



Pilot-wire differential relay RADHL with RXHL 401

Features

- Phase and earth fault protection for cable and overhead lines
- Protect lines with two or more terminals
- High-speed operation (1-2 cycle)
- Stability ensured for external faults
- All line ends trip for fault current from single end
- Pilot-wire voltage limited to 60 V permits use of low cost communication wires (100V)
- 5 kV basic insulation level and 15 kV with pilot-wire isolating transformers
- 1000 ohms and 2 μ F pilot-wire capacitance
- 2000 ohms and 0,7 μ F with pilot-wire isolating transformers
- Direct trip contacts and trip flag indicator
- Test switch included
- Options:
 - Over current monitoring and back-up
 - Pilot-wire supervision
 - Three-phase/+earth overcurrent back-up functions (3 RXIDK 2H or RXHL 401/411)
 - Three-phase thermal overcurrent function (using RXHL 411)
 - Breaker failure current back-up function (using RXHL 411)
 - Reclosing up to four shots (option with RXHL411)

Application

The RADHL pilot-wire relays are used for protection of short to medium length cable or overhead lines. The relays use a dedicated metallic pilot-wire pair. The wire can be a normal low cost twisted pair communications wire. The shield may be aluminum laminated or copper wire type. The pilot-wire loop resistance is matched to 1000 or 2000 ohms.

The standard relay can be applied to circuits with more than two line ends. Therefore three or more terminal applications are possible.

The maximum length of a protected circuit is related to the total line charging current. The leakage current to ground must be limited to 10% of the rated primary current. The earth-

leakage current for a cable may be in the order of 5-15A per km, depending on network voltage and the type and size of cable.

The most sensitive earth-fault detection of the relay is 25% of rated current. This may be fed from one end only, or divided between line ends.

The three-phase fault sensitivity is 72% when fed from one end, or 36% when fed symmetrically from two ends.

All line ends trip for a fault fed from a single-end. This makes the relay suitable for applications with weak infeed, since tripping of weak end is automatically performed.

The relay is secure against power surges, out-of-step and emergency loading conditions as it uses a balanced bridge principle for measurements. The operating principle offers also the advantage of one cycle (50/60Hz) operation.

RADHL versions with current level monitoring relays are used to avoid tripping on load current when there is an open or defective pilot-wire. The current level monitoring relays are also used to provide additional relay functions. There are three alternative standard schemes available in the ordering table;

1. RXIDK 2H - three single phase elements. The overcurrent starting contacts provide monitoring of the differential relay tripping. The time-overcurrent and instantaneous overcurrent functions provide back up to the differential relay.
2. RXHL 401 - three-phase and earth overcurrent relay functions. Three levels of starting, time and instantaneous trip functions.
3. RXHL 411 - three-phase and earth overcurrent relay functions with three setting levels for phase and earth and thermal replica overload, breaker failure and optional reclosing relay functions.

Optional pilot-wire supervision provides alarms for open, short-circuited or reversed pilot-wires.

A simple transfer trip of a remote breaker can be obtained by opening of the RADHL's pilot-wires. The operation of the two RADHL relays then becomes half of the normal operating values, i.e. in the range 12.5 - 63 % of the CT rating, and depends on the type of the through going fault or load current.

Current Transformer requirements

The CT's at each terminal do not need to have the same ratio. Ratio matching can be done with auxiliary CT's or the summation CT. The demands on the main CT's are small because the voltage in the pilot-wire circuit is limited to about 60V by zener-diodes. The protection is fully stable during external faults provided that the main CT's are approximately the same and the secondary limiting e.m.f. (E_{2max}) fulfil the requirement:

$$E_{2max} \geq 20 i_r (R_{CT} + R_L + Z_2 + 5/i_r^2) \text{ where:}$$

- i_r = main CT secondary rated current
- R_{CT} = main CT secondary winding resistance
- R_L = resistance in the wires between the main CT and the summation transformer in RADHL
- Z_2 = impedance of other relays and loads connected to the same CT core

For systems with high resistance earthing, the R_L value is taken for a single length of the wire used and for low resistance or solidly earthed systems the R_L value is for the double length of the wire.

In an isolated or high impedance, resistive earthed network main CT's are only required in two phases if a separate protection is used for detecting earth faults.

1000/2000 Ohms & 5/15kV pilot-wires

The RADHL can operate over pilot-wires having 1000 ohms loop resistance, 2 μ F shunt capacitance and 5 kV difference in earth potential between the terminals. The 5 kV limit can be increased to 15 kV by an isolating transformer (ratio 1:1) at both ends. With a 15 kV transformer of ratio 1:1.7, a 2000 ohm 0,7 μ F pilot-wire can be used.

Multi-terminal applications

It is possible to use the standard RADHL relays for lines having more than two ends. The standard relays are used with pilot-wire padded to 500 ohms per leg. ABB provides more details and application schematics for applications with multi terminal lines.



Fig. 1 pilot-wire supervision equipment

Design

The RADHL differential system compares the magnitude and phase angle of the currents entering and leaving the protected circuit via a pilot-wire. Zener diodes within the relay limit the voltage across the pilot-wires to 60 V and the current to 60 mA.

The pilot-wire resistance is always padded to 1000 Ohms for two terminal applications. For multi-terminal applications, each pilot-wire leg is padded to 500 Ohms (as seen from relay to a pilot-wire midpoint). The calibration of the sensing relay is 10mA corresponding to about 10V at the relay.

The basic two-terminal versions of the RADHL consist of:

- RTXP 18 test switch
- RXDHL 4 measuring module (Fig. 2)
- SLCE 8 three-phase summation (Fig. 3) transformer

The RXDHL 4 measuring relay includes the full wave rectifying diode bridge for the sensing relay, the flag indicator, voltage limiting zener diodes and padding resistors. The indicator flag is located in the front of the relay and has a hand reset knob. The flag indicator also has a voltage operated reset coil that can be activated via a remote push-button.

An essential differential relay system principle is that the pilot-wire circuit is always padded to 1000 ohms regardless of its actual

value via a tapped resistor in the RXDHL 4 unit.

Adjusting resistance (ohms)	Connect COMBIFLEX leads to terminals
0	426-422 and 313-316
33	426-422 and 313-315
66	426-422 and 313-314
100	426-423 and 313-316
133	426-423 and 313-315
166	426-423 and 313-314
200	426-424 and 313-316
233	426-424 and 313-315
266	426-424 and 313-314
300	426-425 and 313-316
333	426-425 and 313-315
366	426-425 and 313-314
400	426-426 and 313-316
433	426-426 and 313-315
466	426-426 and 313-314
499	426-426 and 313-311

The padding resistance is accessed from the rear of the terminal base. A wire is provided for connection via normal 10A COMBIFLEX sockets, see Fig. 6.

The summation current transformer, designed for 5 kV test voltage, see Fig. 3, may be furnished loose for separate mounting. The transformer converts the input currents to a single-phase current which is applied to the pilot-wires



(XX02000627)

Fig. 2 pilot-wire relay RXDHL 4



(SE970868)

Fig. 3 Summation CT type SLCE 8

Pilot-wire supervision (See Fig. 1)

The pilot-wire supervision equipment consists of one unit at the sending end, and one unit at the receiving end.

The dc current measuring unit RXCLK 2 is used in the RADHL pilot-wire supervision sending end to detect and indicate short-circuited and open-circuited pilot-wires. Interchanged connections of two pilot-wire ends are also detected. The sending end unit has two flags indicating the status of the pilot-wires. The alarms are normally delayed a few seconds using the RXXKA 1 timer. The timer range is 0,1-320 seconds.

The pilot-wire supervision equipment also works according to the balanced bridge principle. One side of the bridge consists of the internal resistance of the RADHL relay, the pilot-wire resistance and an additional

4 kohm resistor in the remote end supervision unit. The total loop resistance for the supervision circuit is therefor about 6 kohm.

The other side of the bridge is a variable 6,3 kohm resistor in the dc supply at the pilot-wire supervision feeding end. The bridge is balanced with this resistor at commissioning.

The bridge is supplied with 0 and +/-12V DC from the power supply unit RXTUB 2.

15kV insulation and 2000 Ohm pilot-wires

The RXCLK 2 relay operates when the current exceeds 1 mA. The standard insulation test voltage is 5 kV 50-60 Hz. By feeding the unit from a 15kV isolation transformer it is possible to increase the total insulation level to 15kV.

Pilot isolation transformers are required only when the longitudinally induced voltages in the pilot circuit is likely to exceed 5kV. This may be the case when the system voltage is above 36kV or of sufficient length. The isolation transformers are also used to extend the range of line-lengths possible to protect with pilot-wire relays. A resistance of 2000 Ohms is the limit and maximum capacitance of 0.7 μ F, can be handled with the standard relays.

The 15kV insulated pilot-wire supervision equipment assembly may be housed in another enclosure than the differential relay. For a mounting example of this equipment, please refer to Fig. 4. All equipment is mounted on an insulating back-plane and the enclosure may be made from non-conducting insulating material e.g. fiberglass.

In the assembly shown in Fig. 4, there are three 15kV insulation transformers type SLCE 8 used. One of these transformers isolate the pilot-wire system from the RADHL relay.

The other two are used to provide additional isolation for the supervision equipment. One of these transformers increases the insulation level of the power supply to 15kV. The second provides 15kV isolation for the alarm signal to the "ground" level.



Fig. 4 Example of a fiberglass enclosure for 15 kV insulation.

The 15 kV pilot-wire insulation transformer type SLCE8 comes in two versions with ratio 1:1 or 1:1.7.

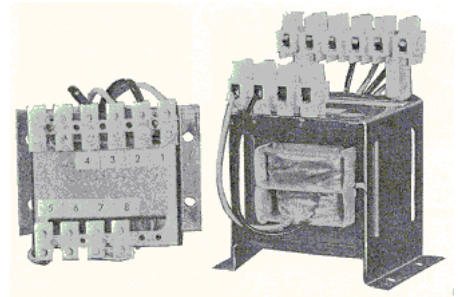


Fig. 5 15kV pilot-wire isolation transformer SLCE 8

Technical data

Rated current, I_r	1 or 5 A		
Ac burden	3 VA, total for three-phase		
Continuous overload capacity	$2 \cdot I_r$		
Frequency	50-60 Hz		
Sensitivity:	2-terminals	3-terminals	4-terminals
earth faults	25-42% of I_r	40-66%	60-100%
phase faults	64-126% of I_r	100-200%	150-300%
Operating time	20 ms at $1,5 I_{pick-up}$		
Maximum pilot-wire resistance	1000 ohms (2000 ohms with isolating transformer ratio 1:1,7)		
Maximum pilot-wire capacitance	2,0 μ F (0,7 μ F with isolating transformer ratio 1:1.7)		
Dielectric tests:			
current circuits	50 Hz, 2,5 kV, 1 min		
pilot-wire	50 Hz, 5,0 kV, 1 min		
remaining circuits	50 Hz, 2,0 kV, 1 min		
Impulse voltage test	1,2/50 μ s, 5 kV, 0,5 J		
Disturbance Tests:			
Power frequency test	50 Hz, 0,5 kV, 2 min		
Fast frequency test	4-8 kV, 2 min		
1 MHz burst test	2,5 kV, 2 s		
Flag relay auxiliary voltage	24-55 V or 110-250 V		
Trip outputs	2 make contacts capable of closing 30A dc for 200ms		

Diagrams

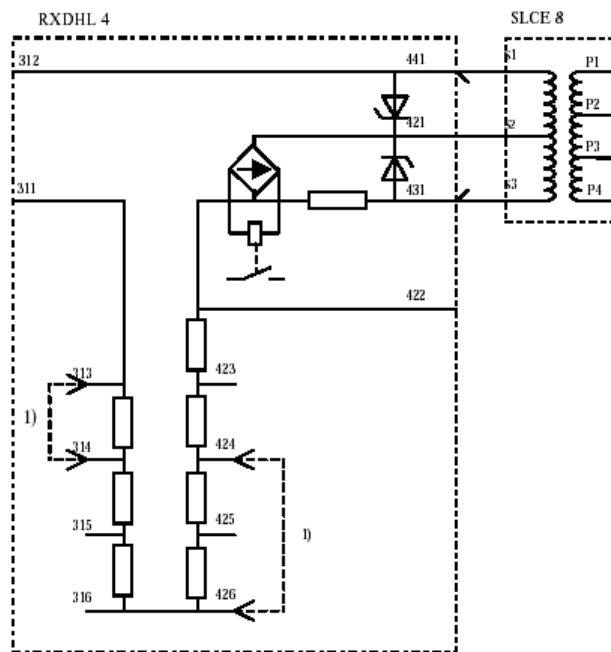


Fig. 6 Terminal diagram for RXDHL 4

Pilot-wire differential relay for lines with two or more terminals

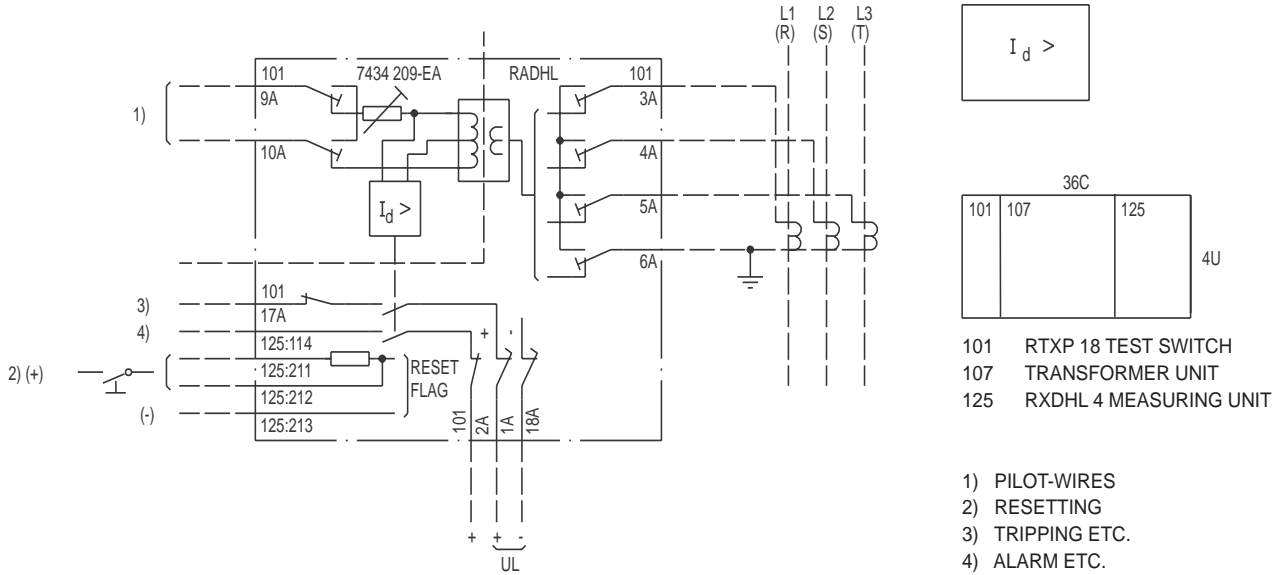


Fig. 7 Terminal diagram No. 7434 209-EAA. Basic version.

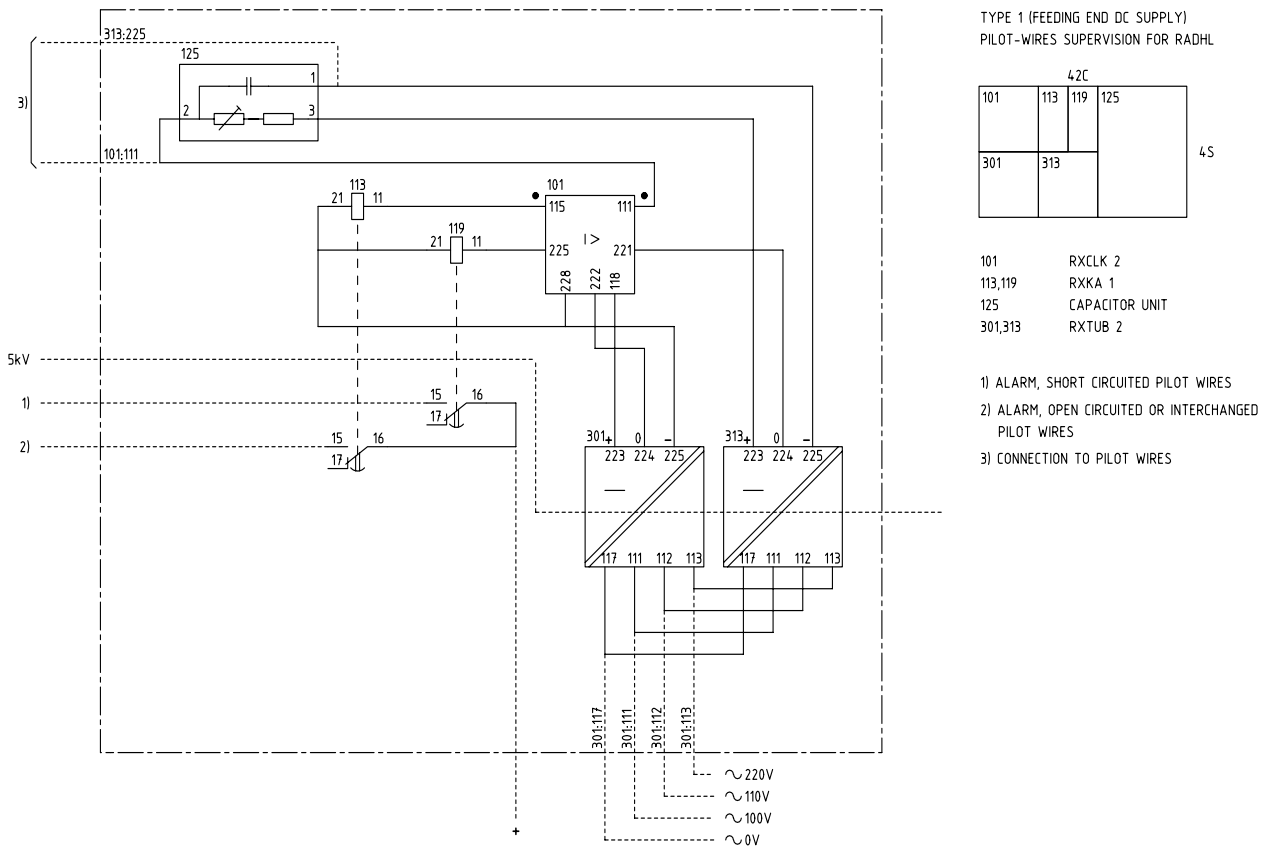


Fig. 8 Circuit diagram No. 1MRK 001 358-AA. Pilot-wire supervision, sending end unit.

Sample specification

Three phase pilot-wire relay for phase and earth fault protection. The relay shall have 5 kV insulation and not impose more than 60V (120V) onto the pilot-wires. The relay shall operate in 1-2 cycles and trip both call ends during single-end infeed of fault current to permit use in weak infeed applications. Pilot-wire supervision equipment, when specified, shall detect shorted, opened and reversed pilot-wires and provide alarm out-

puts. The relay shall handle a 1000 (or 2000) ohms pilot-wire resistance and have a minimum of 5 (or 15) kV insulation level. A minimum of two output trip contacts and trip indication shall be provided. Current supervision and back up functions including thermal overload and breaker failure functions and auto reclosing elements are to be included as integral functions in the same assembly, when specified for the application.

Ordering

Specify:

Quantity

Ordering number

according to table

Rated current

1 A 5 A

Auxiliary voltage UL

24 V

48 V

110 V

125 V

220 V

250 V

Ordering number selection table for two terminals application

Pilot-wire relay	Dimensions	Weight	Terminal diagram	Ordering No.
Basic version (includes summation CT SLCE 8 and test switch RTXP 18)	4U 36C	5,2 kg	7434 209-EAA	RK 612 001-EA
Basic version + output relay RXME 1	4U 42C	5,7 kg	7434 209-GAA	RK 612 001-GA
Basic version + output relay RXMS 1	4U 42C	5,7 kg	7434 209-HAA	RK 612 001-HA
Basic version with summation CT furnished loose	4U 18C	3,0 kg	7434 209-ACA	RK 612 001-AC
Basic version with summation CT furnished loose + output relay RXME 1	4U 24C	5,3 kg	7434 209-BCA	RK 612 001-BC
Basic version with summation CT furnished loose + output relay RXMS 1	4U 24C	5,4 kg	7434 209-DAA	RK 612 001-DA
Pilot-wire supervision equipment:				
Sending end unit	4U 48C	6,5 kg	1MRK 001 358-AAA	1MRK 001 357-AA
Receiving end unit	4U 18C	2,0 kg	7434 211-CA	7434 210-CA
SLCE 8 - 15 kV Pilot-wire isolation transformer		3,6 kg		
Ratio 1:1 for 1000 Ohm pilot-wire				4785 040-AUP
Ratio 1:1,7 for 2000 Ohm pilot-wire				4785 040-BAL
As spare part				
RXDHL 4 loose relay ¹⁾	RX4	1,5 kg	Fig. 6	RK 612 010-EA
SLCE 8 summation CT	5 A	3,6 kg	Fig. 6	4785 040-SY
	1 A	3,6 kg	Fig. 6	4785 040-SV

¹⁾ Please note that terminal base RX4 is not included.

Versions with additional fault detectors

Specify:

Quantity

Ordering number according to table

Rated current 1 A 5 A

AC inputs for RXHL 401 and RXHL 411

Rated phase current $I_r = 1$ A, rated neutral current $IN_r = 0.1$ A 1MRK 000 322-FA

Rated phase current $I_r = 1$ A, rated neutral current $IN_r = 1$ A 1MRK 000 322-FB

Rated phase current $I_r = 5$ A, rated neutral current $IN_r = 0.1$ A 1MRK 000 322-FC

Rated phase current $I_r = 5$ A, rated neutral current $IN_r = 1$ A 1MRK 000 322-FD

Rated phase current $I_r = 5$ A, rated neutral current $IN_r = 5$ A 1MRK 000 322-FE

Ordering number selection table for two terminals application

Pilot-wire relay	Dimensions	Weight	Terminal diagram	Ordering No.
Basic version + 3 single phase fault detectors type RXIDK 2H	4U 60C	7,5 kg	7434 209-FBA	RK 612 001-FB
Basic version + 3 phase and earth fault detectors type RXHL 401	4U 60C	6,5 kg	1MRK002078-AAA	1MRK002077-AA
Basic version + 3 phase and earth fault detectors type RXHL 411	4U 60C	6,5 kg	1MRK002078-AAA	1MRK002077-AB

Options for RXHL 411

Automatic reclosing function with intentional overreach trip function included 1MRK 000 200-BA

Binary I/O module (inputs 4/outputs 4) 1MRK 000 322-ET

Mounting and testing details

- RADHL and the pilot-wire supervision equipment are delivered mounted on apparatus bars.
- Depending on the type of final mounting required, i.e. 19" rack-mounting, or various forms of panel mounting, additional equipment is required.
- On request the 15 kV pilot-wire transformer, can be mounted on an apparatus plate or in a suitable casing.

Reference

RADHL Users guide	1MRK 507 004-UEN
COMBIFLEX mounting hardware details	1MRK 513 003-BEN
COMBITEST test equipment details	1MRK 512 001-BEN
RXIDK 2H current monitoring relay	1MRK 509 002-BEN
RXHL 401 current monitoring relay	1MRK 509 062-BEN
RXHL 411 current monitoring relay	1MRK 509 049-BEN
RXME 1 intertrip auxiliary relay	1MRK 508 015-BEN
RXMS 1 intertrip auxiliary relay	1MRK 508 015-BEN

Manufacturer

ABB Automation Technology Products AB
Substation Automation
SE-721 59 Västerås
Sweden
Telephone +46 (0) 21 34 20 00
Facsimile +46 (0) 21 14 69 18
Internet: www.abb.com/substationautomation