GE Power Management

Bus Bar Protection

BUS1000

Instructions

GEK 98514B

ISO 9000 Registered ISO 9000

Anything you can't find?

Anything not clear enough?

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1. DESCRIPTION

The BUS1000 is a high-speed static protection system aimed at detecting phase to phase and to ground faults in buses at high voltage substations.

The main unit is an overcurrent three phase differential relay with percentage restraint and stabilization resistors.

The relay is provided with a very sensible overcurrent differential unit which provides an alarm and blocks the output of any protection trip in case of an accidental disconnection of any of the measuring units' inputs during the normal operation of the substation.

As an option, the protection system may include a detection device for breaker failures, associated to the differential protection and overcurrent units for individual supervision of tripping from each breaker.

The modular feature of the system allows to carry out various configurations adapted to the specific characteristics of the buses to be protected (multiple or single-bus, breaker and one half, special dispositions, etc.)

Depending on the complexity of the application, the protection system is housed in one or more 19 inches standard racks or, as an option, in complete cabinets.

The outstanding features of the BUS1000 system are:

- Does not need dedicated secondary
- Signalling and tripping contacts independent of location.
- Redundant measuring circuits for self-checking.
- Measuring "units" for line currents and operation and restraint magnitudes in order to ease the set up and maintenance.
- An optional testing system to check the operation of the alarm and measuring units in normal operation conditions.
- Optional overcurrent units for the supervision of the breaker tripping in every position.
- An optional breaker failure detection device. (Several steps logic available)
- Optional lockout relays (86)

The information given hereafter does not intend to cover all the different details or variations of the described equipment neither does it intend to foresee any event that may arise during its set up, operation or maintenance.

Should any further information be requested, or in the event of a specific problem that may need any information other than that provided, refer to GE POWER MANAGEMENT, S.A.

2. TECHNICAL SPECIFICATIONS

2.1. MODEL LIST

BUS	1	-	-	-	-	-	-	-	-	-	-	DESCRIPTION
		1										Single busbar
		2										Double busbar
		3										Split busbar
		4										Triple busbar
			-	-								Specify the number of lines + bus coupler
					A							Without cabinet
					D							In cabinet (2000mmx800mmx800mm)
						1						Without breaker failure
						2						With breaker failure
							2					With test rack & short-cicuitable resistors
							3					Without test rack & short cicuitable
								1				50 Hz
								2				60 Hz
									C			Auxiliary voltage: 125 Vcc.
									D			Auxiliary voltage: 250 Vcc.
									E			Auxiliary voltage: 220 Vcc.
									F			Auxiliary voltage: 110 Vcc.
										-	-	Correlative numbers

Because of the great variety of options and configurations in the BUS1000 systems, a complete list of the models is not included in this document. The specific information corresponding to the customer's model is provided with the chosen equipment. The most usual types of models as well as the basic system components are described below:

- SINGLE-BUS SYSTEMS
- DOUBLE BUS WITH COUPLING SYSTEMS
- SPLIT BUS SYSTEMS
- BREAKER AND A HALF SYSTEMS
- DOUBLE BREAKER SYSTEMS
- MAIN BUS SYSTEMS WITH TRANSFERENCE BUS
- SYSTEMS FOR SPECIAL CONFIGURATIONS

2. TECHNICAL SPECIFICATIONS

Each of the systems may include the following functions:

Basic model .... DIFFERENTIAL PROTECTION
Option 1 .... OVERCURRENT TRIPPING SUPERVISION
Option 2 .... BREAKER FAILURE (Several steps logic available upon request)
Option 3 .... TEST UNIT

System packaging options:

A .... Board mounted standard racks
D .... Complete cabinets

2.2. MECHANICAL

- **Mechanical packing** in a 19” inch 4 units high stainless steel box.
- IP51 Grade **Protection** (IP55 housed in a cabinet).
- Rear connection by means of 16 strips of 8 terminals or 16 strips of 12 terminals. Stair layout of the terminal blocks if mounted in a cabinet.
- **Dimensions**:

  Rack: 484 mm x 179 mm x 349 mm.

  Cabinet: 800 mm x 800 mm x 2000 mm (Pedestal: 750x800x100 mm).
- **Ambient humidity**: up to 95 without condensing.
- **Temperature**:

  Operation: -20º to + 55º C
  Storage: -40º to + 65º C

2.3. ELECTRICAL

- **Frequency**: 50/60Hz
- **Auxiliary voltage**: 110 Vdc or 125 Vdc or 220 Vdc
- **Operation ranges**: 80%to 120% of nominal values
- **Nominal current**: 1 amp
- **Thermal capacity current circuits**:

  Input circuits:

  Continuously.. 2 x In

  For three seconds .... 50 x In

  For one second ....100 x In

  Total current going through the bar:

  Continuously...20 x In
- **Thermal capacity for voltage circuits:**

  Continuous: .... 2.5x Vn

  During 1min: 3.5xVn
- **Loads**:

  Current: 15VA (depending on the tap of the auxiliary transformer used)

  Voltage: 0.2 VA at Vn= 63 V

- **Requirements for Line Current Transformers**
  - Relation between the maximum and minimum C.T. ratios in all the positions connected to the same bus ....10 maximum
  - Minimum saturation voltage required for main C.T's (for IN = 5 amps) 100 V
  - Intermediate Current Transformers: Normal ratios 5/2-1.33-1-0.5-0.2. Other ratios, including multiple ratios are available according to application.
- **Stabilization Resistance**: 250 Ohms.
- **Restraint Percentage**: Adjustable form 0.5 to 0.8 in 0.1 steps
- **Sensitivity**: (for internal faults): Adjustable form 0.2 to 2.0 amps
- **Operation time** (output relay included): Below 10 milliseconds
- **Alarm Unit**:

  Operation threshold: 0.027 Amps.

  Operation time: 10 Seconds.
- **Short-circuit link for coupling currents**: operation time adjustable between 100 and 1600 milliseconds.
- **Line Trip Supervision Units (optional)**
  - Independent Units: Operation threshold between 0.2 and 3.3 amps
  - Dependent units: Operation threshold between 25 and 100% of the breaker failure unit adjustment.
- **Breaker failure units (optional):**

  Operation threshold between 0.2 and 3.3 amps

  Reset time below 12 milliseconds

  Discrimination time between 100 and 730 milliseconds
- **Infeed Source**: 125 VDC. Amps systems consumption in mA.

	Normal	Tripped
Single bus system	280	670
Trip output (per position)	-	65
Supervision and breaker Failure units (per position)	70	140

- **Trip contacts**:

  Make and carry for trip cycle (according to ANSI C37.90)........30 amps

  Break: Resistive 180 VA at 125/250 VDC.

  Break: Inductive 60 VA at 125/250 VDC.
- **Accuracy**:

  Operation current: 5%

  Operation time: 5%

2.4. ELECTROMAGNETIC COMPATIBILITY STANDARDS

The BUS1000 units comply with the following standards, including the GE standard for insulation and electromagnetic compatibility and the standard required by the EU directive 89/336 for the CE marking, according to the harmonised European standard:

Test	Standard	Class.
• Insulation	IEC 255-5	2 kV 50/60 Hz 1 minute
• Impulse 1.2/50 ms	IEC 255-5	5 kV, 0.5 J
• Interference 1 Mhz	IEC 255-22-1	2.5 kV common, 1 kV differential
• Electrostatic discharge	IEC 255-22-2 EN 61000-4-2	Class IV: 8 kV contact, 15 kV air
• Fast Transient	IEC 255-22-4 EN 61000-4-4	Class IV: 4 kV
• Magnetic fields	EN 61000-4-8	30 TA/m
• Radiated Emisivity	EN 50081-2	Class A
• Immunity RF radiated	EN 50082-2 (Items 1.1 &1.2)	10V/m26-1000Mhz 1kHz AM80% 10 V/m 900 Mhz 200 Hz PM 50%
• Immunity RF conducted	EN 50082-2	10 V 0.15-80 Mhz 1 kHz AM 80% (Items 2.1, 3.1, 4.1 & 6.1)

• The units comply as well with the following ANSI standards:

C37.90	(Standard for relays and relay systems)
C37.90.1	(Surge withstand capability)
C37.90.2	(Withstand capability to radiated interference)

3. OPERATION PRINCIPLES

3.1. BASIC PRINCIPLE

The measurement method relies on Kirchhoff´s current law.

This law states that the vectorial sum of all currents flowing into a closed area must be zero. This law applies, in the first instance, to dc current. It applies to ac current for instantaneous values. Thus, the sum of the currents in all feeders of a busbar must be zero at any instant in time.

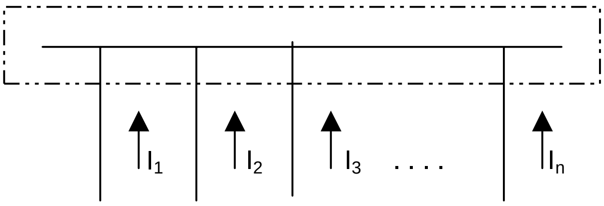


Figure 3.1. *Busbar with “n” feeders*

Assuming that the currents I_1 , I_2 ,I_3 ... I_n flow in the feeders (Fig 3.1) connected to the busbar, the following equation applies in the fault-free condition (the currents flowing towards the busbar are defined as positive, and the currents flowing away from the busbar as negative) :

$$I_1 + I_2 + I_3 \ldots + I_n = 0$$

If this equation is not fulfilled, then there must be some other-impermissible-path through which a current flows. This means that there is a fault in the busbar region.

This law is superior, as the basis for busbar protection, to any other known way of measurement. A single quantity, **the sum of currents**, characterises and can be used to detect faulty conditions. This sum of all currents can be formed at any time and if formed as such, using instantaneous current values, full use of above law can be made. Above law is always valid, whereas with a comparison of only the zero crossing points of the currents or of the current directions may involve phase displacements that would have to be considered accordingly. For instance, in a fault-free three-phase load, the instants of zero current are displaced by 50º or 120º with respect to e. Unbalanced load may produce other displacements. The sum of the currents, on the other hand, remains constantly zero as long as no currents flow through some other path due to a fault.

The above considerations apply strictly to the primary conditions in a high-voltage switching station. Protection systems, however, cannot carry out direct measurements of currents in high-voltage systems. Protection equipment measurement systems, performing the current comparisons, are connected through current transformers. The secondary windings provide the currents scaled down according to the transformation ratio while retaining the same phase relation. Furthermore, the current transformers, due to the isolation of their secondary circuits from the high-voltage system and by appropriate grounding measures, can keep dangerous high voltages away from the protection system.

The current transformers are an integral part of the whole protection system and their characteristics are an important factor for the correct operation of the protection. Their physical locations mark the limits of the protection zone covered by the protection system.

3.2. DIFFERENTIAL UNIT

Figures 1 and 2 represent the simplified connection diagram of the differential protection and its behaviour with internal and external faults respectively, without any saturation on C.T. cores.

Auxiliary intermediate current transformers are aimed at equalising the currents received by the relay for every input position, since the main transformers may have a different transformation ratio. They have been specially designed to provide a homogeneous response (same saturation characteristic) for all the inputs to the measure unit, thus allowing the use of main transformers with different characteristics.

The V_D current is the operation magnitude and it is proportional to the differential current. The V_F voltage is the restraint magnitude and it is proportional to the sum of the currents of all the positions associated to the bus to be protected.

In ideal conditions, for an external fault, current flows through the input circuits of the different positions without differential current; thus, V_D is zero and V_F is equal to twice the value of the fault current, whereas for an internal fault, all the fault current goes through the differential circuit which makes V_D and V_F equal.

Figure 15 shows the block diagram of the percentage restraint differential unit and the supervision differential unit.

For the main measure unit, V_D and V_F voltages are applied to a sum circuit which subtracts from the V_D value part of the V_F restraint voltage value obtaining thus a combined signal which is applied to a level detector. The restraint current ratio K subtracted from the differential voltage is called restraint percentage and it determines the operation characteristic of the unit as well as its sensitivity.

The level detector is a fixed V_O threshold level comparator (factory adjusted), with an operation time of 1.5 milliseconds and a reset time of 40 milliseconds in order to ensure a constant signal in the output relay.

The V_o level of the detector is calculated so that the unit may produce an output when the I_D - K I_F magnitude is over 0.1 Rms. Figure 3 shows the operation characteristic corresponding to this equation.

3.2.1. BEHAVIOUR WITH INTERNAL FAULTS

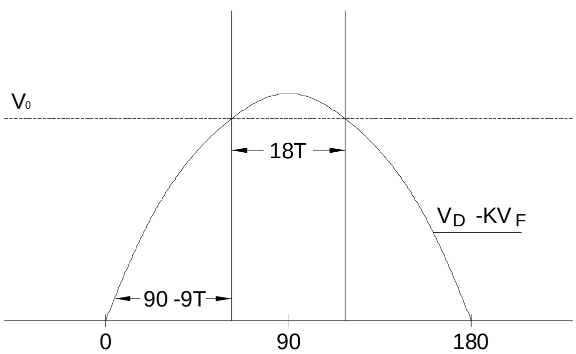
In the case of internal faults, we assume that no current transformer is saturated and therefore the equivalent circuit with its corresponding current distribution is that of fig. 1.

Note that in these conditions all the fault current will pass through the differential unit. From the design of the circuit we have:

$N_{ED} = N_{EF} = N$ (1) Input transformer's ratio

$R_D = R_F = R$ (2) Load resistance of the restraint and differential transformers.

By analysing the behaviour of the differential unit in the first half cycle of the current at a 50 Hz rated frequency in the network we will have:



Where:

V_D = RMS voltage in the differential circuit.
V_F = RMS voltage in the restraint circuit.
V_O= Threshold voltage in the level detector.
I_D = RMS current in the differential circuit.
I_F = RMS current in the restraint circuit.
K= Restraint percent in unit value.
T= Detector time (in ms.).

We will have the following values' ratio:

$$V_D = I_D * N_{ED} * R_D = I_D * N * R$$

$$V_F = I_F * N_{EF} * R_F = I_F * N * R$$

On the other hand, the differential unit will produce an output when the VA value is above the V_O one, that is, when:

$$2*(V_D - K*V_F)*\text{sen}(90-9T) \geq V_O \qquad [5]$$

or what is the same when:

$$I_D - K*I_F \geq V_O*(1/2*\text{sen}(90-9T))*(1/N*R) \qquad [6]$$

The circuit design values are:

V_o = 0.137 V
T = 1.5 ms.
N = 0.01
R = 100 Ω

With these values the equation is reduced to:

$$I_D - K*I_F \geq 0.1 \qquad [7]$$

For an internal fault $I_D = I_F$, so:

$$I_D \geq 0.1/(1-K) \qquad [8]$$

From this equation we obtain the relay's sensitivity in amperes for the different values of K.

3.2.2. BEHAVIOUR WITH EXTERNAL FAULTS

3.2.2.1. Without saturation

During the time prior to the saturation of any of the main C.T's and assuming ideal conditions for an external fault, the fault current flows through input circuits of the various positions without any differential current.

In these conditions the value of $V_D = 0$ and in our case, the value of V_F will be proportional to twice the fault current. See fig. 2.

3.2.2.2. With saturation

In the case of an external fault, saturation may be produced in the current transformers associated to any of the protected bus positions. In this case, the inputs' currents will not be compensated; thus a differential current will be produced which must not lead to the operation of the relay. The combination of the percent restraint operation characteristic together with the R_E stabilization resistance in the differential circuit ensures the correct behaviour of the unit in these circumstances.

The worst case from the point of view of the possibility of false operations with external faults is that of a complete saturation (total absence of signal in the secondary) of only one of the main C.T's while the rest behave correctly.

In our case, the equivalent circuit is shown in fig. 4. Here, the fault current provided by the rest of the current transformers is divided between the totally saturated I_X circuit and the I_D differential circuit in an inversely proportional way to the resistance of every circuit.

Thus, when the R_E resistance value increases in the differential circuit, the differential current flowing erroneously in case of saturation of a current transformer decreases. In the same way, when the K restraint percent value increases, a greater differential current is allowed without providing a trip in the unit since V_F will increase.

3.3. SENSITIVITY EQUATION OF THE PERCENT RESTRAINT UNIT

From fig. 4 we may draw out the following equations.

$$I_D = I_{FAULT} - I_X \quad [9]$$

$$I_D * R_E = I_X * R_{MAX} \quad [10]$$

From (1) and (2) we have:

$$I_{FAULT} = I_D + I_D * (R_E / R_{MAX}) = = I_D * (1 + (R_E / R_{MAX})) \quad [11]$$

$$I_F = I_D * (1 + 2 * (R_E / R_{MAX})) \quad [12]$$

$$I_F = I_{FAULT} + I_X = I_D * (1 + (R_E / R_{MAX})) + I_D * (R_E / R_{MAX}) \quad [13]$$

We find that the unit will produce an output (operate) when:

$$I_D - K * I_F \geq 0.1$$

So:

$$I_D \geq K * I_D * (1 + 2 * (R_E / R_{MAX})) \quad [14]$$

$$I_D * (1 - K * (1 + 2 * (R_E / R_{MAX}))) \geq 0.1 \quad [15]$$

In the same way the unit does not operate when:

$$I_D * (1 - K * (1 + 2 * (R_E / R_{MAX}))) < 0.1 \quad [16]$$

For more security we can say that the unit will not trip if:

$$I_D * (1 - K * (1 + 2 * (R_E / R_{MAX}))) < 0$$

OR

$$1 - K * (1 + 2 * (R_E / R_{MAX})) < 0$$

Thus:

$$1 < K * (1 + 2 * (R_E / R_{MAX})) \quad [17]$$

$$R_{MAX} < K * R_{MAX} + 2 * K * R_E \quad [18]$$

From this we can finally deduce that:

$$R_E > R_{MAX} * (1 - K) / 2K \quad [19]$$

$$R_{MAX} < \frac{2 * K * R_E}{1 - K} \quad [20]$$

The R_E has a fixed value set at 250 Ω, so the R_{MAX} value must be such that the below equation is accomplished in order to avoid false operations with external faults, even in the worst saturation conditions of the main C.T's

3.4. DIFFERENTIAL SUPERVISION UNIT

The supervision differential unit consists of a level detector with similar characteristics to that of the main unit, to which is applied the V_D voltage only, proportional to the differential current. Its operation threshold is directly adjustable in Amps from 0.2 A to 2 A and independently from the K adjustment of the main unit (see block diagram in figure 3).

The combination of both units described provides a great security to the protection, thus guarantying that any failure of a component will not provide a non-desired trip to all the positions associated to the protected bus. Both units must operate simultaneously so that a trip output is produced. In the case where due to a failure only one of the units is operating incorrectly, the alarm unit described below will detect it, thus providing a signalling output and the blocking of the protection.

3.5. ALARM UNIT

The alarm unit associated to the differential protection consists of a very sensitive overcurrent unit (0.027 amps) connected in series to the differential circuit through its own input transformers.

It is aimed at detecting unbalances in the differential circuit due to leaks or accidental disconnection of any of the inputs to the measure unit. It is also provided with a circuit that detects discordance among the outputs of the main measuring units and the outputs of the main measuring and supervision units.

The unit provides a timed output (10 seconds).

Figure 5 shows the block diagram.

3.6. LINE OVERCURRENT AND BREAKER FAILURE SUPERVISION UNITS

These units are optional and may belong to a complete BUS1000 system (current supervision only, breaker failure only or both).

Figures 6 show the block diagrams of a double bus system with both functions for three-phase trip line protection and single-phase trip respectively.

The units are connected in series to the inputs of every position of the bus differential (one for each position), through their own input transducers and signal conditioning. Signals coming from each phase are combined in a selection circuit of the larger before going on to the level detectors of the trip supervision unit (50) and of the breaker failure unit (BF).

The breaker failure unit picks up its timer only when an external signal comes from line protection relays. In the case of lines with single-phase trip protection, the level detector receives only signals from those phases which have been tripped, in order to avoid the operation of the unit with the load current of the non faulted phases. (See drawing 226B6429F20,21,22). Signals 89AY and 89BY provide information to the bus to which the line is connected (double-bus systems), in order to lead the trip to the positions connected to the corresponding bus.

3.7. TEST BOX

As an option, the bus differential protection may be provided with a testing element, whose aim is to check the differential circuit operation (including the stabilization resistors) and the alarm and differential units. These includes the following modules:

- DAL: Alarm board (one per bar).
- DDF: Differential boards (one per pole).
- DRD: Differential output module (one per bar).
- DDI: Differential unit input module (one per bar).

This element is provided with elements (latching relays: 3B/87) for the connection and disconnection of the trip of the differential units (see drawing 22B6429F26).

3.7.1. DESCRIPTION

The test box unit is housed in a 19" rack and consists of the following elements:

- **HLB100** (3B/87 in the schemes) latching relay (one for every differential). This relay inhibits the trips of the corresponding differential units (see drawing 22B6429F26).

- **HLA100** (3P/87 in the schemes) auxiliary relays (one for every differential). This relay is in charge of introducing the test current in the corresponding differential unit (see drawing 22B6429F16).

- **DPR** test module. This module is provided with the following elements:

    - Connection button (green color): This button operates on the HLB100 (3B/87) latching relay allowing the trip output of the differential units.

    - Disconnection button (red color): This button operates on the HLB100 (3B/87) latching relay

    - Test button (white color): This button operates on the HLA100 (3P/87) auxiliary relay following the below sequence:

        a) Disconnection of the trips of the differential unit through the HLB100 (3B/87) latching relay (if connected), while memorising whether it was connected or disconnected. Trips from the breaker failure logic are not disconnected.
        b) It blocks the reset of the HLB100 (3B/87) relay during the whole time the test is being carried out and until all the elements which make up the trip circuits have been reset.
        c) It operates on the HLA100 (3P/87) relay introducing the test current in the differential circuit.
        d) When releasing the button, it carries out the opposite operation firstly disconnecting the test current and connecting secondly (if it were memorised) the trips of the differential units, once the trip circuits have been completely reset.

    - **AL, DIF selector switch**: It allows for selection between the differential unit test and the alarm unit test.

    - **Phase selector switch**: It allows for selection of the phase to be tested.

    - **Current level selector switch**: It allows for selection of three different test current levels.

3.7.2. OPERATION

The testing element, which may be optionally provided with bus differential protection, has been designed to check the alarm and differential units, during maintenance.

In the alarm and differential units test it is not necessary to disconnect the protection through its OFF button. The TEST button itself is, as a step prior to the application of test current, in charge of disconnecting the trips and not allowing for reset until all the elements in the trip circuits have not been reset.

Bear in mind that while doing the test there will come out the Differential Tripping signalling caused by the test, and the Blocking signalling. Do not forget to reset the alarm and the differential modules, whose LED will lit as a probe that each unit has no problem.

3.7.3. DIFFERENTIAL UNITS TEST:

The differential units test will be carried out separately in every phase and with the current level corresponding to the restraint measured in the protection measuring terminals.

Set the AL - DIF selector to the DIF position and we shall then select the phase to be tested and the level corresponding to the restraint, with the appropriate switches.

Once the previous adjustments have been carried out, push the TEST button and check that the selected unit has operated and the unit trip signalling the corresponding LED remains lit.

3.7.4. ALARM UNIT TEST:

The alarm unit test will be carried out separately in every phase. Set the AL - DIF switch to the AL position and we shall then select the phase to be tested with the phase selector switch. In this case the test current is fixed and does not depend on the current level selector switch.

Once the previous adjustments have been carried out, push the TEST button and do not release it until the unit operates (usually 10 seconds). Check that the unit selected has operated and the unit trip signalling LED remains on.

4. APPLICATION

The BUS1000 system has been designed for bus protection in high voltage substations from 30 KV to 500 KV. Its main characteristics are:

- ***Short operation time***, especially where fault levels are high, in order to minimise damage to the switchgear and assist system stability. The BUS1000 is characterised by a high speed selective detection and clearing of any fault produced in the protected area.

- ***Careful design to operate on internal faults***. Busbar faults are rear, only by regular comprehensive routine testing of the BUS1000 can the desired reliability be achieved.

- ***Remain stable during all external faults***. Since many more faults occur externally to busbars than internally, busbar protection is called upon to stabilise many more times than to operate. The protection stability (correct operation with severe external faults that result in a saturation of one of the line current transformers), is assured by selecting the adequate restraint percentage, depending only on the total resistance of the saturated circuit seen from the relay.

- ***Discriminate correctly*, **that is decide on which section of the busbars the fault has occurred, and then trip rapidly only those circuit breakers connected to that section.

- ***Immune from misoperation***.

- ***The protection does not require the use of dedicated current transformers***, neither need the latter be of the same relation and characteristics for all the positions associated with the protected bus. Special intermediate current transformers with the appropriate characteristics and relation are provided as part of the protection system. This BUS1000 feature makes its application possible in existing facilities.

- The BUS1000 system is provided for its application in double bar arrangements with air switches per each position, with latching relays. These relays type HLB connects the secondary currents of the auxiliary CT's (1 Amp. rated current) to the input of its corresponding differential unit (the same bar to which the position is connected.

4.1. SELECTION GUIDE

In order to select adequately the protection system required, the following data must be considered:

- System frequency
- Auxiliary infeed voltage
- Bus disposition
- Transformer relation and characteristics (including burdens and cable lengths) of the current transformers for each position
- Optional functions required:
    - Position overcurrent supervision
    - Breaker failure logic
    - Tests system
    - Housing in separate 19-inch racks or in complete cabinets.

4.2. CALCULATION OF SETTINGS

For a correct application of the BUS1000 protection system and selection of its adjustments, the following points must be considered:

4.2.1. MAIN CURRENT TRANSFORMERS

The BUS1000 system ***does not require the use of dedicated current transformers*** for bus differential protection. Current transformers with positions associated to busses may be of different types and ratios.

Check that the relation between the highest and lowest transformation ratios of the current transformers associated with the protected bus is not greater than 10.

Check that the saturation voltage in every current transformer is at least equal to the quotient between 500 V and the transformation ratio of the auxiliary transformer connected to it. For example, for a position with an auxiliary transformer of a 5/1 ratio, the saturation voltage of the main current transformer must be equal or greater than 100 Volts.

4.2.2. INTERMEDIATE AUXILIARY CURRENT TRANSFORMERS

The transformation ratio of the auxiliary transformers provided for every position must be selected in such a way that the global transformation ratio (resulting from the relation of the main transformers multiplied by the auxiliary transformers) for every position associated to the busses to be protected is the same.

The first step to be taken is to start with the position whose main transformer has the greatest ratio, selecting the lowest possible ratio for its auxiliary transformer, but without overloading the input to the bus protection relay (2 I_N maximum).

As an example, for a bus whose positions are provided with current transformers with 1000/5, 600/5 and 300/5 ratios, 5/1.67, 5/1 and 5/0.5 ratios will be selected respectively. This selection will provide a 600/1 global ratio for bus protection and will result in a full load current of 1.67 amps for inputs corresponding to the circuits with CT ratio of 1000/5 A (full load primary current of 1000 A).

Check that the total of the currents of all the positions applied to the differential protection in maximum current conditions going through the busses is not above 20 I_N.

The auxiliary transformers must be placed preferably as near as possible from the main current transformers, in order to reduce the cable resistance seen by the differential protection and thus allow a lower stabilization resistance value or a lower restraint value. This arrangement also reduces the possibility for an accidental opening of the main current transformers secondary circuit. Fig 17 represents the secondary saturation characteristic of the auxiliary transformers.

4.2.3. MEASUREMENT OF K RESTRAINT PERCENTAGE

Figure 1 shows a simplified diagram of the differential unit and its operation with an internal fault.

Figure 3 shows the operation characteristic of the BUS1000 system percentage restraint differential unit, whose equation is:

$$I_D > K\ I_F + 0.1$$

The K restraint percentage value is defined as the ratio between the current needed in the differential circuit for the operation of the relay I_D and the total in absolute values of all the currents in the I_F relay input circuits (not the current going through the bus).

This unit's sensitivity for internal faults (differential current equal to restraint current) depends on the K adjustment selected according to the table:

K	SENSITIVITY (A)
0.5	0.2
0.6	0.25
0.7	0.33
0.8	0.5

The selection of the K value is related, as will be shown below, to the R_E (stabilization resistance in the differential circuit, 250 Ω). The value of the K required for a complete stability of protection for external faults, which may produce saturation in any of the current transformers.

The K value must be selected in order to obtain the required sensitivity for protection according to the fault 's minimum current.

4.2.4. MEASUREMENT OF R_{MAX}

Figure 9 shows a simplified diagram of the differential unit and its operation on an external fault that produces saturation in the faulted line current transformer.

The selection of the adequate stabilization resistance value in the differential circuit and the operation characteristic of the measuring unit percentage restraint, cause a lack of sensitivity in the protection in these conditions if the following equation is true:

$$R_E > \frac{R_{MAX}\,(1-K)}{2K}$$

R_{MAX} being the total resistance seen from the relay terminal supposing the main current transformer is completely saturated, for the most unfavourable position (greatest resistance value).

The measuring of R_{MAX} must be done calculating the value of R for every position:

$$R = (RsTI + Rp)(NTIX)^2 + Rs$$

Where:

RsTI Secondary resistance of the main transformer

Rp Total resistance (wires and other connected circuits)between the main transformer and the auxiliary transformer
NTIX Transformation ratio of the auxiliary transformer
Rs Total resistance between the auxiliary transformer and the relay

The highest R value found will be considered as R_{MAX}

R values can be determined through direct resistance measurements from the relay terminals, short-circuiting the main current transformer secondary. It is recommended to include these measurements in the protection set up guides.

R_E = 250 Ω, then the values of R_{MAX} should be:

$$R_{MAX} < \left(\frac{NTIX}{NTGL} \right)^2 * 250 * K_X$$

where:

$K_X = 2K/(1-K)$

NTIX: Transformation ratio of the auxiliary transformer

NTGL: Global transformation ratio.

As described in the K RESTRAINT PERCENTAGE MEASUREMENT, if the calculation of the required RS indicates a value above 250 Ω (maximum protection range), the K adjustment value will be increased, resulting in a modification of the protection sensitivity.

4.2.5. ADJUSTMENT OF THE SUPERVISION DIFFERENTIAL UNIT

The supervision unit included in the differential protection is an overcurrent unit independently adjustable between 0.2 and 2 amps. Both the main differential unit and the supervision unit described must operate so that the bus differential relay may trip.

This unit has a double purpose. Firstly, it provides the relay with security, thus avoiding any false trips which may be produced in the case where one of its components should fail; and secondly, it makes it possible to limit the sensitivity of the protection (for example, if the protection operation is to be avoided in the case where the overcurrent transformer secondary circuit opens up) without modifying the restraint characteristics of the main unit.

Should there be no need to limit the relay sensitivity, the adjustment of this unit must be equal to the operation value of the main unit, determined be the selected K unit.

5. HARDWARE DESCRIPTION

WARNING

The BUS1000 module incorporates electronic components that might be affected by electrostatic discharge currents flowing through certain component terminals. The main source of electrostatic discharges is human body, especially under low humidity conditions, with carpet floors or isolating shoes. If such conditions are present special care should be taken while manipulating BUS1000's modules and boards. Operators, before even touching any component, must make sure that their bodies are not charged by either touching a grounded surface or by using an antistatic grounded wrist bracelet.

The following hardware description is general, and includes those relevant aspects that are common to the different equipment included in the BUS1000 system.

5.1. CABINETS

BUS1000 systems are provided in complete cabinets. They are made up of standard 19 inches wide and four units high racks, fully wired to connecting blocks placed in the back. Connections between the different cases are achieved only from their connecting blocks.

All the auxiliary elements, such as stabilization resistors, supply resistors, etc, are provided by the factory in the cabinets, except for the intermediate adapting auxiliary transformers. These are provided separately for their set-up near the main transformers, or in the boards to which their secondary currents are wired for every position.

The cabinets are provided with a transparent front gate and a back gate, both removable for an easy access to the cabinet during its installation.

Figure 23 shows the dimensions of the cabinets.

5.2. PANEL MOUNTED RACKS

The racks provided separately for the installation of BUS1000 board mounted systems are standard, 19 inches wide and their dimensions are shown in figure 22.

The external connections are provided in terminal blocks mounted in the rear part of the rack.

The front cover is made up of plastic material and fits over the case making pressure over a rubber joint located around the enclosure. This produces a tight proof sealing avoiding the entrance of dust. The resetting of the targets is achieved without having to take off the cover, through pushbuttons.

The modules provided with the various protection functions are assembled vertically on the racks. Several types of modules are available depending on their type of installation and extractability.

Name	**Description**	**Modules**
BBD	Single bus differential protection (6 positions) (figure 7.1)	3 DDF 1 DAL 1 DDI 1 DRD 3 DFI 1 DRS
BBR	Input and output modules for additional positions, Maximum: 12 positions per rack.	6 DFI 2 DRS
BZC	latching auxiliary units for current switching in double bus systems. Maximum: 5 positions per	10 HLB100
BTR	Optional test rack for single or double bus systems (figure 7.3)	1 DPR 2 HLB100 2 HLA100
BFR	Supervision and breaker failure overcurrent relay Maximum:5 positions per rack. (figure 7.4)	5 SFI 5 MFI
BAR	Accessory functions	1 DTE 6 HLB100

Figure 7.1 *BBD RACK*

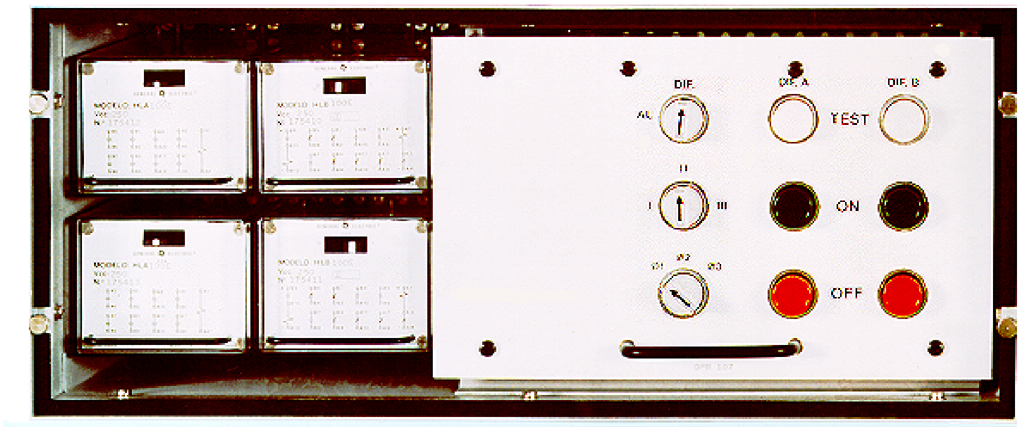


Figure 7.2 *BTR RACK*

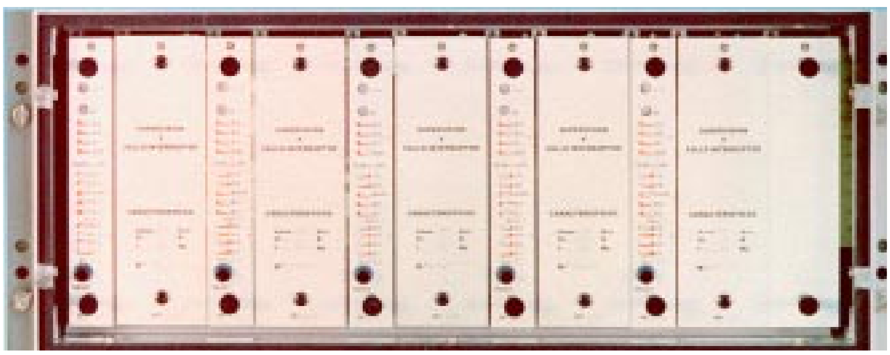


Figure 7.4 *BAR RACK*

Figure 7.5 *BFR RACK*

5.3. MODULES

All the modules are identified by means of a number located in the front plate, which specifies its function and characteristics.

The various configurations available in a bus protection system are carried out combining the number of modular components requested in order to obtain the whole of the desired functions and the number of input and output circuits requested. The BUS1000 is a flexible and modular system made up of the components described below.

The different types of modules are:

NAME	Description	Width Inches	Draw-out
DDF	1 pole, differential unit board	1	YES
DAL	3 poles, alarm unit board	1	YES
DDI	Differential unit input module	2	NO
DRD	Differential unit output module	2.5	NO
DFI	2 lines input module	2	NO
DRS	6 lines tripping output module	2	NO
SFI	1 line breaker failure and supervision unit board	1	YES
MFI	1 line breaker failure and supervision output and input board	2	NO
DTE	Multifunctional module which gathers the following functions: Reduction to single differential, coupling closing system, B.F. general tripping, permanent signalling of differential tripping.	6	NO
DPR	Testing unit module	9,5	NO
MDF	B.F. general tripping module (single bus)	1.5	NO
BPP	Signalling reset module	2	NO

5.3.1. PRINTED CIRCUIT BOARDS

Each module consists of a printed circuit board with a front plate mounted on it through two supports. Over this plate, there are two elements that fit into two nuts on the box that serve the purpose of pulling the module out of the rack or pushing it into it.

The electrical connections are made through a male connector which fits into a female connector located in the box.

5.3.2. OUTPUT MODULES

They are similar to the printed circuit modules except for their structure which consists of a metal plate for the assembly of the output relays and other components. They also use a different connector.

5.3.3. NON- REMOVABLE MODULES

They are used for assembling current transformers input transducers and other components.

They consist of a plate which supports their various components and several connecting blocks with the rest of the modules and with the system.

In order to remove these modules it is necessary to reach the rear part of the rack unscrewing its rear cover and removing the screws which hold the module as well as removing the connecting blocks. The module is drawn out though the front part of the rack. This operation has to be done with the protection system completely out of service and with its current inputs short-circuited.

5.3.4. LATCHING AND AUXILIARY RELAYS

They are unpluggable with their own connection bases located and wired in the racks.

They are provided with their own transparent cover and are removed through the front part of the rack.

They must not be removed without having previously checked that the protection system is out of service and that their current inputs are short-circuited, given that their contacts may be part of the secondary circuit of the current intermediate transformers, which means that their removal could mean the opening of these circuits; this would cause the protection to trip or it would cause the operation of the alarm units, as well as possible permanent damage to the intermediate transformers.

5.3.5. FRONT SIDE DEVICES

Line current measuring terminals (FIG. 7)

They are located in the front plates of the restraint modules (DFI) . They consist of 2 or 3 rows of terminals according to the number of restraint inputs (2 maximum). The lower terminals correspond to the references of each phase and the upper terminals to the inputs in each line, per phase.

The a.c. voltage measured in these terminals corresponds to the current flowing through the line on the 1 A side.

Measuring terminals of the total restraint currents (FIG. 8)

They are located on the front plate of the differential module (DDI), in the upper row. The terminals in the lower row correspond to the reference, which is also common for the measurement of the differential currents.

The continuous voltage measured in these terminals corresponds to 90% of the arithmetical sum of the currents of all the lines in the 1 A side.

Differential trip signalling (FIG. 9)

It is done by means of a red LED located in the front part of the boards in every differential single-phase unit.

It is a continuous signalling and the reset is carried out manually by means of a push-button located in the front part of the same board.

Signalling of operation of the alarm unit (FIG. 10)

It is done by means of three red LEDs (one for every phase) located in the front part of the board, in the alarm unit.

The signalling is continuous and the reset is achieved by means of a push-button placed in the front part of the board itself.

Operation level adjustment of the breaker failure unit (FIG. 11)

It is carried out by means of microswitches placed in the front part of the breaker failure board (SFI).

The minimum adjustment (all the microswitches placed at the left), is 0.2 A on the 1 A side, plus the number corresponding to every microswitch located to the right. The unit adjustment ranges from 0.2 to 3.3 A on the 1 A side, in 0.1 steps.

Operation time adjustment of the breaker failure unit (FIG. 11)

It is carried out by means of microswitches placed in the front part of the breaker failure board (SFI).

The minimum adjustment (all the microswitches placed at the left) is 0.2 s, plus the number corresponding to every microswitch, positioned to the right. The adjustment ranges from 0.1 to 1.6 s in 0.1 steps.

Operation level adjustment of the overcurrent unit (FIG. 11)

Two versions are available for the operation level of the overcurrent unit. In the first case, the level depends on the level adjustment of the breaker failure unit, and in the second the level is totally independent.

Dependent adjustment:

It is done by means of microswitches placed in the front part of the breaker failure board (SFI).

The minimum adjustment (all the microswitches placed at the left) is 0.25 times the adjustment of the breaker failure unit, plus the number corresponding to every microswitch, positioned to the right. The adjustment ranges from 0.25 to 1 time, in 0.05 steps.

Independent adjustment:

The same as the operation level adjustment of the breaker failure unit.

Bus coupling timer adjustment

It is done by means of microswitches placed in the front part of the switching module (MDF).

The minimum adjustment (all the microswitches placed at the left) is 0.2 s, plus the number corresponding to every microswitch, positioned to the right. The adjustment ranges from 0.2 to 1.7 s, in 0.1 steps.

Breaker failure trip signalling (FIG. 11)

It is done by means of a red LED placed in the front part of the boards, in every breaker failure unit.

This signalling is continuous and the reset is achieved manually through a push-button placed in the front part of the board.

Operation signalling of the overcurrent unit (FIG. 11)

It is done by means of a red LED placed in the front part of the boards, in every breaker failure unit.

This signalling is not continuous and stops signalling when the unit is reset.

5.3.6. INTERNAL ADJUSTMENTS

Percent slope adjustment (FIG. 12)

It is placed in the differential board (DDF) and it is achieved by means of a Cambion jumper. The range values are: 0.5, 0.6, 0.7, and 0.8

Differential overcurrent supervision adjustment (FIG. 12)

It is placed in the differential board (DDF) and it is achieved by means of a Cambion jumper. The range values are: 0.2, 0.3, 0.5, 0.8, 1.0, 1.5 and 2.

Alarm operation time adjustment (FIG. 13)

It is placed in the alarm board (DAL) and it is achieved by means of the P1 potentiometer. It is adjusted at 10 s.

Failure pickup command seal in adjustment (fig. 14)

It is placed in the breaker failure board (SFI) and it is done by means of a jumper.

5.3.7. FACTORY ADJUSTMENTS

DDF board (FIG. 12)

- P1 potentiometer: Differential unit operation level adjustment.
- P2 potentiometer: Differential unit operation time adjustment.
- P3 potentiometer: Differential unit recovering time adjustment.
- P4 potentiometer: Supervision unit operation level adjustment.
- P5 potentiometer: Supervision unit operation time adjustment.
- P6 potentiometer: Supervision unit fill-in time adjustment

DAL board (FIG. 13)

P1 potentiometer: Alarm unit recovering time adjustment.

SFI board (FIG. 14)

- P1 potentiometer: Breaker failure operation level adjustment.
- P2 potentiometer: Overcurrent unit operation level adjustment.
- P3 potentiometer: Overcurrent unit fill-in time adjustment.
- P4 potentiometer: Breaker failure unit fill-in time adjustment.
- P5 potentiometer: Overcurrent unit operation time adjustment

NOTE: The potentiometers described above are factory adjusted and it is not recommended to change their original adjustment positions.

5.3.8. Accessories

In systems provided separately, the following accessories are provided for installation inside the board:

5.3.8.1. Auxiliary Transformers

They are single phase units (three for every position and measuring unit) provided separately. Their dimensions and panel drilling are shown in figure 17.

5.3.8.2. Restabilization Resistors

One for each phase and measuring unit.

The resistor dimensions are shown in Figure 21.

5.3.8.3. Non Linear Protection Elements Box

One for each measuring unit. A diagram box is shown in figure 19.

5.3.8.4. Power Supply Resistors Box

One for every differential rack and one for each breaker failure rack.

A diagram with the dimensions is shown in figure 20.

5.3.8.5. Oscillography Auxiliary Current Transformers

They are single-phase units (three for every bar) provided mounted inside the cabinet.

Their dimensions and panel drilling are shown in figure 18.

6. RECEIVING, HANDLING AND STORAGE

The systems are provided to the customer in a special packing unit that properly protects it during transportation, provided it is done under normal conditions.

Immediately after receiving the equipment, the customer should check if there is any evidence of the system having suffered damage during transportation. If injury or damage resulting from rough handling is evident, file a damage claim at once with the Transportation Company and promptly notify the factory.

Reasonable care should be exercised in unpacking the relay in order not to lose the accessories provided in the box.

If the equipment is not going to be installed immediately, it is convenient to store it in its original packing, in a place free from moisture and dust.

It is important to check that the inscription on the nameplate matches the data in the order.

6.1. ACCEPTANCE TESTS AND EQUIPMENT CALIBRATION

It is recommended, once the equipment is received, that a visual inspection and the tests given below be performed to make sure that the relay has not suffered any damage in transportation and the factory calibration has not been altered.

In the description of each test instructions for the calibration of every measuring unit are included. The units must only be readjusted if the values measured are beyond the indicated tolerance limits.

The tests described in chapter 12, can be carried out as installation or acceptance tests, depending on the criteria of the user. Since most users have different procedures for installation and acceptance tests, this section explains all the tests that can be performed on the systems.

7. ACCEPTANCE TESTS

7.1. VISUAL INSPECTION

Check that the model or models indicated in the plates match the data given in the order. Unpack the equipment and check there are no broken parts and no signs that the system has suffered any damage during transportation.

7.2. ELECTRIC TEST

General Considerations on the Power Supply Network and the Measuring Equipment

The bus protection equipment has been calibrated in the factory using a 50 and 60 Hz network with a minimum content of harmonics. In order to achieve consistent results, the tests must be carried out using a power supply network whose wave shape does not contain harmonics.

The dc auxiliary infeed voltage used for tests must not be obtained with rectified a.c. because if this power supply is not properly smooth, it is possible the measuring units do not operate correctly due to possible voltage drops in the power source. Zener diodes, for example, may stop conducting because of power supply voltage drops. As general rule, the dc power supply must not have a ripple higher than 5%.

The ammeters and chronometers used must be calibrated and their precision must be better than that of the relay. The power supply network used in the tests must remain stable, mainly in the levels near the operation thresholds and during the whole operation time of the relay.

It is important to point out that the accuracy with which the test is performed depends on the network and on the instruments used. Functional tests performed with unsuitable power supply network and instruments are useful to check that the relay operates properly and therefore its operating characteristics are verified in an approximate manner. However, if the relay would be calibrated in these conditions, its operational characteristics would be outside the tolerance range values.

7.3. STABILIZATION RESISTORS TEST

- Check the value in Ohms of the stabilization resistor for every phase.
- Adjust the resistors “correderas" to obtain the resistance value calculated for the operation, and check the value in Ohms once the "correderas" bolts have been screwed.

7.4. AUXILIARY CURRENT TRANSFORMERS TEST

- Check the transformation ratio in the different taps, according to the model.
- Apply 300 Va.c. volts to the transformer secondary, with the primary opened and check that the current consumption ranges between 30 and 60 miliamperes.

7.5. PREVIOUS CHECK

According to drawing 226B6429H44 check out the following connections between cabinets:

1. Connect A and B and N terminal of each cabinet to their corresponding A and B and N terminal of the rest of the cabinet. (A1 to A1, B1 to B1, N1 to N1, A2 to A2...).
2. Connect X1 terminal of cabinet 1 to Y1 terminal of cabinet 2,
3. Connect X2 terminal of cabinet 1 to Y2 terminal of cabinet 2.
4. Connect X3 terminal of cabinet 1 to Y3 terminal of cabinet 2.
5. Connect X4 terminal of cabinet 1 to Y4 terminal of cabinet 2.
6. Connect X5 terminal of cabinet 1 to Y7 terminal of cabinet 2.
7. Connect X6 terminal of cabinet 1 to Y8 terminal of cabinet 2.
8. Connect X7 terminal of cabinet 1 to Y11 terminal of cabinet 2.
9. Connect X8 terminal of cabinet 1 to Y12 terminal of cabinet 2.
10. Connect X9 terminal of cabinet 1 to Y15 terminal of cabinet 2.
11. Connect X10 terminal of cabinet 1 to Y16 terminal of cabinet 2.
12. Connect X34 terminal of cabinet 1 to Y19 terminal of cabinet 2.
13. Connect X161 terminal of cabinet 1 to Y20 terminal of cabinet 2.
14. Connect X162 terminal of cabinet 1 to Y21 terminal of cabinet 2.
15. Connect X163 terminal of cabinet 1 to Y22 terminal of cabinet 2.
16. Connect X164 terminal of cabinet 1 to Y23 terminal of cabinet 2

Feed the equipment by connecting the positive of a dc voltage source to X1 borne, and the negative to X2 borne.

Make sure that there is also dc voltage in X7 (+), X8 (-), in Y11 (+), Y12 (-), all the signalling LEDs on the differential (DDF) and alarm (DAL) boards are lit up after pressing the reset button.

Press also the reset buttons of the breaker failure boards (SFI) making sure that the breaker failure LED lights up, in all positions.

7.6. DIFFERENTIAL UNIT CHECK

7.6.1. BUS A

Set the latching relay corresponding to Bus A, in the line 7 (89AX/P7) to the ON position, that is, applied positive to P7- 15 and make a jump between P7-11 & P7-12.

Set the block latching relay corresponding to this differential to the ON position (3B/87A), check that X33-X34 is opened. The green light corresponding to bus A in the test box will be on. If not so, switch it on by pressing the green button.

Make a jumper between stabilization resistors and shorten U1 with U2.

7.6.1.1. Main Unit

Set the following adjustments in the differential boards:

-Slope: 0,5 (bridge on the left side of the board)

-Supervision: 0,2 (bridge on the right side of the board)

Apply current through terminals 23 and 26 of the position for phase 1, through 24 and 26 for phase 2, through 25 and 26 for phase 3 and check that in all 3 instances, the corresponding main units operate according to the following table:

SLOPE	PICKUP CURRENT
0.5	0.190 - 0.210
0.6	0.237 - 0.263
0.7	0.313 - 0.347
0.8	0.475 - 0.525

Also check that contact 1, 2 of the position closes. (if the alarm operates, the contact will open)

Each time the differential unit operates the following contacts will close: X29-X30, X31-X32. These contacts will remain closed until the reset button (place in cabinet 1 front panel) is pushed.

NOTE: Should the alarm go off as a result from the current having been applied for over 10 s, the differential will be blocked and the corresponding red light in the test box will light up, and a message will show up on the alarm's screen. In such event, to proceed with the test, the differential should be reset by pressing the corresponding green button, and acknowledge the alarm to clear up the screen of the alarms.

7.6.1.2. Supervision Units

Set the following adjustments in the differential boards:

-Slope: 0,5 (bridge on the left side of the board)

-Supervision: 0,2 (bridge on the right side of the board)

Apply current through terminals 23 and 26 of the position for phase 1, through 24 and 26 for phase 2, through 25 and 26 for phase 3 and check that in all 3 instances, the corresponding supervision units operate according to the following table:

ADJUSTM. VALUE	**PICKUP VALUE**
0.2	0.190-0.210
0.3	0.285-0.315
0.5	0.475-0.525
0.8	0.760-0.840
1.0	0.950-1.050
1.5	1.425-1.575
2	1.900-2.100

Also check that contact 1, 2 of the position closes. (if the alarm operates, the contact will open)

Each time the differential unit operates the following contacts will close: X29-X30, X31-X32. These contacts will remain closed until the reset bottom (place in cabinet 1 front panel) is pushed.

NOTE: Should the alarm go off as a result from the current having been applied for over 10 s, the differential will be blocked and the corresponding red light in the test box will light up, and a message will show up on the alarm's screen. In such event, to proceed with the test, the differential should be reset by pressing the corresponding green button, and acknowledge the alarm to clear up the screen of the alarms.

Undo the bridges of the stabilization resistors and, applying current through the previous terminals. Check that both the alarms of the three phases operate with 28 mA (range: 27- 29mA) and that the red light of differential A goes off while the red light lights up.

Check as well that X35-X36 contact is closed.

Bear in mind that every time the alarm operates, the differential must be reset by pressing the corresponding green button.

Set the following adjustments in the differential boards of bus A:

-Slope: 0.8 (bridge on the left side of the board)

-Supervision: 1 (bridge on the right side of the board)

Remove jumpers from U1-U2, and P7-11 & P7-12.

7.6.2. BUS B

Set the latching relay corresponding to Bus B, he line 7 (89B/P7) to the ON position, that is, make a jumper between P7-11 & P7-14.

Set the BUSY/AB latching relay to the ON position, contact X45-X46 is closed. Apply positive to P7-13 and these contacts will open.

Set the block latching relay corresponding to this differential to the ON position (3B/87B), check that X41-X42 is opened. The green light corresponding to bus B in the test box should be lit up. If not so, light it up by pressing the green button.

Shorten the stabilization resistors and shorten U3 with U4.

7.6.2.1. Main Unit

Set the following adjustments in the differential boards:

-Slope: 0.5 (bridge on the left side of the board)

-Supervision: 0.2 (bridge on the right side of the board)

Apply current through terminals 23 and 26 of the position for phase 1; through 24 and 26 for phase 2; through 25 and 26 for phase 3 and check that in all three instances, the corresponding main units operate according to the following table:

SLOPE	PICKUP CURRENT
0.5	0.190 - 0.210
0.6	0.237 - 0.263
0.7	0.313 - 0.347
0.8	0.475 - 0.525

Check as well that contacts 1 and 2 of the position close. (if the alarm operates, the contact opens).

Each time the differential unit operates the following contacts will close: X37-X38, X39-X40. These contacts will remain closed until the reset bottom (place in cabinet 1 front panel) is pushed.

NOTE: Should the alarm go off as a result from the current having been applied for over 10 s, the differential will be blocked and the corresponding red light in the test box will light up, and a message will show up on the alarm's screen. In such event, to proceed with the test, the differential should be reset by pressing the corresponding green button, and acknowledge the alarm to clear up the screen of the alarms.

7.6.2.2. Supervision Units

Set the following adjustments in the differential boards:

-Slope: 0,5 (bridge on the left side of the board)

-Supervision: 0,2 (bridge on the right side of the board)

Apply current through terminals 23 and 26 of the position for phase 1, through 24 and 26 for phase 2, through 25 and 26 for phase 3 and check that in all 3 instances, the corresponding supervision units operate according to the following table:

ADJUSTM. VALUE	PICKUP VALUE
0.2	0.190-0.210
0.3	0.285-0.315
0.5	0.475-0.525
0.8	0.760-0.840
1.0	0.950-1.050
1.5	1.425-1.575
2	1.900-2.100

Also check that contact 1, 2 of the position closes. (If the alarm operates, the contact will open)

Each time the differential unit operates the following contacts will close: X37-X38, X39-X40. These contacts will remain closed until the reset bottom (place in cabinet 1 front panel) is pushed.

NOTE: Should the alarm go off as a result from the current having been applied for over 10 s, the differential will be blocked and the corresponding red light in the test box will light up, and a message will show up on the alarm's screen. In such event, to proceed with the test, the differential should be reset by pressing the corresponding green button, and acknowledge the alarm to clear up the screen of the alarms.

Undo the bridges of the stabilization resistors and applying current through the above terminals check that the alarms in all 3 phases operate with 28 mA (range: 27- 29mA); that the operation time is 10 s. (9.5, 10.5) and that the green target of the differential B goes off as the red target lights up.

Check as well that contact X43-X44 closes taking into account that every time the alarm operates the differential must be reset by pressing the corresponding green button.

Set the following adjustments to the differential boards of bus B:

Slope: 0.8 (bridge on the left side of the board)

Supervision: 1 (bridge on the right side of the board)

Remove jumpers from U3 and U4, P7-11 and P7-14. Apply positive to P7-15.

7.7. DIFFERENTIAL TRIPPING OUTPUT CONTACTS TEST

This test has to be repeated for all positions and both bus bars.

Check that the contacts (see table 3: Differential output contacts and table 4: lock out contacts) are open.

Connect the latching corresponding to bus bar A of the feeder being, simulating this situation in terminal blocks applying dc (+) to the corresponding terminal tested, see table 2: Bar connection & disconnection). Check that the lock out contact is closed (see table 4: lock out contacts).

Connect the corresponding bus bar differential. Put the corresponding jumper between terminals U1-U2 for Bar A and U3-U4 for Bar B. Apply 1,2 Amp to terminals (see table 1: Input current)

Check that when the differential trips, contacts (see table 3: Differential output contacts) are closed and the lock out contact is open (see table 4: lock out contacts).

NOTE: When the alarm starts, it will disconnect the tripping contacts but the lock out contacts will remain closed until they are reset (see drawing 226B6429H28):

- Pushing the button located in the BPP module (see cabinet front view 226B6430F15)
- Using an external contact connected between X23-X24.

Check that when the blocking differential A, using its blocking unit (pushing the OFF button of the test block), and applying the previous current, the above mentioned contacts do not close.

Disconnect the latching corresponding to bus bar A, and connect the latching of bus bar B (this can be simulated in terminal blocks applying dc (+) to the corresponding terminals, see table 2: Bar connection and disconnection), and repeat the process.

Repeat the same procedure for phase 2 and for phase 3 (see table 1: Input current).

Repeat the same procedure for bus bar B, for each phase.

TABLE 1: input current for all positions

Phase A	Phase B	Phase C
23-26	24-26	25-26

TABLE 2: Bar connection and disconnection for all positions

BAR A		BAR B	
ON	OFF	ON	OFF
12	13	14	15

TABLE 3: DIFFERENTIAL TRIPPING OUTPUT CONTACTS

CONTACTS
1-2,3-4

TABLE 4: LOCK OUT CONTACTS

CONTACTS
5-6

7.8. BREAKER FAILURE AND 50 UNITS TEST

This test should be done for each one of the positions and both bus bars.

Check that the stabilization resistors are shortened.

Set the adjustment 50 of the position to 100% and BF to 0.9 A and the time of B.F. to 0.4 s, that is first step 100ms (all switches on SFI module should be on the left), second step 300ms (switches on DTE module, common for all positions).

Set up the latching relay of bus A (89AX/P) to the ON position (see table 2: Bar connection & disconnection) that of bus B (89BX/P) in the OFF position (see table 2: Bar connection & disconnection), put a jumper between terminals (see table 6: Compound blocking contacts), initiate the breaker failure protection by applying +P to the terminal (see table 4: Breaker failure initiation) of this position and apply 0.9 A of current through the corresponding terminals of this position (see table 1: Input current) and checking that:

- The differential does not trip;
- The 50 trips with 0.9 A;
- The B.F. trips with 0.9 A and at 0.4 s;
- When testing bar A check that there is voltage in X5 (+P) after 100ms (first step) and in X9 after 300ms (second step).
- When testing bar B check that there is voltage in X6 (+P) after 100ms (first step) and in X10 after 300ms (second step).
- Both LEDs are red;
- Contacts X25-X26 and X27-X28 are closed for Bar A and contacts X37-X38 and X39-X40 are closed for Bar B.
- the restraint measured in the corresponding terminal of the differential module is 0.9;
- contacts (see table 3: breaker failure tripping output contacts) of the position are closed;

Apply the same current through phase 2 (see table 1) and phase 3 (see phase 1).

Disconnect the latching relay of bus A (89AX/P) of the position tested, applying +P to terminal (see table 2: Bar connection & disconnection) of the position. Connect the latching relay of bus B (89BX/P) to the position, applying positive +P to terminal (see table 2: Bar connection & disconnection) of the position.

Set the line latching relays of the next position and repeat the whole process for every position. Repeat the above steps for bar B.

TABLE 1: INPUT CURRENT FOR ALL POSITIONS

Phase A	Phase B	Phase C
23-26	24-26	25-26

TABLE 2: BAR CONNECTION & DISCONNECTION FOR ALL POSITIONS

BAR A		BAR B	
ON	OFF	ON	OFF
12	13	14	15

TABLE 3: BREAKER FAILURE TRIPPING OUTPUT CONTACTS

1st Step	2nd Step
9-10	1-2, 3-4

TABLE 4: BREAKER FAILURE INITIATION

Phase A	Phase B	Phase C	3 Phase
17	18	19	20

7.9. COUPLING DEVICE TEST

Set the three latching relays 52 EB/CS to the OFF position and connect them, applying +EB to terminal EB11, make sure that -EB is applied to terminal EB-13.

7.9.1. BUS A

Set the adjustment 50 of the coupling to 0.9 and set the time to 0.4 s that is:

1.- First step: 100 ms (SFI module).
2.- Second step: 300 ms (DTE module).

Remove the positive from EB11 to EB10. Apply current through EB23 and EB26, checking that:

- the differential does not trip.
- the 50 trips with 0.9 A.
- the restraint measured in the corresponding lead of the differential A is between 0.77-0.85.
- contacts EB1-EB, EB3-EB4, EB 9-EB10 and X25-X26, X27-X28 are closed.

Apply the same current through terminals EB24, EB26, checking as above (phase 2).

The same applies to terminals EB25, EB26 (phase 3).

7.9.2. BUS B

Successively, apply current (0.9 A) through EB27, EB30 (phase l), EB28, EB30 (phase 2), EB29, EB30 (phase 3) and check that in all three cases, the restraint measured in the corresponding terminal of the restraint module of differential B is between 0.77 and 0.85.

Check that the differential and the 50 + B.F. do not operate, making sure that contacts from EB1-EB2 EB3-EB4 EB 9-EB10 and X25-X26, X27-X2 are open.

Set the timer of the coupling to the maximum. Apply a jumper from the positive to terminal EB10. Apply 1.2 A through terminals EB27 and EB30, checking that:

- contact EB1, EB2 closes as soon as the differential trips and opens again after about 1 s.
- the three latching relays 52EB/CS are now in the reset position.
- the current is still closed by the above latching relays.

7.10. SWITCHING DEVICE TEST

Check that the stabilization resistors are shortened.

Set up the following adjustments to all the differential boards:

Slope: 0.8

Supervision: 0.5

Connect position 7 to bus B applying +P to terminals (see table 2: Bar connection & disconnection). The rest of the line latching relays must be in STANDBY position (0). If not so, apply positive to terminals (see table 2: Bar connection & disconnection), corresponding to the positions where there is a latching relay connected (1).

Apply 1 A through terminals (see table 1: Input current, phase A). Trip phase 1 of differential B.

Apply Vdc between X11 (positive) and X12 (negative). In that moment, the three latching relays BUS/AB will operate (they go to 1); differential A trips, while differential B stops tripping.

Connect bus B pushing the green button on the test rack, and reset the DAL module and the DDF module of the phase under test.

In such conditions, check by measuring in the leads of the differential module corresponding to bus A (phase 1) that the restraint is 0.9 Vdc and the differential is 0.9 Vdc. Bus B (phase 1) restraint and differential corresponding measures will be 0.

Disconnect direct current in terminals X11 (+) and X12 (-). In that moment, the three latching relays BUS/AB will operate (they go to O); differential B trips while differential A stops tripping.
In such conditions, check by measuring in the leads of the differential module corresponding to bus B (phase A) That the restraint is 0.9 Vdc and the differential is 0.9 Vdc. Bus A (phase A) restraint and differential corresponding measures will be 0.

Connect bus A pushing the green button on the test rack, and reset the DAL module and the DDF module of the phase under test.

Remove the current applied to terminals (see table 1: Input current, phase A), applying it now, through terminals (see table 1: Input current, phase B). Repeat the same steps, taking into account that the one under test is phase B now.

Remove the current applied to terminals (see table 1: Input current, phase B), applying it now through terminals (see table 1: Input current, phase C). Repeat the same steps, taking into account that the one under test is phase C now.

Remove current and DC from X11 (+), X12 (-), when these terminals had it applied.

Connect the corresponding latching relay of bus A to the position 7, applying positive to terminal (see table 2: Bar connection & disconnection) (1). In that moment, having the bus B latching relay connected (1), the three BUS/AB latching relays will operate (they go to 1).

Disconnect bus A latching relay of position 7, applying positive to terminal (see table 2: Bar connection & disconnection). In that moment, the BUS/AB latching relays will operate again (they go to 0).

Remove the jumpers from the stabilization resistors.

7.11. TEST ELEMENT TEST

7.11.1. AC AND SWITCHES CIRCUIT

Set the AL-DIF switch to position DIF; the TAKES switch (I, II, III) to position II; and switch 01,02,03 to position 01.

Press the TEST button and check that the phase 1, corresponding to the pressed button, trips.

Set switch 01,02,03 to position 03. Press the TEST button and check that the phase 3, corresponding to the button pressed, trips.

Set switch AL-DIF to position DIF; the TAP switch (I, II, III) to position III and proceed with the same check , as above.

NOTE: to test position I of the switch, slope and supervision adjustments must be lowered.

Set AL-DIF switch to position AL; TAP switch (I, II, III) to any position; and 01,02,03 switch to position 01.

Press the TEST button and check that after 10 s., the alarm in phase 1, as well as the alarm corresponding to the button pressed, go off.

Set 01,02,03 switch to position 02. Press the TEST button and check that after 10 s., the phase 2 alarm of the differential corresponding to the button pressed, goes off.

Set 01,02,03 switch to the position 03. Press the TEST button and check that after 10 s., the phase 3 alarm of the differential corresponding to the button pressed, goes off.

7.11.2. ON AND OFF PUSH-BUTTONS CHECK

Check that the differential can be connected and disconnected with the ON and OFF push-buttons; for this purpose, check the following:

When the green light of differential A is on, the latching relay 3B/87A will be in (1) whereas with the red one on , it will be in (0) .

Do the same check with the other differential and with its corresponding 3B/87B latching relay.

7.11.3. TEST MEMORY CHECK

With the green light on, check that as you push the test button, the green light goes off as well as the red one, and the corresponding 3B latching relay goes to (1).

Also check that when releasing the TEST button everything is automatically reset.

Check that while doing the same but with the red light on, this light will stay on with or without pushing the button.

NOTE: Should any of the tests not be satisfactory, refer to UNITS CALIBRATION.

7.12. UNITS CALIBRATION

The units must only be readjusted if the values measured are beyond the indicated tolerance limits.

7.12.1. MAIN UNITS

Prior to the measure units calibration, the currents should be lead to the corresponding differential (double bus). For this purpose, a positive must be applied to terminals (see table 2: Bar connection & disconnection or differential A, and to terminals (see table 2: Bar connection & disconnection) for differential B. These terminals correspond to the position to be used for the carrying out of the test.

Before starting these tests, adjust the SUP. units of every differential board to 0.2 (Instruction Book FIG 20 back Cambion) and shorting the stabilization resistors.

Set the cambion slope (Instruction Book FIG 20 front Cambion) to 0.8. Apply 0.5 A through the leads corresponding to each phase, according to the above list, and adjust with P1 potentiometer of each board for the differential of the corresponding phase to operate with that value.

Check the rest of the pickup currents of each differential for each phase and for each of the rest of the slopes (Instruction Book FIG 20 front Cambion).

SLOPE	PICKUP CURRENT
0.5	0.190 - 0.210
0.6	0.237 - 0.263
0.7	0.313 - 0.347
0.8	0.475 - 0.525

The obtained value will be recorded in the corresponding box.

7.12.2. SUPERVISION UNITS

Before starting with these tests, adjust the slope of the differential units to 0.5 (Instruction Book FIG 20 front Cambion), Check that the stabilization resistors are shorted.

Set the supervision of the differential boards to 0.5 (Instruction Book FIG 20. back Cambion). Apply 0.5 A through the leads corresponding to each phase, according to the above, and adjust with the P4 potentiometer of each board for the differential of the corresponding phase to operate with that value.

Check the rest of the pickup currents of each differential for each phase and for each of the rest of the adjustment values (Instruction Book FIG 20 back Cambion).

ADJUSTM. VALUE	PICKUP VALUE
0.2	0.190-0.210
0.3	0.285-0.315
0.5	0.475-0.525
0.8	0.760-0.840
1.0	0.950-1.050
1.5	1.425-1.575
2	1.900-2.100

The obtained value will be recorded in the corresponding box.

7.12.3. ALARM UNIT CALIBRATION

In order to carry out this test, remove the jumpers in the stabilization resistors.

Apply current through the same terminals as in the previous tests and check for every unit and phase the pickup values of the alarm units and their operation times.

The operation values will be approximately 28 mA and the operation time will be 10 s. If not, adjust with the P1 potentiometer of the alarm board.

NOTE: The terminals to be used for the STOP of the chronometer depend on the type and construction of the equipment.

Double bus. Bus A: terminals X35 - X36.

Double bus. Bus B: terminals X43 - X44.

The obtained value will be recorded in the corresponding box.

7.12.4. OVERCURRENT UNITS AND BREAKER FAILURE CALIBRATION

7.12.4.1.Operation Level Calibration

Set the operation level adjustment of the breaker failure unit to 0.9A Set the unit operation time adjustment to the minimum (0.1 s).

Simulate the pickup of the unit and apply 0.9 A current by adjusting with potentiometer P1 of the board so that the unit may operate with that current (check with an oscilloscope that there are no pulses in D22 anode). Remember that it is timed.

Check the rest of the adjustable values. Operation time calibration.

Set the operation time adjustment of the breaker failure unit to 0.5 s and that of the operation level to 0.2 . Apply 0.5 A and adjust with the P5 potentiometer of the board so that the unit may operate en 0.5 s.

Check the rest of the adjustable values.

7.12.4.2. Overcurrent Unit Calibration

Set the adjustment of the overcurrent unit to 0.9 . Apply 0.9 A and adjust with the P2 potentiometer of the board so that the unit may operate with that value.

Check the rest of the adjustable values.

NOTE: Terminals for chronometer stop.

First step: X25-X26
Second step: X27-X28

Check that the model or models indicated in the plates match the data given in the order. Unpack the equipment and check there are no broken parts and no signs that the system has suffered any damage during transportation.

INTERNAL TEST PER POSITION OF BUSBAR DIFFERENTIAL PROTECTION

LOCATION:

VOLTAGE:

		DIF. TRIP	ALARM BLOCKING	B.F. TRIP.	50	V_L	V_D	V_R	SINGLE DIFF REDUCTION	OPEN SELECTOR	COMMENTS
POS											
	$\phi 1$										
	$\phi 2$										
	$\phi 3$										
POS											
	$\phi 1$										
	$\phi 2$										
	$\phi 3$										
POS											
	$\phi 1$										
	$\phi 2$										
	$\phi 3$										
POS											
	$\phi 1$										
	$\phi 2$										
	$\phi 3$										

MAIN RATIO:

LOCATION:

VOLTAGE:

	ALARM UNIT		DIFFERENTIAL SUPERVISION		DIFFERENTIAL UNIT	
	DIFF A	DIFF B	DIFF A	DIFF B	DIFF A	DIFF B
PHASE 1						
PHASE 2						
PHASE 3						
TIME						

	POSITION	POSITION	POSITION	POSITION	POSITION	POSITION	POSITION	POSITION	POSITION
50 (A)									
B.F. (A)									
B.F. TIME									
LOOP RES. (Ω)									
MAIN CT RATIO									
AUX. CT RATIO									
DEDICATED SECONDARY									

8. FINAL INSTALLATION & COMMISSIONING

8.1. SETPOINTS OF THE DIFFERENTIAL PROTECTION.

In each phase (A, B, C) there are two setpoints that must be accomplished

1. *The value of K*: If there is no high resistance consideration of loop or other, the value that it must of be adopted is that of K = 0.8. With this have a sensibility of 0.33 In.

2. *The value of the supervision circuit*:

- Value of the minimal short circuit current is inferior to In. The adjustment will be the minimum possible. In this way the sensibility will be determined by the value of K.
- Value of the minimal short circuit current is sensibly superior to In. The value of the supervision current, it is preferable to adjust it 1.5, to avoid the tripping of the protection in case of one of current circuits is broken or short-circuited, and thus to give the alarm unit time to act and block the trips. Evidently, in this last case the sensibility is determined by the supervision unit, but is earned in safety.

8.2. SETPOINTS OF THE BREAKER FAILURE

- *Current level adjustment*: The minimum level should be at least 150% of the maximum nominal current. Bear in mind that to calculate this value it must be considered the global ratio of the Substation or Power
- *Time setting*: This value must be inferior to the time set for zone 2 of the distance relays or of the backup protections of the power transformers. The value must also be higher than the trip time of the main protections (zone 1), plus the opening time of the associated breaker, plus a safety margin (i.e., if zone 2 is set to 500 ms., the breaker failure will be adjusted in 300 ms - have assumed a tripping time of distance relay in zone 1 of 30 ms. and a breaker time of 80 ms.).

8.3. INSTALLATION

All the units must be mounted in vertical surface which allows access to the front and rear sides of the equipment. It is not necessary to have access to the lateral surfaces of the equipment mounted.

8.4. PREVIOUS CHECK

Check that the equipment has not suffered any damage during transportation and that its characteristics and adjustments have not been altered

Check that the ratios of the auxiliary transformers are accurate according to the selected global ratio. (See figures from 226B6429H1 to 226B6429H8)

Measure for each line and phase the total impedance of the loop on the 1 A side, from the protection input leads, shorting the main transformer s secondary.

Check that the maximum value obtained in the measurements is less than:

$$R_{max} < (2K/1-K) * RE$$

Where:

Rmax: Max. resistance measured
RE: Stabilization resistance (250 Ω)
K: Adjusted slope

Leave the current circuits of the main transformers secondaries shorted until these currents are applied to the differential protection.

8.5. ARRANGEMENT AND PRELIMINARY LEADS

- Check that the values of each of the Stabilization Resistance measured 250 Ω.
- Short out the Stabilization Resistance.
- Disconnect the trips that go from the differential busbar protection and breaker failure protection, to the circuit breakers of the Substation or Power Plant. It should be done by disconnecting the physical elements (cables), or by the use of switching terminal boards .
- Check that all the leads are down except for the d.c. power supply X1(+)-X2 (-) and X7(+)-x8(-) for the control of the bar connection and disconnection of the feeders.
- Disconnect the two differentials through their OFF buttons.

8.6. TESTS WITHOUT LOAD

Carry out the acceptant test described in chapter 11.

Take into account that terminals mentioned in this chapter are referred to the set of drawings 226B6429. For each scheme, depending on the arrangement of the substation or power plant, and the needs of each utility, the identification and number of the terminals may defer from the ones that appear in 226B6429.

8.7. TESTS WITH LOAD

The objective of this test with real load, is to verify if the protection is correctly balanced: the sum of all the currents in the differential circuit is zero (0.0mV), and that all the polarities are correct.

This test uses the real currents that go through each circuit. Trips must be disconnected, for the differential units it will be enough to push the red button, but for the breaker failure protection check that all the tripping output terminals are brought down, so any mistake during the tests, will not cause a problem in the Substation.

Connect feeder by feeder to differential A and verify:

- The magnitude of the current of restrain is increasing and corresponds to the sum of the absolute values of all the currents connected to it.
- The differential current will increase or decrease weather the line currents are compensated or not.
- The voltage (ac) measured at the front of the panel DFI is proportional to the input current.

Upon connecting the last circuit, the value of differential voltage must be of the order of 0.0 mV, 3 milivolt as maximum (upper values, indicate that there is a wrong connection). The alarm unit should be able to reset by pushing the reset button, the LEDs on the DAL module should be off.

Now transfer all the feeders, one by one to differential B following the same steps as above, and check the magnitudes of the current restrain and the differential current.

Upon connecting the last circuit, the value of differential voltage must be of the order of 0.0 mV, 3 milivolt as maximum (upper values, indicate that there is a wrong connection). The alarm unit should be able to reset by pushing the reset button, the LEDs on the DAL module should be off.

- Arrange the differential according to the actual arrangement of the Substation, and check that the entire alarm unit can be reset (no LED is on), and that the LEDs on the DDF modules are also off.

- Connect the two differentials through their ON buttons.
- Check that the only LED that is on is the green one.
- Remove the jumpers from the Stabilising Resistors.

-***NOTE***: The alarm units in the differentials will remain operated during installation, until all the currents are compensated.

For the measures of the voltage is sufficient the use of in digital multimeter with the range and precision of milivolt.

8.8. OPERATION CRITERIA

Please make sure that the short circuit of the stabilization resistors is disconnected before at the end of the tests.

A very extended criterion is not to connect immediately the trips, but to maintain this situation within a period enhance between 6 months to 1 year (depending on the weather conditions and the customs of the utility). This procedure is based on the importance of not having an undesired trip. Whose origin may be caused by various sources: mistake of some polarity in a current circuit, auxiliary contacts of disconnector switches that they do not are operating correctly, some loose cable, etc.). Therefore is preferred to have the protection in service under real operation environment during a period of test, but unable to trip, although it will give all the signals to the control panels.

Once this period has finished and the performance of the protection is considered as appropriated, the trips should be connected.

9. TESTS AND PERIODICAL MAINTENANCE

Given the importance of the protection relays in the operation of any equipment, a periodical test program is recommended.

The interval between periodical tests varies normally for different types of relays, types of equipment as well as the users' experience on periodical tests.

For systems which are not provided with testing equipment, it is recommended that the points described in CALIBRATION AND RECEIVING TESTS be checked every 1 or 2 years.

The optional equipment described in previous sections, allows for checking on the correct operation of the measure and alarm units and of the output elements, without having to remove the protection. In systems provided with testing equipment, this check can be carried out in short intervals, and does not require specialised personnel. In this case the frequency of the tests described in RECEIVING AND EQUIPMENT CALIBRATION can be reduced

10. FIGURES

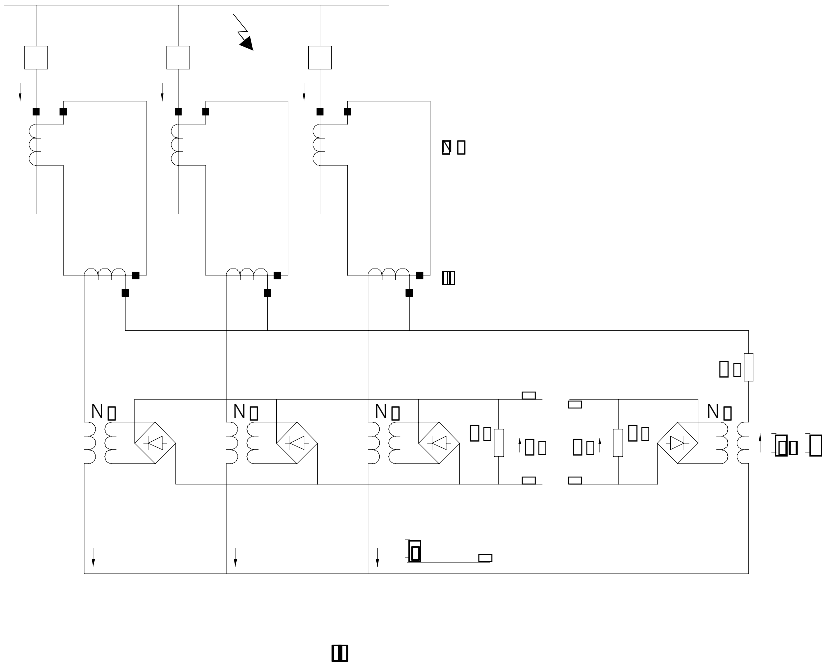
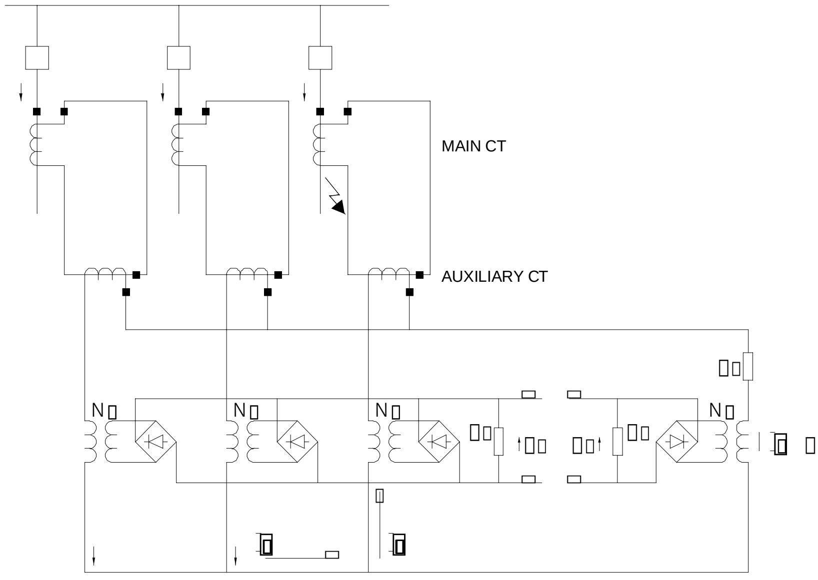


FIGURE 1: SIMPLE CONNECTION DIAGRAM FOR BUS 1000 DIFFERENTIAL PROTECTION INTERNAL FAULT. (226B2211F1)



External Fault

FIGURE 2: SIMPLE CONNECTION DIAGRAM FOR BUS 1000 DIFFERENTIAL PROTECTION. EXTERNAL FAULT WITHOUT SATURATION CT'S. (226B2211F18)

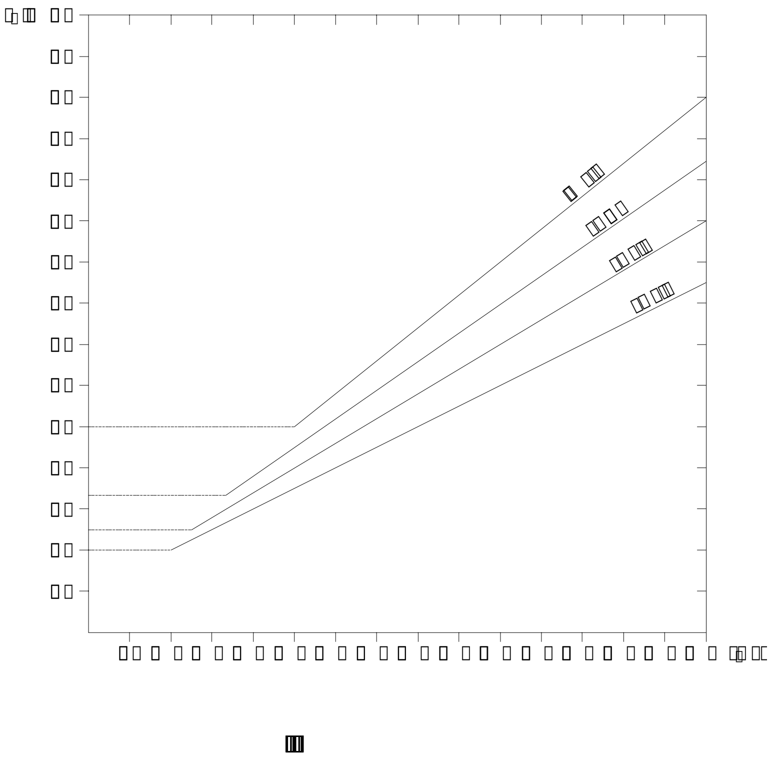


FIGURE 3: OPERATION CHARACTERISTIC. (226B2211F5)

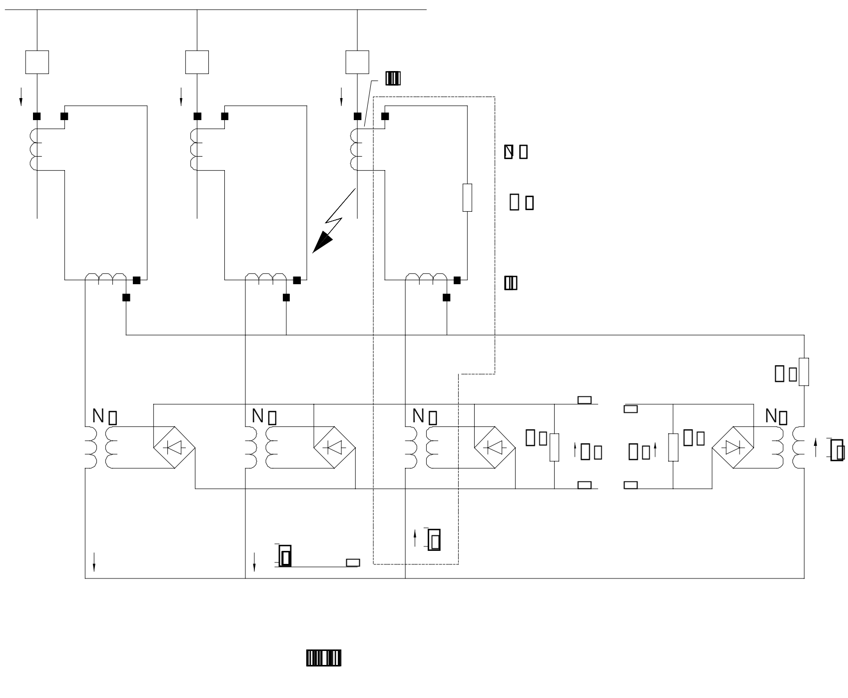


FIGURE 4: SIMPLE CONNECTION DIAGRAM FOR BUS 1000 DIFFERENTIAL PROTECTION. EXTERNAL FAULT WITH SATURATION CORE. (226B2211F2)

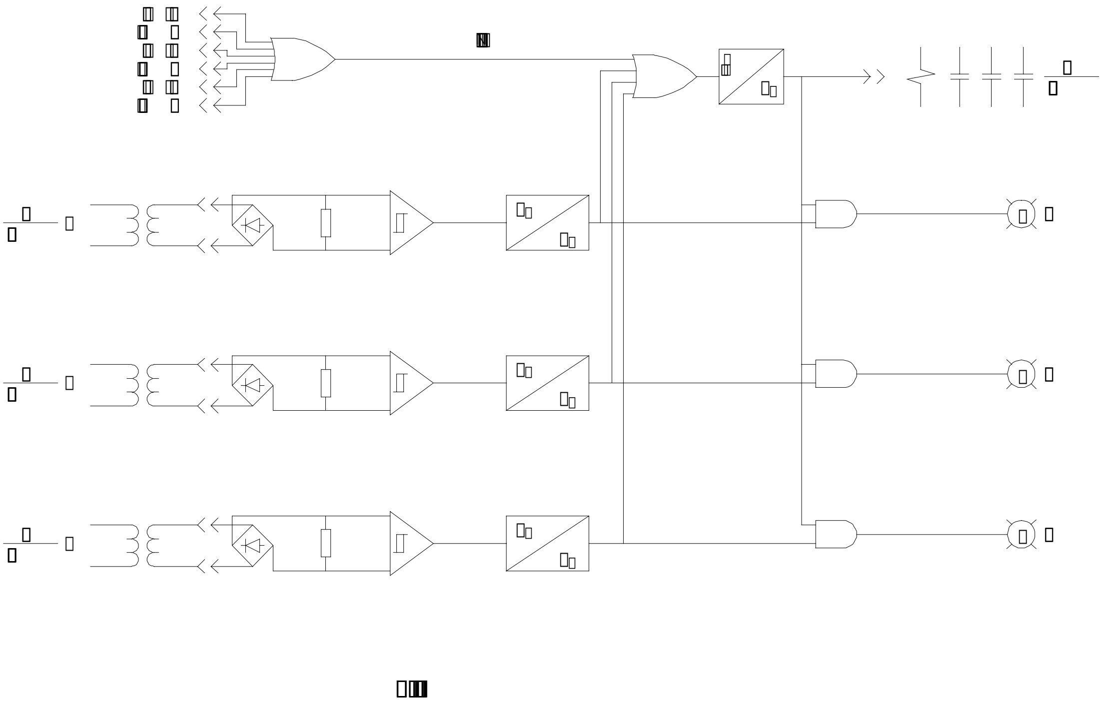


FIGURE 5: ALARM UNIT BLOCK DIAGRAM. (226B2211F4)

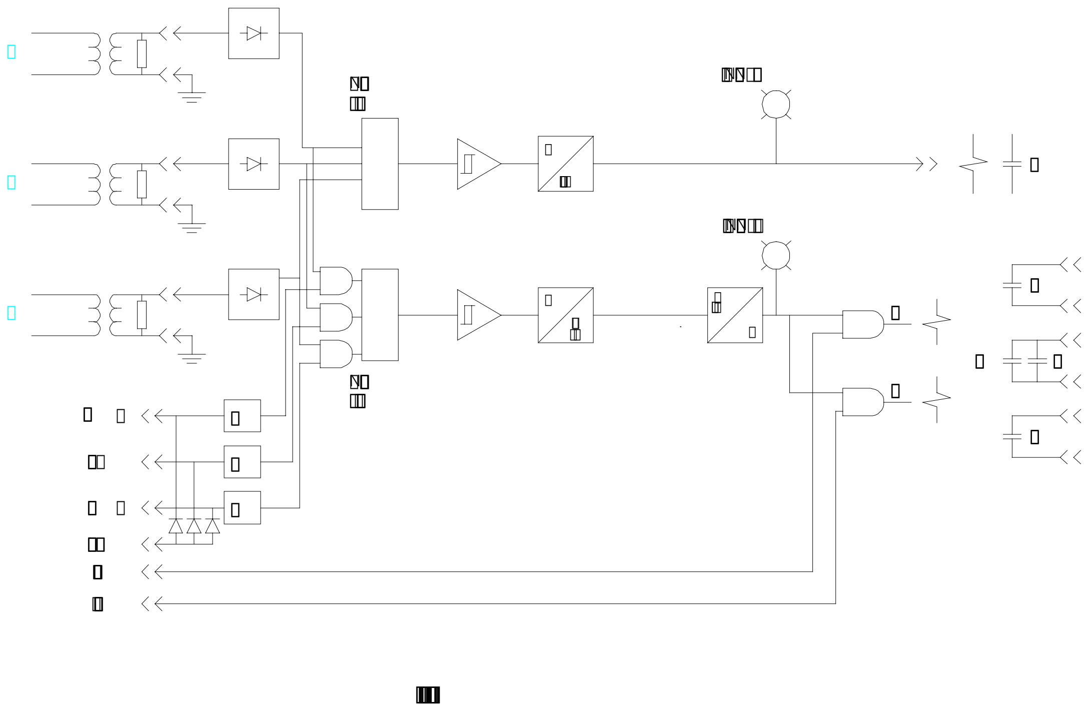
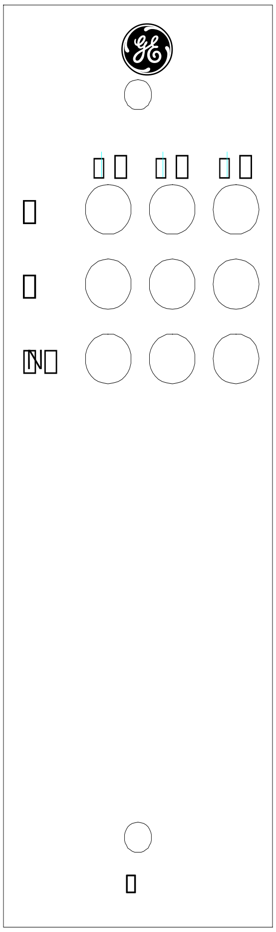
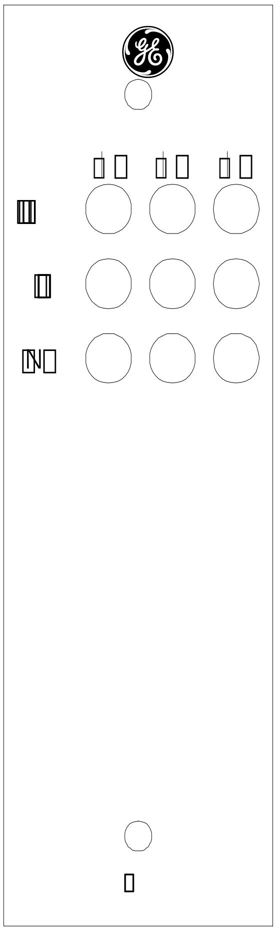


FIGURE 6: BLOCK DIAGRAM FOR CURRENT SUPERVISION AND BREAKER FAILURE UNITS: THREE POLE TRIPPING. (226B2211F7)



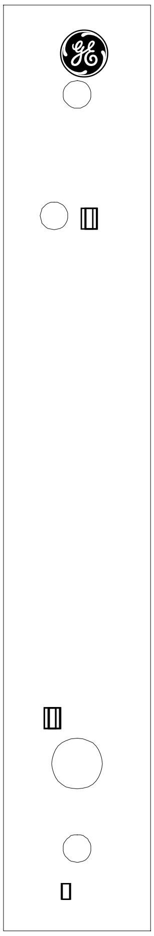
Restrain Module Front View

FIGURE 7: RESTRAIN MODULE FRONT VIEW. (226B2211F15)

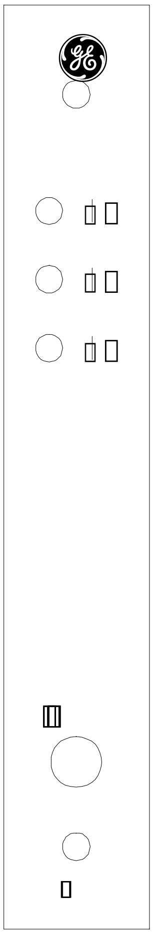


Differential Module Front View

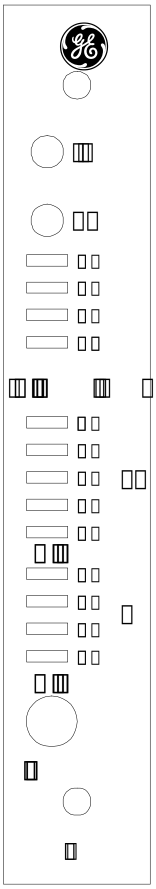
FIGURE 8: DIFFERENTIAL MODULE FRONT VIEW. (226B2211F14)



Differential Board Front View



Alarm Board Front View

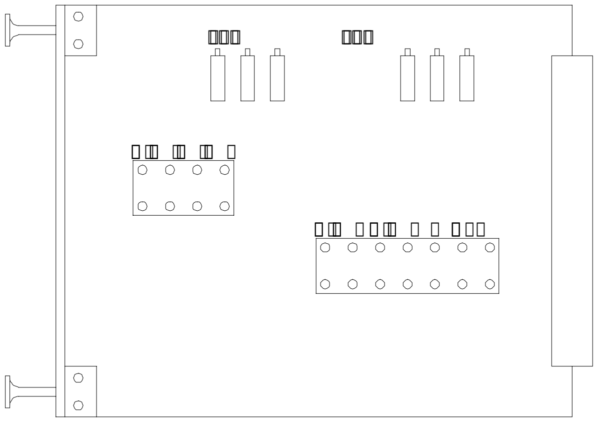


Breaker Failure Board Front View

FIGURE 9:DIFFERENTIAL BOARD FRONT VIEW. (226B2211F12)

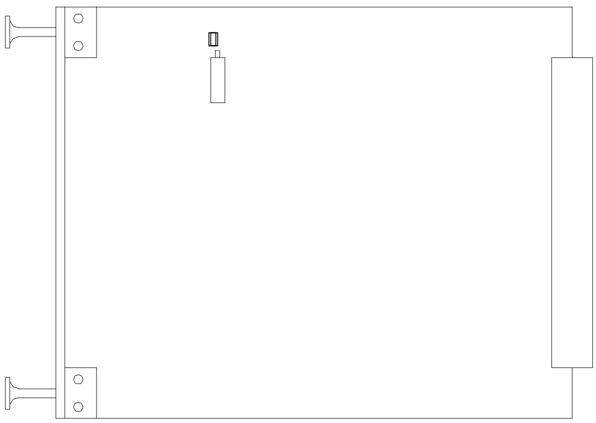
FIGURE 10:ALARM BOARD FRONT VIEW. (226B2211F10)

FIGURE 11:BREAKER FAILURE BOARD FRONT VIEW. (226B2211F16)



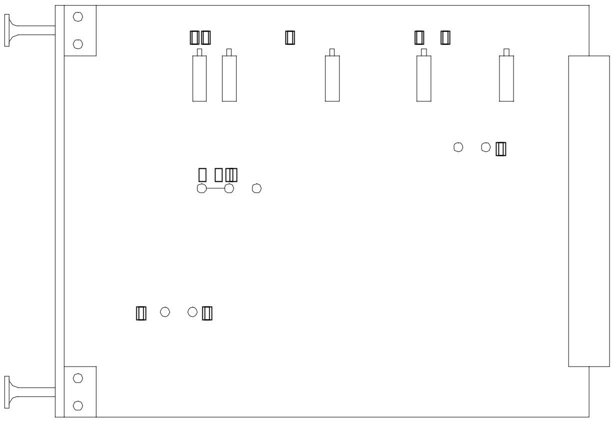
Differential Board - Internal Adjustments

FIGURE 12:DIFFERENTIAL BOARD INTERNAL ADJUSTMENTS. (226B2211F13)



Alarm Board - Internal Adjustments

FIGURE 13:ALARM BOARD INTERNAL ADJUSTMENTS. (226B2211F11)



Breaker Failure Board - Internal Adjustments

FIGURE 14: BREAKER FAILURE BOARD INTERNAL ADJUSTMENTS. (226B2211F17)

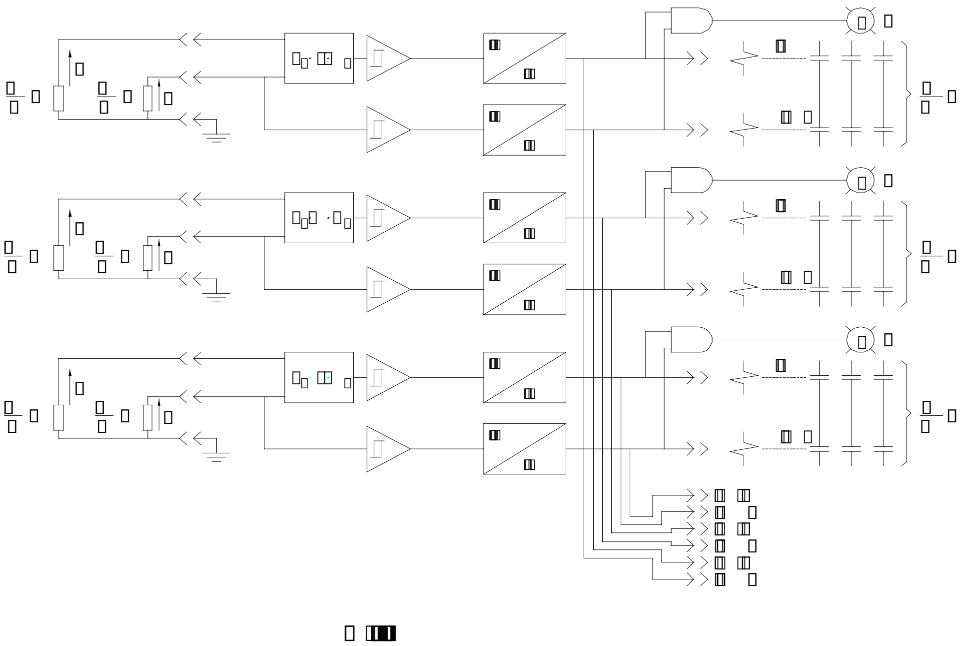


FIGURE 15:DIFFERENTIAL UNIT BLOCK DIAGRAM. (226B2211F3)

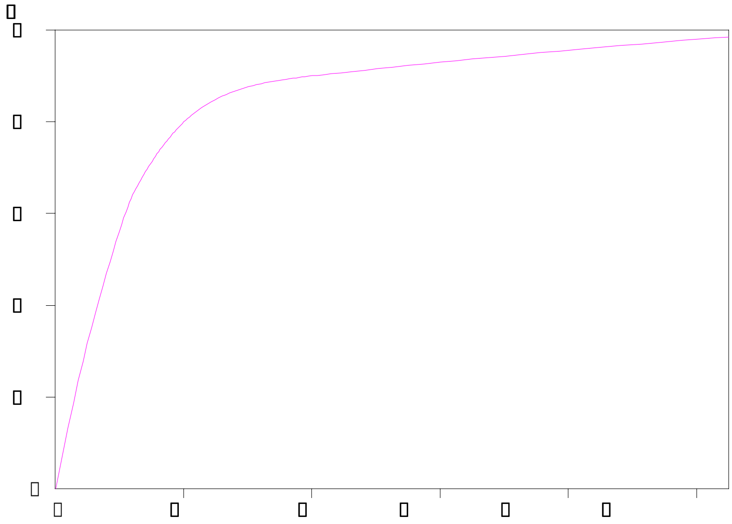
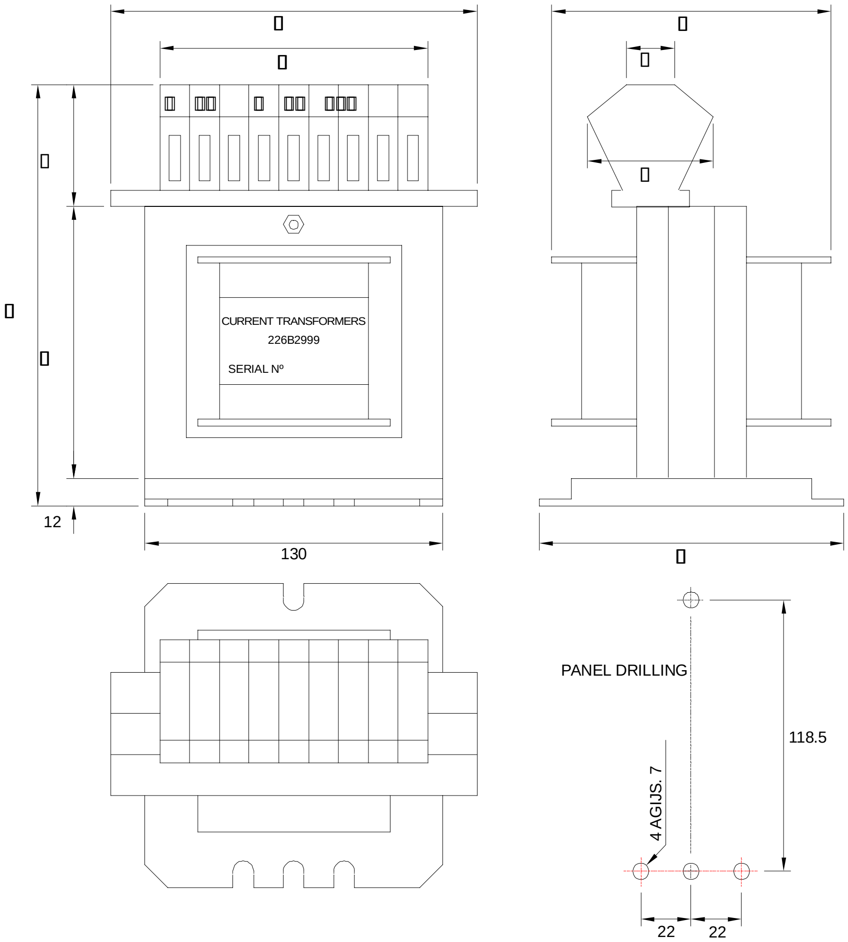


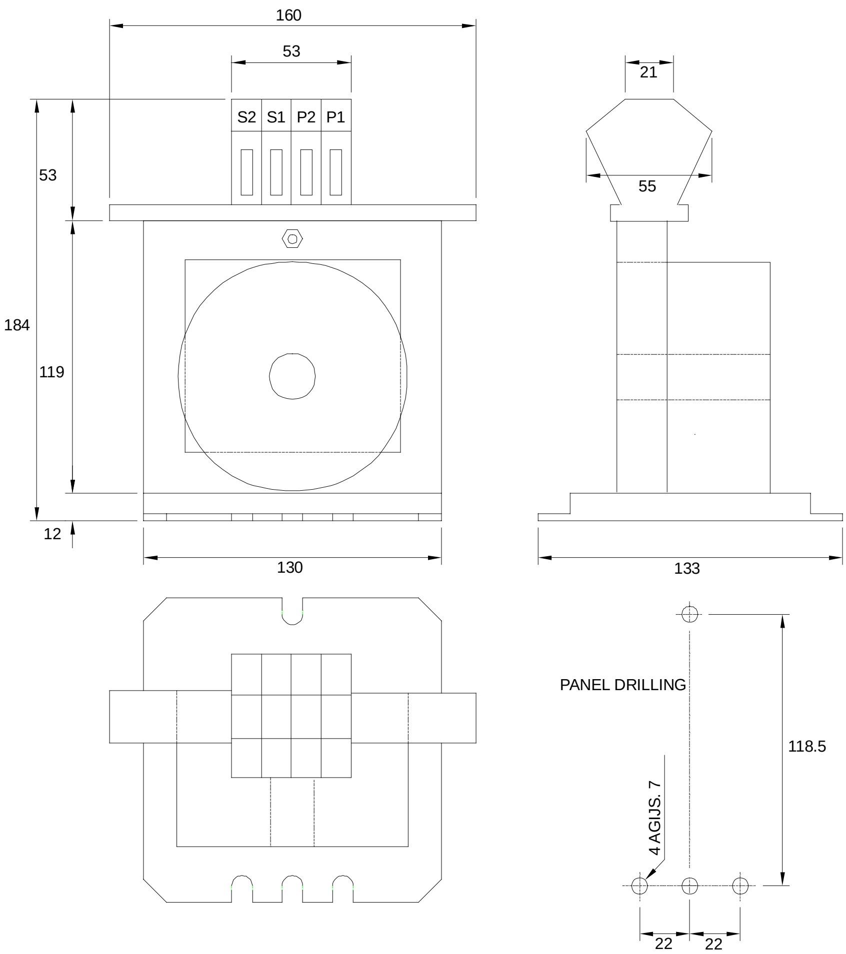
FIGURE 16:CT MAGNETISING CURVE OF THE SECONDARY SIDE. (226B2211F6)

11. DIMENSIONS



Auxiliary current transformer dimensions

FIGURE 17: AUXILIARY CURRENT TRANSFORMER'S. (226B2211F9)



Oscillography Auxiliary current transformer dimensions

FIGURE 18:OSCILOGHAPHY AUXILIARY CURRENT TRANSFORMER. (226B2211F22)

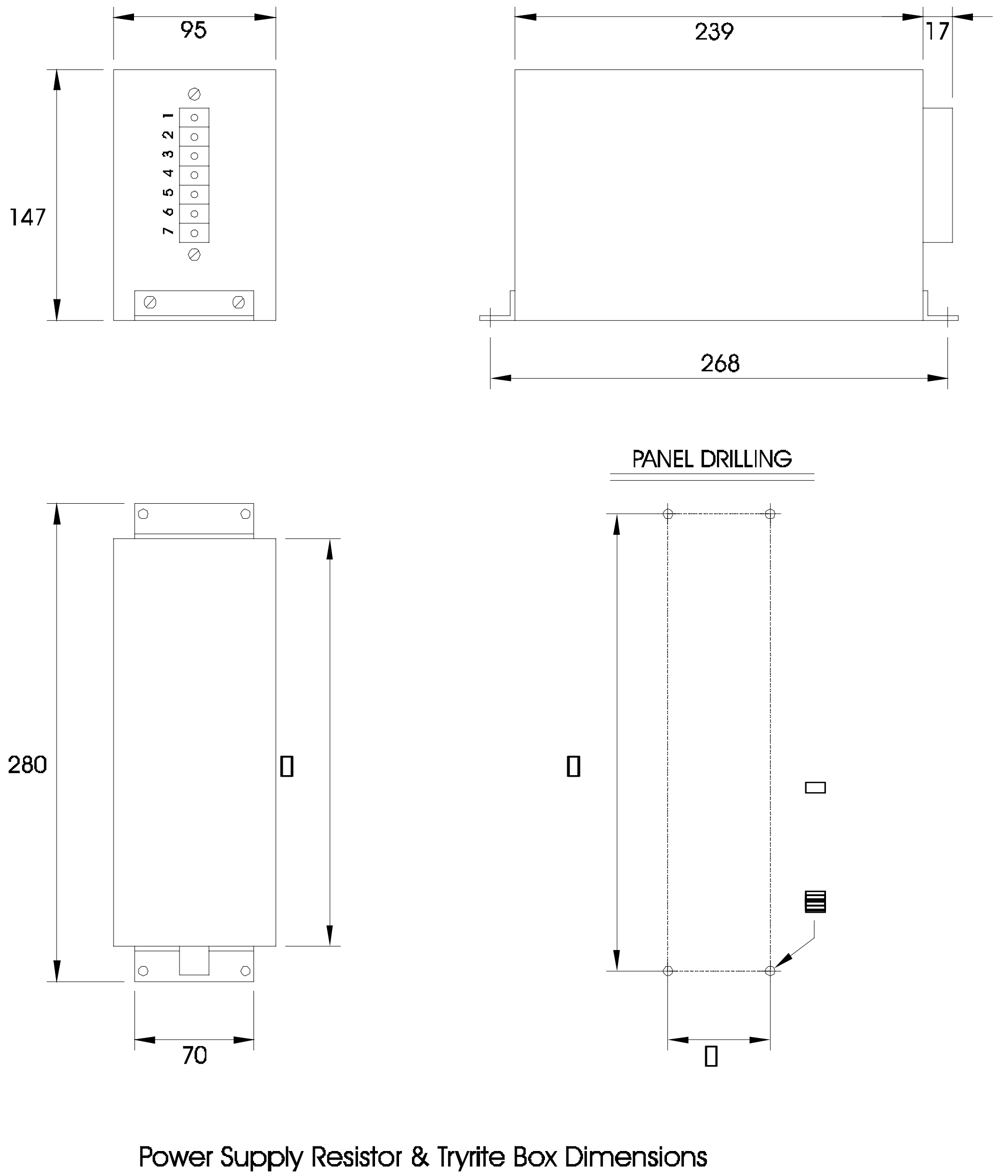
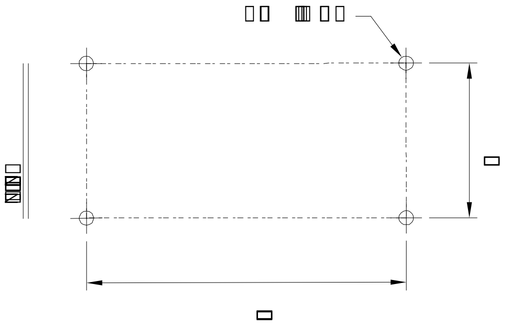


FIGURE 19:POWER SUPPLY OR THYRITE BOXES . (226B2211F18)



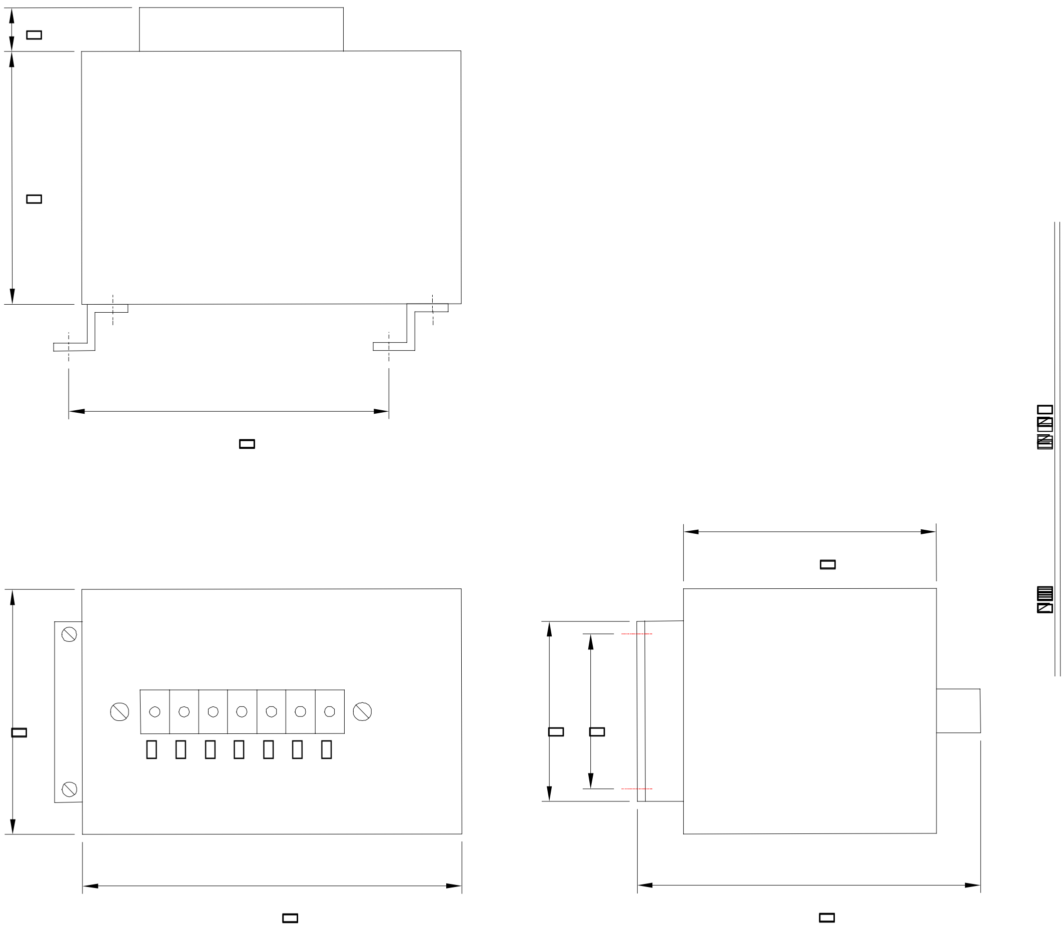


FIGURE 20: BREAKER BLOCK DIAGRAM . (226B2211F23)

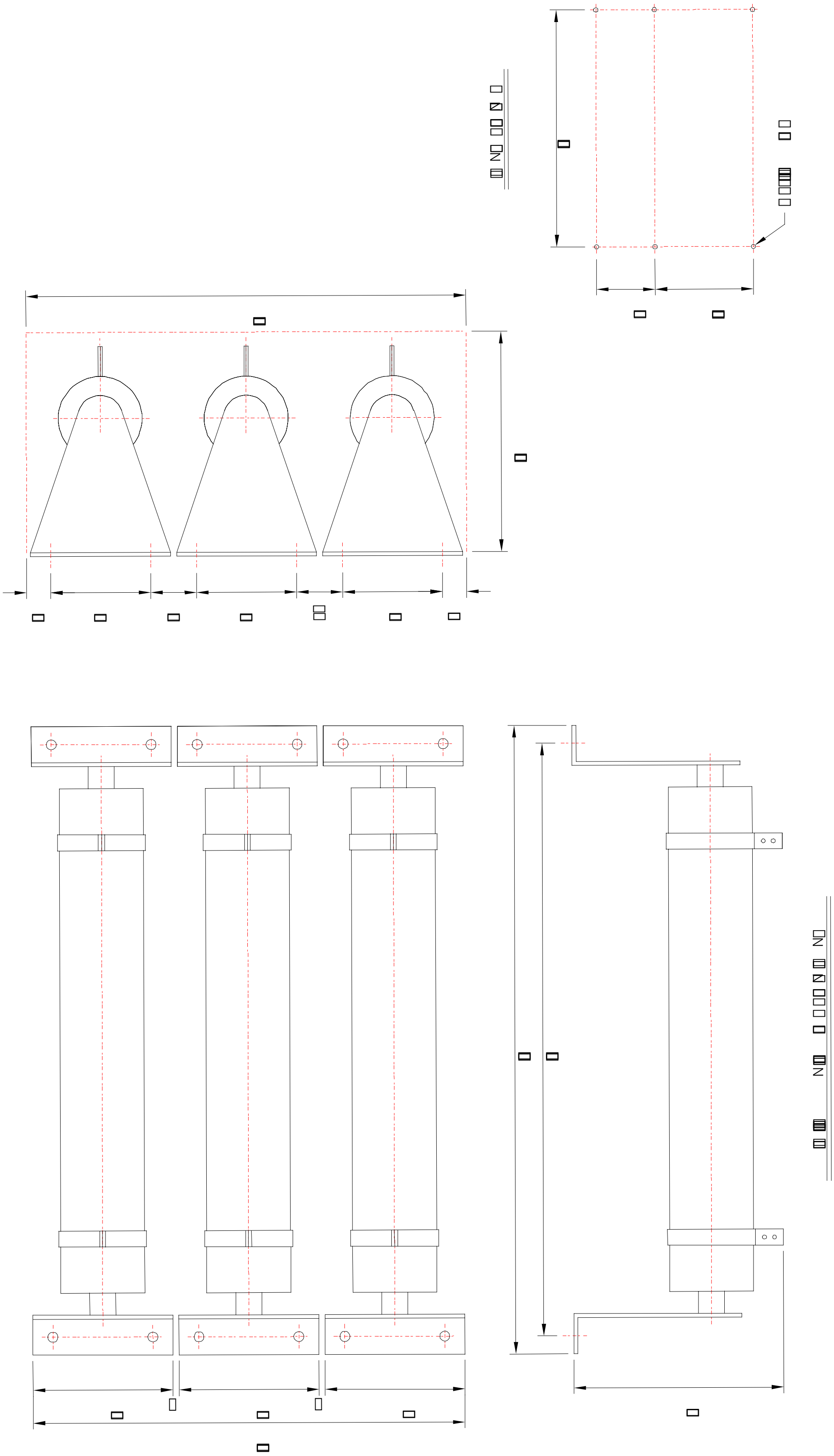


FIGURE 21: STABILIZATION RESISTOR DIMENSIONS . (226B2211F24)

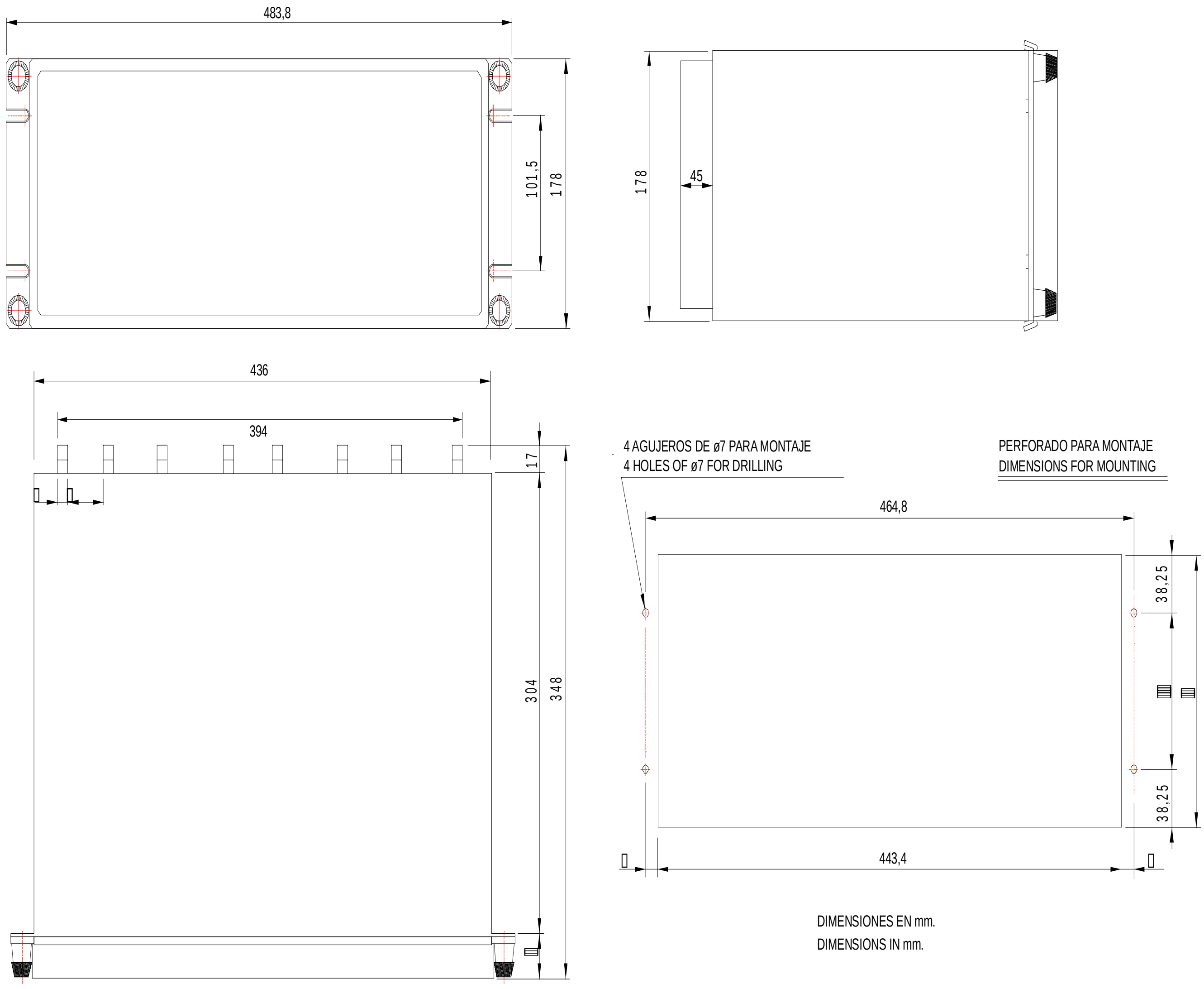


FIGURE 22 RACK . (226B2211F20)

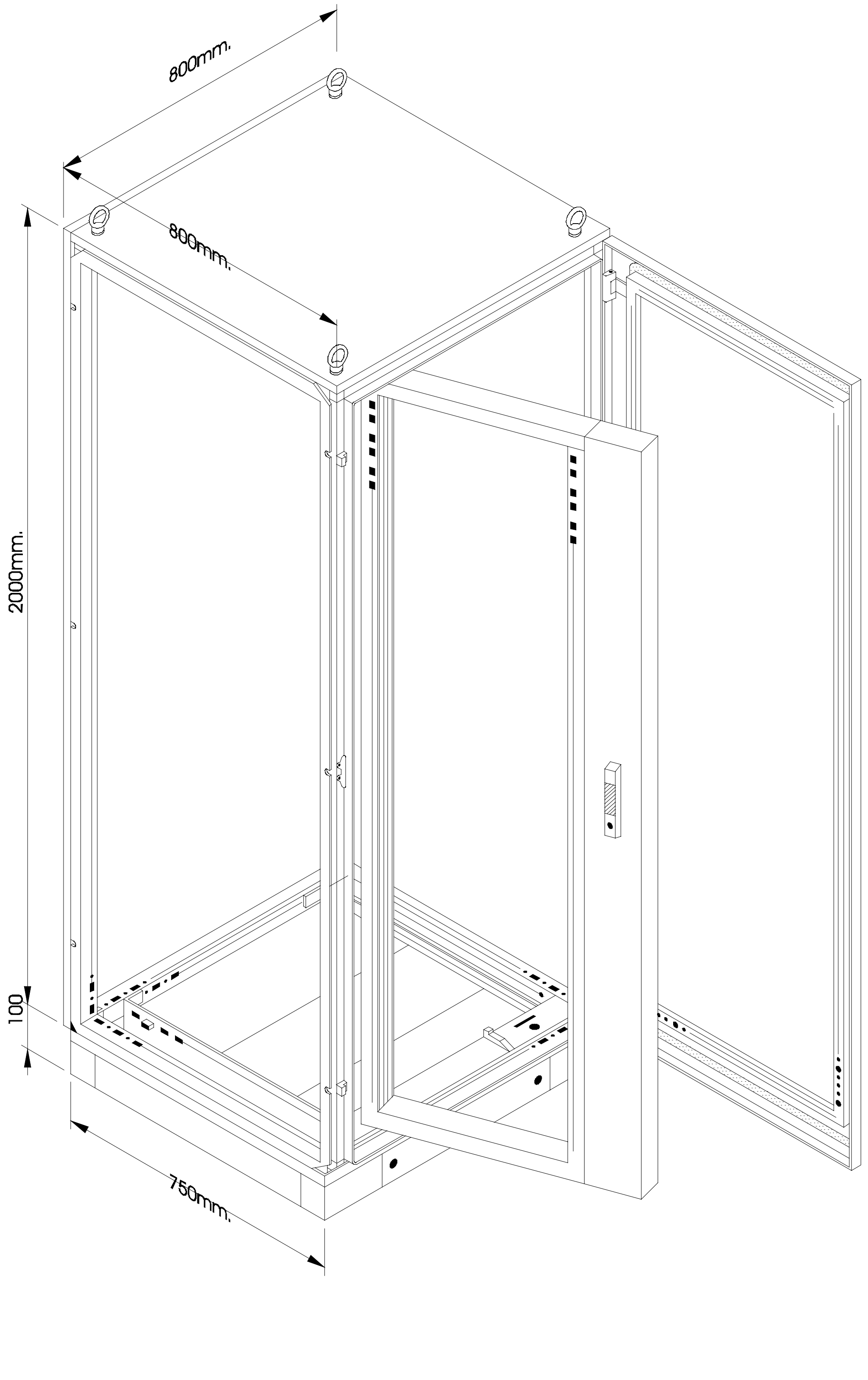


FIGURE 23 CABINET . (226B2211F21)

12. SCHEMATICS SINGLE BUSBAR

The following set of diagrams represents and imaginary substation (based on real cases) with single busbar scheme and 5 positions. These diagrams include optional features that can be supplied upon request, such as:

- Test rack.
- PK: test blocks located at the current inputs.
- PK: test blocks located at the tripping contact outputs.
- 86 block contacts
- Breaker failure of two steps

The diagrams shown are the following:

CONTENTS

NOTE: IN ALL SCHEMES, ELEMENTS ARE SHOWN
DISCONNECTED AND WITHOUT DC POWER SUPPLY

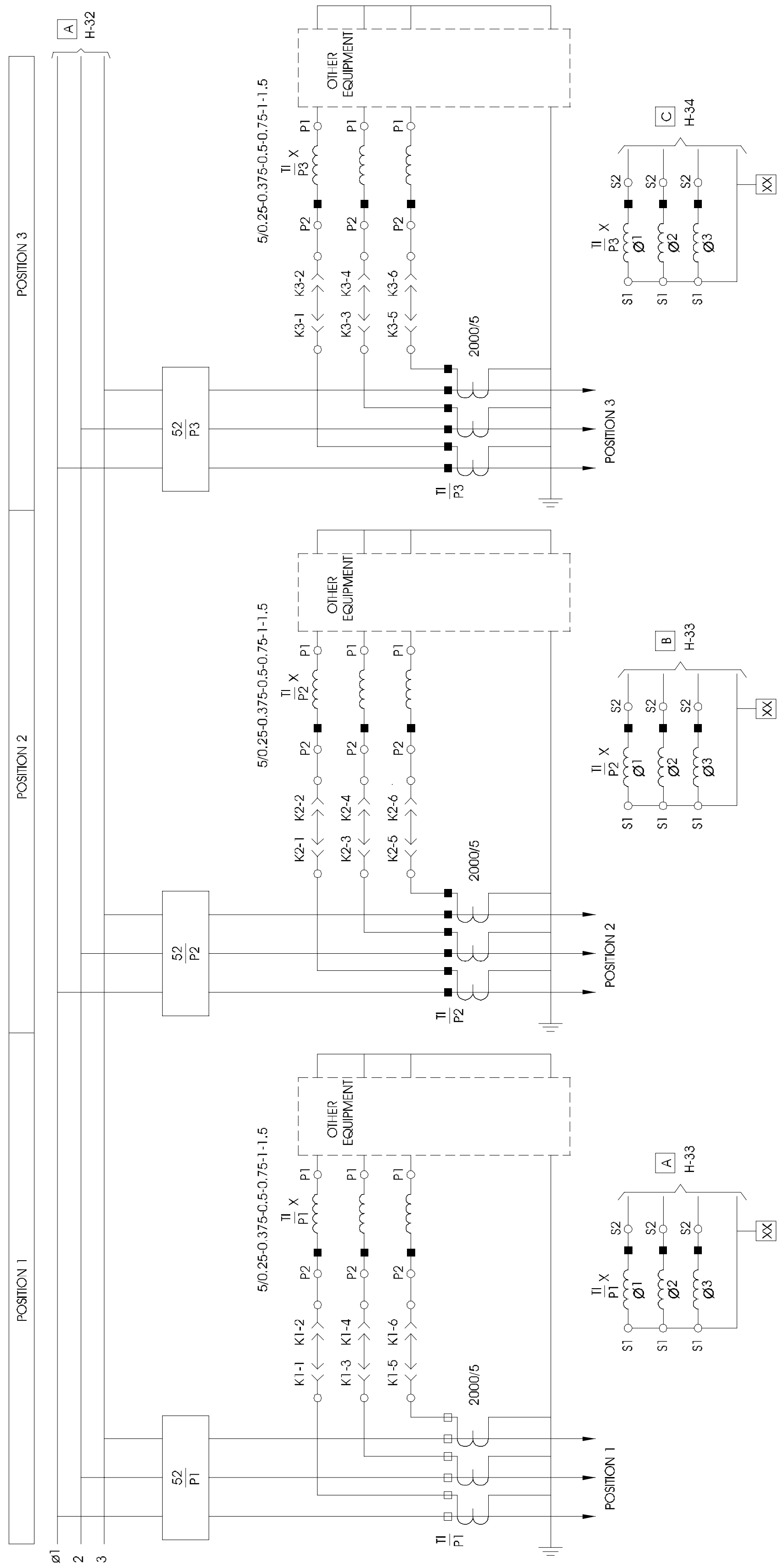


FIGURE B2211F47. THREE LINE CURRENT DIAGRAM. POSITION 1, 2, 3

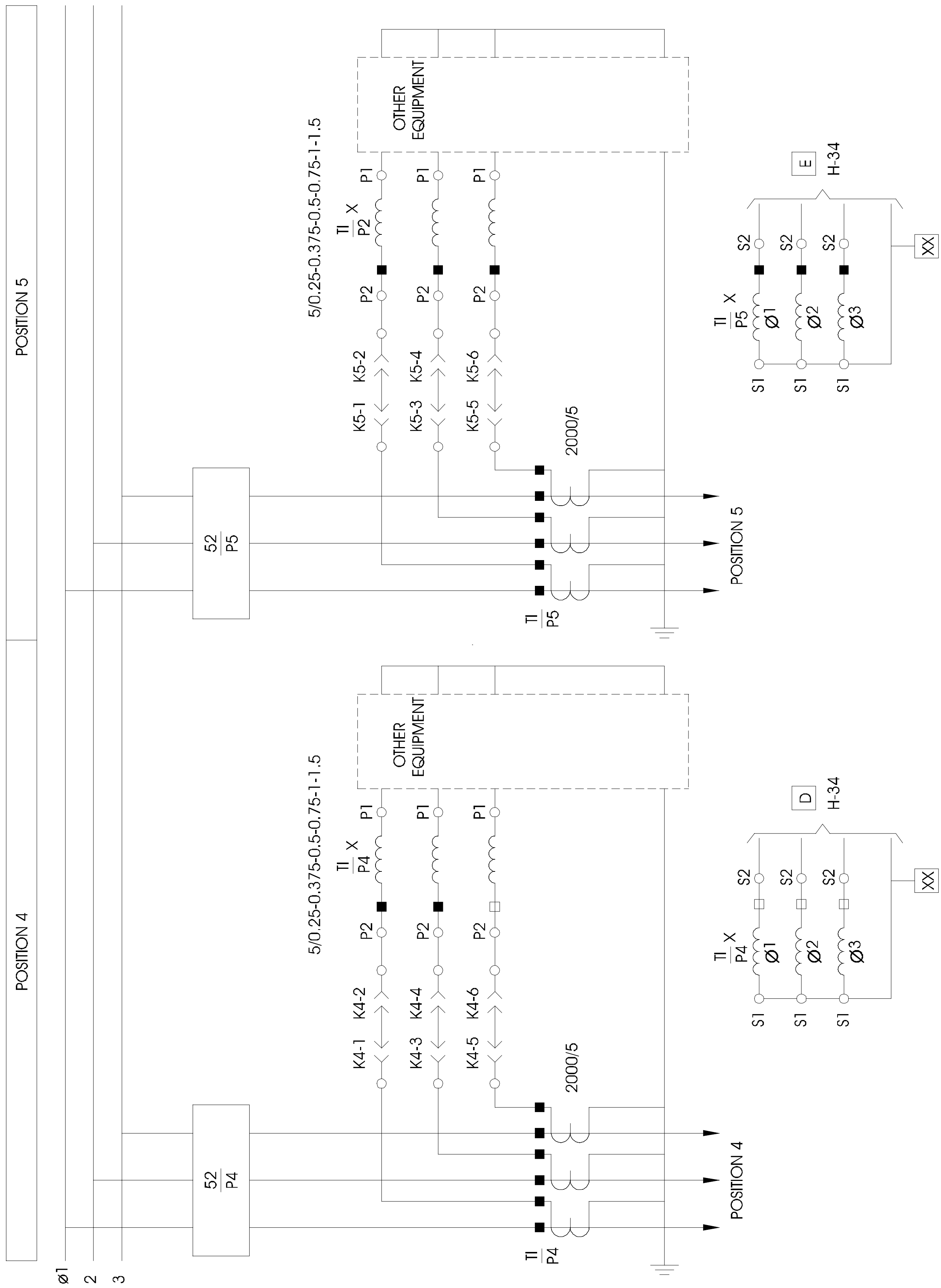


FIGURE B2211F48. THREE LINE CURRENT DIAGRAM. POSITION 4, 5

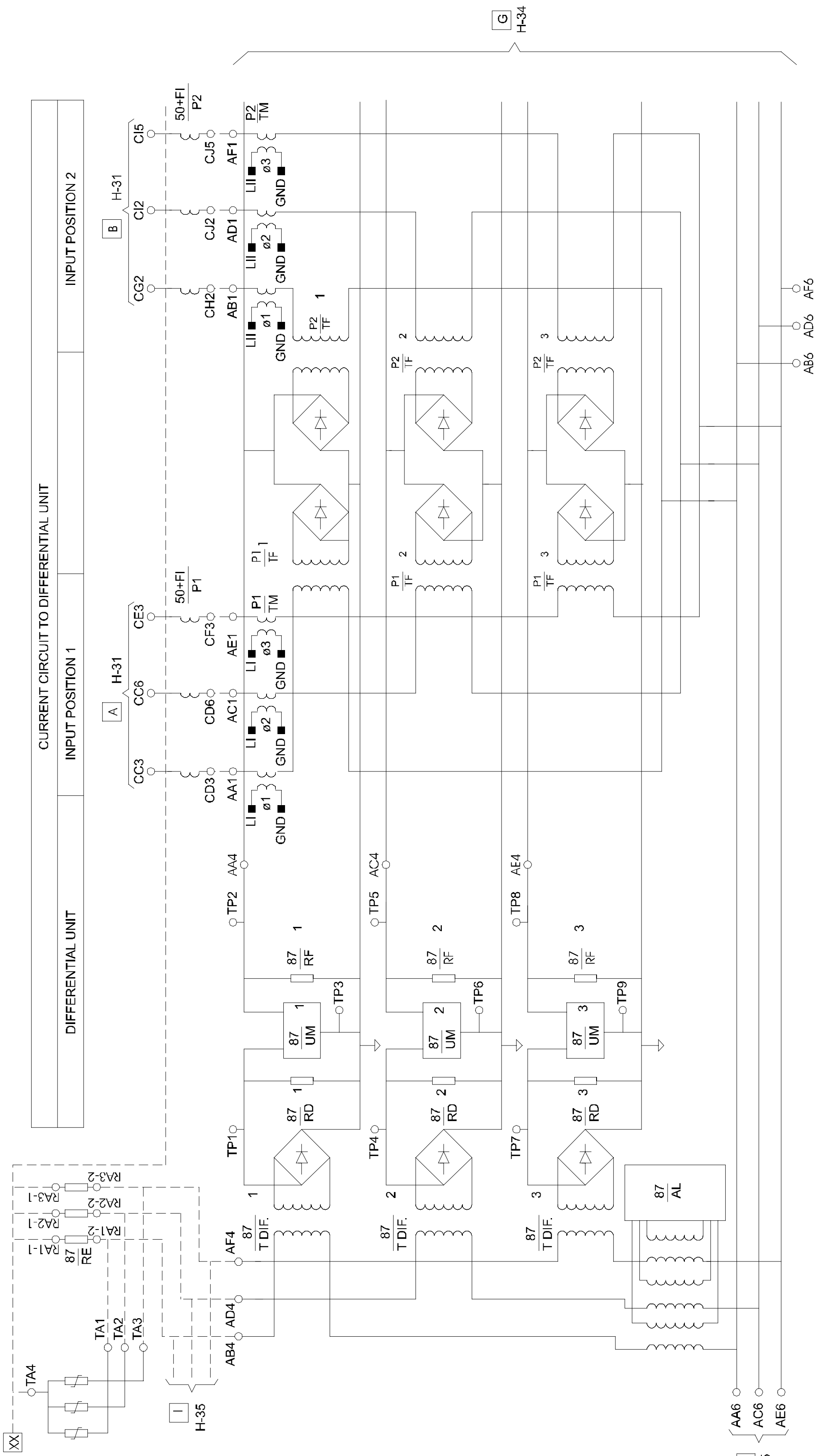


FIGURE B2211F49. DIFFERENTIAL UNIT. CURRENT INPUTS P1 Y P2

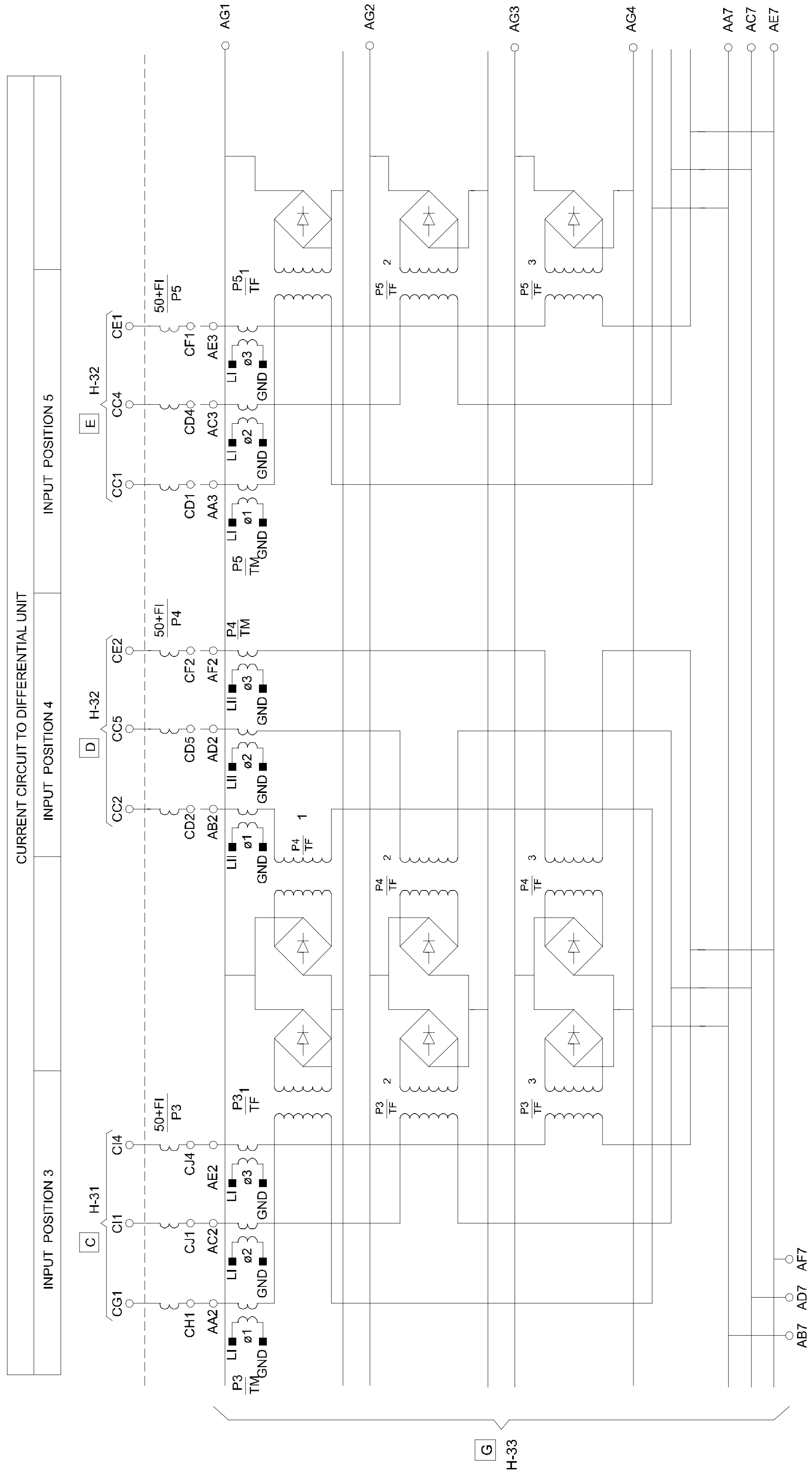


FIGURE B2211F50. CURRENT INPUTS P3, P4, P5 TO DIFFERENTIAL

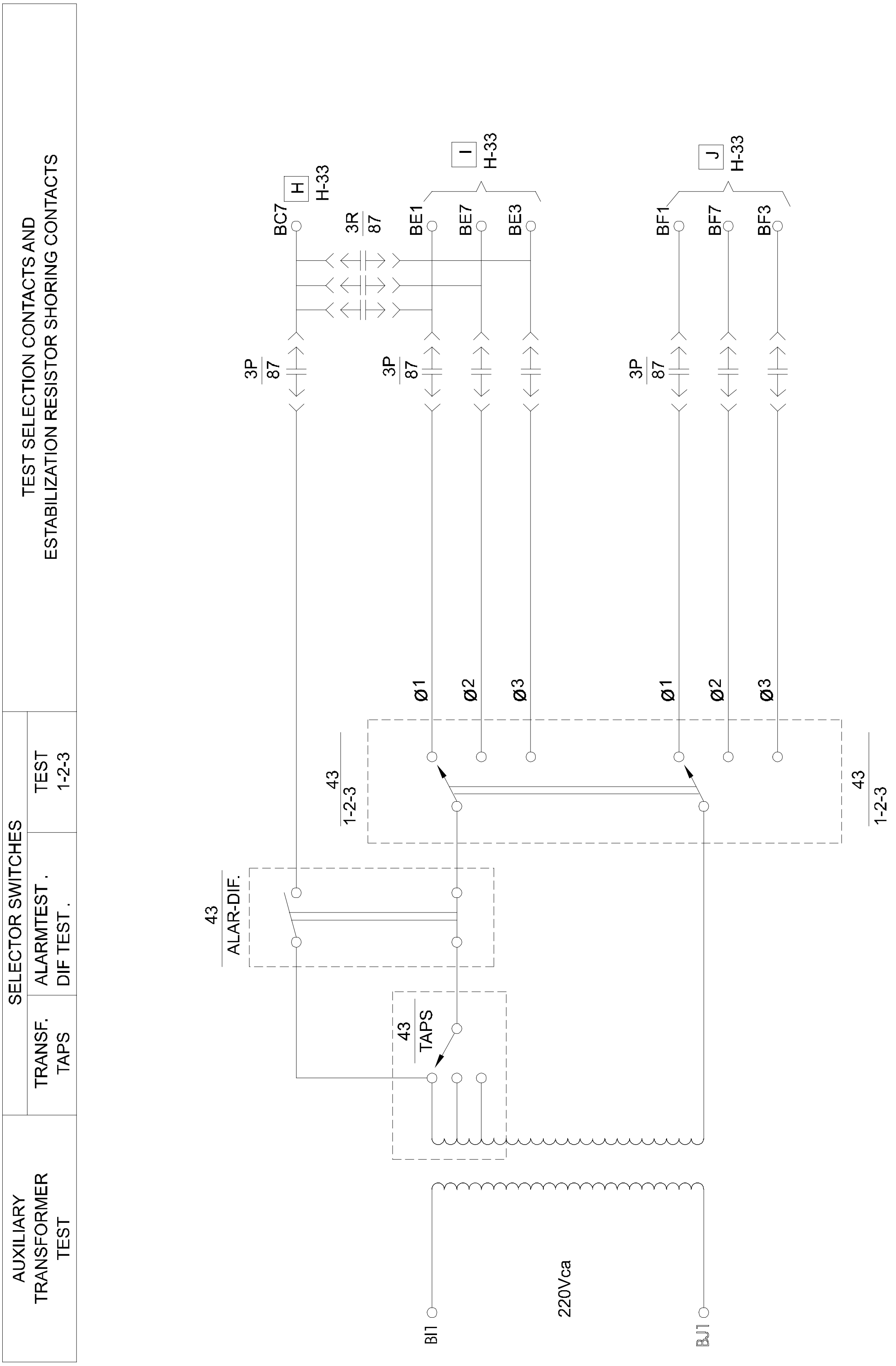


FIGURE B2211F51. TEST CIRCUIT. TEST CURRENT SELECTION

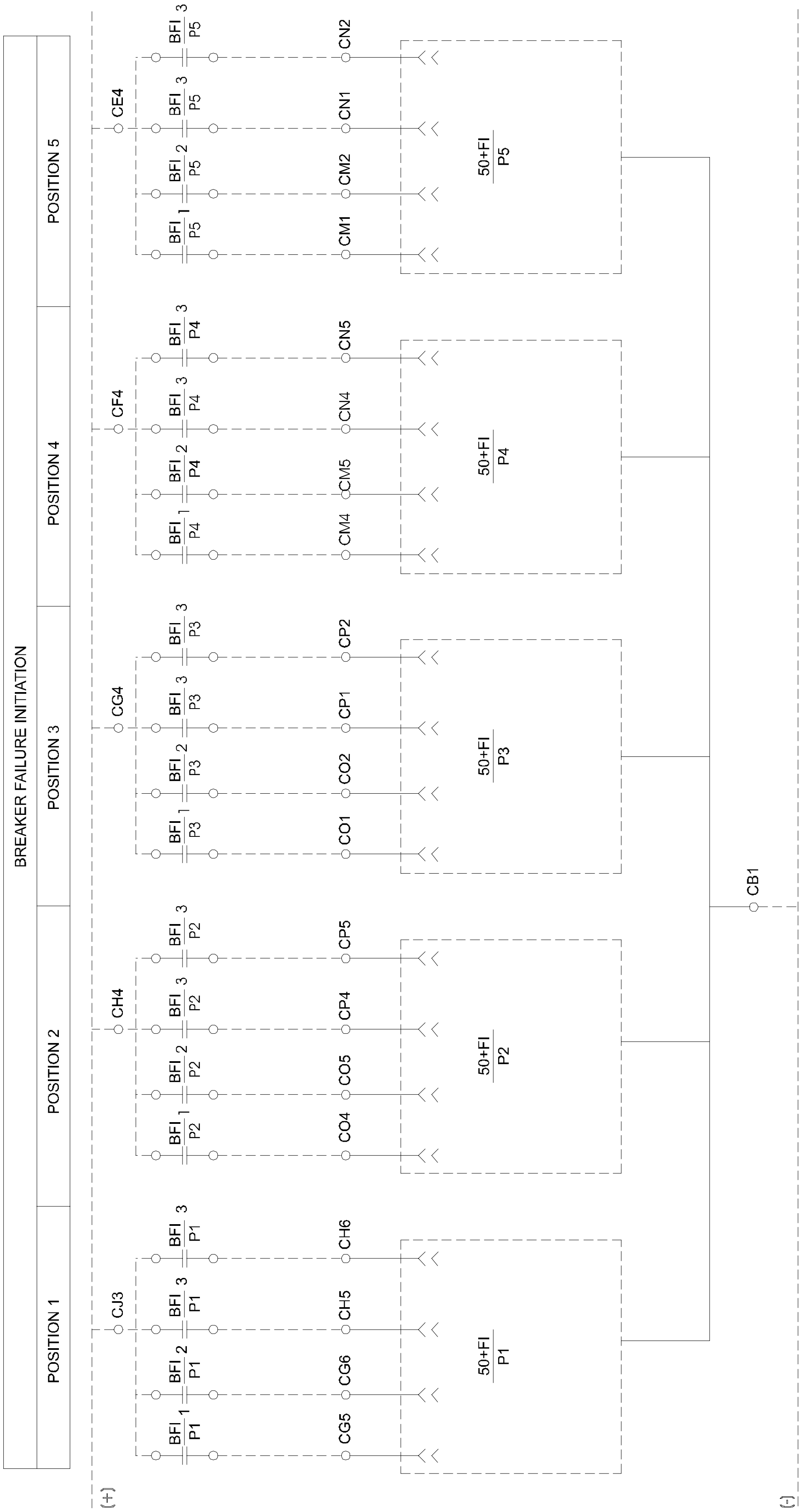


FIGURE B2211F52. BREAKER FAILURE INITIATION. POSITIONS 1, 2, 3, 4, 5

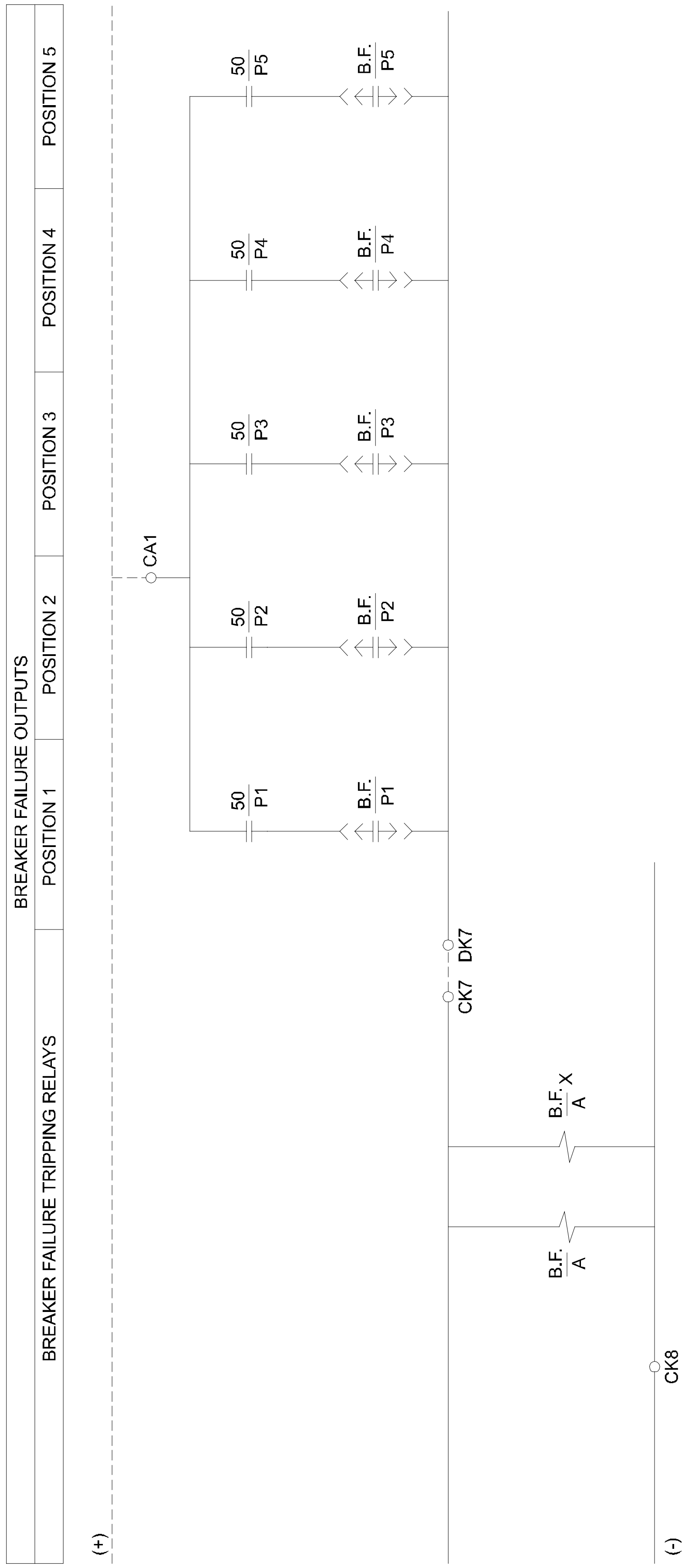


FIGURE B2211F53. TRIPPING RELAYS AND BREAKER FAILURE OUTPUTS

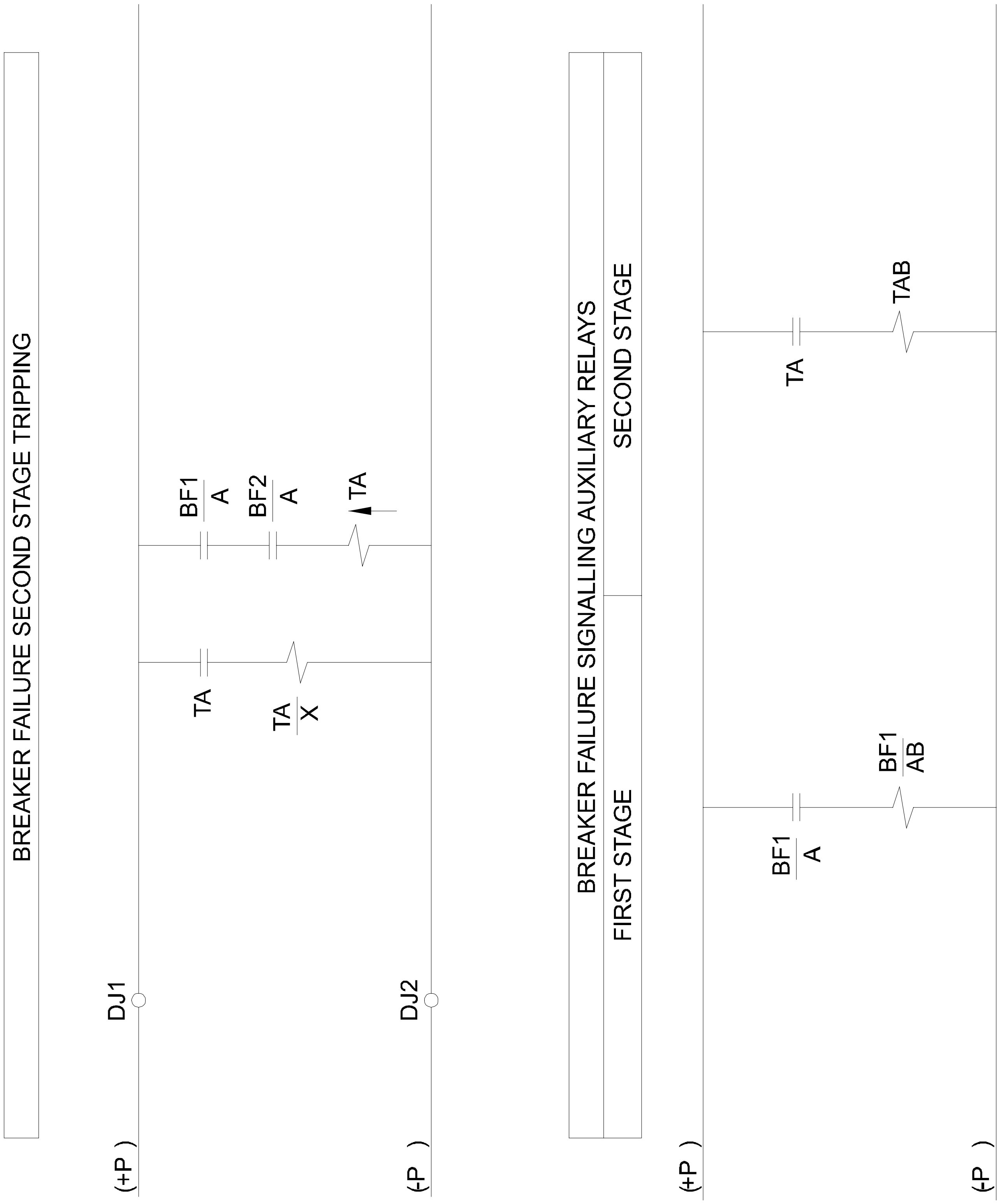


FIGURE B2211F54. BREAKER FAILURE SECOND STAGE TRIPPING AND SIGNALLING

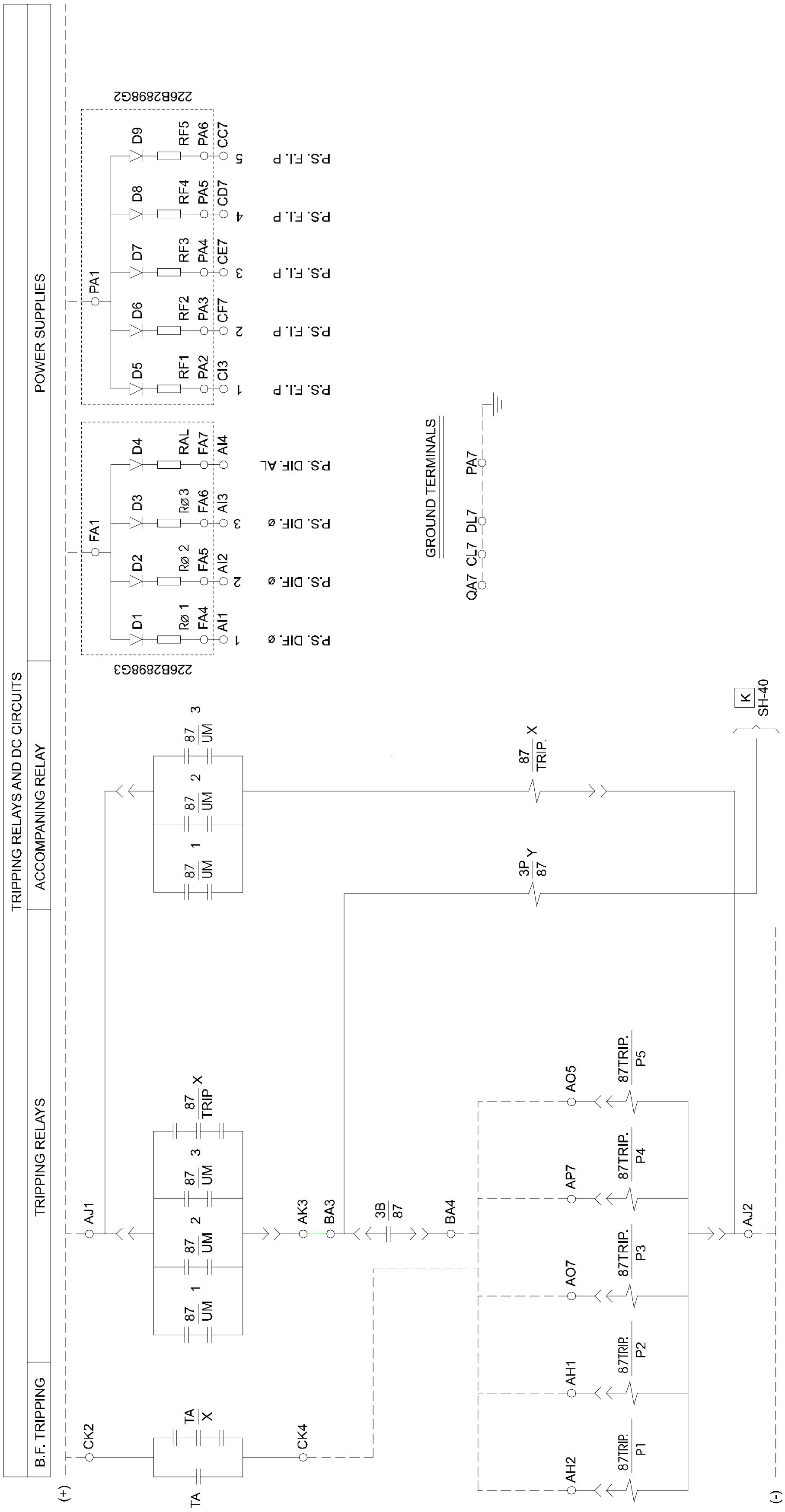


FIGURE B2211F55. TRIPPING RELAYS AND DC CIRCUIT

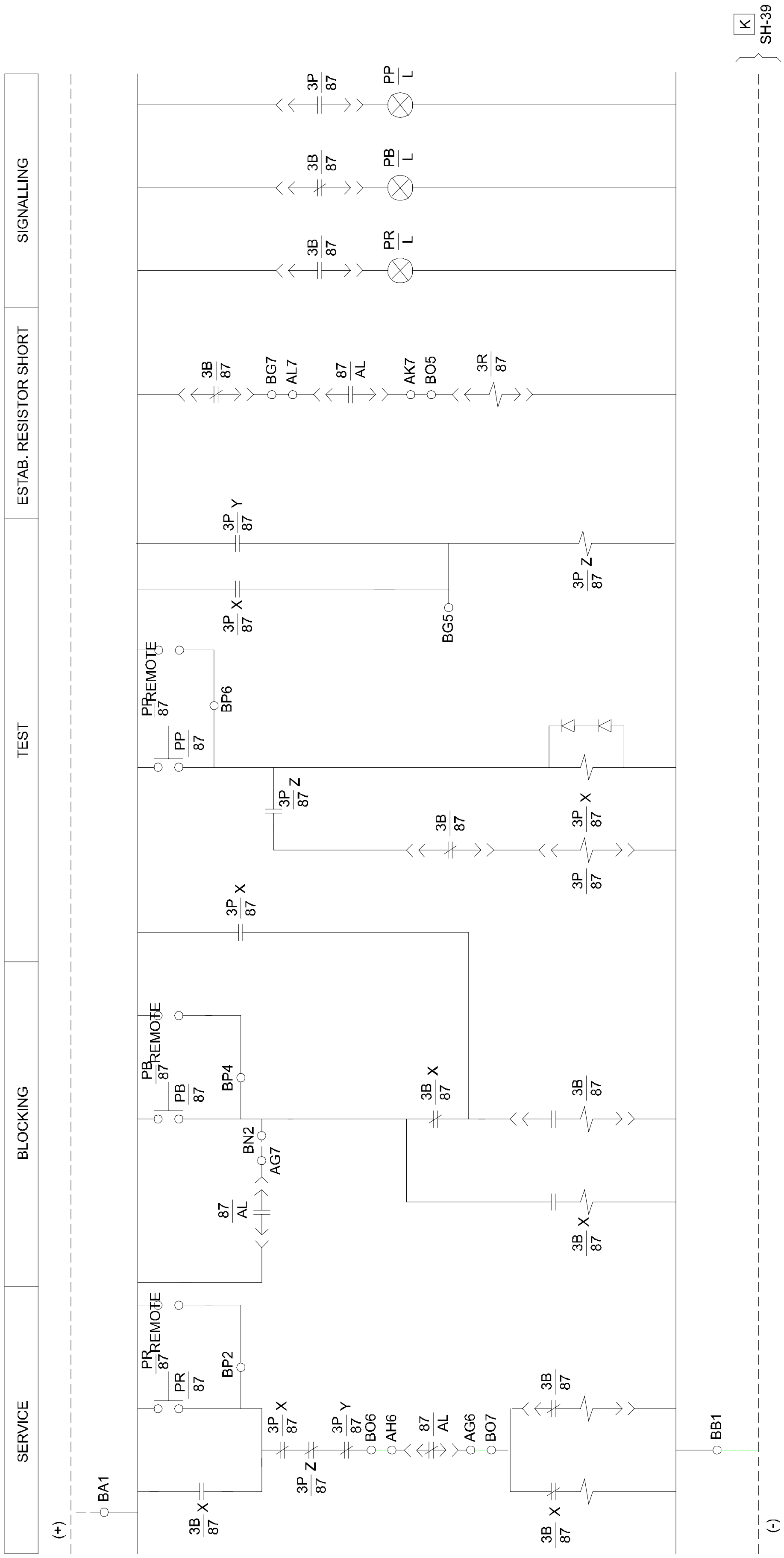


FIGURE B2211F56. CONNECTION-DISCONNECTION-TEST

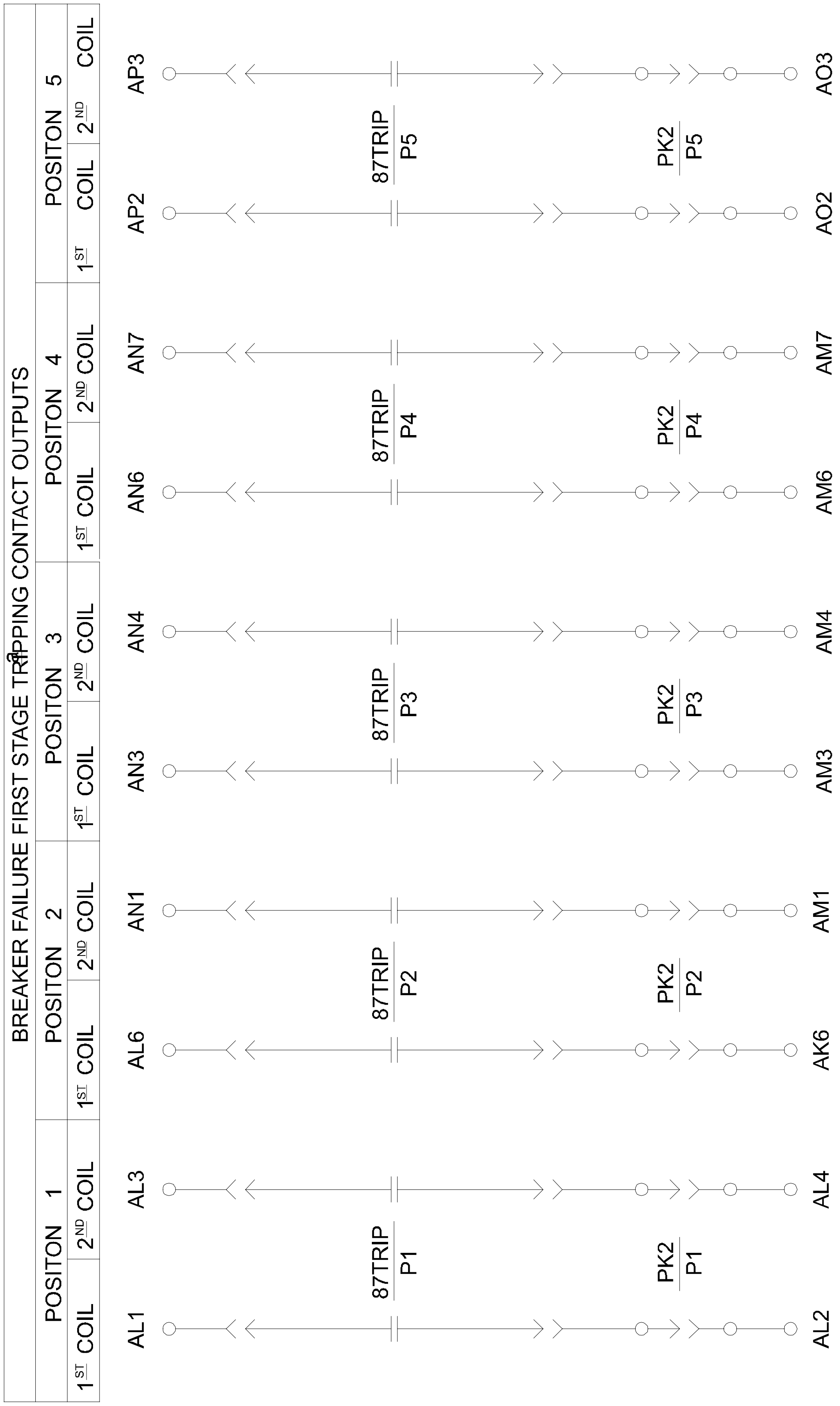


FIGURE B2211F57. BREAKER FAILURE FIRST STAGE TRIPPING CONTACT OUTPUTS P1, P2, P3, P4, P5

FIGURE B2211F58. SIGNALLING CONTACT OUTPUTS

12. SCHEMATICS SINGLE BUSBAR

FUNCTIONAL UNIT		***DEVICE TYPE***	***DESCRIPTION***
3B / 87		LATCHING RELAY	Lockout relay 3B/87
3BX / 87		TEST UNIT	Auxiliary of 3B/87
3P / 87		AUXILIARY RELAY HLA	Testing auxiliary relay
3PX / 87		TEST UNIT	Auxiliary of 3P/87
3PY / 87		TEST UNIT	Testing auxiliary relay
43/AL – DIFF.		TEST UNIT DPR	Selector switch of alarm diff. Test
43/TAPS		TEST UNIT DPR	Selector switch of tap selection
43/ ∅1, 43/2, 43/3		TEST UNIT DPR	Selector switch of phase selection
50 + BF/ P1_ _ _ _ P5		MFI	B.F. & overcurrent supervision relays / positions P1_ _ _ _ P5
50/P1_ _ _ _ P5		MFI	Overcurrent supervision contact positions P1_ _ _ _ P5
52/ P1_ _ _ _ P5		BREAKER	Breaker/ position P1_ _ _ _ P5
87 (∅1, ∅2, ∅3)		BUS1000	Differential relay, phases (∅A, ∅B, ∅C)
	RE	BUS1000	Stabilising resistor
	T. DIF	BUS1000	Differential circuit input current transformer
	AL	BUS1000	Alarm unit
	RD	BUS1000	Differential Voltage resistor
	RF	BUS1000	Restraint Voltage Resistor
	TRIP	BUS1000	Differential trip unit
	UM	BUS1000	Measuring unit
87X/ TRIP		DRD102	Auxiliaries of 87 / TRIP
BF/ P1_ _ _ _ P5		EXTERNAL CONTACT	Breaker failure initiation positions P1_ _ _ P5
P1 _ _ _ _ P5/TF		DFI1	Restraint transf. positions P1 _ _ _ _ P5 (input module)
P1 _ _ _ _ P5/TM		DFI1	Measuring transformer positions P1_ _ _ _ P5
B.F./A		DTE	Breaker failure
B.F./P1_ _ _ _ P5		SFI	Breaker failure positions P1_ _ _ _ P5
B.F./AX		DTE	Auxiliary of BF/AB
PB/L		TEST RACK	Blocking lamp
PB/87		TEST RACK	Blocking pushbutton
PP/L		TEST RACK	Test lamp
PP/87		TEST RACK	Test pushbutton
PR/L		TEST RACK	Reset lamp
PR/87		TEST RACK	Rest pushbutton
TP1_ _ _ _ TP5		Terminal	Differential and restraint voltage measuring points
TI AUX/P1_ _ _ _ P5		TRANSFORMER 226B2999	Auxiliary current transformer / positions P1_ _ _ _ P5
TI/P1_ _ _ _ P5		MAIN C.T.	Main current transformer / positions P1_ _ _ _ P5
PPY/87		AUXILIARY RELAY	Auxiliary remote reset
3R/87		AUXILIARY RELAY 189C6051G1	Stabilisation resistor shorting relay
		226B2898G2	Breaker failure power supply auxiliary resistors box
		226B2898G3	Differential power supply auxiliary resistors box
PK-2		PK-2	Block test 6 poles

NOTE: Terminals starting by A are part of the Differential rack
Terminals starting by B are part of the Test rack
Terminals starting by C are part of the Breaker failure rack
Terminals starting by D are part of the DTE rack
Terminals starting by F are part of the Differential power supply
Terminals starting by K are part of the Test block
Terminals starting by P are part of the breaker failure power supply
Terminals starting by T are part of the Thyrite box

FIGURE B2211F59. LEGEND

13. SCHEMATICS DOUBLE BUSBAR

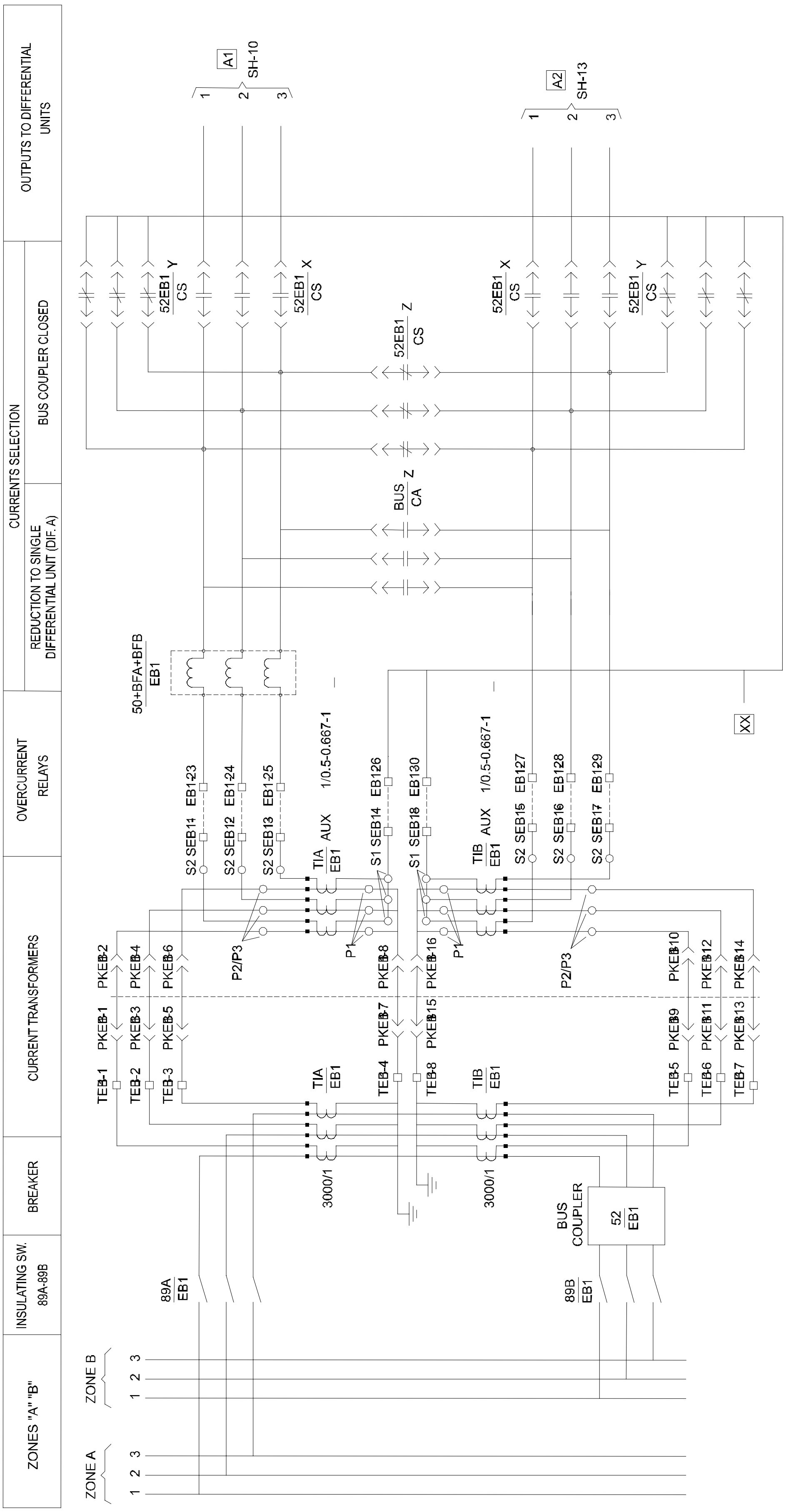
The following sets of drawings represent an imaginary substation (based on real cases) with single and double bus bar arrangements with eight feeders plus a bus coupler (226B6429). This scheme includes some of the optional features that can be provided under request:

- Test rack.
- PK: test blocks located in the current input.
- PK: test blocks located in the tripping output contacts.
- 86 lock out contacts
- Breaker failure with two steps
- Undervoltage supervision. (27)

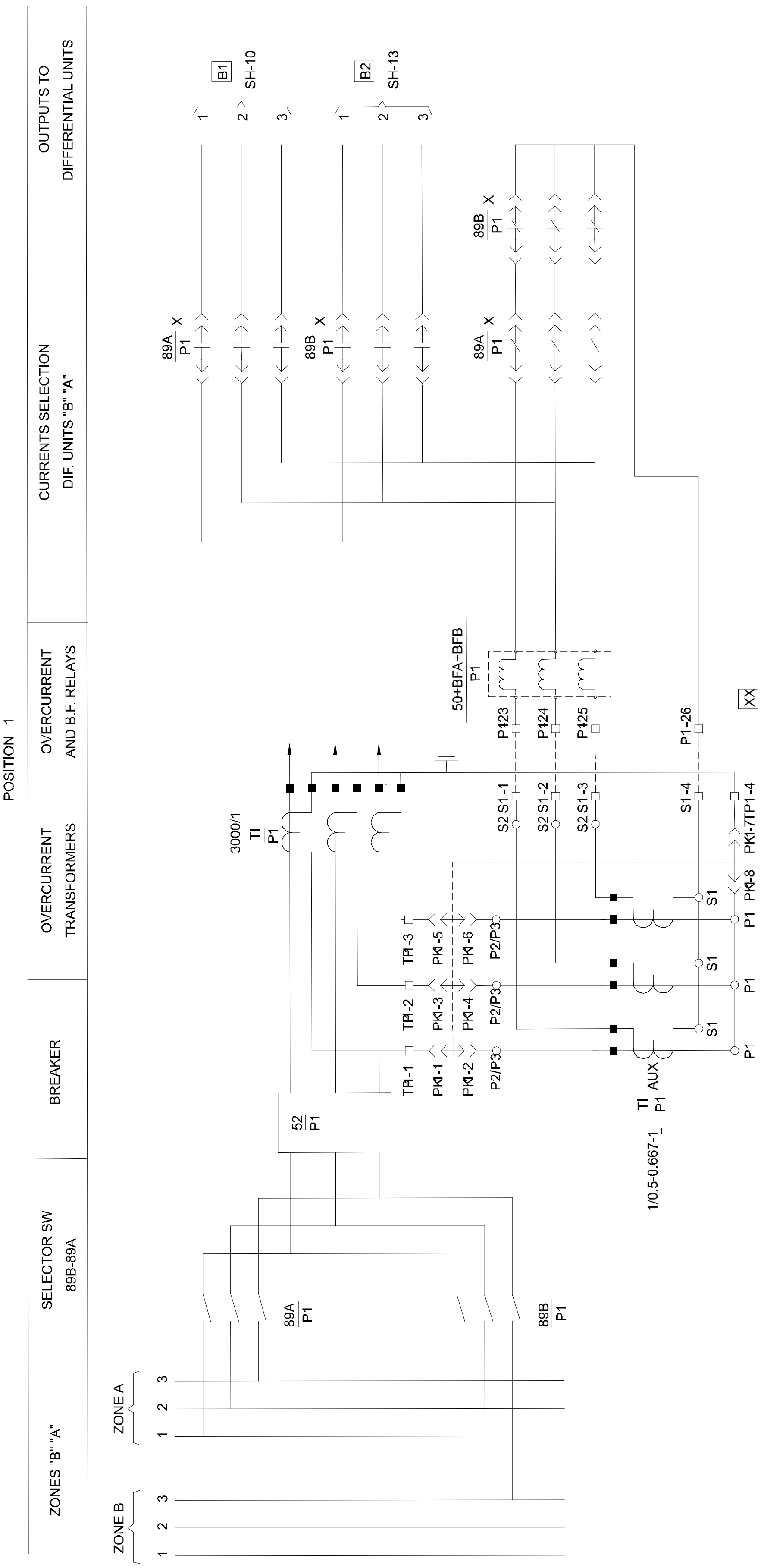
13. SCHEMATICS DOUBLE BUSBAR

DOUBLE BUSBAR ARRANGEMENT

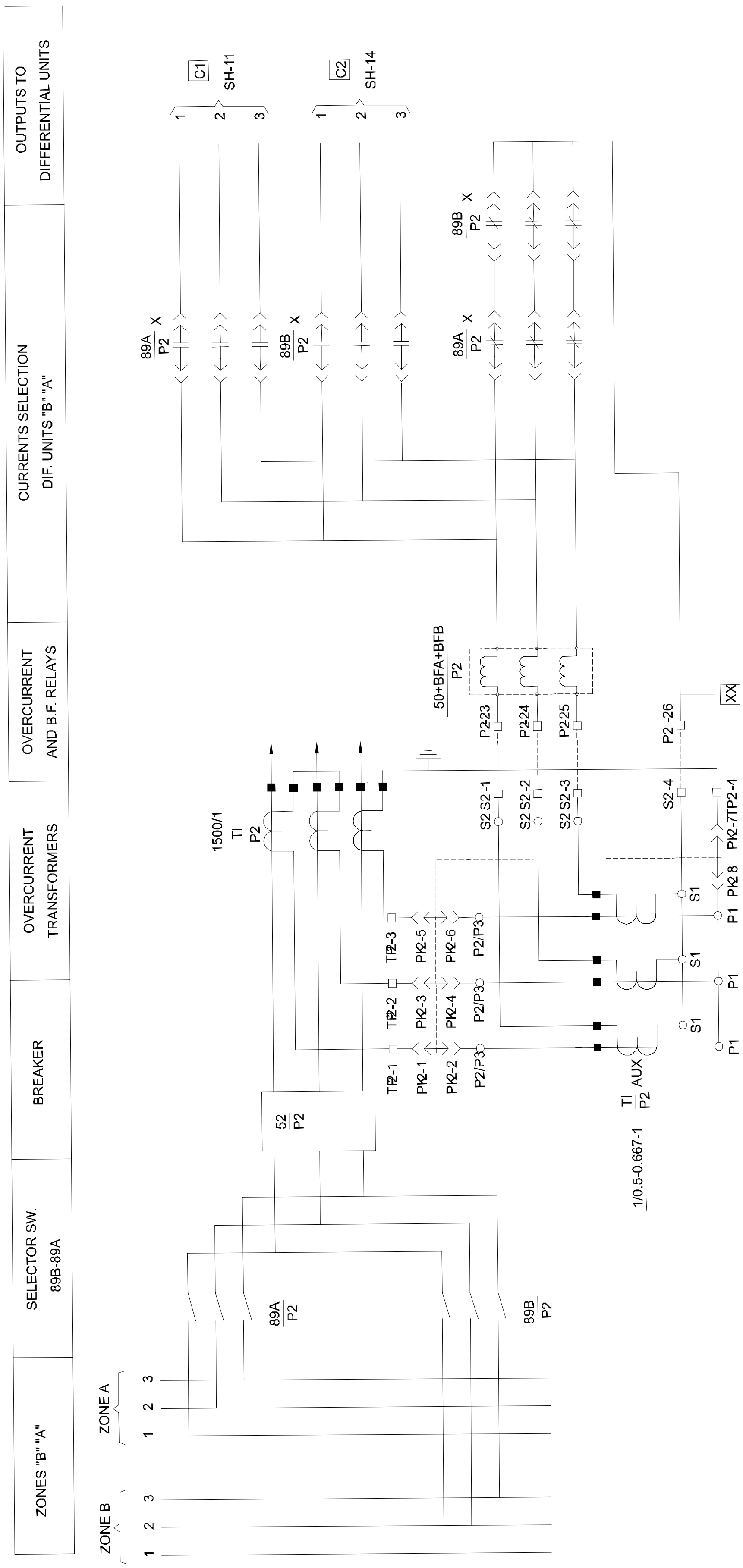
1. Bus coupler EB – Three line current diagram
2. Position 1 – Three line current diagram
3. Position 2 – Three line current diagram
4. Position 3 – Three line current diagram
5. Position 4 – Three line current diagram
6. Position 5 – Three line current diagram
7. Position 6 – Three line current diagram
8. Position 7 – Three line current diagram
9. Position 8 – Three line current diagram
10. Current circuit to “A” differential unit, current input EB, P1.
11. Current circuit to “A” differential unit, current input P2, P3, P4.
12. Current circuit to “A” differential unit, current input P5, P6, P7, P8.
13. Current circuit to “B” differential unit, current input EB, P1.
14. Current circuit to “B” differential unit, current input P2, P3, P4.
15. Current circuit to “B” differential unit, current input P5, P6, P7, P8.
16. Test unit zones A & B
17. Position auxiliary latching relays, positions P1, P2, P3, P4
18. Position auxiliary latching relays, positions P5, P6, P7, P8
19. Bus coupler reduction to single differential unit.
20. First stage breaker failure initiation, positions EB, P1, P2, P3
21. First stage breaker failure initiation, positions P4, P5, P6, P7
22. First stage breaker failure initiation, position P8.
23. First stage breaker failure tripping contact outputs EB, P1, P2, P3, P4
24. First stage breaker failure tripping contact outputs P5, P6, P7, P8
25. Second stage breaker failure tripping & signalling
26. Differential units and breaker failure tripping contact outputs. Tripping relays output. Position EB, P1, P2, P3, P4.
27. Tripping relays output. Position P5, P6, P7, and P8.
28. Differential units A, B, tripping auxiliary relays.
29. A differential unit connection, disconnection, and test.
30. B differential unit connection, disconnection, and test.
31. Power supply auxiliary circuits.
42. Breaker Failure Second Stage and Tripping contact outputs P1, P2, P3, P4, P5, P6, P7, P8
43. Signalling contact outputs
44. Cabinets interconnections
45. Location and distribution of terminal blocks. Cabinet 1
46. Location and distribution of terminal blocks. Cabinet 2
47. Location and distribution of terminal blocks. Cabinet 3
48. Legend



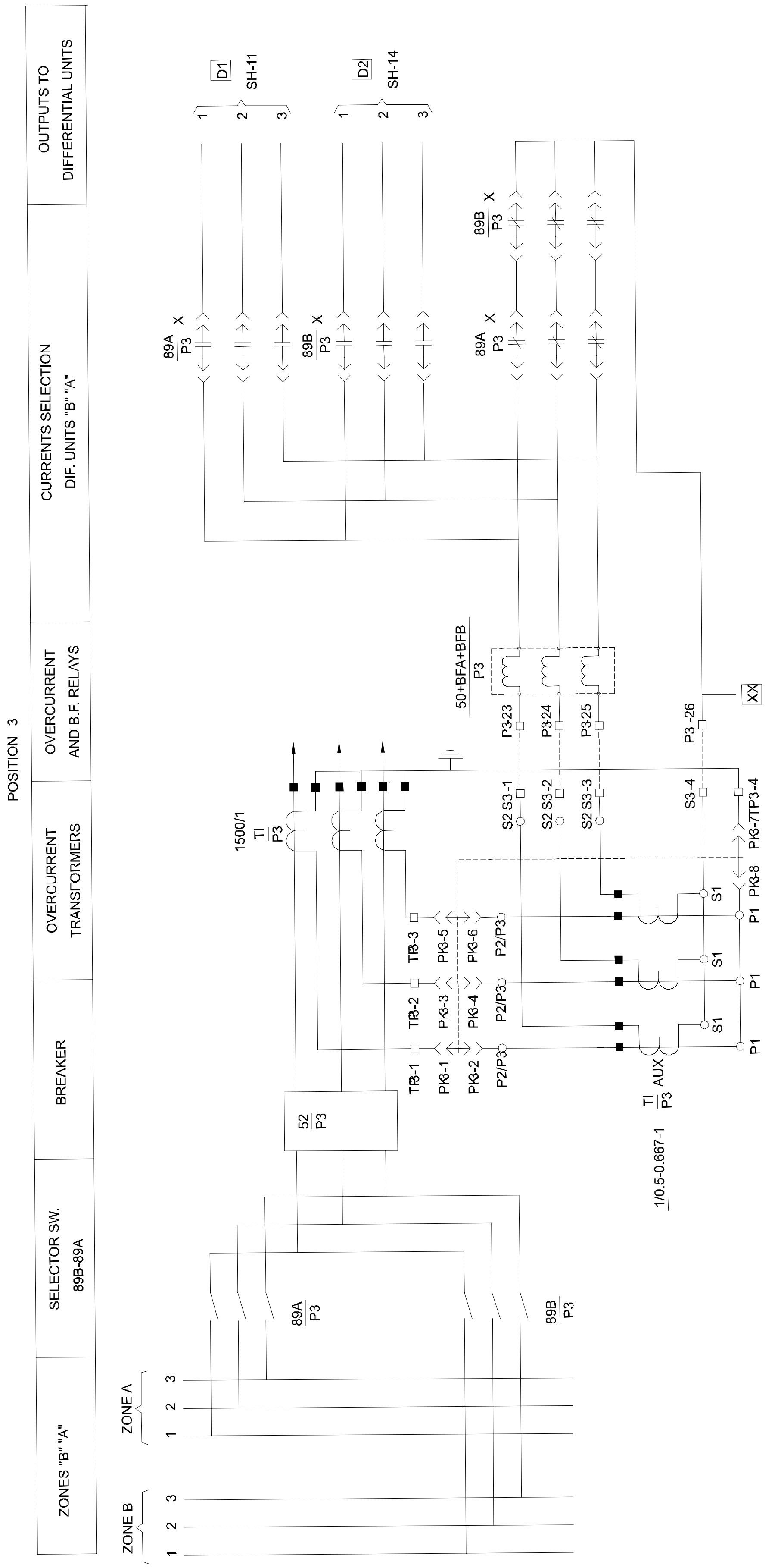
1. BUS COUPLER EB THREE LINE CURRENT DIAGRAM (226B6429F1)



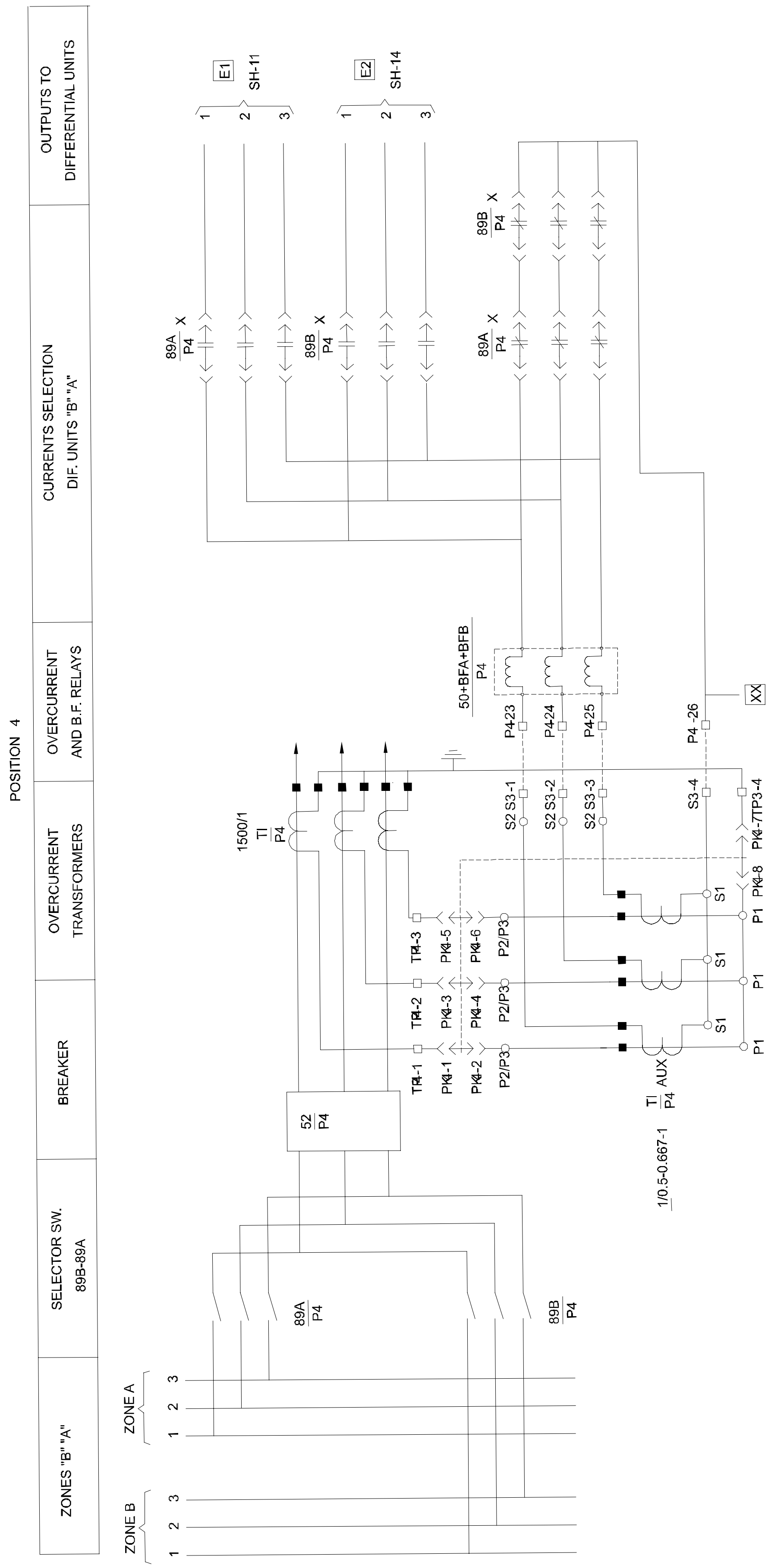
2. POSITION 1. THREE LINE CURRENT DIAGRAM (226B6429F2)



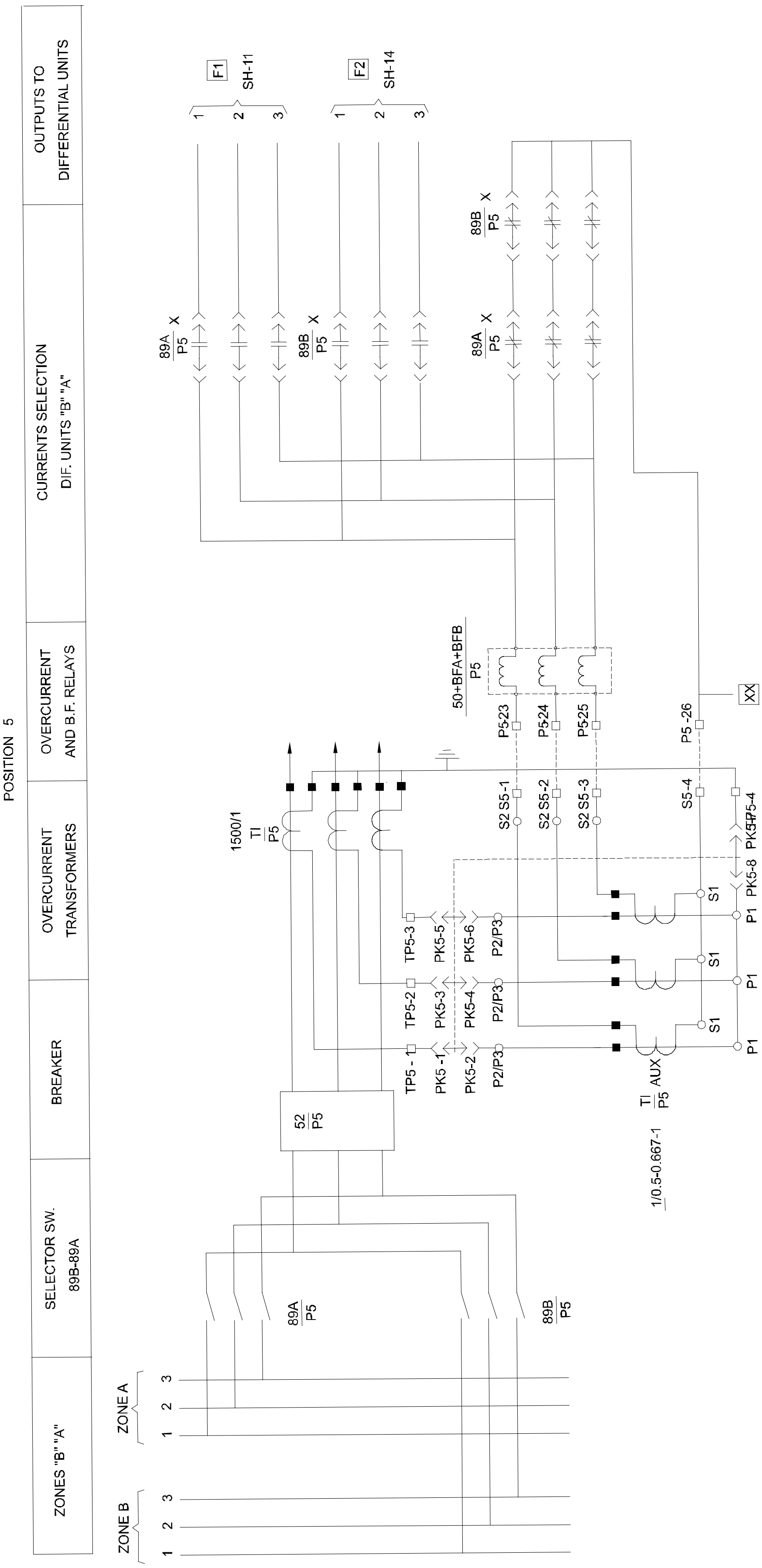
3. POSITION 2. THREE LINE CURRENT DIAGRAM (226B6429F3)



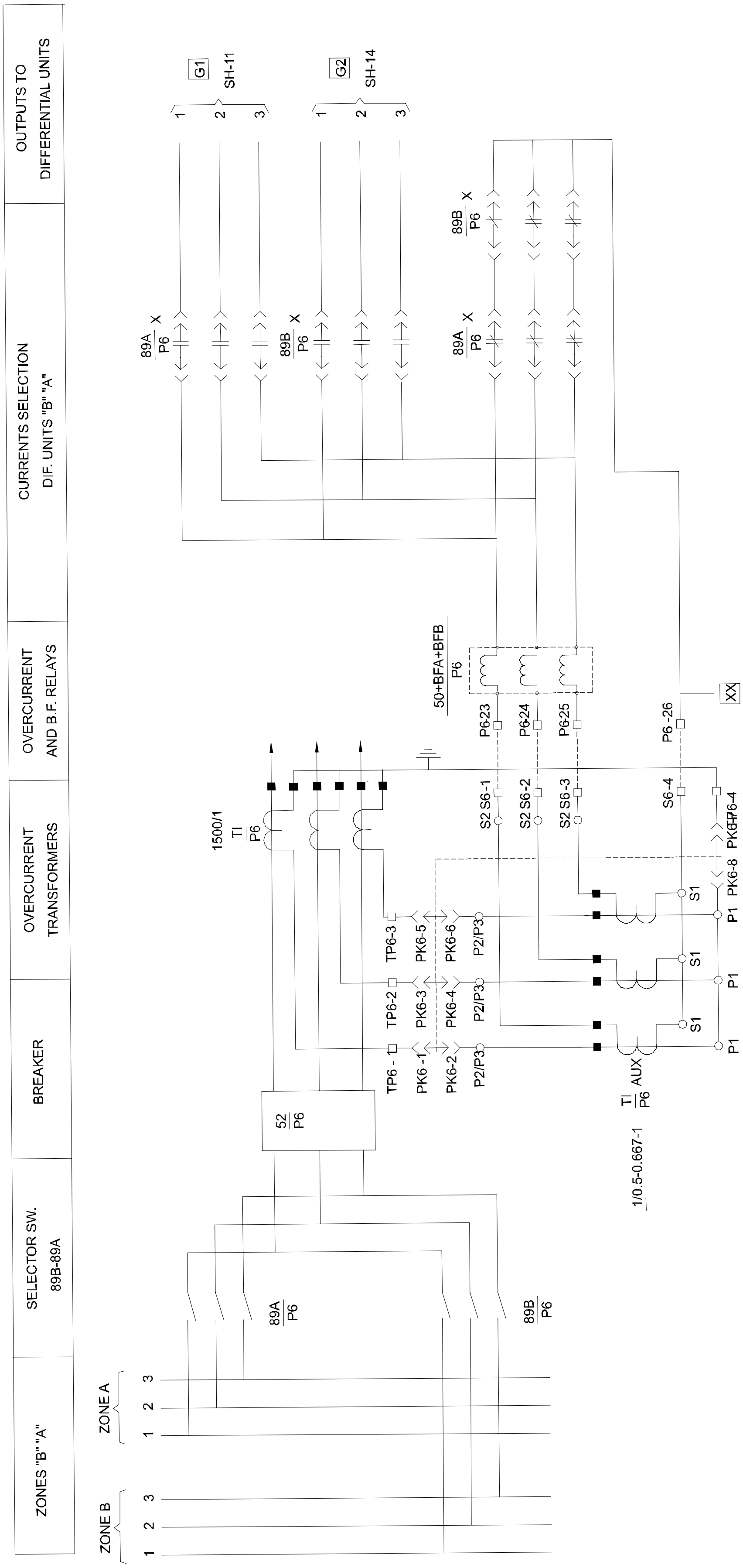
4. POSITION 3. THREE LINE CURRENT DIAGRAM (226B6429F4)



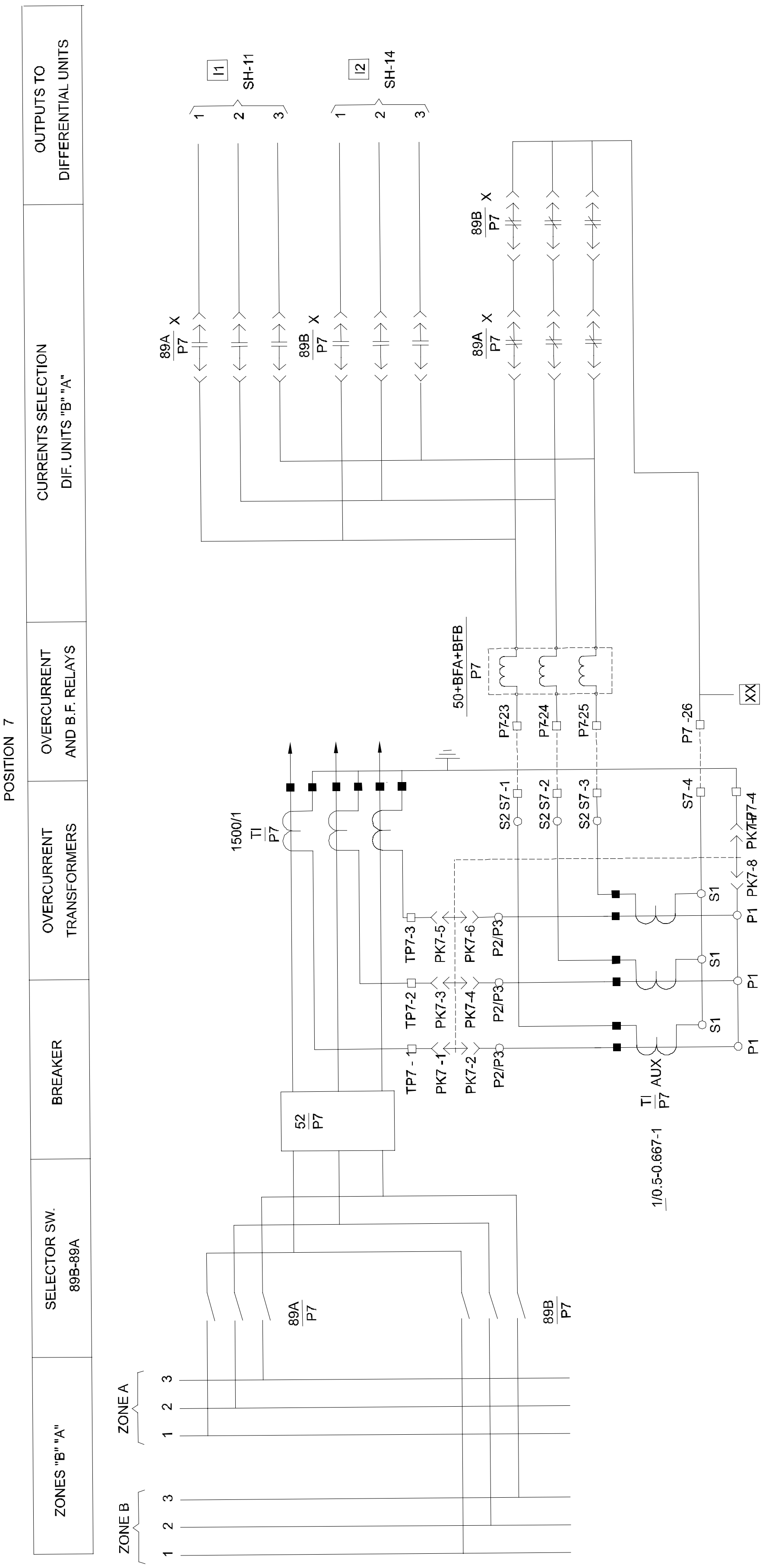
5. POSITION 4. THREE LINE CURRENT DIAGRAM (226B6429F5)



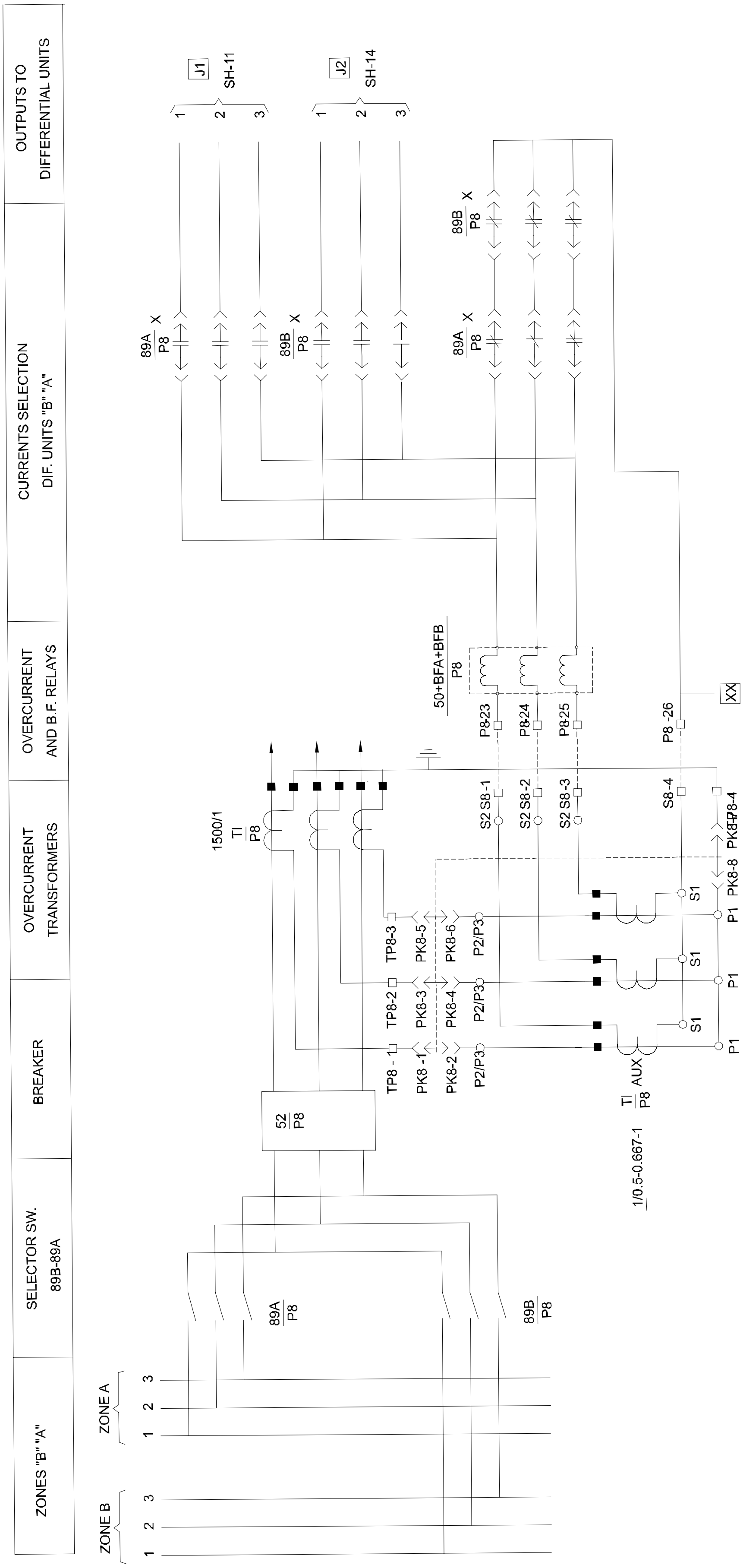
6. POSITION 5. THREE LINE CURRENT DIAGRAM (226B6429F6)



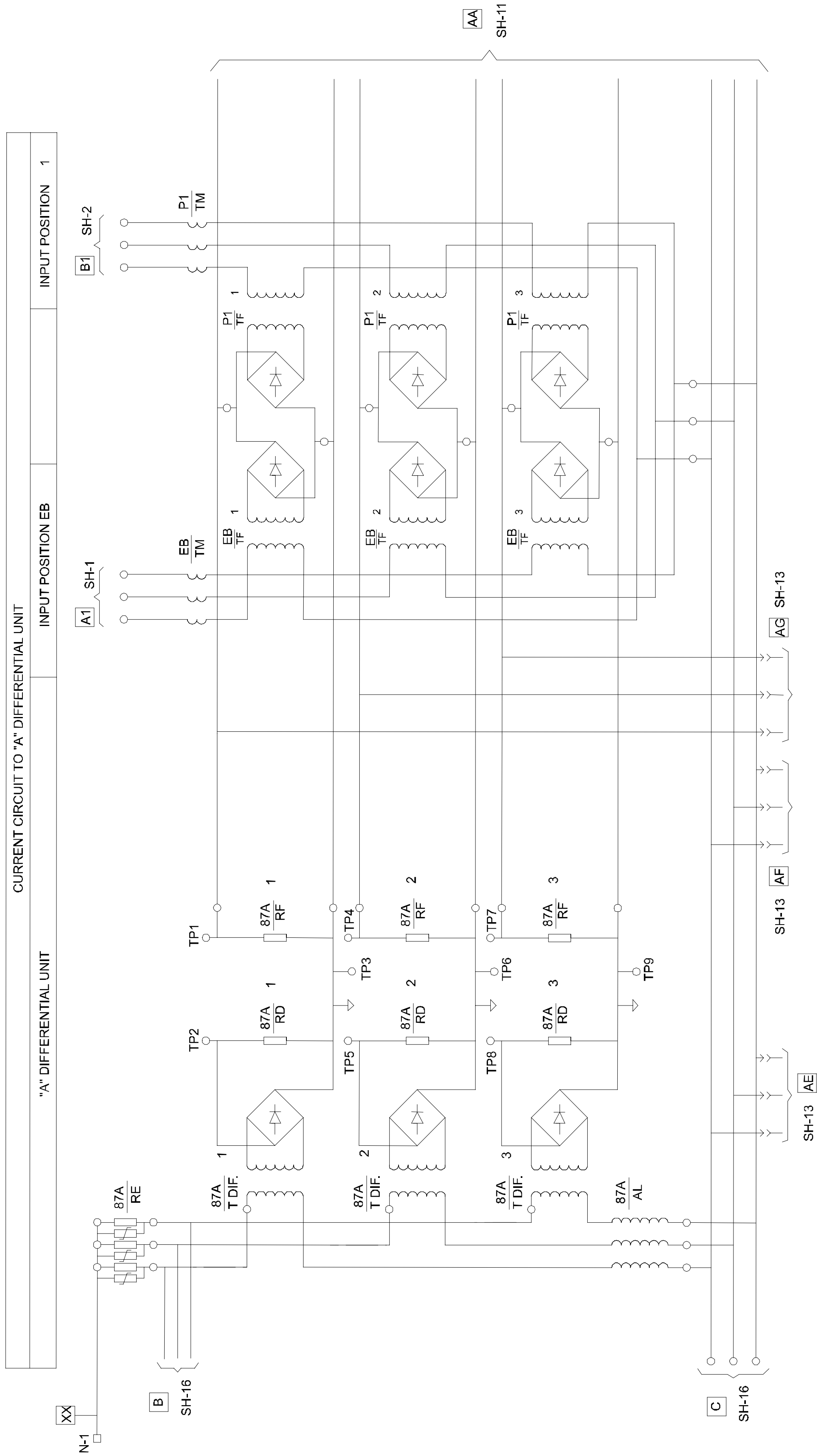
7. POSITION 6. THREE LINE CURRENT DIAGRAM (226B6429F7)



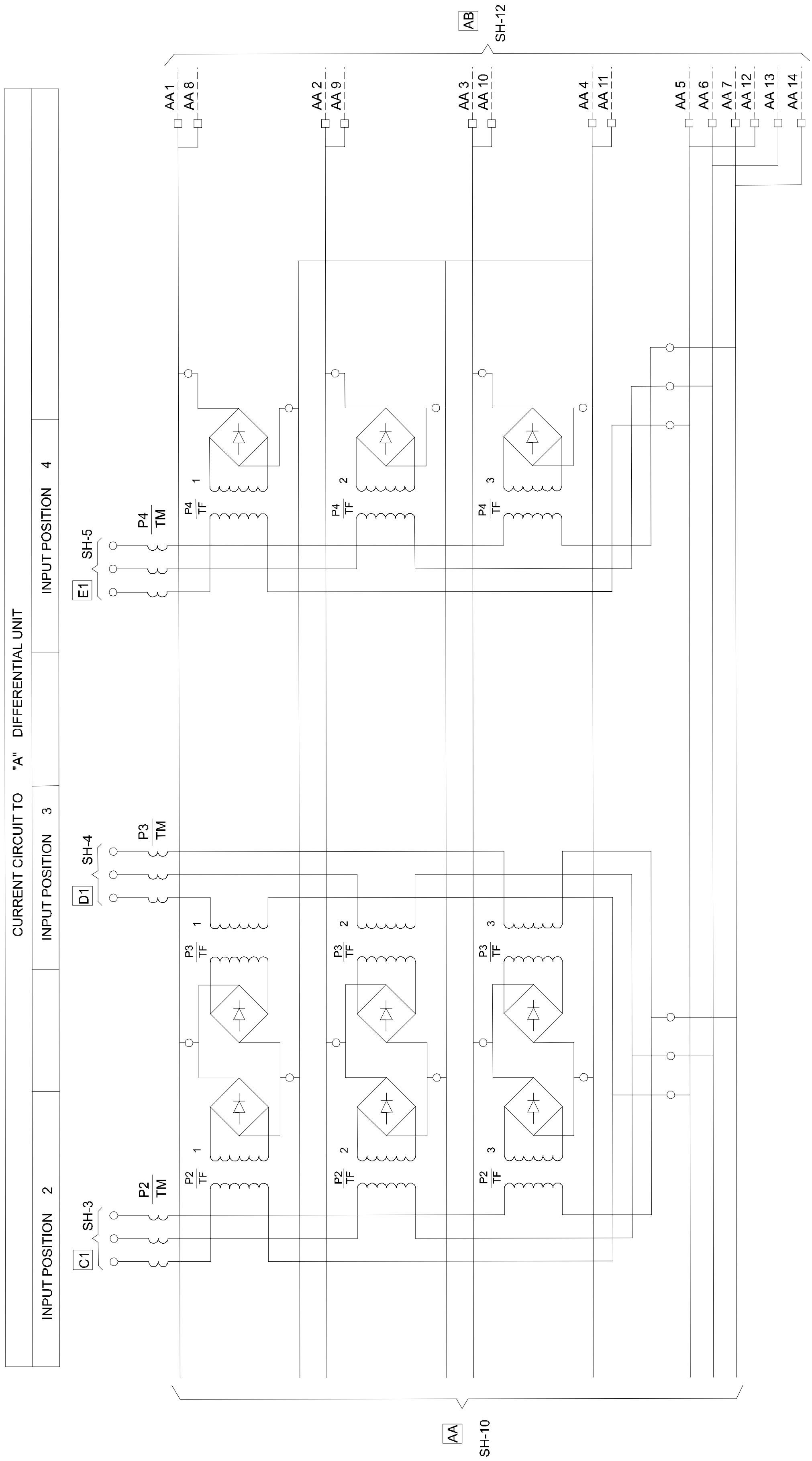
8. POSITION 7. THREE LINE CURRENT DIAGRAM (226B6429F8)



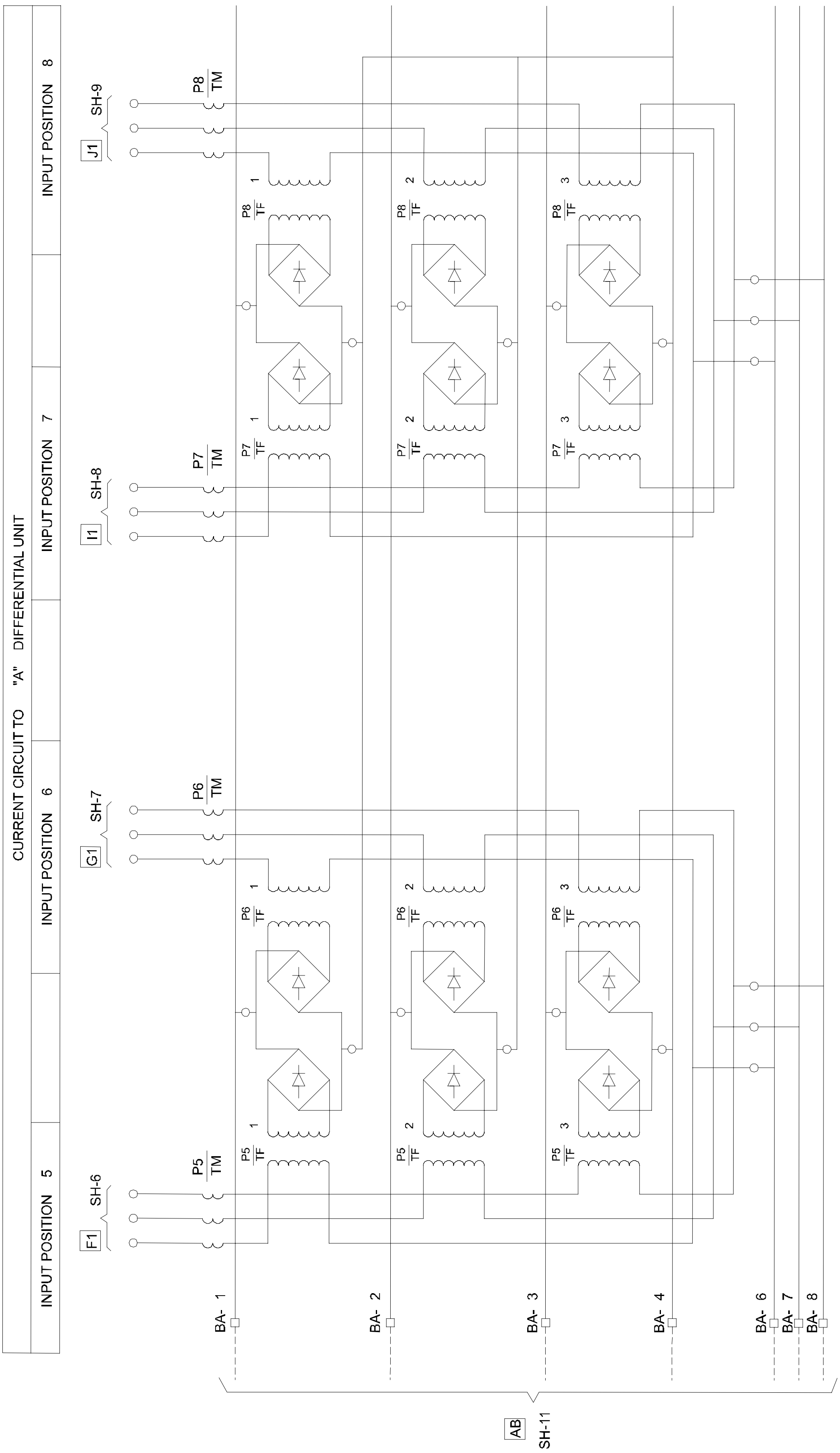
9. POSITION 8. THREE LINE CURRENT DIAGRAM (226B6429F9)



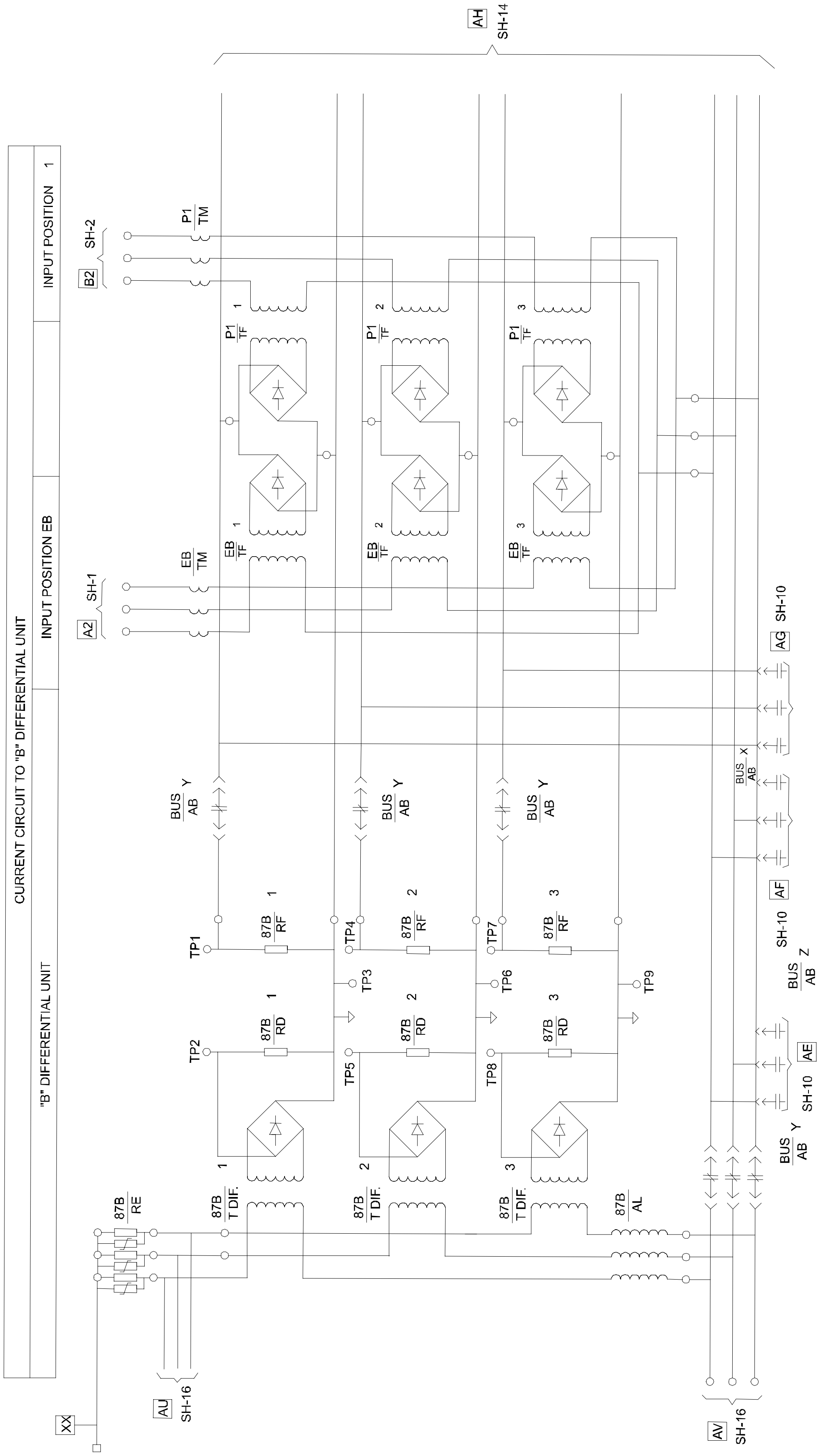
10. CURRENT CIRCUIT TO “A” DIFFERENTIAL UNIT. CURRENT INPUT EB, P1. (226B6429F10)



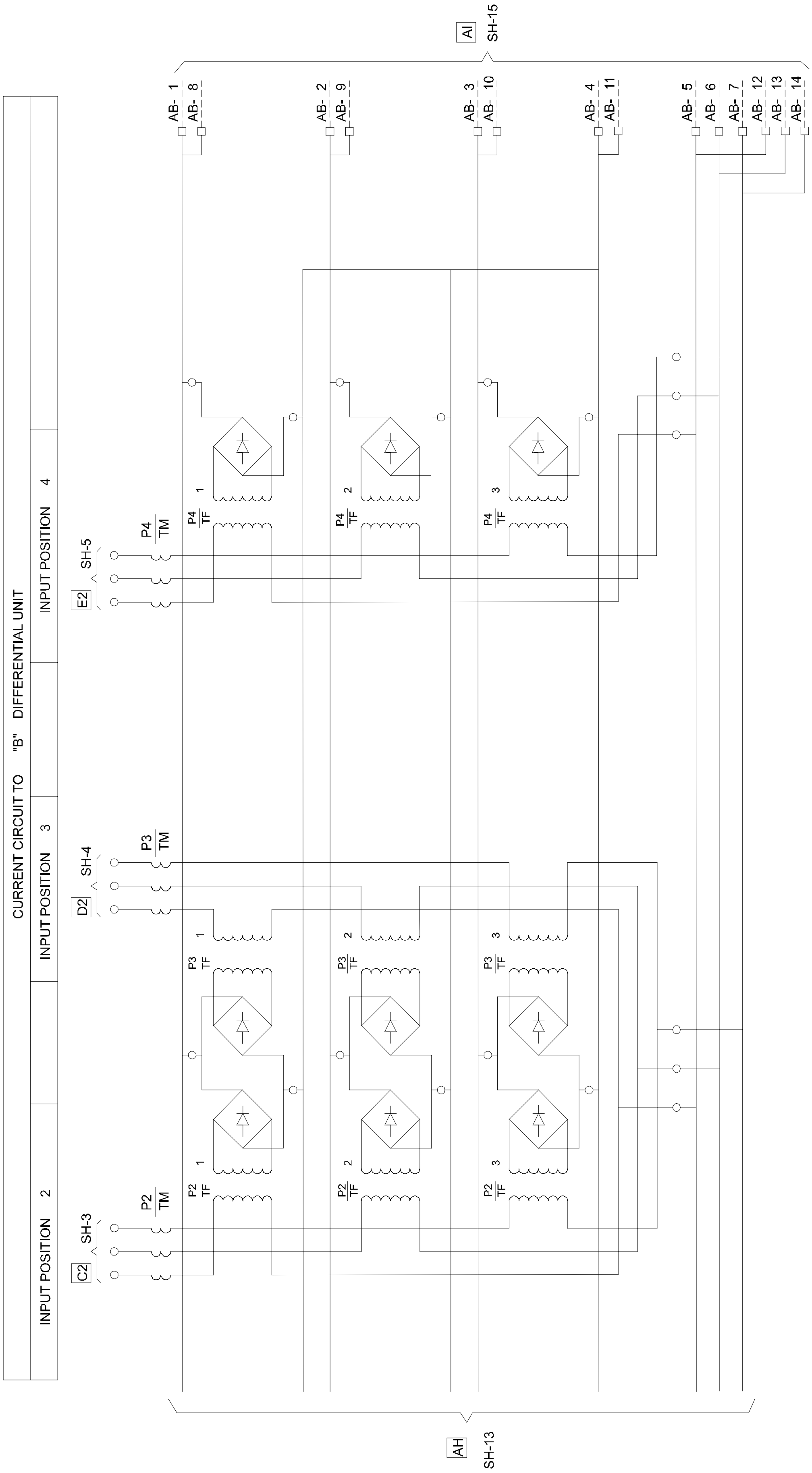
11. CURRENT CIRCUIT TO “A” DIFFERENTIAL UNIT. CURRENT INPUT P2, P3, P4. (226B6429F11)



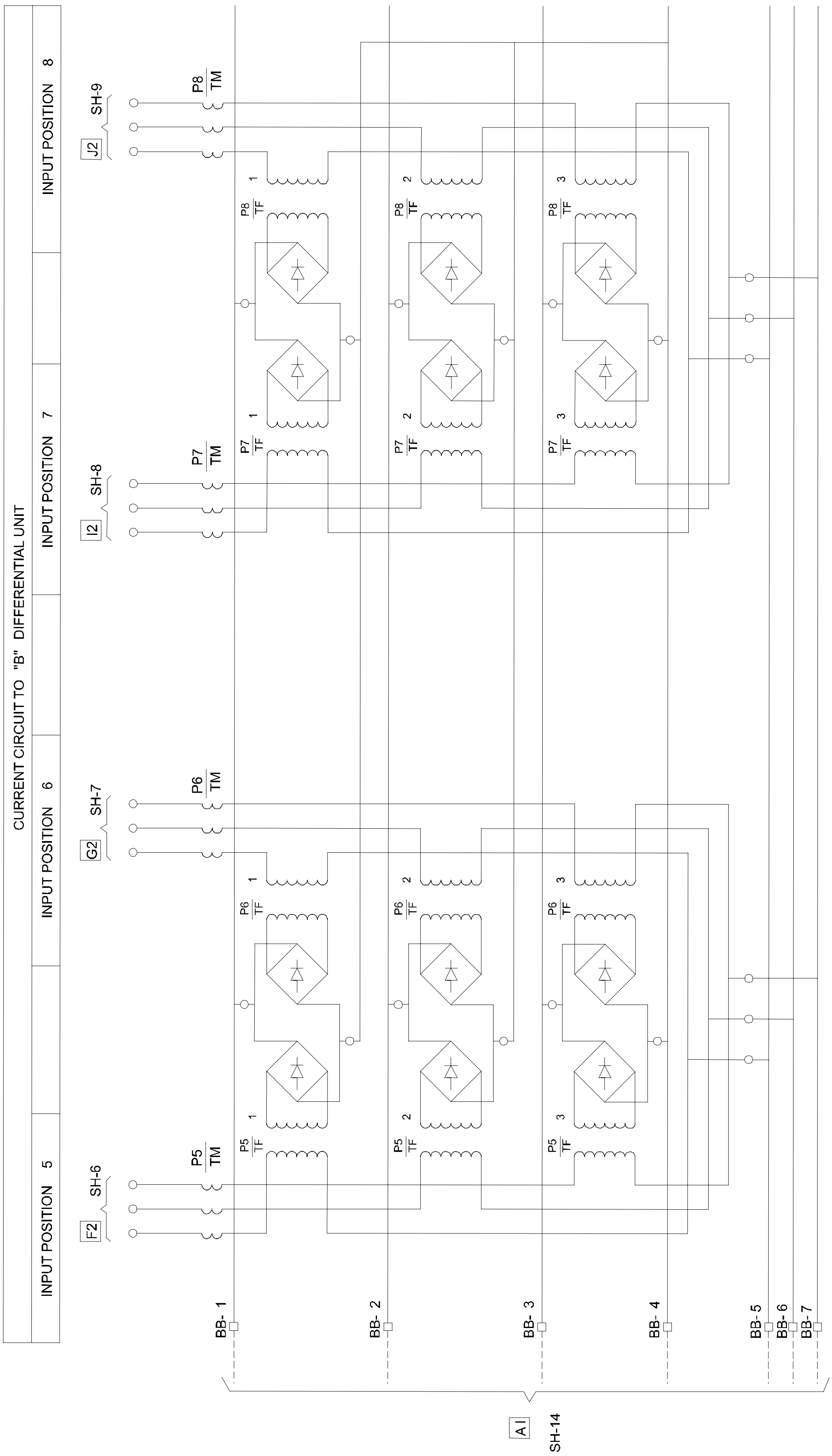
12. CURRENT CIRCUIT TO “A” DIFFERENTIAL UNIT, CURRENT INPUT P5, P6, P7, P8 . (226B6429F12)



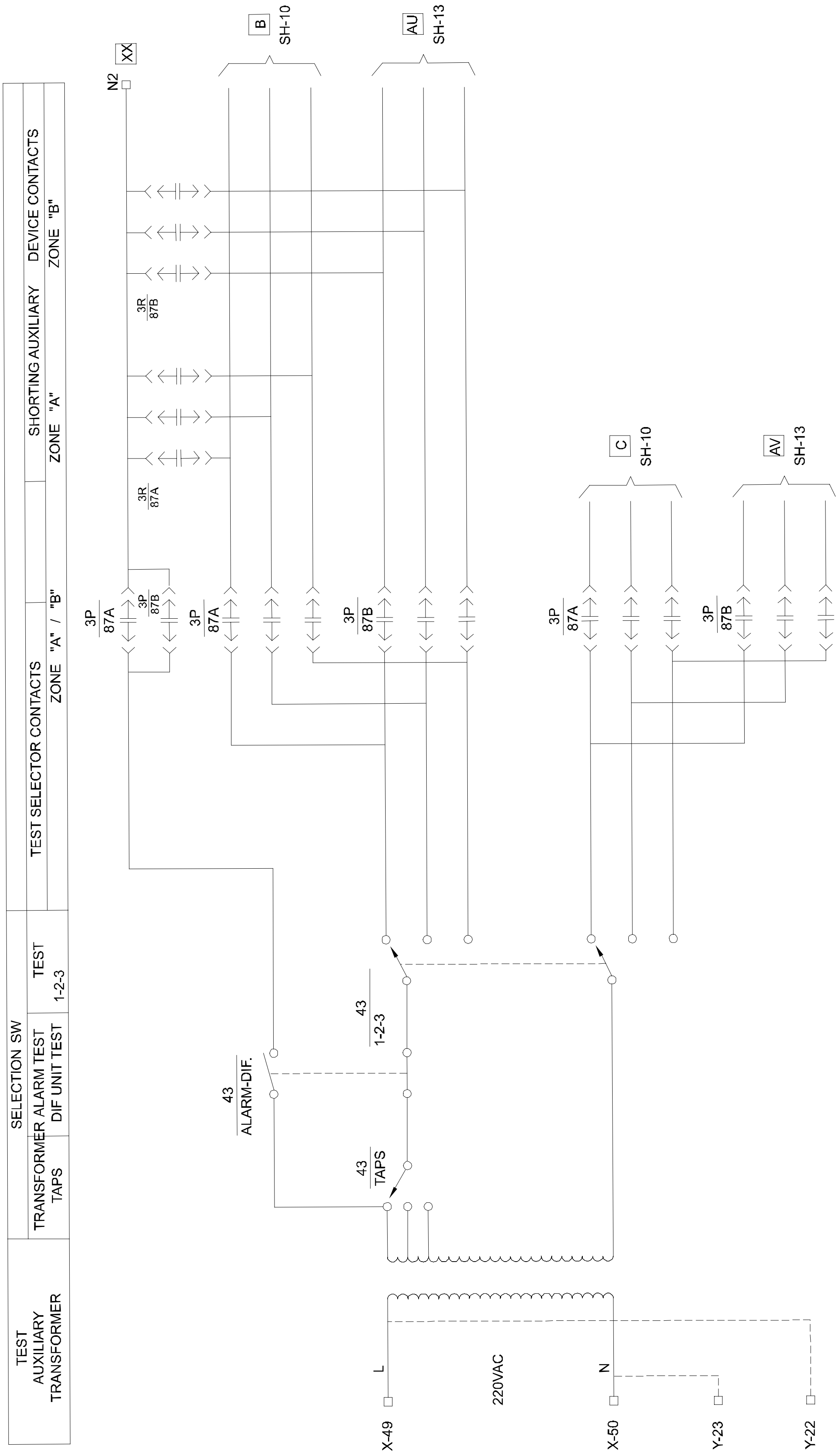
13. CURRENT CIRCUIT TO “B” DIFFERENTIAL UNIT, CURRENT INPUT EB, P1 (226B6429F13)


CURRENT CIRCUIT TO "B" DIFFERENTIAL UNIT
INPUT POSITION 2
INPUT POSITION 3
INPUT POSITION 4
AI
SH-15
AH
SH-13
C2
SH-3
D2
SH-4
E2
SH-5
P2
TM
P3
TM
P4
TM
P2
TF
P3
TF
P4
TF
AB- 1
AB- 8
AB- 2
AB- 9
AB- 3
AB- 10
AB- 4
AB- 11
AB- 5
AB- 6
AB- 7
AB- 12
AB- 13
AB- 14

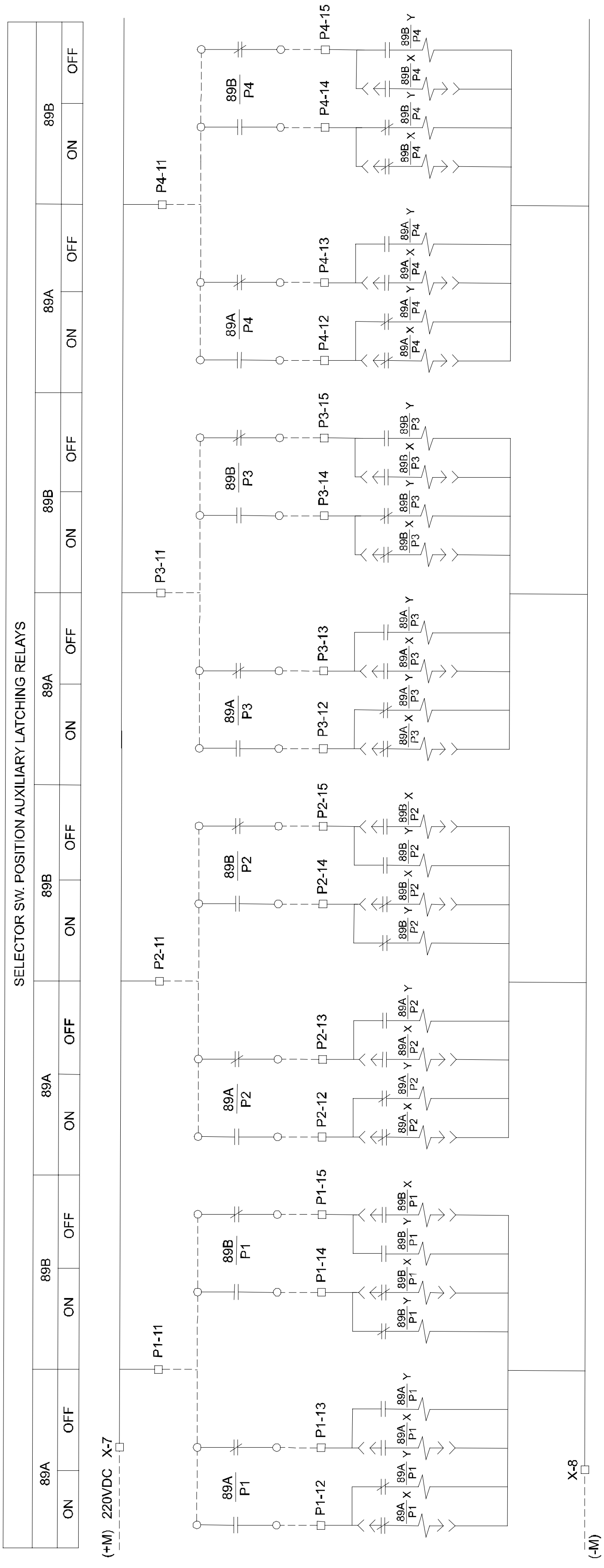
14. CURRENT CIRCUIT TO “B” DIFFERENTIAL UNIT, CURRENT INPUT P2, P3, P4 (226B6429F14)



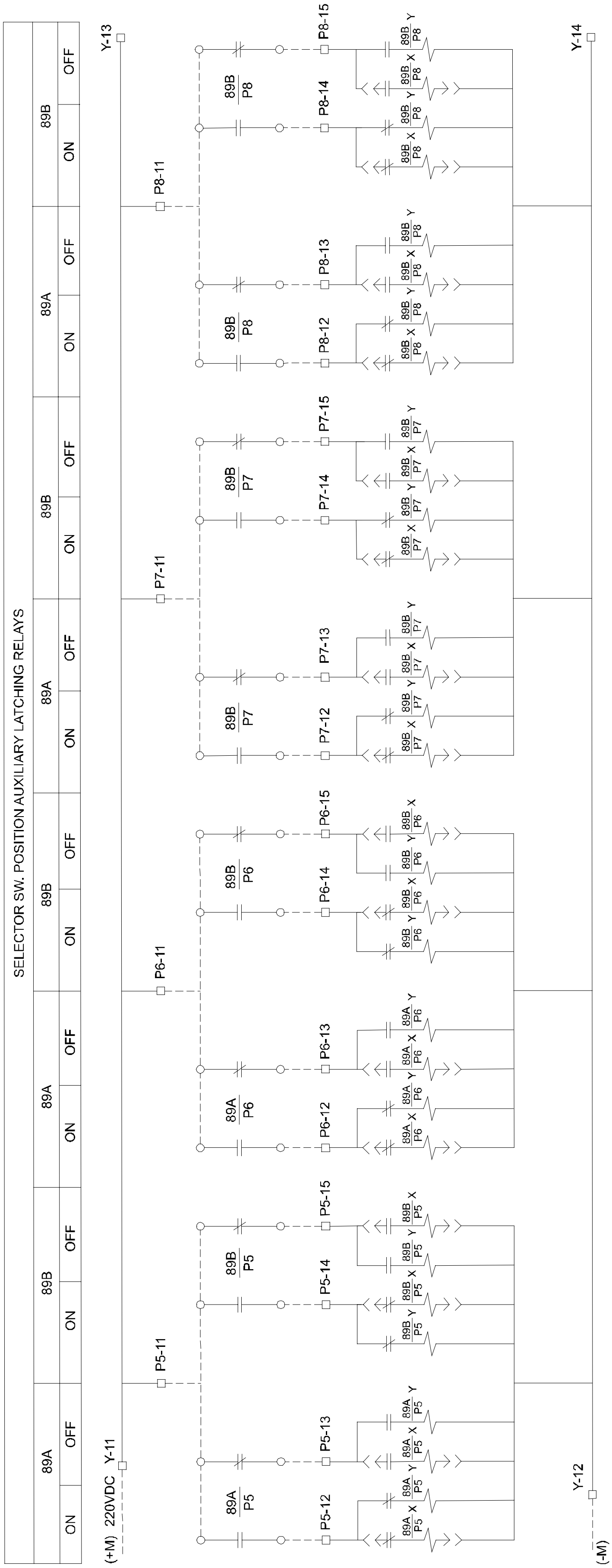
15. CURRENT CIRCUIT TO “B” DIFFERENTIAL UNIT. CURRENT INPUT P5, P6, P7, P8). (226B6429F15)



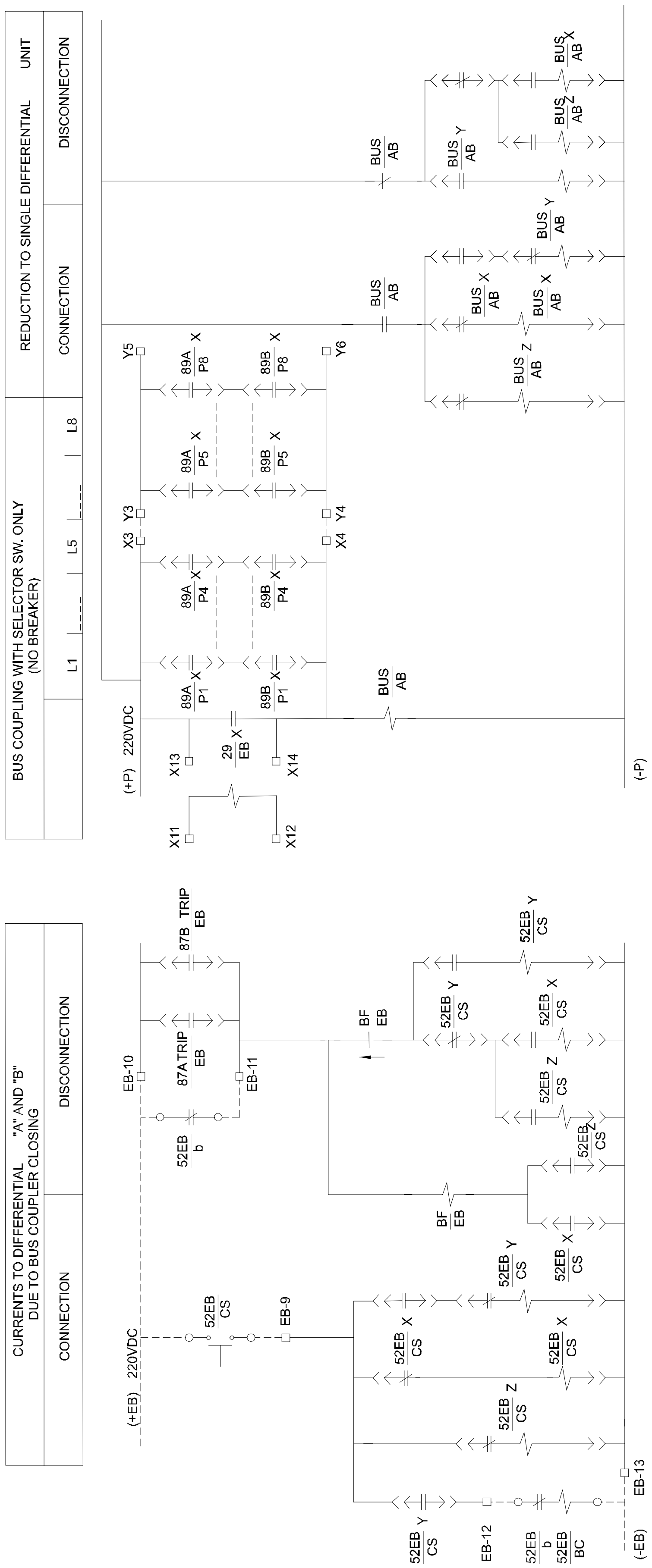
16. TEST UNIT ZONES A & B (226B6429F16)



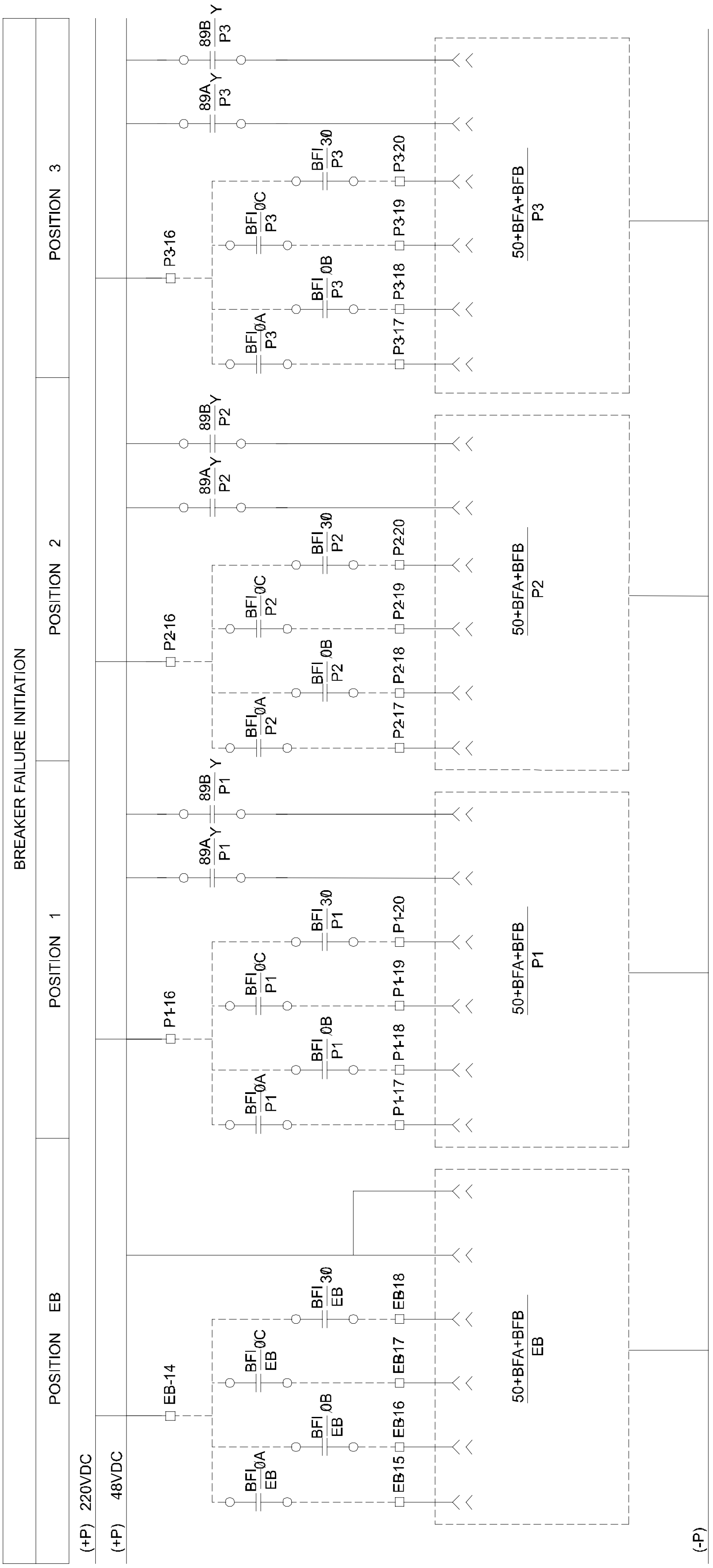
17. POSITION AUXILIARY LATCHING RELAYS, POSITIONS P1, P2, P3, AND P4. (226B6429F17)



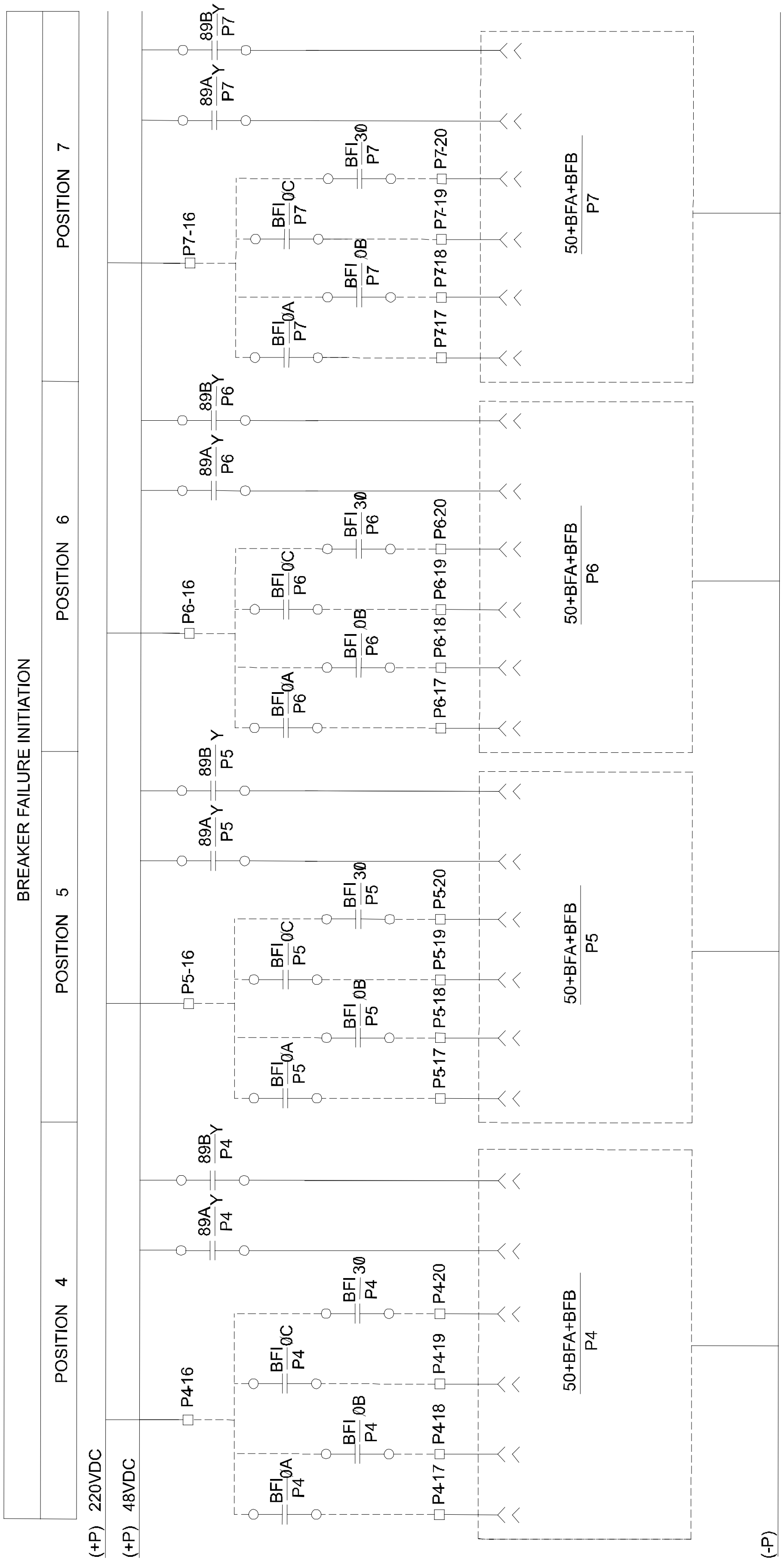
18. POSITION AUXILIARY LATCHING RELAYS, POSITIONS P5, P6, P7, AND P8. (226B6429F18)



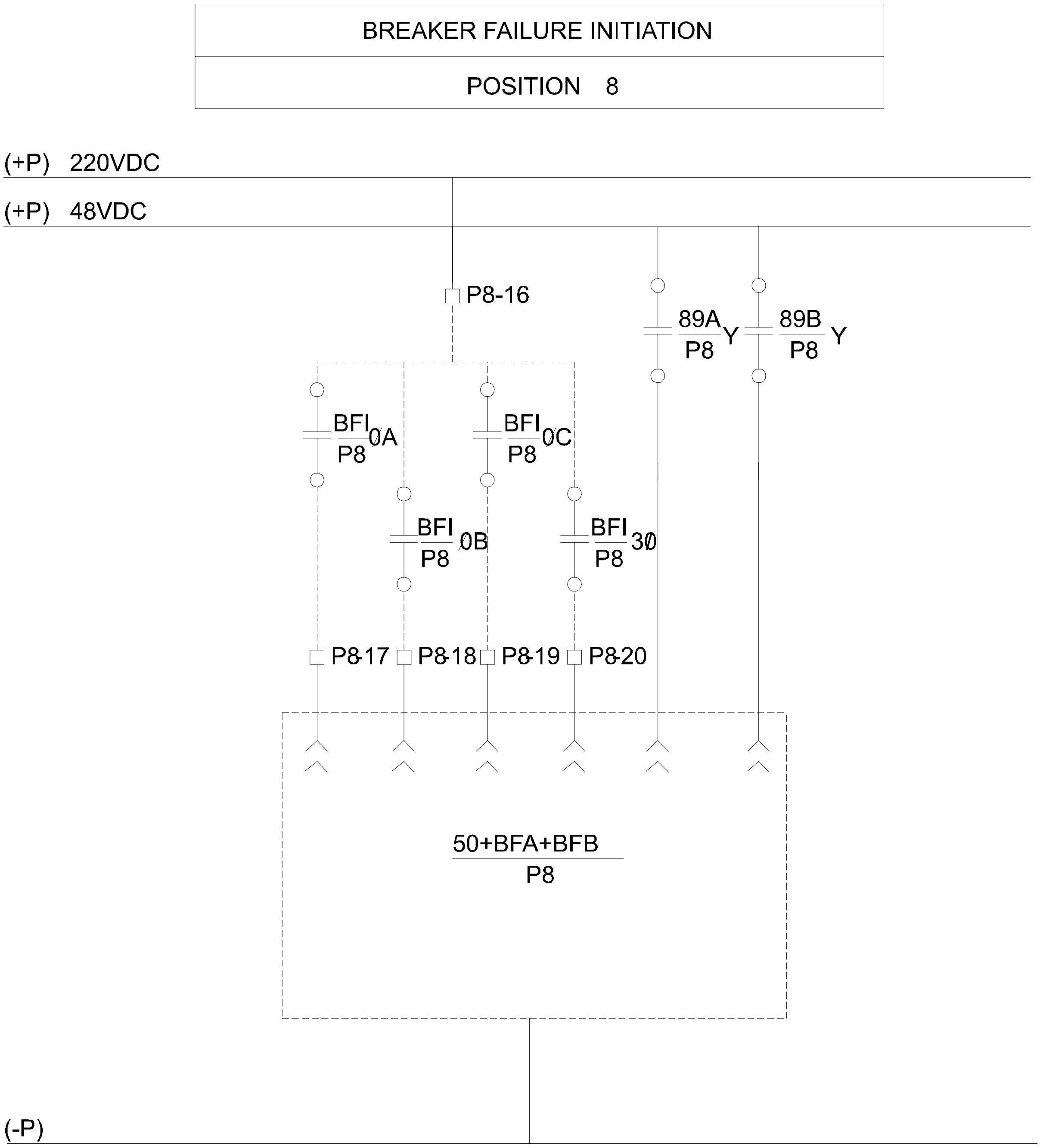
19. BUS COUPLER REDUCTION TO SINGLE DIFFERENTIAL UNIT (226B6429F19)



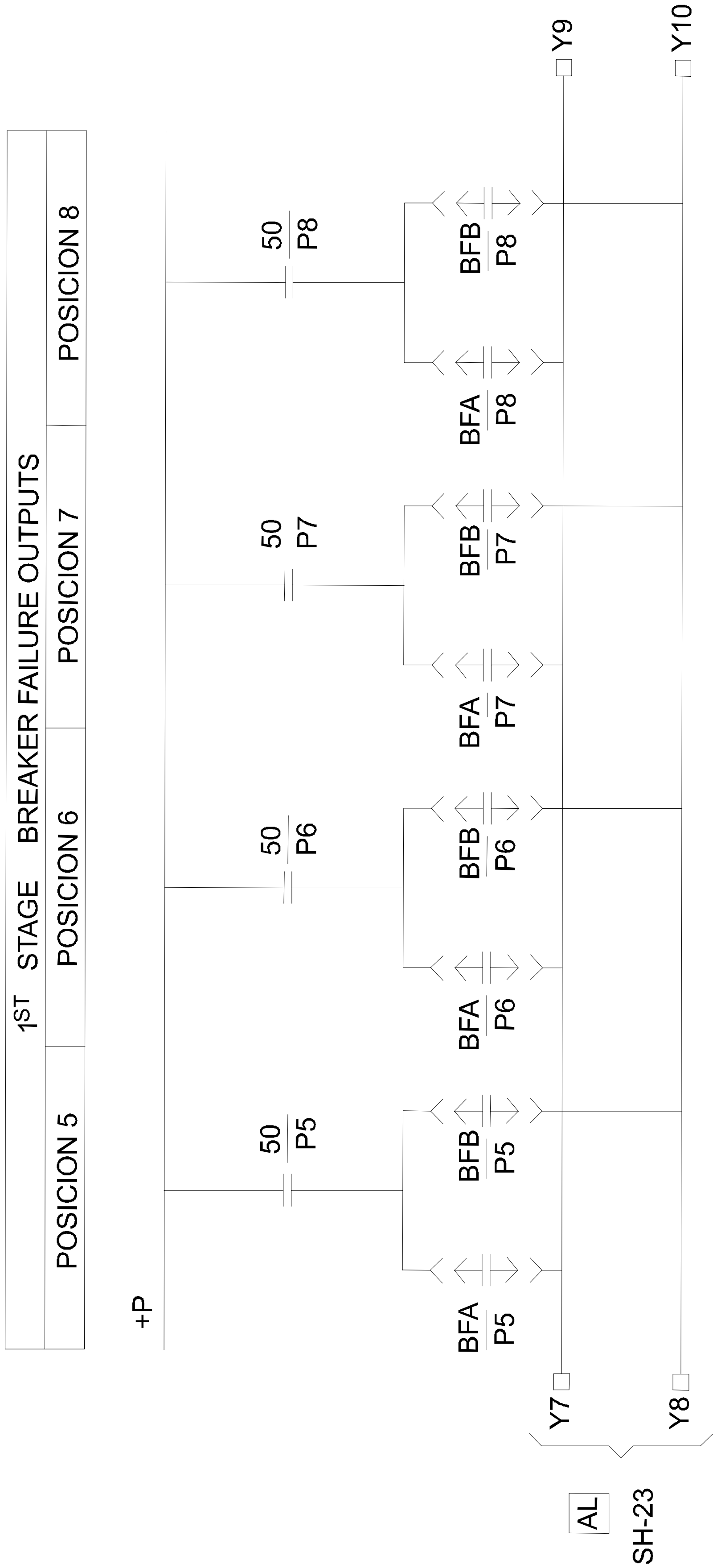
20. FIRST STAGE BREAKER FAILURE INITIATION, POSITIONS EB, P1, P2, P3 (226B6429F20)



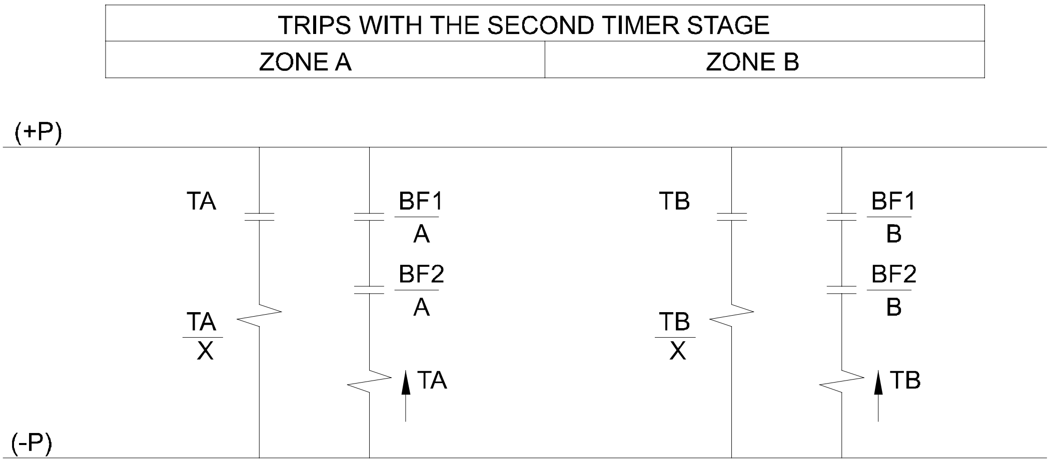
21. FIRST STAGE BREAKER FAILURE INITIATION, POSITIONS P4, P5, P6, P7 (226B6429F21)

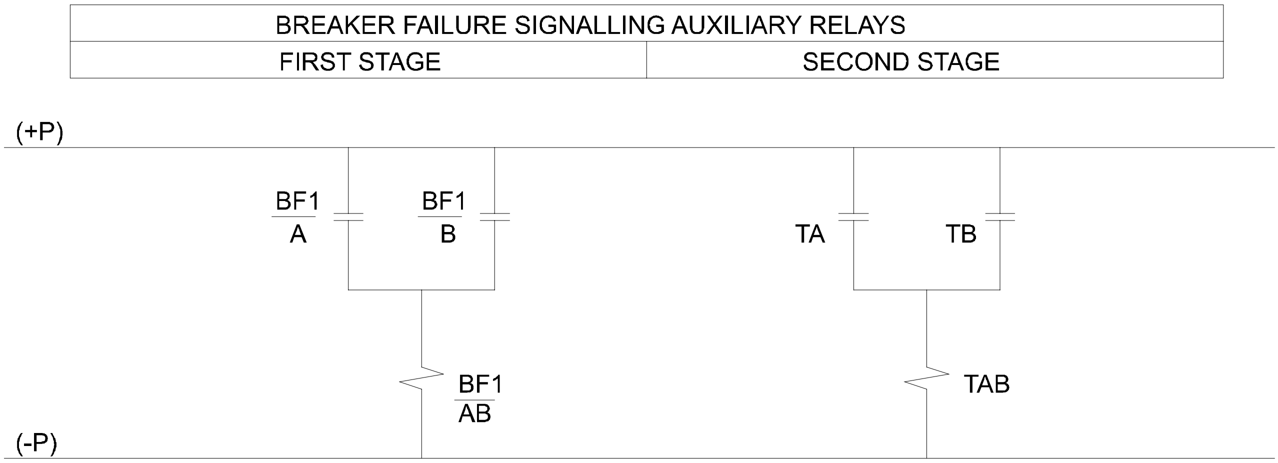


22. FIRST STAGE BREAKER FAILURE INITIATION, POSITION P8 (226B6429F22)

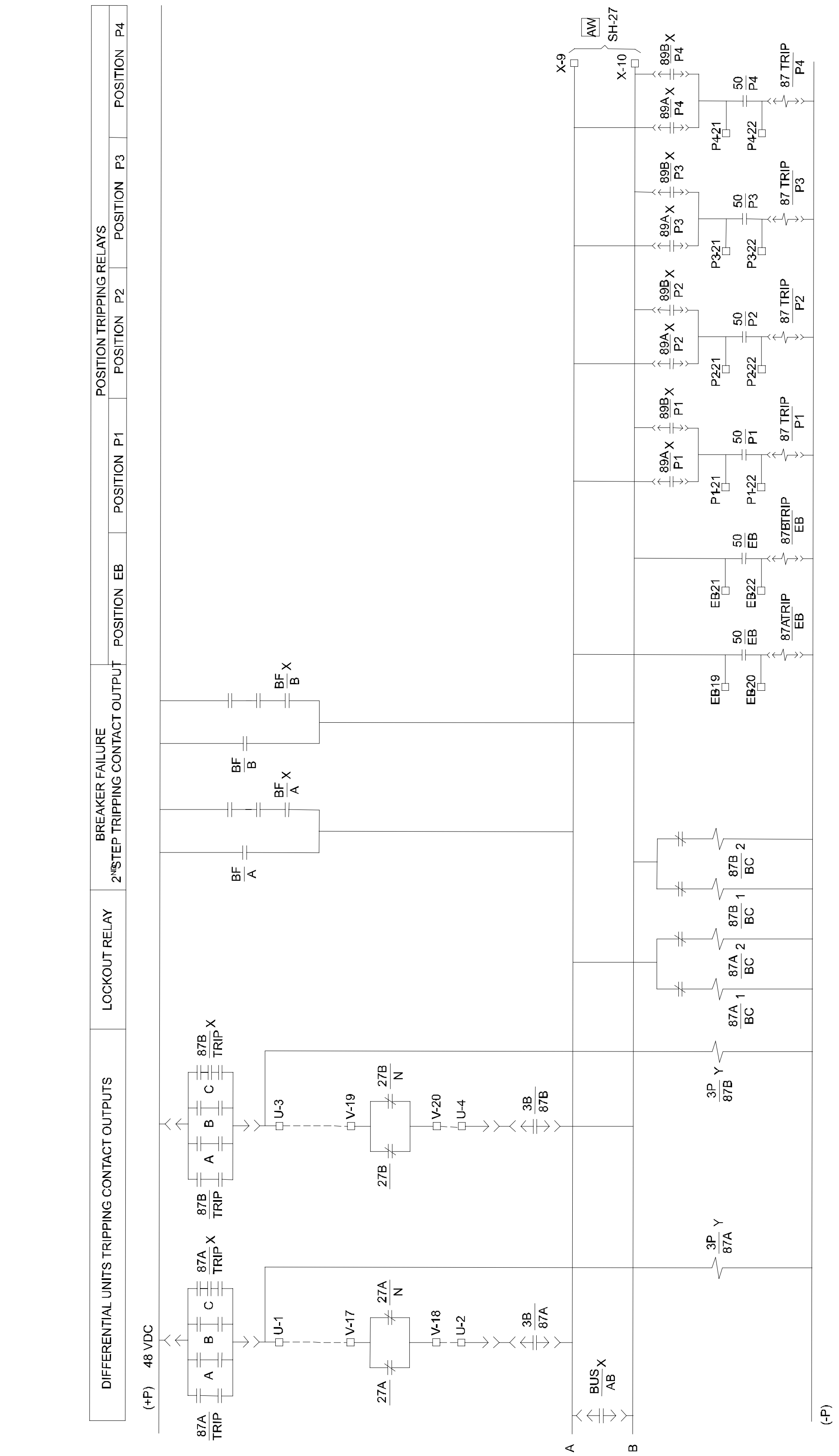


24. FIRST STAGE BREAKER FAILURE TRIPPING CONTACT OUTPUTS P5, P6, P7, P8 (226B6429F24)

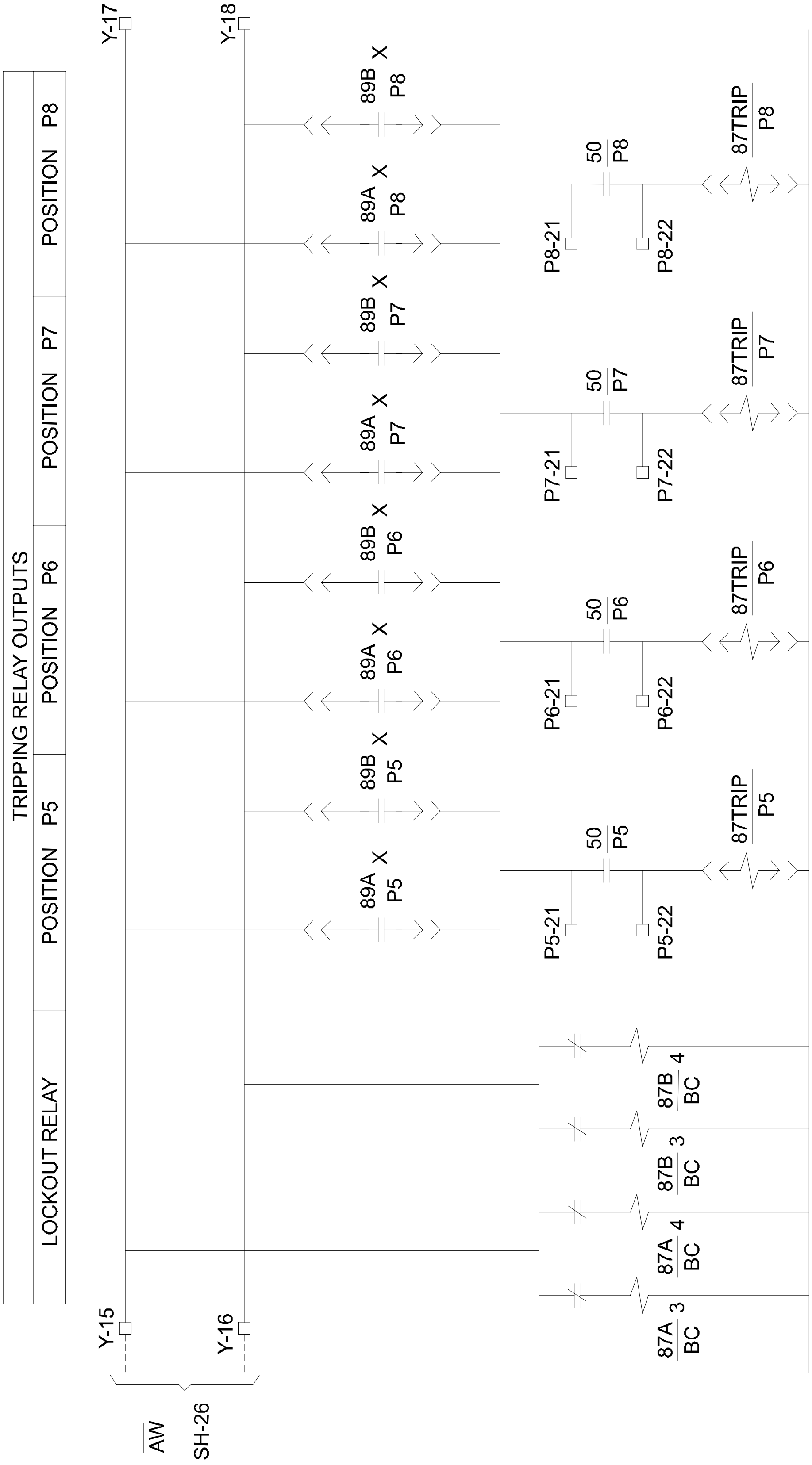




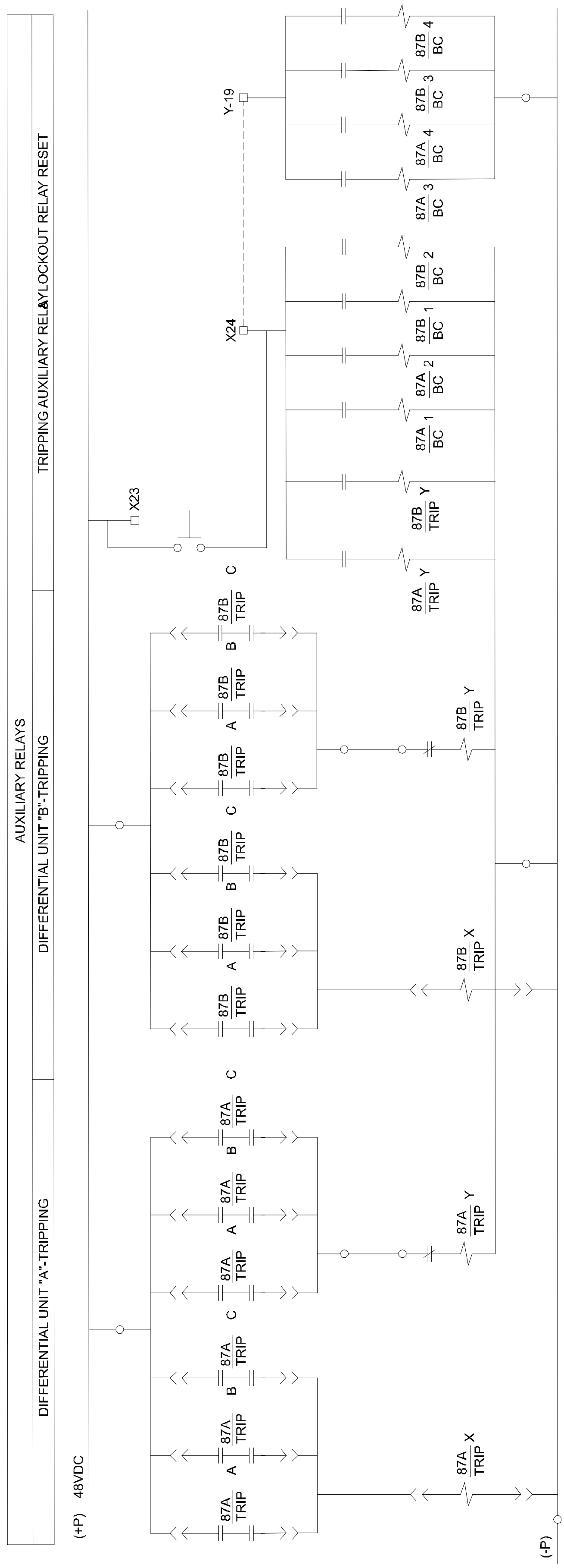
25. SECOND STAGE BREAKER FAILURE TRIPPING & SIGNALLING (226B6429F25)



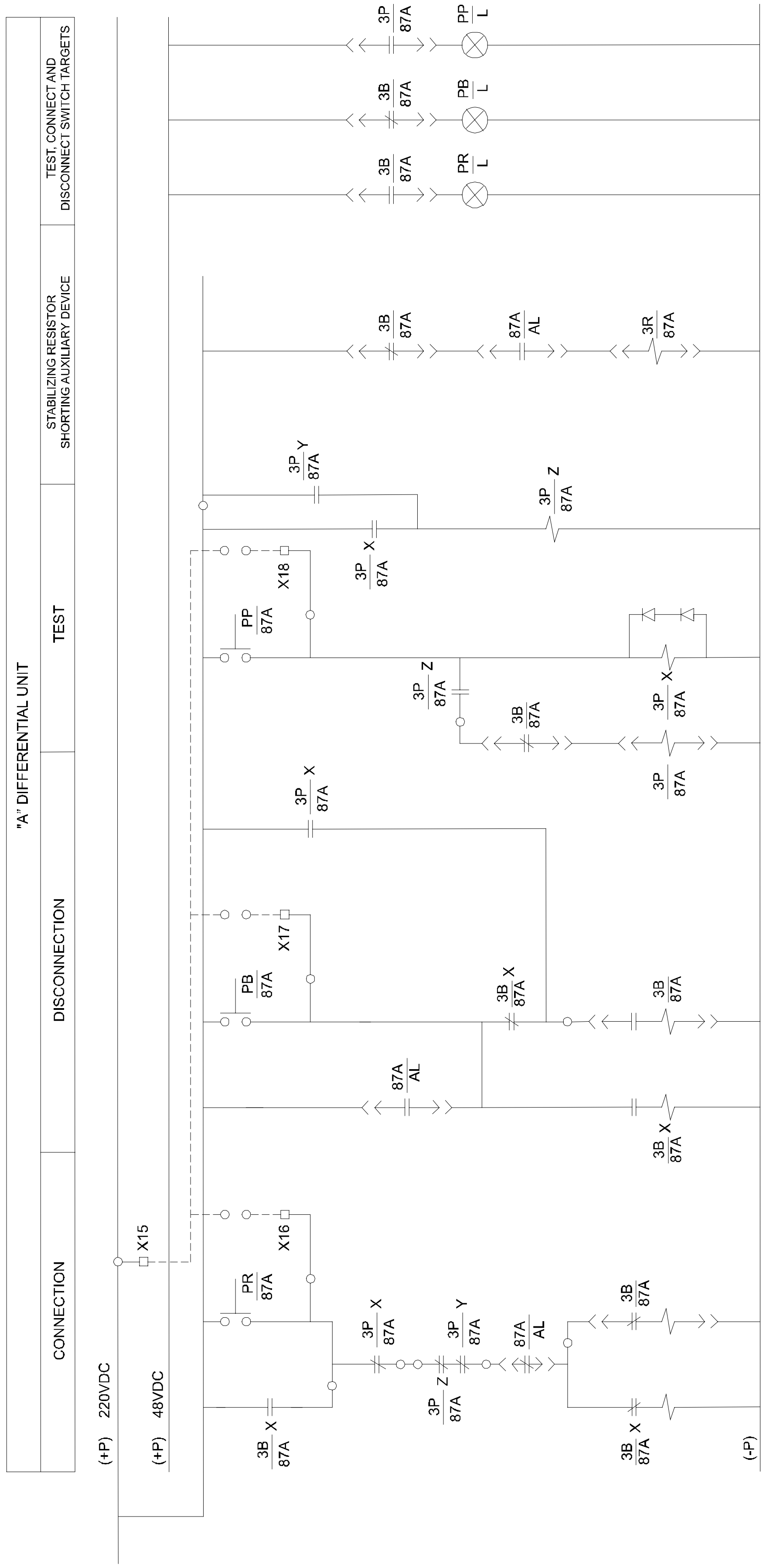
26. DIFFERENTIAL UNITS AND BREAKER FAILURE TRIPPING CONTACT OUTPUTS. TRIPPING RELAYS OUTPUT, POSITION EB, P1, P2, P3, P4 (226B6429F26)



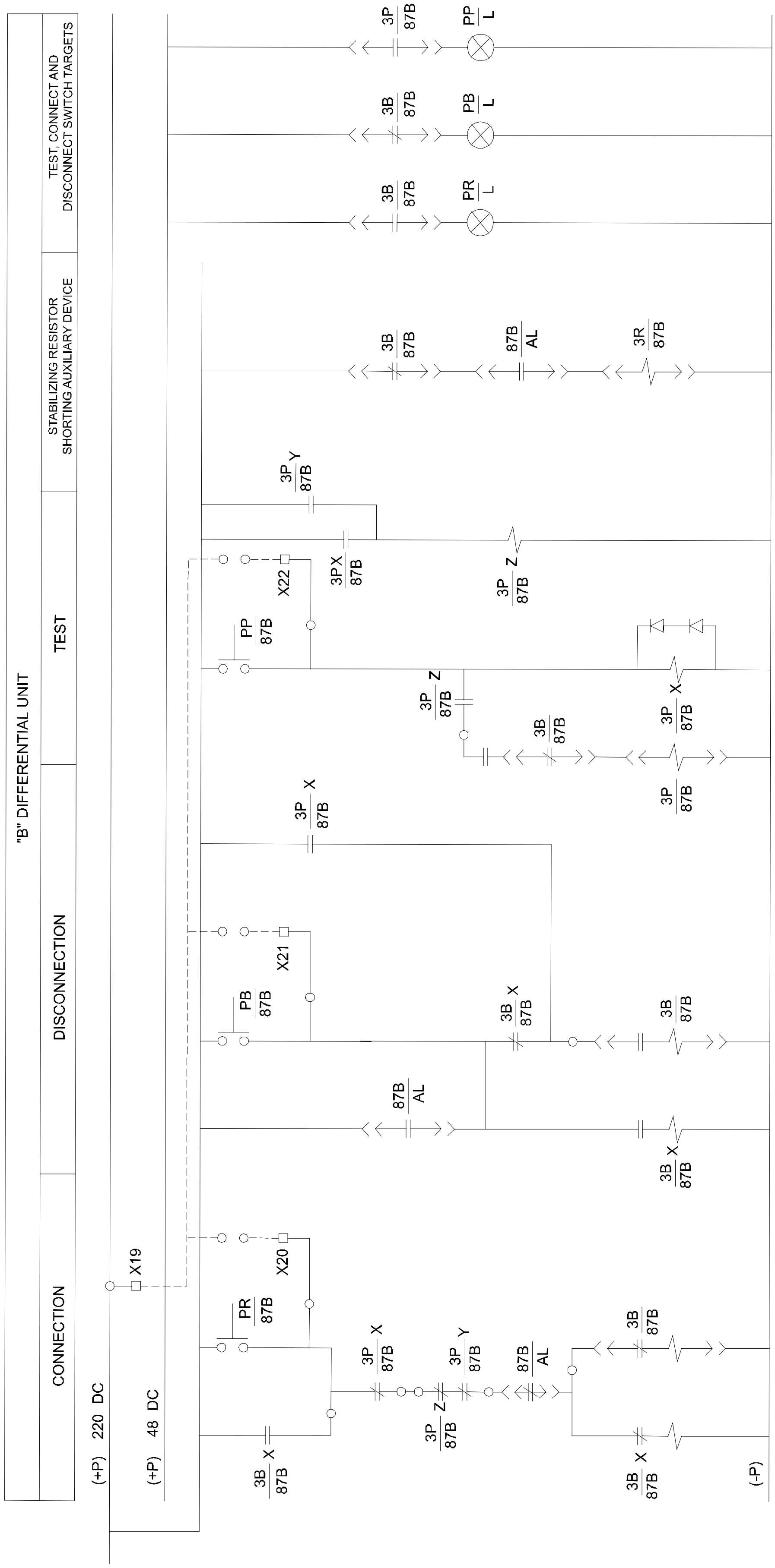
27. TRIPPING RELAYS OUTPUT. POSITION P5, P6, P7, P8 (226B6429F27)



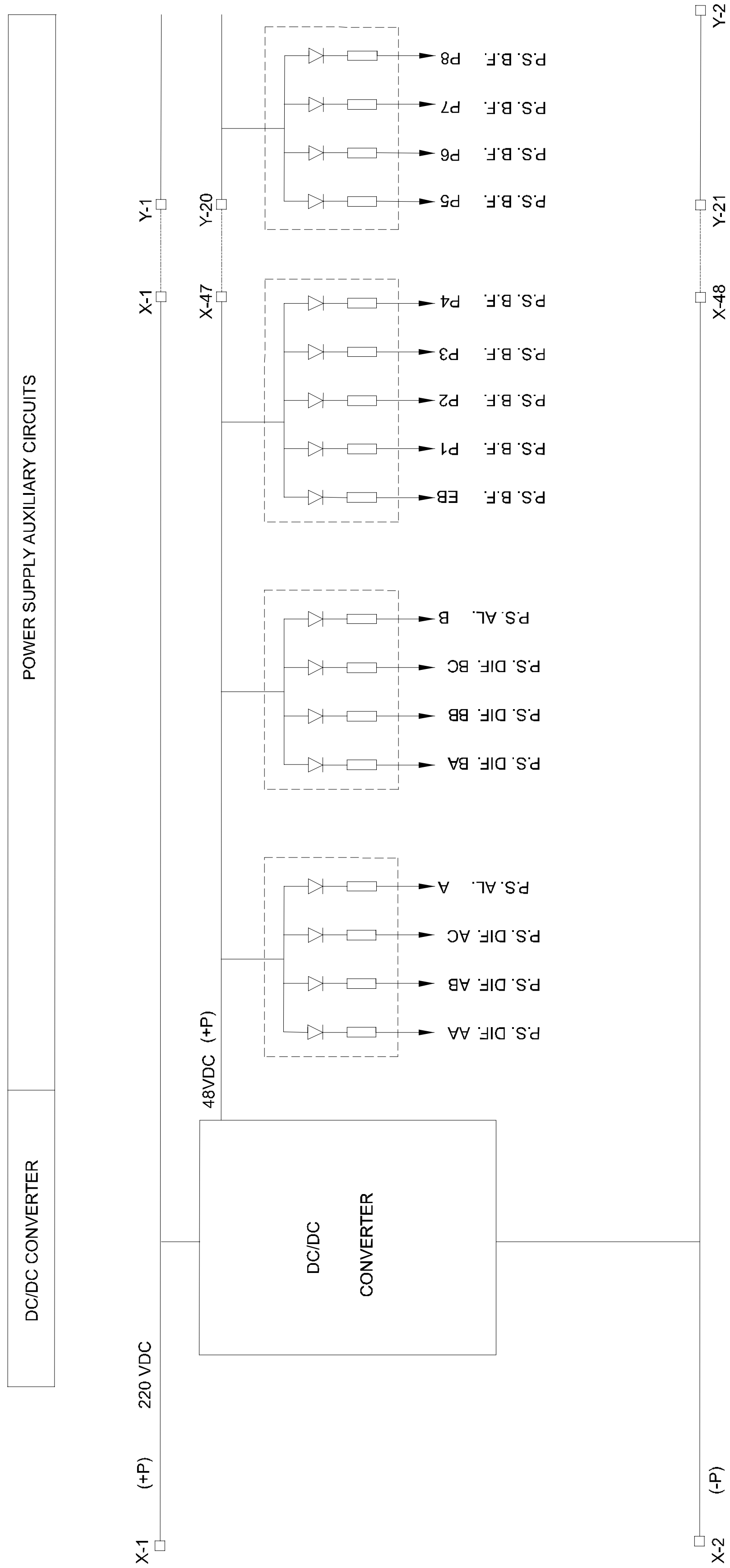
28. DIFFERENTIAL UNITS A, B, TRIPPING AUXILIARY RELAYS (226B6429F28)



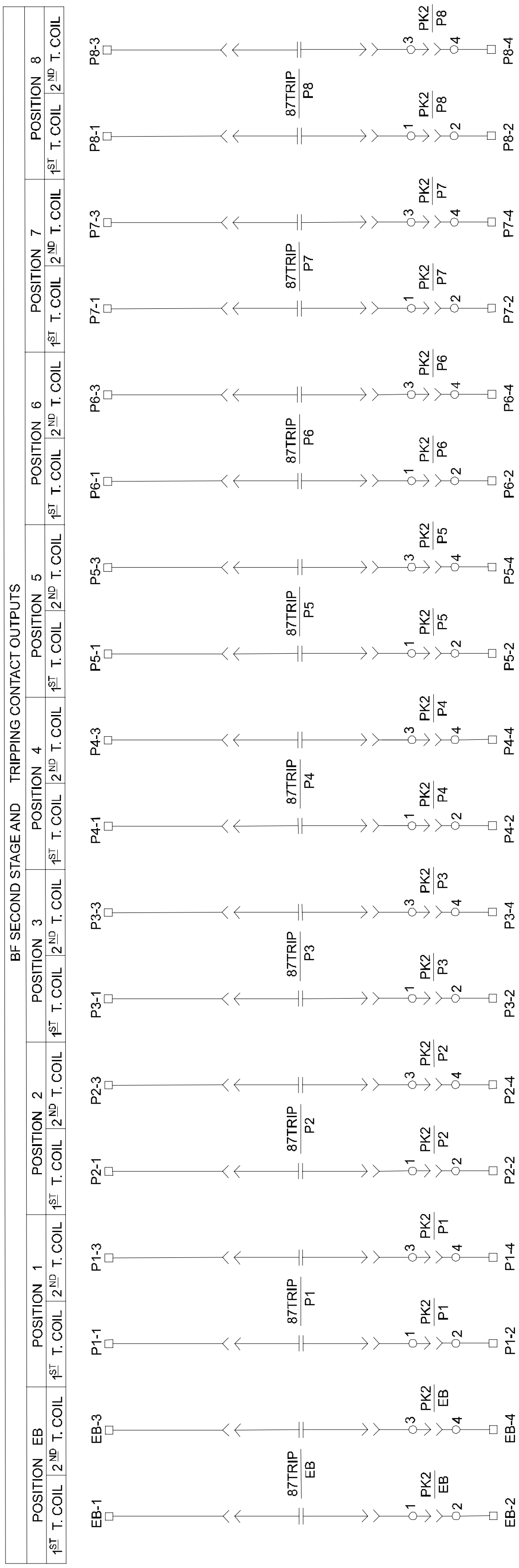
29. "A" DIFFERENTIAL UNIT CONNECTION, DISCONNECTION AND TEST (226B6429F29)



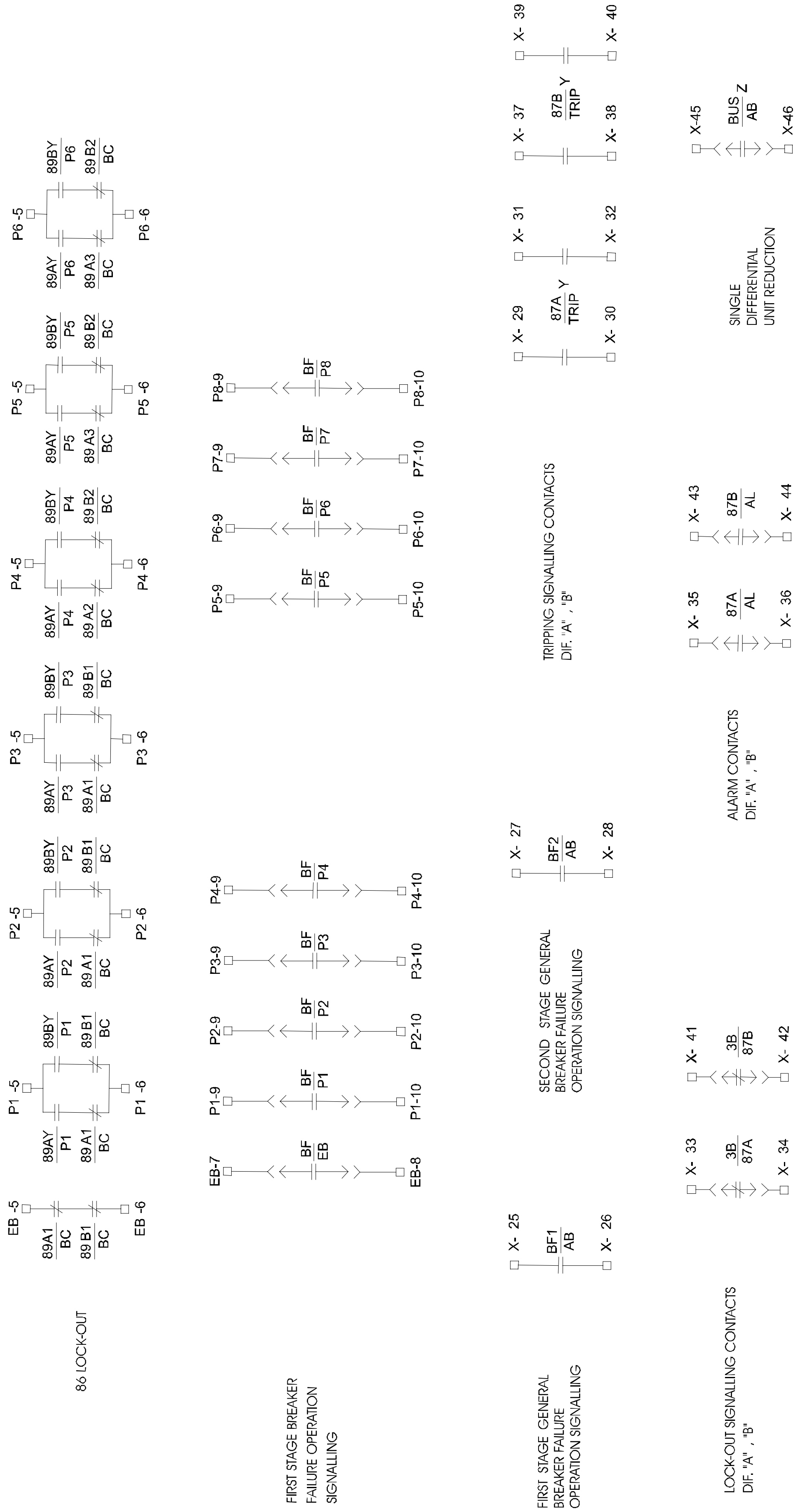
30. “B” DIFFERENTIAL UNIT CONNECTION, DISCONNECTION AND TEST (226B6429F30)



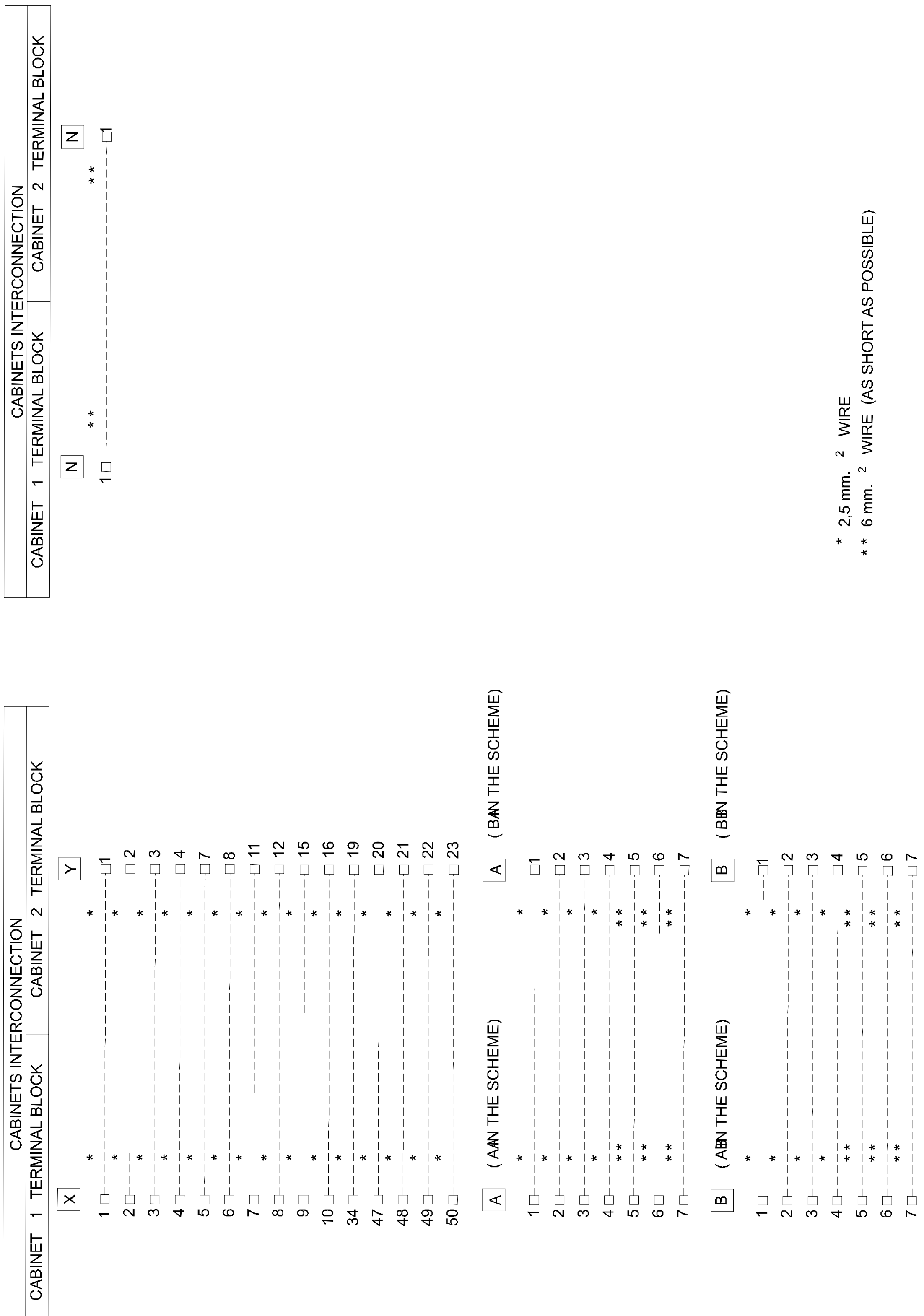
31. POWER SUPPLY AUXILIARY CIRCUITS (226B6429F31)



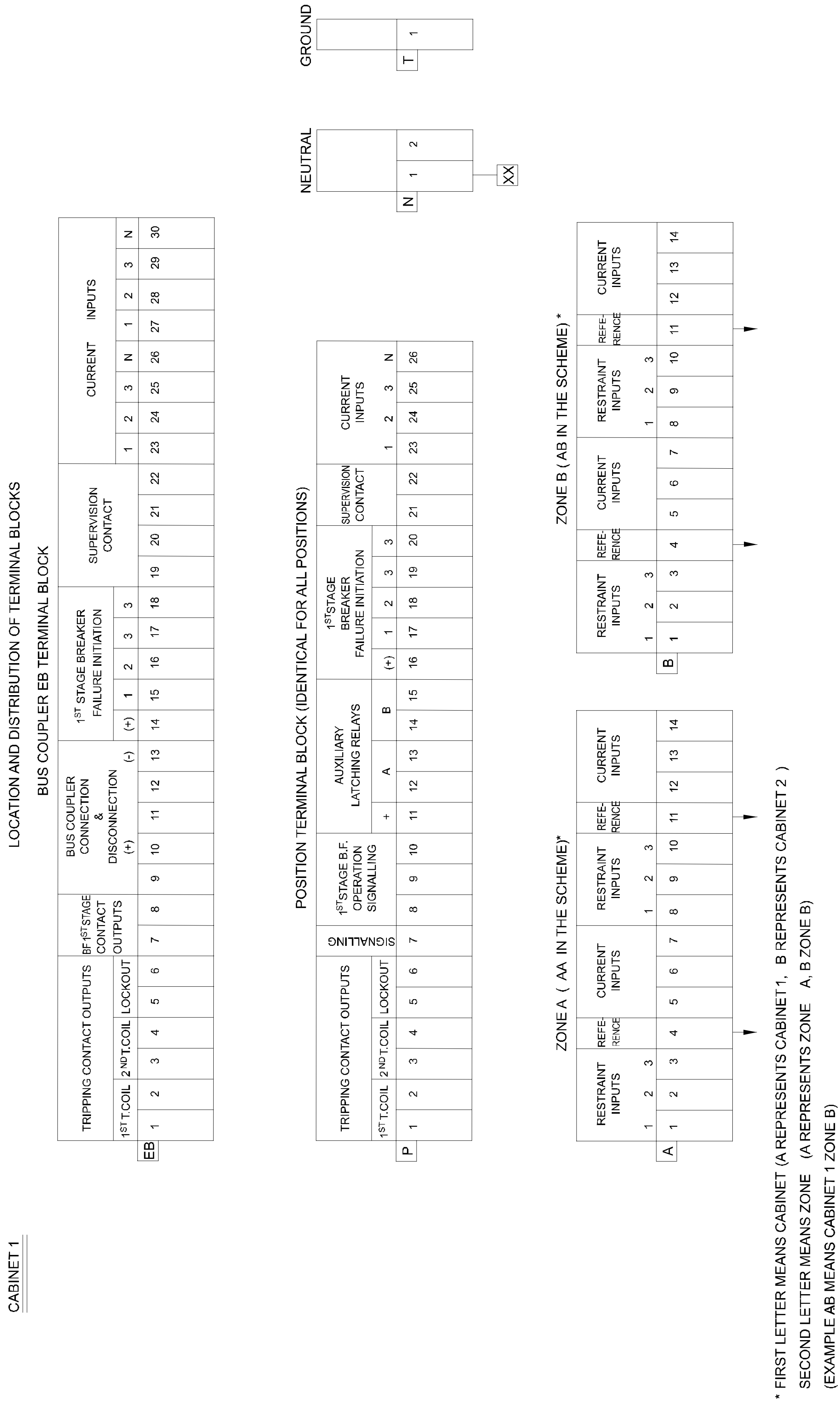
BREAKER FAILURE SECOND STAGE AND TRIPPING CONTACT OUTPUTS P1, P2, P3, P4, P5, P6, P7, P8 (226B6429F42)



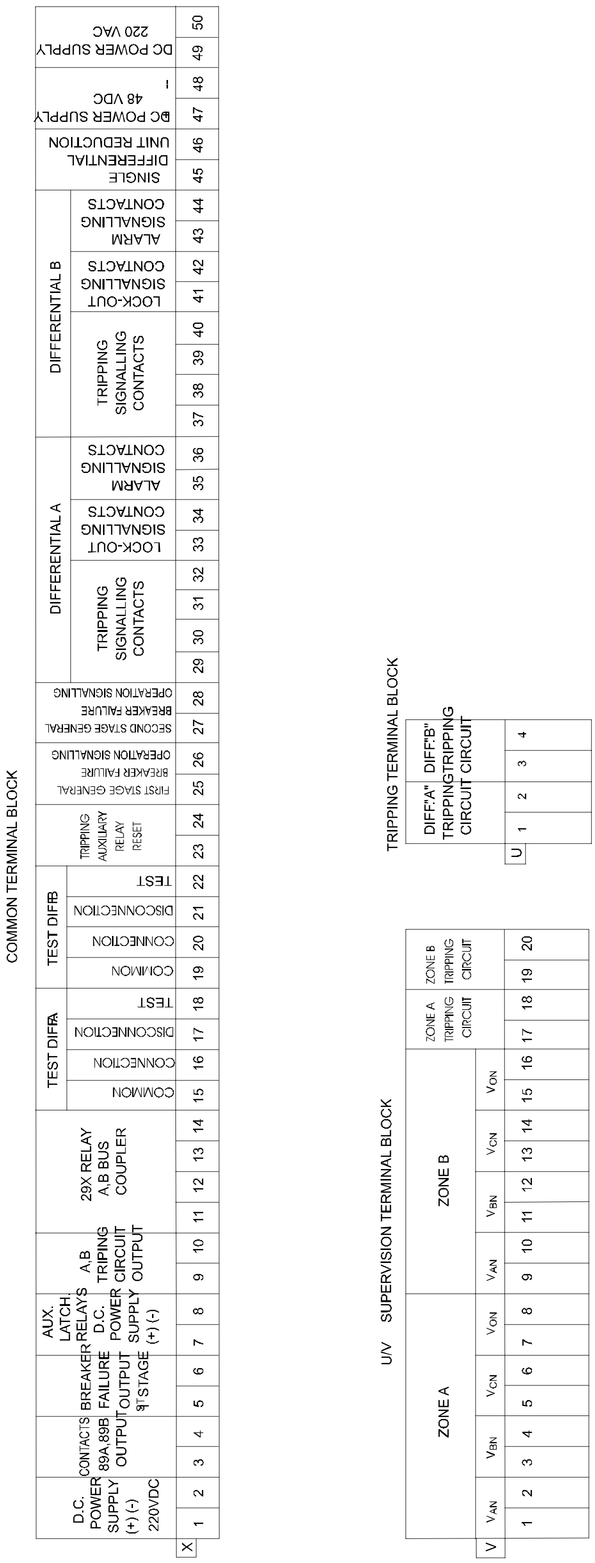
43. SIGNALLING CONTACT OUTPUTS (226B6429F43)



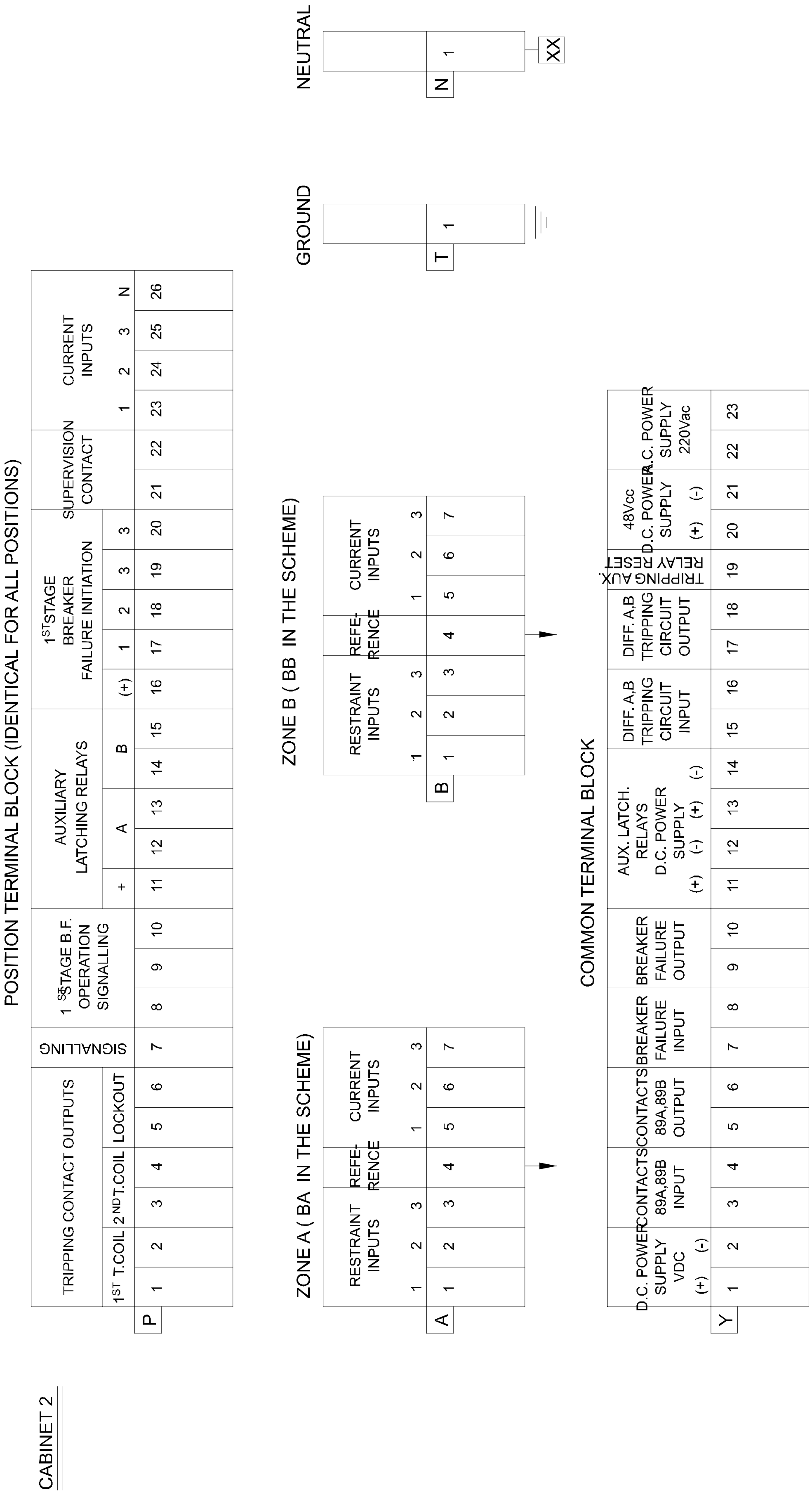
CABINETS INTERCONNECTIONS (226B6429F44)



45. LOCATION AND DISTRIBUTION OF TERMINAL BLOCKS CABINET 1 (226B6429F45)



46. LOCATION AND DISTRIBUTION OF TERMINAL BLOCKS CABINET 1 (226B6429F46)



LOCATION AND DISTRIBUTION OF TERMINAL BLOCKS CABINET 2(226B6429F47)

LEGEND(226B6429F48)

FUNCTIONAL UNIT	*DEVICE TYPE*	*DESCRIPTION*
TP1_ _ _ _ TP8	Terminal	Differential and restraint voltage testing points (for measuring)
EB, P1 _ _ _ _ P8 (∅A, ∅B, ∅C)/TF	DFI	Restraint transf. Bus coupler positions P1 _ _ _ _ P8 (input module)
EB, P1 _ _ _ _ P8/TM	DFI	Measurement of transf. Bus coupler positions P1_ _ _ _ P8 (input module)
43/ALARM – DIFF.	TEST UNIT DPR	Selector switch of alarm diff. Test
43/TAPS	TEST UNIT DPR	Selector switch of tap selection
43/ (∅A, ∅B, ∅C)	TEST UNIT DPR	Selector switch of phase selection
3P / 87 A - 87B	AUXILIARY RELAY HLA	Auxiliary relay for DIFF. A, B test
89AX-89BX / P1_ _ _ _ P8	LATCHING RELAY HLB	Auxiliary of 89 A – 89 B/P1_ _ _ _ P8
52EB / CS	PUSH-BUTTON	Push-button of 52EB closing
52EB / b	PUSH-BUTTON	“b” type contact of 52EB
87 A trip – 87B trip / EB P1_ _ _ _ P8	RELAY	Trip relays
52EB/ABC	BREAKER	52EB closing coil
BF/EB	DTE	Breaker failure/Bus coupler
29X/EB	DTE	Auxiliary for reduction to single differential unit A, B.
BFI/EB	EXTERNAL CONTACT	Breaker failure initiation EB
FIA + FIC + 50 /EB1	MFI	B.F. & overcurrent supervision relays / bus coupler
BFI/A-B	DTE	Breaker failure zones A-B
BFI X / A-B	DTE	Auxiliary of BF / A, B, C
BFI (∅A, ∅B, ∅C) / P1_ _ _ _ P8	EXTERNAL CONTACT	Breaker failure initiation P1_ _ _ _ P8
89AY-89BY/ P1_ _ _ _ P8	LATCHING RELAY (BPP)	Auxiliary of 89 A – 89 B / P1_ _ _ _ P8
50/P1_ _ _ _ P8	MFI	Overcurrent supervision contact positions P1_ _ _ _ P8
87 A, 87B / TRIP ∅A, ∅B, ∅C	DRD	Differential unit tripping contact
87AX, 87BX / TRIP	DRD	Auxiliaries of 87 A, 87B / TRIP
3B / 87 A, 87B	LATCHING RELAY	Lockout relay 3B/87A-87B
3PY / 87A, 87B	TEST UNIT	Auxiliary of 3P / 87A – 87B
87A TRIP, 87B TRIP / EB	DRS	Tripping relay Bus Coupler EB
87TRIP/P1_ _ _ _ P8	DRS	Tripping relay/positions P1_ _ _ _ P8
PR/87A-87B	TEST UNIT	Test switch
PB/87A-87B	TEST UNIT	Connection – disconnection switch
PP/87A-87B	TEST UNIT	Reset switch
3BX / 87A, 87B	TEST UNIT	Auxiliary of 3B/87
3PX, 3PY, 3PZ / 87A	TEST UNIT	Auxiliary of 3P/87A
3PX, 3PY, 3PZ / 87B	TEST UNIT	Auxiliary of 3P/87B
PPY / 87A – 87B – 87C	TEST UNIT	Auxiliary of PP / 87A, 87B, 87C
PR, PB, PP/L	TEST UNIT	Reset connection disconnection test lamps
BFA, BFB / EB P1_ _ _ _ P8	SFI	Breaker failure positions P1_ _ _ _ P8
BFA, BFB / EB P1_ _ _ _ P8	SFI	Breaker failure bus coupler EB
87AY, 87BY / TRIP	DTE	Permanent signalling relay
PK-2	PK-2	Block test 6 poles
52/EB P1_ _ _ _ P8	BREAKER	Breaker/bus coupler, positions P1_ _ _ _ P8
89A, 89B /EB	INSULATING SWITCH	A-B insulating switch / bus coupler
89A-89B / P1_ _ _ _ P8	INSULATING SWITCH	A-B insulating switch / positions P1_ _ _ _ P8
TIA, TIB / EB	MAIN C.T.	Main current transformer / bus coupler A-B
TI/P1_ _ _ _ P8	MAIN C.T.	Main current transformer / positions P1_ _ _ _ P8
TIA AUX, TIB AUX / EB	TRANSFORMER 226B2999	Auxiliary current transformer / bus coupler A-B
TI AUX/P1_ _ _ _ P8	TRANSFORMER 226B2999	Auxiliary current transformer / positions P1_ _ _ _ P8
50 + BFA + BFB / EB	MFI	B.F. & overcurrent supervision relays / bus coupler
50 + BFA + BFB / P1_ _ _ _ P8	MFI	B.F. & overcurrent supervision relays / positions

FUNCTIONAL UNIT		***DEVICE TYPE***	***DESCRIPTION***
			P1_ _ _ _ P8
BUS X – BUS Y – BUS Z / AB		LATCHING RELAYS HLB	L.R. auxiliaries of BUS / AB
52EB X – 52EB Y – 52EB Z / CS		LATCHING RELAYS HLB	Auxiliaries of 52EB1
87A-87B (∅A, ∅B, ∅C)		BUS1000	Differential relay zones A-B, phases (∅A, ∅B, ∅C)
	RE	BUS1000	Stabilising resistor
	T. DIF	BUS1000	Differential circuit input current transformer
	AL	BUS1000	Alarm unit
	RD	BUS1000	Differential Voltage resistor
	RF	BUS1000	Restraint Voltage Resistor
3R/ 87A – 87B		AUXILIARY RELAY	Stabilising Resistor shorting auxiliary device