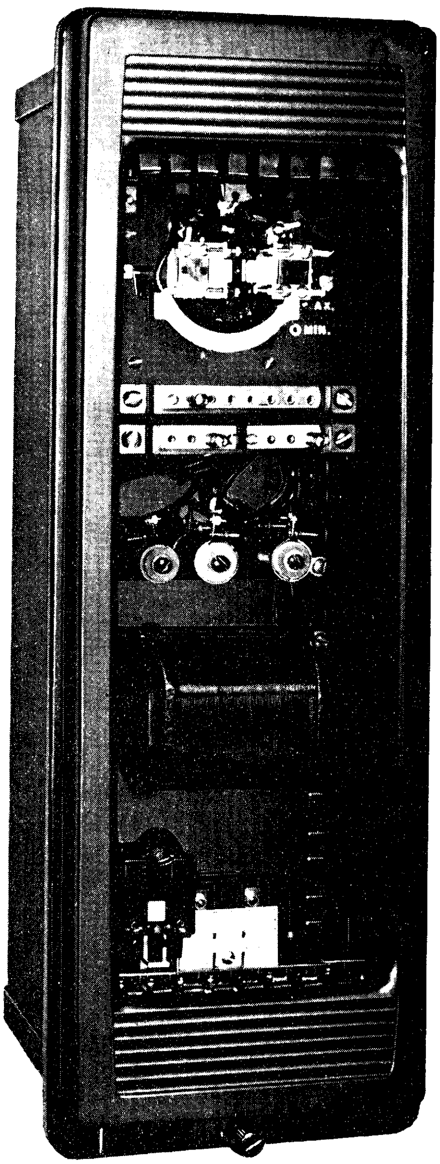
September, 1990
Supersedes Descriptive Bulletin 41-971, pages 1-4, dated August, 1989
Mailed to: E, D, C/41-100A, 41-900A

For Phase and Ground Fault Protection of Transmission Lines
Device Number: 87

Type HCB-1 High-Speed Pilot Wire Relay



Application

The Type HCB-1 relay is a high-speed pilot wire relay designed to provide complete phase and ground fault protection for two or three terminal transmission lines.

Relay operating time is a maximum 20 milliseconds for all types of faults.

Since the HCB-1 is sensitive to negative sequence currents, in addition to positive and zero sequence currents, it provides increased phase-to-phase fault sensitivity making the HCB-1 twice as sensitive to this type of fault as previously available pilot-wire relays.

Installation Requirements

For two-terminal lines, a complete installation consists of two HCB-1 relays, two insulating transformers, and an interconnected pilot wire circuit.

Three terminal lines require three relays, three insulating transformers, and a wye-connected pilot wire circuit having branches of equal series resistance.

Construction

The relay consists of a combination positive, negative, and zero sequence filter, a saturating transformer, two full-wave rectifier units, a polar unit, a zener clipper, and an Indicating Contactor Switch, all mounted in an FT-42 Flexitest®, case.

Usually, an external RC-351 milliammeter and a W-2 test switch is supplied, to periodically check the circulating current in the pilot wires.

Features

Complete Protection: HCB-1 installations protect the entire line against phase and ground faults.

Minimum Equipment Required: Only one relay with one moving element is required at each end of the line.

Single End Feed: Simultaneous tripping of breakers at all terminals occurs even with power flow into the section from only one terminal.

Current Operation: The HCB-1 operates entirely from current, and requires no voltage transformers.

Flexible Application: The pilot wire current, voltage, and wave form are within the limits established for telephone lines, allowing the relay to be used on privately owned or leased lines.

Also, the relay can be applied to all three terminal lines where power does not flow out of the section on internal faults, and on most lines where power does flow out of one terminal on internal faults.

Greater Phase-to-Phase Sensitivity: The HCB-1 is twice as sensitive to phase-to-phase faults as relays previously available. It can be set to pick up at 90% of tap setting for phase-to-phase faults.

Out-of-Step Blocking Included: No additional equipment is required to prevent tripping on out-of-step conditions.

Operation

The HCB-1 operates for faults within the protected line terminals, but will not operate during external faults.

As shown in Figure 2, the composite sequence filter receives three-phase current from the line current transformers. The filter converts this current into a single-phase voltage, V_F, whose magnitude is an adjustable function of the positive, negative and zero sequence components of fault current. The voltage, V_F, is impressed on the primary winding of the saturating transformer whose output voltage, V_S, is applied to the relay coils and pilot wire through the insulating transformer. The saturating transformer and zener clipper limit the energy input to the pilot wires.

External Faults
During an external fault, the magnitude and relative polarity of the voltages, V_S, are as shown in Figure 2. Since the voltages are additive, most of the current will circulate through the restraint coils and pilot wire, with a minimum operating coil current. Thus, the resultant effect of the current is that the relay is restrained from tripping.

Internal Faults
During an internal fault, the relative V_S voltage polarities reverse and most of the current flowing in the restraint coils is forced through the operating coils with a minimum current in the pilot wires. The increased operating current overcomes the restraint effect, and both relays operate. Nominal pickup of the relaying system is equal to the minimum trip current of one relay, multiplied by the number of relays.

For example, if the open pilot wire pickup of one relay is six amperes on a two terminal line, the nominal pickup in terms of total internal fault current is two times six, or 12 amperes.

Characteristics

The voltage, V_F, impressed on the saturating transformer by the filter varies with the tap (A, B, C) setting of the relay.

The sequence network in the relay is arranged for several combinations of sequence components. Using tap C, the output of the network will contain the positive, negative, and zero sequence components of the line current. For this setting, the taps on the upper plate indicate the balanced three-phase amperes (positive sequence amperes) which will pick up the relay with the pilot wire open.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the relay to pick up at 86% of tap setting. For BC faults, pickup is 53% of tap setting. The difference in pickup for different phase-to-phase faults is due to the angles at which the positive and negative sequence components of current add together.

On applications where the maximum load current and minimum fault current are too close together to allow setting the relay so it will pick up at minimum fault current and not operate on load current with the pilot wire open, tap B is used and the three-phase sensitivity is reduced by ½, while the phase-to-phase sensitivity is substantially unchanged. The relay then operates at 90% of tap value for AB and CA faults, and at 65% of tap value for BC faults. (Note that with this setting, other devices must be applied to detect 3-phase faults.)

By using tap A, the relay can be set so that it will not respond to balanced load current or three-phase faults. When A is used, the relay operates at about tap value current for all phase-to-phase faults.

For ground faults, taps G and H are used for adjustment of ground fault sensitivity to ½ or ⅛ of the upper tap value setting.

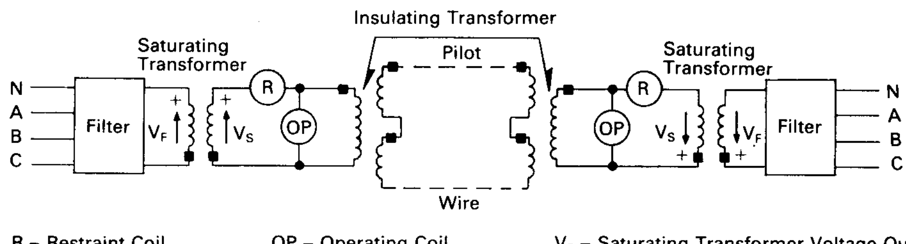
When tap F is used, the relay will not respond to zero sequence current.

Pilot Wire Characteristics
Pilot wire characteristics are shown in Table 4.

Referring to Figure 2, a short-circuited pilot wire will short circuit the relay operating coils. Depending on the location of the pilot wire short circuit, at least one of the relays will fail to trip during an internal fault. An open-circuited pilot wire will cause all the restraint current to flow through the operating coil, and the relay operates as an overcurent device.

Excessive pilot wire series impedance will approach an open-circuited condition, and the relays will operate during external faults.

Excessive pilot wire shunt capacitance will approach a short-circuited condition, and the relays will not operate.



R – Restraint Coil OP – Operating Coil V_S – Saturating Transformer Voltage Output
Relative Polarities Are For Through Current or External Fault

Sub 4
183A061

Fig. 2: Simplified External Schematic.

Single Relay Pickup
(Pilot Wire Open) I_s

Single relay pickup, I_s, is defined as the phase current required to operate one relay with the pilot wire side of the insulating transformer open circuited (H1-H4). The single relay pickup point in terms of filter voltage is:

$$V_F = 0.2T \text{ (Tap B\&C)} \quad (V_F = 0.15T \text{ (Tap A)} \qquad (3)$$

where T is the saturating transformer tap value.

Single relay pickup for taps C and H is defined by equating (2) and (3):

$$0.2T = -0.2\, I_{a1} + .46\, I_{a2} + 4.9\, I_{a0} \qquad (4)$$

Current I_s varies with the type of fault. For example, for a 3-phase fault, $I_s = I_{A1}$, since only positive sequence current is present. Substituting $I_s = I_{A1}$ in Equation (4) and rearranging, the 3-phase fault pickup is:

$$I_s = I_{A1} = \frac{0.2T}{.2} = T \text{ (3-phase fault)} \qquad (5)$$

For 4 tap:

$I_s = T = 4$ amp. (3-phase fault)

For a phase A to ground fault, if $I_{A1} = I_{A2} = I_{A0}$ (I_{A2} is the phase A negative sequence current):

$$0.2T = -.2\, I_{A1} + .46\, I_{A2} + 4.9\, I_{A1}$$

$$I_{A1} = \frac{0.2T}{5.2} = I_{A2} = I_{A0}$$

But: $I_s = I_{A1} + I_{A2} + I_{A0}$
$= 3\, I_{A1}$

$$\text{So: } I_s = 3\, I_{A1} = \frac{(0.2T \times 3)}{5.2} = 0.12T \text{ (A-G fault)} \qquad (6)$$

For $T = 4$
$I_S = 0.5$ ampere

Nominal Pickup (All Relays)

The nominal pickup, I_{nom}, is defined as

$$I_{nom} = KI_S \qquad (7)$$

where I_{nom} = total internal fault current
K = number of relays (2 or 3)
I_s = single-relay pickup with pilot wire disconnected (see above)

For example, for a phase-A-to-ground fault, $I_{A1} = I_{A0}$ with the pilot wire open circuited, and the single-relay pickup was previously determined as $I_{AS} = 0.5$ ampere for 4CH taps. For a two-terminal line, the nominal pickup for a phase-A-to-ground fault (4CH taps) is:

I_{nom} (A to G) $= 0.5 \times 2 = 1.0$ ampere.

Minimum Trip (All Relays)

With equal inputs to all relays and zero pilot-wire shunt capacitance, the relays will operate at their nominal pickup point. The minimum trip points will vary somewhat from nominal value, depending on the pilot-wire constants and the magnitude and phase angle of the various relay input currents.

An example of the characteristics with various current distributions is shown in Figure 3. The filter output voltage, V_F, of each relay, as defined by equation (1) must be in phase or 180 degrees out of phase, in order for Figure 3 to apply.

Insulating Transformer

Unless otherwise noted, all characteristics presented include an insulating transformer with each relay. Two ratios are available: 4:1 and 6:1. The high voltage side is connected to the pilot-wires.

Pilot Wire Requirements

The relays should not be applied with pilot-wire series resistance or shunt capacitance exceeding the following values:

Table 4

Number of Relays	Insulating Transformer Ratio 4:1		6:1	
	R_L	C_s	R_L	C_s
2	2000	1.5	....	..
3	500/LEG	1.8	1000/LEG	0.75

R_L = Series loop resistance in ohms.
C_s = Total shunt capacitance in microfarads. (Total wire to wire capacitance)

A shielded, twisted pilot wire pair, preferably of #19 AWG or larger, is recommended; however, open wires may be used if they are frequently transposed in areas of exposure to power circuit induction. The voltage impressed across either insulating transformer (H-1, H-4 terminals) as a result of induction or a rise in station ground potential, should be less than 7.5 volts to prevent undesired relay operation.

For three-terminal applications, the loop resistance of all legs of the pilot wire must be balanced within 5 percent, with variable resistors. The pilot wire resistance to be balanced is divided by 16 and 36 for the 4 to 1 and 6 to 1 ratio insulating transformers respectively, since the balancing resistors are located on the relay side of the insulating transformers.

Induced voltages and rises in station-ground potential may be handled by the following means:

(a) Neutralizing reactors may be connected in series with the pilot wire to hold the pilot wire potential close to the remote ground potential in the presence of a rise in station-

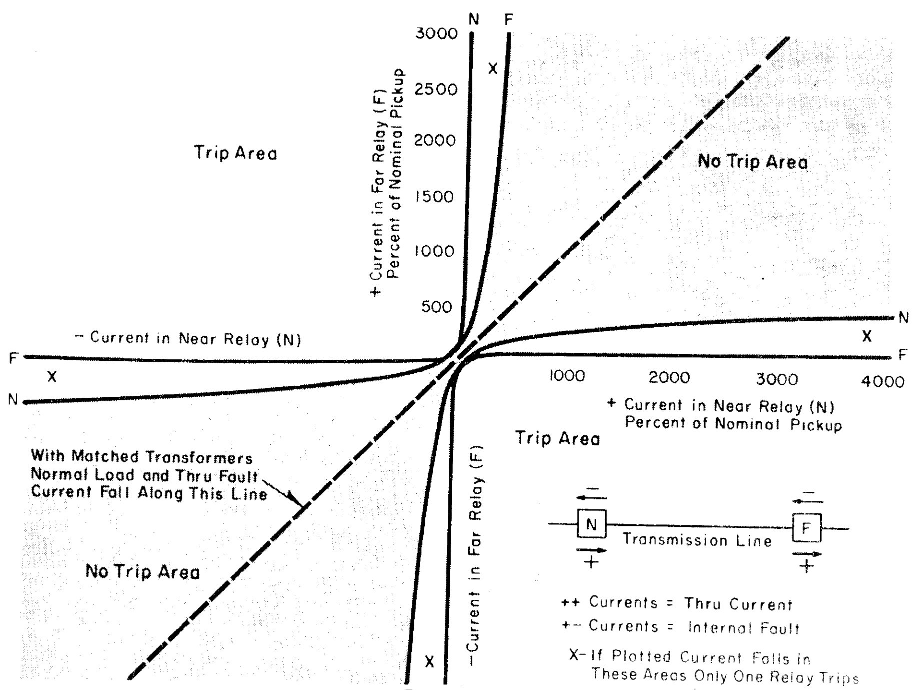


Fig. 3

ground potential. They do not limit pilot-wire voltages to safe values in the presence of a longitudinal induced voltage. When using the neutralizing reactor, the pilot-wire sheath should be insulated from station ground to minimize sheath-to-pair potential in the presence of a rise in station-ground potential. All other pairs in the cable which are connected to station ground should also be protected with neutralizing reactors to minimize pair-to-pair voltages.

(b) Drainage reactors may be connected across the pilot wire and to ground through two sealed gas discharge tubes. The drainage reactor is particularly effective in limiting pair-to-ground voltage in the presence of an induced voltage. When the tube flashes, both wires are connected to ground through the drainage reactor windings which offer a low impedance to ground but maintain a high impedance to an ac voltage across the wires. Thus, the HCB-1 system will operate normally even though the protector tube has flashed over. The drainage reactor is not intended to handle a rise in ground potential.

(c) The neutralizing and drainage reactors may be utilized together. If the neutralizing reactor is to be of any value, the drainage reactor through the gas discharge tube must be connected to remote ground.

Trip Circuit
The main contacts will safely close 30 amperes at 250 volts dc, and the seal-in contacts of the Indicating Contactor Switch will safely carry this current long enough to trip a circuit breaker.

The Indicating Contactor Switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Shipping Weights and Carton Dimensions

Relay Type	Flexitest Case Type	Weight: Lbs. Net	Shipping	Domestic Shipping Carton Dimensions: Inches
HCB-1	FT-42	22	26	12 x 13 x 21

Further Information
List Prices: PL 41-020
Technical Data: TD 41-025
Instructions:
  Type HCB-1, IL 41-971.3
  PM Monitoring Relay, IL 41-973.5
  Pilot Wire Systems, IL 41-971.4
Renewal Parts: RPD 41-936
Flexitest Case Dimensions: DB 41-076
Contactor Switches: DB 41-081
Other Protective Relays:
  Application Selection Guide, TD 41-016

Printed in U.S.A.

March, 1991
Supersedes TD 4-020, Type HCB-1 on page 161, dated October, 1988
Mailed to: E, D, C/41-100A, 41-900A

For Phase and Ground Fault Protection of Transmission Lines

Type HCB-1 High Speed Pilot Wire Relay

Phase and Ground Pilot Wire Relay Schemes (Device Number: 87)

Type	Application	Time Delay On Tripping: Time	Time Delay On Tripping: Volts dc	Indicating Contactor Switch ③	Complete Set: For 3-Phase Protection Per Line Terminal	Relay Data: Internal Schematic	Relay Data: Style Number	Relay Data: Case Size
HCB	2 or 3 terminal lines, 4-15 amp, 60 Hz	Inst.	. . .	0.2/2.0 amps dc	1 HCB spst-cc 1 HCB dpst-cc 1 HCB dpdt	629A310 629A312 764A236	292B930A10ⓢ 292B930A13ⓢ 292B930A16	FT-42
HCB-1	2 or 3 terminal lines, 4-12 amps	Inst.	. . .	0.2/2.0 amps dc	1 HCB-1 spst-cc dpst-cc	763A227 763A628	292B930A29ⓢ 292B930A30ⓢ	FT-42
HCB-2	2 or 3 terminal lines, 4-15 amps	.05-.4 second 0.5-1 second	48/125 48/125		1 HCB-2 spst-cc spst-cc	837A364	292B930A22 292B930A23	
HCB-3		35-50 milliseconds	125		1 HCB-3 spst-cc	848A627	292B930A33	

Order all HCB type relays and auxiliaries on N-1 order with separate item for each style.

1 insulating transformer
1 W-2 switch
1 milliammeter
} **External devices included in price of HCB Type relays**

Order each item by style number from "Auxiliaries" table.

ⓢ Denotes item available from stock.
③ ICS: Indicating Contactor Switch (dc current operated) having seal-in contacts and indicating target which are actuated when the ICS coil is energized at or above pickup current setting. Suitable for dc control voltages up to and including 250 volts dc. Two current ranges available:
(1) 0.2/2.0 amps dc, with tapped coil.
(2) 1.0 amp dc, without taps.

Rating of ICS unit used in specific types of relays is shown in price tables. All other ratings must be negotiated.

When ac current is necessary in a control trip circuit, the ICS unit can be replaced by an ACS unit.

The ACS unit may be supplied in place of an ICS unit at no additional cost. Specify system voltage rating on order.

Auxiliaries for HCB and HCB-1, 2, 3 Schemes

Description	Panel Thickness	Style Number
Insulating transformer 50 or 60 Hertz 4/1	. . . .	7882A26G07ⓢ
6/1	. . . .	7882A26G08ⓢ
W-2 switch	⅛"	508A468G01ⓢ
	1½"	508A468G02
	2½"	508A468G03
RC-351 milliammeter, flush mounting case	⅛"	291B318A09④ⓢ
(60 Hertz ac, 0-5, 0-25 mA)	2"	1964 364④

④ Style number includes auxiliary transformer style number 291B606G09. Not necessary to order 291B606G09 as separate item when ordering RC-351 milliammeter.