Input 1 Target	---	---	---	F46	0 = Self-Test
	13B1	Logic Input 2 Target	---	---	---	F46	0 = Self-Test
	13B2	Logic Input 3 Target	---	---	---	F46	0 = Self-Test
	13B3	Logic Input 4 Target	---	---	---	F46	0 = Self-Test

Table 8–6: 745 MEMORY MAP (Sheet 28 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
LOGIC INPUTS continued	13B4	Logic Input 5 Target	---	---	---	F46	0 = Self-Test
	13B5	Logic Input 6 Target	---	---	---	F46	0 = Self-Test
	13B6	Logic Input 7 Target	---	---	---	F46	0 = Self-Test
	13B7	Logic Input 8 Target	---	---	---	F46	0 = Self-Test
	13B8	Logic Input 9 Target	---	---	---	F46	0 = Self-Test
	13B9	Logic Input 10 Target	---	---	---	F46	0 = Self-Test
	13BA	Logic Input 11 Target	---	---	---	F46	0 = Self-Test
	13BB	Logic Input 12 Target	---	---	---	F46	0 = Self-Test
	13BC	Logic Input 13 Target	---	---	---	F46	0 = Self-Test
	13BD	Logic Input 14 Target	---	---	---	F46	0 = Self-Test
	13BE	Logic Input 15 Target	---	---	---	F46	0 = Self-Test
	13BF	Logic Input 16 Target	---	---	---	F46	0 = Self-Test
VIRTUAL INPUTS	13C0	Virtual Input 1 Function	---	---	---	F30	0 = Disabled
	13C1	Virtual Input 1 Name (9 registers)	---	---	---	F33	"Virtual Input 1"
	13CA	Virtual Input 2 Function	---	---	---	F30	0 = Disabled
	13CB	Virtual Input 2 Name (9 registers)	---	---	---	F33	"Virtual Input 2"
	13D4	Virtual Input 3 Function	---	---	---	F30	0 = Disabled
	13D5	Virtual Input 3 Name (9 registers)	---	---	---	F33	"Virtual Input 3"
	13DE	Virtual Input 4 Function	---	---	---	F30	0 = Disabled
	13DF	Virtual Input 4 Name (9 registers)	---	---	---	F33	"Virtual Input 4"
	13E8	Virtual Input 5 Function	---	---	---	F30	0 = Disabled
	13E9	Virtual Input 5 Name (9 registers)	---	---	---	F33	"Virtual Input 5"
	13F2	Virtual Input 6 Function	---	---	---	F30	0 = Disabled
	13F3	Virtual Input 6 Name (9 registers)	---	---	---	F33	"Virtual Input 6"
	13FC	Virtual Input 7 Function	---	---	---	F30	0 = Disabled
	13FD	Virtual Input 7 Name (9 registers)	---	---	---	F33	"Virtual Input 7"
	1406	Virtual Input 8 Function	---	---	---	F30	0 = Disabled
	1407	Virtual Input 8 Name (9 registers)	---	---	---	F33	"Virtual Input 8"
	1410	Virtual Input 9 Function	---	---	---	F30	0 = Disabled
	1411	Virtual Input 9 Name (9 registers)	---	---	---	F33	"Virtual Input 9"
	141A	Virtual Input 10 Function	---	---	---	F30	0 = Disabled
	141B	Virtual Input 10 Name (9 registers)	---	---	---	F33	"Virtual Input 10"
	1424	Virtual Input 11 Function	---	---	---	F30	0 = Disabled
	1425	Virtual Input 11 Name (9 registers)	---	---	---	F33	"Virtual Input 11"
	142E	Virtual Input 12 Function	---	---	---	F30	0 = Disabled
	142F	Virtual Input 12 Name (9 registers)	---	---	---	F33	"Virtual Input 12"
	1438	Virtual Input 13 Function	---	---	---	F30	0 = Disabled
	1439	Virtual Input 13 Name (9 registers)	---	---	---	F33	"Virtual Input 13"

Table 8–6: 745 MEMORY MAP (Sheet 29 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
VIRTUAL INPUTS continued	1442	Virtual Input 14 Function	---	---	---	F30	0 = Disabled
	1443	Virtual Input 14 Name (9 registers)	---	---	---	F33	"Virtual Input 14"
	144C	Virtual Input 15 Function	---	---	---	F30	0 = Disabled
	144D	Virtual Input 15 Name (9 registers)	---	---	---	F33	"Virtual Input 15"
	1456	Virtual Input 16 Function	---	---	---	F30	0 = Disabled
	1457	Virtual Input 16 Name (9 registers)	---	---	---	F33	"Virtual Input 16"
	1460	Virtual Input 1 Target	---	---	---	F46	0 = Self-Reset
	1461	Virtual Input 2 Target	---	---	---	F46	0 = Self-Reset
	1462	Virtual Input 3 Target	---	---	---	F46	0 = Self-Reset
	1463	Virtual Input 4 Target	---	---	---	F46	0 = Self-Reset
	1464	Virtual Input 5 Target	---	---	---	F46	0 = Self-Reset
	1465	Virtual Input 6 Target	---	---	---	F46	0 = Self-Reset
	1466	Virtual Input 7 Target	---	---	---	F46	0 = Self-Reset
	1467	Virtual Input 8 Target	---	---	---	F46	0 = Self-Reset
	1468	Virtual Input 9 Target	---	---	---	F46	0 = Self-Reset
	1469	Virtual Input 10 Target	---	---	---	F46	0 = Self-Reset
	146A	Virtual Input 11 Target	---	---	---	F46	0 = Self-Reset
	146B	Virtual Input 12 Target	---	---	---	F46	0 = Self-Reset
	146C	Virtual Input 13 Target	---	---	---	F46	0 = Self-Reset
	146D	Virtual Input 14 Target	---	---	---	F46	0 = Self-Reset
	146E	Virtual Input 15 Target	---	---	---	F46	0 = Self-Reset
	146F	Virtual Input 16 Target	---	---	---	F46	0 = Self-Reset
	1470	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	147F	Reserved					
OUTPUT RELAY 1	1480	Output 1 Name (9 registers)	---	---	---	F33	Solid State Trip
	1489	Output 1 Operation	---	---	---	F66	0 = self-resetting
	148A	Output 1 Type	---	---	---	F38	0 = Trip
	148B	Output 1 FlexLogic (20 registers)	---	---	---	F47	---
	149F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	14AF	Reserved					
OUTPUT RELAY 2	14B0	Output 2 Name (9 registers)	---	---	---	F33	"Trip 1"
	14B9	Output 2 Operation	---	---	---	F66	0 = self-resetting
	14BA	Output 2 Type	---	---	---	F38	0 = Trip
	14BB	Output 2 FlexLogic (20 registers)	---	---	---	F47	---
	14CF	Reserved					
	↓	↓	↓	↓	↓	↓	↓

8

Table 8–6: 745 MEMORY MAP (Sheet 30 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
	14DF	Reserved					
OUTPUT RELAY 3	14E0	Output 3 Name (9 registers)	---	---	---	F33	"Trip 2"
	14E9	Output 3 Operation	---	---	---	F66	0 = self-resetting
	14EA	Output 3 Type	---	---	---	F38	0 = Trip
	14EB	Output 3 FlexLogic (20 registers)	---	---	---	F47	---
	14FF	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	150F	Reserved					
OUTPUT RELAY 4	1510	Output 4 Name (9 registers)	---	---	---	F33	Volts/Hertz Trip
	1519	Output 4 Operation	---	---	---	F66	0 = self-resetting
	151A	Output 4 Type	---	---	---	F38	0 = Trip
	151B	Output 4 FlexLogic (20 registers)	---	---	---	F47	---
	152F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	153F	Reserved					
OUTPUT RELAY 5	1540	Output 5 Name (9 registers)	---	---	---	F33	Overflux Alarm
	1549	Output 5 Operation	---	---	---	F66	0 = self-resetting
	154A	Output 5 Type	---	---	---	F38	1 = Alarm
	154B	Output 5 FlexLogic (20 registers)	---	---	---	F47	---
	155F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	156F	Reserved					
OUTPUT RELAY 6	1570	Output 6 Name (9 registers)	---	---	---	F33	Frequency Trip 1
	1579	Output 6 Operation	---	---	---	F66	0 = self-resetting
	157A	Output 6 Type	---	---	---	F38	0 = Trip
	157B	Output 6 FlexLogic (20 registers)	---	---	---	F47	---
	158F	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	159F	Reserved					
OUTPUT RELAY 7	15A0	Output 7 Name (9 registers)	---	---	---	F33	Frequency Trip 2
	15A9	Output 7 Operation	---	---	---	F66	0 = self-resetting
	15AA	Output 7 Type	---	---	---	F38	0 = Trip
	15AB	Output 7 FlexLogic (20 registers)	---	---	---	F47	---
	15BF	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	15CF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 31 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
OUTPUT RELAY 8	15D0	Output 8 Name (9 registers)	---	---	---	F33	Frequency Trip 3
	15D9	Output 8 Operation	---	---	---	F66	0 = self-resetting
	15DA	Output 8 Type	---	---	---	F38	0 = Trip
	15DB	Output 8 FlexLogic (20 registers)	---	---	---	F47	---
	15EF	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	15FF	Reserved					
TRACE MEMORY	1600	Number of Pre-Trigger Cycles	1 to 15	1	cycles	F1	12 cycles
	1601	Trace Memory Trigger FlexLogic (10 registers)	---	---	---	F47	---
	160B	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	19FF	Reserved					
VIRTUAL OUTPUTS	1A00	Virtual Output 1 FlexLogic (10 registers)	---	---	---	F47	---
	1A0A	Virtual Output 2 FlexLogic (10 registers)	---	---	---	F47	---
	1A14	Virtual Output 3 FlexLogic (10 registers)	---	---	---	F47	---
	1A1E	Virtual Output 4 FlexLogic (10 registers)	---	---	---	F47	---
	1A28	Virtual Output 5 FlexLogic (10 registers)	---	---	---	F47	---
	1A32	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1D7F	Reserved					
TIMERS	1D80	Timer 1 Start	---	---	---	F62	0 = End
	1D81	Timer 1 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D82	Timer 1 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D83	Timer 2 Start	---	---	---	F62	0 = End
	1D84	Timer 2 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D85	Timer 2 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D86	Timer 3 Start	---	---	---	F62	0 = End
	1D87	Timer 3 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D88	Timer 3 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D89	Timer 4 Start	---	---	---	F62	0 = End
	1D8A	Timer 4 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D8B	Timer 4 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D8C	Timer 5 Start	---	---	---	F62	0 = End
	1D8D	Timer 5 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D8E	Timer 5 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D8F	Timer 6 Start	---	---	---	F62	0 = End
	1D90	Timer 6 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D91	Timer 6 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s

Table 8–6: 745 MEMORY MAP (Sheet 32 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
TIMERS continued	1D92	Timer 7 Start	---	---	---	F62	0 = End
	1D93	Timer 7 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D94	Timer 7 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D95	Timer 8 Start	---	---	---	F62	0 = End
	1D96	Timer 8 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D97	Timer 8 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D98	Timer 9 Start	---	---	---	F62	0 = End
	1D99	Timer 9 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D9A	Timer 9 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D9B	Timer 10 Start	---	---	---	F62	0 = End
	1D9C	Timer 10 Pickup Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D9D	Timer 10 Dropout Delay	0.00 to 600.00	0.01	s	F3	0.00 s
	1D9E	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1DFF	Reserved					
FORCE OUTPUT RELAYS	1E00	Force Output Relays Function	---	---	---	F30	0 = Disabled
	1E01	Force Output Relay 1	---	---	---	F34	0 = De-energized
	1E02	Force Output Relay 2	---	---	---	F34	0 = De-energized
	1E03	Force Output Relay 3	---	---	---	F34	0 = De-energized
	1E04	Force Output Relay 4	---	---	---	F34	0 = De-energized
	1E05	Force Output Relay 5	---	---	---	F34	0 = De-energized
	1E06	Force Output Relay 6	---	---	---	F34	0 = De-energized
	1E07	Force Output Relay 7	---	---	---	F34	0 = De-energized
	1E08	Force Output Relay 8	---	---	---	F34	0 = De-energized
	1E09	Force Self-Test Relay	---	---	---	F34	0 = De-energized
	1E0A	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1E0F	Reserved					
FORCE ANALOG OUTPUTS	1E10	Force Analog Outputs Function	---	---	---	F30	0 = Disabled
	1E11	Force Analog Output 1	0 to 100	1	%	F1	0%
	1E12	Force Analog Output 2	0 to 100	1	%	F1	0%
	1E13	Force Analog Output 3	0 to 100	1	%	F1	0%
	1E14	Force Analog Output 4	0 to 100	1	%	F1	0%
	1E15	Force Analog Output 5	0 to 100	1	%	F1	0%
	1E16	Force Analog Output 6	0 to 100	1	%	F1	0%
	1E17	Force Analog Output 7	0 to 100	1	%	F1	0%
	1E18	Reserved					
	↓	↓	↓	↓	↓	↓	↓

Table 8–6: 745 MEMORY MAP (Sheet 33 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
	1E1F	Reserved					
SIMULATION SETUP	1E20	Simulation Function	---	---	---	F48	0 = Disabled
	1E21	Block Operation of Outputs	---	---	---	F67	255 = 12345678
	1E22	Start Fault Mode Signal	---	---	---	F88	0 = Disabled
	1E23	Start Playback Mode Signal	---	---	---	F88	0 = Disabled
	1E24	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1E27	Reserved					
SIMULATION PREFAULT VALUES	1E28	Prefault Wdg 1 Phase ABC Current Magnitudes	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E29	Prefault Wdg 2 Phase ABC Current Magnitudes	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E2A	Prefault Wdg 3 Phase ABC Current Magnitudes	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E2B	Prefault Voltage Input Magnitude	0.0 to 2.0	0.1	× VT	F2	10 = 1.0 × VT
	1E2C	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1E2F	Reserved					
SIMULATION FAULT VALUES	1E30	Fault Winding 1 Phase A Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E31	Fault Winding 1 Phase A Current Angle	---	---	°	F1	0°
	1E32	Fault Winding 1 Phase B Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E33	Fault Winding 1 Phase B Current Angle	0 to 359	1	° Lag	F1	120° Lag
	1E34	Fault Winding 1 Phase C Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E35	Fault Winding 1 Phase C Current Angle	0 to 359	1	° Lag	F1	240° Lag
	1E36	Fault Winding 1 Ground Current Magnitude	0.0 to 40.0	0.1	× CT	F2	0.0 x CT
	1E37	Fault Winding 1 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	1E38	Fault Winding 2 Phase A Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E39	Fault Winding 2 Phase A Current Angle	0 to 359	1	° Lag	F1	0° Lag
	1E3A	Fault Winding 2 Phase B Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E3B	Fault Winding 2 Phase B Current Angle	0 to 359	1	° Lag	F1	120° Lag
	1E3C	Fault Winding 2 Phase C Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E3D	Fault Winding 2 Phase C Current Angle	0 to 359	1	° Lag	F1	240° Lag
	1E3E	Fault Winding 2 Ground Current Magnitude	0.0 to 40.0	0.1	× CT	F2	0.0 × CT
	1E3F	Fault Winding 2 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	1E40	Fault Winding 3 Phase A Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E41	Fault Winding 3 Phase A Current Angle	0 to 359	1	° Lag	F1	330° Lag
	1E42	Fault Winding 3 Phase B Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E43	Fault Winding 3 Phase B Current Angle	0 to 359	1	° Lag	F1	90° Lag
	1E44	Fault Winding 3 Phase C Current Magnitude	0.0 to 40.0	0.1	× CT	F2	10 = 1.0 × CT
	1E45	Fault Winding 3 Phase C Current Angle	0 to 359	1	° Lag	F1	210° Lag
	1E46	Fault Winding 3 Ground Current Magnitude	0.0 to 40.0	0.1	× CT	F2	0.0 × CT

Table 8–6: 745 MEMORY MAP (Sheet 34 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
SIMULATION FAULT VALUES continued	1E47	Fault Winding 3 Ground Current Angle	0 to 359	1	° Lag	F1	0° Lag
	1E48	Fault Voltage Input Magnitude	0.0 to 2.0	0.1	× VT	F2	10 = 1.0 × VT
	1E49	Fault Voltage Input Angle	0 to 359	1	° Lag	F1	0° Lag
	1E4A	Fault Frequency	45.00 to 60.00	0.01	Hz	F3	60.00 Hz
	1E4B	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	1FFF	Reserved					
Setpoint Group 1/2/3/4 (Addresses 2000 to 3FFF) - Read / Write							
PERCENT DIFFERENTIAL	2000	Percent Differential Function	---	---	---	F30	1 = Enabled
	2001	Percent Differential Target	---	---	---	F46	1 = Latched
	2002	Percent Differential Pickup	0.05 to 1.00	0.01	× CT	F3	30 = 0.30 × CT
	2003	Percent Differential Slope 1	15 to 100	1	%	F1	25%
	2004	Percent Differential Break Point	1.0 to 20.0	0.1	× CT	F2	20 = 2.0 × CT
	2005	Percent Differential Slope 2	50 to 200	1	%	F1	100%
	2006	Percent Differential Block	---	---	---	F87	0 = Disabled
	2007	Reserved					
HARMONIC INHIBIT	2008	Harmonic Inhibit Function	---	---	---	F30	1 = Enabled
	2009	Harmonic Inhibit Parameters	---	---	---	F64	0 = 2nd
	200A	Harmonic Averaging	---	---	---	F30	0 = Disabled
	200B	Harmonic Inhibit Level	0.1 to 65.0	0.1	% f_0	F2	200 = 20.0% f_0
	200C	Reserved					
ENERGIZATION INHIBIT	200D	Energization Inhibit Function	---	---	---	F30	1 = Enabled
	200E	Energization Inhibit Parameters	---	---	---	F64	0 = 2nd
	200F	Harmonic Averaging	---	---	---	F30	1 = Enabled
	2010	Energization Inhibit Level	0.1 to 65.0	0.1	% f_0	F2	200 = 20.0% f_0
	2011	Energization Inhibit Duration	0.05 to 600.00	0.01	s	F1	10 = 0.10 s
	2012	Energization Sensing By Current	---	---	---	F30	1 = Enabled
	2013	Minimum Energization Current	0.10 to 0.50	0.01	× CT	F3	10 = 0.10 × CT
	2014	Energization Sensing By Voltage	---	---	---	F30	0 = Disabled
	2015	Minimum Energization Voltage	0.50 to 0.99	0.01	× VT	F3	85 = 0.85 × VT
	2016	Breakers Are Open Signal	---	---	---	F88	0 = Disabled
	2017	Parallel Transformer Breaker Close Signal	---	---	---	F88	0 = Disabled
	2018	Reserved					
5TH HARMONIC INHIBIT	2019	5th Harmonic Inhibit Function	---	---	---	F30	0 = Disabled
	201A	Harmonic Averaging	---	---	---	F30	0 = Disabled
	201B	5th Harmonic Inhibit Level	0.1 to 65.0	0.1	% f_0	F2	100 = 10.0% f_0
	201C	Reserved					
	↓	↓	↓	↓	↓	↓	↓

8

Table 8–6: 745 MEMORY MAP (Sheet 35 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
	201F	Reserved					
INST DIFFERENTIAL	2020	Inst Differential Function	---	---	---	F30	1 = Enabled
	2021	Inst Differential Target	---	---	---	F46	1 = Latched
	2022	Inst Differential Pickup	3.00 to 20.00	0.01	× CT	F3	800 = 8.00 × CT
	2023	Inst Differential Block	---	---	---	F87	0 = Disabled
	2024	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	203F	Reserved					
WINDING 1 PHASE TIME O/C	2040	Winding 1 Phase Time O/C Function	---	---	---	F30	1 = Enabled
	2041	Winding 1 Phase Time O/C Target	---	---	---	F46	1 = Latched
	2042	Winding 1 Phase Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	120 = 1.20 × CT
	2043	Winding 1 Phase Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2044	Winding 1 Phase Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2045	Winding 1 Phase Time O/C Reset	---	---	---	F68	1 = Linear
	2046	Winding 1 Phase Time O/C Block	---	---	---	F87	0 = Disabled
	2047	Winding 1 Harmonic Derating Correction	---	---	---	F30	0 = Disabled
	2048	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	204F	Reserved					
WINDING 2 PHASE TIME O/C	2050	Winding 2 Phase Time O/C Function	---	---	---	F30	1 = Enabled
	2051	Winding 2 Phase Time O/C Target	---	---	---	F46	1 = Latched
	2052	Winding 2 Phase Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	120 = 1.20 × CT
	2053	Winding 2 Phase Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2054	Winding 2 Phase Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2055	Winding 2 Phase Time O/C Reset	---	---	---	F68	1 = Linear
	2056	Winding 2 Phase Time O/C Block	---	---	---	F87	0 = Disabled
	2057	Winding 2 Harmonic Derating Correction	---	---	---	F30	0 = Disabled
	2058	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	205F	Reserved					
WINDING 3 PHASE TIME O/C	2060	Winding 3 Phase Time O/C Function	---	---	---	F30	1 = Enabled
	2061	Winding 3 Phase Time O/C Target	---	---	---	F46	1 = Latched
	2062	Winding 3 Phase Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	120 = 1.20 × CT
	2063	Winding 3 Phase Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2064	Winding 3 Phase Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2065	Winding 3 Phase Time O/C Reset	---	---	---	F68	1 = Linear
	2066	Winding 3 Phase Time O/C Block	---	---	---	F87	0 = Disabled
	2067	Winding 3 Harmonic Derating Correction	---	---	---	F30	0 = Disabled

Table 8–6: 745 MEMORY MAP (Sheet 36 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
	2068	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	206F	Reserved					
WINDING 1 PHASE INST O/C 1	2070	Winding 1 Phase Inst O/C 1 Function	---	---	---	F30	1 = Enabled
	2071	Winding 1 Phase Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2072	Winding 1 Phase Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	1000 = 10.00 x CT
	2073	Winding 1 Phase Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2074	Winding 1 Phase Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2075	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	207F	Reserved					
WINDING 2 PHASE INST O/C 1	2080	Winding 2 Phase Inst O/C 1 Function	---	---	---	F30	1 = Enabled
	2081	Winding 2 Phase Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2082	Winding 2 Phase Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	10.00 x CT
	2083	Winding 2 Phase Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2084	Winding 2 Phase Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2085	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	208F	Reserved					
WINDING 3 PHASE INST O/C 1	2090	Winding 3 Phase Inst O/C 1 Function	---	---	---	F30	1 = Enabled
	2091	Winding 3 Phase Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2092	Winding 3 Phase Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	2093	Winding 3 Phase Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2094	Winding 3 Phase Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2095	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	209F	Reserved					
WINDING 1 PHASE INST O/C 2	20A0	Winding 1 Phase Inst O/C 2 Function	---	---	---	F30	1 = Enabled
	20A1	Winding 1 Phase Inst O/C 2 Target	---	---	---	F46	1 = Latched
	20A2	Winding 1 Phase Inst O/C 2 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	20A3	Winding 1 Phase Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	20A4	Winding 1 Phase Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	20A5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20AF	Reserved					
WINDING 2 PHASE INST O/C 2	20B0	Winding 2 Phase Inst O/C 2 Function	---	---	---	F30	1 = Enabled
	20B1	Winding 2 Phase Inst O/C 2 Target	---	---	---	F46	1 = Latched
	20B2	Winding 2 Phase Inst O/C 2 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT

8

Table 8–6: 745 MEMORY MAP (Sheet 37 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 2 PHASE INST O/C 2 continued	20B3	Winding 2 Phase Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	20B4	Winding 2 Phase Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	20B5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20BF	Reserved					
WINDING 3 PHASE INST O/C 2	20C0	Winding 3 Phase Inst O/C 2 Function	---	---	---	F30	1 = Enabled
	20C1	Winding 3 Phase Inst O/C 2 Target	---	---	---	F46	1 = Latched
	20C2	Winding 3 Phase Inst O/C 2 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	20C3	Winding 3 Phase Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	20C4	Winding 3 Phase Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	20C5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20CF	Reserved					
WINDING 1 NEUTRAL TIME O/C	20D0	Winding 1 Neutral Time O/C Function	---	---	---	F30	1 = Enabled
	20D1	Winding 1 Neutral Time O/C Target	---	---	---	F46	1 = Latched
	20D2	Winding 1 Neutral Time O/C Pickup	0.05 to 20.00	0.01	x CT	F3	85 = 0.85 x CT
	20D3	Winding 1 Neutral Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	20D4	Winding 1 Neutral Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	20D5	Winding 1 Neutral Time O/C Reset	---	---	---	F68	1 = Linear
	20D6	Winding 1 Neutral Time O/C Block	---	---	---	F87	0 = Disabled
	20D7	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20DF	Reserved					
WINDING 2 NEUTRAL TIME O/C	20E0	Winding 2 Neutral Time O/C Function	---	---	---	F30	0 = Disabled
	20E1	Winding 2 Neutral Time O/C Target	---	---	---	F46	1 = Latched
	20E2	Winding 2 Neutral Time O/C Pickup	0.05 to 20.00	0.01	x CT	F3	85 = 0.85 x CT
	20E3	Winding 2 Neutral Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	20E4	Winding 2 Neutral Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	20E5	Winding 2 Neutral Time O/C Reset	---	---	---	F68	1 = Linear
	20E6	Winding 2 Neutral Time O/C Block	---	---	---	F87	0 = Disabled
	20E7	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20EF	Reserved					
WINDING 3 NEUTRAL TIME O/C	20F0	Winding 3 Neutral Time O/C Function	---	---	---	F30	0 = Disabled
	20F1	Winding 3 Neutral Time O/C Target	---	---	---	F46	1 = Latched
	20F2	Winding 3 Neutral Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	85 = 0.85 × CT
	20F3	Winding 3 Neutral Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	20F4	Winding 3 Neutral Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00

8

Table 8–6: 745 MEMORY MAP (Sheet 38 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 3 NEUTRAL TIME O/C continued	20F5	Winding 3 Neutral Time O/C Reset	---	---	---	F68	1 = Linear
	20F6	Winding 3 Neutral Time O/C Block	---	---	---	F87	0 = Disabled
	20F7	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	20FF	Reserved					
WINDING 1 NEUTRAL INST O/C 1	2100	Winding 1 Neutral Inst O/C 1 Function	---	---	---	F30	1 = Enabled
	2101	Winding 1 Neutral Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2102	Winding 1 Neutral Inst O/C 1 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2103	Winding 1 Neutral Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2104	Winding 1 Neutral Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2105	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	210F	Reserved					
WINDING 2 NEUTRAL INST O/C 1	2110	Winding 2 Neutral Inst O/C 1 Function	---	---	---	F30	0 = Disabled
	2111	Winding 2 Neutral Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2112	Winding 2 Neutral Inst O/C 1 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2113	Winding 2 Neutral Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2114	Winding 2 Neutral Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2115	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	211F	Reserved					
WINDING 3 NEUTRAL INST O/C 1	2120	Winding 3 Neutral Inst O/C 1 Function	---	---	---	F30	0 = Disabled
	2121	Winding 3 Neutral Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2122	Winding 3 Neutral Inst O/C 1 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2123	Winding 3 Neutral Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2124	Winding 3 Neutral Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2125	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	212F	Reserved					
WINDING 1 NEUTRAL INST O/C 2	2130	Winding 1 Neutral Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	2131	Winding 1 Neutral Inst O/C 2 Target	---	---	---	F46	1 = Latched
	2132	Winding 1 Neutral Inst O/C 2 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2133	Winding 1 Neutral Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	2134	Winding 1 Neutral Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	2135	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	213F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 39 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 2 NEUTRAL INST O/C 2	2140	Winding 2 Neutral Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	2141	Winding 2 Neutral Inst O/C 2 Target	---	---	---	F46	1 = Latched
	2142	Winding 2 Neutral Inst O/C 2 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2143	Winding 2 Neutral Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	2144	Winding 2 Neutral Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	2145	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	214F	Reserved					
WINDING 3 NEUTRAL INST O/C 2	2150	Winding 3 Neutral Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	2151	Winding 3 Neutral Inst O/C 2 Target	---	---	---	F46	1 = Latched
	2152	Winding 3 Neutral Inst O/C 2 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2153	Winding 3 Neutral Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	2154	Winding 3 Neutral Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	2155	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	215F	Reserved					
WINDING 1 GROUND TIME O/C	2160	Winding 1 Ground Time O/C Function	---	---	---	F30	1 = Enabled
	2161	Winding 1 Ground Time O/C Target	---	---	---	F46	1 = Latched
	2162	Winding 1 Ground Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	85 = 0.85 × CT
	2163	Winding 1 Ground Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2164	Winding 1 Ground Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2165	Winding 1 Ground Time O/C Reset	---	---	---	F68	1 = Linear
	2166	Winding 1 Ground Time O/C Block	---	---	---	F87	0 = Disabled
	2167	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	216F	Reserved					
WINDING 2 GROUND TIME O/C	2170	Winding 2 Ground Time O/C Function	---	---	---	F30	0 = Disabled
	2171	Winding 2 Ground Time O/C Target	---	---	---	F46	1 = Latched
	2172	Winding 2 Ground Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	85 = 0.85 × CT
	2173	Winding 2 Ground Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2174	Winding 2 Ground Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2175	Winding 2 Ground Time O/C Reset	---	---	---	F68	1 = Linear
	2176	Winding 2 Ground Time O/C Block	---	---	---	F87	0 = Disabled
	2177	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	217F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 40 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 3 GROUND TIME O/C	2180	Winding 3 Ground Time O/C Function	---	---	---	F30	0 = Disabled
	2181	Winding 3 Ground Time O/C Target	---	---	---	F46	1 = Latched
	2182	Winding 3 Ground Time O/C Pickup	0.05 to 20.00	0.01	x CT	F3	85 = 0.85 x CT
	2183	Winding 3 Ground Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2184	Winding 3 Ground Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2185	Winding 3 Ground Time O/C Reset	---	---	---	F68	1 = Linear
	2186	Winding 3 Ground Time O/C Block	---	---	---	F87	0 = Disabled
	2187	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	218F	Reserved					
WINDING 1 GROUND INST O/C 1	2190	Winding 1 Ground Inst O/C 1 Function	---	---	---	F30	0 = Disabled
	2191	Winding 1 Ground Inst O/C 1 Target	---	---	---	F46	1 = Latched
	2192	Winding 1 Ground Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	2193	Winding 1 Ground Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	2194	Winding 1 Ground Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	2195	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	219F	Reserved					
WINDING 2 GROUND INST O/C 1	21A0	Winding 2 Ground Inst O/C 1 Function	---	---	---	F30	0 = Disabled
	21A1	Winding 2 Ground Inst O/C 1 Target	---	---	---	F46	1 = Latched
	21A2	Winding 2 Ground Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	21A3	Winding 2 Ground Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	21A4	Winding 2 Ground Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	21A5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21AF	Reserved					
WINDING 3 GROUND INST O/C 1	21B0	Winding 3 Ground Inst O/C 1 Function	---	---	---	F30	0 = Disabled
	21B1	Winding 3 Ground Inst O/C 1 Target	---	---	---	F46	1 = Latched
	21B2	Winding 3 Ground Inst O/C 1 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	21B3	Winding 3 Ground Inst O/C 1 Delay	0 to 60000	1	ms	F1	0 ms
	21B4	Winding 3 Ground Inst O/C 1 Block	---	---	---	F87	0 = Disabled
	21B5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21BF	Reserved					
WINDING 1 GROUND INST O/C 2	21C0	Winding 1 Ground Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	21C1	Winding 1 Ground Inst O/C 2 Target	---	---	---	F46	1 = Latched
	21C2	Winding 1 Ground Inst O/C 2 Pickup	0.05 to 20.00	0.01	x CT	F3	1000=10.00 x CT
	21C3	Winding 1 Ground Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms

Table 8–6: 745 MEMORY MAP (Sheet 41 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 1 GROUND INST OC 2 continued	21C4	Winding 1 Ground Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	21C5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21CF	Reserved					
WINDING 2 GROUND INST O/C 2	21D0	Winding 2 Ground Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	21D1	Winding 2 Ground Inst O/C 2 Target	---	---	---	F46	1 = Latched
	21D2	Winding 2 Ground Inst O/C 2 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	21D3	Winding 2 Ground Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	21D4	Winding 2 Ground Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	21D5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21DF	Reserved					
WINDING 3 GROUND INST O/C 2	21E0	Winding 3 Ground Inst O/C 2 Function	---	---	---	F30	0 = Disabled
	21E1	Winding 3 Ground Inst O/C 2 Target	---	---	---	F46	1 = Latched
	21E2	Winding 3 Ground Inst O/C 2 Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	21E3	Winding 3 Ground Inst O/C 2 Delay	0 to 60000	1	ms	F1	0 ms
	21E4	Winding 3 Ground Inst O/C 2 Block	---	---	---	F87	0 = Disabled
	21E5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21EF	Reserved					
WINDING 1 RESTD GND FAULT	21F0	Winding 1 Restricted Ground Fault Function	---	---	---	F30	0 = Disabled
	21F1	Winding 1 Restricted Ground Fault Target	---	---	---	F46	1 = Latched
	21F2	Winding 1 Restricted Ground Fault Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	21F3	Winding 1 Restricted Ground Fault Slope	0 to 100	1	%	F1	10%
	21F4	Winding 1 Restricted Ground Fault Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	21F5	Winding 1 Restricted Ground Fault Block	---	---	---	F87	0 = Disabled
	21F6	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	21FF	Reserved					
WINDING 2 RESTD GND FAULT	2200	Winding 2 Restricted Ground Fault Function	---	---	---	F30	0 = Disabled
	2201	Winding 2 Restricted Ground Fault Target	---	---	---	F46	1 = Latched
	2202	Winding 2 Restricted Ground Fault Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	2203	Winding 2 Restricted Ground Fault Slope	0 to 100	1	%	F1	10%
	2204	Winding 2 Restricted Ground Fault Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	2205	Winding 2 Restricted Ground Fault Block	---	---	---	F87	0 = Disabled
	2206	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	220F	Reserved					

8

Table 8–6: 745 MEMORY MAP (Sheet 42 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 3 RESTD GND FAULT	2210	Winding 3 Restricted Ground Fault Function	---	---	---	F30	0 = Disabled
	2211	Winding 3 Restricted Ground Fault Target	---	---	---	F46	1 = Latched
	2212	Winding 3 Restricted Ground Fault Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	2213	Winding 3 Restricted Ground Fault Slope	0 to 100	1	%	F1	10%
	2214	Winding 3 Restricted Ground Fault Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	2215	Winding 3 Restricted Ground Fault Block	---	---	---	F87	0 = Disabled
	2216	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	221F	Reserved					
WINDING 1 RESTD GND TREND	2220	Winding 1 Restricted Ground Trend Function	---	---	---	F30	0 = Disabled
	2221	Winding 1 Restricted Ground Trend Target	---	---	---	F46	1 = Latched
	2222	Winding 1 Restricted Ground Trend Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	2223	Winding 1 Restricted Ground Trend Slope	0 to 100	1	%	F1	90%
	2224	Winding 1 Restricted Ground Trend Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	2225	Winding 1 Restricted Ground Trend Block	---	---	---	F87	0 = Disabled
	2226	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	222F	Reserved					
WINDING 2 RESTD GND TREND	2230	Winding 2 Restricted Ground Trend Function	---	---	---	F30	0 = Disabled
	2231	Winding 2 Restricted Ground Trend Target	---	---	---	F46	1 = Latched
	2232	Winding 2 Restricted Ground Trend Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	2233	Winding 2 Restricted Ground Trend Slope	0 to 100	1	%	F1	90%
	2234	Winding 2 Restricted Ground Trend Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	2235	Winding 2 Restricted Ground Trend Block	---	---	---	F87	0 = Disabled
	2236	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	223F	Reserved					
WINDING 3 RESTD GND TREND	2240	Winding 3 Restricted Ground Trend Function	---	---	---	F30	0 = Disabled
	2241	Winding 3 Restricted Ground Trend Target	---	---	---	F46	1 = Latched
	2242	Winding 3 Restricted Ground Trend Pickup	0.05 to 20.00	0.01	× CT	F3	8 = 0.08 × CT
	2243	Winding 3 Restricted Ground Trend Slope	0 to 100	1	%	F1	90%
	2244	Winding 3 Restricted Ground Trend Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	2245	Winding 3 Restricted Ground Trend Block	---	---	---	F87	0 = Disabled
	2246	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	224F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 43 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 1 NEG SEQ TIME O/C	2250	Winding 1 Neg Seq Time O/C Function	---	---	---	F30	0 = Disabled
	2251	Winding 1 Neg Seq Time O/C Target	---	---	---	F46	1 = Latched
	2252	Winding 1 Neg Seq Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	25 = 0.25 × CT
	2253	Winding 1 Neg Seq Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2254	Winding 1 Neg Seq Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2255	Winding 1 Neg Seq Time O/C Reset	---	---	---	F68	1 = Linear
	2256	Winding 1 Neg Seq Time O/C Block	---	---	---	F87	0 = Disabled
	2257	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	225F	Reserved					
WINDING 2 NEG SEQ TIME O/C	2260	Winding 2 Neg Seq Time O/C Function	---	---	---	F30	0 = Disabled
	2261	Winding 2 Neg Seq Time O/C Target	---	---	---	F46	1 = Latched
	2262	Winding 2 Neg Seq Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	25 = 0.25 × CT
	2263	Winding 2 Neg Seq Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2264	Winding 2 Neg Seq Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2265	Winding 2 Neg Seq Time O/C Reset	---	---	---	F68	1 = Linear
	2266	Winding 2 Neg Seq Time O/C Block	---	---	---	F87	0 = Disabled
	2267	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	226F	Reserved					
WINDING 3 NEG SEQ TIME O/C	2270	Winding 3 Neg Seq Time O/C Function	---	---	---	F30	0 = Disabled
	2271	Winding 3 Neg Seq Time O/C Target	---	---	---	F46	1 = Latched
	2272	Winding 3 Neg Seq Time O/C Pickup	0.05 to 20.00	0.01	× CT	F3	25 = 0.25 × CT
	2273	Winding 3 Neg Seq Time O/C Shape	---	---	---	F36	0 = Ext Inverse
	2274	Winding 3 Neg Seq Time O/C Multiplier	0.00 to 100.00	0.01	---	F3	100 = 1.00
	2275	Winding 3 Neg Seq Time O/C Reset	---	---	---	F68	1 = Linear
	2276	Winding 3 Neg Seq Time O/C Block	---	---	---	F87	0 = Disabled
	2277	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	227F	Reserved					
WINDING 1 NEG SEQ INST O/C	2280	Winding 1 Neg Seq Inst O/C Function	---	---	---	F30	0 = Disabled
	2281	Winding 1 Neg Seq Inst O/C Target	---	---	---	F46	1 = Latched
	2282	Winding 1 Neg Seq Inst O/C Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2283	Winding 1 Neg Seq Inst O/C Delay	0 to 60000	1	ms	F1	0 ms
	2284	Winding 1 Neg Seq Inst O/C Block	---	---	---	F87	0 = Disabled
	2285	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	228F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 44 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 2 NEG SEQ INST O/C	2290	Winding 2 Neg Seq Inst O/C Function	---	---	---	F30	0 = Disabled
	2291	Winding 2 Neg Seq Inst O/C Target	---	---	---	F46	1 = Latched
	2292	Winding 2 Neg Seq Inst O/C Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	2293	Winding 2 Neg Seq Inst O/C Delay	0 to 60000	1	ms	F1	0 ms
	2294	Winding 2 Neg Seq Inst O/C Block	---	---	---	F87	0 = Disabled
	2295	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	229F	Reserved					
WINDING 3 NEG SEQ INST O/C	22A0	Winding 3 Neg Seq Inst O/C Function	---	---	---	F30	0 = Disabled
	22A1	Winding 3 Neg Seq Inst O/C Target	---	---	---	F46	1 = Latched
	22A2	Winding 3 Neg Seq Inst O/C Pickup	0.05 to 20.00	0.01	× CT	F3	1000=10.00 × CT
	22A3	Winding 3 Neg Seq Inst O/C Delay	0 to 60000	1	ms	F1	0 ms
	22A4	Winding 3 Neg Seq Inst O/C Block	---	---	---	F87	0 = Disabled
	22A5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22AF	Reserved					
UNDER FREQUENCY 1	22B0	Underfrequency 1 Function	---	---	---	F30	0 = Disabled
	22B1	Underfrequency 1 Target	---	---	---	F46	0 = Self-reset
	22B2	Underfrequency 1 Minimum Operating Current	0.05 to 1.00	0.01	× CT	F3	20 = 0.20 × CT
	22B3	Underfrequency 1 Pickup	45.00 to 59.99	0.01	Hz	F3	5900 = 59.0 Hz
	22B4	Underfrequency 1 Delay	0.00 to 600.00	0.01	s	F3	100 = 1.00 s
	22B5	Underfrequency 1 Block	---	---	---	F87	0 = Disabled
	22B6	Underfrequency 1 Current Sensing	---	---	---	F30	1 = Enabled
	22B7	Underfrequency 1 Minimum Operating Voltage	0.10 to 0.99	0.01	× VT	F3	50 = 0.50 × VT
	22B8	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22BF	Reserved					
UNDER FREQUENCY 2	22C0	Underfrequency 2 Function	---	---	---	F30	0 = Disabled
	22C1	Underfrequency 2 Target	---	---	---	F46	1 = Latched
	22C2	Underfrequency 2 Minimum Operating Current	0.05 to 1.00	0.01	× CT	F3	20 = 0.20 × CT
	22C3	Underfrequency 2 Pickup	45.00 to 59.99	0.01	Hz	F3	5880 = 58.8 Hz
	22C4	Underfrequency 2 Delay	0.00 to 600.00	0.01	s	F3	10 = 0.10 s
	22C5	Underfrequency 2 Block	---	---	---	F87	0 = Disabled
	22C6	Underfrequency 2 Current Sensing	---	---	---	F30	1 = Enabled
	22C7	Underfrequency 2 Minimum Operating Voltage	0.01 to 0.99	0.01	× VT	F3	50 = 0.50 × VT
	22C8	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22CF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 45 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
FREQUENCY DECAY	22D0	Frequency Decay Function	---	---	---	F30	0 = Disabled
	22D1	Frequency Decay Target	---	---	---	F46	1 = Latched
	22D2	Frequency Decay Minimum Operating Current	0.05 to 1.00	0.01	× CT	F3	20 = 0.20 × CT
	22D3	Frequency Decay Threshold	45.00 to 59.99	0.01	Hz	F3	5950 = 59.5 Hz
	22D4	Frequency Decay Rate 1	0.1 to 5.0	0.1	Hz/s	F2	4 = 0.4 Hz/s
	22D5	Frequency Decay Rate 2	0.1 to 5.0	0.1	Hz/s	F2	10 = 1.0 Hz/s
	22D6	Frequency Decay Rate 3	0.1 to 5.0	0.1	Hz/s	F2	20 = 2.0 Hz/s
	22D7	Frequency Decay Rate 4	0.1 to 5.0	0.1	Hz/s	F2	40 = 4.0 Hz/s
	22D8	Frequency Decay Block	---	---	---	F87	0 = Disabled
	22D9	Frequency Decay Current Sensing	---	---	---	F30	1 = Enabled
	22DA	Frequency Decay Minimum Operating Voltage	0.10 to 0.99	0.01	× VT	F3	50 = 0.50 × VT
	22DB	Frequency Decay Delay	0.00 to 600.00	0.01	s	F3	0 = 0.00 s
	22DC	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22DF	Reserved					
OVER-FREQUENCY	22E0	Overfrequency Function	---	---	---	F30	0 = Disabled
	22E1	Overfrequency Target	---	---	---	F46	1 = Latched
	22E2	Overfrequency Minimum Operating Current	0.05 to 1.00	0.01	× CT	F3	20 = 0.20 × CT
	22E3	Overfrequency Pickup	50.01 to 65.00	0.01	Hz	F3	6050 = 60.5 Hz
	22E4	Overfrequency Delay	0.00 to 600.00	0.01	s	F3	500 = 5.00 s
	22E5	Overfrequency Block	---	---	---	F87	0 = Disabled
	22E6	Overfrequency Current Sensing	---	---	---	F30	1 = Enabled
	22E7	Overfrequency Minimum Operating Voltage	0.10 to 0.99	0.01	× VT	F3	50 = 0.50 × VT
	22E8	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22EF	Reserved					
5th HARMONIC LEVEL	22F0	5th Harmonic Level Function	---	---	---	F30	0 = Disabled
	22F1	5th Harmonic Level Target	---	---	---	F46	0 = Self-reset
	22F2	5th Harmonic Level Min.Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	22F3	5th Harmonic Level Pickup	0.1 to 99.9	0.1	% f_o	F1	100 = 10.0% f_o
	22F4	5th Harmonic Level Delay	0 to 60000	1	s	F1	10 s
	22F5	5th Harmonic Level Block	---	---	---	F87	0 = Disabled
	22F6	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	22FF	Reserved					
VOLTS-PER-HERTZ 1	2300	Volts-Per-Hertz 1 Function	---	---	---	F30	0 = Disabled
	2301	Volts-Per-Hertz 1 Target	---	---	---	F46	0 = Self-reset
	2302	Volts-Per-Hertz 1 Minimum Operating Voltage	0.10 to 0.99	0.01	× VT	F3	10 = 0.10 × VT

Table 8–6: 745 MEMORY MAP (Sheet 46 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
VOLTS-PER-HERTZ 1 continued	2303	Volts-Per-Hertz 1 Pickup	1.00 to 4.00	0.01	V/Hz	F3	236 = 2.36 V/Hz
	2304	Volts-Per-Hertz 1 Shape	---	---	---	F86	0 = Def. Time
	2305	Volts-Per-Hertz 1 Delay	0.00 to 600.00	0.01	s	F3	200 = 2.00 s
	2306	Volts-Per-Hertz 1 Reset	0.0 to 6000.0	0.1	s	F2	0.0 s
	2307	Volts-Per-Hertz 1 Block	---	---	---	F87	0 = Disabled
	2308	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	230F	Reserved					
VOLTS-PER-HERTZ 2	2310	Volts-Per-Hertz 2 Function	---	---	---	F30	0 = Disabled
	2311	Volts-Per-Hertz 2 Target	---	---	---	F46	1 = Latched
	2312	Volts-Per-Hertz 2 Min. Operating Voltage	0.10 to 0.99	0.01	x VT	F3	10 = 0.10 x VT
	2313	Volts-Per-Hertz 2 Pickup	1.00 to 4.00	0.01	V/Hz	F3	214 = 2.14 V/Hz
	2314	Volts-Per-Hertz 2 Shape	---	---	---	F86	0 = Def. Time
	2315	Volts-Per-Hertz 2 Delay	0.00 to 600.00	0.01	s	F3	4500 = 45.00 s
	2316	Volts-Per-Hertz 2 Reset	0.0 to 6000.0	0.1	s	F2	0.0 s
	2317	Volts-Per-Hertz 2 Block	---	---	---	F87	0 = Disabled
	2318	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	231F	Reserved					
WINDING 1 THD LEVEL	2320	Winding 1 THD Level Function	---	---	---	F30	0 = Disabled
	2321	Winding 1 THD Level Target	---	---	---	F46	0 = Self-reset
	2322	Winding 1 THD Level Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2323	Winding 1 THD Level Pickup	0.1 to 50.0	0.1	% *fo*	F2	500 = 50.0%
	2324	Winding 1 THD Level Delay	0 to 60000	1	s	F1	10 s
	2325	Winding 1 THD Level Block	---	---	---	F87	0 = Disabled
	2326	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	232F	Reserved					
WINDING 2 THD LEVEL	2330	Winding 2 THD Level Function	---	---	---	F30	0 = Disabled
	2331	Winding 2 THD Level Target	---	---	---	F46	0 = Self-reset
	2332	Winding 2 THD Level Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2333	Winding 2 THD Level Pickup	0.1 to 50.0	0.1	% *fo*	F2	500 = 50.0%
	2334	Winding 2 THD Level Delay	0 to 60000	1	s	F1	10 s
	2335	Winding 2 THD Level Block	---	---	---	F87	0 = Disabled
	2336	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	233F	Reserved					

8

Table 8–6: 745 MEMORY MAP (Sheet 47 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 3 THD LEVEL	2340	Winding 3 THD Level Function	---	---	---	F30	0 = Disabled
	2341	Winding 3 THD Level Target	---	---	---	F46	0 = Self-reset
	2342	Winding 3 THD Level Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2343	Winding 3 THD Level Pickup	0.1 to 50.0	0.1	% ƒo	F2	500 = 50.0%
	2344	Winding 3 THD Level Delay	0 to 60000	1	s	F1	10 s
	2345	Winding 3 THD Level Block	---	---	---	F87	0 = Disabled
	2346	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	234F	Reserved					
WINDING 1 HARMONIC DERATING	2350	Winding 1 Harm Derating Function	---	---	---	F30	0 = Disabled
	2351	Winding 1 Harm Derating Target	---	---	---	F46	0 = Self-reset
	2352	Winding 1 Harm Derating Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2353	Winding 1 Harm Derating Pickup	0.01 to 0.98	0.01	---	F3	90 = 0.90
	2354	Winding 1 Harm Derating Delay	0 to 60000	1	s	F1	10 s
	2355	Winding 1 Harm Derating Block	---	---	---	F87	0 = Disabled
	2356	Reserved					
	:	:					
	235F	Reserved					
WINDING 2 HARMONIC DERATING	2360	Winding 2 Harm Derating Function	---	---	---	F30	0 = Disabled
	2361	Winding 2 Harm Derating Target	---	---	---	F46	0 = Self-reset
	2362	Winding 2 Harm Derating Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2363	Winding 2 Harm Derating Pickup	0.01 to 0.98	0.01	---	F3	90 = 0.90
	2364	Winding 2 Harm Derating Delay	0 to 60000	1	s	F1	10 s
	2365	Winding 2 Harm Derating Block	---	---	---	F87	0 = Disabled
	2366	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	236F	Reserved					
WINDING 3 HARMONIC DERATING	2370	Winding 3 Harm Derating Function	---	---	---	F30	0 = Disabled
	2371	Winding 3 Harm Derating Target	---	---	---	F46	0 = Self-reset
	2372	Winding 3 Harm Derating Min. Operating Current	0.03 to 1.00	0.01	× CT	F3	10 = 0.10 × CT
	2373	Winding 3 Harm Derating Pickup	0.01 to 0.98	0.01	---	F3	90 = 0.90
	2374	Winding 3 Harm Derating Delay	0 to 60000	1	s	F1	10 s
	2375	Winding 3 Harm Derating Block	---	---	---	F87	0 = Disabled
	2376	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	237F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 48 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
HOTTEST-SPOT LIMIT	2380	Hottest-spot Limit Function	---	---	---	F30	0 = Disabled
	2381	Hottest-spot Limit Target	---	---	---	F46	0 = Self-reset
	2382	Hottest-spot Limit Pickup	50 to 300	1	° C	F1	150° C
	2383	Hottest-spot Limit Delay	0 to 60000	1	min	F1	10 min
	2384	Hottest-spot Limit Block	---	---	---	F87	0 = Disabled
	2385	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	238F	Reserved					
LOSS-OF-LIFE LIMIT	2390	Loss-of-Life Limit Function	---	---	---	F30	0 = Disabled
	2391	Loss-of-Life Limit Target	---	---	---	F46	0 = Self-reset
	2392	Loss-of-Life Limit Pickup	0 to 20000	1	hrs x 10	F1	16000=160000 hrs
	2393	Loss-of-Life Limit Block	---	---	---	F87	0 = Disabled
	2394	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	239F	Reserved					
ANALOG INPUT LEVEL 1	23A0	Analog Input Level 1 Function	---	---	---	F30	0 = Disabled
	23A1	Analog Input Level 1 Target	---	---	---	F46	0 = Self-reset
	23A2	Analog Input Level 1 Pickup	1 to 65000	1	<Units>	F1	10 <Units>
	23A3	Analog Input Level 1 Delay	0 to 60000	1	s	F1	50 s
	23A4	Analog Input Level 1 Block	---	---	---	F87	0 = Disabled
	23A5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23AF	Reserved					
ANALOG INPUT LEVEL 2	23B0	Analog Input Level 2 Function	---	---	---	F30	0 = Disabled
	23B1	Analog Input Level 2 Target	---	---	---	F46	0 = Self-reset
	23B2	Analog Input Level 2 Pickup	1 to 65000	1	<Units>	F1	100 <Units>
	23B3	Analog Input Level 2 Delay	0 to 60000	1	s	F1	100 s
	23B4	Analog Input Level 2 Block	---	---	---	F87	0 = Disabled
	23B5	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23BF	Reserved					
WINDING 1 CURRENT DEMAND	23C0	Winding 1 Current Demand Function	---	---	---	F30	0 = Disabled
	23C1	Winding 1 Current Demand Target	---	---	---	F46	0 = Self-reset
	23C2	Winding 1 Current Demand Pickup	---	---	A	F78	100 A
	23C3	Winding 1 Current Demand Block	---	---	---	F87	0 = Disabled
	23C4	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23CF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 49 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
WINDING 2 CURRENT DEMAND	23D0	Winding 2 Current Demand Function	---	---	---	F30	0 = Disabled
	23D1	Winding 2 Current Demand Target	---	---	---	F46	0 = Self-reset
	23D2	Winding 2 Current Demand Pickup	---	---	A	F79	400 A
	23D3	Winding 2 Current Demand Block	---	---	---	F87	0 = Disabled
	23D4	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23DF	Reserved					
WINDING 3 CURRENT DEMAND	23E0	Winding 3 Current Demand Function	---	---	---	F30	0 = Disabled
	23E1	Winding 3 Current Demand Target	---	---	---	F46	0 = Self-reset
	23E2	Winding 3 Current Demand Pickup	---	---	A	F80	400 A
	23E3	Winding 3 Current Demand Block	---	---	---	F87	0 = Disabled
	23E4	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23EF	Reserved					
XFORMER OVERLOAD	23F0	Transformer Overload Function	---	---	---	F30	0 = Disabled
	23F1	Transformer Overload Target	---	---	---	F46	0 = Self-reset
	23F2	Transformer Overload Pickup	50 to 300	1	% rated	F1	208% rated
	23F3	Transformer Overload Delay	0 to 60000	1	s	F1	10 s
	23F4	Transformer Overload Block	---	---	---	F87	0 = Disabled
	23F5	Transformer Overtemperature Alarm Signal	---	---	---	F88	0 = Disabled
	23F6	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	23FF	Reserved					
AGING FACTOR LIMIT	2400	Aging Factor Limit Function	---	---	---	F30	0 = Disabled
	2401	Aging Factor Limit Target	---	---	---	F46	0 = Self-reset
	2402	Aging Factor Limit Pickup	1.1 to 10.0	0.1	--	F2	20 = 2.0
	2403	Aging Factor Limit Delay	0 to 60000	1	minutes	F1	10 minutes
	2404	Aging Factor Limit Block	---	---	---	F87	0 = Disabled
	2405	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	240F	Reserved					
TAP CHANGER FAILURE	2410	Tap Changer Failure Function	---	---	---	F30	0 = Disabled
	2411	Tap Changer Failure Target	---	---	---	F46	0 = Self-reset
	2412	Tap Changer Failure Delay	0 to 600.00	0.01	s	F3	500 = 5.00 s
	2413	Tap Changer Failure Block	---	---	---	F87	0 = Disabled
	2414	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	3FFF	Reserved					

8

Table 8–6: 745 MEMORY MAP (Sheet 50 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
Trace Memory (Addresses 4000 to 47FF) - Read Only							
TRACE MEMORY	4000	Trace Memory Last Clear Date (2 registers)	---	---	---	F23	---
	4002	Trace Memory Last Clear Time (2 registers)	---	---	---	F22	---
	4004	Total Number of Trace Triggers Since Last Clear	0 to 65535	1	---	F1	---
	4005	Trace Buffer Selector Index (XX) [read/write]	1 to 65535	1	---	F1	---
	4006	Trace Channel Selector Index (YY) [read/write]	---	---	---	F65	---
	4007	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	400F	Reserved					
	4010	Trace Buffer XX Trigger Date (2 registers)	---	---	---	F23	---
	4012	Trace Buffer XX Trigger Time (2 registers)	---	---	---	F22	---
	4014	Trace Buffer XX Trigger Cause	---	---	---	F85	---
	4015	Trace Buffer XX Trigger Sample Index	0 to 1023	1	---	F1	---
	4016	Trace Buffer XX System Frequency	2.00 to 65.00	0.01	Hz	F3	---
	4017	Trace Buffer XX Channel YY Sample 0	---	---	---	F70	---
	4018	Trace Buffer XX Channel YY Sample 1	---	---	---	F70	---
	↓	↓	↓	↓	↓	↓	↓
	4416	Trace Buffer XX Channel YY Sample 1023	---	---	---	F70	---
	4417	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	47FF	Reserved					
Playback Memory (Addresses 4800 to 4FFF) - Read / Write							
PLAYBACK MEMORY	4800	Playback Channel Selector Index (XX)	---	---	---	F69	---
	4801	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	480F	Reserved					
	4810	Playback Channel XX Sample 0	---	---	---	F70	---
	4811	Playback Channel XX Sample 1	---	---	---	F70	---
	↓	↓	↓	↓	↓	↓	↓
	4C0F	Playback Channel XX Sample 1023	---	---	---	F70	---
	4C10	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	4FFF	Reserved					
Factory Service (Addresses 5000 to 7FFF) - Read / Write							
FACTORY SERVICE	5000	Factory Service Function Passcode	---	---	---	F1	0
	5001	Factory Service Commands	---	---	---	F71	0
	5002	Force LED Status Column 1	---	---	---	F54	0
	5003	Force LED Status Column 2	---	---	---	F54	0

8

Table 8–6: 745 MEMORY MAP (Sheet 51 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
FACTORY SERVICE continued	5004	Force LED Status Column 3	---	---	---	F54	0
	5005	Force Other Hardware	---	---	---	F72	0
	5006	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	5009	Reserved					
SETTING ERRORS	500A	FlexLogic Equation Error	---	---	---	F76	0 = None
	500B	Bad Transformer Settings Error	---	---	---	F77	0 = None
	500C	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	500F	Reserved					
SELF-TEST ERROR FLAGS	5010	Logic Input Error Flag	---	---	---	F52	0
	5011	Analog Output Error Flag	---	---	---	F52	0
	5012	Calibration Error Flag	---	---	---	F52	0
	5013	EEPROM Error Flag	---	---	---	F52	0
	5014	Real Time Clock Error Flag	---	---	---	F52	0
	5015	Battery Error Flag	---	---	---	F52	0
	5016	Emulation Software Error Flag	---	---	---	F52	0
	5017	Internal Temperature Error Flag	---	---	---	F52	0
	5018	Flexlogic Error Flag	---	---	---	F52	0
	5019	DSP Error Flag	---	---	---	F52	0
	501A	Bad Settings Error Flag	---	---	---	F52	0
	501B	IRIG-B Signal Error Flag	---	---	---	F52	0
	501C	Access Denied Error Flag	---	---	---	F52	0
	501D	Ambient Temperature Error Flag	---	---	---	F52	---
	501E	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	501F	Reserved					
HARDWARE DIAGNOSTICS	5020	Operating Hours of Relay	0 to 65535	1	hours	F1	0
	5021	Internal Temperature	–55.0 to 150.0	0.1	°C	F5	---
	5022	Minimum Internal Temperature	–55.0 to 150.0	0.1	°C	F5	---
	5023	Maximum Internal Temperature	–55.0 to 150.0	0.1	°C	F5	---
	5024	0-1 mA Analog Input	0 to 65535	1	μA	F1	---
	5025	0-20 mA Analog Input	0 to 65535	1	μA	F1	---
	5026	Last Front Panel Key Pressed	---	---	---	F55	00 h = No Key
	5027	DSP Diagnostic Flags	---	---	---	F51	---
	5028	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	502F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 52 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
SOFTWARE DIAGNOSTICS	5030	Unexpected Interrupt Counter	0 to 65535	1	---	F1	0
	5031	Last Unexpected Interrupt Vector	0 to 255	1	---	F1	0
	5032	Unexpected Reset Counter	0 to 65535	1	---	F1	0
	5033	Last Unexpected Reset Cause	0 to 255	1	---	F1	0
	5034	EEPROM Scrub Counter	0 to 65535	1	---	F1	0
	5035	A/D Virtual Ground Error Counter	0 to 65535	1	---	F1	0
	5036	Front RS232 Error Counter	0 to 65535	1	---	F1	0
	5037	COM1 Error Counter	0 to 65535	1	---	F1	0
	5038	COM2 Error Counter	0 to 65535	1	---	F1	0
	5039	Processor Usage	0.0 to 100.0	0.1	%	F2	---
	503A	RAM Memory Usage	0.0 to 100.0	0.1	%	F2	---
	503B	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	503F	Reserved					
COMPILE DATE/TIME	5040	Boot Program Compile Date (2 registers)	---	---	---	F23	---
	5042	Boot Program Compile Time (2 registers)	---	---	---	F22	---
	5044	Main Program Compile Date (2 registers)	---	---	---	F23	---
	5046	Main Program Compile Time (2 registers)	---	---	---	F22	---
	5048	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	50FF	Reserved					
CALIBRATION DATA	5100	Date of Last Calibration (2 registers)	---	---	---	F23	---
	5102	Date of Original Calibration (2 registers)	---	---	---	F23	---
	5104	x8 to x1 Saturation Level	0 to 32767	1	counts	F1	3000 counts
	5105	Winding 1 Phase A Current x1 Offset	–100 to +100	1	---	F4	0
	5106	Winding 1 Phase A Current x1 Gain	0 to 20000	1	---	F1	15556
	5107	Winding 1 Phase A Current x8 Offset	–100 to +100	1	---	F4	0
	5108	Winding 1 Phase A Current x8 Gain	0 to 20000	1	---	F1	15556
	5109	Winding 1 Phase B Current x1 Offset	–100 to +100	1	---	F4	0
	510A	Winding 1 Phase B Current x1 Gain	0 to 20000	1	---	F1	15556
	510B	Winding 1 Phase B Current x8 Offset	–100 to +100	1	---	F4	0
	510C	Winding 1 Phase B Current x8 Gain	0 to 20000	1	---	F1	15556
	510D	Winding 1 Phase C Current x1 Offset	–100 to +100	1	---	F4	0
	510E	Winding 1 Phase C Current x1 Gain	0 to 20000	1	---	F1	15556
	510F	Winding 1 Phase C Current x8 Offset	–100 to +100	1	---	F4	0
	5110	Winding 1 Phase C Current x8 Gain	0 to 20000	1	---	F1	15556
	5111	Winding 1/2 Ground Current x1 Offset	–100 to +100	1	---	F4	0
	5112	Winding 1/2 Ground Current x1 Gain	0 to 20000	1	---	F1	15556

Table 8–6: 745 MEMORY MAP (Sheet 53 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
CALIBRATION DATA continued	5113	Winding 1/2 Ground Current x8 Offset	–100 to +100	1	---	F4	0
	5114	Winding 1/2 Ground Current x8 Gain	0 to 20000	1	---	F1	15556
	5115	Winding 2 Phase A Current x1 Offset	–100 to +100	1	---	F4	0
	5116	Winding 2 Phase A Current x1 Gain	0 to 20000	1	---	F1	15556
	5117	Winding 2 Phase A Current x8 Offset	–100 to +100	1	---	F4	0
	5118	Winding 2 Phase A Current x8 Gain	0 to 20000	1	---	F1	15556
	5119	Winding 2 Phase B Current x1 Offset	–100 to +100	1	---	F4	0
	511A	Winding 2 Phase B Current x1 Gain	0 to 20000	1	---	F1	15556
	511B	Winding 2 Phase B Current x8 Offset	–100 to +100	1	---	F4	0
	511C	Winding 2 Phase B Current x8 Gain	0 to 20000	1	---	F1	15556
	511D	Winding 2 Phase C Current x1 Offset	–100 to +100	1	---	F4	0
	511E	Winding 2 Phase C Current x1 Gain	0 to 20000	1	---	F1	15556
	511F	Winding 2 Phase C Current x8 Offset	–100 to +100	1	---	F4	0
	5120	Winding 2 Phase C Current x8 Gain	0 to 20000	1	---	F1	15556
	5121	Winding 2/3 Ground Current x1 Offset	–100 to +100	1	---	F4	0
	5122	Winding 2/3 Ground Current x1 Gain	0 to 20000	1	---	F1	15556
	5123	Winding 2/3 Ground Current x8 Offset	–100 to +100	1	---	F4	0
	5124	Winding 2/3 Ground Current x8 Gain	0 to 20000	1	---	F1	15556
	5125	Winding 3 Phase A Current x1 Offset	–100 to +100	1	---	F4	0
	5126	Winding 3 Phase A Current x1 Gain	0 to 20000	1	---	F1	15556
	5127	Winding 3 Phase A Current x8 Offset	–100 to +100	1	---	F4	0
	5128	Winding 3 Phase A Current x8 Gain	0 to 20000	1	---	F1	15556
	5129	Winding 3 Phase B Current x1 Offset	–100 to +100	1	---	F4	0
	512A	Winding 3 Phase B Current x1 Gain	0 to 20000	1	---	F1	15556
	512B	Winding 3 Phase B Current x8 Offset	–100 to +100	1	---	F4	0
	512C	Winding 3 Phase B Current x8 Gain	0 to 20000	1	---	F1	15556
	512D	Winding 3 Phase C Current x1 Offset	–100 to +100	1	---	F4	0
	512E	Winding 3 Phase C Current x1 Gain	0 to 20000	1	---	F1	15556
	512F	Winding 3 Phase C Current x8 Offset	–100 to +100	1	---	F4	0
	5130	Winding 3 Phase C Current x8 Gain	0 to 20000	1	---	F1	15556
	5131	Voltage Input ×1 Offset	–100 to +100	1	---	F4	0
	5132	Voltage Input ×1 Gain	0 to 20000	1	---	F1	1412
	5133	Voltage Input ×8 Offset	–100 to +100	1	---	F4	0
	5134	Voltage Input ×8 Gain	0 to 20000	1	---	F1	1412
	5135	Tap Changer Input Low Offset	–600 to +600	1	---	F4	0
	5136	Tap Changer Input Low Gain	0 to 10000	1	---	F1	5779
	5137	Tap Changer Input High Offset	–600 to +600	1	---	F4	0
	5138	Tap Changer Input High Gain	0 to 1000	1	---	F1	578

Table 8–6: 745 MEMORY MAP (Sheet 54 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
CALIBRATION DATA continued	5139	Ambient Temperature RTD Input Low Offset	–600 to +600	1	---	F4	0
	513A	Ambient Temperature RTD Input Low Gain	0 to 20000	1	---	F1	8192
	513B	Ambient Temperature RTD Input High Offset	–600 to +600	1	---	F4	0
	513C	Ambient Temperature RTD Input High Gain	0 to 20000	1	---	F1	8192
	513D	Analog Input 1 mA Offset	–600 to +600	1	---	F4	0
	513E	Analog Input 1 mA Gain	0 to 2000	1	---	F1	1112
	513F	Analog Input 20 mA Offset	–600 to +600	1	---	F4	0
	5140	Analog Input 20 mA Gain	0 to 30000	1	---	F1	22244
	5141	Analog Output #1 Min Scale	0 to 4095	1	---	F1	0
	5142	Analog Output #1 Max Scale	0 to 4095	1	---	F1	4095
	5143	Analog Output #2 Min Scale	0 to 4095	1	---	F1	0
	5144	Analog Output #2 Max Scale	0 to 4095	1	---	F1	4095
	5145	Analog Output #3 Min Scale	0 to 4095	1	---	F1	0
	5146	Analog Output #3 Max Scale	0 to 4095	1	---	F1	4095
	5147	Analog Output #4 Min Scale	0 to 4095	1	---	F1	0
	5148	Analog Output #4 Max Scale	0 to 4095	1	---	F1	4095
	5149	Analog Output #5 Min Scale	0 to 4095	1	---	F1	0
	514A	Analog Output #5 Max Scale	0 to 4095	1	---	F1	4095
	514B	Analog Output #6 Min Scale	0 to 4095	1	---	F1	0
	514C	Analog Output #6 Max Scale	0 to 4095	1	---	F1	4095
	514D	Analog Output #7 Min Scale	0 to 4095	1	---	F1	0
	514E	Analog Output #7 Max Scale	0 to 4095	1	---	F1	4095
	514F	Analog Output #8 Reference	0 to 4095	1	---	F1	4095
	5150	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	515F	Reserved					
ANALOG OUTPUT D/A COUNTS	5160	Force Analog Output 1 D/A Count	0 to 4095	1	---	F1	0
	5161	Force Analog Output 2 D/A Count	0 to 4095	1	---	F1	0
	5162	Force Analog Output 3 D/A Count	0 to 4095	1	---	F1	0
	5163	Force Analog Output 4 D/A Count	0 to 4095	1	---	F1	0
	5164	Force Analog Output 5 D/A Count	0 to 4095	1	---	F1	0
	5165	Force Analog Output 6 D/A Count	0 to 4095	1	---	F1	0
	5166	Force Analog Output 7 D/A Count	0 to 4095	1	---	F1	0
	5167	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	516F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 55 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
RMS PRESENT, MIN, MAX READINGS	5170	Winding 1 Phase A RMS Current	---	---	× CT	F53	---
	5171	Winding 1 Phase A RMS Current Minimum	---	---	× CT	F53	---
	5172	Winding 1 Phase A RMS Current Maximum	---	---	× CT	F53	---
	5173	Winding 1 Phase B RMS Current	---	---	× CT	F53	---
	5174	Winding 1 Phase B RMS Current Minimum	---	---	× CT	F53	---
	5175	Winding 1 Phase B RMS Current Maximum	---	---	× CT	F53	---
	5176	Winding 1 Phase C RMS Current	---	---	× CT	F53	---
	5177	Winding 1 Phase C RMS Current Minimum	---	---	× CT	F53	---
	5178	Winding 1 Phase C RMS Current Maximum	---	---	× CT	F53	---
	5179	Winding 1/2 Ground RMS Current	---	---	× CT	F53	---
	517A	Winding 1/2 Ground RMS Current Minimum	---	---	× CT	F53	---
	517B	Winding 1/2 Ground RMS Current Maximum	---	---	× CT	F53	---
	517C	Winding 2 Phase A RMS Current	---	---	× CT	F53	---
	517D	Winding 2 Phase A RMS Current Minimum	---	---	× CT	F53	---
	517E	Winding 2 Phase A RMS Current Maximum	---	---	× CT	F53	---
	517F	Winding 2 Phase B RMS Current	---	---	× CT	F53	---
	5180	Winding 2 Phase B RMS Current Minimum	---	---	× CT	F53	---
	5181	Winding 2 Phase B RMS Current Maximum	---	---	× CT	F53	---
	5182	Winding 2 Phase C RMS Current	---	---	× CT	F53	---
	5183	Winding 2 Phase C RMS Current Minimum	---	---	× CT	F53	---
	5184	Winding 2 Phase C RMS Current Maximum	---	---	× CT	F53	---
	5185	Winding 2/3 Ground RMS Current	---	---	× CT	F53	---
	5186	Winding 2/3 Ground RMS Current Minimum	---	---	× CT	F53	---
	5187	Winding 2/3 Ground RMS Current Maximum	---	---	× CT	F53	---
	5188	Winding 3 Phase A RMS Current	---	---	× CT	F53	---
	5189	Winding 3 Phase A RMS Current Minimum	---	---	× CT	F53	---
	518A	Winding 3 Phase A RMS Current Maximum	---	---	× CT	F53	---
	518B	Winding 3 Phase B RMS Current	---	---	× CT	F53	---
	518C	Winding 3 Phase B RMS Current Minimum	---	---	× CT	F53	---
	518D	Winding 3 Phase B RMS Current Maximum	---	---	× CT	F53	---
	518E	Winding 3 Phase C RMS Current	---	---	× CT	F53	---
	518F	Winding 3 Phase C RMS Current Minimum	---	---	× CT	F53	---
	5190	Winding 3 Phase C RMS Current Maximum	---	---	× CT	F53	---
	5191	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	519F	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 56 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
CALIBRATION SAMPLE DATA	51A0	Winding 1 Phase A Current Sample	---	---	---	F70	---
	51A1	Winding 1 Phase B Current Sample	---	---	---	F70	---
	51A2	Winding 1 Phase C Current Sample	---	---	---	F70	---
	51A3	Winding 1/2 Ground Current Sample	---	---	---	F70	---
	51A4	Winding 2 Phase A Current Sample	---	---	---	F70	---
	51A5	Winding 2 Phase B Current Sample	---	---	---	F70	---
	51A6	Winding 2 Phase C Current Sample	---	---	---	F70	---
	51A7	Winding 2/3 Ground Current Sample	---	---	---	F70	---
	51A8	Winding 3 Phase A Current Sample	---	---	---	F70	---
	51A9	Winding 3 Phase B Current Sample	---	---	---	F70	---
	51AA	Winding 3 Phase C Current Sample	---	---	---	F70	---
	51AB	Voltage Sample	---	---	---	F70	---
	51AC	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	51AF	Reserved					
CALIBRATION GROUND CURRENTS	51B0	Winding 1/2 Ground Current - RMS Magnitude	---	---	A	F81 / F82	---
	51B1	Winding 2/3 Ground Current - RMS Magnitude	---	---	A	F82 / F83	---
	51B2	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	51BF	Reserved					
SERIAL A/D COUNTS	51C0	20 mA Analog Input Count	0 to 65535	---	---	F1	---
	51C1	1 mA Analog Input Count	0 to 65535	---	---	F1	---
	51C2	RTD High-Gain Count	0 to 65535	---	---	F1	---
	51C3	RTD Low-Gain Count	0 to 65535	---	---	F1	---
	51C4	RTD No-Sensor Count	0 to 65535	---	---	F1	---
	51C5	Tap Position High-Gain Count	0 to 65535	---	---	F1	---
	51C6	Tap Position Low-Gain Count	0 to 65535	---	---	F1	---
	51C7	32V Analog Output Monitor	0 to 65535	---	---	F1	---
	51C8	Internal Temperature Zero Bias	0 to 65535	---	---	F1	---
	51C9	Internal Temperature	0 to 65535	---	---	F1	---
	51CA	Zero Reference	0 to 65535	---	---	F1	---
	51CB	Half-Scale Test	0 to 65535	---	---	F1	---
	51CC	Zero-Scale Test	0 to 65535	---	---	F1	---
	51CD	Full-Scale Test	0 to 65535	---	---	F1	---
	51CE	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	51FF	Reserved					

Table 8–6: 745 MEMORY MAP (Sheet 57 of 57)

GROUP	ADDR (HEX)	DESCRIPTION	RANGE	STEP VALUE	UNITS	FORMAT CODE	FACTORY DEFAULT
FRONT PANEL DISPLAY	5200	Front Panel Display Buffer (20 registers)	---	---	---	F33	---
	5214	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	521F	Reserved					
	5220	Override Message Function	---	---	---	F30	---
	5221	Override Message (20 registers)	---	---	---	F33	---
	5235	Reserved					
	↓	↓	↓	↓	↓	↓	↓
	7FFF	Reserved					

8.3.2 MEMORY MAP DATA FORMATS

Table 8–7: 745 DATA FORMATS (Sheet 1 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
F1	**16 bits**	**UNSIGNED VALUE**
	Example: 1234 stored as 1234	
F2	**16 bits**	**UNSIGNED VALUE 1 DECIMAL PLACE**
	Example: 123.4 stored as 1234	
F3	**16 bits**	**UNSIGNED VALUE 2 DECIMAL PLACES**
	Example: 12.34 stored as 1234	
F4	**16 bits**	**2's COMPLEMENT SIGNED VALUE**
	Example: –1234 stored as –1234	
F5	**16 bits**	**2's COMPLEMENT SIGNED VALUE, 1 DECIMAL PLACE**
	Example: –123.4 stored as –1234	
F6	**16 bits**	**2's COMPLEMENT SIGNED VALUE, 2 DECIMAL PLACES**
	Example: –12.34 stored as –1234	
F7	**32 bits**	**UNSIGNED LONG VALUE**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: 123456 stored as 123456	
F8	**32 bits**	**UNSIGNED LONG VALUE, 1 DECIMAL PLACE**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: 12345.6 stored as 123456	
F9	**32 bits**	**UNSIGNED LONG VALUE, 2 DECIMAL PLACES**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: 1234.56 stored as 123456	
F10	**32 bits**	**2's COMPLEMENT SIGNED LONG VALUE**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: -123456 stored as -123456	
F11	**32 bits**	**2's COMPLEMENT SIGNED LONG VALUE, 1 DECIMAL PLACE**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: –12345.6 stored as –123456	

Table 8–7: 745 DATA FORMATS (Sheet 2 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
F12	**32 bits**	**2's COMPLEMENT SIGNED LONG VALUE, 2 DECIMAL PLACES**
	1st 16 bits	high order word of long value
	2nd 16 bits	low order word of long value
	Example: –1234.56 stored as –123456	
F13	**16 bits**	**HARDWARE REVISION**
	0000 0000 0000 0001	1 = A
	0000 0000 0000 0010	2 = B
	↓	↓
	0000 0000 0001 1010	26 = Z
F14	**16 bits**	**SOFTWARE REVISION**
	xxxx 1111 xxxx xxxx	Major Revision Number 0 to 9 in steps of 1
	xxxx xxxx 1111 xxxx	Minor Revision Number 0 to 9 in steps of 1
	xxxx xxxx xxxx 1111	Ultra Minor Revision Number 0 to 9 in steps of 1
	Example: Revision 2.83 stored as 0283 hex	
F15	**16 bits**	**INSTALLED OPTIONS**
	xxxx xxxx xxxx xxx1	Windings Per Phase (0 = Two Windings, 1 = Three Windings)
	xxxx xxxx xxxx xx1x	Rating of Winding 1 Phase Current Inputs (0 = 1 A, 1 = 5 A)
	xxxx xxxx xxxx x1xx	Rating of Winding 2 Phase Current Inputs (0 = 1 A, 1 = 5 A)
	xxxx xxxx xxxx 1xxx	Rating of Winding 3 Phase Current Inputs (0 = 1 A, 1 = 5 A)
	xxxx xxxx xxx1 xxxx	Rating of Winding 1/2 Ground Current Inputs (0 = 1 A, 1 = 5 A)
	xxxx xxxx xx1x xxxx	Rating of Winding 2/3 Ground Current Inputs (0 = 1 A, 1 = 5 A)
	xxxx xxxx x1xx xxxx	Control Power (0=LO [20-60 Vdc], 1 = HI [90-300 Vdc/70-265 Vac])
	xxxx xxxx 1xxx xxxx	Analog Input/Outputs (0 = Not Installed, 1 = Installed)
	xxxx xxx1 xxxx xxxx	Loss-Of-Life (0 = Not Installed, 1 = Installed)
	xxxx xx1x xxxx xxxx	Restricted Ground Fault (0 = Not Installed, 1 = Installed)
F16	**16 bits**	**DEMAND INTERVAL/RESPONSE**
	0000 0000 0000 0000	0 = 5 min
	0000 0000 0000 0001	1 = 10 min
	0000 0000 0000 0010	2 = 15 min

8

Table 8–7: 745 DATA FORMATS (Sheet 3 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0011	3 = 20 min
	0000 0000 0000 0100	4 = 30 min
	0000 0000 0000 0101	5 = 60 min
F17	**16 bits**	**COMMUNICATION HARDWARE**
	0000 0000 0000 0000	0 = RS485
	0000 0000 0000 0001	1 = RS422
F18	**16 bits**	**MAXIMUM DEMAND PHASE**
	0000 0000 0000 0000	0 = in phase A
	0000 0000 0000 0001	1 = in phase B
	0000 0000 0000 0010	2 = in phase C
F19	**16 bits**	**COMMAND OPERATION CODE**
	0000 0000 0000 0000	0000 = NO OPERATION
	0000 0000 0000 0001	0001 = REMOTE RESET
	0000 0000 0000 0010	0002 = TRIGGER TRACE MEMORY
	0000 0000 0000 0011	0003 = CLEAR MAX DEMAND DATA
	0000 0000 0000 0100	0004 = CLEAR EVENT RECORDER
	0000 0000 0000 0110	0006 = CLEAR TRACE MEMORY
	0000 0000 0000 0111	0007 = CLEAR ENERGY DATA
F20	**16 bits**	**RELAY STATUS**
	xxxx xxxx xxxx xxx1	745 In Service (0= Not In Service, 1= In Service)
	xxxx xxxx xxxx xx1x	Self-Test Error (0 = No Error, 1 = Error(s))
	xxxx xxxx xxxx x1xx	Test Mode (0 = Disabled, 1 = Enabled)
	xxxx xxxx xxxx 1xxx	Differential Blocked (0 = Not Blocked, 1 = Blocked)
	xxxx xxxx x1xx xxxx	Local (0 = Off, 1 = On)
	xxxx xxxx 1xxx xxxx	Message (0 = No Diagnostic Messages, 1 = Active Diagnostic Message(s))
F21	**16 bits**	**SYSTEM STATUS**
	xxxx xxxx xxxx xxx1	Transformer De-energized (0 = Energized, 1 = De-energized)
	xxxx xxxx xxxx xx1x	Transformer Overload (0 = Normal, 1 = Overload)
	xxxx xxxx xxxx x1xx	Load-Limit Reduced (0 = Not Reduced, 1 = Reduced)
	xxxx xxxx xxx1 xxxx	Setpoint Group 1 (0 = Not Active, 1 = Active)
	xxxx xxxx xx1x xxxx	Setpoint Group 2 (0 = Not Active, 1 = Active)
	xxxx xxxx x1xx xxxx	Setpoint Group 3 (0 = Not Active, 1 = Active)

Table 8–7: 745 DATA FORMATS (Sheet 4 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx xxxx 1xxx xxxx	Setpoint Group 4 (0 = Not Active, 1 = Active)
F22	**32 bits**	**TIME**
	1st 16 bits	**Hours / Minutes (HH:MM:xx.xxx)**
	1111 1111 xxxx xxxx	Hours
	0000 0000	0 = 12 am
	0000 0001	1 = 1 am
	↓	↓
	0001 0111	23 = 11 pm
	xxxx xxxx 1111 1111	Minutes
		0 to 59 in steps of 1
	2nd 16 bits	**Seconds (xx:xx:SS.SSS)**
	0000 0000 0000 0000	0 = 0.000 s
	0000 0000 0000 0001	1 = 0.001 s
	↓	↓
	1110 1010 0101 1111	59999 = 59.999 s
	Note: If the time has never been set then all 32 bits will be 1.	
F23	**32 bits**	**DATE**
	1st 16 bits	**Month / Day (MM/DD/xxxx)**
	1111 1111 xxxx xxxx	Month
	0000 0001	1 = January
	0000 0010	2 = February
	↓	↓
	0000 1100	12 = December
	xxxx xxxx 1111 1111	Day
		1 to 31 in steps of 1
	2nd 16 bits	**Year (xx/xx/YYYY)**
		1990 to 2089 in steps of 1
	Note: If the date has never been set then all 32 bits will be 1.	
F24	**16 bits**	**TYPE/CAUSE OF EVENT**
	1111 xxxx xxxx xxxx	TYPE OF EVENT
	0000 xxxx xxxx xxxx	0 = None
	0001 xxxx xxxx xxxx	1 = Off
	0010 xxxx xxxx xxxx	2 = On
	0011 xxxx xxxx xxxx	3 = Pickup
	0100 xxxx xxxx xxxx	4 = Operate
	0101 xxxx xxxx xxxx	5 = Dropout
	0110 xxxx xxxx xxxx	6 = Error!
	Xxxx 1111 1111 1111	CAUSE OF EVENT
	xxxx 0000 0000 0000	0 = No Event

Table 8–7: 745 DATA FORMATS (Sheet 5 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx 0000 0000 0001	1 = Percent Differential
	xxxx 0000 0000 0010	2 = Inst Differential
	xxxx 0000 0000 0011	3 = W1 Phase Time OC
	xxxx 0000 0000 0100	4 = W2 Phase Time OC
	xxxx 0000 0000 0101	5 = W3 Phase Time OC
	xxxx 0000 0000 0110	6 = W1 Phase Inst 1 OC
	xxxx 0000 0000 0111	7 = W2 Phase Inst 1 OC
	xxxx 0000 0000 1000	8 = W3 Phase Inst 1 OC
	xxxx 0000 0000 1001	9 = W1 Phase Inst 2 OC
	xxxx 0000 0000 1010	10 = W2 Phase Inst 2 OC
	xxxx 0000 0000 1011	11 = W3 Phase Inst 2 OC
	xxxx 0000 0000 1100	12 = W1 Neutral Time OC
	xxxx 0000 0000 1101	13 = W2 Neutral Time OC
	xxxx 0000 0000 1110	14 = W3 Neutral Time OC
	xxxx 0000 0000 1111	15 = W1 Neutral Inst 1 OC
	xxxx 0000 0001 0000	16 = W2 Neutral Inst 1 OC
	xxxx 0000 0001 0001	17 = W3 Neutral Inst 1 OC
	xxxx 0000 0001 0010	18 = W1 Neutral Inst 2 OC
	xxxx 0000 0001 0011	19 = W2 Neutral Inst 2 OC
	xxxx 0000 0001 0100	20 = W3 Neutral Inst 2 OC
	xxxx 0000 0001 0101	21 = W1 Ground Time OC
	xxxx 0000 0001 0110	22 = W2 Ground Time OC
	xxxx 0000 0001 0111	23 = W3 Ground Time OC
	xxxx 0000 0001 1000	24 = W1 Ground Inst 1 OC
	xxxx 0000 0001 1001	25 = W2 Ground Inst 1 OC
	xxxx 0000 0001 1010	26 = W3 Ground Inst 1 OC
	xxxx 0000 0001 1011	27 = W1 Ground Inst 2 OC
	xxxx 0000 0001 1100	28 = W2 Ground Inst 2 OC
	xxxx 0000 0001 1101	29 = W3 Ground Inst 2 OC
	xxxx 0000 0001 1110	30 = W1 Restd Gnd Fault
	xxxx 0000 0001 1111	31 = W2 Restd Gnd Fault
	xxxx 0000 0010 0000	32 = W3 Restd Gnd Fault
	xxxx 0000 0010 0001	33 = W1 Restd Gnd Trend
	xxxx 0000 0010 0010	34 = W2 Restd Gnd Trend
	xxxx 0000 0010 0011	35 = W3 Restd Gnd Trend
	xxxx 0000 0010 0100	36 = W1 Neg Seq Time OC
	xxxx 0000 0010 0101	37 = W2 Neg Seq Time OC
	xxxx 0000 0010 0110	38 = W3 Neg Seq Time OC
	xxxx 0000 0010 0111	39 = W1 Neg Seq Inst OC
	xxxx 0000 0010 1000	40 = W2 Neg Seq Inst OC

Table 8–7: 745 DATA FORMATS (Sheet 6 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx 0000 0010 1001	41 = W3 Neg Seq Inst OC
	xxxx 0000 0010 1010	42 = Underfrequency 1
	xxxx 0000 0010 1011	43 = Underfrequency 2
	xxxx 0000 0010 1100	44 = Frequency Decay 1
	xxxx 0000 0010 1101	45 = Frequency Decay 2
	xxxx 0000 0010 1110	46 = Frequency Decay 3
	xxxx 0000 0010 1111	47 = Frequency Decay 4
	xxxx 0000 0011 0000	48 = Overfrequency
	xxxx 0000 0011 0001	49 = 5th Harmonic Level
	xxxx 0000 0011 0010	50 = Volts-Per-Hertz 1
	xxxx 0000 0011 0011	51 = Volts-Per-Hertz 2
	xxxx 0000 0011 0100	52 = W1 THD Level
	xxxx 0000 0011 0101	53 = W2 THD Level
	xxxx 0000 0011 0110	54 = W3 THD Level
	xxxx 0000 0011 0111	55 = W1 Harmonic Derating
	xxxx 0000 0011 1000	56 = W2 Harmonic Derating
	xxxx 0000 0011 1001	57 = W3 Harmonic Derating
	xxxx 0000 0011 1010	58 = Hottest Spot Limit
	xxxx 0000 0011 1011	59 = Loss-Of-Life Limit
	xxxx 0000 0011 1100	60 = Analog Level 1
	xxxx 0000 0011 1101	61 = Analog Level 2
	xxxx 0000 0011 1110	62 = W1 Current Demand
	xxxx 0000 0011 1111	63 = W2 Current Demand
	xxxx 0000 0100 0000	64 = W3 Current Demand
	xxxx 0000 0100 0001	65 = Transformer Overload
	xxxx 0000 0100 0010	66 = Logic Input 1
	xxxx 0000 0100 0011	67 = Logic Input 2
	xxxx 0000 0100 0100	68 = Logic Input 3
	xxxx 0000 0100 0101	69 = Logic Input 4
	xxxx 0000 0100 0110	70 = Logic Input 5
	xxxx 0000 0100 0111	71 = Logic Input 6
	xxxx 0000 0100 1000	72 = Logic Input 7
	xxxx 0000 0100 1001	73 = Logic Input 8
	xxxx 0000 0100 1010	74 = Logic Input 9
	xxxx 0000 0100 1011	75 = Logic Input 10
	xxxx 0000 0100 1100	76 = Logic Input 11
	xxxx 0000 0100 1101	77 = Logic Input 12
	xxxx 0000 0100 1110	78 = Logic Input 13
	xxxx 0000 0100 1111	79 = Logic Input 14
	xxxx 0000 0101 0000	80 = Logic Input 15

Table 8–7: 745 DATA FORMATS (Sheet 7 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx 0000 0101 0001	81 = Logic Input 16
	xxxx 0000 0101 0010	82 = Virtual Input 1
	xxxx 0000 0101 0011	83 = Virtual Input 2
	xxxx 0000 0101 0100	84 = Virtual Input 3
	xxxx 0000 0101 0101	85 = Virtual Input 4
	xxxx 0000 0101 0110	86 = Virtual Input 5
	xxxx 0000 0101 0111	87 = Virtual Input 6
	xxxx 0000 0101 1000	88 = Virtual Input 7
	xxxx 0000 0101 1001	89 = Virtual Input 8
	xxxx 0000 0101 1010	90 = Virtual Input 9
	xxxx 0000 0101 1011	91 = Virtual Input 10
	xxxx 0000 0101 1100	92 = Virtual Input 11
	xxxx 0000 0101 1101	93 = Virtual Input 12
	xxxx 0000 0101 1110	94 = Virtual Input 13
	xxxx 0000 0101 1111	95 = Virtual Input 14
	xxxx 0000 0110 0000	96 = Virtual Input 15
	xxxx 0000 0110 0001	97 = Virtual Input 16
	xxxx 0000 0110 0010	98 = Output Relay 1
	xxxx 0000 0110 0011	99 = Output Relay 2
	xxxx 0000 0110 0100	100 = Output Relay 3
	xxxx 0000 0110 0101	101 = Output Relay 4
	xxxx 0000 0110 0110	102 = Output Relay 5
	xxxx 0000 0110 0111	103 = Output Relay 6
	xxxx 0000 0110 1000	104 = Output Relay 7
	xxxx 0000 0110 1001	105 = Output Relay 8
	xxxx 0000 0110 1010	106 = Self-Test Relay
	xxxx 0000 0110 1011	107 = Virtual Output 1
	xxxx 0000 0110 1100	108 = Virtual Output 2
	xxxx 0000 0110 1101	109 = Virtual Output 3
	xxxx 0000 0110 1110	110 = Virtual Output 4
	xxxx 0000 0110 1111	111 = Virtual Output 5
	xxxx 0000 0111 0000	112 = Setpoint Group 1
	xxxx 0000 0111 0001	113 = Setpoint Group 2
	xxxx 0000 0111 0010	114 = Setpoint Group 3
	xxxx 0000 0111 0011	115 = Setpoint Group 4
	xxxx 0000 0111 0100	116 = Test Mode
	xxxx 0000 0111 0101	117 = Simulation Disabled
	xxxx 0000 0111 0110	118 = Simulation Prefault
	xxxx 0000 0111 0111	119 = Simulation Fault
	xxxx 0000 0111 1000	120 = Simulation Playback

Table 8–7: 745 DATA FORMATS (Sheet 8 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx 0000 0111 1001	121 = Logic Input Reset
	xxxx 0000 0111 1010	122 = Front Panel Reset
	xxxx 0000 0111 1011	123 = Comm Port Reset
	xxxx 0000 0111 1100	124 = Manual Trace Trigger
	xxxx 0000 0111 1101	125 = Auto Trace Trigger
	xxxx 0000 0111 1110	126 = Control Power
	xxxx 0000 0111 1111	127 = Logic Input Power
	xxxx 0000 1000 0000	128 = Analog Output Power
	xxxx 0000 1000 0001	129 = Unit Not Calibrated
	xxxx 0000 1000 0010	130 = EEPROM Memory
	xxxx 0000 1000 0011	131 = Real-Time Clock
	xxxx 0000 1000 0100	132 = Battery
	xxxx 0000 1000 0101	133 = Emulation Software
	xxxx 0000 1000 0110	134 = Int Temperature
	xxxx 0000 1000 0111	135 = Flexlogic Equation
	xxxx 0000 1000 1000	136 = DSP Processor
	xxxx 0000 1000 1001	137 = Bad Xfmr Settings
	xxxx 0000 1000 1010	138 = IRIG-B Signal
	xxxx 0000 1000 1011	139 = Setpt Access Denied
	xxxx 0000 1000 1100	140 = Aging factor Limit
	xxxx 0000 1000 1101	141 = Ambient Temperature
	xxxx 0000 1000 1110	142 = Tap Changer Failure
F25	**16 bits**	**2's COMPLEMENT SIGNED VALUE, 3 DECIMAL PLACES**
	Example: –1.234 stored as –1234	
F26	**16 bits**	**ANALOG OUTPUT RANGE**
	0000 0000 0000 0000	0 = 0-1 mA
	0000 0000 0000 0001	1 = 0-5 mA
	0000 0000 0000 0010	2 = 4-20 mA
	0000 0000 0000 0011	3 = 0-20 mA
	0000 0000 0000 0100	4 = 0-10 mA
F27	**16 bits**	**PHASE SEQUENCE**
	0000 0000 0000 0000	0 = ABC
	0000 0000 0000 0001	1 = ACB
F28	**16 bits**	**TRANSFORMER TYPE**
	0000 0000 0000 0000	0 = 2W (extn correction)
	0000 0000 0000 0001	1 = Y/y0°
	0000 0000 0000 0010	2 = Y/y180°
	0000 0000 0000 0011	3 = Y/d30°
	0000 0000 0000 0100	4 = Y/d150°

8

Table 8–7: 745 DATA FORMATS (Sheet 9 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0101	5 = Y/d210°
	0000 0000 0000 0110	6 = Y/d330°
	0000 0000 0000 0111	7 = D/d0°
	0000 0000 0000 1000	8 = D/d60°
	0000 0000 0000 1001	9 = D/d120°
	0000 0000 0000 1010	10 = D/d180°
	0000 0000 0000 1011	11 = D/d240°
	0000 0000 0000 1100	12 = D/d300°
	0000 0000 0000 1101	13 = D/y30°
	0000 0000 0000 1110	14 = D/y150°
	0000 0000 0000 1111	15 = D/y210°
	0000 0000 0001 0000	16 = D/y330°
	0000 0000 0001 0001	17 = Y/z30°
	0000 0000 0001 0010	18 = Y/z150°
	0000 0000 0001 0011	19 = Y/z210°
	0000 0000 0001 0100	20 = Y/z330°
	0000 0000 0001 0101	21 = D/z0°
	0000 0000 0001 0110	22 = D/z60°
	0000 0000 0001 0111	23 = D/z120°
	0000 0000 0001 1000	24 = D/z180°
	0000 0000 0001 1001	25 = D/z240°
	0000 0000 0001 1010	26 = D/z300°
	0000 0000 0001 1011	27 = 3W (extn correction)
	0000 0000 0001 1100	28 = Y/y0°/d30°
	0000 0000 0001 1101	29 = Y/y0°/d150°
	0000 0000 0001 1110	30 = Y/y0°/d210°
	0000 0000 0001 1111	31 = Y/y0°/d330°
	0000 0000 0010 0000	32 = Y/y180°/d30°
	0000 0000 0010 0001	33 = Y/y180°/d150°
	0000 0000 0010 0010	34 = Y/y180°/d210°
	0000 0000 0010 0011	35 = Y/y180°/d330°
	0000 0000 0010 0100	36 = Y/d30°/y0°
	0000 0000 0010 0101	37 = Y/d30°/y180°
	0000 0000 0010 0110	38 = Y/d30°/d30°
	0000 0000 0010 0111	39 = Y/d30°/d150°
	0000 0000 0010 1000	40 = Y/d30°/d210°
	0000 0000 0010 1001	41 = Y/d30°/d330°
	0000 0000 0010 1010	42 = Y/d150°/y0°
	0000 0000 0010 1011	43 = Y/d150°/y180°
	0000 0000 0010 1100	44 = Y/d150°/d30°

Table 8–7: 745 DATA FORMATS (Sheet 10 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0010 1101	45 = Y/d150°/d150°
	0000 0000 0010 1110	46 = Y/d150°/d210°
	0000 0000 0010 1111	47 = Y/d150°/d330°
	0000 0000 0011 0000	48 = Y/d210°/y0°
	0000 0000 0011 0001	49 = Y/d210°/y180°
	0000 0000 0011 0010	50 = Y/d210°/d30°
	0000 0000 0011 0011	51 = Y/d210°/d150°
	0000 0000 0011 0100	52 = Y/d210°/d210°
	0000 0000 0011 0101	53 = Y/d210°/d330°
	0000 0000 0011 0110	54 = Y/d330°/y0°
	0000 0000 0011 0111	55 = Y/d330°/y180°
	0000 0000 0011 1000	56 = Y/d330°/d30°
	0000 0000 0011 1001	57 = Y/d330°/d150°
	0000 0000 0011 1010	58 = Y/d330°/d210°
	0000 0000 0011 1011	59 = Y/d330°/d330°
	0000 0000 0011 1100	60 = D/d0°/d0°
	0000 0000 0011 1101	61 = D/d0°/d60°
	0000 0000 0011 1110	62 = D/d0°/d120°
	0000 0000 0011 1111	63 = D/d0°/d180°
	0000 0000 0100 0000	64 = D/d0°/d240°
	0000 0000 0100 0001	65 = D/d0°/d300°
	0000 0000 0100 0010	66 = D/d0°/y30°
	0000 0000 0100 0011	67 = D/d0°/y150°
	0000 0000 0100 0100	68 = D/d0°/y210°
	0000 0000 0100 0101	69 = D/d0°/y330°
	0000 0000 0100 0110	70 = D/d60°/d0°
	0000 0000 0100 0111	71 = D/d60°/d60°
	0000 0000 0100 1000	72 = D/d60°/d240°
	0000 0000 0100 1001	73 = D/d60°/y30°
	0000 0000 0100 1010	74 = D/d60°/y210°
	0000 0000 0100 1011	75 = D/d120°/d0°
	0000 0000 0100 1100	76 = D/d120°/d120°
	0000 0000 0100 1101	77 = D/d120°/d180°
	0000 0000 0100 1110	78 = D/d120°/y150°
	0000 0000 0100 1111	79 = D/d120°/y330°
	0000 0000 0101 0000	80 = D/d180°/d0°
	0000 0000 0101 0001	81 = D/d180°/d120°
	0000 0000 0101 0010	82 = D/d180°/d180°
	0000 0000 0101 0011	83 = D/d180°/d300°
	0000 0000 0101 0100	84 = D/d180°/y150°

Table 8–7: 745 DATA FORMATS (Sheet 11 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0101 0101	85 = D/d180°/y330°
	0000 0000 0101 0110	86 = D/d240°/d0°
	0000 0000 0101 0111	87 = D/d240°/d60°
	0000 0000 0101 1000	88 = D/d240°/d240°
	0000 0000 0101 1001	89 = D/d240°/y30°
	0000 0000 0101 1010	90 = D/d240°/y210°
	0000 0000 0101 1011	91 = D/d300°/d0°
	0000 0000 0101 1100	92 = D/d300°/d180°
	0000 0000 0101 1101	93 = D/d300°/d300°
	0000 0000 0101 1110	94 = D/d300°/y150°
	0000 0000 0101 1111	95 = D/d300°/y330°
	0000 0000 0110 0000	96 = D/y30°/d0°
	0000 0000 0110 0001	97 = D/y30°/d60°
	0000 0000 0110 0010	98 = D/y30°/d240°
	0000 0000 0110 0011	99 = D/y30°/y30°
	0000 0000 0110 0100	100 = D/y30°/y210°
	0000 0000 0110 0101	101 = D/y150°/d0°
	0000 0000 0110 0110	102 = D/y150°/d120°
	0000 0000 0110 0111	103 = D/y150°/d180°
	0000 0000 0110 1000	104 = D/y150°/d300°
	0000 0000 0110 1001	105 = D/y150°/y150°
	0000 0000 0110 1010	106 = D/y150°/y330°
	0000 0000 0110 1011	107 = D/y210°/d0°
	0000 0000 0110 1100	108 = D/y210°/d60°
	0000 0000 0110 1101	109 = D/y210°/d240°
	0000 0000 0110 1110	110 = D/y210°/y30°
	0000 0000 0110 1111	111 = D/y210°/y210°
	0000 0000 0111 0000	112 = D/y330°/d0°
	0000 0000 0111 0001	113 = D/y330°/d120°
	0000 0000 0111 0010	114 = D/y330°/d180°
	0000 0000 0111 0011	115 = D/y330°/d300°
	0000 0000 0111 0100	116 = D/y330°/y150°
	0000 0000 0111 0101	117 = D/y330°/y330°
	0000 0000 0111 0110	118 = Y/z30°/z30°
	0000 0000 0111 0111	119 = Y/y0°/y0°
F29	**16 bits**	**745 OPERATION**
	0000 0000 0000 0000	0 = Not Programmed
	0000 0000 0000 0001	1 = Programmed
F30	**16 bits**	**ENABLED/DISABLED**
	0000 0000 0000 0000	0 = Disabled

Table 8–7: 745 DATA FORMATS (Sheet 12 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0001	1 = Enabled
F31	**16 bits**	**BAUD RATE**
	0000 0000 0000 0000	0 = 300 Baud
	0000 0000 0000 0001	1 = 1200 Baud
	0000 0000 0000 0010	2 = 2400 Baud
	0000 0000 0000 0011	3 = 4800 Baud
	0000 0000 0000 0100	4 = 9600 Baud
	0000 0000 0000 0101	5 = 19200 Baud
F32	**32 bits**	**DEFAULT MESSAGE**
		Internally Defined
F33	**16 bits**	**ASCII TEXT CHARACTERS**
	xxxx xxxx 1111 1111	Second ASCII Character
	1111 1111 xxxx xxxx	First ASCII Character
F34	**16 bits**	**RELAY STATE**
	0000 0000 0000 0000	0 = De-energized
	0000 0000 0000 0001	1 = Energized
F35	**16 bits**	**CONDITIONS**
	xxxx xxxx xxxx xxx1	Trip (0 = No Active Trip Condition, 1 = Active Trip Condition)
	xxxx xxxx xxxx xx1x	Alarm (0=No Active Alarm Conditions, 1=Active Alarm Condition(s))
	xxxx xxxx xxxx x1xx	Pickup (0 = No Pickup, 1 = Pickup)
	xxxx xxxx xxx1 xxxx	Phase A (1 = Phase A Fault)
	xxxx xxxx xx1x xxxx	Phase B (1 = Phase B Fault)
	xxxx xxxx x1xx xxxx	Phase C (1 = Phase C Fault)
	xxxx xxxx 1xxx xxxx	Ground (1 = Ground Fault)
F36	**16 bits**	**OVERCURRENT CURVE SHAPE**
	0000 0000 0000 0000	0 = Ext Inverse
	0000 0000 0000 0001	1 = Very Inverse
	0000 0000 0000 0010	2 = Norm Inverse
	0000 0000 0000 0011	3 = Mod Inverse
	0000 0000 0000 0100	4 = Definite Time
	0000 0000 0000 0101	5 = IEC Curve A
	0000 0000 0000 0110	6 = IEC Curve B
	0000 0000 0000 0111	7 = IEC Curve C
	0000 0000 0000 1000	8 = IEC Short In
	0000 0000 0000 1001	9 = IAC Ext Inv
	0000 0000 0000 1010	10 = IAC Very Inv
	0000 0000 0000 1011	11 = IAC Inverse
	0000 0000 0000 1100	12 = IAC Short Inv

Table 8–7: 745 DATA FORMATS (Sheet 13 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 1101	13 = FlexCurve A
	0000 0000 0000 1110	14 = FlexCurve B
	0000 0000 0000 1111	15 = FlexCurve C
F37	**16 bits**	**RATED WINDING TEMPERATURE RISE**
	0000 0000 0000 0000	0 = 55° C (oil)
	0000 0000 0000 0001	1 = 65° C (oil)
	0000 0000 0000 0010	2 = 80° C (dry)
	0000 0000 0000 0011	3 = 115° C (dry)
	0000 0000 0000 0100	4 = 150° C (dry)
F38	**16 bits**	**OUTPUT TYPE**
	0000 0000 0000 0000	0 = Trip
	0000 0000 0000 0001	1 = Alarm
	0000 0000 0000 0010	2 = Control
F39	**16 bits**	**COOLING TYPE FOR OIL-FILLED TRANSFORMER**
	0000 0000 0000 0000	0 = OA
	0000 0000 0000 0001	1 = FA
	0000 0000 0000 0010	2 = Non-Directed FOA/FOW
	0000 0000 0000 0011	3 = Directed FOA/FOW
F40	**16 bits**	**WINDING SELECTION**
	0000 0000 0000 0000	0 = None
	0000 0000 0000 0001	1 = Winding 1
	0000 0000 0000 0010	2 = Winding 2
	0000 0000 0000 0011	3 = Winding 3
F41	**16 bits**	**RTD TYPE**
	0000 0000 0000 0000	0 = 100 ohm Platinum
	0000 0000 0000 0001	1 = 120 ohm Nickel
	0000 0000 0000 0010	2 = 100 ohm Nickel
	0000 0000 0000 0011	3 = Monthly Average
F42	**16 bits**	**ANALOG INPUT RANGE**
	0000 0000 0000 0000	0 = 0-1 mA
	0000 0000 0000 0001	1 = 0-5 mA
	0000 0000 0000 0010	2 = 4-20 mA
	0000 0000 0000 0011	3 = 0-20 mA
F43	**16 bits**	**NOT ASSERTED / ASSERTED**
	0000 0000 0000 0000	0 = Not Asserted
	0000 0000 0000 0001	1 = Asserted
F44	**16 bits**	**OPERATION STATUS**
	xxxx xxxx xxxx xxx1	Code Programming Mode (0 = Disabled, 1 = Enabled)

Table 8–7: 745 DATA FORMATS (Sheet 14 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx xxxx xxxx xx1x	Setpoint Access Jumper (0 = Disabled, 1 = Enabled)
	xxxx xxxx xxxx x1xx	Factory Service Mode (0 = Disabled, 1 = Enabled)
	xxxx xxxx xxxx 1xxx	Comm Port Passcode Access (0 = Read & Write, 1 = Read Only)
F45	**16 bits**	**ANALOG OUTPUT VALUE**
	0000 0000 0000 0000	0 = W1 øA Current
	0000 0000 0000 0001	1 = W1 øB Current
	0000 0000 0000 0010	2 = W1 øC Current
	0000 0000 0000 0011	3 = W2 øA Current
	0000 0000 0000 0100	4 = W2 øB Current
	0000 0000 0000 0101	5 = W2 øC Current
	0000 0000 0000 0110	6 = W3 øA Current
	0000 0000 0000 0111	7 = W3 øB Current
	0000 0000 0000 1000	8 = W3 øC Current
	0000 0000 0000 1001	9 = W1 Loading
	0000 0000 0000 1010	10 = W2 Loading
	0000 0000 0000 1011	11 = W3 Loading
	0000 0000 0000 1100	12 = W1 øA THD
	0000 0000 0000 1101	13 = W1 øB THD
	0000 0000 0000 1110	14 = W1 øC THD
	0000 0000 0000 1111	15 = W2 øA THD
	0000 0000 0001 0000	16 = W2 øB THD
	0000 0000 0001 0001	17 = W2 øC THD
	0000 0000 0001 0010	18 = W3 øA THD
	0000 0000 0001 0011	19 = W3 øB THD
	0000 0000 0001 0100	20 = W3 øC THD
	0000 0000 0001 0101	21 = W1 Derating
	0000 0000 0001 0110	22 = W2 Derating
	0000 0000 0001 0111	23 = W3 Derating
	0000 0000 0001 1000	24 = Frequency
	0000 0000 0001 1001	25 = Tap Position
	0000 0000 0001 1010	26 = Voltage
	0000 0000 0001 1011	27 = W1 øA Demand
	0000 0000 0001 1100	28 = W1 øB Demand
	0000 0000 0001 1101	29 = W1 øC Demand
	0000 0000 0001 1110	30 = W2 øA Demand
	0000 0000 0001 1111	31 = W2 øB Demand
	0000 0000 0010 0000	32 = W2 øC Demand
	0000 0000 0010 0001	33 = W3 øA Demand

Table 8–7: 745 DATA FORMATS (Sheet 15 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0010 0010	34 = W3 øB Demand
	0000 0000 0010 0011	35 = W3 øC Demand
	0000 0000 0010 0100	36 = Analog Input
	0000 0000 0010 0101	37 = Max Event W1 Ia
	0000 0000 0010 0110	38 = Max Event W1 Ib
	0000 0000 0010 0111	39 = Max Event W1 Ic
	0000 0000 0010 1000	40 = Max Event W1 Ig
	0000 0000 0010 1001	41 = Max Event W2 Ia
	0000 0000 0010 1010	42 = Max Event W2 Ib
	0000 0000 0010 1011	43 = Max Event W2 Ic
	0000 0000 0010 1100	44 = Max Event W2 Ig
	0000 0000 0010 1101	45 = Max Event W3 Ia
	0000 0000 0010 1110	46 = Max Event W3 Ib
	0000 0000 0010 1111	47 = Max Event W3 Ic
	0000 0000 0011 0000	48 = Max Event W3 Ig
F46	**16 bits**	**TARGET TYPES**
	0000 0000 0000 0000	0 = Self-reset
	0000 0000 0000 0001	1 = Latched
	0000 0000 0000 0010	2 = None
F47	**16 bits**	**FLEXLOGIC EQUATION**
	0000 0000 0000 0000	Token = END
	0000 0001 0000 0000	Token = OFF
	0000 0010 0000 0000	Token = ON
	0000 0011 0000 0000	Token = NOT gate
	0000 0100 xxxx xxxx	Token = OR gate
	0000 0010	2 = 2 input OR gate
	0000 0011	3 = 3 input OR gate
	↓	↓
	0001 0011	19 = 19 input OR gate
	0000 0101 xxxx xxxx	Token = AND gate
	0000 0010	2 = 2 input AND gate
	0000 0011	3 = 3 input AND gate
	↓	↓
	0001 0011	19 = 19 input AND gate
	0000 0110 xxxx xxxx	Token = NOR gate
	0000 0010	2 = 2 input NOR gate
	0000 0011	3 = 3 input NOR gate
	↓	↓
	0001 0011	19 = 19 input NOR gate
	0000 0111 xxxx xxxx	Token = NAND gate

Table 8–7: 745 DATA FORMATS (Sheet 16 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0010	2 = 2 input NAND gate
	0000 0011	3 = 3 input NAND gate
	↓	↓
	0001 0011	19 = 19 input NAND gate
	0000 1000 xxxx xxxx	Token = XOR gate
	0000 0010	2 = 2 input XOR gate
	0000 0011	3 = 3 input XOR gate
	↓	↓
	0001 0011	19 = 19 input XOR gate
	0000 1001 xxxx xxxx	Token = Element Pickup
	0000 0000	0= Any Element
	0000 0001	1 = Any W1 Overcurrent
	0000 0010	2 = Any W2 Overcurrent
	0000 0011	3 = Any W3 Overcurrent
	0000 0100	4 = Percent Differential
	0000 0101	5 = Inst Differential
	0000 0110	6 = Winding 1 Phase Time O/C
	0000 0111	7 = Winding 2 Phase Time O/C
	0000 1000	8 = Winding 3 Phase Time O/C
	0000 1001	9 = Winding 1 Phase Inst O/C 1
	0000 1010	10 = Winding 2 Phase Inst O/C 1
	0000 1011	11 = Winding 3 Phase Inst O/C 1
	0000 1100	12 = Winding 1 Phase Inst O/C 2
	0000 1101	13 = Winding 2 Phase Inst O/C 2
	0000 1110	14 = Winding 3 Phase Inst O/C 2
	0000 1111	15 = Winding 1 Neutral Time O/C
	0001 0000	16 = Winding 2 Neutral Time O/C
	0001 0001	17 = Winding 3 Neutral Time O/C
	0001 0010	18 = Winding 1 Neutral Inst O/C 1
	0001 0011	19 = Winding 2 Neutral Inst O/C 1
	0001 0100	20 = Winding 3 Neutral Inst O/C 1
	0001 0101	21 = Winding 1 Neutral Inst O/C 2
	0001 0110	22 = Winding 2 Neutral Inst O/C 2
	0001 0111	23 = Winding 3 Neutral Inst O/C 2
	0001 1000	24 = Winding 1 Ground Time O/C
	0001 1001	25 = Winding 2 Ground Time O/C
	0001 1010	26 = Winding 3 Ground Time O/C
	0001 1011	27 = Winding 1 Ground Inst O/C 1
	0001 1100	28 = Winding 2 Ground Inst O/C 1
	0001 1101	29 = Winding 3 Ground Inst O/C 1

Table 8–7: 745 DATA FORMATS (Sheet 17 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0001 1110	30 = Winding 1 Ground Inst O/C 2
	0001 1111	31 = Winding 2 Ground Inst O/C 2
	0010 0000	32 = Winding 3 Ground Inst O/C 2
	0010 0001	33=Winding 1 Restricted Ground Fault
	0010 0010	34=Winding 2 Restricted Ground Fault
	0010 0011	35=Winding 3 Restricted Ground Fault
	0010 0100	36=Winding 1 Restricted Ground Trend
	0010 0101	37=Winding 2 Restricted Ground Trend
	0010 0110	38=Winding 3 Restricted Ground Trend
	0010 0111	39 = Winding 1 Neg. Seq. Time O/C
	0010 1000	40 = Winding 2 Neg. Seq. Time O/C
	0010 1001	41 = Winding 3 Neg. Seq. Time O/C
	0010 1010	42 = Winding 1 Neg. Seq. Inst O/C
	0010 1011	43 = Winding 2 Neg. Seq. Inst O/C
	0010 1100	44 = Winding 3 Neg. Seq. Inst O/C
	0010 1101	45 = Underfrequency 1
	0010 1110	46 = Underfrequency 2
	0010 1111	47 = Frequency Decay Rate 1
	0011 0000	48 = Frequency Decay Rate 2
	0011 0001	49 = Frequency Decay Rate 3
	0011 0010	50 = Frequency Decay Rate 4
	0011 0011	51 = Overfrequency
	0011 0100	52 = 5th Harmonic Level
	0011 0101	53 = Volts-Per-Hertz 1
	0011 0110	54 = Volts-Per-Hertz 2
	0011 0111	55 = Winding 1 THD Level
	0011 1000	56 = Winding 2 THD Level
	0011 1001	57 = Winding 3 THD Level
	0011 1010	58 = Winding 1 Harmonic Derating
	0011 1011	59 = Winding 2 Harmonic Derating
	0011 1100	60 = Winding 3 Harmonic Derating
	0011 1101	61 = Hottest-Spot Temperature Limit
	0011 1110	62 = Loss-Of-Life Limit
	0011 1111	63 = Analog Input Level 1
	0100 0000	64 = Analog Input Level 2
	0100 0001	65 = Winding 1 Current Demand
	0100 0010	66 = Winding 2 Current Demand
	0100 0011	67 = Winding 3 Current Demand
	0100 0100	68 = Transformer Overload
	0100 0101	69 = Aging Factor Limit

Table 8–7: 745 DATA FORMATS (Sheet 18 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0100 0110	70 = Tap Changer Failure
	0000 1010 xxxx xxxx	Token = Element Operated (data same as for Element Pickup)
	0000 1011 xxxx xxxx	Token = Logic Input Asserted
	0000 0000	0 = Logic Input 1
	0000 0001	1 = Logic Input 2
	0000 0010	2 = Logic Input 3
	0000 0011	3 = Logic Input 4
	0000 0100	4 = Logic Input 5
	0000 0101	5 = Logic Input 6
	0000 0110	6 = Logic Input 7
	0000 0111	7 = Logic Input 8
	0000 1000	8 = Logic Input 9
	0000 1001	9 = Logic Input 10
	0000 1010	10 = Logic Input 11
	0000 1011	11 = Logic Input 12
	0000 1100	12 = Logic Input 13
	0000 1101	13 = Logic Input 14
	0000 1110	14 = Logic Input 15
	0000 1111	15 = Logic Input 16
	0000 1100 xxxx xxxx	Token = Virtual Input Asserted
	0000 0000	0 = Virtual Input 1
	0000 0001	1 = Virtual Input 2
	0000 0010	2 = Virtual Input 3
	0000 0011	3 = Virtual Input 4
	0000 0100	4 = Virtual Input 5
	0000 0101	5 = Virtual Input 6
	0000 0110	6 = Virtual Input 7
	0000 0111	7 = Virtual Input 8
	0000 1000	8 = Virtual Input 9
	0000 1001	9 = Virtual Input 10
	0000 1010	10 = Virtual Input 11
	0000 1011	11 = Virtual Input 12
	0000 1100	12 = Virtual Input 13
	0000 1101	13 = Virtual Input 14
	0000 1110	14 = Virtual Input 15
	0000 1111	15 = Virtual Input 16
	0000 1101 xxxx xxxx	Token = Output Relay Operated
	0000 0000	0 = Output Relay 1
	0000 0001	1 = Output Relay 2

Table 8–7: 745 DATA FORMATS (Sheet 19 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0010	2 = Output Relay 3
	0000 0011	3 = Output Relay 4
	0000 0100	4 = Output Relay 5
	0000 0101	5 = Output Relay 6
	0000 0110	6 = Output Relay 7
	0000 0111	7 = Output Relay 8
	0000 1000	8 = Self-Test Relay
	0000 1110 xxxx xxxx	Token = Virtual Output Operated
	0000 0000	0 = Virtual Output 1
	0000 0001	1 = Virtual Output 2
	0000 0010	2 = Virtual Output 3
	0000 0011	3 = Virtual Output 4
	0000 0100	4 = Virtual Output 5
	0000 1111 xxxx xxxx	Token = Timer Operated
	0000 0000	0 = Timer 1
	0000 0001	1 = Timer 2
	0000 0010	2 = Timer 3
	0000 0011	3 = Timer 4
	0000 0100	4 = Timer 5
	0000 0101	5 = Timer 6
	0000 0110	6 = Timer 7
	0000 0111	7 = Timer 8
	0000 1000	8 = Timer 9
	0000 1001	9 = Timer 10
F48	**16 bits**	**SIMULATION FUNCTION**
	0000 0000 0000 0000	0 = Disabled
	0000 0000 0000 0001	1 = Prefault Mode
	0000 0000 0000 0010	2 = Fault Mode
	0000 0000 0000 0011	3 = Playback Mode
F49	**16 bits**	**INPUT STATES**
	xxxx xxxx xxxx xxx1	Input 1 (0 = Open, 1 = Closed)
	xxxx xxxx xxxx xx1x	Input 2 (0 = Open, 1 = Closed)
	xxxx xxxx xxxx x1xx	Input 3 (0 = Open, 1 = Closed)
	xxxx xxxx xxxx 1xxx	Input 4 (0 = Open, 1 = Closed)
	xxxx xxxx xxx1 xxxx	Input 5 (0 = Open, 1 = Closed)
	xxxx xxxx xx1x xxxx	Input 6 (0 = Open, 1 = Closed)
	xxxx xxxx x1xx xxxx	Input 7 (0 = Open, 1 = Closed)
	xxxx xxxx 1xxx xxxx	Input 8 (0 = Open, 1 = Closed)
	xxxx xxx1 xxxx xxxx	Input 9 (0 = Open, 1 = Closed)
	xxxx xx1x xxxx xxxx	Input 10 (0 = Open, 1 = Closed)

Table 8–7: 745 DATA FORMATS (Sheet 20 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx x1xx xxxx xxxx	Input 11 (0 = Open, 1 = Closed)
	xxxx 1xxx xxxx xxxx	Input 12 (0 = Open, 1 = Closed)
	xxx1 xxxx xxxx xxxx	Input 13 (0 = Open, 1 = Closed)
	xx1x xxxx xxxx xxxx	Input 14 (0 = Open, 1 = Closed)
	x1xx xxxx xxxx xxxx	Input 15 (0 = Open, 1 = Closed)
	1xxx xxxx xxxx xxxx	Input 16 (0 = Open, 1 = Closed)
F50	**16 bits**	**OUTPUT RELAY STATES**
	xxxx xxxx xxxx xxx1	Output Relay 1 (0 = De-energized, 1 = Energized)
	xxxx xxxx xxxx xx1x	Output Relay 2 (0 = De-energized, 1 = Energized)
	xxxx xxxx xxxx x1xx	Output Relay 3 (0 = De-energized, 1 = Energized)
	xxxx xxxx xxxx 1xxx	Output Relay 4 (0 = De-energized, 1 = Energized)
	xxxx xxxx xxx1 xxxx	Output Relay 5 (0 = De-energized, 1 = Energized)
	xxxx xxxx xx1x xxxx	Output Relay 6 (0 = De-energized, 1 = Energized)
	xxxx xxxx x1xx xxxx	Output Relay 7 (0 = De-energized, 1 = Energized)
	xxxx xxxx 1xxx xxxx	Output Relay 8 (0 = De-energized, 1 = Energized)
	xxxx xxx1 xxxx xxxx	Self-Test Relay (0 = De-energized, 1 = Energized)
F51	**16 bits**	**DSP DIAGNOSTIC FLAGS**
	xxxx xxxx xxxx xxx1	A/D Virtual Ground (0 = Okay, 1 = Out of Tolerance)
	xxxx xxxx xxxx xx1x	A/D Subsystem (0 = Okay, 1 = Not Responding)
F52	**16 bits**	**LOGIC FLAG**
	xxxx xxxx xxxx xxx1	Pickup Flag (0= Not Picked Up, 1= Picked Up)
	xxxx xxxx xxxx xx1x	Operated Flag (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx x1xx	Latched Flag (0 = Not Latched, 1 = Latched)
	xxxx xxxx xxxx 1xxx	Self test flag (0= No error, 1= Error)
	xxxx xxx1 xxxx xxxx	Phase A Flag (0 = No Fault, 1 = Fault)
	xxxx xx1x xxxx xxxx	Phase B Flag (0 = No Fault, 1 = Fault)
	xxxx x1xx xxxx xxxx	Phase C Flag (0 = No Fault, 1 = Fault)
	xxxx 1xxx xxxx xxxx	Ground Flag (0 = No Fault, 1 = Fault)

Table 8–7: 745 DATA FORMATS (Sheet 21 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
F53	**16 bits**	**UNSIGNED VALUE, 3 DECIMAL PLACES**
	Example: 1.234 stored as 1234	
F54	**16 bits**	**FORCE LED STATE**
	xxxx xxxx 1111 1111	LED On/Off State (0 = Off, 1 = On)
	xxxx xxxx xxxx xxx1	LED #1 (Top)
	xxxx xxxx xxxx xx1x	LED #2
	xxxx xxxx xxxx x1xx	LED #3
	xxxx xxxx xxxx 1xxx	LED #4
	xxxx xxxx xxx1 xxxx	LED #5
	xxxx xxxx xx1x xxxx	LED #6
	xxxx xxxx x1xx xxxx	LED #7
	xxxx xxxx 1xxx xxxx	LED #8 (Bottom)
F55	**16 bits**	**FRONT PANEL KEY**
	0000 0000 0000 0000	0 = '0'
	0000 0000 0000 0001	1 = '1'
	0000 0000 0000 0010	2 = '2'
	0000 0000 0000 0011	3 = '3'
	0000 0000 0000 0100	4 = '4'
	0000 0000 0000 0101	5 = '5'
	0000 0000 0000 0110	6 = '6'
	0000 0000 0000 0111	7 = '7'
	0000 0000 0000 1000	8 = '8'
	0000 0000 0000 1001	9 = '9'
	0000 0000 0000 1010	10 = '.'
	0000 0000 0000 1011	11 = 'Value Up'
	0000 0000 0000 1100	12 = 'Value Down'
	0000 0000 0000 1101	13 = 'Message Up'
	0000 0000 0000 1110	14 = 'Message Down'
	0000 0000 0000 1111	15 = 'Next'
	0000 0000 0001 0000	16 = 'Enter'
	0000 0000 0001 0001	17 = 'Escape'
	0000 0000 0001 0010	18 = 'Setpoints'
	0000 0000 0001 0011	19 = 'Actual'
	0000 0000 0001 0100	20 = 'Reset'
	0000 0000 0001 0101	21 = 'Help'
F56	**16 bits**	**INPUT ASSERT FLAGS**
	xxxx xxxx xxxx xxx1	Input 1 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx xxxx xx1x	Input 2 (0 = Not Asserted, 1 = Asserted)

Table 8–7: 745 DATA FORMATS (Sheet 22 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx xxxx xxxx x1xx	Input 3 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx xxxx 1xxx	Input 4 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx xxx1 xxxx	Input 5 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx xx1x xxxx	Input 6 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx x1xx xxxx	Input 7 (0 = Not Asserted, 1 = Asserted)
	xxxx xxxx 1xxx xxxx	Input 8 (0 = Not Asserted, 1 = Asserted)
	xxxx xxx1 xxxx xxxx	Input 9 (0 = Not Asserted, 1 = Asserted)
	xxxx xx1x xxxx xxxx	Input 10 (0 = Not Asserted, 1 = Asserted)
	xxxx x1xx xxxx xxxx	Input 11 (0 = Not Asserted, 1 = Asserted)
	xxxx 1xxx xxxx xxxx	Input 12 (0 = Not Asserted, 1 = Asserted)
	xxx1 xxxx xxxx xxxx	Input 13 (0 = Not Asserted, 1 = Asserted)
	xx1x xxxx xxxx xxxx	Input 14 (0 = Not Asserted, 1 = Asserted)
	x1xx xxxx xxxx xxxx	Input 15 (0 = Not Asserted, 1 = Asserted)
	1xxx xxxx xxxx xxxx	Input 16 (0 = Not Asserted, 1 = Asserted)
F57	**16 bits**	**OUTPUT RELAY OPERATE FLAGS**
	xxxx xxxx xxxx xxx1	Output Relay 1 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx xx1x	Output Relay 2 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx x1xx	Output Relay 3 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx 1xxx	Output Relay 4 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxx1 xxxx	Output Relay 5 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xx1x xxxx	Output Relay 6 (0 = Not Operated, 1 = Operated)
	xxxx xxxx x1xx xxxx	Output Relay 7 (0 = Not Operated, 1 = Operated)
	xxxx xxxx 1xxx xxxx	Output Relay 8 (0 = Not Operated, 1 = Operated)
	xxxx xxx1 xxxx xxxx	Self-Test Relay (0 = Not Operated, 1 = Operated)
F58	**16 bits**	**DEMAND METER TYPE**

Table 8–7: 745 DATA FORMATS (Sheet 23 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0000	0 = Thermal
	0000 0000 0000 0001	1 = Block Interval
	0000 0000 0000 0010	2 = Rolling Demand
F59	**16 bits**	**VIRTUAL OUTPUT OPERATE FLAGS**
	xxxx xxxx xxxx xxx1	Virtual Output 1 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx xx1x	Virtual Output 2 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx x1xx	Virtual Output 3 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx 1xxx	Virtual Output 4 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxx1 xxxx	Virtual Output 5 (0 = Not Operated, 1 = Operated)
F60	**16 bits**	**ACTIVE SETPOINT GROUP**
	0000 0000 0000 0000	0 = Group 1
	0000 0000 0000 0001	1 = Group 2
	0000 0000 0000 0010	2 = Group 3
	0000 0000 0000 0011	3 = Group 4
F61	**16 bits**	**TIMER OPERATE FLAGS**
	xxxx xxxx xxxx xxx1	Timer 1 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx xx1x	Timer 2 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx x1xx	Timer 3 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxxx 1xxx	Timer 4 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xxx1 xxxx	Timer 5 (0 = Not Operated, 1 = Operated)
	xxxx xxxx xx1x xxxx	Timer 6 (0 = Not Operated, 1 = Operated)
	xxxx xxxx x1xx xxxx	Timer 7 (0 = Not Operated, 1 = Operated)
	xxxx xxxx 1xxx xxxx	Timer 8 (0 = Not Operated, 1 = Operated)
	xxxx xxx1 xxxx xxxx	Timer 9 (0 = Not Operated, 1 = Operated)
	xxxx xx1x xxxx xxxx	Timer 10 (0 = Not Operated, 1 = Operated)
F62	**16 bits**	**FLEXLOGIC EQUATION (NO GATES)**
Format F47 for tokens 0000 01111 and greater - i.e. no gates)		
F63	**16 bits**	**VOLTAGE INPUT PARAMETERS**
	0000 0000 0000 0000	0 = W1 Van
	0000 0000 0000 0001	1 = W1 Vbn

Table 8–7: 745 DATA FORMATS (Sheet 24 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0010	2 = W1 Vcn
	0000 0000 0000 0011	3 = W1 Vab
	0000 0000 0000 0100	4 = W1 Vbc
	0000 0000 0000 0101	5 = W1 Vca
	0000 0000 0000 0110	6 = W2 Van
	0000 0000 0000 0111	7 = W2 Vbn
	0000 0000 0000 1000	8 = W2 Vcn
	0000 0000 0000 1001	9 = W2 Vab
	0000 0000 0000 1010	10 = W2 Vbc
	0000 0000 0000 1011	11 = W2 Vca
	0000 0000 0000 1100	12 = W3 Van
	0000 0000 0000 1101	13 = W3 Vbn
	0000 0000 0000 1110	14 = W3 Vcn
	0000 0000 0000 1111	15 = W3 Vab
	0000 0000 0001 0000	16 = W3 Vbc
	0000 0000 0001 0001	17 = W3 Vca
F64	**16 bits**	**HARMONIC PARAMETERS**
	0000 0000 0000 0000	0 = 2nd
	0000 0000 0000 0001	1 = 2nd+5th
F65	**16 bits**	**TRACE MEMORY CHANNEL**
	0000 0000 0000 0000	0 = W1 Ia
	0000 0000 0000 0001	1 = W1 Ib
	0000 0000 0000 0010	2 = W1 Ic
	0000 0000 0000 0011	3 = W2 Ia
	0000 0000 0000 0100	4 = W2 Ib
	0000 0000 0000 0101	5 = W2 Ic
	0000 0000 0000 0110	6 = W3 Ia
	0000 0000 0000 0111	7 = W3 Ib
	0000 0000 0000 1000	8 = W3 Ic
	0000 0000 0000 1001	9 = W1/2 Ig
	0000 0000 0000 1010	10 = W2/3 Ig
	0000 0000 0000 1011	11 = Voltage
	0000 0000 0000 1100	12 = Logic Inputs
	0000 0000 0000 1101	13 = Output Relays
F66	**16 bits**	**OUTPUT OPERATION**
	0000 0000 0000 0000	0 = Self-resetting
	0000 0000 0000 0001	1 = Latched
F67	**16 bits**	**BLOCK OPERATION OF OUTPUTS**
	xxxx xxxx xxxx xxx1	Output Relay 1 (0 = Allow Operation, 1 = Block Operation)

Table 8–7: 745 DATA FORMATS (Sheet 25 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	xxxx xxxx xxxx xx1x	Output Relay 2 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx xxxx x1xx	Output Relay 3 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx xxxx 1xxx	Output Relay 4 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx xxx1 xxxx	Output Relay 5 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx xx1x xxxx	Output Relay 6 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx x1xx xxxx	Output Relay 7 (0 = Allow Operation, 1 = Block Operation)
	xxxx xxxx 1xxx xxxx	Output Relay 8 (0 = Allow Operation, 1 = Block Operation)
F68	**16 bits**	**RESET TIME**
	0000 0000 0000 0000	0 = Instantaneous
	0000 0000 0000 0001	1 = Linear
F69	**16 bits**	**PLAYBACK MEMORY CHANNEL**
	0000 0000 0000 0000	0 = W1 Ia
	0000 0000 0000 0001	1 = W1 Ib
	0000 0000 0000 0010	2 = W1 Ic
	0000 0000 0000 0011	3 = W2 Ia
	0000 0000 0000 0100	4 = W2 Ib
	0000 0000 0000 0101	5 = W2 Ic
	0000 0000 0000 0110	6 = W3 Ia
	0000 0000 0000 0111	7 = W3 Ib
	0000 0000 0000 1000	8 = W3 Ic
	0000 0000 0000 1001	9 = W1/2 Ig
	0000 0000 0000 1010	10 = W2/3 Ig
	0000 0000 0000 1011	11 = Voltage
F70	**16 bits**	**TRACE/PLAYBACK MEMORY DATA**
Trace/Playback Channel Selector Index = 0 – 10 (i.e. any current input) 2'S COMPLEMENT SIGNED VALUE Examples: 1.000 x CT stored as 500; -0.500 x CT stored as -250		
Trace/Playback Channel Selector Index = 11 (i.e. Voltage) 2'S COMPLEMENT SIGNED VALUE Examples: 1.000 x VT stored as 1000; -0.500 x VT stored as -500		
Trace Channel Selector Index = 12 (i.e. Logic Inputs) AS PER FORMAT F49 Example: "Logic Inputs 1 and 3 closed" stored as 0005 hex		
Trace Channel Selector Index = 13 (i.e. Output Relays) AS PER FORMAT F50 Example: "Output Relays 2 and 4 energized" stored as 000A hex		
F71	**16 bits**	**FACTORY SERVICE COMMANDS**
	0000 0000 0000 0000	0 = Clear Any Pending Commands

Table 8–7: 745 DATA FORMATS (Sheet 26 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0001	1 = Load Factory Default Setpoints
	0000 0000 0000 0010	2 = Load Default Calibration Data
	0000 0000 0000 0011	3 = Clear Diagnostic Data
	0000 0000 0000 0100	4 = Clear RMS Min/Max Data
F72	**16 bits**	**FORCE OTHER HARDWARE**
	xxxx xxxx xxxx xxx1	LEDs (0=Normal, 1= Use LED force codes)
	xxxx xxxx xxxx xx1x	Beeper (0=Normal, 1= On)
	xxxx xxxx xxxx x1xx	External Watchdog (0=Normal, 1=Stop Updating)
	xxxx xxxx xxxx 1xxx	Internal Watchdog (0=Normal, 1=Stop Updating)
F73	**16 bits**	**PARITY**
	0000 0000 0000 0000	0 = None
	0000 0000 0000 0001	1 = Odd
	0000 0000 0000 0010	2 = Even
F74	**16 bits**	**EDIT SETPOINT GROUP**
	0000 0000 0000 0000	0 = Group 1
	0000 0000 0000 0001	1 = Group 2
	0000 0000 0000 0010	2 = Group 3
	0000 0000 0000 0011	3 = Group 4
	0000 0000 0000 0100	4 = Active Group
F75	**16 bits**	**VIRTUAL INPUT PROGRAMMED STATE**
	0000 0000 0000 0000	0 = Open
	0000 0000 0000 0001	1 = Closed
F76	**16 bits**	**FLEXLOGIC EQUATION ERROR**
	0000 0000 0000 0000	0 = None
	0000 0000 0000 0001	1 = Output Relay 1
	0000 0000 0000 0010	2 = Output Relay 2
	0000 0000 0000 0011	3 = Output Relay 3
	0000 0000 0000 0100	4 = Output Relay 4
	0000 0000 0000 0101	5 = Output Relay 5
	0000 0000 0000 0110	6 = Output Relay 6
	0000 0000 0000 0111	7 = Output Relay 7
	0000 0000 0000 1000	8 = Output Relay 8
	0000 0000 0000 1001	9 = Trace Memory Trigger
	0000 0000 0000 1010	10 = Virtual Output 1
	0000 0000 0000 1011	11 = Virtual Output 2
	0000 0000 0000 1100	12 = Virtual Output 3
	0000 0000 0000 1101	13 = Virtual Output 4

Table 8–7: 745 DATA FORMATS (Sheet 27 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 1110	14 = Virtual Output 5
F77	**16 bits**	**BAD TRANSFORMER SETTINGS ERROR**
	0000 0000 0000 0000	0 = None
	0000 0000 0000 0001	1 = W1-W2 Ratio Mismatch
	0000 0000 0000 0010	2 = W1-W3 Ratio Mismatch
	0000 0000 0000 0011	3 = Load Loss
	0000 0000 0000 0100	4 = W1 Eddy-Current Loss
	0000 0000 0000 0101	5 = W2 Eddy-Current Loss
	0000 0000 0000 0110	6 = W3 Eddy-Current Loss
	0000 0000 0000 0111	7 = W1 Rated Load
	0000 0000 0000 1000	8 = W2 Rated Load
	0000 0000 0000 1001	9 = W3 Rated Load
F78	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 1 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	
F79	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 2 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	

Table 8–7: 745 DATA FORMATS (Sheet 28 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
F80	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 3 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	
F81	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 1 GROUND CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 2 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	
	For CT PRIMARY greater than 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	
F82	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 2 GROUND CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234)	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 200 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	

8

Table 8–7: 745 DATA FORMATS (Sheet 29 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	For CT PRIMARY > 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	
F83	**16 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 3 GROUND CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Unsigned value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Unsigned value, scaled by 10 Example: 12340 stored as 1234	
F84	**16 bits**	**IRIG-B SIGNAL TYPE**
	0000 0000 0000 0000	0 = None
	0000 0000 0000 0001	1 = DC Shift
	0000 0000 0000 0010	2 = Amplitude Modulated
F85	**16 bits**	**TRACE MEMORY TRIGGER CAUSE**
	0000 0000 0000 0000	0 = No Trigger
	0000 0000 0000 0001	1 = Manual Trigger
	0000 0000 0000 0010	2 = Automatic Trigger
F86	**16 bits**	**VOLTS-PER-HERTZ CURVE SHAPES**
	0000 0000 0000 0000	0 = Definite Time
	0000 0000 0000 0001	1 = Inv Curve 1
	0000 0000 0000 0010	2 = Inv Curve 2
	0000 0000 0000 0011	3 = Inv Curve 3
F87	**16 bits**	**BLOCK SIGNAL**
	0000 0000 0000 0000	0 = Disabled
	0000 0000 0000 0001	1 = Logic Input 1
	0000 0000 0000 0010	2 = Logic Input 2
	0000 0000 0000 0011	3 = Logic Input 3
	0000 0000 0000 0100	4 = Logic Input 4
	0000 0000 0000 0101	5 = Logic Input 5
	0000 0000 0000 0110	6 = Logic Input 6
	0000 0000 0000 0111	7 = Logic Input 7
	0000 0000 0000 1000	8 = Logic Input 8
	0000 0000 0000 1001	9 = Logic Input 9

Table 8–7: 745 DATA FORMATS (Sheet 30 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 1010	10 = Logic Input 10
	0000 0000 0000 1011	11 = Logic Input 11
	0000 0000 0000 1100	12 = Logic Input 12
	0000 0000 0000 1101	13 = Logic Input 13
	0000 0000 0000 1110	14 = Logic Input 14
	0000 0000 0000 1111	15 = Logic Input 15
	0000 0000 0001 0000	16 = Logic Input 16
	0000 0000 0001 0001	17 = Virtual Input 1
	0000 0000 0001 0010	18 = Virtual Input 2
	0000 0000 0001 0011	19 = Virtual Input 3
	0000 0000 0001 0100	20 = Virtual Input 4
	0000 0000 0001 0101	21 = Virtual Input 5
	0000 0000 0001 0110	22 = Virtual Input 6
	0000 0000 0001 0111	23 = Virtual Input 7
	0000 0000 0001 1000	24 = Virtual Input 8
	0000 0000 0001 1001	25 = Virtual Input 9
	0000 0000 0001 1010	26 = Virtual Input 10
	0000 0000 0001 1011	27 = Virtual Input 11
	0000 0000 0001 1100	28 = Virtual Input 12
	0000 0000 0001 1101	29 = Virtual Input 13
	0000 0000 0001 1110	30 = Virtual Input 14
	0000 0000 0001 1111	31 = Virtual Input 15
	0000 0000 0010 0000	32 = Virtual Input 16
	0000 0000 0010 0001	33 = Output Relay 1
	0000 0000 0010 0010	34 = Output Relay 2
	0000 0000 0010 0011	35 = Output Relay 3
	0000 0000 0010 0100	36 = Output Relay 4
	0000 0000 0010 0101	37 = Output Relay 5
	0000 0000 0010 0110	38 = Output Relay 6
	0000 0000 0010 0111	39 = Output Relay 7
	0000 0000 0010 1000	40 = Output Relay 8
	0000 0000 0010 1001	41 = Self-Test Relay
	0000 0000 0010 1010	42 = Virtual Output 1
	0000 0000 0010 1011	43 = Virtual Output 2
	0000 0000 0010 1100	44 = Virtual Output 3
	0000 0000 0010 1101	45 = Virtual Output 4
	0000 0000 0010 1110	46 = Virtual Output 5
F88	**16 bits**	**ASSERT SIGNAL**
	0000 0000 0000 0000	0 = Disabled
	0000 0000 0000 0001	1 = Logic Input 1

Table 8–7: 745 DATA FORMATS (Sheet 31 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0010	2 = Logic Input 2
	0000 0000 0000 0011	3 = Logic Input 3
	0000 0000 0000 0100	4 = Logic Input 4
	0000 0000 0000 0101	5 = Logic Input 5
	0000 0000 0000 0110	6 = Logic Input 6
	0000 0000 0000 0111	7 = Logic Input 7
	0000 0000 0000 1000	8 = Logic Input 8
	0000 0000 0000 1001	9 = Logic Input 9
	0000 0000 0000 1010	10 = Logic Input 10
	0000 0000 0000 1011	11 = Logic Input 11
	0000 0000 0000 1100	12 = Logic Input 12
	0000 0000 0000 1101	13 = Logic Input 13
	0000 0000 0000 1110	14 = Logic Input 14
	0000 0000 0000 1111	15 = Logic Input 15
	0000 0000 0001 0000	16 = Logic Input 16
F89	**16 bits**	**LOW VOLTAGE WINDING RATING**
	0000 0000 0000 0000	0 = Above 5 kV
	0000 0000 0000 0001	1 = 1 kV to 5 kV
	0000 0000 0000 0010	2 = Below 1 kV
F90	**16 bits**	**UNSIGNED VALUE AUTORANGING VOLTAGE / RATED LOAD / MIN TAP VOLTAGE**
	For LOW VOLTAGE WINDING RATING ≥ 5 kV Format: Unsigned value, 1 decimal place Example: 123.4 stored as 1234	
	For 1 kV ≤ LOW VOLTAGE WINDING RATING < 5 kV Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For LOW VOLTAGE WINDING RATING < 1 kV Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
F91	**16 bits**	**UNSIGNED VALUE, AUTORANGING VOLTAGE INCREMENT PER TAP**
	For LOW VOLTAGE WINDING RATING ≥ Above 5 kV Format: Unsigned value, 2 decimal places Example: 12.34 stored as 1234	
	For 1 kV ≤ LOW VOLTAGE WINDING RATING < 5 kV Format: Unsigned value, 3 decimal places Example: 1.234 stored as 1234	
	For LOW VOLTAGE WINDING RATING < 1 kV Format: Unsigned value, 4 decimal places Example: 0.1234 stored as 1234	
F92	**16 bits**	**HARMONIC NUMBER**
	0000 0000 0000 0010	0 = 2nd
	0000 0000 0000 0011	1 = 3rd

Table 8–7: 745 DATA FORMATS (Sheet 32 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	0000 0000 0000 0100	2 = 4th
	0000 0000 0000 0101	3 = 5th
	0000 0000 0000 0110	4 = 6th
	0000 0000 0000 0111	5 = 7th
	0000 0000 0000 1000	6 = 8th
	0000 0000 0000 1001	7 = 9th
	0000 0000 0000 1010	8 = 10th
	0000 0000 0000 1011	9 = 11th
	0000 0000 0000 1100	10 = 12th
	0000 0000 0000 1101	11 = 13th
	0000 0000 0000 1110	12 = 14th
	0000 0000 0000 1111	13 = 15th
	0000 0000 0001 0000	14 = 16th
	0000 0000 0001 0001	15 = 17th
	0000 0000 0001 0010	16 = 18th
	0000 0000 0001 0011	17 = 19th
	0000 0000 0001 0100	18 = 20th
	0000 0000 0001 0101	19 = 21st
F93	**16 bits**	**SIGNED VALUE AUTORANGING BASED ON WINDING 1 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F94	**16 bits**	**SIGNED VALUE AUTORANGING BASED ON WINDING 2 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	

Table 8–7: 745 DATA FORMATS (Sheet 33 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F95	**16 bits**	**SIGNED VALUE AUTORANGING BASED ON WINDING 3 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F96	**32 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 1 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F97	**32 bits**	**UNSIGNED VALUE AUTORANGING BASED ON WINDING 2 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	

Table 8–7: 745 DATA FORMATS (Sheet 34 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F98	**32 bits**	**UNSIGNED VALUE, AUTORANGING BASED ON WINDING 3 PHASE CT PRIMARY**
	For CT PRIMARY ≤ 2 A Format: Signed value, 3 decimal places Example: 1.234 stored as 1234	
	For 2 A < CT PRIMARY ≤ 20 A Format: Signed value, 2 decimal places Example: 12.34 stored as 1234	
	For 20 A < CT PRIMARY ≤ 200 A Format: Signed value, 1 decimal place Example: 123.4 stored as 1234	
	For 200 A < CT PRIMARY ≤ 2000 A Format: Signed value Example: 1234 stored as 1234	
	For CT PRIMARY > 2000 A Format: Signed value, scaled by 10 Example: 12340 stored as 1234	
F99	**16 bits**	**Port used for DNP**
	0000 0000 0000 0000	0=None
	0000 0000 0000 0001	1=Com 1
	0000 0000 0000 0010	2=Com 2
	0000 0000 0000 0011	3=Front
F100	**16 bits**	**Cooling Type For Dry Transformer**
	0000 0000 0000 0000	0=Sealed Self Cooled
	0000 0000 0000 0001	1=Vented Self cooled
	0000 0000 0000 0010	2=Forced-cooled
F101	**16 bits**	**Unsigned value, Autoranging Load Loss at Rated Load**
	Low Volt. Winding rating ≥ 5 KV Unsigned Value, 0 Decimal Places Example: 1234 stored as 1234	
	1 KV ≤ Low Volt. Winding rating < 5 KV Unsigned Value, 1 Decimal Place Example: 123.4 stored as 1234	
	Low Volt. Winding rating < 1 KV Unsigned Value, 2 Decimal Places Example: 12.34 stored as 1234)	

8

Table 8–7: 745 DATA FORMATS (Sheet 35 of 35)

FORMAT CODE	APPLICABLE BITS	DEFINITION
F102	**16 bits**	**Data Link Confirmation Mode**
	0000 0000 0000 0000	0=Never
	0000 0000 0000 0001	1=Sometimes
	0000 0000 0000 0010	2=Always

8

DNP 3.0
DEVICE PROFILE DOCUMENT

Vendor Name: General Electric Power Management Inc.

Device Name: 745 Transformer Management Relay

Highest DNP Level Supported:	Device Function:
For Requests: Level 2 For Responses: Level 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):
- Binary Input (Object 1, Variations 1 and 2)
- Binary Output (Object 10, Variation 2)
- Analog Input (Object 30, Variations 1, 2, 3 and 4)
- Analog Input Change (Object 32, Variations 1, 2, 3 and 4)
- Warm Restart (Function code 14)

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted: 292 Received: 292	Transmitted: 2048 Received: 2048

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☐ None ☐ Fixed ☒ Configurable (Note 1)	☒ None ☐ Configurable

Requires Data Link Layer Confirmation:
- ☐ Never
- ☐ Always
- ☐ Sometimes
- ☒ Configurable (Note 1)

Requires Application Layer Confirmation:
- ☐ Never
- ☐ Always
- ☒ When reporting Event Data
- ☐ When sending multi-fragment responses
- ☐ Sometimes
- ☐ Configurable

Timeouts while waiting for:

Data Link Confirm	☐ None	☐ Fixed	☐ Variable	☒ Configurable (Note 1)
Complete Appl. Fragment	☒ None	☐ Fixed	☐ Variable	☐ Configurable
Application Confirm	☒ None	☐ Fixed	☐ Variable	☐ Configurable
Complete Appl. Response	☒ None	☐ Fixed	☐ Variable	☐ Configurable
Others:	(None)			

DNP 3.0
DEVICE PROFILE DOCUMENT (Continued)

Executes Control Operations:

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Count > 1	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse Off	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Latch Off	☐ Never	☐ Always	☒ Sometimes	☐ Configurable

(For an explanation of the above, refer to the discussion accompanying the point list for the Binary Output/ Control Relay Output Block objects)

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Reports Binary Input Change Events when no specific variations requested:
- ☐ Never
- ☒ Only time-tagged
- ☐ Only non-time-tagged
- ☐ Configurable to send both, one or the other

Reports time-tagged Binary Input Change Events when no specific variation requested:
- ☐ Never
- ☒ Binary Input Change With Time
- ☐ Binary Input Change With Relative Time
- ☐ Configurable

Sends Unsolicited Responses:
- ☒ Never
- ☐ Configurable
- ☐ Only certain objects
- ☐ Sometimes
- ☐ ENABLE/DISABLE UNSOLICITED Function codes supported

Sends Static Data in Unsolicited Responses:
- ☒ Never
- ☐ When Device Restarts
- ☐ When Status Flags Change

Default Counter Object/Variation:
- ☒ No Counters Reported
- ☐ Configurable
- ☐ Default Object
  Default Variation
- ☐ Point-by-point list attached

Counters Roll Over at:
- ☒ No Counters Reported
- ☐ Configurable
- ☐ 16 Bits
- ☐ 32 Bits
- ☐ Other Value
- ☐ Point-by-point list attached

Sends Multi-Fragment Responses: ☐ Yes ☒ No

Notes:

1. The data link layer confirmation mode, confirmation timeout, and number of retries are all configurable. Refer to the setpoints defined under **S1 745 SETUP / COMMUNICATIONS / DNP** for more details. Additional setpoints related to DNP are discussed in Section 5.3.5: DNP COMMUNICATIONS on page 5–27.

8

8.4.2 IMPLEMENATION TABLE

The table below gives a list of all objects recognized and returned by the relay. Additional information is provided on the following pages including a list of the default variations returned for each object and lists of defined point numbers for each object.

IMPLEMENTATION TABLE						
OBJECT			REQUEST		RESPONSE	
Obj	Var	Description	Func. Codes	Qual Codes (Hex)	Func. Codes	Qual Codes (Hex)
1	0	Binary Input - All Variations	1	06		
1	1	Binary Input	1	00, 01, 06	129	00, 01
1	2	Binary Input With Status	1	00, 01, 06	129	00, 01
2	0	Binary Input Change - All Variations	1	06, 07, 08		
2	1	Binary Input Change Without Time	1	06, 07, 08	129	17, 28
2	2	Binary Input Change With Time	1	06, 07, 08	129	17, 28
10	0	Binary Output - All Variations	1	06		
10	2	Binary Output Status	1	00, 01, 06	129	00, 01
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	17, 28
30	0	Analog Input - All Variations	1	06		
30	1	32-Bit Analog Input With Flag	1	00, 01, 06	129	00, 01
30	2	16-Bit Analog Input With Flag	1	00, 01, 06	129	00, 01
30	3	32-Bit Analog Input Without Flag	1	00, 01, 06	129	00, 01
30	4	16-Bit Analog Input Without Flag	1	00, 01, 06	129	00, 01
32	0	Analog Input Change - All Variations	1	06, 07, 08		
32	1	32-Bit Analog Input Change Without Time	1	06, 07, 08	129	17, 28
32	2	16-Bit Analog Input Change Without Time	1	06, 07, 08	129	17, 28
32	3	32-Bit Analog Input Change With Time	1	06, 07, 08	129	17, 28
32	4	16-Bit Analog Input Change With Time	1	06, 07, 08	129	17, 28
50	1	Time and Date	1, 2	07 (Note 1)	129	07
60	1	Class 0 Data (Note 2)	1	06	129	
60	2	Class 1 Data (Note 3)	1	06, 07, 08	129	
60	3	Class 2 Data (Note 3)	1	06, 07, 08	129	
60	4	Class 3 Data (Note 3)	1	06, 07, 08	129	
80	1	Internal Indications	2	00 (Note 4)	129	
		No object	13			
		No object	14			
		No object	23			

Table Notes:

1. For this object, the quantity specified in the request must be exactly 1 as there is only one instance of this object defined in the relay.
2. All static input data known to the relay is returned in response to a request for Class 0. This includes all objects of type 1 (Binary Input), type 10 (Binary Output) and type 30 (Analog Input).
3. The point tables for Binary Input and Analog Input objects contain a field which defines to which event class the corresponding static data has been assigned.
4. For this object, the qualifier code must specify an index of 7 only.

8

The following table specifies the default variation for all objects returned by the relay. These are the variations that will be returned for the object in a response when no specific variation is specified in a request.

DEFAULT VARIATIONS		
Object	**Description**	**Default Variation**
1	Binary Input - Single Bit	1
2	Binary Input Change With Time	2
10	Binary Output Status	2
30	16-Bit Analog Input Without Flag	4
32	16-Bit Analog Input Change Without Time	2

8.5.1 POINT LIST TABLES

POINT LIST FOR:	BINARY INPUT (OBJECT 01) BINARY INPUT CHANGE (OBJECT 02)		
Index	**Description**	**Event Class Assigned To**	**Notes**
0	Logic Input 1 Operated	Class 1	Note 1
1	Logic Input 2 Operated	Class 1	Note 1
2	Logic Input 3 Operated	Class 1	Note 1
3	Logic Input 4 Operated	Class 1	Note 1
4	Logic Input 5 Operated	Class 1	Note 1
5	Logic Input 6 Operated	Class 1	Note 1
6	Logic Input 7 Operated	Class 1	Note 1
7	Logic Input 8 Operated	Class 1	Note 1
8	Logic Input 9 Operated	Class 1	Note 1
9	Logic Input 10 Operated	Class 1	Note 1
10	Logic Input 11 Operated	Class 1	Note 1
11	Logic Input 12 Operated	Class 1	Note 1
12	Logic Input 13 Operated	Class 1	Note 1
13	Logic Input 14 Operated	Class 1	Note 1
14	Logic Input 15 Operated	Class 1	Note 1
15	Logic Input 16 Operated	Class 1	Note 1
16	Output Relay 1 Energized	Class 1	Note 1
17	Output Relay 2 Energized	Class 1	Note 1
18	Output Relay 3 Energized	Class 1	Note 1
19	Output Relay 4 Energized	Class 1	Note 1
20	Output Relay 5 Energized	Class 1	Note 1
21	Output Relay 6 Energized	Class 1	Note 1
22	Output Relay 7 Energized	Class 1	Note 1
23	Output Relay 8 Energized	Class 1	Note 1
24	Self-Test Relay Energized	Class 1	Note 1
25	Setpoint Group 1 Active	Class 1	Note 1
26	Setpoint Group 2 Active	Class 1	Note 1
27	Setpoint Group 3 Active	Class 1	Note 1
28	Setpoint Group 4 Active	Class 1	Note 1

Notes:

1. Any detected change in the state of any point will cause the generation of an event object.

POINT LIST FOR:	BINARY OUTPUT (OBJECT 10) CONTROL RELAY OUTPUT BLOCK (OBJECT 12)
Index	**Description**
0	Reset
1	Virtual Input 1
2	Virtual Input 2
3	Virtual Input 3
4	Virtual Input 4
5	Virtual Input 5
6	Virtual Input 6
7	Virtual Input 7
8	Virtual Input 8
9	Virtual Input 9
10	Virtual Input 10
11	Virtual Input 11
12	Virtual Input 12
13	Virtual Input 13
14	Virtual Input 14
15	Virtual Input 15
16	Virtual Input 16

The following restrictions should be observed when using object 12 to control the points listed in the above table.

1. The Count field is checked first. If it is zero, the command will be accepted but no action will be taken. If this field is non-zero, the command will be executed exactly once regardless of its value.
2. The Control Code field of object 12 is then inspected:
   - •The Queue and Clear sub-fields are ignored.
   - •For point 0, the valid Control Code values are "Pulse On" (1 hex), "Latch On" (3 hex), or "Close - Pulse On" (41 hex). Any of these may be used to initiate the function (Reset) associated with the point
   - •Virtual inputs may be set (i.e. asserted) via a Control Code value of "Latch On" (3 hex), "Close - Pulse On" (41 hex), or "Close - Latch On" (43 hex), A Control Code value of "Latch Off" (4 hex), "Trip Pulse - On" (81 hex), or "Trip - Latch On" (83 hex) may be used to clear a Virtual Input.
   - •Any value in the Control Code field not specified above is invalid and will be rejected.
3. The On Time and Off Time fields are ignored. Since all controls take effect immediately upon receipt, timing is irrelevant.
4. The Status field in the response will reflect the success or failure of the control attempt thus:
   - •A Status of "Request Accepted" (0) will be returned if the command was accepted.
   - •A Status of "Request not Accepted due to Formatting Errors" (3) will be returned if the Control Code field was incorrectly formatted.
   - •If select/operate was used, a status of "Arm Timeout" (1) or "No Select" (2) is returned if the associated failure condition is detected.

An operate of the Reset point may fail to clear active targets (although the response to the command will always indicate successful operation) due to other inputs or conditions (e.g. blocks) existing at the time. To verify the success or failure of an operate of this point, it is necessary to examine the associated Binary Input(s) after the control attempt is performed.

When using object 10 to read the status of a Binary Output, a read of point 0 will always return zero. For other points, the current state of the corresponding Virtual Input will be returned.

In the following table, the entry in the “Format” column indicates that the format of the associated data point can be determined by looking up the entry in the *Memory Map Data Formats* table. For example, an “F1” format is described in that table as a (16-bit) unsigned value without any decimal places. Therefore, the value read should be interpreted in this manner.

POINT LIST FOR:		ANALOG INPUT (OBJECT 30) ANALOG INPUT CHANGE (OBJECT 32)			
(Note 5) Index when Point Mapping Is:		Format	Description	Event Class Assigned To	Notes
Disabled	Enabled				
n/a	0	-	User Map Value 1		
n/a	1	-	User Map Value 2		
.	.	-	.		
.	.	-	.		
.	.	-	.		
n/a	118	-	User Map Value 119		
n/a	119	-	User Map Value 120		
0	120	F1	Winding 1 Phase CT Primary	Class 1	Notes 2,6
1	121	F1	Winding 2 Phase CT Primary	Class 1	Notes 2,7
2	122	F1	Winding 3 Phase CT Primary	Class 1	Notes 2,5,8
3	123	F1	Winding 1 Ground CT Primary	Class 1	Notes 2,9
4	124	F1	Winding 2 Ground CT Primary	Class 1	Notes 2,10
5	125	F1	Winding 3 Ground CT Primary	Class 1	Notes 2,5,11
6	126	F78	Winding 1 Phase A Current Magnitude	Class 1	Note 6
7	127	F78	Winding 1 Phase B Current Magnitude	Class 1	Note 6
8	128	F78	Winding 1 Phase C Current Magnitude	Class 1	Note 6
9	129	F78	Winding 1 Neutral Current Magnitude	Class 1	Note 6
10	130	F81	Winding 1 Ground Current Magnitude	Class 1	Notes 5,9
11	131	F1	Winding 1 Loading	Class 1	
12	132	F78	Winding 1 Average Phase Current Magnitude	Class 1	Note 6
13	133	F79	Winding 2 Phase A Current Magnitude	Class 1	Note 7
14	134	F79	Winding 2 Phase B Current Magnitude	Class 1	Note 7
15	135	F79	Winding 2 Phase C Current Magnitude	Class 1	Note 7
16	136	F79	Winding 2 Neutral Current Magnitude	Class 1	Note 7
17	137	F82	Winding 2 Ground Current Magnitude	Class 1	Note 5,10
18	138	F1	Winding 2 Loading	Class 1	
19	139	F79	Winding 2 Average Phase Current Magnitude	Class 1	Note 7
20	140	F80	Winding 3 Phase A Current Magnitude	Class 1	Notes 5,8
21	141	F80	Winding 3 Phase B Current Magnitude	Class 1	Notes 5,8
22	142	F80	Winding 3 Phase C Current Magnitude	Class 1	Notes 5,8
23	143	F80	Winding 3 Neutral Current Magnitude	Class 1	Notes 5,8
24	144	F83	Winding 3 Ground Current Magnitude	Class 1	Notes 5,11
25	145	F1	Winding 3 Loading	Class 1	Note 5
26	146	F80	Winding 3 Average Phase Current Magnitude	Class 1	Notes 5,8
27	147	F78	Winding 1 Positive Sequence Current Magnitude	Class 1	Note 6

POINT LIST FOR:		ANALOG INPUT (OBJECT 30) ANALOG INPUT CHANGE (OBJECT 32) (Continued)			
(Note 5) Index when Point Mapping Is:		Format	Description	Event Class Assigned To	Notes
Disabled	Enabled				
28	148	F79	Winding 2 Positive Sequence Current Magnitude	Class 1	Note 7
29	149	F80	Winding 3 Positive Sequence Current Magnitude	Class 1	Notes 5,8
30	150	F78	Winding 1 Negative Sequence Current Magnitude	Class 1	Note 6
31	151	F79	Winding 2 Negative Sequence Current Magnitude	Class 1	Note 7
32	152	F80	Winding 3 Negative Sequence Current Magnitude	Class 1	Notes 5,8
33	153	F78	Winding 1 Zero Sequence Current Magnitude	Class 1	Note 6
34	154	F79	Winding 2 Zero Sequence Current Magnitude	Class 1	Note 7
35	155	F80	Winding 3 Zero Sequence Current Magnitude	Class 1	Notes 5,8
36	156	F3	Phase A Differential Current Magnitude	Class 1	
37	157	F3	Phase B Differential Current Magnitude	Class 1	
38	158	F3	Phase C Differential Current Magnitude	Class 1	
39	159	F53	Winding 1 Ground Differential Current	Class 1	Note 5
40	160	F53	Winding 2 Ground Differential Current	Class 1	Note 5
41	161	F53	Winding 3 Ground Differential Current	Class 1	Note 5
42	162	F2	Winding 1 Phase A Total Harmonic Distortion	Class 1	
43	163	F2	Winding 1 Phase B Total Harmonic Distortion	Class 1	
44	164	F2	Winding 1 Phase C Total Harmonic Distortion	Class 1	
45	165	F2	Winding 2 Phase A Total Harmonic Distortion	Class 1	
46	166	F2	Winding 2 Phase B Total Harmonic Distortion	Class 1	
47	167	F2	Winding 2 Phase C Total Harmonic Distortion	Class 1	
48	168	F2	Winding 3 Phase A Total Harmonic Distortion	Class 1	Note 5
49	169	F2	Winding 3 Phase B Total Harmonic Distortion	Class 1	Note 5
50	170	F2	Winding 3 Phase C Total Harmonic Distortion	Class 1	Note 5
51	171	F3	System Frequency	Class 1	Note 3
52	172	F1	Tap Changer Position	Class 1	
53	173	F3	System Line-To-Line Voltage	Class 1	Note 5
54	174	F3	Volts-Per-Hertz	Class 1	Note 5
55	175	F3	Line-To-Neutral Voltage Magnitude	Class 1	Note 5
56	176	F4	Ambient Temperature	Class 1	Note 5
57	177	F4	Hottest-Spot Winding Temperature	Class 1	Note 5
58	178	F2	Insulation Aging Factor	Class 1	Note 5
59	179	F7	Total Accumulated Loss Of Life (Note 12)	Class 1	Note 5
60	180	F1	Analog Input	Class 1	Note 5
61	181	F93	Winding 1 Real Power	Class 1	Notes 5,6
62	182	F93	Winding 1 Reactive Power	Class 1	Notes 5,6
63	183	F93	Winding 1 Apparent Power	Class 1	Notes 5,6
64	184	F3	Winding 1 Power Factor	Class 1	Note 5
65	185	F94	Winding 2 Real Power	Class 1	Notes 5,7
66	186	F94	Winding 2 Reactive Power	Class 1	Notes 5,7

8

POINT LIST FOR: ANALOG INPUT (OBJECT 30) ANALOG INPUT CHANGE (OBJECT 32) (Continued)					
(Note 5) Index when Point Mapping Is:		Format	Description	Event Class Assigned To	Notes
Disabled	Enabled				
67	187	F94	Winding 2 Apparent Power	Class 1	Notes 5,7
68	188	F3	Winding 2 Power Factor	Class 1	Note 5
69	189	F95	Winding 3 Real Power	Class 1	Note 5,8
70	190	F95	Winding 3 Reactive Power	Class 1	Note 5,8
71	191	F95	Winding 3 Apparent Power	Class 1	Note 5,8
72	192	F3	Winding 3 Power Factor	Class 1	Note 5

Table Notes:

1. Unless otherwise specified, an event object will be generated for a point if the current value of the point changes by an amount greater than or equal to two percent of its previous value.
2. An event object is created for these points if the current value of a point is in any way changed from its previous value.
3. An event object is created for the System Frequency point if the system frequency changes by 0.04 Hz or more from its previous value.
4. The data returned by a read of the User Map Value points is determined by the values programmed into the corresponding User Map Address registers (which are only accessible via Modbus). Refer to the section titled "Accessing Data Via The User Map" in this chapter for more information. Changes in User Map Value points never generate event objects. Because of the programmable nature of the user map, it cannot be determined at read time if the source value is signed or unsigned. For this reason, the data returned in a 32-bit variation is never sign-extended even if the source value is negative.
5. Depending upon the configuration and/or programming of the SR745, this value may not be available. Should this be the case, a value of zero will be returned.
6. Points with format F78 and F93 are scaled based upon the value of the Winding 1 Phase CT Primary setpoint (point 0). It is necessary to read point 0 and refer to the descriptions of these formats (in the "SR745 Data Formats" table) in order to determine the scale factor.
7. As for note 6 except the affected formats are F79 & F94 and the scaling is determined by the value read from point 1.
8. As for note 6 except the affected formats are F80 & F95 and the scaling is determined by the value read from point 2.
9. As for note 6 except the affected format is F81 and the scaling is determined by the value read from point 3.
10. As for note 6 except the affected format is F82 and the scaling is determined by the value read from point 4.
11. As for note 6 except the affected format is F83 and the scaling is determined by the value read from point 5.
12. The "Total Accumulated Loss Of Life" is a 32-bit, unsigned, positive value. As a consequence, a master performing 16-bit reads cannot be guaranteed to be able to read this point under all conditions. When this point's value exceeds 65535 (0xffff hex), a 16-bit read will return 0xffff (hex) and the over-range bit in the flag returned with the data will be set. Because of this possibility of over-range, the default variation for this object is 2 (i.e., 16-bit analog input with flag).
13. There are two defined maps for Analog Output points. The map used is specified by the setting of the "Point Mapping" setpoint at Modbus address 10D1 (hex). This setpoint may be set to a value of "Disabled" or "Enabled". When "Disabled", only the preassigned Analog Output points are available at indices 0 through 72.

When "Enabled", the User Map Values are assigned to points 0 through 119 with the preassigned Analog Outputs following beginning with point index 120. The value read from points 0 through 119 will depend upon the value programmed into the corresponding User Map Address setpoint (note that programming of these setpoints can only be accomplished via Modbus). Refer to the section in this chapter titled Accessing Data Via The User Map for more information.

Please note that changes in User Map Values never generate event objects.

9.1.1 DESCRIPTION

The 745PC program, provided with every 745 relay, allows easy access to all relay setpoints and actual values via a personal computer running Windows® 3.1/95 or higher and one RS232 port (COM1 or COM2). 745PC allows the user to:

- Program/modify setpoints
- Load/save setpoint files from/to disk
- Read actual values
- Monitor status
- Plot/print/view trending graphs of selected actual values
- Perform waveform capture (oscillography)
- Download and “playback” waveforms (Simulation Mode)
- View the Event Recorder
- View the harmonic content of any phase current in real time
- Get help on any topic

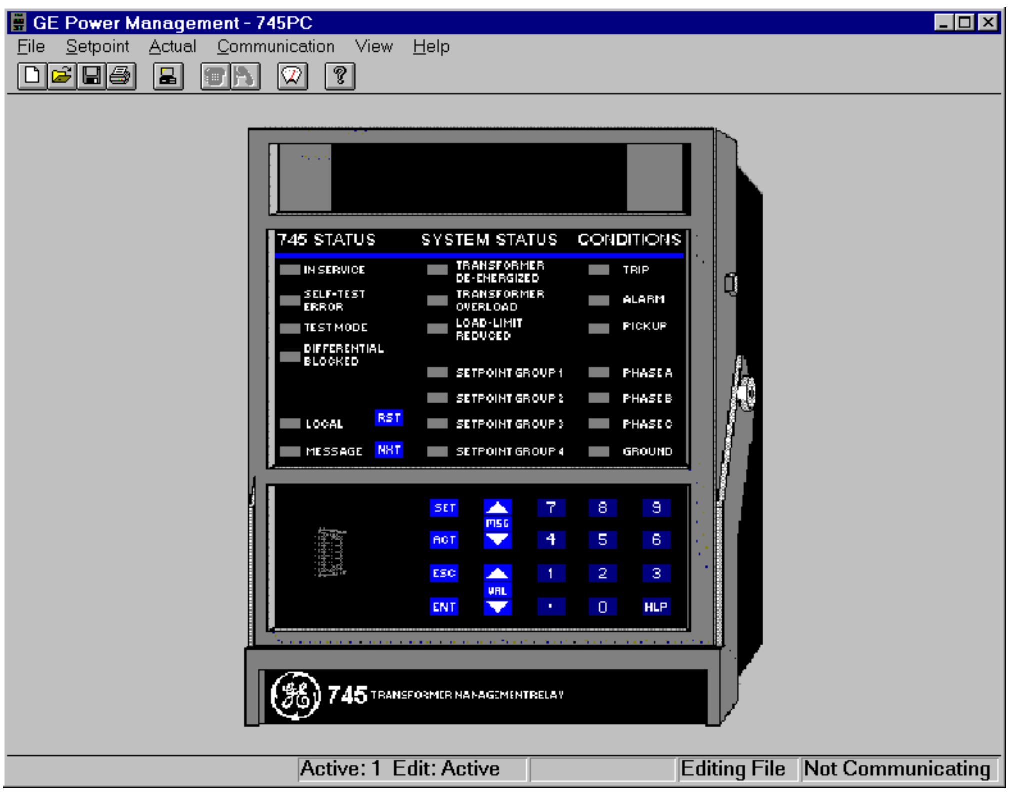


Figure 9–1: 745PC PROGRAM STARTUP WINDOW

The 745PC program can be used “stand-alone”, without a 745 relay, to create or edit 745 setpoint files.

9

9.1.2 HARDWARE & SOFTWARE REQUIREMENTS

The configuration listed is for both a minimum configured and an optimal configured system. Running on a minimum configuration causes the performance of the PC program to slow down.

Processor: minimum 486, Pentium or higher recommended

Memory: minimum 4 MB, 16 MB recommended, minimum 540K of conventional memory

Hard Drive: 20 MB free space required before installation of PC program.

ADDITIONAL WINDOWS 3.1/3.11 CONSIDERATIONS

- Installation of SHARE.EXE required.
- Close other applications (spreadsheet or word processor) before running the PC program to eliminate any problems because of low memory.

9.1.3 MENU SUMMARY

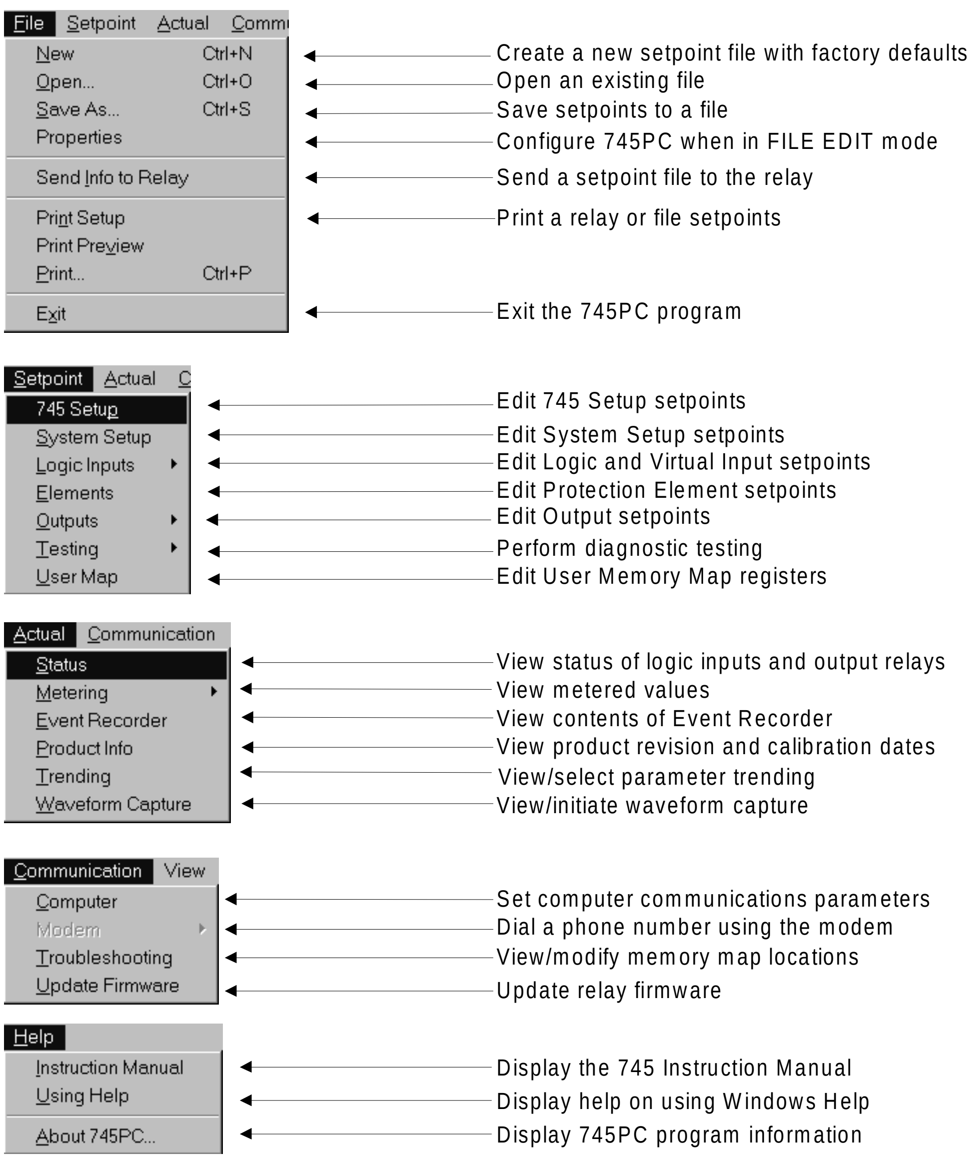


Figure 9–2: 745PC TOP LEVEL MENU SUMMARY

9

9.1.4 TOOLBAR

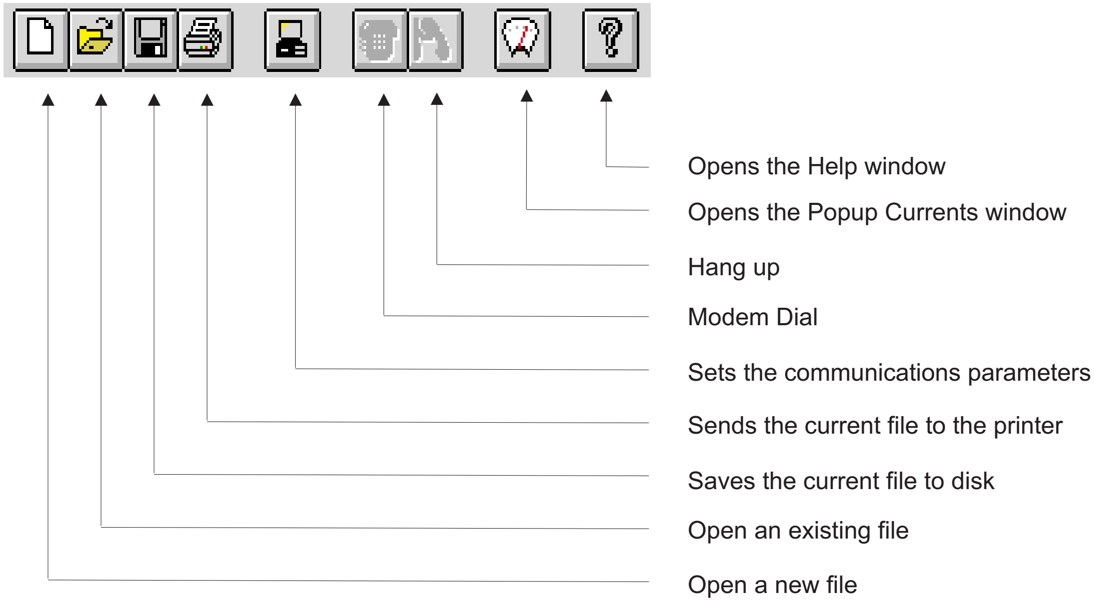


Figure 9–3: 745PC TOOLBAR SUMMARY

9.1.5 HARDWARE CONFIGURATION

The 745PC program can communicate to the 745 via the front panel RS232 port or the rear terminal RS485 ports. Figure 9.2 shows the connections required for the RS232 front panel interface which consists of the following:

- A standard "straight through" serial cable with the SR745 end as a DB-9 male and the computer end as DB-9 or DB-25 female for COM1 or COM2 respectively.

Figure 9.3 shows the required connections and equipment for the RS485 rear terminal interface. The interface consists of the following:

- GE Power Management F485 RS232-to-RS485 converter.
- A standard "straight through" serial cable connected from your computer to the GE Power Management F485 Converter box. The converter box end should be DB-9 male and the computer end DB-9 or DB-25 female for COM1 or COM2 respectively.

Shielded twisted pair (20, 22 or 24 AWG) cable from converter box to the SR745 rear terminals. The converter box (+, -, GND) terminals end up connected to (B1, B2, B3) respectively. The line should also be terminated in an RC network (i.e. 120ohm, 1nF) as described in Section 3.2.16: RS485 / RS422 COMMUNICATION PORTS on page 3–12.

9

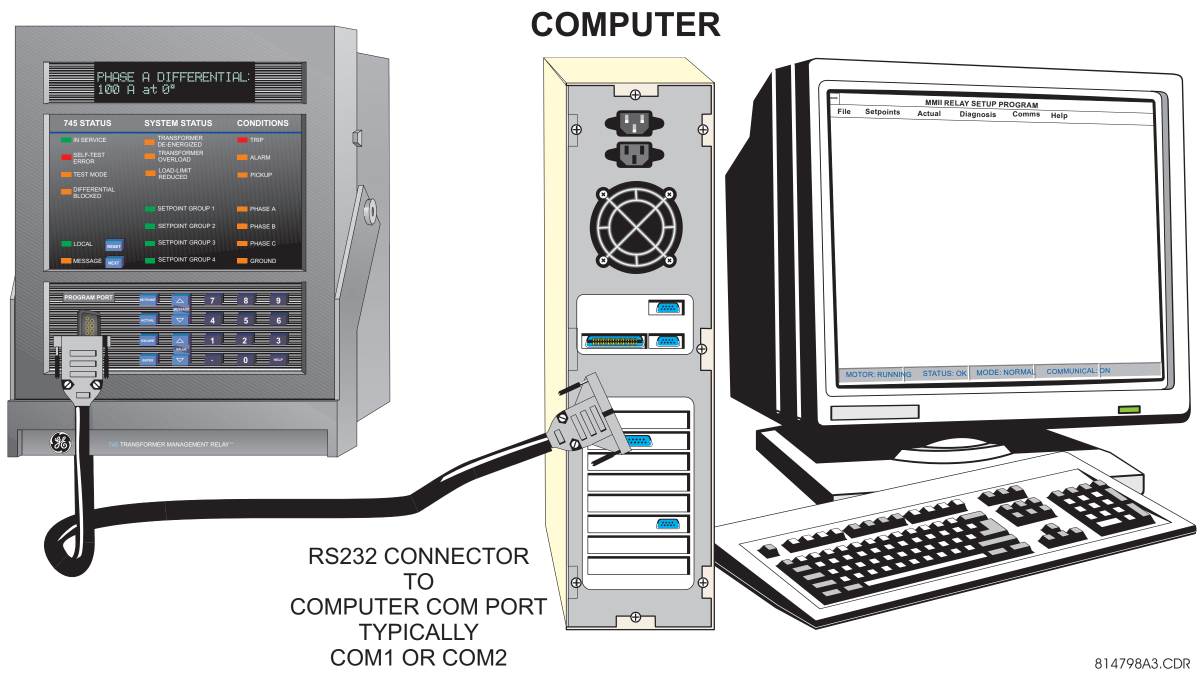


Figure 9–4: RS232 COMMUNICATIONS SETUP

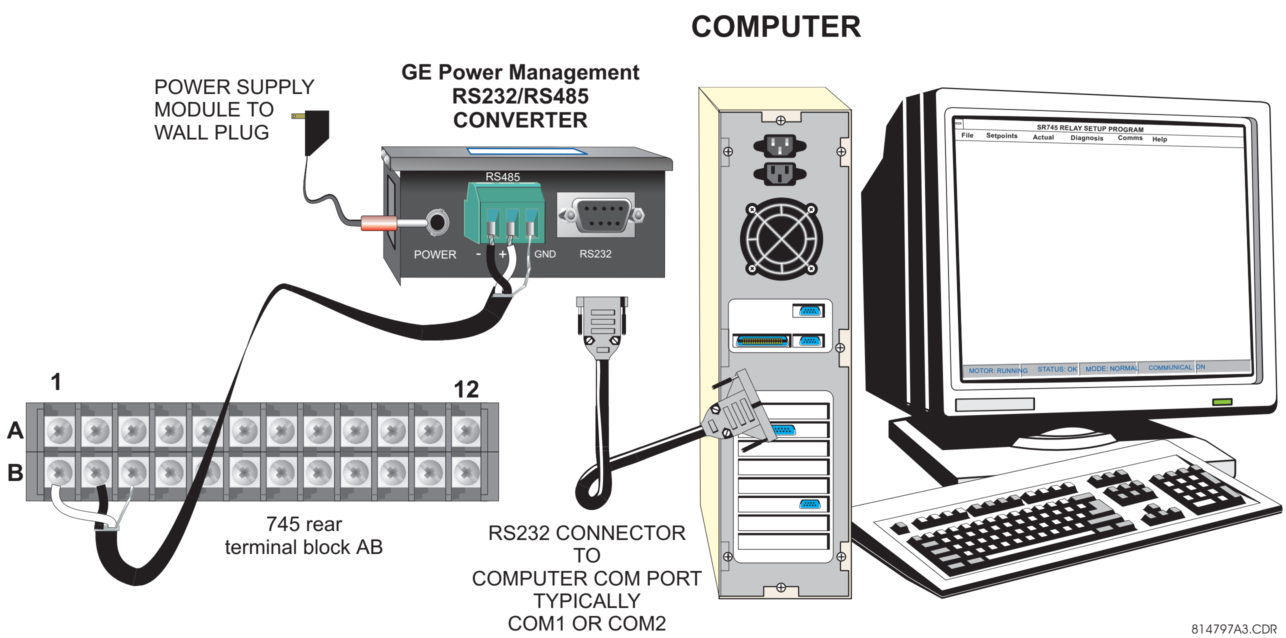


Figure 9–5: RS485 COMMUNICATIONS SETUP

9

9.2.1 745PC INSTALLATION

Installation of the 745PC software is accomplished as follows:

1. Ensure that Windows is running on the local PC.
2. Insert the GE Power Management Products CD into your CD-ROM drive or point your web browser to the GE Power Management website at www.ge.com/indsys/pm. Under Windows 95/98, the Product CD will launch the welcome screen automatically. Since the Products CD is essentially a “snapshot” of the GE Power Management website, the procedures for installation from the CD and the web are identical.

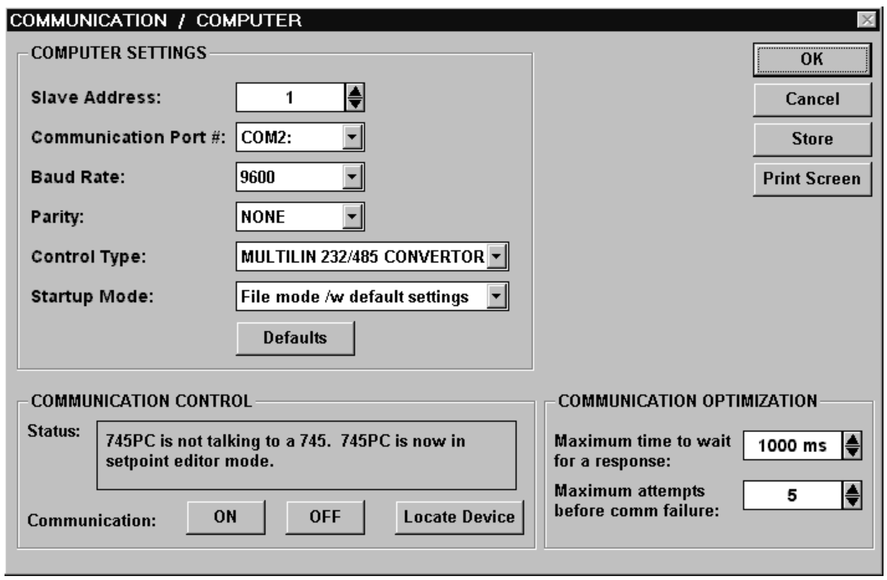
Figure 9–6: GE POWER MANAGEMENT WELCOME SCREEN

3. Click the **Index by Product Name** item from the main page and select **745 Transformer Management Relay** from the product list to open the 745 product page.
4. Click the **Software** item from the Product Resources list to bring you to the 745 software page.
5. The latest version of the 745PC program will be shown. Click on the **745PC Program** item to download the installation program to your local PC. Run the installation program and follow the prompts to install to the desired directory. When complete, a new GE Power Management group window will appear containing the 745PC icon.

9.2.2 STARTUP & COMMUNICATIONS CONFIGURATION

Startup of the 745PC software is accomplished as follows:

1. Double-click on the **745** program icon inside the **GE Power Management** group or select from the Windows Start menu to launch 745PC. The 745 to PC communications status is displayed on the bottom right corner of the screen:
2. To configure communications, select the **Communication > Computer** menu item. The **COMMUNICATION / COMPUTER** dialog box will appear containing the various communications settings for the local PC. These settings should be modified as shown below:



Set the **Startup Mode** based on user preference. In “Communicate with Relay” mode, 745PC will attempt to establish communications immediately upon startup. While in the “File mode /w default settings”, 745PC waits for the user to click the ON button before attempting communications – this mode is preferred when the 745PC is being used without an attached 745 relay.

Set **Control Type** to match the type of RS232/RS485 converter. If connected through the 745 front panel RS232 port, select “No Control Type”. If connected through a GE Power Management F485 converter unit, select “MULTILIN RS232/RS485 CONVERTOR”. If connected through a modem, select “Modem”. If a third-party RS232/RS485 converter is being used, select the appropriate control type from the available list based on the manufacturer’s specifications.

Set **Parity** to match the 745 PARITY setpoint (see S1 745 SETUP). If connected through the 745 front panel RS232 port, set to “None”.

Set **Baud Rate** to match the 745 BAUD RATE setpoint (see S1 745 SETUP).

Set **Communcation Port #** to ***the COM port on your local PC*** where the 745 relay is connected (e.g. COM1 or COM2). On most computers, COM1 is used by the mouse device and as such COM2 is usually available for communications.

Set **Slave Address** to match the 745 SLAVE ADDRESS setpoint (see S1 745 SETUP).

Figure 9–7: COMMUNICATION/COMPUTER DIALOG BOX

3. To begin communications, click on the **ON** button in the in the **Communication** section of the dialog box. The **Status** section indicates the communication status. If communications is established, the message “Program is now talking to a Multilin device” is displayed. As well, the status at the bottom right hand corner of the screen indicates “Communicating”.

9.3.1 SAVING SETPOINTS TO A FILE

Saving setpoints to a file on the local PC is accomplished as follows:

1. If the local PC is not connected to a 745 relay, select the **File > Properties** menu item. The dialog box shown below appears, allowing for the configuration of the 745PC program for the options ordered for a particular 745 relay. 745PC needs to know the correct options when creating a setpoint file so that setpoints that are not available for that particular relay are not downloaded.

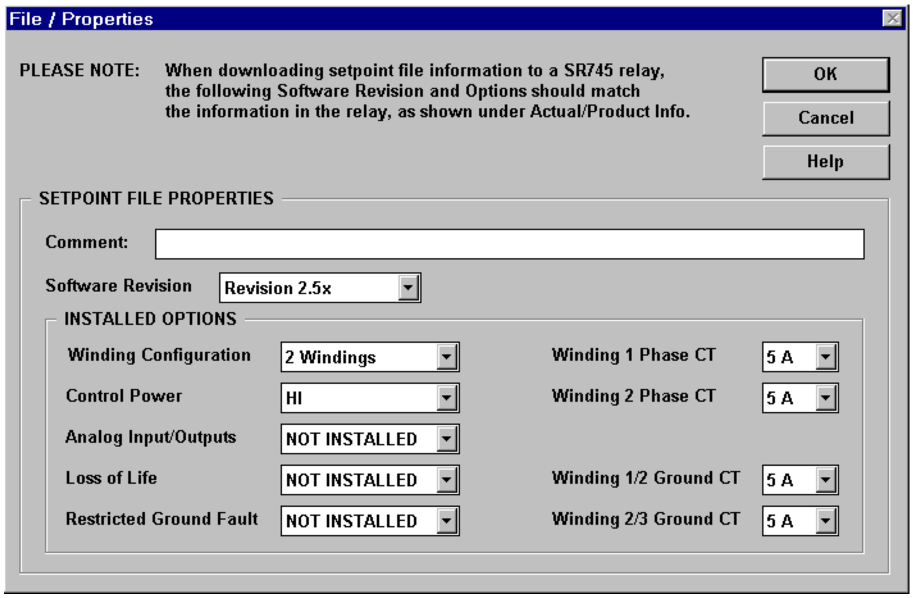


Figure 9–8: FILE/PROPERTIES DIALOG BOX

2. Select the installed options from the drop down menus. After configuration, select the **File > Save As** menu item. This launches the following dialog box. Enter the file name under which the file will be saved in the **File Name** box or click on any of the file names displayed. All 745 setpoint files should have the extension `.745` (for example, `xfrmr01.745`). Click **OK** to proceed.

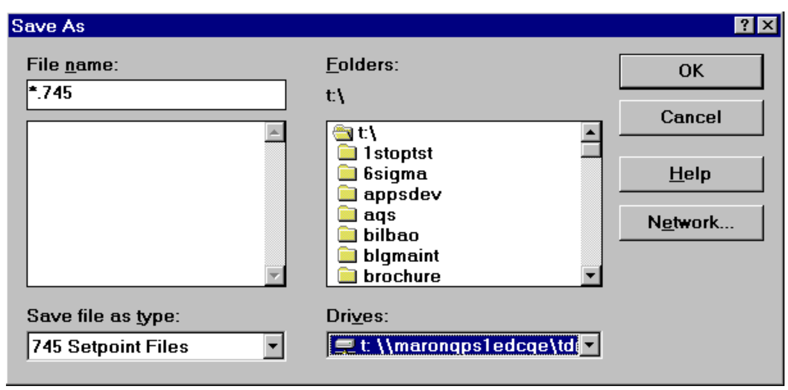


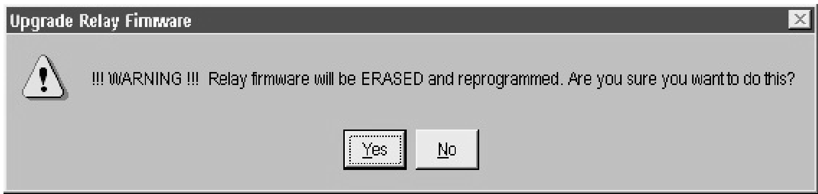
Figure 9–9: SAVING SETPOINTS

3. The program reads all the relay setpoint values and stores them to the selected file.

9.3.2 745 FIRMWARE UPGRADES

Prior to downloading new firmware to the 745, it is necessary to *save* the 745 setpoints to a file (see previous section). Loading new firmware into the 745's *flash* memory is accomplished as follows:

1. Select the **Communications > Update Firmware** menu item.
2. The following warning message will appear. Click Yes to proceed or No to abort.



3. Next, 745PC requests the name of the file containing the new firmware. Locate the appropriate file(s) by changing drives and/or directories until a list of file names appears in the file list box. File names for released 745 firmware have the following format:

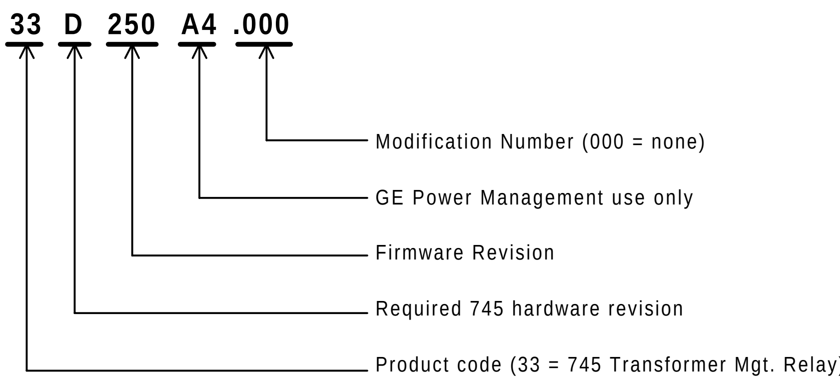


Figure 9–10: 745 FIRMWARE FILE FORMAT

4. The 745PC program automatically lists file names beginning with **33**. Click on the appropriate file name such that it appears in the **File Name** box. Click **OK** to continue.
5. 745PC will prompt with the following dialog box. This will be the last chance to cancel the firmware upgrade before the flash memory is erased. Click **Yes** to continue.

6. Upon completion the program place the relay back into "normal mode".
7. Upon successful updating of the 745 firmware, the next step is reloading the saved setpoints back to the 745. See the following section for details.

9.3.3 LOADING SETPOINTS FROM A FILE

Loading the 745 with setpoints from a file is accomplished as follows:

1. Select the **File > Open** menu item.
2. 745PC launches the Open dialog box listing all filenames in the 745 default directory with the extension **745**. Select the setpoint file to download and click OK to continue.

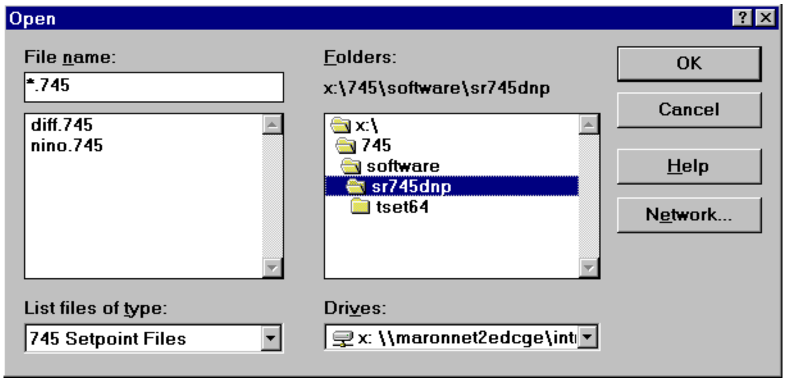


Figure 9–11: OPEN SETPOINTS FILE DIALOG BOX

3. Select the **File > Send Info to Relay** menu item. 745PC will prompt to confirm or cancel the setpoint file load. Click **Yes** to download the setpoints to the 745 relay or **No** to cancel.

9.3.4 ENTERING SETPOINTS

The following example illustrates the entering of setpoints from the 745PC program.

1. Select the **Setpoint > System Setup** menu item
2. Click the **Transformer** button in the **System Setup** window.
3. The following dialog box prompts for the transformer setpoint information. Note that the number of selections shown is dependent on the 745 installed options.

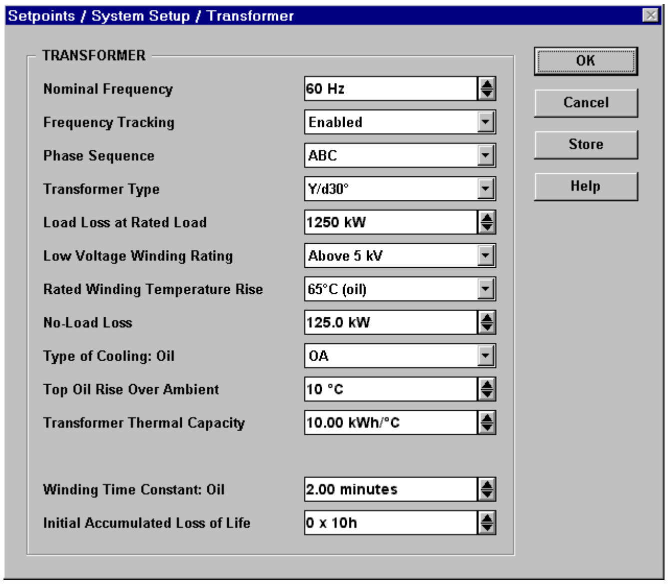


Figure 9–12: TRANSFORMER SETPOINTS DIALOG BOX

9

4. For setpoints requiring numerical values (e.g. **Load Loss at Rated Load**), click the mouse pointer anywhere inside the setpoint box. This displays a numerical keypad showing the OLD value, RANGE and INCREMENT of the setpoint value being modified.

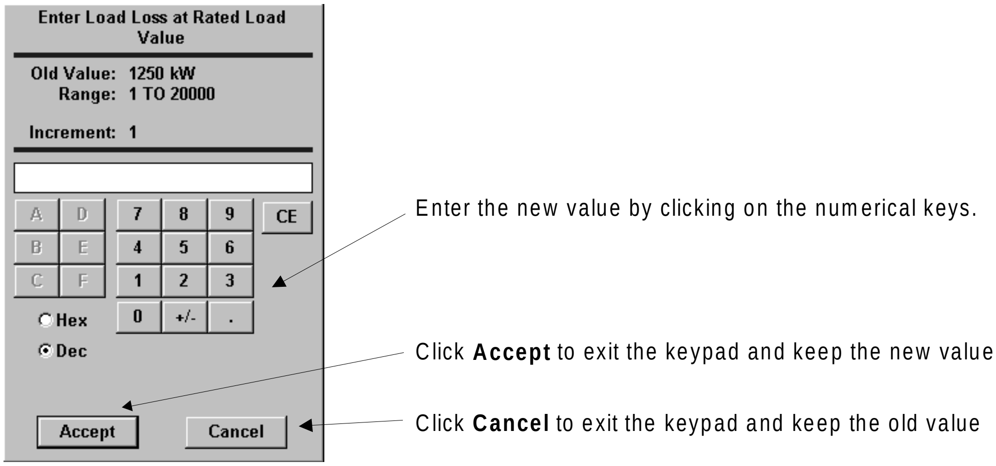
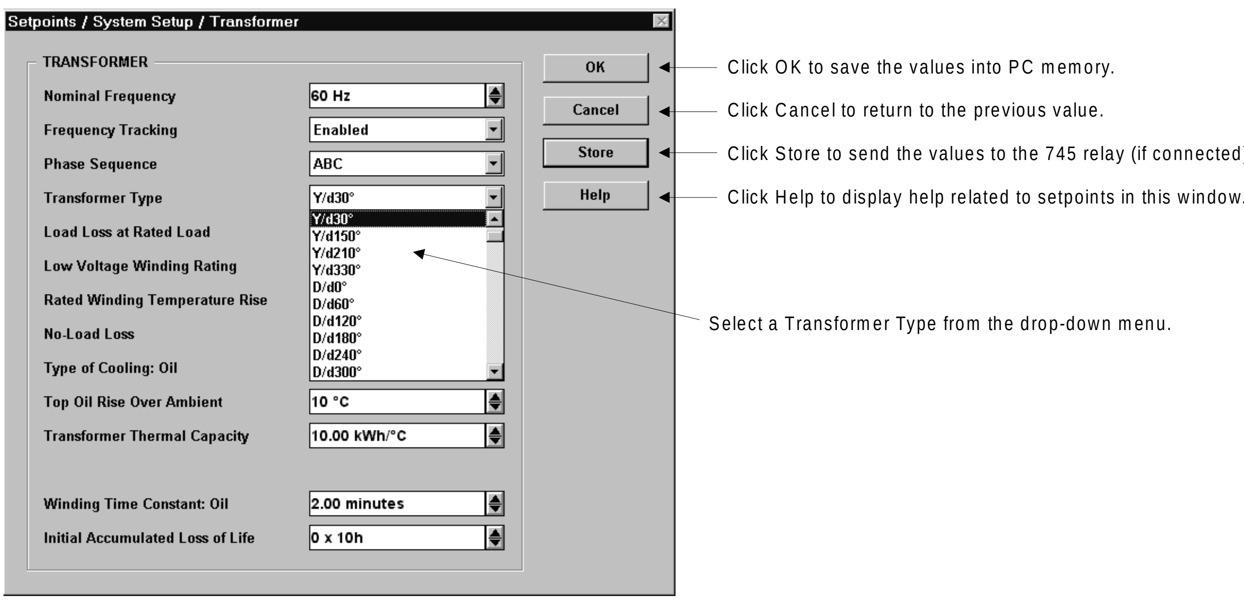


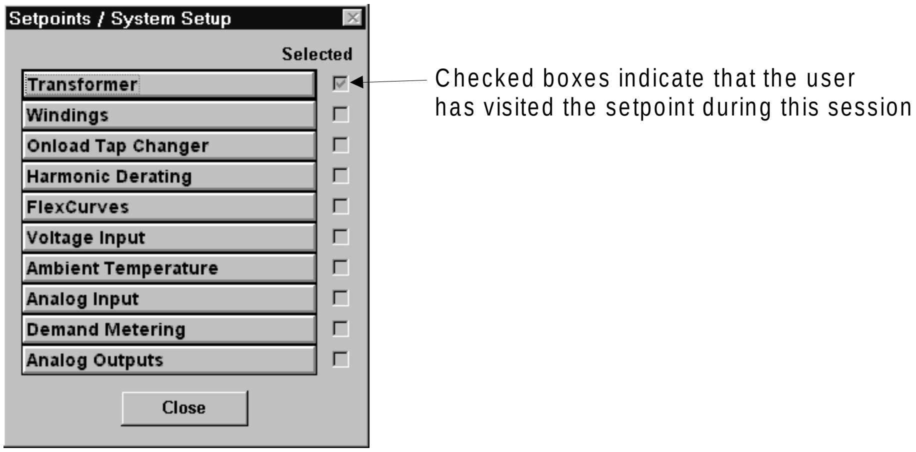
Figure 9–13: NUMERICAL SETPOINT ENTRY

5. For setpoints requiring non-numerical values (e.g. **Transformer Type**), clicking anywhere inside the setpoint box will causes selection menu to be displayed.



9

Checked boxes indicate that the user has visited the setpoint during this session.



9.3.5 VIEWING ACTUAL VALUES

The following example illustrates how any of the measured or monitored values can be displayed. In the following example the winding currents are examined:

1. Select the **Actual > Metering > Currents** menu item.
2. 745PC displays the following dialog box detailing the winding currents. To view any of the currents available click on the desired tab shown at the top of the box. For example, to view the positive, negative and zero sequence currents in any of the windings click on the **Sequence** tab.

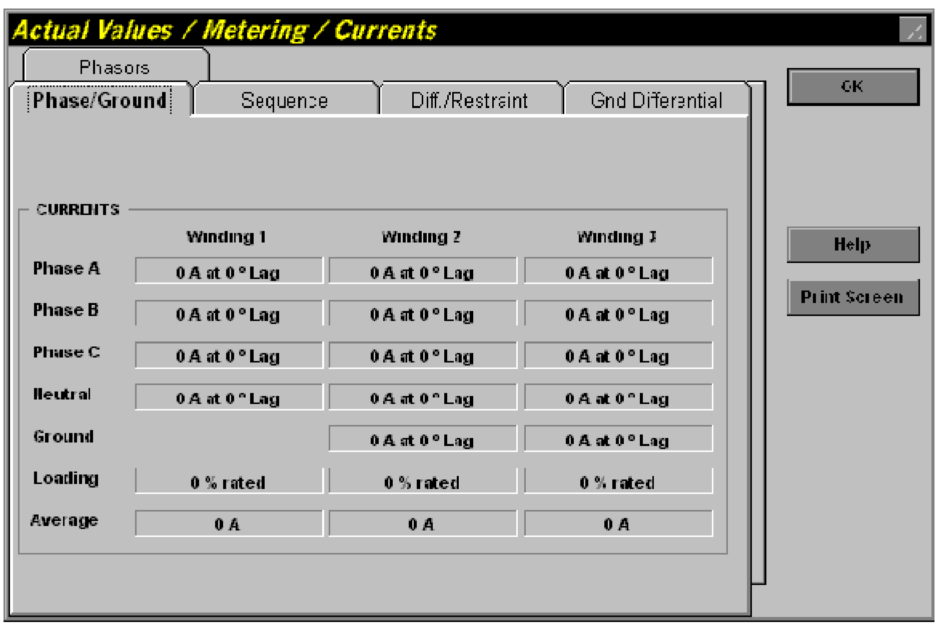


Figure 9–14: 745PC ACTUAL VALUES WINDOW

10.1.1 INTRODUCTION

The procedures contained in this section can be used to verify the correct operation of the 745 Transformer Management Relay® prior to placing it into service for the first time. These procedures may also be used to verify the relay on a periodic basis. Although not a total functional verification, the tests in this chapter verify the major operating points of all features of the relays. Before commissioning the relay, users should read Chapter 3: INSTALLATION, which provides important information about wiring, mounting, and safety concerns. The user should also become familiar with the relay as described in Chapter 2: GETTING STARTED and Chapter 5: SETPOINTS.

Test personnel must be familiar with general relay testing practices and safety precautions to avoid personal injuries or equipment damage.

This chapter is divided into several sections, as follows:

- **GENERAL**: outlines safety precautions, conventions used in the test procedures.
- **TEST EQUIPMENT**: the test equipment required.
- **GENERAL PRELIMINARY WORK**
- **LOGIC INPUTS AND OUTPUT RELAYS**: tests all digital and analog inputs, the A/D data acquisition system, and relay and transistor outputs.
- **DISPLAY, METERING, COMMUNICATIONS, & ANALOG OUTPUTS**: tests all values derived from the AC current and voltage inputs.
- **PROTECTION SCHEMES**: tests all features that can cause a trip, including differential, overcurrent, over and underfrequency elements.
- **AUXILIARY PROTECTION/MONITORING FUNCTIONS**
- **PLACING RELAY INTO SERVICE**

10.1.2 TESTING PHILOSOPHY

The 745 is realized with digital hardware and software algorithms, using extensive internal monitoring. Consequently, it is expected that, if the input circuits, CTs, VTs, power supply, auxiliary signals, etc., are functioning correctly, all the protection and monitoring features inside the relay will also perform correctly, as per applied settings. It is therefore only necessary to perform a calibration of the input circuits and cursory verification of the protection and monitoring features to ensure that a fully-functional relay is placed into service.

Though tests are presented in this section to verify the correct operation of all features contained in the 745, only those features which are placed into service need be tested. Skip all sections which cover features not included or not enabled when the relay is in service, except for the proviso of the next paragraph.

Some features such as the Local/Remote Reset of targets, display messages and indications are common to all the protection features and hence are tested only once. Testing of these features has been included with the Harmonic Restraint Percent Differential, which will almost always be enabled. If, for some reasons, this element is not enabled when the relay is in service, you will need to test the Local/Remote Reset when testing another protection element.

10.1.3 SAFETY PRECAUTIONS

CAUTION **HIGH VOLTAGES ARE PRESENT ON THE REAR TERMINALS OF THE RELAY, CAPABLE OF CAUSING DEATH OR SERIOUS INJURY. USE CAUTION AND FOLLOW ALL SAFETY RULES WHEN HANDLING, TESTING, OR ADJUSTING THE EQUIPMENT.**

CAUTION **DO NOT OPEN THE SECONDARY CIRCUIT OF A LIVE CT, SINCE THE HIGH VOLTAGE PRODUCED IS CAPABLE OF CAUSING DEATH OR SERIOUS INJURY, OR DAMAGE TO THE CT INSULATION.**

CAUTION **THE RELAY USES COMPONENTS WHICH ARE SENSITIVE TO ELECTROSTATIC DISCHARGES. WHEN HANDLING THE UNIT, CARE SHOULD BE TAKEN TO AVOID ELECTRICAL DISCHARGES TO THE TERMINALS AT THE REAR OF THE RELAY.**

CAUTION **ENSURE THAT THE CONTROL POWER APPLIED TO THE RELAY, AND THE AC CURRENT AND VOLTAGE INPUTS, MATCH THE RATINGS SPECIFIED ON THE RELAY NAMEPLATE. DO NOT APPLY CURRENT TO THE CT INPUTS IN EXCESS OF THE SPECIFIED RATINGS.**

CAUTION **ENSURE THAT THE LOGIC INPUT WET CONTACTS ARE CONNECTED TO VOLTAGES BELOW THE MAXIMUM VOLTAGE SPECIFICATION OF 300 V DC.**

10.1.4 CONVENTIONS

The following conventions are used for the remainder of this chapter:

- All setpoints and actual values are mentioned with their path as a means of specifying where to find the particular message. For instance, the setpoint **WINDING 1 PHASE CT PRIMARY**, which in the message structure is located under setpoints page S2, would be written as:

  SETPOINTS/S2 SYSTEM SETUP/WINDING 1/WINDING 1 PHASE CT PRIMARY
- Normal phase rotation of a three-phase power system is ABC.
- The phase angle between a voltage signal and a current signal is positive when the voltage leads the current.
- Phase A to neutral voltage is indicated by V_{an} (arrowhead on the "a").
- Phase A to B voltage is indicated by V_{ab} (arrowhead on the "a").
- The neutral current signal is the $3I_o$ signal derived from the three phase currents for any given winding.
- The ground current is the current signal measured by means of a CT in the power transformer connection to ground.

10.2.1 TEST SETUP

It is possible to completely verify the 745 relay operation using the built-in test and simulation features described earlier in this manual. However, some customers prefer to perform simple signal-injection tests to verify the basic operation of each element placed into service. The procedures described in this chapter have been designed for this purpose. To use the built-in facilities, refer to the appropriate sections in this manual.

The conventional, decades-old approach to testing relays utilized adjustable voltage and current sources, variacs, phase shifters, multimeters, timing device, and the like. In the last few years several instrumentation companies have offered sophisticated instrumentation to test protective relays. Generally this equipment offers built-in sources of AC voltage and current, DC voltage and current, timing circuit, variable frequency, phase shifting, harmonic generation, and complex fault simulation. If using such a test set, refer to the equipment manufacturer's instructions to generate the appropriate signals required by the procedures in this section. If you do not have a sophisticated test set, then you will need the following "conventional" equipment:

- Variable current source able to supply up to 40 A (depends on relay settings)
- Variable power resistors to control current amplitude
- Ten-turn 2 KΩ low-power potentiometer
- Power rectifier to build a circuit to generate 2nd harmonics
- Accurate timing device
- Double-pole single-throw contactor suitable for at least 40 amperes AC.
- Combined fundamental & 5th-harmonic adjustable current supply for elements involving the 5^{th} harmonic.
- Variable-frequency source of current or voltage to test over/underfrequency and frequency trend elements.
- Ammeters (RMS-responding), multimeters, voltmeters
- variable dc mA source
- variable dc mV source
- single-pole single-throw contactor

The simple test setup shown below can be used for the majority of tests. When the diode is not shorted and the two currents are summed together prior to the switch, the composite current contains the 2^{nd} harmonic necessary to verify the 2^{nd} harmonic restraint of the harmonic restraint percent differential elements. With the diode shorted and the two currents fed to separate relay inputs, the slope of the differential elements can be measured. With only I_1 connected (with a return path) the pickup level of any element can be measured.

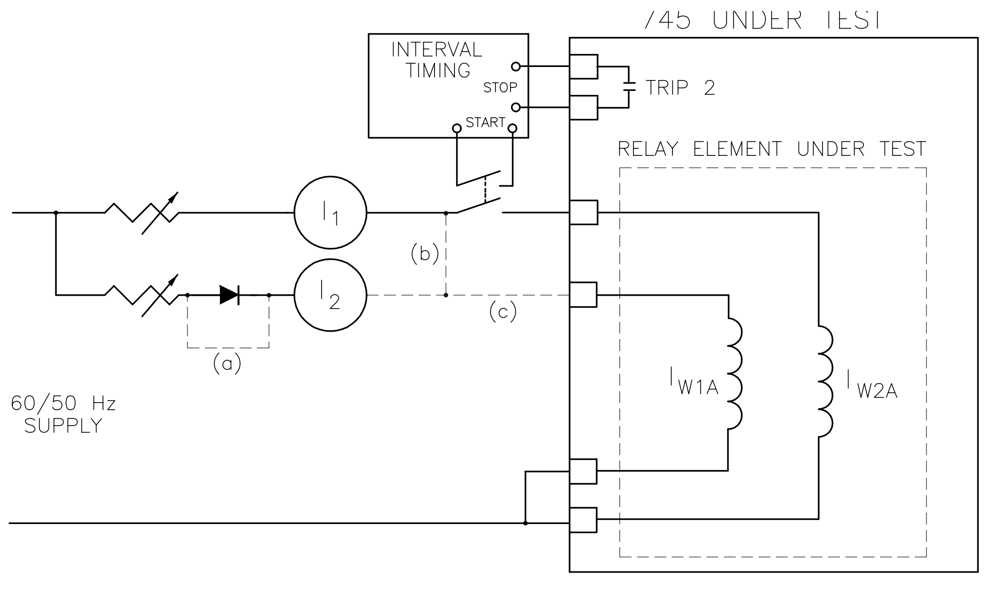


Figure 10–1: TEST SETUP

10.3.1 DESCRIPTION

1. Review appropriate sections of this manual to familiarize yourself with the relay. Confidence in the commissioning process comes with knowledge of the relay features and methods of applying settings.
2. Verify the installation to ensure correct connections of all inputs and outputs.
3. Review the relay settings and/or determine features and settings required for your installation. In large utilities a central group is often responsible for determining which relay features will be enabled and which settings are appropriate. In a small utility or industrial user, the on-site technical person is responsible both for the settings and also for the complete testing of the relay.
4. Set the relay according to requirements. Ensure that the correct relay model has been installed. A summary table is available in this manual for users to record all the relay settings. When the testing is completed, users should verify the applied relay settings, and verify that all desired elements have been enabled, using the 745PC program or the relay front panel.
5. Verify that the relay rated AC current matches the CT secondary value.
6. Verify that the relay rated AC voltage matches the VT secondary value.
7. Verify that the relay rated frequency setting matches the power system frequency.
8. Open all blocking switches so as not to issue an inadvertent trip signal to line breakers.
9. Verify that the auxiliary supply matches relay nameplate. Turn the auxiliary supply ON.
10. Verify that all grounding connections are correctly made.

To facilitate testing it is recommended that all functions be initially set to Disabled. Every feature which will be used in the application should be set per desired settings, enabled for the specific commissioning test for the feature, then returned to Disabled at completion of its test. Each feature can then be tested without complications caused by operations of other features. At the completion of all commissioning tests all required features are then Enabled.

CAUTION

It is necessary to keep track of modifications/changes made to settings during the course of these commissioning steps and ensure that all settings are returned to the "in-service" values at the end of the tests, prior to placing the relay into service.

10.3.2 DIELECTRIC STRENGTH TESTING

The 745 is rated for 2000 V DC isolation between relay contacts, CT inputs, VT inputs and the safety ground terminal G12. Some precautions are required to prevent 745 damage during these tests.

Filter networks and transient protection clamps are used between control power and the filter ground terminal G11. This filtering is intended to filter out high voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI). The filter capacitors and transient suppressors could be damaged by application continuous high voltage. Disconnect filter ground terminal G11 during testing of control power and trip coil supervision. CT inputs, VT inputs, and output relays do not require any special precautions. Low voltage inputs (< 30 V) such as RTDs, analog inputs, analog outputs, digital inputs, and RS485 communication ports are not to be tested for dielectric strength under any circumstance.

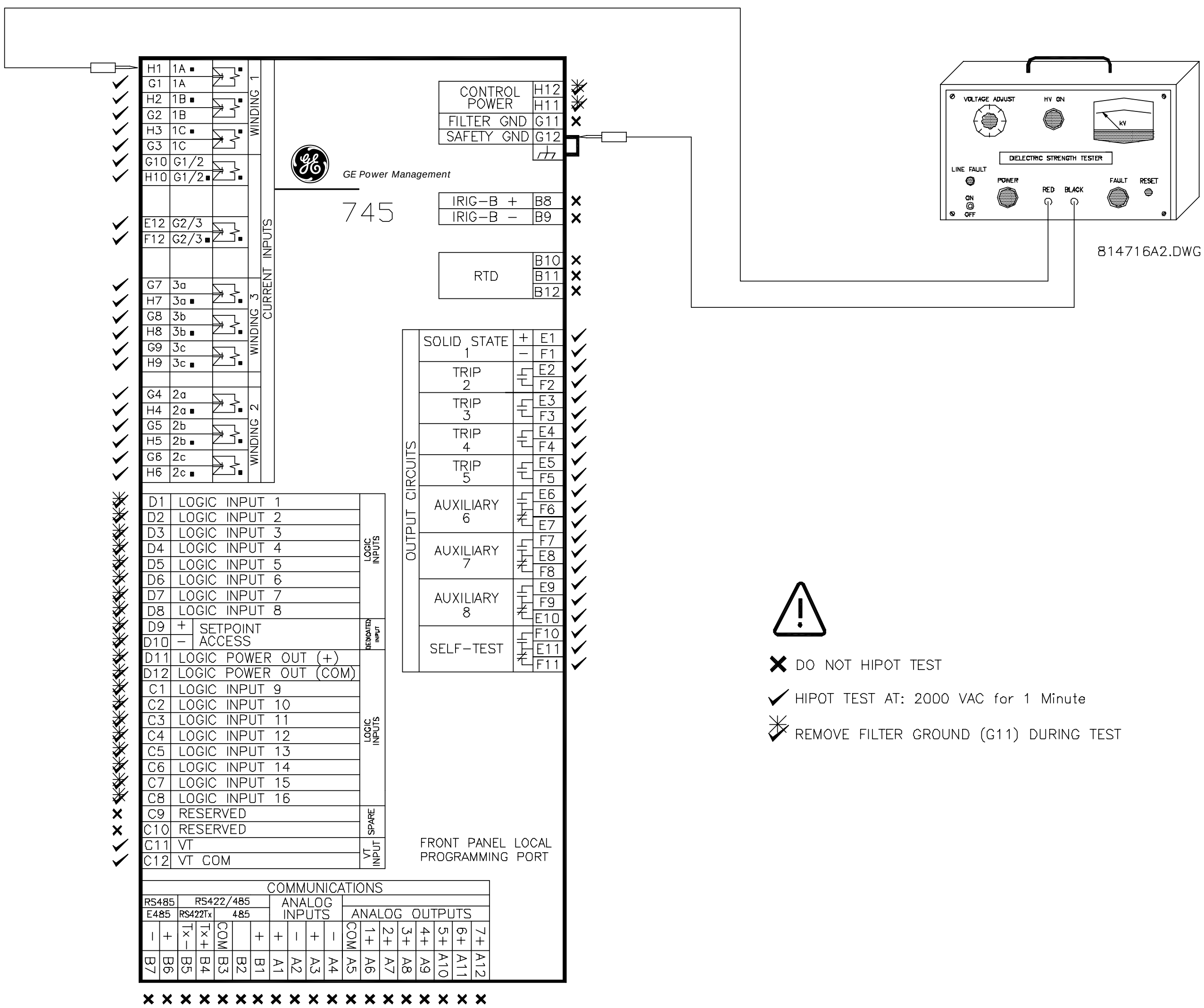


Figure 10–2: TESTING FOR DIELECTRIC STRENGTH

10.4.1 LOGIC INPUTS

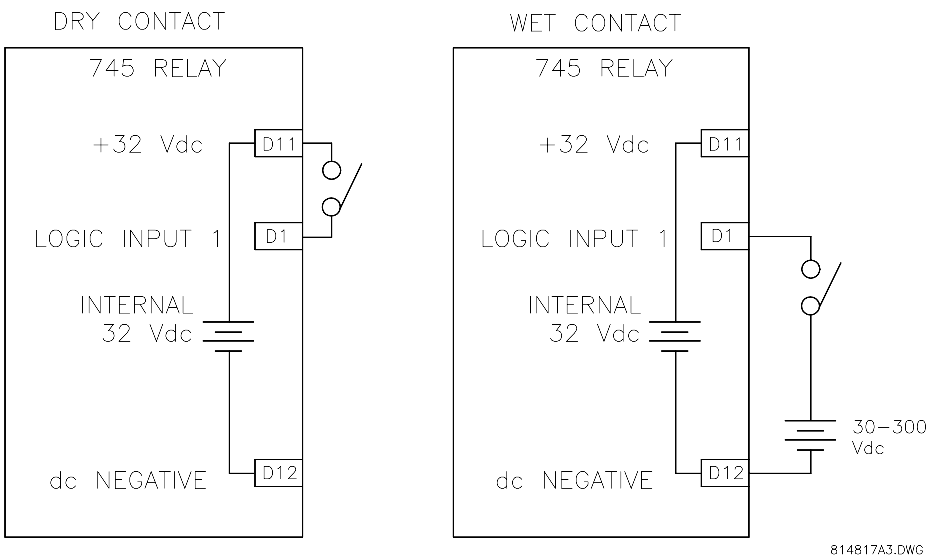


Figure 10–3: LOGIC INPUTS

a) PROCEDURE

1. Prior to energizing any of the Logic Inputs, ensure that doing so will not cause a relay trip signal to be issued beyond the blocking switches. These should have been opened prior to starting on these tests. If you wish, you can disable the Logic Input functions by setting:

   SETPOINTS/S3 LOGIC INPUTS/LOGIC INPUT 1 (2-16)/LOGIC INPUT 1 FUNCTION: Disabled

2. Connect a switch between LOGIC INPUT 1 (terminal D1) and +32 V DC (terminal D12), as shown in Figure 10-3: LOGIC INPUTS (alternatively, use the wet contact approach shown in the same figure). Logic Inputs can be asserted with either an opened or closed contact, per the user choice. Verify/set the type of Logic Input to be used with the following setpoint:

   SETPOINTS/S3 LOGIC INPUTS/LOGIC INPUTS/LOGIC INPUT 1 (2-16)/INPUT 1 ASSERTED STATE

3. Display the status of the Logic Input using the actual value item:

   ACTUAL VALUES/A1 STATUS/LOGIC INPUTS/LOGIC INPUT 1 (2-16) STATE

4. With the switch contact open (or closed), check that the input state is detected and displayed as Not Asserted.
5. Close (open) the switch contacts. Check that the input state is detected and displayed as Asserted.
6. Repeat for all the relay logic inputs which are used in your application.

10.4.2 OUTPUT RELAYS

a) PROCEDURE:

1. To verify the proper functioning of the output relays, enable the "Force Output Relays Function" built into the 745 by setting:

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT RELAYS FUNCTION: Enabled

   The TEST MODE LED on the front of the relay will come ON, indicating that the relay is in test mode and no longer in service. In test mode all output relays can be controlled manually.

2. Set the **FORCE OUTPUT 1** to **FORCE OUTPUT8** setpoints as follows:
3. Under **SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 1 (2 to 8)** set:

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 1: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 2: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 3: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 4: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 5: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 6: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 7: De-energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 8: De-energized

4. Using a multimeter, check that all outputs are de-energized. For outputs 2 to 5, the outputs are dry N.O. contacts and for outputs 6 to 8, the outputs are throwover contacts (form C). Output 1 is a solid state output. When de-energized, the resistance across E1 and F1 will be greater than 2 MW; when energized, and with the multimeter positive lead on E1, the resistance will be in the 20 to 30 kW.
5. Now change the settings to:

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 1: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 2: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 3: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 4: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 5: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 6: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 7: Energized

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT 8: Energized

6. Using a multimeter, check that all outputs are now energized.
7. Now return all output forcing to De-energized and disable the relay forcing function by setting:

   SETPOINTS/S6 TESTING/OUTPUT RELAYS/FORCE OUTPUT RELAYS FUNCTION: Disabled

8. All the output relays should reset.

10.5.1 DESCRIPTION

Accuracy of readings taken in this section should be compared with the specified relay accuracies, chapter 1. If the measurements obtained during this commissioning procedure are "out-of-specification" verify your instrumentation accuracy. If the errors are truly in the relay, advise the company representative.

10.5.2 CURRENT INPUTS

The general approach used to verify the AC current inputs is to supply rated currents in all the input CTs. Displayed readings will then confirm that the relay is correctly measuring all the inputs and performing the correct calculations to derive sequence components, loading values, etc. Since the displayed values are high-side values, you can use this test to verify that the CT ratios have been correctly entered.

1. If you are using a single phase current supply, connect this current signal to all the input CTs in series, winding 1, 2 and 3, if using a 3-winding configuration, and the ground CT input(s). Adjust the current level to 1 A for 1-amp-rated relays and to 5 A for 5-amp-rated relays.

NOTE

Some elements may operate under these conditions unless all elements have been disabled.

2. With the above current signals ON, read the Actual Values displayed under:

   ACTUAL VALUES/A2 METERING/CURRENT

   The actual values can be quickly read using the 745PC program.

3. Read the rms magnitude and the phase of the current signal in each phase of each winding. **Note that phase A, winding #1 current is used as the reference for all angle measurements.**

   $I_{phase\ rms\ displayed} = I_{phase\ input}$ x CT ratio for that winding

   The phase angle will be 0° for all phase currents if the same current is injected in all phase input CTs. Sequence components will be:

   $$I_1 = \text{CT Ratio} \times \frac{I_a + aI_b + a^2 I_c}{3} = 0 \text{ since the three currents are in phase.}$$

   where $a = 1\angle 120°$

   $$I_2 = \text{CT Ratio} \times \frac{I_a + a^2 I_b + aI_c}{3} = 0 \text{ since the three currents are in phase.}$$

   $I_{zero\ sequence}$ = CT ratio × input current

   $I_{neutral}$ = 3 × Phase CT ratio × input current

   I_{Ground} = Ground CT ratio × input current into ground CT

4. Since the transformer load is calculated using the A-phase current, the displayed load should be:

   $$\%\ \text{Loading} = \frac{\text{Actual Current}}{\text{Rated MVA Current}} \times 100\%$$

   $$\text{where Rated MVA Current} = \frac{\text{MVA}}{\sqrt{3}kV_{L-L}}$$

5. Verify the harmonic content display: should be zero, or equal to distortion of input current.

   ACTUAL VALUES/A2 METERING/HARMONIC CONTENT/THD/W1...W2...W3

6. Verify frequency: 60 or 50 Hz, as per frequency of input current on phase A.

   ACTUAL VALUES/A2 METERING/FREQUENCY/SYSTEM FREQUENCY

7. To verify the positive and negative sequence component values, apply the current signal to phase A of each winding in series. Read the values of positive and negative sequence current displayed by the relay.

$$I_1 = \frac{1}{3} \times \text{CT Ratio} \times (I_a + aI_b + a^2 I_c) = \frac{1}{3} \times \text{CT Ratio} \times I_a \quad \text{since } I_b = I_c = 0$$

   where a = $1\angle 120°$

$$I_2 = \frac{1}{3} \times \text{CT Ratio} \times (I_a + a^2 I_b + aI_c) = \frac{1}{3} \times \text{CT Ratio} \times I_a \quad \text{since } I_b = I_c = 0$$

   All angles will be 0°.

   These values are displayed with the following actual values:

   ACTUAL VALUES/A2 METERING/CURRENT/POSITIVE SEQUENCE/W1...W2...W3

   ACTUAL VALUES/A2 METERING/CURRENT/NEGATIVE SEQUENCE/W1...W2...W3

8. Now, lower the current amplitude while displaying the system frequency. Verify that the frequency is displayed correctly with current levels down to approximately 50 mA rms input. Decrease current to 0 A.

10.5.3 VOLTAGE INPUT

1. Connect an AC voltage to the voltage input (if the input voltage feature is enabled) to terminals C11 and C12. Set the level at the expected VT secondary voltage on the VT for your installation.
2. Remove all current signals from the relay.
3. Verify the voltage reading with the following actual value:

   ACTUAL VALUES/A2 METERING/VOLTAGE/SYSTEM VOLTAGE

   The reading should be: Input voltage × VT Ratio

NOTE

The displayed system voltage is always the line-to-line voltage regardless of the input VT signal. Earlier versions of the 745 may display the same voltage as the selected input, i.e. phase-to-neutral if the input is a phase-to-neutral signal and phase-to-phase if the input is phase-to-phase.

4. With the voltage signal still ON, read the displayed system frequency under:

   ACTUAL VALUES/A2 METERING/FREQUENCY/SYSTEM FREQUENCY

5. Lower the voltage amplitude while displaying the system frequency. Verify that the frequency is displayed correctly with voltage levels down to less than 3 V RMS input (when the lower limit is reached, the system frequency will be displayed as 0.00 Hz). Verify that at less than 1.0 V, frequency is displayed as 0.00 Hz.

10.5.4 TRANSFORMER-TYPE SELECTION

The 745 automatically configures itself to correct for CT ratio mismatch, phase shift, etc., provided that the input CTs are all connected in wye. The following example illustrates the automatic setting feature of the 745.

a) AUTOMATIC TRANSFORMATION PERFORMED IN THE 745

The automatic configuration routines examine the CT ratios, the transformer voltage ratios, the transformer phase shift, etc., and apply correction factors to match the current signals under steady state conditions.

Consider the case of a Y:D30° power transformer with the following data (using a 1 A CT secondary rating for the relay):

10

Winding #1: 100 MVA, 220 kV, 250/1 CT ratio (rated current is 262.4 A, hence CT ratio of 250/1)
Winding #2: 100 MVA, 69 kV, 1000/1 CT ratio (rated current is 836.8 A, hence CT ratio of 1000/1)

The 1000/1 CT ratio is not a perfect match for the 250/1 ratio. The high-side CT produces a secondary current of 262.5/250 = 1.05 A whereas the low-side CT produces a current of 0.837 A. The 745 automatically applies an amplitude correction factor to the Winding 2 currents to match them to the Winding 1 currents. The following illustrates how the correction factor is computed:

$$\mathrm{CT}_2(\text{ideal}) = \mathrm{CT}_1 \times \frac{V_1}{V_2} = \frac{250}{1} \times \frac{220\ \mathrm{V}}{69\ \mathrm{V}} = 797.1$$

The mismatch factor is therefore $\dfrac{\text{Ideal CT Ratio}}{\text{Actual CT Ratio}} = \dfrac{797.1}{1000} = 0.7971$

Winding 2 currents are divided by this factor to obtain balanced conditions for the differential elements.

If this transformer were on line, fully loaded, and protected by a properly set 745 relay, the actual current values read by the relay would be:

Winding 1: 262.5 A ∠0° (this is the reference winding)
Winding 2: 836.8 A ∠210° (30° lag due to transformer and 180° lag due to CT connections)
Differential current: less than 0.03 × CT as the two winding currents are equal once correctly transformed inside the relay.
The loading of each winding would be 100% of rated.

The above results can be verified with two adjustable sources of three-phase current. With a single current source, how the relay performs the necessary phase angle corrections must be taken into account. Table 5–1: TRANSFORMER TYPES on page 5–10 shows that the Y-side currents are shifted by 30° to match the Delta secondary side. The 30° phase shift is obtained from the equations below:

$$I_{W1a'} = \frac{I_{W1a} - I_{W1c}}{\sqrt{3}}, \quad I_{W1b'} = \frac{I_{W1b} - I_{W1a}}{\sqrt{3}}, \quad I_{W1c'} = \frac{I_{W1c} - I_{W1b}}{\sqrt{3}}$$

By injecting a current into phase A of Winding 1 and phase A of Winding 2 only, $I_{W1b} = I_{W1c} = 0$ A. Therefore, if we assume an injected current of 1 × CT, the *transformed* Y-side currents will be:

$$I_{W1a'} = \frac{1 \times \mathrm{CT}}{\sqrt{3}}, \quad I_{W1b'} = \frac{-1 \times \mathrm{CT}}{\sqrt{3}}, \quad I_{W1c'} = \frac{0 \times \mathrm{CT}}{\sqrt{3}}$$

For the purposes of the differential elements only, the transformation has reduced the current to 0.57 times its original value into phase A, and created an apparent current into phase B, for the described injection condition. If a 1 × CT is now injected into phase A Winding 1, the following values for the differential currents for all three phases should be obtained:

A-phase differential: 0.57 × CT ∠0° Lag
B-phase differential: 0.57 × CT ∠180° Lag
C-phase: 0 × CT.

b) EFFECTS OF ZERO-SEQUENCE COMPONENT REMOVAL

NOTE

The transformation used to obtain the 30° phase shift on the Y-side automatically removes the zero-sequence current from those signals. The 745 always removes the zero-sequence current from the delta winding currents.

If the zero-sequence component is removed from the Delta-side winding currents, the Winding 2 current values will change under unbalanced conditions. Consider again the case described above, with the 1 × CT injected into phase A of Winding 2.

For the 1 × CT current, the zero-sequence value is 1/3 of 1.0 × CT or 0.333 × CT A. The value for $I_{W2a'}$ is therefore (1.0 – 0.333) × CT = 0.6667 × CT A. This value must be divided by the CT error correction factor of 0.797 as described above.

Therefore, the value of differential current for phase A, when injecting 1 × CT in Winding 2 only, is:

$$I_{A(differential)} = \frac{0.667 \times \text{CT A}}{0.797} = 0.84 \times \text{CT A}$$

The action of removing the zero-sequence current results in a current equal to the zero-sequence value introduced into phases B and C. Hence, the differential current for these two elements is:

$$I_{B(differential)} = I_{C(differential)} = \frac{0.333 \times \text{CT A}}{0.797} = 0.84 \times \text{CT A}$$

Now, applying 1 × CT into phase A Winding 1 and the same current into phase A Winding 2, but 180° out-of-phase to properly represent CT connections, the total differential current in the A-phase element will be (0.57 – 0.84) × CT = –0.26 × CT. The injection of currents into phase A of Windings 1 and 2 in this manner introduces a differential current of (–0.57 × CT + 0.42 × CT) = –0.15 × CT into phase B and (0.0 × CT + 0.42 × CT) = 0.42 × CT into phase C.

10.5.5 AMBIENT TEMPERATURE INPUT

a) BASIC CALIBRATION OF RTD INPUT

1. Enable ambient temperature sensing through the following setpoint:

   SETPOINTS/S2 SYSTEM SETUP/AMBIENT TEMP/ AMBIENT TEMPERATURE SENSING

2. Connect a thermocouple to the relay terminals B10,11,12 and read through actual value:

   ACTUAL VALUES/A2 METERING/AMBIENT TEMP/AMBIENT TEMPERATURE

3. Compare the displayed value of temperature against known temperature at the location of the sensor. Use a thermometer or other means of obtaining actual temperature.

An alternative approach is to perform a more detailed calibration per the procedure outlined below.

b) DETAILED CALIBRATION OF RTD INPUT

1. Alter the following setpoints as shown:

   SETPOINT S2: SYSTEM SETUP/AMBIENT TEMP/AMBIENT TEMPERATURE SENSING: Enabled
   SETPOINT S2: SYSTEM SETUP/AMBIENT TEMP/AMBIENT RTD TYPE/(select desired type)

2. The measured values should be ±2°C or ±4°F. Alter the resistance applied to the RTD input (note the 3-input connection must be used for the measurements to be valid) as per the *typical* table below to simulate RTDs and verify accuracy of the measured values. View the measured values in:

   ACTUAL VALUES A2/METERING/AMBIENT TEMP.

Refer to RTD tables included in this manual for calibration of resistance versus temperature.

Table 10–1: MEASURED RTD TEMPERATURE – 100 Ω PLATINUM

100 Ω PLATINUM RESISTANCE	EXPECTED RTD READING		MEASURED RTD TEMPERATURE _____°C _____°F (select one)
	°C	°F	
80.31	–50	–58	
100.00	0	32	
119.39	50	122	
138.50	100	212	
157.32	150	302	
175.84	200	392	
194.08	250	482	

Table 10–2: MEASURED RTD TEMPERATURE – 120 Ω NICKEL

120 Ω NICKEL RESISTANCE	EXPECTED RTD READING		MEASURED RTD TEMPERATURE _____°C _____°F (select one)
	°C	°F	
86.17	–50	–58	
120.0	0	32	
157.74	50	122	
200.64	100	212	
248.95	150	302	
303.46	200	392	
366.53	250	482	

Table 10–3: MEASURED RTD TEMPERATURE – 100 Ω NICKEL

100 Ω NICKEL RESISTANCE	EXPECTED RTD READING		MEASURED RTD TEMPERATURE _____°C _____°F (select one)
	°C	°F	
71.81	–50	–58	
100.00	0	32	
131.45	50	122	
167.20	100	212	
207.45	150	302	
252.88	200	392	
305.44	250	482	

c) AMBIENT TEMPERATURE BY MONTHLY AVERAGES

1. If the ambient temperature is entered as 12 monthly averages, program the value for the month during which the relay is being commissioned.

2. Examine the following actual value to verify the programmed temperature:

   ACTUAL VALUES A2/METERING/AMBIENT TEMP.

3. Verify that values entered for other months do not affect the value for the present month.

10.5.6 ANALOG OUTPUTS

1. The analog output settings are located in the following setpoints section:

   SETPOINTS/S2 SYSTEM SETUP/ANALOG OUTPUTS/...

2. Connect a milliammeter to the Analog Output contacts, COM on A5, A.O. #1 on A6, A.O. #2 on A7, A.O. #3 on A8, A.O. #4 on A9, A.O. #5 on A10, A.O. #6 on A11 or A.O. #7 on A12.
3. From the settings used for the tested Analog output, determine the mA range for the output and the driving signal and its range for the full range of output current.
4. Apply the input signal and vary its amplitude over the full range and ensure the Analog Output current is the correct amplitude. Record the results in the table below. Duplicate as required for each Analog Output.

Table 10–4: CALIBRATION RESULTS FOR ANALOG OUTPUTS

Analog Output Number: ________ Analog Output Value: ________ Analog Output Range: ________	Analog Output Min.: ________ Analog Output Max.: ________	
INPUT SIGNAL AMPLITUDE (percent of full range)	**EXPECTED mA OUTPUT**	**MEASURED mA OUTPUT**
0		
25		
50		
75		
100		

10.5.7 TAP POSITION

1. The Analog Input used to sense tap position is programmed with the following setpoints:

   SETPOINTS/S2 SYSTEM SETUP/ONLOAD TAP CHANGER/.....

2. To verify the operation of this circuit, connect a variable resistor across terminals A3 and A4. The resistor range should cover the full range of resistance produced by the tap changer mechanism. The tap position is displayed under:

   ACTUAL VALUES/A2 METERING/TAP CHANGER/TAP CHANGER POSITION

3. Adjust the resistance to simulate the minimum tap position and verify that a 1 is displayed. Now gradually increase the resistance up to the value which represents the maximum tap value, verifying that the tap position indicator tracks the resistance.

10.6.1 WARNING

CAUTION **Keep track of modifications/changes made to settings during the course of these commissioning steps and ensure that all settings are returned to the "in-service" values at the end of the tests.**

10.6.2 HARMONIC RESTRAINED PERCENT DIFFERENTIAL

The harmonic restrained percent differential element setpoint are under:

SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/PERCENT DIFFERENTIAL/...

Disable all other protection elements to ensure that trip relay(s) and auxiliary relays are operated by element under test only. With a multimeter, monitor the appropriate output contact(s) per intended settings of the FlexLogic. Refer to the relay settings to find out which relay(s) should operate when a given element operates.

a) MINIMUM PICKUP

1. The minimum pickup of the A-phase element is measured by applying a fundamental frequency AC current to terminals H1 and G1, Winding 1 phase A. Monitor the appropriate trip and auxiliary contact(s) as the current is increased from 0 A. Compare the current value at which operation is detected against:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/PERCENT DIFFERENTIAL/PERCENT DIFFERENTIAL PICKUP

   Since the operating point is normally set quite low, fine control of the current signal will be required to obtain accurate results.

2. The currents in the winding may be phase shifted or may have the zero-sequence component removed due to auto-configuration (see Section 5.2: AUTO-CONFIGURATION on page 5–3). As an alternate to calculating to relation of input current to differential current, the differential current is displayed under:

   ACTUAL VALUES/A2 METERING/CURRENT/DIFFERENTIAL/...

   Ensure that the displayed value is the same as the minimum pickup setting when the element operates.

3. Check that the TRIP and MESSAGE indicators are flashing and the following trip message is displayed:

```
▌▌ OPERATED (LATCHED)∅A
▌▌ Percent Differentl
```

NOTE The message will indicate either OPERATED or LATCHED depending on the setting under:

SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/PERCENT DIFFERENTIAL/PERCENT DIFFERENTIAL TARGET

4. To independently verify that auto-configuration causes the currents to be as measured, follow the rules outlined in steps 5 to 9 below.
5. Look up transformer type in Table 5–1: TRANSFORMER TYPES on page 5–10.
6. For the phase shift shown for the particular set of vectors, determine the processing applied to the current vectors for that winding from Table 5–2: PHASE SHIFTS on page 5–23.
7. Calculate the "dashed" current values using the equations in Table 5–2: PHASE SHIFTS on page 5–23. If applicable, use the zero-sequence removal computation. This is applicable for all Delta windings and for both windings of a wye-wye transformer. Compute the processed current vectors to obtain the "dashed" values for that winding.
8. Calculate the CT correction factor for Windings 2 (and 3 if applicable) and apply as necessary.
9. Turn the equations around to compute the threshold differential currents in terms of the applied currents.

NOTE

To check the threshold without performing computations, inject balanced 3-phase currents into any winding. With balanced conditions, there is no effect on magnitude due to phase shifting and zero-sequence removal has no effect. However, the CT ratio mismatch is still applicable.

10. Repeat the minimum pickup level measurements for the B-phase (inputs H2 and G2) and the C-phase element (inputs H3 and G3).

The above tests have effectively verified the minimum operating level of the three harmonic restrained differential elements. If desired the above measurements may be repeated for the phase inputs for the other winding(s). The results should be identical.

b) VERIFICATION OF LOCAL RESET MODE

1. Set the differential element with a latched target. Apply enough current to cause the relay to operate, then remove the current. The trip LED and the phase LED should be latched on.
2. Set Local Reset Block to Disabled as follows:

   SETPOINTS/S1 745 SETUP / RESETTING / LOCAL RESET BLOCK: Disabled

3. Press the RESET key. The target should reset.
4. Set Local Reset Block to Logic Input 1 (2-16) as follows:

   SETPOINTS/S1 745 SETUP / RESETTING / LOCAL RESET BLOCK: Logc Inpt 1 (2-16)

5. Press the RESET key and verify that the target does not reset if the logic input is not asserted. Verify the status of selected logic input through the actual value:

   ACTUAL VALUES/A1 STATUS / LOGIC INPUTS / LOGIC INPUT 1 (2-16)

6. Assert the selected logic input, apply the current to cause the target to latch and verify that pressing the RESET button does not reset the LED. The following message should appear:

```
INAVLID KEY: MUST
BE IN LOCAL MODE
```

c) VERIFICATION OF REMOTE RESET MODE

1. Set the differential element with a latched target. Apply enough current to cause the relay to operate, then remove the current. The trip LED and the phase LED should be latched on.
2. Set Remote Reset Signal to Logic Input 1 (2-16) under:

   SETPOINTS/S1 745 SETUP / RESETTING / REMOTE RESET SIGNAL: Logc Inpt 1 (2-16)

3. Assert Logic Input 1. The target should reset.

d) VERIFICATION OF SOLID STATE OUTPUT

1. If the solid state output is used to drive auxiliary relays, verify that these relays operate whenever the relay is in a trip condition. Ensure that the current though the auxiliary coils is interrupted by an external contactor between each test.
2. To avoid operating the breaker during the commissioning process when the solid state output operates the breaker directly, use the circuit shown in Figure 10–4: SOLID STATE OUTPUT TEST CIRCUIT to verify this output. Whenever the relay is in a trip state, current flows through the load resistor. Select the resistor for approximately 1 × CT of DC current with the normal DC supply voltage used in your relay scheme.

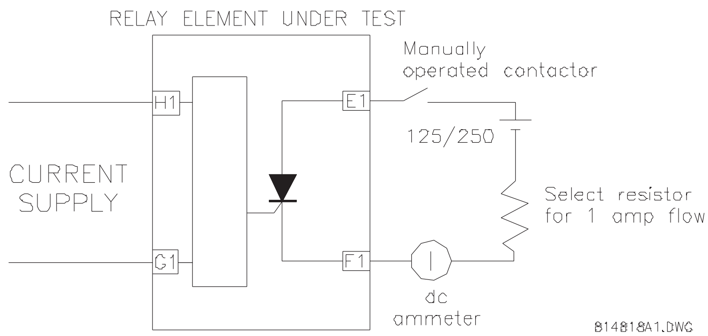


Figure 10–4: SOLID STATE OUTPUT TEST CIRCUIT

e) BASIC OPERATING TIME

1. To measure the basic operating time of the harmonic restrained differential elements, connect an AC current signal to terminals H1 and G1, through a double-pole single-throw switch. The second pole of the switch starts a timer circuit which is stopped by the operation of the relay trip contact. Refer to the figure below for details.
2. Close the switch and set the current level to 3 times the minimum pickup value measured earlier. Re-open the switch and reset all targets on the relay. Ensure that timer circuit functions correctly.
3. Close the switch and record operating time of relay.

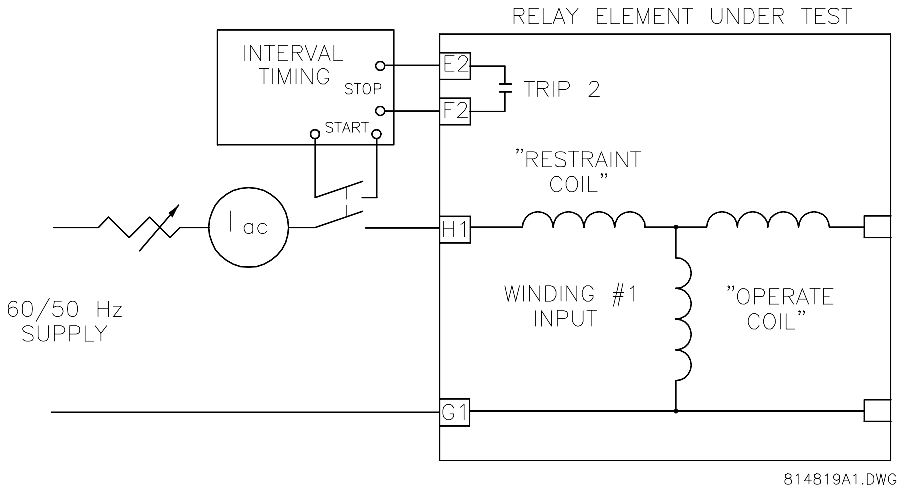


Figure 10–5: TIMER TEST CIRCUIT

f) SLOPE MEASUREMENTS

The auto configuration processes the currents to correct for phase shifts, CT mismatch, and zero sequence component removal. As such, it more complex to measure the slope from an external single phase injection. Therefore, the use of displayed actual values is recommended.

The differential and restraint currents are displayed the actual values sections:

ACTUAL VALUES/A2 METERING/CURRENTS/DIFFERENTIAL/PHASE A DIFFERENTIAL CURRENT
ACTUAL VALUES A2 METERING/CURRENTS/RESTRAINT/PHASE A RESTRAINT CURRENT

1. To measure the slope, connect current signals to the relay as shown in the figure below:

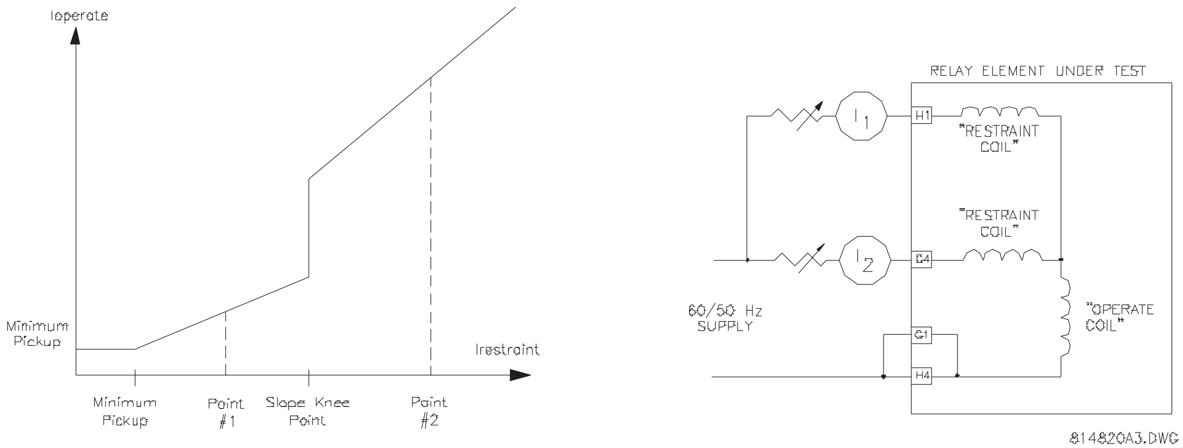


Figure 10–6: CURRENT SIGNAL CONNECTIONS

2. If I_1 = 1.5 × CT and I_2 = 0, the element is operated as all the current appears as a differential current.
3. The slope is calculated from the values of $I_{differential}$ and $I_{restraint}$ as shown below:

$$\%\text{slope} = \frac{I_{differential}}{I_{restraint}} \times 100\%$$

4. Slowly increase I_2. As I_2 is increased, the element will reset when the differential current drops below the minimum pickup.
5. As I_2 continues to increase, the element operates again when both the initial slope and the minimum pickup conditions are satisfied. Calculate the initial slope 1 value at this point.
6. As I_2 increases further, the element may reset again, depending on the setting of the slope kneepoint. This is caused by the current values moving into the slope 2 region.
7. Continue increasing I_2 until the element operates again. Compute the slope 2 value at this point.

g) SLOPE KNEEPOINT

1. To measure the approximate location of the kneepoint, follow the procedure above, setting I_1 at a value equal to the kneepoint. Gradually increase I_2 until the element resets. Calculate the first slope at this point. The value thus obtained should be equal to the initial slope setting. Increase I_2 until the element operates again. Calculate the slope at this point – it should be equal to the final slope. If the kneepoint is much different than the selected value of I_1, the two values of slope will be the same.
2. For an accurate measurement of the kneepoint, select a value of I_1 just above the kneepoint value.
3. Increase I_2 until the element resets. Calculate the slope – the value should be equal to the initial slope value.
4. Increase I_1 by a small amount, say 10%, and adjust I_2 until a new operating point is obtained. Calculate the slope. Repeat until the slope value equals the final slope. The kneepoint value is the value of the restraint current at which the slope changed in value.

NOTE

Keep in mind the effects of auto-configuration on the magnitude of the current signal fed to the differential elements when conducting the slope kneepoint test.

h) 2nd HARMONIC RESTRAINT

To measure the percentage of second harmonic required to block the operation of the harmonic-restraint differential elements, use the connection diagram shown below. Current is supplied as an operating current to the A-phase element.

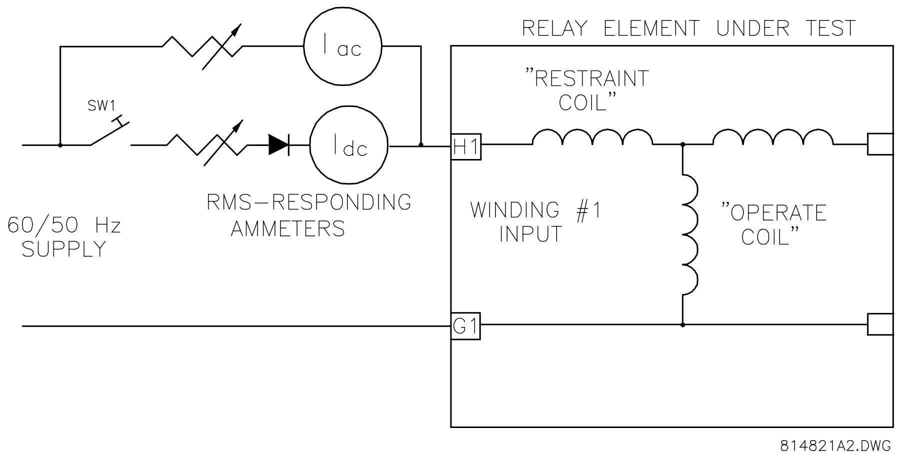


Figure 10–7: 2ND HARMONIC RESTRAINT TEST

1. Close switch S1. Set the AC current, I_{AC} to twice rated CT secondary current. Set I_{DC} to obtain harmonic content above the 2nd harmonic restraint setting under:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/HARMONIC INHIBIT/HARMONIC INHIBIT LEVEL

2. Calculate the percent second harmonic content from the equations below:

   If the current is measured with average-responding/reading meters:

$$\%2nd = \frac{100 \times 0.141 \times I_{DC}}{I_{DC} + 0.9 \times I_{AC}}$$

b) if the current is measured with rms-responding/reading meters:

$$\%2nd = \frac{100 \times 0.141 \times I_{DC}}{I_{DC} + 1.414 \times I_{AC}}$$

3. Open and reclose S1. The relay should not operate.
4. Decrease I_{DC} until the element operates. Calculate the percent of second harmonic at this point using the equations above. The calculated percent harmonic value should equal the relay setting.

i) 5th HARMONIC RESTRAINT

Verifying the operation of the 5th harmonic restraint requires test equipment capable of generating a current signal containing a fundamental and 5th harmonic. Most modern dedicated relay test instruments, such as Powertec's (or Manta) DFR, Doble, or Multiamp instruments are capable of generating appropriate signals. A power operational amplifier with a suitably rated output, or a power audio amplifier, may also be used to generate the appropriate signal.

1. Connect the test setup as below to supply the A-phase element. Set the fundamental current level to the CT rated secondary value. The harmonic restraint differential element of phase A should be operated.

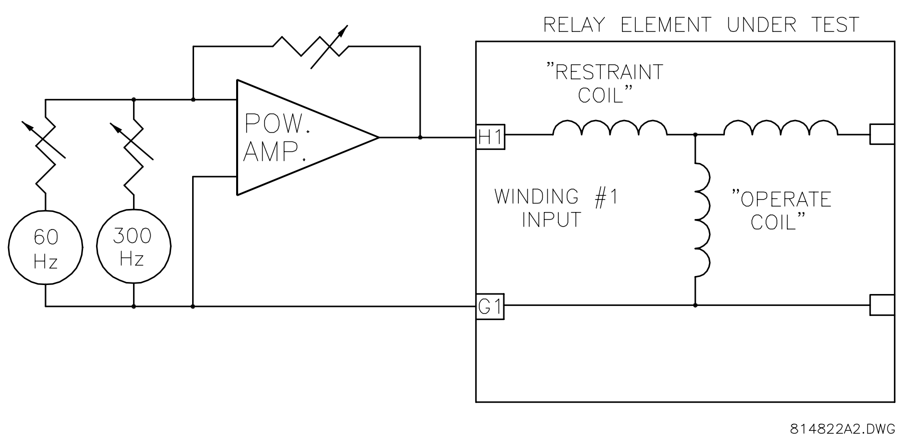


Figure 10–8: 5TH HARMONIC RESTRAINT TEST

2. Increase the 5th harmonic component to a value well above the 5th harmonic restraint setting shown in:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/5th HARM INHIBIT/5th HARMONIC INHIBIT LEVEL

3. Remove the total current signal and reapply. The relay should not operate. Decrease the 5th harmonic component until the element operates.

4. Calculate the percentage 5th harmonic to restrain from the following equation:

$$\%5\text{th} = \frac{100 \times \text{level of 5th harmonic}}{\text{level of fundamental}}$$

5. Compare this value to the relay setting.

j) ENERGIZATION DETECTION SCHEME

Refer to Section 5.6.4 DIFFERENTIAL on page 5–46 for a description of this feature. This feature is activated by up to three inputs: breaker auxiliary switch, current below a threshold, or absence of voltage. The procedure below will test the current-level enabling feature. A similar approach can be used to verify the other two enabling functions, with the proper test equipment.

1. Enable the Energization Detection Scheme with the following setpoint:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/ENERGIZATION INHIBIT FUNCTION: Enabled

2. Make the following setpoint changes:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/ENERGIZATION IHIBIT PARMETERS: 2nd
   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/HARMONIC AVERAGING: Disabled
   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/ENERGIZATION INHIBIT LEVEL: 15%
   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/ENERGIZATION INHIBIT DURATION: 5 s
   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/ENERGIZATION SENSING BY CURRENT: Enabled
   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/ENERGIZATION INHIBIT/MINIMUM ENERGIZATION CURRENT: 0.10 × CT

3. Preset current with harmonic content just above the Energization Inhibit Level used during the "energization period". Apply the current signal and measure the operating time. The time should be equal to "energization period" plus approximately 50 ms.

4. Disable the energization detection scheme and repeat the timing test. The operate time should be the normal operating time of Harmonic Restraint Differential element.

k) TARGET, OUTPUT CONTACT, & DISPLAY OPERATION

Verify the correct operation of all targets and output contacts and display messages during the above Percent Differential tests.

l) BLOCKING FROM LOGIC INPUTS

Each element can be programmed to be blocked by a logic input, virtual input, virtual output, output relay operation, or self-test relay operation. This procedure verifies that the differential element is blockable by Logic Input 1.

1. Select Logic Input 1 as shown:

   SETPOINTS/S4 ELEMENTS/DIFFERENTIAL/PERCENT DIFFERENTIAL/PERCENT DIFFERENTIAL BLOCK: Logc Inpt 1

2. Apply current to operate the differential element then assert Logic Input 1. Verify that the element has reset and that all targets can be reset.
3. With Logic Input 1 asserted, remove the current and reapply. Verify that the element did not operate.

10.6.3 INSTANTANEOUS DIFFERENTIAL PROTECTION

Settings for this element are under the setpoints group:

SETPOINTS/S4 ELEMENTS/INST DIFFERENTIAL/...

All other protective elements must be disabled to ensure that trip relay(s) and auxiliary relays are operated by element under test. Monitor the appropriate contact per intended settings of the FlexLogic.

a) MINIMUM PICKUP

1. The operating level of the A-phase element is measured by applying an AC current to terminals H1 and G1. Monitor the appropriate trip and auxiliary contact(s) as the current is increased from 0 A. Due to the auto-configuration feature, it may be easier to read the actual differential current on the relay rather computing it. Compare the value of the differential current at which operation is detected against the setpoint:

   SETPOINTS/ S4 ELEMENTS/INST DIFFERENTIAL/INST DIFFERENTIAL PICKUP

2. Check that the TRIP and MESSAGE indicators are flashing and the following trip message is displayed:

```
LATCHED: ∅A (BC)
Inst Differential
```

NOTE

The message may show operated instead of latched if the target is set to Self-Reset.

b) OPERATING TIME

1. To measure the basic operating time of the instantaneous differential elements, connect an AC current signal to terminals H1 and G1 through a double-pole, single-throw switch. The second pole of the switch starts a timer circuit that will be stopped by the operation of the relay trip contact. Refer to Figure 10–5: TIMER TEST CIRCUIT on page 10–16.
2. Close the switch and set the current level to 2 times the pickup value measured earlier. Re-open the switch and reset all targets on the relay. Ensure that the timer circuit functions correctly.
3. Close the switch and record operating time of relay.

NOTE

All the differential currents are calculated using the same principal used in Section 10.5.4: TRANSFORMER-TYPE SELECTION on page 10–9. The differential current derivation is affected by phase shift compensation and zero sequence removal.

c) TARGET, OUTPUT CONTACT, & DISPLAY OPERATION

Verify the correct operation of all targets and output contacts and display messages during testing.

d) BLOCKING FROM LOGIC INPUTS

Each element is programmable to be blocked by a logic input, virtual input, virtual output, output relay operation, or self-test relay operation. This test verifies that the differential element can be blocked by Logic Input 1.

1. Select logic input 1 as shown below:

   SETPOINTS/S4 ELEMENTS/INST DIFFERENTIAL/INST DIFFERENTIAL BLOCK: Logc Inpt 1

2. Apply current to operate the differential element then assert Logic Input 1. Verify that the element has reset and that all targets can be reset.
3. With Logic Input 1 asserted, remove the current and reapply. Verify that the element did not operate.

10.6.4 PHASE TIME OVERCURRENT

This procedure verifies that the phase time overcurrent element performance matches the in-service settings. Since these elements can have any one of a multitude of timing curves, a table of expected operating times versus applied current should be prepared prior to testing the elements. Refer to Section 5.9: TIME OVERCURRENT CURVES on page 5–91 for information on timing curves.

If the relay elements are set for a "Linear" reset characteristic when measuring the operating times, ensure that there is sufficient time between test current injections for the element to reset fully; otherwise, erroneous timing measurements will be obtained.

The settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/PHASE OC/W1..., W2..., W3...

a) WINDING #1 ELEMENTS

To ensure that only the Phase Time overcurrent elements operate the trip relays (and any other output relays) selected by the logic, disable all protection features except Phase Time Overcurrent. Use the general test setup shown below:

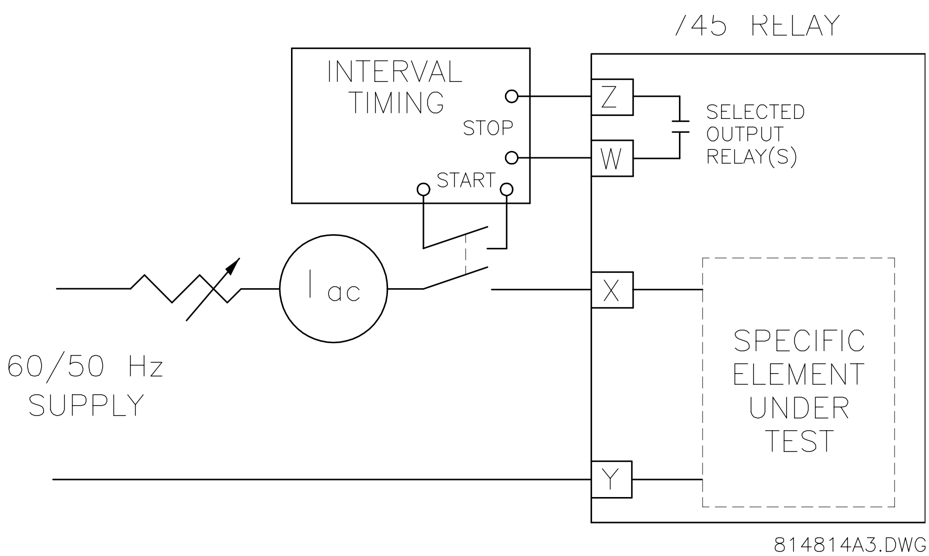


Figure 10–9: GENERAL TEST SETUP

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 A-phase element. Monitor the appropriate output relays per the FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and increase its magnitude slowly until the trip relay and all the selected auxiliary relays operate. If the element has a very inverse time characteristic, it is easier and more accurate to increase the current far above the pickup level until the trip relay operates then reduce the current to just above the operate level. Then, current can be slowly reduced below the operate level and observed for a reset action on the trip relay. This reset level for the current should be approximately 98% of the pickup level. Once the relay drops out, slowly increase the current until the trip contact closes. The operate level should correspond to the pickup setting.
2. Check that the following message is displayed:

```
▌▌ LATCHED (OPERATED) ∅A
▌▌ W1 Phase Time OC
```

The message will indicate LATCHED or OPERATED, depending on the setting for the target.

c) OPERATING TIME

Using a table like the one shown below, select 3 or 4 values of current multiples at which the timing is to be measured. Enter the expected operating times from the timing curve applied in the settings. Using the setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21 and the Interval Timer enabled, set the current level to the desired value and apply suddenly by closing the double-pole switch. Record the operating time and compare it to the expected value. Repeat for all desired values of current.

CURRENT MULTIPLE	NOMINAL TIME	MEASURED TIME
1.5		
3		
5		

d) RESET TIME

A precise measurement of the reset time requires a relay test set capable of dynamic operation, with three sequenced stages, each with programmable current levels and time duration external contact, and flexible triggering. To perform such a test, please contact GE Power Management for detailed test instructions.

A simple verification the selected reset mode can be obtained using Figure 10–9: GENERAL TEST SETUP on page 10–21. The procedure consists of performing repetitive operating time measurements in quick succession. If the reset is selected for instantaneous, the operating time will always be equal to the nominal time derived from the selected curve. If the reset is selected as linear, the operating time will vary as a function of the time between successive application of the current signal. If performed at current multiples of 2 to 3 times the pickup level, the variations in operating time will be easier to detect.

e) PHASE B AND C ELEMENTS

If the A-phase element performed correctly and met specifications, repeat the PICKUP LEVEL portion of the above test for the B and C phases of Winding 1. For the B-phase, X = H2 and Y = G2. For the C-phase, X = H3 and Y = G3. The displayed message should change to indicate the correct phase, winding, and element that operated.

f) WINDING #2 AND #3 ELEMENTS

Because the Winding 2 and 3 elements can be set with completely different parameters than the elements for Winding 1, it is necessary to repeat the full set of tests described above for each winding.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.5 PHASE INSTANTANEOUS OVERCURRENT 1

This procedure verifies that the Phase Instantaneous overcurrent performance matches the in-service settings. The settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/PHASE OC/W1 PHASE INST. OC 1, W2..., W3...

The testing occurs at current multiples of at least five times the rated CT secondary value. *Do not leave the current signal on for more than a few seconds!*

a) WINDING #1 ELEMENTS

To ensure that only the Phase Instantaneous Overcurrent 1 element operates the trip relays (and any other output relays) selected by the logic, disable all protection features except Phase Instantaneous Overcurrent 1. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 A-phase element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and increase its magnitude until the trip relay (and all selected auxiliary relays) operate. Compare the measured operating level against the relay setpoints:

   SETPOINTS/S4 ELEMENTS/PHASE O/C/W1 PHASE INST OC 1/W1 PHASE INST OC 1 PICKUP

2. Check that TRIP, PICKUP, and PHASE A (B or C) come on when the element operates. Check that the following message is displayed:

```
▌ LATCHED (OPERATED) ∅A
▌ W1 Phase Inst OC 1
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets, the TRIP and PHASE indicators should remain on if the TARGET was selected as latched. Otherwise, only the TRIP indicator should stay on.

4. Reset indicators and clear messages.

c) OPERATING TIME

Using the setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21 and the Interval Timer enabled, set the current level to 1.5 times the operating level of the element. Apply current suddenly by closing the double-pole switch. Record the operate time and compare it to the setpoint value for:

SETPOINTS/S4 ELEMENTS/PHASE O/C/W1 PHASE INST OC 1/W1 PHASE INST OC 1 DELAY

d) PHASE B AND C ELEMENTS

If the A-phase element performed correctly and met specifications, repeat the PICKUP LEVEL portion of the above test for phases B and C of Winding 1. For the B-phase, X = H2 and Y = G2. For the C-phase, X = H3 and Y = G3. The displayed message should change to indicate the correct phase, winding, and element that operated.

e) WINDING #2 AND #3 ELEMENTS

Because the Winding 2 and 3 elements can be set with completely different parameters than the Winding 1 elements, it is necessary to repeat the full set of tests described above for each winding.

10.6.6 PHASE INSTANTANEOUS OVERCURRENT 2

The Phase Instantaneous Overcurrent 2 elements are identical to the Phase Instantaneous Overcurrent 1 elements. As such, the same test procedure can be used to verify their correct operation. Disable all protection features except the Phase Instantaneous Overcurrent 2 elements and follow the steps in Section 10.6.5: PHASE INSTANTANEOUS OVERCURRENT 1 on page 10–23, making the appropriate changes for the display indications and output relays which are operated by the Phase Instantaneous Overcurrent 2 elements.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.7 NEUTRAL TIME OVERCURRENT

This procedure verifies that the Neutral Time Overcurrent performance matches the in-service settings. Since these elements can have any one of a multitude of timing curves, a table of expected operating times versus applied current should be prepared prior to testing. The neutral element measures the derived zero-sequence current signal as an input. Refer to Section 5.9: TIME OVERCURRENT CURVES on page 5–91 for information on timing curves.

If the relay elements are set for the "Linear" reset characteristic when measuring the operating times, ensure there is sufficient time between test current injections for the element to reset fully. Otherwise, erroneous timing measurements will be obtained.

The settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NEUTRAL TIME OC, W2..., W3...

Note that there can only be one or two Neutral Time Overcurrent elements in service at the same time.

a) WINDING #1 ELEMENT

To ensure that only the Neutral Time Overcurrent element under test operates the trip relays (and any other output relays) selected by the logic, disable all protection features except Neutral Time Overcurrent. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 neutral element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and slowly increase its magnitude until the trip relay (and all the selected auxiliary relays) operate.
2. If the relay under test has a very inverse time characteristic, it is easier and more accurate to increase the current far above the pickup level until the trip relay operates, then reduce the current to just above the expected operate level. Slowly reduce the current below the operate level and observe for a reset action on the trip relay. This current reset level should be approximately 98% of the pickup level setting. Once the relay drops out, *slowly* increase the current until the trip contact closes. The operate level should correspond to the pickup setpoint:

   SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NTRL TIME OC/W1 NEUTRAL TIME OC PICKUP

   Since current is being introduced into one phase only, the input current signal is equal to the $3I_0$ signal used by the element.

3. When the element operates, check that the TRIP, PICKUP and PHASE LEDs are on and the following message is displayed:

```
▌▌ LATCHED (OPERATED)
▌▌ W1 Ntrl Time OC
```

4. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets, the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise only the TRIP indicator remains on.

5. Reset indicators and clear messages.

c) OPERATING TIME

Using a table like the one shown below, select 3 or 4 values of current multiples at which timing is to be measured. Enter the expected operating times from the timing curve applied in the settings. Using the setup in Figure 10–9: GENERAL TEST SETUP on page 10–21 and the Interval Timer enabled, set the current level to the desired value and apply suddenly by closing the double-pole switch. Record the operate time and compare to the expected value. Repeat for all desired values of current.

CURRENT MULTIPLE	NOMINAL TIME	MEASURED TIME
1.5		
3		
5		

d) RESET TIME

A precise measurement of the reset time requires a relay test set capable of dynamic operation, with three sequenced stages, each with programmable current levels and time duration, and flexible external contact triggering. To perform such a test, contact GE Power Management for detailed test instructions.

A simple verification of the reset mode selected under:

SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NTRL TIME OC/W1 NEUTRAL TIME OC RESET

is obtained using the setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21. The test consists of repetitive operating time measurements in quick succession. If the reset is set for INSTANTANEOUS, the operating time is always equal to the nominal time derived from the selected curve. If the reset is set as LINEAR, the operating time varies as a function of the time between successive applications of current. The variations in operating time are easier to detect if this test is performed at current multiples of 2 to 3 times the pickup level.

e) WINDING #2 OR WINDING #3 ELEMENTS

Since the Winding 2 and 3 elements can be set with completely different parameters than the Winding 1 elements, it is necessary to repeat the full set of tests described above for each winding. To test Winding 2 elements, disable all protection elements except for **W2 NEUTRAL TIME OVERCURRENT**. Connect the current signal to X = H4 and Y = G4 and repeat tests in this section. To test Winding 3 elements, disable all protection elements except for **W3 NEUTRAL TIME OVERCURRENT**. Connect the current signal to X = H7 and Y = G7 and repeat the tests in this section.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.8 NEUTRAL INSTANTANEOUS OVERCURRENT 1

This procedure verifies that the Neutral Instantaneous Overcurrent performance is as per the in-service settings. Settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NTRL INST OC 1/

If the relay settings require testing at current multiples of several times the rated CT secondary value, *do not leave the current signal on for more than a few seconds*.

a) WINDING #1 ELEMENT

To ensure that only the Neutral Instantaneous Overcurrent 1 element operates the trip relays (and any other output relays) selected by the logic, disable all protection features except Neutral Instantaneous Overcurrent 1. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 A-phase element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and increase its magnitude until the trip relays (and all the selected auxiliary relays) operate. Compare the measured operating level against the value in:

   SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NTRL INST OC 1/W1 NEUTRAL INST OC 1 PICKUP

2. Check that, when the element operates, the TRIP and PICKUP indicators are on and the following message is displayed:

```
▌▌ LATCHED (OPERATED)
▌▌ W1 Ntrl Inst OC 1
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets, the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise only the TRIP indicator should stay on.

4. Reset indicators and clear messages.

c) OPERATING TIME

With the setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21 and the Interval Timer enabled, set the current level to 1.5 times the operate level of the element and apply suddenly by closing the double-pole switch. Record the operate time and compare to the value in:

SETPOINTS/S4 ELEMENTS/NEUTRAL OC/W1 NTRL INST OC 1/W1 NEUTRAL INST OC 1 DELAY

d) WINDING 2 AND 3 ELEMENTS

NOTE

Only two Neutral Instantaneous Overcurrent 1 elements can be in service simultaneously.

Because the Winding 2 and 3 elements can be set with completely different parameters than the Winding 1 elements, it is necessary to repeat the full set of tests described in this section for each winding.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.9 NEUTRAL INSTANTANEOUS OVERCURRENT 2

The Neutral Instantaneous Overcurrent 2 elements are identical to the Neutral Instantaneous Overcurrent 1 elements. Consequently, the same test procedure can be used to verify their correct operation. Disable all protection features except Neutral Instantaneous Overcurrent 2. Follow the steps in Section 10.6.8: NEUTRAL INSTANTANEOUS OVERCURRENT 1 on page 10–26, making the appropriate changes for the display indications and output relays operated by the Neutral Instantaneous Overcurrent 2 elements.

10.6.10 GROUND TIME OVERCURRENT

This procedure verifies that the Ground Time Overcurrent performance matches the in-service settings. Since these elements can be assigned a multitude of timing curves, a table of expected operating times versus applied current should be prepared prior to testing. The ground element measures the current signal connected to the ground current input CT, H10 and G10 or F12 and E12. Refer to Section 5.9: TIME OVERCURRENT CURVES on page 5–91 for information on timing curves. There can only be one or two Ground Time Overcurrent elements in service at the same time.

If the relay elements are set for the "Linear" reset characteristic when measuring the operating times, ensure there is sufficient time between test current injections for the element to reset fully. Otherwise, erroneous timing measurements will be obtained.

The settings for these elements will be found under:

SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND TIME OC/...

a) WINDING 1 ELEMENT

To ensure that only the Ground Time Overcurrent element operates the trip relays (and any other output relays) selected by the logic, disable all protection features except Ground Time Overcurrent. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H10 and Y = G10 to test the Winding 1 ground element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and slowly increase its magnitude until the trip relay (and all the selected auxiliary relays) operate.
2. If the relay has a very inverse time characteristic, it is easier and more accurate to increase the current far above the pickup level until the trip relay operates and then reduce the current to just above the operate level. Then slowly reduce the current below the operate level and observe for a reset action on the trip relay. This reset level for the current should be approximately 98% of the pickup level. Once the relay drops out, *slowly* increase the current until the trip contact closes. The operate level should correspond to the pickup setting in:

   SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND TIME OC/W1 GROUND TIME OC PICKUP

3. When the element operates, check that the TRIP, GROUND and PICKUP LEDs are on and the following message is displayed:

```
▌ LATCHED (OPERATED):
▌ W1 Gnd Time OC
```

4. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise, only the TRIP indicator should remain on.
5. Reset indicators and clear messages.

c) OPERATING TIME

Using a table like the one shown blow, select 3 or 4 values of current multiples at which the timing is to be measured. Enter the expected operating times from the timing curve applied in the settings. Using Figure 10–9: GENERAL TEST SETUP on page 10–21 with the Interval Timer enabled, set the current level to the desired value and apply suddenly by closing the double-pole switch. Record the operate time and compare to the expected value. Repeat for the all the desired values of current.

CURRENT MULTIPLE	NOMINAL TIME	MEASURED TIME
1.5		
3		
5		

d) RESET TIME

A precise measurement of the reset time requires a relay test set capable of dynamic operation, with three sequenced stages, each with programmable current levels and time duration, and flexible external contact triggering. To perform such a test, contact GE Power Management for detailed test instructions.

A simple verification of the reset mode selected under:

SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND TIME OC/W1 GROUND TIME OC RESET

is obtained using the setup in Figure 10–9: GENERAL TEST SETUP on page 10–21. The procedure consists of repetitive operating time measurements in quick succession. If the reset is selected for Instantaneous, the operating time always equals the nominal time derived from the selected curve. If the reset is selected as Linear, the operating time varies as a function of the time between successive applications of the current signal. If this test is performed at current multiples of 2 to 3 times the pickup level, the variations in operating time are easier to detect.

e) WINDING 2 OR 3 ELEMENTS

Because the second Ground Time Overcurrent element could be set with completely different parameters than the element for the first winding, it is necessary to repeat the full set of tests described above for each winding.

To test the second element, disable all protection elements except for the **W2 GROUND TIME OVERCURRENT** (or **W3 GROUND TIME OVERCURRENT**) element. Connect the current signal to X = F12 and Y = E12. Repeat all the tests described for the Winding 1 Ground Time Overcurrent element in this section.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.11 GROUND INSTANTANEOUS OVERCURRENT 1

This procedure verifies that the Ground Instantaneous O/C performance matches the in-service settings. Settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND INST OC 1/...

If your relay settings require you to test at current multiples of several times the rated CT secondary value do not leave the current signal on for more than a few seconds.

a) WINDING 1 ELEMENT

To ensure only the Ground Instantaneous Overcurrent 1 element operates the trip relays (and any other output relays) selected by the logic, disable all protection features except Ground Instantaneous Overcurrent 1. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H10 and Y = G10 to test the Winding 1 element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and increase its magnitude until the trip relay (and all the selected auxiliary relays) operate. Compare the measured operating level against the setpoint:

   SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND INST OC 1/W1 GND INST OC 1 PICKUP

2. When the element operates, check that the TRIP and MESSAGE indicators are flashing and the following message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌ W1 Gnd Inst OC 1
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets the TRIP, GROUND and message indicators should remain on if the TARGET was selected as latched. Otherwise, only the TRIP indicator should stay on.
4. Reset indicators and clear messages.

c) OPERATING TIME

Using the setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21 with the Interval Timer enabled, set the current level to 1.5 times the element operate level and apply suddenly by closing the double-pole switch. Record the operate time and compare to the setting value in:

SETPOINTS/S4 ELEMENTS/GROUND OC/W1 GND INST OC 1/W1 GND INST OC 1 DELAY

d) WINDING 2 OR ELEMENT

NOTE

Only two Ground Instantaneous Overcurrent 1 elements can be in service simultaneously.

Because the Winding 2 and 3 elements can be set with completely different parameters than the Winding 1 elements, it is necessary to repeat the full set of tests described in this section for each winding.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.12 GROUND INSTANTANEOUS OVERCURRENT 2

The Ground Instantaneous Overcurrent 2 elements are identical to the Ground Instantaneous Overcurrent 1 elements. Consequently, the same test procedure may be used to verify their correct operation. Disable all protection features except Ground Instantaneous Overcurrent 2. Make the appropriate changes for the display indications and output relays operated by the Ground Instantaneous Overcurrent 2 elements.

10.6.13 RESTRICTED GROUND FAULT

This procedure verifies that the Restricted Ground Fault performance matches the in-service settings. The ground element measures the current signal connected to the ground current input CT, H10 and G10 or F12 and E12. The neutral ($3I_0$) current is calculated from the vector sum of the three phase currents. Injecting current into one phase automatically produces a neutral current (i.e. $3I_0 = I_A$). Settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/RESTRICTED GROUND/W1 RESTD GND FAULT/...

a) WINDING #1 ELEMENT

To ensure that only the Restricted Ground Fault element operates the trip relays (and any other output relays selected by the logic) disable all protection features except Restricted Ground Fault.

Using a current supply as shown in the figure below, connect the I_1 current source to terminals H1 and G1 for the Winding 1 phase current element and I_2 to terminals G10 and H10 as shown for the ground current element. Monitor the appropriate output relays as per the relay FlexLogic settings.

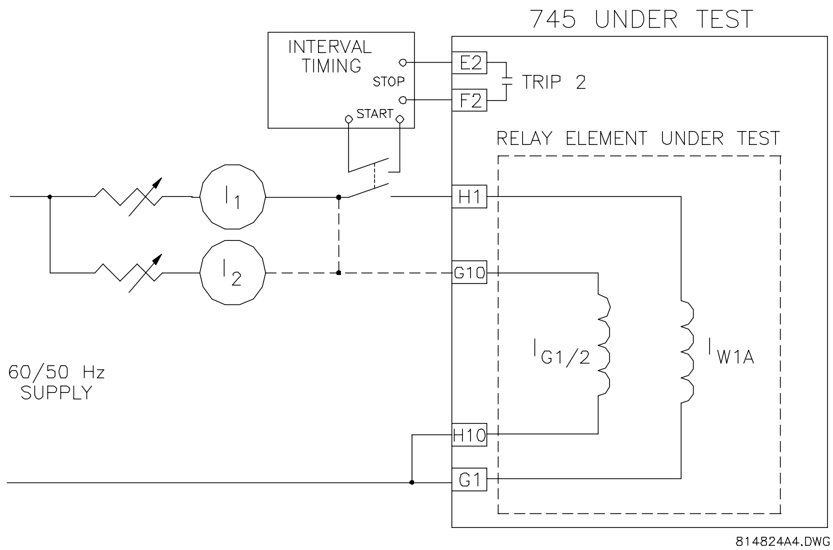


Figure 10–10: RESTRICTED GROUND TEST SETUP

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal feeding the phase current element and increase its magnitude slowly until the trip relay, and all the selected auxiliary relays, operate. The operate level should correspond to the pickup setting in:

   SETPOINTS/S4 ELEMENTS/RESTRICTED GROUND/W1 RESTD GND FAULT/W1 RESTD GND FAULT PICKUP

2. When the element operates, check that the TRIP, GROUND and PICKUP LEDs are on and the following message is displayed:

```
▌▌ LATCHED (OPERATE):
▌▌ W1 Restd Gnd Fault
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets, the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise, only the TRIP indicator should remain on.
4. Reset indicators and clear messages.

c) OPERATING TIME

Select 3 or 4 delay times at which the timing is to be measured. With the Interval Timer enabled, set the current level to the desired value and apply suddenly by closing the double-pole switch. Record the operate time and compare to the expected value. Repeat for the all the desired values of current.

d) SLOPE

1. To measure the slope, connect current signals to the relay as shown in Figure 10–10: RESTRICTED GROUND TEST SETUP on page 10–30.
2. Inject the I_1 current such that the ground differential pickup value divided by the I_1 current is less than the slope setting. Set I_2 = 0 A. The element will operate as since the current appears as ground differential.
3. The slope is calculated from the values of $I_{ground\ differential}$ and I_{max} as shown below:

$$\%\text{slope} = \frac{I_{ground\ differential}}{I_{max}} \times 100\%$$

I_{max} represents the maximum phase current for the winding being measured.

4. As I_2 is increased, the element will reset when the percentage of slope drops below the slope setting. Slowly increase I_2 until the element operates again. Calculate the slope at this point.
5. Decrease the slope setting to 0% then continue to increase the I_2 current until the element resets. Slowly increase I_2 until the element operates again.
6. The reset level should be 97% of the operate level. When the element resets, the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise only the TRIP indicator should remain on.

e) WINDING 2 OR 3 ELEMENTS

Since the second Restricted Ground Fault element can be set with completely different parameters than the first element winding, it is necessary to repeat the full set of tests described in this section for each winding.

To test the second element, disable all protection elements except for the W2 (or W3 as appropriate) Restricted Ground Fault element. Connect the ground current signal to F12 and E12. Repeat all the tests described for the Winding 1 element in this section.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.14 NEGATIVE SEQUENCE TIME OVERCURRENT

This procedure verifies that the Negative Sequence Time Overcurrent performance matches the in-service settings. Since these elements can have any one of a multitude of timing curves, a table of expected operating times versus applied current should be prepared prior to testing the elements. The negative-sequence element measures the derived negative-sequence component of the phase current signals connected to the phase input CTs. Refer to Section 5.9: TIME OVERCURRENT CURVES on page 5–91 for additional information on timing curves.

If the relay elements are set for Linear reset characteristic when measuring the operating times, ensure that there is sufficient time between test current injections for the element to reset fully. Otherwise, erroneous timing measurements will be obtained.

Settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ TIME OC/...

a) WINDING #1 ELEMENT

10

To ensure that only the Negative Sequence Time Overcurrent element operates the trip relays (and any other output relays selected by the logic) disable all protection features except Negative Sequence Time Overcurrent. Use the general test setup shown in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 negative-sequence element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and slowly increase its magnitude until the trip relay and all selected auxiliary relays operate. If the relay has a very inverse time characteristic, it is easier and more accurate to increase the current far above the pickup level until the trip relay operates then reduce the current to just above the operate level. Then, slowly reduce the current below the operate level and observe for a reset action on the trip relay. This reset level for the current should be approximately 98% of the pickup level. Once the relay drops out, *slowly* increase the current until the trip contact closes. The operate level should correspond to the pickup setting:

   SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ TIME OC/W1 NEG SEQ TIME OC PICKUP

   NOTE: With current applied to a single phase, the negative sequence current component is calculated from:

   $$I_{neg\ seq} = \frac{1}{3} \times I_{phase}$$

   Hence, the phase current will be three times the pickup setting.

2. Check that, when the element operates, the TRIP and PICKUP LEDs are on and the following message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌ W1 Neg Seq Time OC
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise only the TRIP indicator remains on.

Reset indicators and clear messages.

c) OPERATING TIME

Using a table like the one shown below, select 3 or 4 values of current multiples at which the timing is to be measured. Enter the expected operating times from the timing curve applied in the settings. Using the setup in Figure 10–9: GENERAL TEST SETUP on page 10–21 with the Interval Timer enabled, set the current level to the desired value (taking into account the relationship mentioned above) and apply suddenly by closing the double-pole switch. Record the operate time and compare to the expected value. Repeat for all desired values of current.

CURRENT MULTIPLE	NOMINAL TIME	MEASURED TIME
1.5		
3		
5		

d) RESET TIME

A simple verification of which reset mode, selected with the following setpoint:

SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ TIME OC/W1 NEG SEQ TIME OC RESET

can be obtained using the simple test setup in Figure 10–9: GENERAL TEST SETUP on page 10–21. The procedure consists of repetitive operating time measurements in quick succession. If the reset is selected for Instantaneous, the operating time is always equal to the nominal time derived from the selected curve. If the reset is selected as Linear, the operating time varies as a function of the time between successive applications of the current signal. If this test is performed at current multiples of 2 to 3 times the pickup level, the variations in operating time are easier to detect.

e) WINDINGS 2 AND 3 ELEMENTS

Because the Negative Sequence Time Overcurrent elements on Windings 2 and/or 3 can be set with completely different parameters than those for the first element, it is necessary to repeat the full set of tests described in this section for each winding.

To test these elements, disable all protection elements except for W2 Negative Sequence Time Overcurrent. Connect the current signal to X = H4 and Y = G4. Repeat all the tests described for the Winding #1 element in this section. For Winding 3, connect the current signal to X = H7 and Y = G7.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.15 NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT

This procedure verifies that the Negative Sequence Instantaneous Overcurrent performance matches the in-service settings. Settings for these elements are found under:

SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ INST OC/...

If the relay settings require testing at current multiples of several times the rated CT secondary value, *do not leave the current signal on for more than a few seconds.*

a) WINDING 1 ELEMENT

To ensure that only the Negative Sequence Instantaneous Overcurrent element operates the trip relays (and any other output relays selected by the logic), disable all protection features except Negative Sequence Instantaneous Overcurrent. Use the general test setup in Figure 10–9: GENERAL TEST SETUP on page 10–21.

Connect the current supply to terminals X = H1 and Y = G1 to test the Winding 1 element. Monitor the appropriate output relays as per the relay FlexLogic settings.

b) PICKUP LEVEL

1. With the interval timer disabled, apply the current signal and increase its magnitude until the trip relay and all selected auxiliary relays operate. Compare the measured operating level against the relay settings in:

   SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ INST OC/W1 NEG SEQ INST OC PICKUP

   NOTE

   With current applied to a single phase, the negative sequence current component is calculated from:

   $$I_{neg\ seq} = \frac{1}{3} \times I_{phase}$$

   Hence, the phase current will be three times the pickup setting.

10

2. When the element operates, check that the TRIP and PICKUP LEDs are on and the following is displayed:

```
▌ LATCHED (OPERATED):
▌ W1 Neg Seq Inst OC
```

3. Reduce the current until the element resets. The reset level should be 97% of the operate level. When the element resets, the TRIP and message indicators should remain on if the TARGET was selected as latched. Otherwise, only the TRIP indicator should remain on.
4. Reset indicators and clear messages.

c) OPERATING TIME

Using the setup in Figure 10–9: GENERAL TEST SETUP on page 10–21 with the Interval Timer enabled, set the current level to 1.5 times the operate level of the element and apply suddenly by closing the double-pole switch. Record the operate time and compare to the setting under:

SETPOINTS/S4 ELEMENTS/NEG SEQ OC/W1 NEG SEQ INST OC/W1 NEG SEQ INST OC DELAY

d) WINDING 2 AND 3 ELEMENTS

Because the Winding 2 and 3 elements can be set with completely different parameters than the element for Winding 1, it is necessary to repeat the full set of tests described for the Winding 1 element in this section.

Connect the current supply to terminals X = H4 and Y = G4 to test the Winding 2 element. Use X = H7 and Y = G7 for the Winding 3 element.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.16 FREQUENCY ELEMENTS

The power system frequency is measured from the voltage input if it has been enabled. If there is no voltage input, it is measured from the phase A Winding #1 current signal. These tests require a variable-frequency current source for relays without a voltage input and a variable-frequency voltage and current source for relays with a voltage input. Connections are shown in the figure below. Only perform tests specific to the relay model.

NOTE

The underfrequency, overfrequency, and frequency decay elements are all supervised by optional adjustable minimum current and minimum voltage level detectors. When testing the performance of these elements on a 745 with the voltage input enabled, it may be necessary to inject a current signal into Winding 1 phase A if the current supervision is enabled, or else the detectors will not operate.

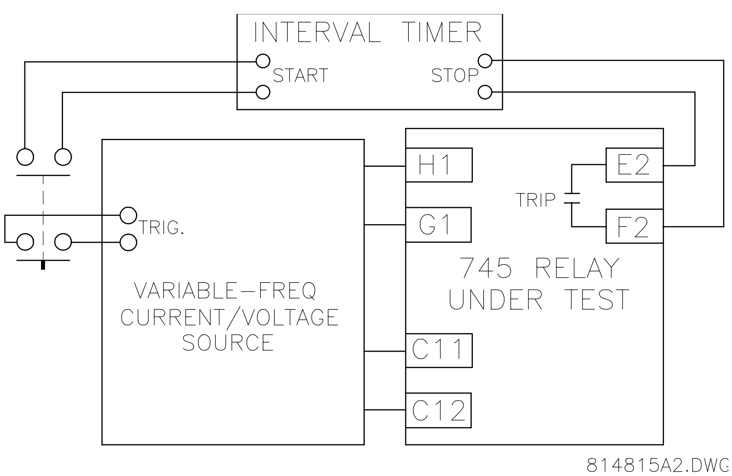


Figure 10–11: FREQUENCY ELEMENT TESTING

10

10.6.17 UNDERFREQUENCY 1

a) PRELIMINARIES

Disable all protection functions except the Underfrequency 1 function. Verify that settings match the in-service requirements. Settings can be entered or modified under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 1/...

b) VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED)

1. Using the variable-frequency voltage/current source connected to terminals C11 and C12 for the voltage signal and H1 and G1 for the current signal, set the frequency to 60.00 Hz (or 50.00 Hz for 50 Hz systems) and the voltage amplitude to the rated VT secondary voltage.
2. Set the current amplitude to rated CT secondary. Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications on the relay. The relay display should remain with no trip indications.
3. Slowly decrease the frequency until the output relay(s) operate. Check that the operation took place at the selected frequency setting.
4. As the frequency is varies, verify that the correct system frequency is displayed under:

   ACTUAL VALUES/A2 METERING/FREQUENCY/SYSTEM FREQUENCY

5. Slowly reduce the voltage and note the voltage at which the output relay(s) reset. Check that this dropout voltage is approximately the value of voltage supervision set under.

   SETPOINTS/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 1/MINIMUM OPERATING VOLTAGE

NOTE

If voltage supervision is set to 0.0, then the element remains operated until the voltage is decreased below approximately 2%, the level at which measurements become unreliable.

6. Slowly increase the voltage and check that the element operates when the voltage reaches 2% above the supervision level. Return the voltage to nominal value.
7. Slowly decrease the current until the element resets. Check that this dropout current level is equal to the setting:

   SETPOINTS/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 1/MINIMUM OPERATING CURRENT

NOTE

If current sensing is disabled in the element, it will remain operated with current reduced to 0.0 A.

8. Slowly increase the current and ensure the element operates when the current reaches a value just above the setting. Set the current to rated CT secondary.
9. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
LATCHED (OPERATED):
Underfrequency 1
```

10. Slowly increase the frequency until the PICKUP indicator and output relays reset. Note the dropout level, which should be the pickup plus 0.03 Hz. Check that the TRIP indicator is still on. The trip message will stay on if the TARGET setting is Latched; if set to Self-resetting, the message will reset when frequency is above the setpoint.
11. For timing tests, the signal generator must be capable of triggering into step-wise changing of frequency or ramping down to a pre-selected frequency in only a few milliseconds. Connect the Signal Source and Timer Start triggers as shown in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34.

12. Set the voltage to rated VT secondary value, the current to rated CT secondary, and the pre-trigger frequency to the nominal frequency (60 or 50 Hz). If current sensing is not enabled, it is not necessary to connect the current signal.
13. Set the post-trigger to 0.5 Hz below the setting for Underfrequency 1. Reset all targets and relays, if necessary. Reset the timer.
14. Initiate the frequency step and timer start. The Interval Timer will record the operating time of element. Compare this time to the setpoint value:

    SETPOINT/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 1 DELAY

15. Provided that the operate times are not scattered over a wide range, it may be desirable to repeat this test several times and average the results. If there is a wide scatter, verify the test setup and ensure the signal source behaves in a consistent manner.

c) CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED)

If the Frequency elements are using the A-phase Winding 1 current signal as a source, verify the operation of the element using the instructions below.

1. Using the variable-frequency current source connected to terminals H1 and G1 with no voltage connections, set the frequency to 60.00 Hz (or 50.00 Hz) and the amplitude to the rated CT secondary current. Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications. The display should remain unchanged with no trip indications.
2. Slowly decrease the frequency until the output relay(s) operate. Check that the frequency at which operation took place is the selected frequency setting.
3. Slowly reduce the current. Note the current at which the output relay(s) reset. Check that this dropout current is the minimum operating current selected in the settings.

NOTE

If current sensing is not enabled, then the element will continue working all the way down to a current level of 0.02 × CT A.

4. Increase the current back to nominal. Verify that the relay(s) operate.
5. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌ LATCHED (OPERATED):
▌ Underfrequency 1
```

6. Slowly increase the frequency until the PICKUP indicator and output relays reset. Note the dropout level, which should be the pickup plus 0.03 Hz. Check that the TRIP indicator is still on. The trip message remains on if the TARGET setting is Latched; if set to Self-resetting, the message resets when frequency is above the setpoint.
7. For timing tests, the signal generator must be capable of triggering into step-wise changing of frequency or ramping down to a pre-selected frequency in only a few milliseconds. Connect the Signal Source and Timer Start triggers as shown in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34.
8. Set the current to rated CT secondary value, no voltage connection, and the pre-trigger frequency to the nominal frequency (60 or 50 Hz).
9. Set the post-trigger to 0.5 Hz below the Underfrequency 1 setting. If necessary, reset all targets and relays. Reset the timer.
10. Initiate the frequency step and timer start. The Interval Timer will record the operating time of element. Compare this time to setting under:

    SETPOINT/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 1 DELAY

11. Provided that the operate times are not scattered over a wide range, it may be desirable to repeat this test several times and average the results. If there is a wide scatter, verify the test setup and ensure the signal source behaves in a consistent manner.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.18 UNDERFREQUENCY 2

1. Disable all protection functions except the Underfrequency 2 function.
2. Verify that settings match in-service requirements. Enter/modify settings and logic under:

   SETPOINTS/S4 ELEMENTS/FREQUENCY/UNDERFREQUENCY 2/...

3. Repeat the appropriate steps of Section 10.6.17: UNDERFREQUENCY 1 on page 10–35 for this element. The results must be compared to the settings for the Underfrequency 2 element.

10.6.19 OVERFREQUENCY

a) PRELIMINARIES

Disable all protection functions except Overfrequency. Verify that settings match in-service requirements. Overfrequency settings are modified under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/OVERFREQUENCY/...

b) VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED)

1. Using the variable-frequency voltage/current source connected to terminals C11 and C12 for the voltage signal and H1 and G1 for the current signal, set the frequency to 60.00 Hz (or 50.00 Hz) and the voltage amplitude to the rated VT secondary voltage. Set the current amplitude to rated CT secondary. Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications on the relay. The 745 display should remain unchanged with no trip indications.
2. Slowly increase the frequency until the output relay(s) operate. Check that the frequency at which operation took place is the selected frequency setting. As the frequency is varied, verify that the display indicates the correct value of system frequency under:

   ACTUAL VALUES/A2 METERING/FREQUENCY/SYSTEM FREQUENCY

3. Slowly reduce the voltage. Note the voltage at which the output relay(s) reset. Check that this dropout voltage is equal to the voltage level set under:

   SETPOINTS/S4 ELEMENTS/FREQUENCY/OVERFREQUENCY/MINIMUM OPERATING VOLTAGE

   Note that this level can be set down to 0.00 A, in which case the element remains operated to a voltage level of approximately 2% of nominal.

4. Slowly increase the voltage and check that the element operates when the voltage reaches 2% above the set level. Return the voltage to nominal value.
5. Slowly decrease the current until the element resets. Check that this dropout current level is equal to the setting under:

   SETPOINTS/S4 ELEMENTS/FREQUENCY/OVERFREQUENCY/MINIMUM OPERATING CURRENT

   If current sensing has not been enabled for this element, the element remains operated for current levels down to 0.00 A.

6. Slowly increase the current and check that the element operates when the current reaches a value just above the setting. Set the current to rated CT secondary.

7. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌ LATCHED (OPERATED):
▌ Overfrequency
```

8. Slowly decrease the frequency until the PICKUP indicator and output relays reset. Note the dropout level, which should be the pickup minus 0.03 Hz. Check that the TRIP indicator is still on. The trip message remains on if the TARGET setting is Latched; if set to Self-resetting, the message resets when frequency is below the setpoint.
9. For timing tests, the signal generator must be capable of triggering into step-wise changing of frequency or ramping down to a pre-selected frequency in only a few milliseconds. Connect the Signal Source and Timer Start triggers as shown in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34.
10. Set the voltage to rated VT secondary value, the current to rated CT secondary, and the pre-trigger frequency to the nominal frequency (60 or 50 Hz). The current signal is not required if current sensing has not been enabled for this element.
11. Set the post-trigger to 0.5 Hz above the setting of the Overfrequency element. If necessary, reset all targets and relays. Reset the timer.
12. Initiate the frequency step and timer start. The Interval Timer records the operating time of element. Compare this time to setting under:

    SETPOINT/S4 ELEMENTS/FREQUENCY/OVERFREQUENCY DELAY
13. Provided that the operate times are not scattered over a wide range, it may be desirable to repeat this test several times and average the results. If there is a wide scatter, verify the test setup and ensure the signal source behaves in a consistent manner.

c) CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED)

If the voltage input is disabled, the Frequency elements use the A-phase Winding #1 current signal as a source. Verify the operation of the element using the procedure below.

1. Using the variable-frequency current source connected to terminals H1 and G1, no voltage connections, set the frequency to 60.00 Hz (or 50.00 Hz) and the amplitude to the rated CT secondary current. Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications on the relay. The relay display should remain unchanged with no trip indications.
2. Slowly increase the frequency until the output relay(s) operate. Check that the frequency at which operation took place is the selected frequency setting.
3. Slowly reduce the current. Note the current at which the output relay(s) reset. Check that this dropout current is the minimum operating current selected in the settings.

   If current sensing has been disabled for this element, then operation continues down to 0.00 A.
4. Increase the current back to nominal. Check that the relay(s) operate.
5. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌ LATCHED (OPERATED):
▌ Overfrequency
```

6. Slowly decrease the frequency until the PICKUP indicator and output relays reset. Note the dropout level, which should be the pickup minus 0.03 Hz. Check that the TRIP indicator is still on. The trip message stays on if the TARGET setting is Latched; if it is Self-resetting, the message resets when frequency is below the setpoint.

7. For timing tests, the signal generator must be capable of triggering into step-wise changing of frequency or ramping down to a pre-selected frequency in only a few milliseconds. Connect the Signal Source and Timer Start triggers as shown in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34.
8. Set the current to rated CT secondary value, no voltage connection, and the pre-trigger frequency to the nominal frequency (60 or 50 Hz).
9. Set the post-trigger to 0.5 Hz above the setting of the Overfrequency element. Reset all targets and relays, if necessary. Reset the timer.
10. Initiate the frequency step and timer start. The Interval Timer records the element operating time. Compare this time to the setting:

    SETPOINT/S4 ELEMENTS/FREQUENCY/OVERFREQUENCY DELAY

11. Provided that the operate times are not scattered over a wide range, it may be desirable to repeat this test several times and average the results. If there is a wide scatter, verify the test setup and ensure the signal source behaves in a consistent manner.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.6.20 FREQUENCY DECAY RATE 1

a) PRELIMINARIES

NOTE

A high-quality programmable function generator is required to verify this element. Since the frequency rates of change are measured over a narrow range, the test instrumentation must accurately simulate frequency decay rates without any significant jitter. It is the experience of GE Power Management that some commercial dedicated relay test equipment with built-in frequency ramping functions is not accurate enough to verify the 745 performance.

Disable all protection functions except the Frequency Decay function. Verify that settings match in-service requirements. The settings are entered and modified under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/FREQUENCY DECAY/...

b) VOLTAGE INPUT FUNCTION (VOLTAGE INPUT ENABLED)

1. Use a frequency-ramping programmable voltage/current source connected to terminals C11 and C12, for the voltage signal and H1 and G1 for the current signal. Set the frequency to 60.00 Hz (or 50.00 Hz) and the voltage amplitude to the rated VT secondary voltage. Set the current amplitude to rated CT secondary. (*Note: If current sensing has been disabled for this element, the current signal is not required for the tests.)* Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications on the relay. The relay display should remain unchanged with no trip indications.
2. Program the function generator to simulate a frequency rate-of-change just above Rate 1. The start frequency should be the nominal frequency of the relay; the end frequency must be below the Frequency Decay Threshold if the relay is to operate. Note that operation occurs if the rate criterion is satisfied and the frequency is below the threshold.
3. Initiate ramping action and verify element operation once the frequency drops below the threshold.
4. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌ Free Decay Rate 1
```

    If the target was selected as Latched, the trip LED and the message remain on.

5. Reduce the voltage to below the voltage supervision level set under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/FREQUENCY DECAY/MINIMUM OPERATING VOLTAGE

6. Repeat ramping action and verify that element does not operate. *If the voltage supervision level has been set to 0.00, the element continues to operate correctly down to approximately 2% or nominal.*
7. Return voltage to nominal value.
8. If current sensing is enabled, set the current level below the Minimum Operating Current value set under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/FREQUENCY DECAY/MINIMUM OPERATING CURRENT

9. Repeat ramping action and verify that element does not operate.
10. For timing tests, an approximate operate time is obtained if a timer is triggered at the same time as the ramping action and the time interval between the trigger point and the relay operation measured. From that measured time, subtract the time required for the frequency to reach the threshold value.

c) CURRENT INPUT FUNCTION (VOLTAGE INPUT DISABLED)

1. Using a frequency-ramping programmable voltage/current source connected to terminals H1 and G1 for the current signal, set the frequency to 60.00 Hz (or 50Hz). Set the current amplitude to rated CT secondary. Monitor the appropriate trip and auxiliary relays. Reset all alarms and indications on the relay. The relay display should remain unchanged with no trip indications.
2. Program the function generator to simulate a frequency rate-of-change just above Rate 1. The start frequency should be the nominal frequency of the relay. The end frequency must be below the Frequency Decay Threshold if the relay is to operate. Note that operation occurs if the rate criterion is satisfied and the frequency is below the threshold.
3. Initiate ramping action and verify that the element operates once the frequency drops below the threshold.
4. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌ Freq Decay Rate 1
```

If the target was selected as Latched, the trip LED and the message remain on.

5. Set the current level to a value below the Minimum Operating Current set under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/FREQUENCY DECAY/MINIMUM OPERATING CURRENT:

6. Repeat ramping action and verify that element does not operate. *If current sensing has been disabled for this element, operation will continue down to a current level of approximately 2% of nominal.*
7. For timing tests, an approximate operate time is obtained if a timer is triggered at the same time as the ramping action and the time interval between the trigger point and the relay operation measured. From that measured time, subtract the time required for the frequency to reach the threshold value. The expected time must be computed using the rate of change and the effect of the time delay set under:

SETPOINTS/S4 ELEMENTS/FREQUENCY/FREQUENCY DECAY/FREQUENCY DECAY DELAY:

d) FREQUENCY DECAY RATE 2, 3, & 4

Repeat the above procedure for remainder of decay rate elements, making the necessary changes where appropriate.

10.6.21 VOLTS-PER-HZ 1(2)

The volts-per-hertz operating levels are set in terms of the relay-input voltage divided by the frequency of that voltage.

1. Disable all elements except Volts-per-hertz 1(2). Monitor the appropriate contact. Use the test setup in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34 with variable-frequency voltage source.
2. The Volts-per-hertz settings are found under:

   SETPOINTS S4 ELEMENTS / OVEREXCITATION / VOLTS-PER-HERTZ 1(2) /...

3. Apply a voltage starting at 60 Hz and increase the magnitude until the element operates. Reduce the frequency in steps of 5 Hz and repeat the measurement. The element should operate at a consistent value of V/Hz equal to the setting of the element.
4. Check that the TRIP and PICKUP LEDs are on and the following trip message is displayed:

```
▌ LATCHED (OPERATED):
▌ Volts-Per-Hertz 1(2)
```

5. For timing tests, prepare a table of expected operating time versus applied V/Hz signal from the selected timing curve for the element. Using the variable frequency function generator to simulate the different V/Hz ratios, apply suddenly to the relay and measure the operating time.

10.6.22 5TH HARMONIC SCHEME

The 5th Harmonic Scheme operates if the 5th harmonic content of any current signal connected to the relay exceeds the threshold setting, for the set time, provided that the level is above the set threshold.

1. Disable all protection functions except the 5th Harmonic function.
2. The 5th Harmonic scheme settings are under:

   SETPOINTS S4 ELEMENTS/OVEREXCITATION/5th HARMONIC LEVEL

3. This test requires a current generator capable of producing a fundamental and 5th harmonic component. Connect the current signal to H1 and G1 and set the fundamental component level above the threshold setting.
4. Slowly increase the amplitude of the 5th harmonic component until the element operates. Calculate the ratio of 5th harmonic to fundamental at which operation occurred and compare this value to the setting of the element.
5. Check that the TRIP, PICKUP (and if selected ALARM) LEDs are on, and the following trip message is displayed:

```
▌ LATCHED (OPERATED):
▌ 5th Harmonic Level
```

6. Reduce the 5th harmonic component until the element resets. The reset level should be 97% of the operate level. Reset indicators and clear messages.
7. Repeat the above steps with a fundamental current level below the threshold setting. Ensure that the element does not operate.
8. For timing tests, simulate an operating condition as above and apply suddenly to the relay and measure the operating time. The time should be the same as the setting in the element.

10.6.23 INSULATION AGING

a) PRELIMINARIES

The three elements under the Insulation Aging feature, ***Hottest-Spot Limit***, ***Aging Factor Limit*** and ***Loss of Life Limit***, must be tested with a valid set of transformer data programmed into the relay. The ambient temperature must also be programmed (obtained from an RTD or programmed as 12-month averages). The tests consist of simulating transformer loading by applying a current signal to Winding 1 Phase A at the correct frequency.

b) HOTTEST SPOT LIMIT

The hottest-spot temperature value is a function of load, ambient temperature, and transformer rating. Apply a current to Winding 1 phase A to represent at least a 100% load on the transformer. Use the actual value

ACTUAL VALUES/A2 METERING/LOSS OF LIFE/HOTTEST-SPOT WINDING TEMPERATURE

to observe the hottest spot temperature increases gradually. The simulated load to may be increased for a faster temperature rise. When the hottest spot temperature reaches the programmed operating level:

SETPOINTS/S4 ELEMENTS/INSULATION AGING/HOTTEST-SPOT LIMIT/HOTTEST-SPOT LIMIT PICKUP

the element should operate. Verify all programmed relay operations as per FlexLogic settings. Verify that all the targets and messages are as expected and programmed.

The time delay can be verified with a watch as the delay is normally set in minutes.

c) AGING FACTOR LIMIT

The Aging Factor value is also a function of load, ambient temperature, and transformer ratings. Apply a current to Winding 1 phase A to represent at least a 100% transformer load. Use the actual value

ACTUAL VALUES/A2 METERING/LOSS OF LIFE/INSULATION AGING FACTOR

to observe that the aging factor increases gradually. You may want to increase the simulated load or the simulated or programmed ambient temperature to cause a faster increase. When the aging factor reaches the programmed operating level under:

SETPOINTS/S4 ELEMENTS/INSULATION AGING/AGING FACTOR LIMIT/AGING FACTOR LIMIT PICKUP

the element should operate. Verify all programmed relay operations as per FlexLogic settings. Verify that all the targets and messages are as expected and programmed.

The time delay can be verified with a watch as the delay is normally set in minutes.

d) LOSS-OF-LIFE LIMIT

Typical settings for the Loss-of-Life Limit element dictate that either the limit be changed or the initial transformer loss-of-life be changed temporarily. Verification of this function is recommended by programming an initial loss-of-life above the element threshold. The element operates instantly as it has no associated time delay.

10.6.24 TAP MONITOR FAILURE

The tap monitor failure element operates when the sensed resistance is 150% larger than the programmed values for the monitor circuit. Connect a resistance to simulate the tap changer resistance and increase this resistance until the element operates. Calculate that the resistance at which the element operated is 150% of the resistance that would be present at the maximum tap position.

Verify all relay, targets and messages for correct operation per programmed values.

10.7.1 THD LEVEL SCHEME

The THD settings are under:

SETPOINTS/S4 ELEMENTS/HARMONICS/W1 THD LEVEL/....

a) MINIMUM PICKUP

1. Testing of this element uses with the same setup used in testing the harmonic restraint percent differential elements (see Figure 10–1: TEST SETUP on page 10–3).
2. To test the Winding 1 THD element, connect the composite current signal to terminals H1 and G1. Since the DC component actually consists of a half-wave rectified signal, it contains all even harmonics which the relay measures and operates on. Note that the fundamental component is required to prevent saturation of the input CTs. Monitor the output relays as per the relay FlexLogic assignment.
3. Set the fundamental component to rated CT secondary (1 or 5 A). Gradually increase the DC component to produce even harmonics until the THD Level element operates. Display the total harmonic content under:

   ACTUAL/A2 METERING/HARMONIC CONTENT/THD/W1(%fo) THDa:....
4. The displayed value of THD at which operation took place should be the same as the programmed value.
5. Check that the TRIP, PICKUP (and ALARM if selected) LEDs are on and the following trip message displayed:

```
▌ LATCHED (OPERATED):
▌ W1 THD Level
```

6. Lower the DC component until the element resets. The reset value should be approximately 2% less than the operate value. Verify that the Phase, Pickup and Alarm LEDs reset if the target function is set to Self-resetting. The trip LED should remain latched.

b) OPERATING TIME

To measure the basic operating time of this element, preset a fundamental and DC component composite current signal to cause the element to operate. Using the setup of Figure 10-1, apply the current suddenly, at the same time as you trigger the timer. The measured operating time should correspond to the time delay setting for the element.

c) MINIMUM OPERATING CURRENT

The THD elements will only operate if the amplitude of the fundamental component is above the threshold setting. To verify this threshold, initially set the fundamental component above the threshold, with a harmonic content high enough to cause the element to operate. Now reduce the fundamental component only. This will have for effect to increase the THD level. When the fundamental component reaches a value below the set threshold, the element will reset.

CAUTION

If an RMS-responding meter is used to measure the current signal, the reading is the *total value* of current. To determine the fundamental component only, use the relay values in **ACTUAL VALUES/A2 METERING/CURRENT/W1 RMS CURRENT**. These values represent the fundamental component only.

d) OTHER THD ELEMENTS

A THD element can be programmed for each winding of the transformer. Use the above procedure to verify the element(s) on the other winding(s).

10.7.2 HARMONIC DERATING FUNCTION

NOTE

Testing of the Harmonic Derating Function requires that accurate transformer parameters such as Load Losses at Rated Load and Winding Resistance be entered. This feature makes use of the Harmonic Derating Factor (HDF) computed by the relay, using the harmonic content of the current signals and the transformer data (refer to IEEE C57.110-1986 for the computation method). Once the derating factor falls below a set value, the 745 can trip and/or alarm.

The harmonic derating settings are under:

SETPOINTS/S4 ELEMENTS/HARMONICS/W1 (2) HARM DERATING/...

a) OPERATING LEVEL

1. To verify the correct operation of this element, a current signal containing harmonics must be introduced into one phase of the relay. The test setup of Figure 10–1: TEST SETUP on page 10–3 is to accomplish this. Set the fundamental component at rated CT secondary into phase A Winding #1. Gradually increase the second harmonic component (and the rest of the even harmonics) while displaying the harmonic derating factor under:

   ACTUAL VALUES/A2 METERING/HARMONIC CONTENT/HARMONIC DERATING/HARMONIC DERATING FACTOR

   The element should operate when the displayed HDF equals the element setting.

2. Check that the TRIP, PICKUP (and ALARM if selected) LEDs are on, and the following trip message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌
```

3. Lower the DC component until the element resets. The reset value should be approximately 2% larger than the operate value. Verify that the Pickup and Alarm LEDs reset if the target function is set to Self-resetting. The trip LED should remain latched.

b) OPERATING TIME

To measure the basic operating time of this element, preset a fundamental and DC component composite current signal to cause the element to operate. Using the setup of Figure 10–1: TEST SETUP on page 10–3, apply the current suddenly, at the same time the timer is triggered. The measured operating time should correspond to the time delay setting for the element.

10.7.3 TRANSFORMER OVERLOAD

NOTE

The transformer overload element uses the A-phase current of each winding to compute a transformer loading. The computation assumes a rated voltage on the wInding, hence the loading is effectively a percent of rated load current.

The transformer overload settings are under:

SETPOINTS / S4 SETPOINTS/XFORMER OVERLOAD/...

a) OPERATING LEVEL

1. Inject a fundamental-frequency current into phase A of winding #1. Increase the current signal to a value just above the Transformer Overload Pickup setting (take into account the CT ratio and the rated-MVA phase current to set the current correctly). The element should operate after its set time delay.
2. Check that the TRIP and PICKUP (and ALARM if selected) LEDs are on, and the following trip message is displayed:

```
▌▌ LATCHED (OPERATED):
▌▌ Xformer Overload
```

3. Lower the current until the element resets. The reset value should be approximately 97% of the operate value. Verify that the Pickup and Alarm LEDs reset if the target function is set to ***Self-resetting***. The trip LED should remain latched.

b) OPERATING TIME

Using the setup in Figure 10–11: FREQUENCY ELEMENT TESTING on page 10–34 with the Interval Timer enabled, set the current level to 1.5 times the operate level of the element and apply suddenly by closing the double pole switch. Record the operate time and compare to the setting under:

SETPOINTS/S4 ELEMENTS/XFORMER OVERLOAD/TRANSFORMER OVERLOAD DELAY.

NOTE

The blocking from logic input, if enabled, can be tested as described in earlier tests for other elements.

10.8.1 DESCRIPTION

NOTE

The procedure outlined in this subsection is explicitly concerned with the 745 relay and does not include the operation/commissioning or placing into service of any equipment external to the 745. Users should have already performed such tests as phasing of CTs, ratio measurement, verification of saturation curve, insulation test, continuity and resistance measurements.

1. Restore all settings and logic to the desired in-service values. Verify against the check list prepared while testing the relay.
2. Upload all the 745 setpoints to a computer file and print for a final inspection to confirm that all setpoints are correct.
3. Set the 745 clock (date and time).
4. Clear all historical values stored in the relay by entering "YES" at the following messages:

   ACTUAL VALUES/A3 EVENT RECORDER/EVENT DATA CLEAR/CLEAR EVENT RECORDER

5. Remove all test connections, supplies, monitoring equipment from the relay terminals and relay panels except for equipment to be used to monitor first transformer energization. Restore all panel wiring to normal except for those changes made intentionally for the first energization (blocking of some tripping functions for example).
6. Perform a complete visual inspection to confirm that the 745 is ready to be placed into service. Ensure that the relay is properly inserted in its case. Energize the relay power supply and verify that the **RELAY IN SERVICE** indicator is ON, and that the SELF-TEST ERROR indicator is OFF, establishing that the relay is operating normally.

11.1.1 S1 745 SETUP

Table 11–1: SETPOINTS PAGE 1 – 745 SETUP

DESCRIPTION	DEFAULT	USER VALUE
PREFERENCES		
Beeper	Enabled	
Flash Message Time	4.0 s	
Default Message Timeout	300 s	
Default Message Intensity	25 %	
COMMUNICATIONS		
Slave Address	254	
COM1 Baud Rate	19200 Baud	
COM1 Parity	None	
COM1 Hardware	RS485	
COM2 Baud Rate	19200 Baud	
COM2 Parity	None	
Front Baud Rate	19200 Baud	
Front Parity	None	
DNP COMMUNICATIONS		
DNP port	None	
DNP Point Mapping	Enabled	
Transmission delay	0 ms	
Data Link Confirm	Never	
Data Link Confirm Timeout	1000 ms	
Data Link Confirm Retries	3	
Select/Operate Arm Timeout	10000 ms	
Write Time Interval	0 min	
Cold Restart Inhibit	Disabled	
RESETTING		
Local Reset Block	Disabled	
Remote Reset Signal	Disabled	
CLOCK		
IRIG-B Signal Type	None	

11.1.2 S2 SYSTEM SETUP

Table 11–2: S2 SYSTEM SETUP(Sheet 1 of 2)

DESCRIPTION	DEFAULT	USER VALUE
TRANSFORMER		
Nominal Frequency	60 Hz	
Frequency Tracking	Enabled	
Phase Sequence	ABC	
Transformer Type	Y/d30°	
Load Loss at Rated Load	1250 kW	
Low Voltage Winding Rating	Above 5 kV	
Rated Winding Temp Rise	65°C (oil)	
No-Load Loss (KW)	125.0 kW	
Type of Cooling	OA	
Rated Top Oil Rise Over Ambient	10°C	
XFMR THRML capacity	1.00 kWh/°C	
Winding Time Constant	2.00 min.	
Set Accumulated Loss of Life	0 x 10 h	
WINDING 1		
Nom. Voltage	220.0 kV	
Rated Load	100.0 MVA	
Phase CT Primary	500 A	
Ground CT Primary	500 A	
Series 3Ø Resistance	10.700 W	
WINDING 2		
Nom. Voltage	69.0 V	
Rated Load	100.0 MVA	
Phase CT Primary	1500 A	
Ground CT Primary	1500 A	
Series 3Ø Resistance	2.100 W	
WINDING 3		
Nom. Voltage	69.0 kV	
Rated Load	100.0 MVA	
Phase CT Primary	1500 A	
Ground CT Primary	1500 A	
Series 3Ø Resistance	2.100 W	

DESCRIPTION	DEFAULT	USER VALUE
ONLOAD TAP CHANGER		
Winding With Tap Changer	None	
Number of Tap Positions	33	
Min. Tap Position Voltage (kV)	61.0	
Voltage Increment Per Tap (kV)	0.50	
Res. Increment Per Tap (W)	33	
HARMONIC DERATING		
Estimation	Disabled	
FLEXCURVES		
see Table 11–3: FLEXCURVES TABLE on page 11–4		
VOLTAGE INPUT		
Voltage Sensing	Disabled	
Voltage Input Parameter	W1 Van	
Nominal VT Secondary Voltage	120.0 V	
VT Ratio	1000:1	
AMBIENT TEMPERATURE		
Ambient Temperature Sensing	Disabled	
Ambient RTD Type	100 W Pl.	
ANALOG INPUT		
Analog Input Name	ANALOG INPUT	
Analog Input Units	"uA"	
Analog Input Range	0-1 mA	
Analog Input Minimum Value	0 <Units>	
Analog Input Maximum Value	1000 <Units>	
DEMAND METERING		
Current Demand Meter Type	Thermal	
Thermal 90% Response Time	15 min.	
Time Interval	20 min.	

Table 11–2: S2 SYSTEM SETUP(Sheet 2 of 2)

DESCRIPTION	DEFAULT	USER VALUE
ANALOG OUTPUT 1		
Function	Disabled	
Value	W1 øA Current	
Range	4-20 mA	
Minimum	0 A	
Maximum	1000 A	
ANALOG OUTPUT 2		
Function	Disabled	
Value	W1 øB Current	
Range	4-20 mA	
Minimum	0 A	
Maximum	1000 A	
ANALOG OUTPUT 3		
Function	Disabled	
Value	W1 øC Current	
Range	4-20 mA	
Minimum	0 A	
Maximum	1000 A	
ANALOG OUTPUT 4		
Function	Disabled	
Value	W1 Loading	
Range	4-20 mA	
Minimum	0%	
Maximum	100%	

DESCRIPTION	DEFAULT	USER VALUE
ANALOG OUTPUT 5		
Function	Disabled	
Value	Voltage	
Range	4-20 mA	
Minimum	0.00 kV	
Maximum	14.40 kV	
ANALOG OUTPUT 6		
Function	Disabled	
Value	Frequency	
Range	4-20 mA	
Minimum	57.00 Hz	
Maximum	63.00 Hz	
ANALOG OUTPUT 7		
Function	Disabled	
Value	Tap Position	
Range	4-20 mA	
Minimum	1	
Maximum	33	

11.1.3 FLEXCURVES

Table 11–3: FLEXCURVES TABLE

PICKUP (I/Ipkp)	TRIP TIME (ms)	PICKUP (I/Ipkp)	TRIP TIME (ms)	PICKUP (I/Ipkp)	TRIP TIME (ms)	PICKUP (I/Ipkp)	TRIP TIME (ms)
1.03		2.9		4.9		10.5	
1.05		3.0		5.0		11.0	
1.1		3.1		5.1		11.5	
1.2		3.2		5.2		12.0	
1.3		3.3		5.3		12.5	
1.4		3.4		5.4		13.0	
1.5		3.5		5.5		13.5	
1.6		3.6		5.6		14.0	
1.7		3.7		5.7		14.5	
1.8		3.8		5.8		15.0	
1.9		3.9		5.9		15.5	
2.0		4.0		6.0		16.0	
2.1		4.1		6.5		16.5	
2.2		4.2		7.0		17.0	
2.3		4.3		7.5		17.5	
2.4		4.4		8.0		18.0	
2.5		4.5		8.5		18.5	
2.6		4.6		9.0		19.0	
2.7		4.7		9.5		19.5	
2.8		4.8		10.0		20.0	

11.1.4 S3 LOGIC INPUTS

Table 11–4: S3 LOGIC INPUTS

LOGIC INPUTS	FUNCTION	INPUT TARGET	NAMES	ASSERTED STATE
DEFAULTS	Disabled	Self -Reset	Logic Input “X”	Closed
#1				
#2				
#3				
#4				
#5				
#6				
#7				
#8				
#9				
#10				
#11				
#12				
#13				
#14				
#15				
#16				

VIRTUAL INPUTS	FUNCTION	INPUT TARGET	NAMES	ASSERTED STATE
DEFAULTS	Disabled	Self -Reset	Logic Input “X”	Closed
#1				
#2				
#3				
#4				
#5				
#6				
#7				
#8				
#9				
#10				
#11				
#12				
#13				
#14				
#15				
#16				

11

11.1.5 S4 ELEMENTS

Table 11–5: S4 ELEMENTS SETPOINT GROUPS

SETPOINT GROUP	DEFAULT	USER VALUE
ACTIVE SETPOINT GROUP	Group 1	
EDIT SETPOINT GROUP	Active	
GROUP 2 ACTIVATE SIGNAL	Disabled	
GROUP 3 ACTIVATE SIGNAL	Disabled	
GROUP 4 ACTIVATE SIGNAL	Disabled	

Table 11–6: S4 ELEMENTS (Sheet 1 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
DIFFERENTIAL					
Percent Differential Function	Enabled				
Percent Differential Target	Latched				
Percent Differential Pickup	0.30 x CT				
Percent Differential Slope 1	25%				
Percent Differential Kneepoint	2.0 x CT				
Percent Differential Slope 2	100%				
Percent Differential Block	Disabled				
Harmonic Inhibit Function	Enabled				
Harmonic Inhibit Parameters	2nd				
Harmonic Avg	Disabled				
Harmonic Inhibit Level	20.0% ƒo				
Energization Function	Enabled				
Energization Parameters	2nd				
Harmonic Avg	Enabled				
Energization Level	20.0% ƒo				
Energization Duration	0.10 s				
Energization Current Sensing	Enabled				
Energization Min. Current	0.10 x CT				
Energization Voltage Sensing	Disabled				
Energization Min. Voltage	0.85 x VT				
Brkrs Open Signal	Disabled				
Parallel Xfmr Brkr	Disabled				
5th Harmonic Inhibit Function	Disabled				
Harmonic Avg	Disabled				

Table 11–6: S4 ELEMENTS (Sheet 2 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
5th Harmonic Inhibit Level	10.0% ƒo				
INSTANTANEOUS DIFFERENTIAL					
Inst. Differential Function	Enabled				
Inst. Differential Target	Latched				
Inst. Differential Pickup	8.00 x CT				
Inst. Differential Block	Disabled				
PHASE OVERCURRENT					
W1 Phase Time O/C Function	Enabled				
W1 Phase Time O/C Target	Latched				
W1 Phase Time O/C Pickup	1.20 x CT				
W1 Phase Time O/C Shape	Ext Inverse				
W1 Phase Time O/C Multiplier	1.00				
W1 Phase Time O/C Reset	Linear				
W1 Phase Time O/C Block	Disabled				
W1 Phase Time O/C Harm Derating	Disabled				
W2 Phase Time O/C Function	Enabled				
W2 Phase Time O/C Target	Latched				
W2 Phase Time O/C Pickup	1.20 x CT				
W2 Phase Time O/C Shape	Ext Inverse				
W2 Phase Time O/C Multiplier	1.00				
W2 Phase Time O/C Reset	Linear				
W2 Phase Time O/C Block	Disabled				
W2 Phase Time O/C Harm Derating	Disabled				
W3 Phase Time O/C Function	Enabled				
W3 Phase Time O/C Target	Latched				
W3 Phase Time O/C Pickup	1.20 x CT				
W3 Phase Time O/C Shape	Ext Inverse				
W3 Phase Time O/C Multiplier	1.00				
W3 Phase Time O/C Reset	Linear				
W3 Phase Time O/C Block	Disabled				
W3 Phase Time O/C Harm Derating	Disabled				
W1 Phase Inst O/C 1 Function	Enabled				
W1 Phase Inst O/C 1 Target	Latched				
W1 Phase Inst O/C 1 Pickup	10.00 x CT				
W1 Phase Inst O/C 1 Delay	0 ms				

Table 11–6: S4 ELEMENTS (Sheet 3 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W1 Phase Inst O/C 1 Block	Disabled				
W2 Phase Inst O/C 1 Function	Enabled				
W2 Phase Inst O/C 1 Target	Latched				
W2 Phase Inst O/C 1 Pickup	10.00 x CT				
W2 Phase Inst O/C 1 Delay	0 ms				
W2 Phase Inst O/C 1 Block	Disabled				
W3 Phase Inst O/C 1 Function	Enabled				
W3 Phase Inst O/C 1 Target	Latched				
W3 Phase Inst O/C 1 Pickup	10.00 x CT				
W3 Phase Inst O/C 1 Delay	0 ms				
W3 Phase Inst O/C 1 Block	Disabled				
W1 Phase Inst O/C 2 Function	Enabled				
W1 Phase Inst O/C 2 Target	Latched				
W1 Phase Inst O/C 2 Pickup	10.00 x CT				
W1 Phase Inst O/C 2 Delay	0 ms				
W1 Phase Inst O/C 2 Block	Disabled				
W2 Phase Inst O/C 2 Function	Enabled				
W2 Phase Inst O/C 2 Target	Latched				
W2 Phase Inst O/C 2 Pickup	10.00 x CT				
W2 Phase Inst O/C 2 Delay	0 ms				
W2 Phase Inst O/C 2 Block	Disabled				
W3 Phase Inst O/C 2 Function	Enabled				
W3 Phase Inst O/C 2 Target	Latched				
W3 Phase Inst O/C 2 Pickup	10.00 x CT				
W3 Phase Inst O/C 2 Delay	0 ms				
W3 Phase Inst O/C 2 Block	Disabled				
NEUTRAL OVERCURRENT					
W1 Ntrl Time O/C Function	Enabled				
W1 Ntrl Time O/C Target	Latched				
W1 Ntrl Time O/C Pickup	0.85 x CT				
W1 Ntrl Time O/C Shape	Ext Inverse				
W1 Ntrl Time O/C Multiplier	1.00				
W1 Ntrl Time O/C Reset	Linear				
W1 Ntrl Time O/C Block	Disabled				
W2 Ntrl Time O/C Function	Disabled				

Table 11–6: S4 ELEMENTS (Sheet 4 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W2 Ntrl Time O/C Target	Latched				
W2 Ntrl Time O/C Pickup	0.85 x CT				
W2 Ntrl Time O/C Shape	Ext Inverse				
W2 Ntrl Time O/C Multiplier	1.00				
W2 Ntrl Time O/C Reset	Linear				
W2 Ntrl Time O/C Block	Disabled				
W3 Ntrl Time O/C Function	Disabled				
W3 Ntrl Time O/C Target	Latched				
W3 Ntrl Time O/C Pickup	0.85 x CT				
W3 Ntrl Time O/C Shape	Ext Inverse				
W3 Ntrl Time O/C Multiplier	1.00				
W3 Ntrl Time O/C Reset	Linear				
W3 Ntrl Time O/C Block	Disabled				
W1 Ntrl Inst O/C 1 Function	Enabled				
W1 Ntrl Inst O/C 1 Target	Latched				
W1 Ntrl Inst O/C 1 Pickup	10.00 x CT				
W1 Ntrl Inst O/C 1 Delay	0 ms				
W1 Ntrl Inst O/C 1 Block	Disabled				
W2 Ntrl Inst O/C 1 Function	Disabled				
W2 Ntrl Inst O/C 1 Target	Latched				
W2 Ntrl Inst O/C 1 Pickup	10.00 x CT				
W2 Ntrl Inst O/C 1 Delay	0 ms				
W2 Ntrl Inst O/C 1 Block	Disabled				
W3 Ntrl Inst O/C 1 Function	Disabled				
W3 Ntrl Inst O/C 1 Target	Latched				
W3 Ntrl Inst O/C 1 Pickup	10.00 x CT				
W3 Ntrl Inst O/C 1 Delay	0 ms				
W3 Ntrl Inst O/C 1 Block	Disabled				
W1 Ntrl Inst O/C 2 Function	Disabled				
W1 Ntrl Inst O/C 2 Target	Latched				
W1 Ntrl Inst O/C 2 Pickup	10.00 x CT				
W1 Ntrl Inst O/C 2 Delay	0 ms				
W1 Ntrl Inst O/C 2 Block	Disabled				
W2 Ntrl Inst O/C 2 Function	Disabled				
W2 Ntrl Inst O/C 2 Target	Latched				

Table 11–6: S4 ELEMENTS (Sheet 5 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W2 Ntrl Inst O/C 2 Pickup	10.00 x CT				
W2 Ntrl Inst O/C 2 Delay	0 ms				
W2 Ntrl Inst O/C 2 Block	Disabled				
W3 Ntrl Inst O/C 2 Function	Disabled				
W3 Ntrl Inst O/C 2 Target	Latched				
W3 Ntrl Inst O/C 2 Pickup	10.00 x CT				
W3 Ntrl Inst O/C 2 Delay	0 ms				
W3 Ntrl Inst O/C 2 Block	Disabled				
GROUND OVERCURRENT					
W1 Gnd Time O/C Function	Enabled				
W1 Gnd Time O/C Target	Latched				
W1 Gnd Time O/C Pickup	0.85 x CT				
W1 Gnd Time O/C Shape	Ext Inverse				
W1 Gnd Time O/C Multiplier	1.00				
W1 Gnd Time O/C Reset	Linear				
W1 Gnd Time O/C Block	Disabled				
W2 Gnd Time O/C Function	Disabled				
W2 Gnd Time O/C Target	Latched				
W2 Gnd Time O/C Pickup	0.85 x CT				
W2 Gnd Time O/C Shape	Ext Inverse				
W2 Gnd Time O/C Multiplier	1.00				
W2 Gnd Time O/C Reset	Linear				
W2 Gnd Time O/C Block	Disabled				
W3 Gnd Time O/C Function	Disabled				
W3 Gnd Time O/C Target	Latched				
W3 Gnd Time O/C Pickup	0.85 x CT				
W3 Gnd Time O/C Shape	Ext Inverse				
W3 Gnd Time O/C Multiplier	1.00				
W3 Gnd Time O/C Reset	Linear				
W3 Gnd Time O/C Block	Disabled				
W1 Gnd Inst O/C 1 Function	Disabled				
W1 Gnd Inst O/C 1 Target	Latched				
W1 Gnd Inst O/C 1 Pickup	10.00 x CT				
W1 Gnd Inst O/C 1 Delay	0 ms				
W1 Gnd Inst O/C 1 Block	Disabled				

Table 11–6: S4 ELEMENTS (Sheet 6 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W2 Gnd Inst O/C 1 Function	Disabled				
W2 Gnd Inst O/C 1 Target	Latched				
W2 Gnd Inst O/C 1 Pickup	10.00 x CT				
W2 Gnd Inst O/C 1 Delay	0 ms				
W2 Gnd Inst O/C 1 Block	Disabled				
W3 Gnd Inst O/C 1 Function	Disabled				
W3 Gnd Inst O/C 1 Target	Latched				
W3 Gnd Inst O/C 1 Pickup	10.00 x CT				
W3 Gnd Inst O/C 1 Delay	0 ms				
W3 Gnd Inst O/C 1 Block	Disabled				
W1 Gnd Inst O/C 2 Function	Disabled				
W1 Gnd Inst O/C 2 Target	Latched				
W1 Gnd Inst O/C 2 Pickup	10.00 x CT				
W1 Gnd Inst O/C 2 Delay	0 ms				
W1 Gnd Inst O/C 2 Block	Disabled				
W2 Gnd Inst O/C 2 Function	Disabled				
W2 Gnd Inst O/C 2 Target	Latched				
W2 Gnd Inst O/C 2 Pickup	10.00 x CT				
W2 Gnd Inst O/C 2 Delay	0 ms				
W2 Gnd Inst O/C 2 Block	Disabled				
W3 Gnd Inst O/C 2 Function	Disabled				
W3 Gnd Inst O/C 2 Target	Latched				
W3 Gnd Inst O/C 2 Pickup	10.00 x CT				
W3 Gnd Inst O/C 2 Delay	0 ms				
W3 Gnd Inst O/C 2 Block	Disabled				
RESTRICTED GROUND FAULT					
W1 Rstd Gnd Fault Function	Disabled				
W1 Rstd Gnd Fault Target	Latched				
W1 Rstd Gnd Fault Pickup	0.08 x CT				
W1 Rstd Gnd Fault Slope	10%				
W1 Rstd Gnd Fault Delay	0.10 s				
W1 Rstd Gnd Fault Block	Disabled				
W2 Rstd Gnd Fault Function	Disabled				
W2 Rstd Gnd Fault Target	Latched				
W2 Rstd Gnd Fault Pickup	0.08 x CT				

Table 11–6: S4 ELEMENTS (Sheet 7 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W2 Rstd Gnd Fault Slope	10%				
W2 Rstd Gnd Fault Delay	0.10 s				
W2 Rstd Gnd Fault Block	Disabled				
W3 Rstd Gnd Fault Function	Disabled				
W3 Rstd Gnd Fault Target	Latched				
W3 Rstd Gnd Fault Pickup	0.08 x CT				
W3 Rstd Gnd Fault Slope	10%				
W3 Rstd Gnd Fault Delay	0.10 s				
W3 Rstd Gnd Fault Block	Disabled				
W1 Rst Gnd Inst O/C Function	Disabled				
W1 Rst Gnd Inst O/C Target	Latched				
W1 Rst Gnd Inst O/C Pickup	10.00 x CT				
W1 Rst Gnd Inst O/C Delay	0 ms				
W1 Rst Gnd Inst O/C Block	Disabled				
W2 Rst Gnd Inst O/C Function	Disabled				
W2 Rst Gnd Inst O/C Target	Latched				
W2 Rst Gnd Inst O/C Pickup	10.00 x CT				
W2 Rst Gnd Inst O/C Delay	0 ms				
W2 Rst Gnd Inst O/C Block	Disabled				
W3 Rst Gnd Inst O/C Function	Disabled				
W3 Rst Gnd Inst O/C Target	Latched				
W3 Rst Gnd Inst O/C Pickup	10.00 x CT				
W3 Rst Gnd Inst O/C Delay	0 ms				
W3 Rst Gnd Inst O/C Block	Disabled				
NEGATIVE SEQUENCE OVERCURRENT					
W1 Neg Seq Time O/C Function	Disabled				
W1 Neg Seq Time O/C Target	Latched				
W1 Neg Seq Time O/C Pickup	0.25 x CT				
W1 Neg Seq Time O/C Shape	Ext Inverse				
W1 Neg Seq Time O/C Multiplier	1.00				
W1 Neg Seq Time O/C Reset	Linear				
W1 Neg Seq Time O/C Block	Disabled				
W2 Neg Seq Time O/C Function	Disabled				
W2 Neg Seq Time O/C Target	Latched				
W2 Neg Seq Time O/C Pickup	0.25 x CT				

Table 11–6: S4 ELEMENTS (Sheet 8 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W2 Neg Seq Time O/C Shape	Ext Inverse				
W2 Neg Seq Time O/C Multiplier	1.00				
W2 Neg Seq Time O/C Reset	Linear				
W2 Neg Seq Time O/C Block	Disabled				
W3 Neg Seq Time O/C Function	Disabled				
W3 Neg Seq Time O/C Target	Latched				
W3 Neg Seq Time O/C Pickup	0.25 x CT				
W3 Neg Seq Time O/C Shape	Ext Inverse				
W3 Neg Seq Time O/C Multiplier	1.00				
W3 Neg Seq Time O/C Reset	Linear				
W3 Neg Seq Time O/C Block	Disabled				
W1 Neg Seq Inst O/C Function	Disabled				
W1 Neg Seq Inst O/C Target	Latched				
W1 Neg Seq Inst O/C Pickup	10.00 x CT				
W1 Neg Seq Inst O/C Delay	0 ms				
W1 Neg Seq Inst O/C Block	Disabled				
W2 Neg Seq Inst O/C Function	Disabled				
W2 Neg Seq Inst O/C Target	Latched				
W2 Neg Seq Inst O/C Pickup	10.00 x CT				
W2 Neg Seq Inst O/C Delay	0 ms				
W2 Neg Seq Inst O/C Block	Disabled				
W3 Neg Seq Inst O/C Function	Disabled				
W3 Neg Seq Inst O/C Target	Latched				
W3 Neg Seq Inst O/C Pickup	10.00 x CT				
W3 Neg Seq Inst O/C Delay	0 ms				
W3 Neg Seq Inst O/C Block	Disabled				
FREQUENCY					
Underfrequency 1 Function	Disabled				
Underfrequency 1 Target	Self-reset				
Current Sensing	Enabled				
Underfrequency 1 Min. Current	0.20 x CT				
Minimum Operating Voltage	0.50 x VT				
Underfrequency 1 Pickup	59.00 Hz				
Underfrequency 1 Delay	1.00 s				
Underfrequency 1 Block	Disabled				

11

Table 11–6: S4 ELEMENTS (Sheet 9 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
Underfrequency 2 Function	Disabled				
Underfrequency 2 Target	Self-reset				
Underfrequency 2 Min. Current	0.20 x CT				
Underfrequency 2 Pickup	58.80 Hz				
Underfrequency 2 Delay	1.00 s				
Underfrequency 2 Block	Disabled				
Frequency Decay Function	Disabled				
Frequency Decay Target	Latched				
Current Sensing	Enabled				
Frequency Decay Min. Current	0.20 x CT				
Minimum Operating Voltage	0.50 x VT				
Frequency Decay Threshold	59.50 Hz				
Frequency Decay Delay	0.00 s				
Frequency Decay Rate 1	0.4 Hz/s				
Frequency Decay Rate 2	1.0 Hz/s				
Frequency Decay Rate 3	2.0 Hz/s				
Frequency Decay Rate 4	4.0 Hz/s				
Frequency Decay Block	Disabled				
Overfrequency Function	Disabled				
Overfrequency Target	Latched				
Current Sensing	Enabled				
Overfrequency Min. Current	0.20 x CT				
Minimum Operating Voltage	0.50 x VT				
Overfrequency Pickup	60.50 Hz				
Overfrequency Delay	5.00 s				
Overfrequency Block	Disabled				
OVEREXCITATION					
5th Harmonic Level Function	Disabled				
5th Harmonic Level Target	Self-reset				
5th Harmonic Level Min. Current	0.10 x CT				
5th Harmonic Level Pickup	10.0% ƒo				
5th Harmonic Level Delay	10 s				
5th Harmonic Level Block	Disabled				
Volts-Per-Hertz 1 Function	Disabled				
Volts-Per-Hertz 1 Target	Self-reset				

Table 11–6: S4 ELEMENTS (Sheet 10 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
Volts-Per-Hertz 1 Min. Voltage	0.10 x VT				
Volts-Per-Hertz 1 Pickup	2.36 V/Hz				
Volts-Per-Hertz 1 Shape	Def. Time				
Volts-Per-Hertz 1 Delay	2.00 s				
Volts-Per-Hertz 1 Reset	0.0 s				
Volts-Per-Hertz 1 Block	Disabled				
Volts-Per-Hertz 2 Function	Disabled				
Volts-Per-Hertz 2 Target	Self-reset				
Volts-Per-Hertz 2 Min. Voltage	0.10 x VT				
Volts-Per-Hertz 2 Pickup	2.14 V/Hz				
Volts-Per-Hertz 2 Shape	Def. Time				
Volts-Per-Hertz 2 Delay	45.00 s				
Volts-Per-Hertz 2 Reset	0.0 s				
Volts-Per-Hertz 2 Block	Disabled				
HARMONICS					
W1 THD Level Function	Disabled				
W1 THD Level Target	Self-reset				
W1 THD Level Min. Current	0.10 x CT				
W1 THD Level Pickup	50.0 % f_0				
W1 THD Level Delay	10 s				
W1 THD Level Block	Disabled				
W2 THD Level Function	Disabled				
W2 THD Level Target	Self-reset				
W2 THD Level Min. Current	0.10 x CT				
W2 THD Level Pickup	50.0 % f_0				
W2 THD Level Delay	10 s				
W2 THD Level Block	Disabled				
W3 THD Level Function	Disabled				
W3 THD Level Target	Self-reset				
W3 THD Level Min. Current	0.10 x CT				
W3 THD Level Pickup	50.0 % f_0				
W3 THD Level Delay	10 s				
W3 THD Level Block	Disabled				
W1 Harmonic Derating Function	Disabled				
W1 Harmonic Derating Target	Self-reset				

Table 11–6: S4 ELEMENTS (Sheet 11 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
W1 Harm. Derating Min Current	0.10 x CT				
W1 Harmonic Derating Pickup	0.90				
W1 Harmonic Derating Delay	10 s				
W1 Harmonic Derating Block	Disabled				
W2 Harmonic Derating Function	Disabled				
W2 Harmonic Derating Target	Self-reset				
W2 Harm. Derating Min. Current	0.10 x CT				
W2 Harmonic Derating Pickup	0.90				
W2 Harmonic Derating Delay	10 s				
W2 Harmonic Derating Block	Disabled				
W3 Harmonic Derating Function	Disabled				
W3 Harmonic Derating Target	Self-reset				
W3 Harm. Derating Min. Current	0.10 x CT				
W3 Harmonic Derating Pickup	0.90				
W3 Harmonic Derating Delay	10 s				
W3 Harmonic Derating Block	Disabled				
INSULATION AGING					
Hottest Spot Limit	Disabled				
Hottest Spot Limit Target	Self-Reset				
Hottest Spot Limit Pickup	150ºC				
Hottest Spot Limit Delay	10 min				
Hottest Spot Limit Block	Disabled				
AGING FACTOR LIMIT					
Aging Factor Limit Function	Disabled				
Aging Factor Limit Target	Self -reset				
Aging Factor Limit Pickup	2.0				
Aging Factor Limit Delay	10 min				
Aging Factor Limit Block	disabled				
LOSS-OF-LIFE LIMIT					
Loss of Life Limit Function	Disabled				
Loss of Life Limit Target	Self-Reset				
Loss of Life Limit Pickup	16000 x 10h				
Loss of Life Limit Block	Disabled				
ANALOG INPUT					
Analog Level 1 Function	Disabled				

Table 11–6: S4 ELEMENTS (Sheet 12 of 12)

DESCRIPTION	DEFAULT	GROUP 1	GROUP 2	GROUP 3	GROUP 4
Analog Level 1 Target	Self-reset				
Analog Level 1 Pickup	10 mA				
Analog Level 1 Delay	50 s				
Analog Level 1 Block	Disabled				
Analog Level 2 Function	Disabled				
Analog Level 2 Target	Self-reset				
Analog Level 2 Pickup	100 mA				
Analog Level 2 Delay	100 s				
Analog Level 2 Block	Disabled				
CURRENT DEMAND					
W1 Current Demand Function	Disabled				
W1 Current Demand Target	Self-reset				
W1 Current Demand Pickup	100 A				
W1 Current Demand Block	Disabled				
W2 Current Demand Function	Disabled				
W2 Current Demand Target	Self-reset				
W2 Current Demand Pickup	400 A				
W2 Current Demand Block	Disabled				
W3 Current Demand Function	Disabled				
W3 Current Demand Target	Self-reset				
W3 Current Demand Pickup	400 A				
W3 Current Demand Block	Disabled				
TRANSFORMER OVERLOAD					
Xformer Overload Function	Disabled				
Xformer Overload Target	Self-reset				
Xformer Overload Pickup	208%				
Xformer Overload Delay	10 s				
Xformer Overload Block	Disabled				
Overtemp Alarm Signal	Disabled				
Tap changer failure					
Tap changer failure Function	Disabled				
Tap changer failure Target	Self-Reset				
Tap changer failure Delay	5.0 s				
Tap changer failure Block	Disabled				

11.1.6 S5 OUTPUTS

Table 11–7: S5 OUTPUTS (Sheet 1 of 5)

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 1		
Name	Solid State Trip	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Percent Diff OP	
FlexLogic 02	Inst Diff OP	
FlexLogic 03	Any W1 OC OP	
FlexLogic 04	Any W2 OC OP	
FlexLogic 05	OR (4 inputs)	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 2		
Name	“Trip 1”	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Percent Diff OP	
FlexLogic 02	Inst Diff OP	
FlexLogic 03	Any W1 OC OP	
FlexLogic 04	Any W2 OC OP	
FlexLogic 05	OR (4 inputs)	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

Table 11–7: S5 OUTPUTS (Sheet 2 of 5)

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 3		
Name	"Trip 2"	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Percent Diff OP	
FlexLogic 02	Inst Diff OP	
FlexLogic 03	Any W1 OC OP	
FlexLogic 04	Any W2 OC OP	
FlexLogic 05	OR (4 inputs)	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 4		
Name	"Volts/Hertz Trip"	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Volts/Hertz 1 OP	
FlexLogic 02	Volts/Hertz 2 OP	
FlexLogic 03	OR (2 inputs)	
FlexLogic 04	END	
FlexLogic 05	END	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

Table 11–7: S5 OUTPUTS (Sheet 3 of 5)

DESCRIPTION	DEFAULT	USER VALUE	DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 5			**OUTPUT 6**		
Name	Overflux Alarm		Name	Frequency Trip 1	
Operation	Self-resetting		Operation	Self-resetting	
Type	Alarm		Type	Trip	
FlexLogic 01	W1 THD Level OP		FlexLogic 01	Underfreq 1 OP	
FlexLogic 02	W2 THD Level OP		FlexLogic 02	Freq Decay R1 OP	
FlexLogic 03	Xfmr Overload OP		FlexLogic 03	OR (2 inputs)	
FlexLogic 04	5th HarmLevel OP		FlexLogic 04	END	
FlexLogic 05	OR (4 inputs)		FlexLogic 05	END	
FlexLogic 06			FlexLogic 06		
FlexLogic 07			FlexLogic 07		
FlexLogic 08			FlexLogic 08		
FlexLogic 09			FlexLogic 09		
FlexLogic 10			FlexLogic 10		
FlexLogic 11			FlexLogic 11		
FlexLogic 12			FlexLogic 12		
FlexLogic 13			FlexLogic 13		
FlexLogic 14			FlexLogic 14		
FlexLogic 15			FlexLogic 15		
FlexLogic 16			FlexLogic 16		
FlexLogic 17			FlexLogic 17		
FlexLogic 18			FlexLogic 18		
FlexLogic 19			FlexLogic 19		
FlexLogic 20			FlexLogic 20		

Table 11–7: S5 OUTPUTS (Sheet 4 of 5)

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 7		
Name	Frequency Trip 2	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Underfreq 2 OP	
FlexLogic 02	Freq Decay R2 OP	
FlexLogic 03	OR (2 inputs)	
FlexLogic 04	END	
FlexLogic 05	END	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

DESCRIPTION	DEFAULT	USER VALUE
OUTPUT 8		
Name	Frequency Trip 3	
Operation	Self-resetting	
Type	Trip	
FlexLogic 01	Underfreq 3 OP	
FlexLogic 02	Freq Decay R3 OP	
FlexLogic 03	OR (2 inputs)	
FlexLogic 04	END	
FlexLogic 05	END	
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
FlexLogic 11		
FlexLogic 12		
FlexLogic 13		
FlexLogic 14		
FlexLogic 15		
FlexLogic 16		
FlexLogic 17		
FlexLogic 18		
FlexLogic 19		
FlexLogic 20		

Table 11–7: S5 OUTPUTS (Sheet 5 of 5)

DESCRIPTION	DEFAULT	USER VALUE
TRACE		
Pre-Trigger	12 cycles	
FlexLogic 01	Any Element Pkp	
FlexLogic 02	END	
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
VIRTUAL 1		
FlexLogic 01	END	
FlexLogic 02	END	
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
VIRTUAL 2		
FlexLogic 01	END	
FlexLogic 02	END	
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		

DESCRIPTION	DEFAULT	USER VALUE
VIRTUAL 3		
FlexLogic 01	END	
FlexLogic 02	END	
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
VIRTUAL 4		
FlexLogic 01		
FlexLogic 02		
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		
VIRTUAL 5		
FlexLogic 01		
FlexLogic 02		
FlexLogic 03		
FlexLogic 04		
FlexLogic 05		
FlexLogic 06		
FlexLogic 07		
FlexLogic 08		
FlexLogic 09		
FlexLogic 10		

Table 11–8: TIMER SETTINGS

TIMER	START	PICKUP DELAY	DROPUT DELAY
#1			
#2			
#3			
#4			
#5			
#6			
#7			
#8			
#9			
#10			

A.1.1 LIST OF FIGURES

FIGURE 1–1: SINGLE LINE DIAGRAM 1-3
FIGURE 1–2: 745 ORDER CODES........ 1-4
FIGURE 3–1: CASE DIMENSIONS........ 3-1
FIGURE 3–2: SINGLE AND DOUBLE SR RELAY PANEL CUTOUT 3-1
FIGURE 3–3: CASE MOUNTING 3-2
FIGURE 3–4: SLIDING RELAY OUT OF CASE........ 3-3
FIGURE 3–5: DRAWOUT SEAL........ 3-3
FIGURE 3–6: REAR TERMINAL LAYOUT........ 3-4
FIGURE 3–7: TYPICAL WIRING DIAGRAM 3-6
FIGURE 3–8: TYPICAL WIRING DIAGRAM FOR GENERATOR STEP-UP 3-7
FIGURE 3–9: ZERO-SEQUENCE (CORE BALANCE) CT INSTALLATION........ 3-8
FIGURE 3–10: CONTROL POWER CONNECTION........ 3-9
FIGURE 3–11: DRY AND WET CONTACT CONNECTIONS 3-10
FIGURE 3–12: ANALOG OUTPUT CONNECTION 3-11
FIGURE 3–13: RS485 CONNECTION 3-12
FIGURE 3–14: RS422 CONNECTION 3-13
FIGURE 3–15: RS232 CONNECTION 3-13
FIGURE 3–16: IRIG-B FUNCTION........ 3-14
FIGURE 4–1: 745 FRONT PANEL 4-1
FIGURE 4–2: PROGRAM PORT........ 4-4
FIGURE 5–1: TAP POSITION INPUT 5-5
FIGURE 5–2: EXAMPLE TRANSFORMER........ 5-6
FIGURE 5–3: PHASORS FOR ABC SEQUENCE........ 5-6
FIGURE 5–4: PHASORS FOR ACB SEQUENCE........ 5-7
FIGURE 5–5: WYE / DELTA (30× LAG) TRANSFORMER 5-8
FIGURE 5–6: PERCENT DIFFERENTIAL OPERATING PRINCIPLE 5-47
FIGURE 5–7: PERCENT DIFFERENTIAL – DUAL SLOPE CHARACTERISTIC 5-47
FIGURE 5–8: HARMONIC DERATING CORRECTION........ 5-53
FIGURE 5–9: RESTRICTED EARTH GROUND FAULT PROTECTION 5-59
FIGURE 5–10: RESISTANCE GROUNDED WYE WINDING 5-59
FIGURE 5–11: FAULT CURRENTS VS. FAULT POINT FROM NEUTRAL 5-60
FIGURE 5–12: RGF AND PERCENT DIFFERENTIAL ZONES OF PROTECTION 5-60
FIGURE 5–13: RESTRICTED GROUND FAULT IMPLEMENTATION........ 5-61
FIGURE 5–14: FLEXLOGIC™ EXAMPLE........ 5-82
FIGURE 5–15: FLEXLOGIC EXAMPLE IMPLEMENTED 5-83
FIGURE 5–16: INVERSE CURVE 1........ 5-97
FIGURE 5–17: INVERSE CURVE 2........ 5-98
FIGURE 5–18: INVERSE CURVE 3........ 5-99
FIGURE 7–1: DIFFERENTIAL SCHEME LOGIC – PERCENT DIFFERENTIAL 7-2
FIGURE 7–2: DIFFERENTIAL SCHEME LOGIC – 5TH HARMONIC INHIBIT........ 7-3
FIGURE 7–3: DIFFERENTIAL SCHEME LOGIC – ENERGIZATION INHIBIT 7-4
FIGURE 7–4: DIFFERENTIAL SCHEME LOGIC – ENERGIZATION INHIBIT 7-5
FIGURE 7–5: DIFFERENTIAL SCHEME LOGIC – 5TH HARMONIC INHIBIT........ 7-6
FIGURE 7–6: INSTANTANEOUS DIFFERENTIAL SCHEME LOGIC........ 7-7
FIGURE 7–7: PHASE TIME O/C SCHEME LOGIC........ 7-8
FIGURE 7–8: PHASE INST O/C 1 SCHEME LOGIC........ 7-9
FIGURE 7–9: PHASE INST O/C 2 SCHEME LOGIC........ 7-10
FIGURE 7–10: NEUTRAL TIME O/C SCHEME LOGIC........ 7-11
FIGURE 7–11: NEUTRAL INST O/C 1 SCHEME LOGIC 7-12
FIGURE 7–12: NEUTRAL INST O/C 2 SCHEME LOGIC 7-13
FIGURE 7–13: GROUND TIME O/C SCHEME LOGIC........ 7-14
FIGURE 7–14: GROUND INST O/C 1 SCHEME LOGIC 7-15
FIGURE 7–15: GROUND INST O/C 2 SCHEME LOGIC 7-16
FIGURE 7–16: RESTRICTED GROUND FAULT SCHEME LOGIC 7-17
FIGURE 7–17: NEGATIVE SEQUENCE TIME O/C SCHEME LOGIC 7-18
FIGURE 7–18: NEGATIVE SEQUENCE INST O/C SCHEME LOGIC........ 7-19
FIGURE 7–19: UNDERFREQUENCY SCHEME LOGIC 7-20

FIGURE 7–20: FREQUENCY DECAY SCHEME LOGIC 7-21
FIGURE 7–21: OVERFREQUENCY SCHEME LOGIC 7-22
FIGURE 7–22: 5TH HARMONIC LEVEL SCHEME LOGIC 7-23
FIGURE 7–23: VOLTS-PER-HERTZ SCHEME LOGIC 7-24
FIGURE 7–24: THD LEVEL SCHEME LOGIC 7-25
FIGURE 7–25: HARMONIC DERATING SCHEME LOGIC 7-26
FIGURE 7–26: ANALOG INPUT SCHEME LOGIC 7-27
FIGURE 7–27: CURRENT DEMAND SCHEME LOGIC 7-28
FIGURE 7–28: TRANSFORMER OVERLOAD 7-29
FIGURE 7–29: OUTPUT RELAYS 1-8 7-30
FIGURE 7–30: SELF-TEST RELAY 7-31
FIGURE 7–31: HOTTEST-SPOT LIMIT 7-32
FIGURE 7–32: AGING FACTOR LIMIT 7-33
FIGURE 7–33: LOSS OF LIFE LIMIT 7-34
FIGURE 7–34: TAP CHANGER FAILURE 7-35
FIGURE 9–1: 745PC PROGRAM STARTUP WINDOW 9-1
FIGURE 9–2: 745PC TOP LEVEL MENU SUMMARY 9-2
FIGURE 9–3: 745PC TOOLBAR SUMMARY 9-3
FIGURE 9–4: RS232 COMMUNICATIONS SETUP 9-4
FIGURE 9–5: RS485 COMMUNICATIONS SETUP 9-4
FIGURE 9–6: GE POWER MANAGEMENT WELCOME SCREEN 9-5
FIGURE 9–7: COMMUNICATION/COMPUTER DIALOG BOX 9-6
FIGURE 9–8: FILE/PROPERTIES DIALOG BOX 9-7
FIGURE 9–9: SAVING SETPOINTS 9-7
FIGURE 9–10: 745 FIRMWARE FILE FORMAT 9-8
FIGURE 9–11: OPEN SETPOINTS FILE DIALOG BOX 9-9
FIGURE 9–12: TRANSFORMER SETPOINTS DIALOG BOX 9-9
FIGURE 9–13: NUMERICAL SETPOINT ENTRY 9-10
FIGURE 9–14: 745PC ACTUAL VALUES WINDOW 9-11
FIGURE 10–1: TEST SETUP 10-3
FIGURE 10–2: TESTING FOR DIELECTRIC STRENGTH 10-5
FIGURE 10–3: LOGIC INPUTS 10-6
FIGURE 10–4: SOLID STATE OUTPUT TEST CIRCUIT 10-16
FIGURE 10–5: TIMER TEST CIRCUIT 10-16
FIGURE 10–6: CURRENT SIGNAL CONNECTIONS 10-17
FIGURE 10–7: 2ND HARMONIC RESTRAINT TEST 10-18
FIGURE 10–8: 5TH HARMONIC RESTRAINT TEST 10-19
FIGURE 10–9: GENERAL TEST SETUP 10-21
FIGURE 10–10: RESTRICTED GROUND TEST SETUP 10-30
FIGURE 10–11: FREQUENCY ELEMENT TESTING 10-34

A

A.1.2 LIST OF TABLES

TABLE: 5–1 TRANSFORMER TYPES 5-10
TABLE: 5–2 PHASE SHIFTS 5-23
TABLE: 5–3 LOW VOLTAGE WINDING RATING 5-34
TABLE: 5–4 RTD RESISTANCE VS. TEMPERATURE 5-39
TABLE: 5–5 FLEXLOGIC™ OUTPUT TYPES 5-80
TABLE: 5–6 FLEXLOGIC™ INPUT TYPES 5-81
TABLE: 5–7 FLEXLOGIC™ GATES 5-81
TABLE: 5–8 OUTPUT RELAY DEFAULT FLEXLOGIC 5-84
TABLE: 5–9 SIMULATION MODES 5-89
TABLE: 5–10 ANSI CURVE CONSTANTS 5-91
TABLE: 5–11 ANSI CURVE TRIP TIMES (IN SECONDS) 5-92
TABLE: 5–12 IEC CURVE CONSTANTS 5-93
TABLE: 5–13 IEC CURVE TRIP TIMES 5-94
TABLE: 5–14 IAC CURVE CONSTANTS 5-95
TABLE: 5–15 IAC CURVE TRIP TIMES 5-96

TABLE: 6–1 TYPES/CAUSES OF EVENTS 6-16
TABLE: 6–2 745 PROTECTION ELEMENTS 6-20
TABLE: 6–3 SELF-TEST ERROR INTERPRETATION 6-22
TABLE: 8–1 GE POWER MANAGEMENT FUNCTION CODES 8-5
TABLE: 8–2 SUMMARY OF OPERATION CODES FOR FUNCTION CODE 05H........ 8-7
TABLE: 8–3 ERROR CODES 8-10
TABLE: 8–4 MEMORY MAP LOCATIONS TO BE ACCESSED........ 8-12
TABLE: 8–5 MEMORY MAP ORGANIZATION........ 8-16
TABLE: 8–6 745 MEMORY MAP 8-17
TABLE: 8–7 745 DATA FORMATS........ 8-74
TABLE: 10–1 MEASURED RTD TEMPERATURE – 100 Ω PLATINUM 10-12
TABLE: 10–2 MEASURED RTD TEMPERATURE – 120 Ω NICKEL 10-12
TABLE: 10–3 MEASURED RTD TEMPERATURE – 100 Ω NICKEL 10-12
TABLE: 10–4 CALIBRATION RESULTS FOR ANALOG OUTPUTS........ 10-13
TABLE: 11–1 SETPOINTS PAGE 1 – 745 SETUP........ 11-1
TABLE: 11–2 S2 SYSTEM SETUP 11-2
TABLE: 11–3 FLEXCURVES TABLE........ 11-4
TABLE: 11–4 S3 LOGIC INPUTS 11-5
TABLE: 11–5 S4 ELEMENTS SETPOINT GROUPS........ 11-6
TABLE: 11–6 S4 ELEMENTS 11-6
TABLE: 11–7 S5 OUTPUTS........ 11-18
TABLE: 11–8 TIMER SETTINGS........ 11-23

A

EU DECLARATION OF CONFORMITY

Applicable Council Directives: 73/23/EEC The Low Voltage Directive
89/336/EEC The EMC Directive

Standard(s) to Which Conformity is Declared:

IEC 947-1	Low Voltage Switchgear and Controlgear
IEC1010-1:1990+ A 1:1992+ A 2:1995	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
CISPR 11 / EN 55011:1997	Class A – Industrial, Scientific, and Medical Equipment
EN 50082-2:1997	Electromagnetic Compatibility Requirements, Part 2: Industrial Environment
IEC100-4-3 / EN 61000-4-3	Immunity to Radiated RF
EN 61000-4-6	Immunity to Conducted RF

Manufacturer's Name: General Electric Power Management Inc.

Manufacturer's Address: 215 Anderson Ave.
Markham, Ontario, Canada
L6E 1B3

Manufacturer's Representative in the EU: Christina Bataller Mauleon
GE Power Management
Avenida Pinoa 10
48710 Zamudio, Spain
Tel.: 34-94-4858835 Fax: 34-94-4858838

Type of Equipment: Transformer Protection Relay

Model Number: 745

First Year of Manufacture: 1998

I the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards

Full Name: John Saunders

Position: Manufacturing Manager

Signature:

Place: GE Power Management

Date: 1998

C.1.1 WARRANTY

GE POWER MANAGEMENT RELAY WARRANTY

General Electric Power Management Inc. (GE Power Management) warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Power Management will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Power Management authorized factory outlet.

GE Power Management is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to GE Power Management Standard Conditions of Sale.

C

Numerics

2ND HARMONIC RESTRAINT 10-18
5TH HARMONIC INHIBIT
 logic diagram 7-3, 7-6
 setpoints 5-51
5TH HARMONIC LEVEL
 logic diagram 7-23
 setpoints 5-68
 testing 10-41
5TH HARMONIC RESTRAINT 10-18, 10-19
745PC
 see SOFTWARE

A

A1 STATUS 6-2
A2 METERING 6-4
A3 EVENT RECORDER 6-13
A4 PRODUCT INFO 6-17
ACTUAL KEY 4-5
ACTUAL VALUES
 introduction 6-1, 6-2
 organization 6-1
 viewing with PC 9-11
AGING FACTOR LIMIT
 logic diagram 7-33
 setpoints 5-74
 testing 10-42
ALARM INDICATOR 4-4
AMBIENT TEMPERATURE 5-39, 6-10, 10-11, 10-12
ANALOG INPUT
 actual values 6-11
 setpoints 5-40, 5-76
 typical wiring 3-10
ANALOG INPUT SCHEME 7-27
ANALOG LEVEL
 setpoints 5-76
ANALOG OUTPUTS
 commissioning 10-13
 connection 3-11
 setpoints 5-42, 5-87
 typical wiring 3-11
ANSI CURVES 5-91, 5-92
AUTO-CONFIGURATION 5-3
AUTOMATIC TRANSFORMATION 10-9

B

BLOCK DIAGRAMS 7-2
BLOCKING FROM LOGIC INPUTS 10-20, 10-21

C

CALIBRATION 6-18
CASE
 description 3-1
 dimensions 3-1
 mounting 3-2
CAUSES OF EVENT 6-16
CLOCK 5-28
COMMISSIONING
 conventions 10-2
 preliminary work 10-4
 test equipment 10-3
COMMUNICATIONS
 dnp 5-27
 electrical interface 8-2
 physical layer 8-1
 protocols 8-1
 RS232 .... 3-13, 9-4
 RS422 .... 3-12, 3-13
 RS485 .... 3-12, 9-4
 setpoints 5-26, 5-27
CONDITIONS 4-4
CONTROL KEYS 4-5
CONTROL POWER 3-9
CRC-16 ALGORITHM 8-4
CT INPUTS 3-8
CURRENT DEMAND
 actual values 6-10
 logic diagram 7-28
 setpoints 5-77

D

DATE 6-2
DEFAULT MESSAGES 5-29
DEFINITE TIME CURVE 5-93
DEMAND DATA CLEAR 6-9
DEMAND METERING
 actual values 6-9
 setpoints 5-41
DIELECTRIC STRENGTH TESTING 10-5
DIFFERENTIAL
 5th harmonic inhibit 7-3, 7-6
 energization inhibit 7-4, 7-5
 instantaneous differential 5-52, 7-7
 percent differential 5-46, 7-2
 setpoints 5-46
DIFFERENTIAL BLOCKED INDICATOR 4-3
DIFFERENTIAL CURRENT 6-6
DISPLAY 4-2
DNP COMMUNICATIONS
 device profile document 8-92
 implementation table 8-94
 point list table 8-96
 setpoints 5-27
DRAWOUT SEAL 3-3
DRY CONTACT CONNECTIONS 3-10
DYNAMIC CT RATIO MISMATCH 5-3

E

ELEMENTS
 introduction 5-45
 setpoints 5-45
ENERGIZATION DETECTION SCHEME 10-19
ENERGIZATION INHIBIT 5-49
 logic diagram 7-4, 7-5
ENERGY 6-12
ENERGY DATA CLEAR 6-12

ENTER KEY 4-5
ESCAPE KEY 4-5
EU DECLARATION OF CONFORMITY B-1
EVENT CAUSES 6-16
EVENT DATA RESET 6-13
EVENT RECORDER 6-13, 8-11
EVENT RECORDS...6-13
EVENT TYPES 6-16

F

FACTORY SERVICE...5-90
FAULT VALUES 5-90
FIGURE LIST A-1
FIRMWARE
file format 9-8
upgrading... 9-8
FLASH MESSAGES 6-23
FLEXCURVES 5-37, 11-4
FLEXLOGIC
example 5-82, 5-83
gates 5-81
input types 5-81
introduction 5-80
ouput types 5-80
rules 5-82
FREQUENCY
actual values 6-8
commissioning 10-34
logic diagrams 7-20
setpoints 5-65
FREQUENCY DECAY
logic diagram 7-21
setpoints 5-66
testing 10-39, 10-40
FRONT PANEL 4-1
FRONT PANEL PORT 3-13

G

GROUND DIFFERENTIAL CURRENT 6-6
GROUND INDICATOR 4-4
GROUND INSTANTANEOUS OVERCURRENT
logic diagrams 7-15, 7-16
setpoints 5-58
testing 10-28, 10-29
GROUND OVERCURRENT SETPOINTS 5-57
GROUND TIME OVERCURRENT
logic diagram 7-14
setpoints 5-57
testing 10-27

H

HARMONIC CONTENT 6-7
HARMONIC DERATING
actual values 6-8
correction..5-53
logic diagram 7-26
setpoints 5-71
testing 10-44
HARMONIC INHIBIT 5-49
HARMONIC SUB-COMPONENTS.................................6-7
HARMONICS 5-37, 5-70
HELP KEY...4-6
HI-POT TESTING 3-14
see DIELECTRIC STRENGTH TESTING
HOTTEST-SPOT LIMIT
logic diagram 7-32
setpoints 5-72
testing 10-42

I

IAC CURVES.. 5-95, 5-96
IEC CURVES.. 5-93, 5-94
IN SERVICE INDICATOR 4-2
INDICATORS
see LEDs and entries for individual indicators
INPUTS
AC voltage 3-8
commissioning 10-8
specifications 1-5
INSERTION 3-2
INSTALLATION
setpoints 2-6, 5-30
software 9-5
INSTANTANEOUS DIFFERENTIAL
logic diagram 7-7
setpoints 5-52
testing 10-20
INSULATION AGING 10-42
setpoints 5-72, 5-73
INVERSE CURVE 1 5-97
INVERSE CURVE 2 5-98
INVERSE CURVE 3 5-99
IRIG-B 3-14

K

KEYPAD
actual key 4-5
control keys 4-5
enter key 4-5
escape key 4-5
help key 4-6
message keys 4-5
next key 4-6
number keys 4-6
reset key 4-6
setpoint key 4-5
value keys 4-5
KNEEPOINT 10-17

L

LEDs
alarm 4-4
description 4-2
differential blocked 4-3
ground 4-4
in logic diagrams 7-1

in service 4-2
load-limit reduced 4-3
LOCAL 4-3
message 4-3
phase A 4-4
phase B 4-4
phase C 4-4
pickup 4-4
self-test error 4-2
setpoint group 1 4-3
setpoint group 2 4-3
setpoint group 3 4-3
setpoint group 4 4-3
system status 4-3
test mode 4-2
transformer de-energized 4-3
transformer overload 4-3
trip 4-4
LIST OF FIGURES A-1
LIST OF TABLES A-2
LOAD-LIMIT REDUCED INDICATOR 4-3
LOCAL INDICATOR 4-3
LOCAL RESET MODE 10-15
LOGIC 7-1
LOGIC DIAGRAMS 7-1
LOGIC INPUTS 3-9, 5-43, 6-2
commissioning 10-6
LOSS OF LIFE 6-10
LOSS OF LIFE LIMIT 7-34
LOSS-OF-LIFE 5-72
LOSS-OF-LIFE LIMIT 5-75, 10-42
LOW VOLTAGE WINDING RATING 5-34

M

MANEUVERING 2-1
MEASUREMENT UNITS 7-1
MEMORY MAP 8-17
MESSAGE INDICATOR 4-3
MESSAGE KEYS 4-5
METERING 6-4
MINIMUM OPERATING CURRENT 10-43
MINIMUM PICKUP 10-14, 10-20, 10-43
MODBUS
data formats 8-74
data frame format 8-2
data packet format 8-3
description 8-2
error codes 8-10
exception responses 8-10
function code 03h 8-6, 8-15
function code 04h 8-6, 8-15
function code 05h 8-7, 8-15
function code 06h 8-8, 8-16
function code 10h 8-9
memory map 8-17
memory map data formats 8-74
memory map organization 8-16
supported function codes 8-5
user map 8-12

N

NEGATIVE SEQUENCE CURRENT 6-5
NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT
logic diagram 7-19
setpoints 5-64
testing 10-33
NEGATIVE SEQUENCE OVERCURRENT 5-63
NEGATIVE SEQUENCE TIME OVERCURRENT
logic diagram 7-18
setpoints 5-63
testing 10-31
NEUTRAL INSTANTANEOUS OVERCURRENT
logic diagrams 7-12, 7-13
setpoints 5-56
testing 10-26, 10-27
NEUTRAL OVERCURRENT 5-55
NEUTRAL TIME OVERCURRENT
logic diagram 7-11
setpoints 5-55
testing 10-24
NEXT KEY 4-6
NUMBER KEYS 4-6
NUMERICAL SETPOINTS 2-3

O

ONLOAD TAP CHANGER 5-36
OPERATING TIME 10-16
OPTIONS
ordering 1-4
ORDER CODES 1-4
OUTPUT RELAYS 6-3
commissioning 10-6, 10-7
default flexlogic 5-84
description 3-11
logic diagram 7-30
setpoints 5-84, 5-87
typical wiring 3-11
OUTPUTS
specifications 1-9
OVERCURRENT
ground instantaneous 5-58
ground time 5-57
logic diagrams 7-8
negative sequence instantaneous 5-64
negative sequence time 5-63
neutral instantaneous 5-56
neutral time 5-55
phase 5-52
TOC curves 5-91
OVEREXCITATION
5th harmonic level 5-68, 7-23
description 5-68
setpoints 5-68
volts-per-hertz 5-69, 7-24
OVERFREQUENCY
logic diagram 7-22
setpoints 5-67
testing 10-37
OVERVIEW 1-1

P

PANEL CUTOUT 3-1
PASSCODE
  changing 2-6
  security 2-6, 2-7
  setpoints 5-24
PERCENT DIFFERENTIAL
  dual-slope characteristic 5-47
  harmonic restrained 10-14
  logic diagram 7-2
  operating principle 5-47
  setpoints 5-46
  zones of protection 5-60
PHASE A INDICATOR 4-4
PHASE ANGLE CORRECTION.................................... 5-8
PHASE B INDICATOR 4-4
PHASE C INDICATOR 4-4
PHASE INSTANTANEOUS OVERCURRENT
  logic diagrams...7-9, 7-10
  setpoints 5-54
  testing 10-23, 10-24
PHASE OVERCURRENT 5-52
PHASE SEQUENCE 3-8
PHASE SHIFTS 5-23
  description 5-23
  three-phase transformers... 5-6
PHASE TIME OVERCURRENT
  logic diagram 7-8
  setpoints 5-52
  testing 10-21
PHASORS
  ABC sequence 5-6
  ACB sequence 5-7
PICKUP INDICATOR 4-4
PLACING THE RELAY INTO SERVICE.....................10-46
POSITIVE SEQUENCE CURRENT 6-5
POWER 6-11
PREFAULT VALUES...5-89
PREFERENCES 5-25
PRODUCT INFO...6-17
PROGRAM PORT 4-4
PROTECTION ELEMENTS
  specifications 1-6
  target messages...6-20
PROTECTION SCHEMES
  5th harmonic 5-68, 10-41
  energization detection 10-19
  features 1-2
  frequency decay 5-66
  frequency decay rate 10-39, 10-40
  ground instantaneous o/c..5-58
  ground instantaneous overcurrent 10-28, 10-29
  ground time o/c 5-57
  ground time overcurrent..10-27
  harmonic restrained percent differential..................10-14
  instantaneous differential 5-52, 10-20
  insulation aging 5-73, 10-42
  negative sequence instantaneous o/c 5-64
  negative sequence instantaneous overcurrent 10-33
  negative sequence time o/c 5-63
  negative sequence time overcurrent........................10-31
  neutral instantaneous o/c...5-56
  neutral instantaneous overcurrent 10-26, 10-27
  neutral time o/c 5-55
  neutral time overcurrent..10-24
  overfrequency 5-67, 10-37
  phase instantaneous o/c 5-54
  phase instantaneous overcurrent 10-23, 10-24
  phase time o/c 5-52
  phase time overcurrent 10-21
  restricted ground 5-59
  restricted ground fault 10-30
  THD level 5-70, 10-43
  underfrequency 5-65, 10-35, 10-37
  volts-per-hertz 5-69, 10-41

R

REAR TERMINAL ASSIGNMENTS 3-5
REAR TERMINAL LAYOUT 3-4
RELAY INSERTION 3-3
RELAY WITHDRAWAL...3-2
REMOTE RESET MODE 10-15
RESET KEY 4-6
RESETTING 5-28
RESISTANCE GROUNDED WYE WINDING................5-59
RESTRAINT CURRENT 6-6
RESTRICTED GROUND
  implementation...5-61
  logic 7-17
  setpoints 5-59
  settings example 5-61
  testing 10-30
  zones of protection 5-60
REVISION CODES 6-17
RS232 COMMUNICATIONS 3-13, 9-4
RS422 COMMUNICATIONS 3-12, 3-13
RS485 COMMUNICATIONS 3-12, 9-4
RTD
  calibration 10-11
  driver/sensor 3-10
  measured temperature 10-12
  resistance vs. temperature......................................5-39

S

S1 745 SETUP 5-24, 11-1
S2 SYSTEM SETUP 5-33, 11-2
S3 LOGIC INPUTS 5-43, 11-5
S4 ELEMENTS 5-45, 11-6
S5 OUTPUTS 5-80, 11-18
S6 TESTING 5-87
SCHEME LOGIC 7-1
SCRATCHPAD 5-30
SELF-TEST ERROR INDICATOR 4-2
SELF-TEST ERRORS 6-3, 6-21, 6-22
SELF-TEST RELAY 7-31
SERVICING..10-46
SETPOINT ENTRY 5-2
SETPOINT GROUP 5-46
SETPOINT GROUP 1 INDICATOR 4-3
SETPOINT GROUP 2 INDICATOR 4-3
SETPOINT GROUP 3 INDICATOR 4-3
SETPOINT GROUP 4 INDICATOR 4-3

SETPOINT GROUPS 5-1
SETPOINT KEY 4-5
SETPOINT WRITE ACCESS 5-2
SETPOINTS
  745 setup 5-24
  access jumper 2-3
  changing 2-3
  elements 5-45
  entering through software 9-9, 9-10
  groups 5-1
  in logic diagrams 7-1
  loading through software 9-9
  logic inputs 5-43
  numerical 2-4
  outputs 5-80
  saving to a file 9-7
  system setup 5-33
  testing 5-87
  text-based 2-5
SIMULATION 5-88
SIMULATION MODES 5-89
SINGLE LINE DIAGRAM 1-3
SOFTWARE
  actual values 9-11
  communications 9-6
  description 9-1
  entering setpoints 9-9, 9-10
  installation 9-5
  loading setpoints 9-9
  menus 9-2
  requirements 9-2
  saving setpoints 9-7
  toolbar summary 9-3
SOLID STATE OUTPUT TEST CIRCUIT 10-16
SOLID STATE TRIP OUTPUT 3-11
SPECIFICATIONS 1-5
STATUS INDICATORS 4-2
SYSTEM STATUS INDICATORS 4-3

T

TABLE LIST A-2
TAP CHANGER 6-8
TAP CHANGER FAILURE 5-79, 7-35
TAP MONITOR FAILURE 10-42
TAP POSITION 10-13
TAP POSITION INPUT 3-10, 5-5
TARGET MESSAGES 6-19
TECHNICAL SUPPORT 6-17
TEMPERATURE
  ambient 5-39, 6-10, 10-11, 10-12
  RTD 10-12
TEST MODE INDICATOR 4-2
TEST SETUP 10-21
TEXT SETPOINTS 2-5
THD LEVEL
  logic diagram 7-25
  setpoints 5-70
  testing 10-43
TIME 6-2
TIME DELAYS 7-1
TIME-OVERCURRENT CURVES
  see TOC CURVES
TIMER SETTINGS 11-23
TIMERS 5-86
TOC CURVES
  ANSI 5-91, 5-92
  definite time 5-93
  IAC 5-95, 5-96
  IEC 5-93, 5-94
TOTAL HARMONIC DISTORTION
  see THD
TRACE MEMORY 5-85, 8-11
TRANSFORMER 5-33
TRANSFORMER DE-ENERGIZED INDICATOR 4-3
TRANSFORMER OVERLOAD 5-78, 7-29, 10-45
TRANSFORMER OVERLOAD INDICATOR 4-3
TRANSFORMER POLARITY 3-8
TRANSFORMER TYPES 5-10
TRANSFORMER TYPES TABLE 5-10
TRANSFORMER-TYPE SELECTION 10-9
TRIP INDICATOR 4-4
TYPICAL WIRING DIAGRAM 3-6

U

UNDERFREQUENCY
  logic diagram 7-20
  setpoints 5-65, 5-69
  testing 10-35, 10-37
UPGRADE OPTIONS 5-31, 5-32
USER MAP 8-12

V

VALUE KEYS 4-5
VIRTUAL INPUTS 5-44, 6-2
VIRTUAL OUTPUTS 5-85, 6-3
VOLTAGE 6-9
VOLTAGE INPUT 3-8, 5-38
  commissioning 10-9
VOLTS-PER-HERTZ
  logic diagram 7-24
  setpoints 5-69
  testing 10-41

W

WARRANTY C-1
WEBSITE 9-5
WET CONTACT CONNECTIONS 3-10
WINDING CURRENT 6-4
WIRING DIAGRAM 3-6
WITHDRAWAL 3-2
WYE / DELTA TRANSFORMER 5-8

Z

ZERO-SEQUENCE COMPONENT REMOVAL 5-9, 10-10
ZERO-SEQUENCE CT INSTALLATION 3-8
ZERO-SEQUENCE CURRENT 6-5

NOTES

GE POWER MANAGEMENT WEBSITE

The latest product information for the 745 Transformer Management Relay is available on the Internet via the GE Power Management home page:

http://www.GEindustrial.com/pm

This site provides access to the following customer services:

- Digital Products Directory
  A brief description of products can be viewed online.
- Product Catalog
  Individual product brochures can be downloaded and printed
- Product Selector Guide
  A graphical tool for finding the product you are interested in
- Sales Offices
  A complete listing of world-wide sales offices
- Technical Support
  Complete contact information is available
- Instruction Manuals
  Manuals for many products are now available online
- GE Product Software
  The latest working versions of product software
- Technical Drawings
  Many technical drawings are available in either AutoCAD, CorelDRAW, or PDF formats.
- Order Codes
  Order codes for many products can be downloaded and printed
- Technical Publications
  Papers related to power management

Much more is also available. Visit us online at: **www.GEindustrial.com/pm**.