ABB Network Partner AB

RXPPK 2H and RAPPK Reverse power relay and protection assemblies

User´s Guide
1MRK 509 042-UEN

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General

RXPPK is used to detect reverse power or low forward power to prevent damage of the prime mover (turbine or motor). If the driving torque to a generator becomes less than the total losses in the generator and the prime mover, the generator starts to work as a synchronous compensator and severe damage can be done to the prime mover. The reverse power protection RAPPK effectively prevents such damage and, at the same time, allows full utilization of the protected object.

The COMBIFLEX® reverse power protection RAPPK monitors the active power by measuring current and the phase angle between current and voltage. RAPPK is a single-phase reverse power protection using the measuring relay RXPPK 2H. The relay is a micro-processor based time directional overcurrent relay with settings for active current operate value and time delays. The relay has one measuring stage, with a wide setting range 0,3 to 15% of the set current. It has two different definite time delay stages.

All RAPPK protections are:

- mounted in the COMBIFLEX® modularised system
- available with or without test switch
- available with or without DC-DC converter
- available with or without additional heavy duty tripping relay

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1 Application

The purpose of the reverse power relay is basically to prevent damage on the prime mover (turbine or motor). If the driving torque becomes less than the total losses in the generator and the prime mover, the generator starts to work as a synchronous compensator, taking necessary active power from the network. In case of steam turbines, a reduction of the steam flow reduces the cooling effect of the turbines blades and overheating may occur.

Hydro turbines of the Kaplan type and bulb type may also be damaged due to the fact that the turbine blade surf on the water and set up an axial pressure on the bearing. Diesel engines may be damaged due to insufficient lubrication.

The total losses at rated speed, as a percentage of the rated power of the generator, are approximately:

Type	Total loss
Steam turbine	1 - 3%
Hydraulic turbine	1 - 3%
Gas turbine	5%
Diesel engine	25%

These values apply to the case when the power input to the prime mover is completely cut off. Thus, in the case when the total losses of a unit are covered partly by the prime mover and partly by electrical power from the system, the actual power drawn by a generator, during certain motoring conditions, may be much less than the above percentage values.

The generator currents remain balanced when the machine is working as a motor, hence, a single-pole relay is fully sufficient if the sensitivity is high. For large turbo units, an additional relay may be connected to a different phase in order to obtain redundancy.

When the generator is working as a motor the small active current to the machine may be combined with a substantial reactive current delivered by the machine. Hence, the angular error of voltage and current transformers feeding sensitive reverse power relays should be small.

For large turbo-generators, where the reverse power may be substantially less than one percent, reverse power protection is obtained by a minimum power relay, which normally is set to trip the machine when the active power output is less than one percent of rated value, low forward power principles (see Fig. 5).

The time step t_1 is mainly intended to be released by an auxiliary contact on the turbine stop valve. It will then trip the field and the generator breaker with a short time delay, typically 2 - 3 seconds after operation of the reverse power measuring function.

The reverse power function with time step t_1 can be used in the normal decommissioning routine to avoid excessive overspeeding when taking steam powered generators off service. The function can also be used to interlock the generator breaker tripping for non-urgent faults.

The purpose of the second stage is to prevent excessively high temperature and possible mechanical damage to the prime mover. The time delay can be longer in this case, typically 10 - 15 seconds. A reset delay, of 5 seconds can be activated to ensure operation, even if power swing makes the current function pick up and reset during the measuring period.

The relay should be connected to receive a polarizing voltage that is in phase with the measured current for an active current when measuring forward power. When measuring reverse power conditions the current should be out-of-phase.

A rather common arrangement in older power plants is the use of V-connected voltage transformers. The VT's then have no neutral point available. Polarizing voltage to a RXPPK 2H relay, measuring the current in L1, can be arranged with two 2000 Ω, 5 W resistors shown in Fig. 1. The difference in resistance value between the two resistors should be kept as low as 10 ohms in order not to introduce appreciable angular errors if the operate value of RXPPK 2H is set to 1% of rated generator current or lower.

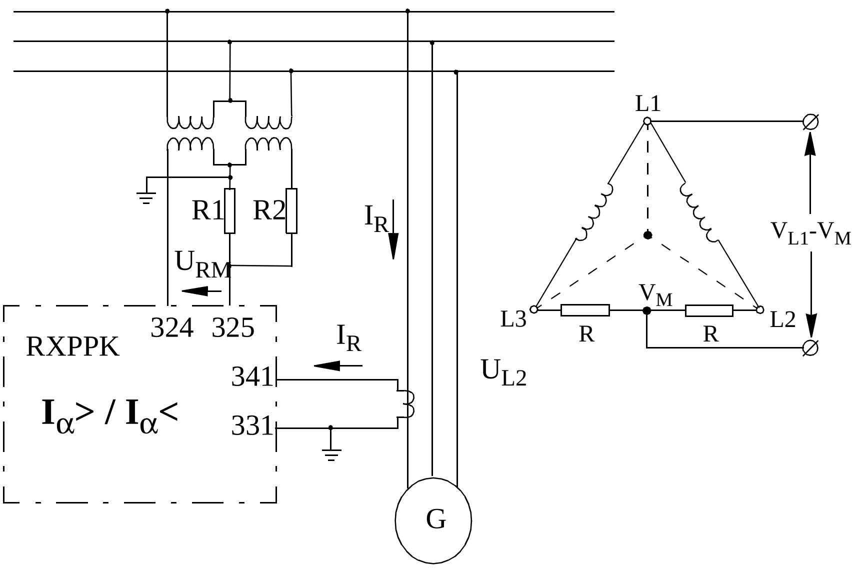

Fig. 1 V-connected voltage transformers polarizing RXPPK 2H.

2 Measurement Principles

The RXPPK 2H relay constitutes the measuring unit of RAPPK. For setting of operate values, see Section 4.

The simplified logic diagram in Fig. 2 describes the operation of the RXPPK 2H relay.

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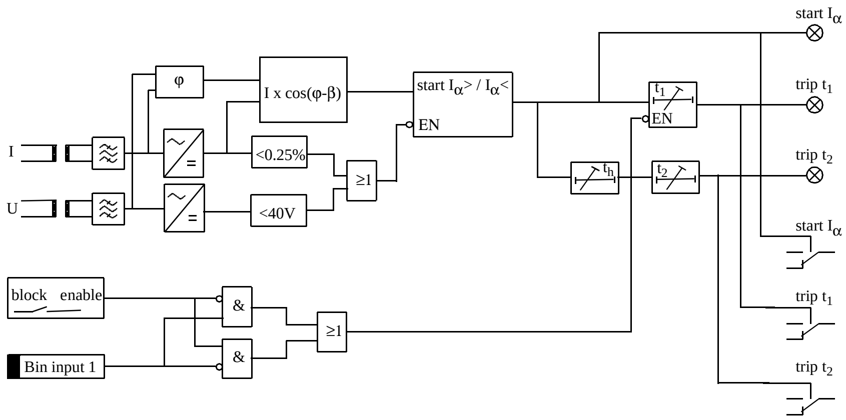


Fig. 2 Simplified logic diagram for the RXPPK 2H relay

To provide a suitable voltage for the electronic measurement circuits the relays are provided with a current transformer and a voltage transformer. The voltage from the current transformer and the voltage transformer is filtered with 4th order bandpass filters with a centre frequency equal to 55 Hz.

The filtered values are applied to zero detectors and a new phase-angle is calculated in the microprocessor every zero-crossing.

The current and voltage values are filtered with a moving average filter to reduce ripple. The filtered current is multiplied with cos(φ–α–β). The calculated value, I x cos(φ–α–β) is filtrated with a eight-point moving average filter. The phase angle φ is positive if I lags U. The RXPPK 2H start unit operates according to Fig 3 and 4.

Switch	Start when:
S1:1 = I_α> (reverse power)	I x cos(φ–β–180°) ≥ I_α>
S1:1 = I_α< (low forward power)	I x cos(φ–β) ≤ I_α<

Fig. 3 *Start conditions for the RXPDK 2H start function Iα.*

The characteristic angle α is set to 0° or 180° depending on the S1:1 setting. The relay is provided with a system angle compensation, the β angle. It is possible to compensate for a system angle inaccurrancy within the range -3° to 3°. When the S1:1 is set to I_α<, the low-forward function is blocked when current is below 0,3% of I_r.

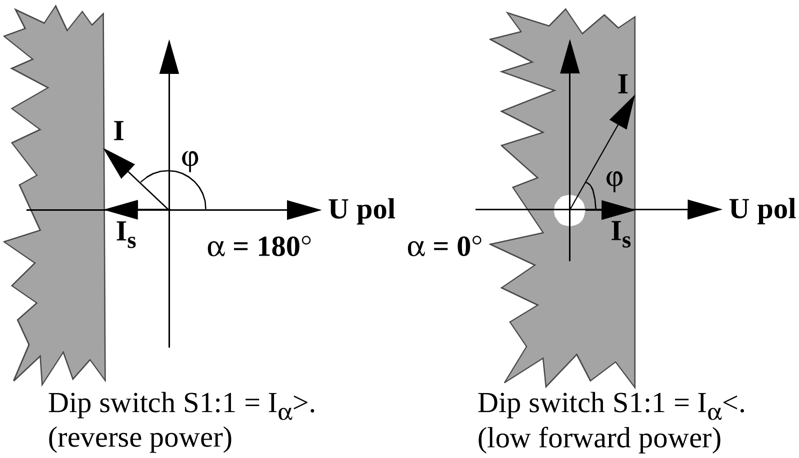


Fig. 4 Function characteristics for the RXPPK 2H relay.

The relay is also provided with two definite time-delays with corresponding trip relays according to Fig. 5.

Setting	Delayed time
t_1 (short-time delay)	0 to 4 sec.
t_2 (long-time delay)	0 to 30 sec.

Fig. 5 The definite time-delays t_1 and t_2

The long-time delay Trip t_2 is connected to a hold-function settable to 0 or 5 seconds with S1:6. When the hold function is set to 5 seconds the Trip t_2 will not reset until start has been absent for more than 5 seconds.

There are two binary inputs on the relay. The first binary input is used for remote blocking or enabling of Trip t_1 depending on the S1:5 setting.

The second binary input is used for remote resetting of the “Trip t_1” and “Trip t_2” LEDs. The binary inputs are galvanically separated from the electronics with an opto-coupler.

The processor executes a self test sequence when initiated. If the processor fails to start in a proper way the LEDs will indicate by flashing according to Fig. 6 or the “In serv.” LED will not be lit. The program in the microprocessor is executed in a fixed loop with a constant looptime. The loop is supervised by an internal watch dog which initiates a program restart if the program malfunctions.

Test sequence	Test error indication
Register configuration	All LED’s flash in clockwise rotation.
RAM	Left red LED flashes.
ROM	Right red LED flashes.
A/D	All red LED’s flash.

Fig. 6 Self test error indication of the RXPPK 2H relay

The reset button has two functions, LED check and resetting the LEDs. When the button is depressed, the “Start I_{α}”, “Trip t_1” and “Trip t_2” LEDs are lit and the “In serv.” LED is switched off, in order to check the LEDs. When the button is released the “Start I_{α}”, “Trip t_1” and “Trip t_2” LEDs are reset to show the actual status and “In serv.” LED is relit.

3 Design

The generator reverse power protection type RAPPK is designed for single-phase application. Each protection is available with or without test switch RTXP 18, DC-DC converter RXTUG 22H or tripping relay RXME 18.

All the protections are built up by modules in the COMBIFLEX® modular system mounted on apparatus bars. The connections to the protections are done by COMBIFLEX® socket equipped leads.

The type of modules and their physical position and the modular size of the protection are shown in the *Buyer´s Guide* and in the Circuit Diagram of the respective protection. The following modules can be included.

3.1 Test switch

The test switch RTXP 18 is a part of the COMBITEST testing system described in the *Buyer´s Guide*, document No. 1MRK 512 001-BEN. A complete secondary testing of the protection can be performed by using a test-plug handle RTXH 18, connected to a test set. When the test-plug handle is inserted into the test switch, preparations for testing are automatically carried out in a proper sequence, i.e. blocking of tripping circuits, short-circulating of current circuits, opening of voltage circuits and making the protection terminals available for secondary testing. Test switch RTXP 18 has the modular dimensions 4U 6C.

All input currents can be measured by a test plug RTXM connected to an ammeter. The tripping circuits can be blocked by a trip-block plug RTXB and the protection can be totally blocked by a block-plug handle RTXF 18.

3.2 DC-DC converter

The DC-DC converter RXTUG 22H converts the applied battery voltage to an alternating voltage which is then transformed, rectified, smoothed and in this application regulated to ±24 V DC. The auxiliary voltage is in that way adapted to the measuring relays. In addition, the input and output validates will be galvanically separated, which contributes to damping of possible transients in the auxiliary voltage supply to the measuring relays. The converter has a built-in signal relay and a green LED for supervision of the output voltage.

RXTUG 22H has the modular dimensions 4U 6C. It is described in the *Buyer´s Guide*, document No. 1MRK 513 001-BEN.

3.3 Measuring relay

The reverse power relay RXPPK 2H is a static, microprocessor-based relay with one reverse/low forward power stage and two built-in definite time delays. The relay consists mainly of an input transformer for voltage adaptation and isolation, filter circuits, analog digital converter, microprocessor, MMI consisting of programming switches and potentiometers and LEDs for start, trip and in- service indications, and three output relays. Each output relay has a change-over contact, for the Start I_{α}, Trip t_1 and Trip t_2 functions respectively. The relay has two binary inputs, one for remote resetting of the LED indications for “Trip t_1” and “Trip t_2” and the other for remote blocking or enabling of Trip t_1.

The operate values of the stage is set by potentiometers and programming switches in the front. The “Trip t_1” stage and the “Trip t_2” stage definite-time delays is set with corresponding potentiometers.

RXPPK 2H has the modular dimensions 4U 6C.

3.4 Tripping relay

The auxiliary relay RXME 18 is used as a tripping relay. It has two heavy duty make contacts and a red flag. The flag will be visible when the armature picks up and is manually reset by a knob in the front of the relay. Typical operate time is 35 ms.

RXME 18 has the modular dimensions 2U 6C. The relay is described in the *Buyer´s Guide*, document No. 1MRK 508 015-BEN.

4 Setting and Connection

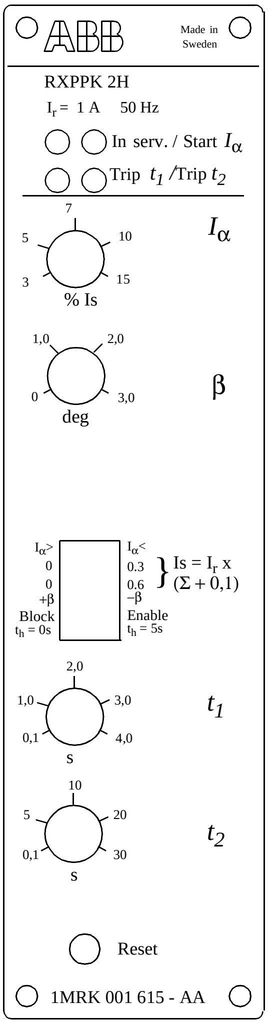


Fig. 7 Front layout

Rated voltage of the relay U_r = 120V.
Rated current of the relay I_r = 1A or 5A.
Rated frequency of the relay f_r = 50 Hz or 60 Hz.
Phase angle φ, positive if I lags U.

LED indicators:
In serv. (green): indicates relay in service.
Start I_α (yellow): indicates operation of I_α.
Trip t_1 (red): indicates operation after the set t_1 time delay.
Trip t_2 (red): indicates operation after the set t_2 time delay.

I_α reverse / low-forward characteristic:
Potentiometer (P1) for setting of the operate value for the function
I_α>: Operates when I x cos(φ–β–180°) ≥ set I_α.
I_α<: Operates when I x cos(φ–β) ≤ set I_α.

Potentiometer (P2) for setting of the compensation angle β.

6-pole programming switch (S1) for setting of the function characteristics, the scale-constant I_s, the polarity of the compensation angle β, the operation characteristic of the binary input function and the hold-time delay t_h for Trip t_2.

Potentiometer (P3) for setting of the definite time delay t_1.

Potentiometer (P4) for setting of the definite time delay t_2.

Reset push-button

4.1 Connection

The RXPPK 2H relay requires a dc-dc converter type RXTUG for auxiliary supply ±24 V. Connection of voltage RL shall be made only when the binary input is used.

The relay is delivered with a short-circuiting connector RTXK for mounting on the rear of the terminal base. This connector will automatically short-circuit the current input when the relay is removed from its terminal base.

NOTE! The auxiliary voltage supply should be interrupted or the output circuits should be blocked to avoid the risk of unwanted alarm or tripping, before the relay is plugged into or withdrawn from its terminal base.

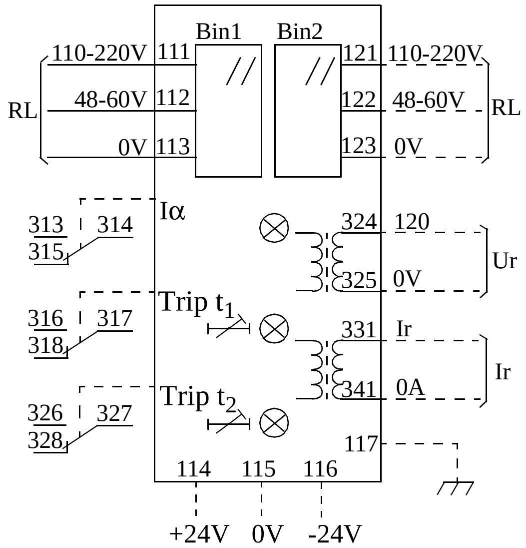


Fig. 8 Terminal diagram RXPPK 2H

4.2 Settings

All settings can be changed while the relay is in normal service.

1. Setting of the reverse / low-forward current characteristics.
The reverse current characteristic, operates when
I x $\cos(\varphi-\beta-180°) \geq$ set I_α, is set with switch S1:1 at I_α>.
The low forward current characteristic, operates when
I x $\cos(\varphi-\beta) \leq$ set I_α, is set with switch S1:1 at I_α<.

2. Setting of the scale-constant I_s.
I_s is set with the programming switches S1:2 and S1:3. Available settings are 0,1, 0,4, 0,7 and 1,0 x rated current I_r.

3. Setting of the operate value for the reverse / low-forward current stage I_α.
The operate value I_α is set with potentiometer P1 in percent of I_s.

4. The time delay t_1.
The time delay t_1 is set with potentiometer P3 within the range of 0,1 to 4,0 seconds.

5. The time delay t_2.
The time delay t_2 is set with potentiometer P4 within the range of 0,1 to 30 seconds.

6. Setting of the system inaccurrancy compensation angle β.
The compensation angle is set with P2 within the range of 0° to 3°.
The polarity of the angle β is set with S1:4

7. Setting of the remote block / enable function.
The remote block / enable function of the Trip t_1 stage is set with S1:5.
When the function is set to Block, active signal on RL1 (Bin 1) will block the Trip t_1 function. When the function is set to Enable, active signal on RL1 will enable the Trip t_1 function.

8. Setting of the hold-time delay t_h.
The hold-time delay seal-in the input for the Trip t_2 function and is set with S1:6 to 0 or 5 seconds. When the hold-time is set to 5 seconds the Trip t_2 function will not reset until the start I_α stage has been reset for more than 5 seconds. This will ensure operation when power-swing occurs.

NOTE! The Trip t_2 function should be set to a longer time than t_h, to prevent unwanted operation.

9. The remote resetting of the LED indicators.
The second binary input (Bin 2) is used for remote reset of the Trip t_1 and Trip t_2 LED indicators. The function is activated when a voltage is applied to input RL2.

4.3 Indication

There are four LED indicators. The trip indicators seal-in and are reset manually by the Reset push-button, while the start indicator resets automatically when the relay resets.

When the Reset push-button is depressed during normal operating conditions, all LEDs except In serv. will light up.

When connecting RXPPK 2H to the supply voltage, the relay performs a self test. The In serv. LED is alight, after performing the self test and when the relay is ready for operation. In case of a fault, the LEDs will start flashing.

4.4 Tripping and start outputs

The RXPPK 2H relay has one start and two tripping outputs. Each output is provided with one change-over contact. All outputs reset automatically when the measured value decreases below the resetting value of the relay.

4.5 ESD

The relay contains electronic circuits which can be damaged if exposed to static electricity. Always avoid to touch the circuit board when the relay cover is removed during the setting procedure.

5 Technical data

Current input

Rated voltage U_r	120 V
Rated current I_r	1A or 5A
Scale constant I_s for 1A variant 5A variant	 0,1, 0,4, 0,7 and 1,0 A 0,5, 2, 3,5 and 5A
Effective voltage range	(0,4 - 2,5) x U_r
Effective current range	(0,003 - 1,70) x I_r
Voltage block level	U < 0,4 x U_r
The function is blocked and the start is reset when the current is:	0,3% of I_r
Rated frequency f_r Operating frequency range	50 Hz or 60 Hz 45 - 66 Hz
Power consumption for: U = U_r = 100 V 1A variant I = I_r 5A variant I = I_r	 0,2 VA 100 mVA 150 mVA
Overload capacity voltage circuit: continuously during 10 s Overload capacity current circuit: 1A variant continuously during 1 s 5A variant continuously during 1 s	 250 V 300 V 4 A 100 A 20 A 350 A

Power functions

Function	Power functions I_α> / I_α<
Function characteristic selectable in the front between: I_α>: Reverse power function I_α<: Low forward power function	 I x cos(φ-β-α) ≥ set I_α> see Fig. 2 (α = 180°) I x cos(φ-β–α) ≤ set I_α<(α = 0°)
Setting range I_α	0,3 - 15% of I_r
Setting range β (adjustment for correction of system angle inaccuracy)	±3°
Consistency of set operate value	<5% for current <0,02 x I_r <2% for current >0,02 x I_r
Phase angle φ consistency	<0,5°
Angle φ between U and I	Positive if I lags U
Typical operate time I = 0 => 2 x set operate value	100 ms
Typical reset time I = 2 => 0 x set operate value	100 ms
Typical reset ratio	80%
Frequency dependence within frequency ±5% of rated frequency ±10% of rated frequency	 <0,8° <1,5°
Temperature dependence within range -5°C to +55°C	<0,5°
Binary input 1, selectable in the front between: Block Enable	 Active signal blocking Trip t_1 function Active signal enables Trip t_1 function

Time functions

Time function	Trip t_1	Trip t_2
Time delay	Definite time	
Setting range	0 - 4 s	0 - 30 s
Accuracy	1% and ±20 ms	
Reset delay, t_h (for function at power swing)	-	0 - 5 s

Auxiliary DC voltage supply

Auxiliary voltage EL for RXTUG 22H Auxiliary voltage for the relay	24 - 250 V DC, ±20% ±24 V (from RXTUG 22H)
Power consumption at RXTUG 22H input 24-250 V before operation after operation without RXTUG 22H ±24 V before operation after operation	 max. 5,5 W max. 6,5 W max. 3,0 W max. 4,0 W

Binary inputs

Binary input voltage RL	48-60 V and 110-220 V DC, -20% to +10%
Power consumption 48-60 V 110-220 V	 Max. 0,3 W / input Max. 1,5 W / input

Output relays

Contacts	3 change-over
Maximum system voltage	250 V AC / DC
Current carrying capacity continuous during 1 s	 5 A 15 A
Making capacity at inductive load with L/R >10 ms during 200 ms during 1 s	 30 A 10 A
Breaking capacity AC, max. 250 V, cos φ > 0,4 DC, with L/R < 40 ms 48 V 110 V 220 V 250 V	 8 A 1 A 0,4 A 0,2 A 0,15 A

Electromagnetic compatibility (EMC), Immunity tests

All tests are performed together with the DC/DC-converter, RXTUG 22H

Test	**Severity**	**Standard**
Surge	1 and 2 kV, normal service 2 and 4 kV, withstand test	IEC 61000-4-5, class 3 IEC 61000-4-5, class 4
AC injection	500 V, AC	SS 436 15 03, PL 4
Power frequency magnetic field	1000 A/m	IEC 61000-4-8
1 MHz burst	2,5 kV	IEC 60255-22-1, class 3
Spark	4-8 kV	SS 436 15 03, PL 4
Fast transient	4 kV	IEC 60255-22-4, class 4
Electrostatic discharge In normal service with cover on	 8 kV (contact) 15 kV (air) 8 kV, indirect application	 IEC 60255-22-2, class 4 IEC 60255-22-2, class 4 IEC 61000-4-2, class 4
Radiated electromagnetic field	10 V/m, 80-1000 MHz	IEC 61000-4-3, Level 3
Radiated pulse electromagnetic field test	10 V/m, 900 MHz	ENV 50204
Conducted electromagnetic	10 V, 0,15-80 MHz	IEC 61000-4-6, Level 3
Interruptions in auxiliary voltage 24 V DC, no resetting for interruptions 110 V DC, no resetting for interruptions 250 V DC, no resetting for interruptions	2 - 200 ms < 20 ms < 50 ms < 250 ms	IEC 60255-11

Electromagnetic compatibility (EMC), emission tests

Test	**Severity**	**Standard**
Conducted	0,15-30 MHz, class A	EN 50081- 2
Radiated	30-1000 MHz, class A	EN 50081- 2

Insulation tests

Test	**Severity**	**Standard**
Dielectric Current circuit to circuit and current circuit to earth Circuit to circuit and circuit to earth Over open contact	 2,5 kV AC, 1 min 2,0 kV AC, 1 min 1,0 kV AC, 1 min	 IEC 60255-5
Impulse voltage	5 kV, 1,2/50 μs, 0,5 J	IEC 60255-5
Insulation resistance	> 100 MΩ at 500 V DC	IEC 60255-5

Mechanical tests

Test	**Severity**		**Standard**
Vibration	Response: Endurance:	2,0 g, 10-150-10 Hz 2,0 g, 10-150-10 Hz, 20 sweeps	IEC 60255-21-1, class 2
Shock	Response: Withstand:	5 g, 11 ms, 3 pulses 15 g, 11 ms, 3 pulses	IEC 60255-21-2, class 1
Bump	Withstand:	10 g, 16 ms, 1000 pulses	IEC 60255-21-2, class 1
Seismic	X axis: Y axis: Z axis:	3,0 g, 1-35-1 Hz 3,0 g, 1-35-1 Hz 2,0 g, 1-35-1 Hz	IEC 60255-21-3, class 2, extended (Method A)

Temperature range

Storage	-20°C to +70°C
Permitted ambient temperature	-5°C to +55°C

Weight and dimensions

Equipment	**Weight**	**Height**	**Width**
RXPPK 2H without RXTUG 22H	0,7 kg	4U	6C

6 Receiving, Handling and Storage

6.1 Receiving and Handling

Remove the protection package from the transport case and make a visual inspection for transport damages. Check that all screws are firmly tightened and all relay elements are securely fastened.

Check that all units are included in accordance with the apparatus list.

Normal ESD (Electrostatic Discharge) precautions for microprocessor relays should be observed when handling the relays.

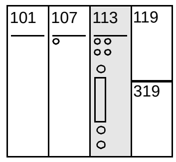
6.2 Storage

If the protection package is to be stored before installation, this must be done in a dry and dust-free place, preferably in the original transport case.

7 Installation, Testing and Commissioning

7.1 Installation

The relays and the RXTUG 22H DC-DC converter are plugged into COMBIFLEX® terminal bases type RX 4 or RX 2H. The terminal bases and the RTXP test switch, when included, are fixed on apparatus bars to make up the protection assembly.



101 RTXP 18
107 RXTUG 22H
113 RXPPK 2H
119 RXME 18
319 RXME 18

Fig. 9 RAPPK reverse power protection, acc. to Circuit diagram 1MRK 001 058-EA

The protection assembly can be mounted in the following ways:

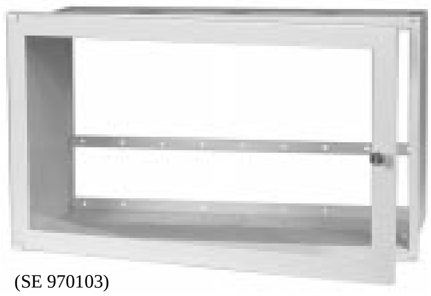
- on apparatus bars
- in a 19” equipment frame
- in RHGX case
- in RHGS case

The height and width of the protection assembly are given in the circuit diagram with height (U) and width (C) modules, where U = 44,45 mm and C = 7 mm. The depth of the protection assembly, including space for the connection wires, is approximately 200 mm.

All internal connections are made and the protection assembly is tested before delivery from factory.

Equipment frames and relay cases.
Detailed information on the COMBIFLEX® connection and installation components is given in Catalogue 1MRK 513 003-BEN. Information on the relay mounting system is given in Catalogue 1MRK 514 001-BEN.

RHGS 30



(SE 970103)

Fig. 10 RHGS case

RHGS cases for 19” cubicle mounting or surface mounting
This type of case can be used for all common ways of mounting. The RHGS cases are available in three different sizes, which can be combined with mounting accessories to get maximum flexibility. The cases can also be combined together with the protections in the 500 range.

RHGX 8

(SE 81702)

Fig. 11 RHGX case

RHGX cases for flush- or semi-flush panel mounting
The RHGX cases are available in five sizes. The case, a metal box open at the back, has a flange (with a rubber sealing strip) at the front which acts as a stop when the case is inserted into a front panel opening. At the front of the case there is a door with a window and a rubber seal.

Size: 4U 19”

(SE 96399)

Fig. 12 19” equipment frame

19” equipment frames
These types of equipment frames are used for cubicle mounting or panel mounting of plug-in units in the COMBIFLEX® range. The frames are available in 3 sizes:

4U (17” x 19”)

8U (14” x 19”)

12U (21” x 19”)

for mounting 20, 40 and 60 module seats respectively.

Connections

The external connections (dotted lines on the terminal and circuit diagrams) are made with leads with 20 A COMBIFLEX® sockets to the RTXP 18 test switch and with 10 A sockets to the relay terminal bases.

Each unit in the protection assembly has a unique item designation. The item designations are based on a coordinate system of U and C modules, where the first figure stands for the U module position starting from the top and the next two figures stand for the C module position, starting from the left-hand side - seen from the front side of the protection assembly. The RTXP test switch in Fig. 13 has item designation 101, where the first figure stands for the U module position and the next two figures stand for the C module designation.

The terminal designations include the item designation number of the unit followed by the terminal number marked on the rear of the terminal socket.

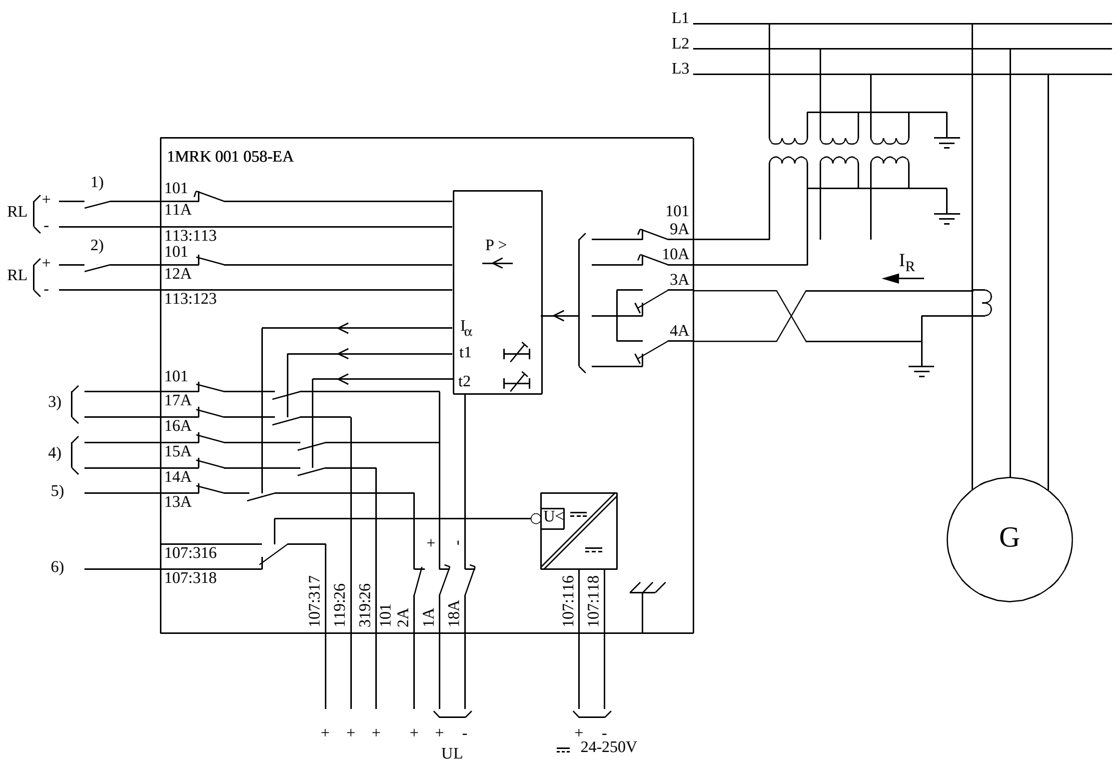


Fig. 13 Terminal diagram 1MRK 001 058-EAA

For plug-in units size 2H an additional figure 1 or 3 defines if the terminal is in the upper resp. lower part of the assembly. Compare terminal designations 107:118 and 107:318 in Fig. 14.

Fig. 14 shows the rear of protection assembly RAPPK, Order No. 1MRK 001 057-EA. The position of the terminals, which are used for external connections according to connection diagram 1MRK 001 058-EAA, is shown.

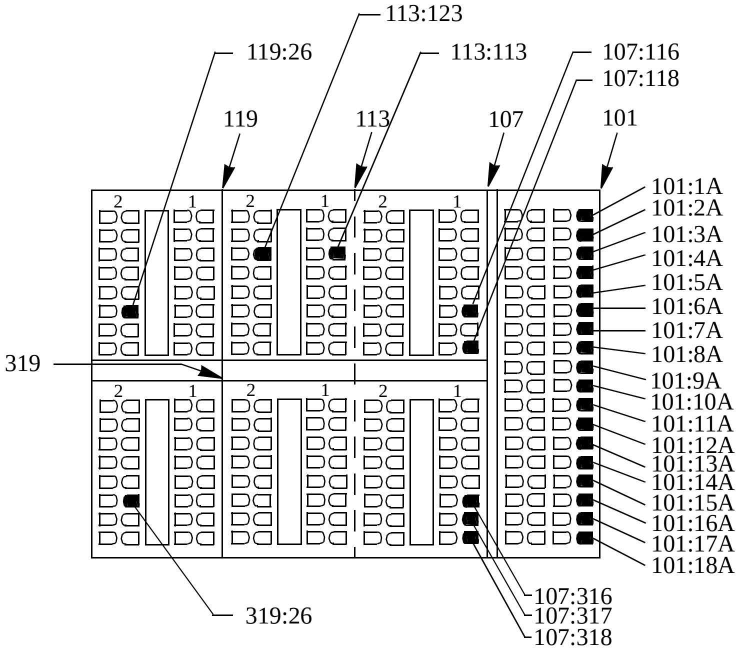


Fig. 14 Location of the terminals shown on diagram 1MRK 001 058-EAA

7.2 Testing

Secondary injection testing

The standard relay protection (Order No's 1MRK 001 057-EA) are provided with the COMBITEST test switch type RTXP 18.

When the test-plug handle RTXP 18 is inserted in the test switch, preparations for testing are automatically carried out in the proper sequence, i.e. blocking of tripping circuits, short-circuiting of CTs, opening of VT circuits and making relay terminals accessible for testing.

When the test handle is in the intermediate position, only the tripping circuits are opened. When the test handle is fully inserted, the relay is completely disconnected from the instrument transformers and ready for secondary injection testing.

Relays which are not provided with test switch have to be tested in the proper way from external circuit terminals.

Suitable test equipment:

- Test set for injection of current and voltage
- RTXH 18 test plug with test leads

Fig. 15 shows as an example the connection of test set for secondary testing of the 1-phase reverse / low-forward power protection RAPPK, Connection Diagram 1MRK 001 058-EAA. When testing, even the actual circuit diagram of the protection, which shows the internal connections, should be available.

When testing protections with directional current relays RXPPK 2H, a voltage more than 40 V should be applied to each individual phase or RXPPK relay when testing the reverse power function. The phase angle is positive when I lags U.

1. Connections: Insert the test-plug into the test switch and connect the test set according to Fig. 15 to test the relay functions.

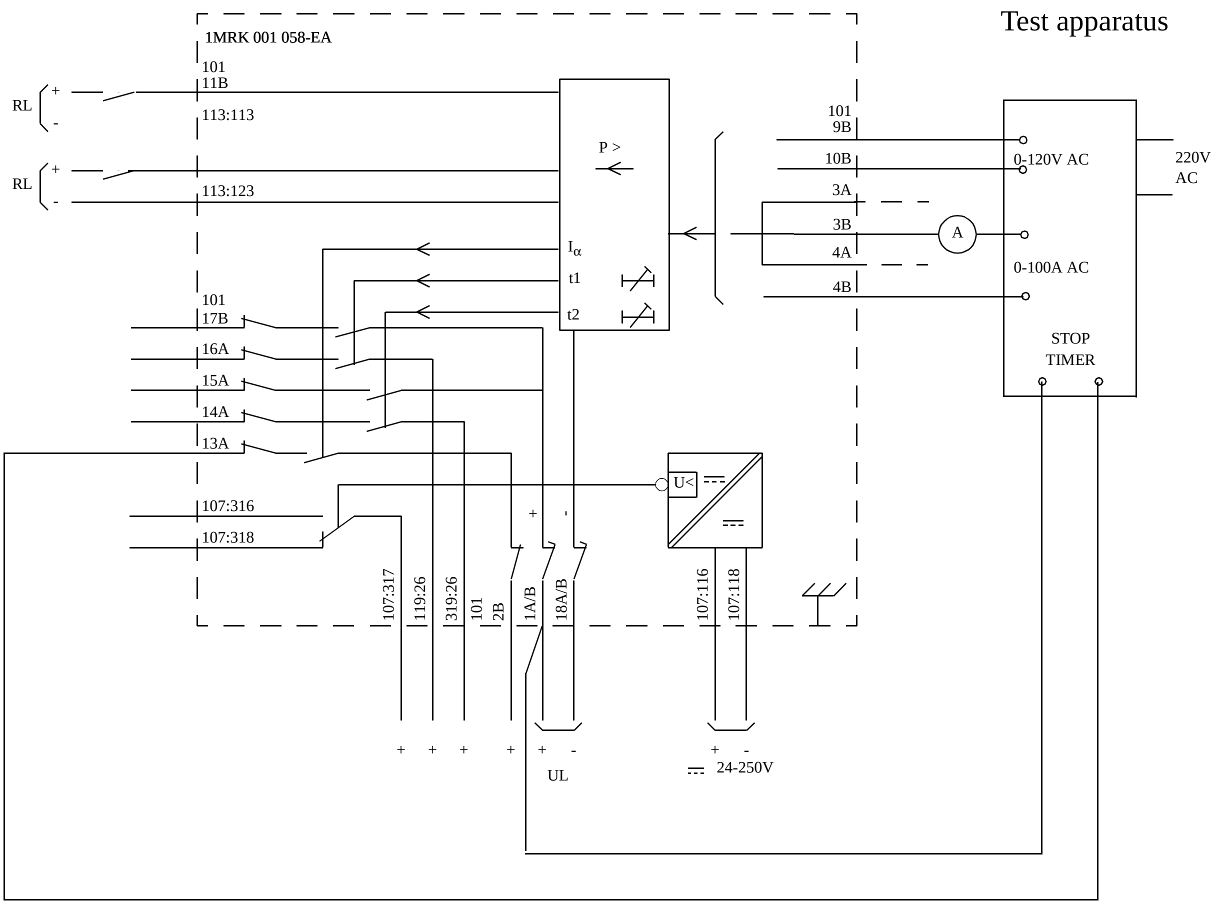


Fig. 15 Connection of test apparatus, with test handle RTXH 18 inserted.

2. Settings: Make the appropriate settings of relay functions, operate current, time delays and the function of the digital input. Guide for the setting of the switches and potentiometers on the front of the relays is given in *Section 4*, Setting and connection.

Connect auxiliary voltage to test terminal 11 to activate the digital input if this is required for the relay function.

3. Test of the directional current function:

3.1 Test of the I_α>: Set the I_α stage to operate at I_α>. Energize the relay with current and voltage with phase angle at 180°. Increase the current until the start relay (I_α) operates (output voltage on test terminal 13). Check the reset value. Apply 0,4 x I_r on the current input and U_r on the voltage input. Increase the phase angle, from 90°, until the start relay (I_α) operates. The set current I_α shall be equal to I x cos(φ -180° - $\beta \pm$ 0,5°).

3.2 Test of the I_α<: Set the I_α stage to operate at I_α<. Energize the relay with current and voltage with phase angle at 0°. Decrease the current until the start relay (I_α) operates (note the low current block when I ≤ 0,25%). Check the reset value. Apply 0,4 x I_r on the current input and U_r on the voltage input. Increase the phase angle until the start relay (I_α) operates. The set current I_α shall be equal to I x cos(φ - $\beta \pm$ 0,5°).

Check also that the LED indicator for start is activated when I_α operates. Check the resetting values.

4. Testing the time delays: Move the timer stop wire to the test terminal 17 (t_1). Energize the relay with U_r and with I_r with φ equal to 0° (I>). Change the phase angle to 180° and check the time delay and that the designated LED indicator is activated (“Trip t_1”). Repeat the procedure for test terminal 15 (“Trip t_2”). When the hold-time t_h is set to 5s the reset time for the t_2 stage will be 5 seconds.

Press the reset button and check that the LED indicators resets properly. Check also that the Binary input 2 resets the LED indicators.

5. Testing selected function: Set the I_α stage to operate at desired function. Check that the binary input operates properly according to *Section 4*, Setting and connection.

7.3 Commissioning

The commissioning work includes a check of all external circuits connected to the protection and a check of the current ratio for the current transformers.

For generators where only a small active power is required to run the machine in case of loss of power input to the turbine, a real functional test with loss of power input to the turbine should be performed. If possible, the operation of the reverse power function should be checked for the combination of no input to the turbine and a delivered reactive current of 30 to 40% of rated generator current. Observe the time limitations to avoid risk of damage to the turbine.

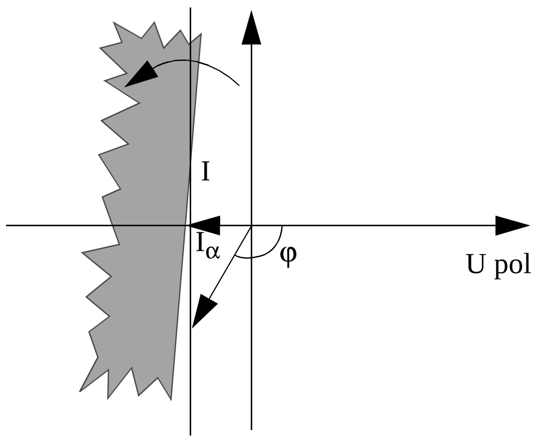


Fig. 16 Compensation of angular error, reactive output (I lags U), by decreasing β.

If the relay resets when the reactive current increases, the angular error of the system should be compensated by decreasing β, according to Fig. 16. Do not over compensate, since this reduces the operating range of the function in case of negative reactive Var output power at loss of the input to the turbine.

When used as low forward power relay, the time delay set on RXPPK 2H must be sufficiently long to allow the generator control equipment to increase the load current after closure of the breaker to a value higher than the set relay operate current before the time delay expires.

The DC circuits and tripping circuits should be checked, including operation of the circuit breaker(s).

8 Maintenance

Under normal conditions, the reverse power protection relays requires no special maintenance. The covers should be mounted correctly in position and the holes for the resetting knobs sealed with plastic plugs.

In exceptional cases, burned contacts on the output relays can be dressed with a diamond file.

Under normal operating conditions and when the surrounding atmosphere is of non-corrosive nature, it is recommended that the relays be routine tested every four to five years.

9 Circuit and terminal diagrams

The table below shows the different variants of the reverse power protection type RAPPK**.**

Type	Test-switch	DC-DC con-verter	Tripping relays	Ordering No. 1MRK 001	Circuit Diagram 1MRK 001	Terminal diagram 1MRK 001	Diagram
RAPPK 1	x			057-BA	058-BA	058-BAA	On request
RAPPK 1		x		057-CA	058-CA	058-CAA	On request
RAPPK 1	x	x		057-DA	058-DA	058-DAA	On request
RAPPK 1	x	x	x	057-EA	058-EA	058-EAA	Fig. 17, 18

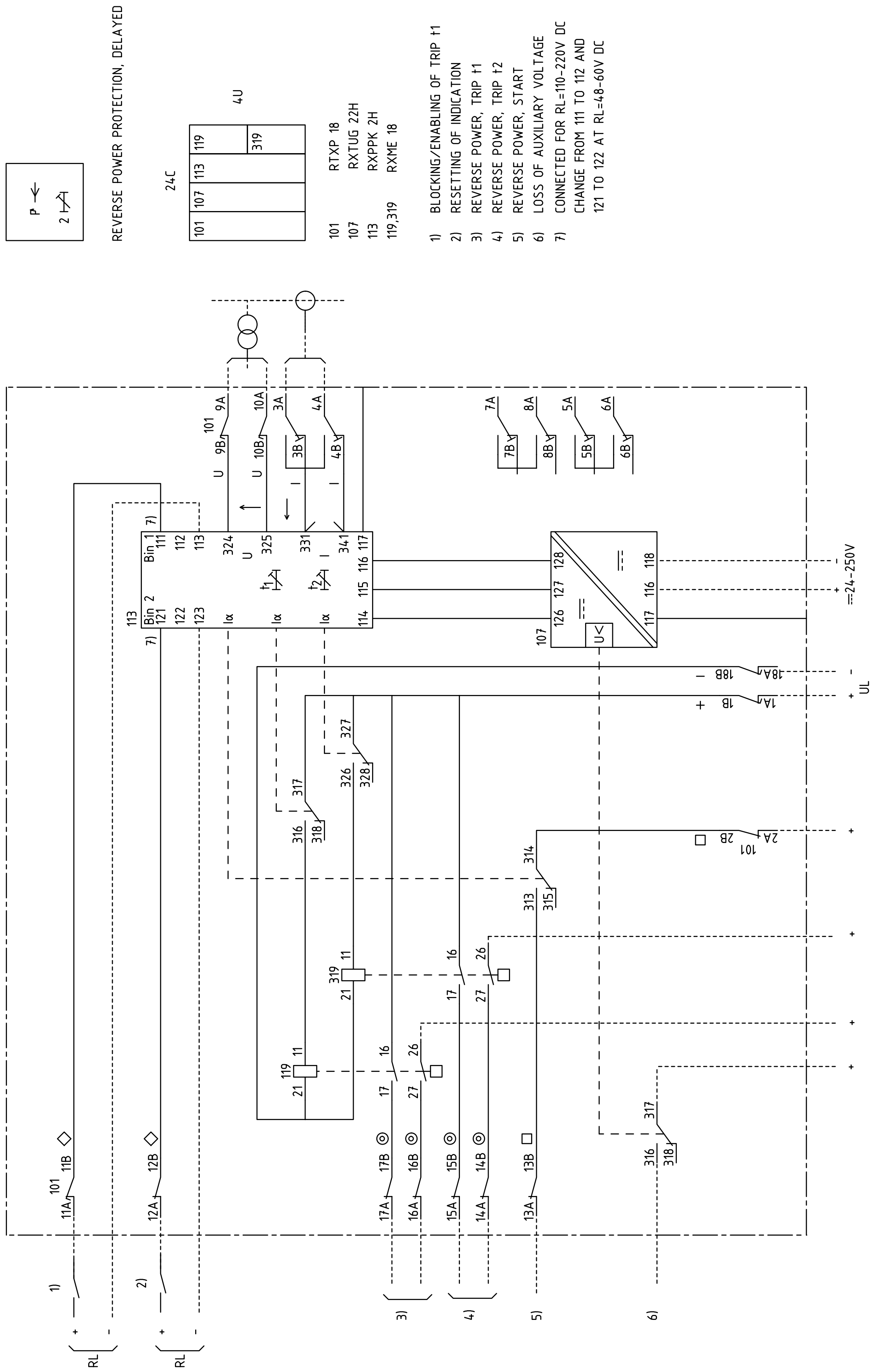


Fig. 17 Circuit diagram 1MRK 001 058-EA

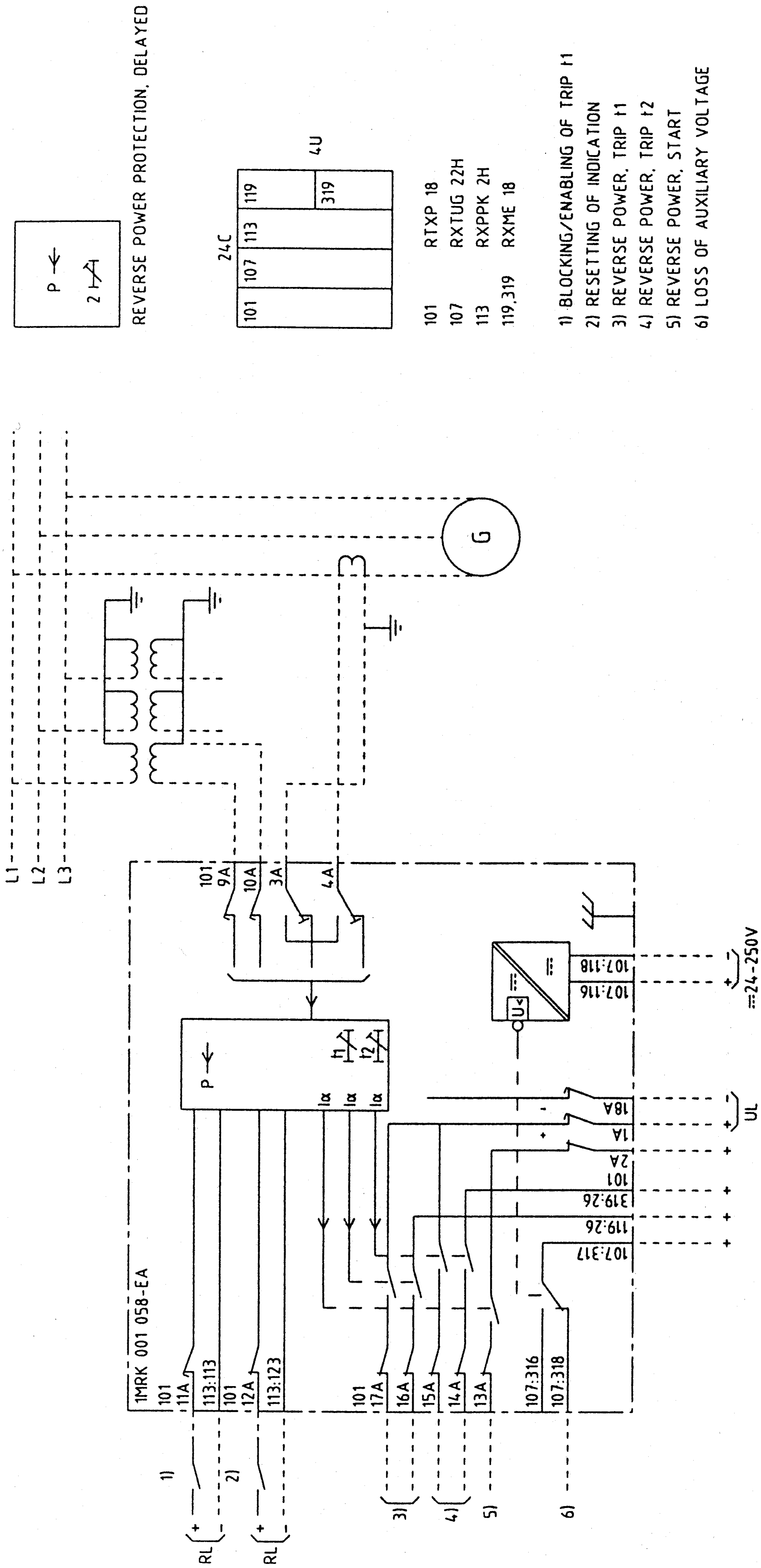


Fig. 18 Terminal diagram 1MRK 001 058-EAA

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