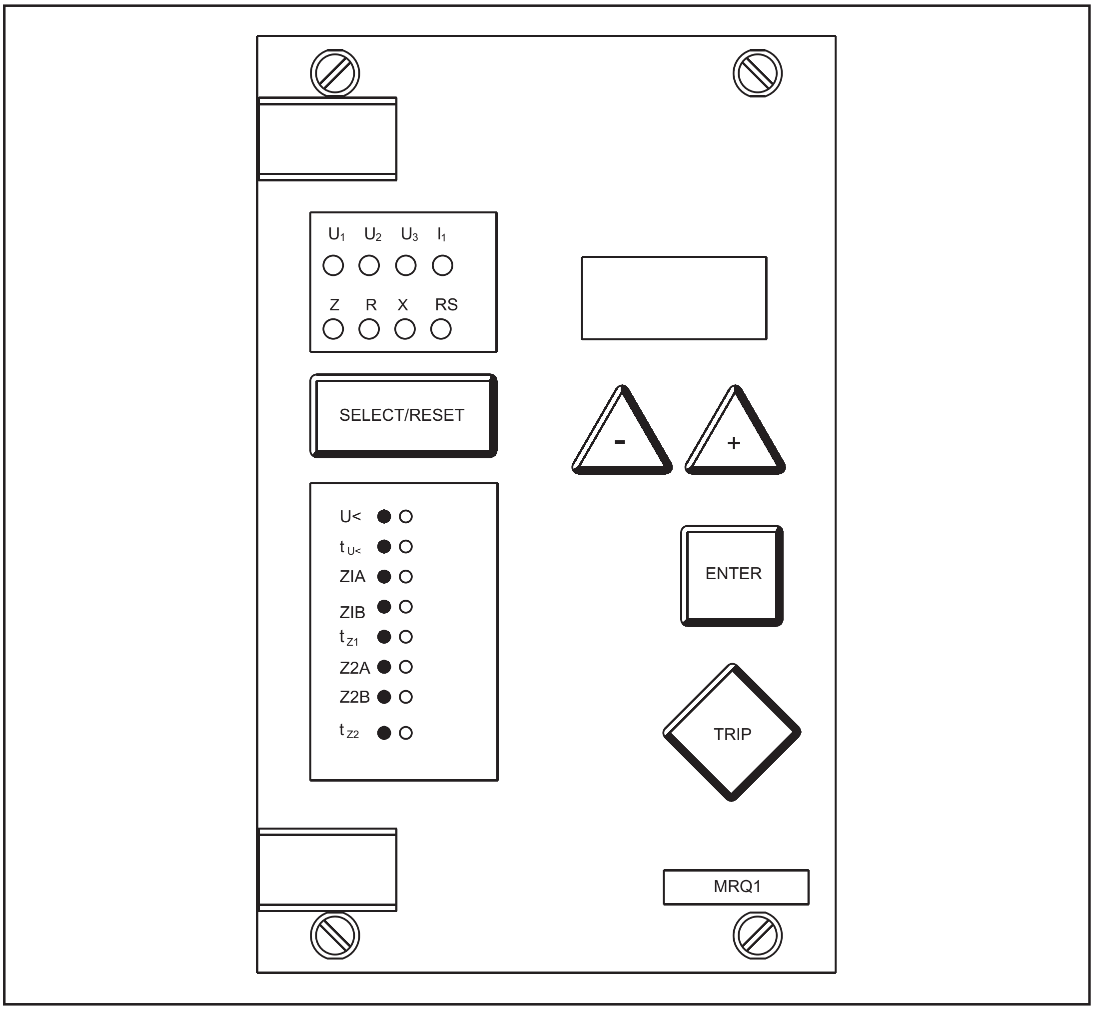
High-Tech Range

MRQ1- Field failure relay



Controls & Switchgear Group

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1. Introduction and application

The field failure relay ***MRQ1*** protects synchronous generators against operation outside the stable operation area due to loss of excitation. When partial or complete loss of excitation occurs on a synchronous machine, reactive power flows from the system into the machine and the apparent impedance as viewed from the machine terminals goes into the negative X region in the R-X diagram.

The ***MRQ1*** detects the low or under impedance condition and trips the generator circuit breaker, thus preventing damage due to out of step operation and system instability.

The under impedance measurement provides two elements with separate impedance and time settings. Therefore setting according to the dynamic and steady state stability curve is possible.

MRQ1 calculates the momentary impedance value from the generator current and voltage and compares this value with the two settings of the under impedance elements.

Under impedance circle no. 1 reproduces the steady state stability area of the generator. Element no. 1 may be used for alarm purposes and corrective measures like boost excitation.

Element no. 2 reproduces the dynamic stability area of the generator. The time delay is set to a lower value. It provides fast clearing on complete loss of field and backs up element no. 1. Element no. 2 should trip the generator circuit breaker quickly.

The following factors determine the setting of the two elements: Stability diagram of the generator, excitation system of the generator and the system configuration.

2. Features and characteristics

- Digital protection relay with powerful microcontroller
- Three phase voltage supervision in delta-connection
- Current measurement in phase L1
- Alphanumeric display for easy setting of the protection relay, reading of measured and calculated values and read out of the fault memory
- Digital filtering of the measured values by use of discrete Fourier analysis to suppress higher harmonics and d.c. components induced by faults or system operations
- Optimum adaptation to the stability characteristic of synchronous machines by two under impedance elements with separate set points and time delays
- Indication of the impedance measurement: absolute, real and imaginary value
- Under voltage blocking of the under impedance elements to prevent maloperation due to missing measuring voltage, e.g. fuse failure or near by short circuit of the generator
- Self adjusting sample frequency for precise operation between 40 Hz and 70 Hz
- External blocking and reset inputs
- Communication via serial interface RS485
- Five output relays:

  Trip relay: Underimpedance elements 1 and 2

  Alarm relay: Underimpedance element 1

  Alarm relay: Underimpedance element 2

  Trip relay: undervoltage

  Self supervision

3. Design

3.1 Connections

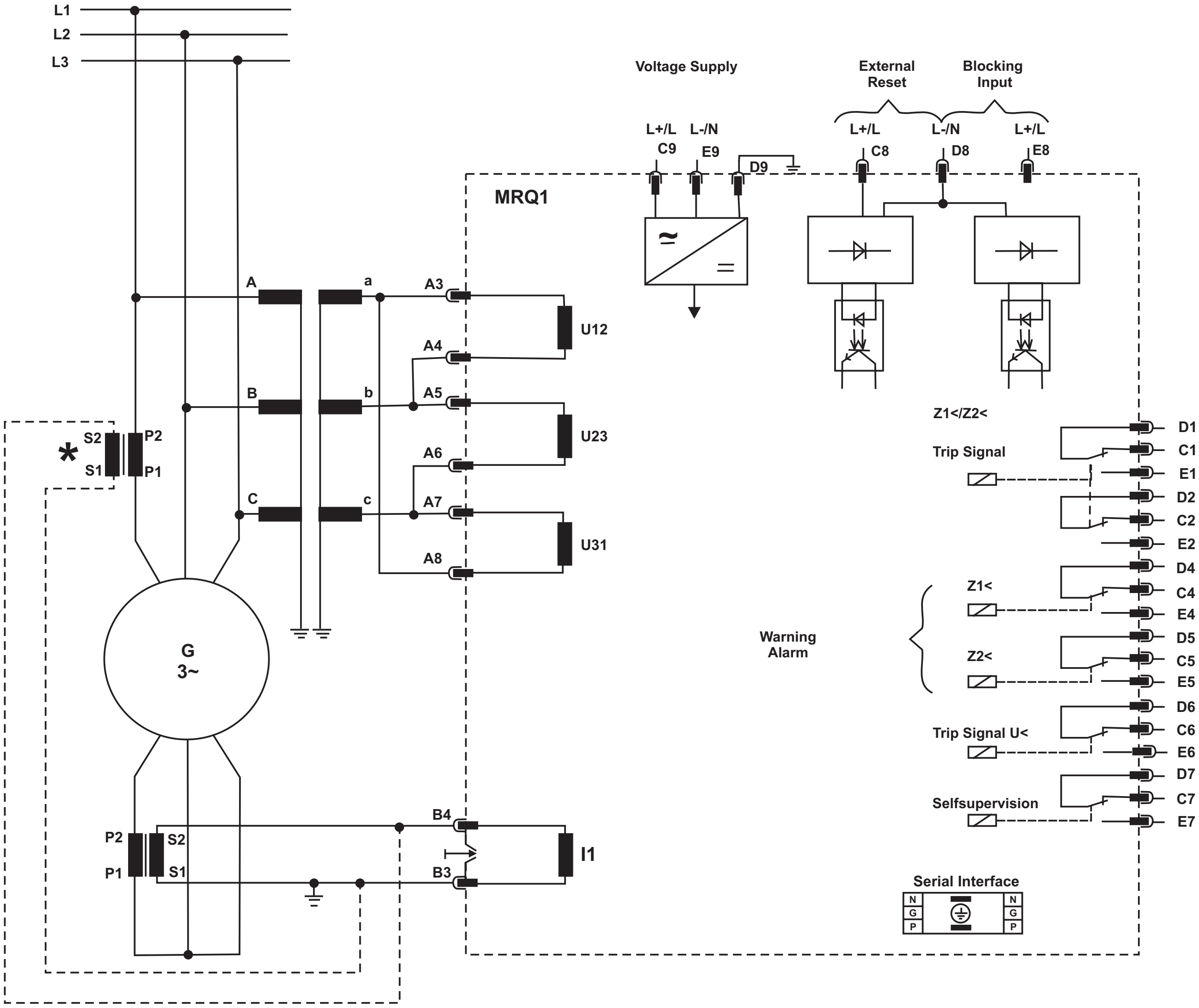


Fig. 3.1: Connection diagram

* Hint:

The current transformer in phase 1 can also be connected to the outgoing line of the generator.

3.1.1 Analog input circuits

The *MRQ1* receives the analog input signal of phase current L1 (B3-B4) and the line to line voltages U12 (A3/A4), U23 (A5/A6), U31 (A7/A8). The under voltage element measures all three line-to-line voltages, whereas the under impedance elements use voltage U23 and phase current L1 for the impedance calculation.

3.1.2 Blocking input

Connection of the auxiliary voltage to the blocking input D8/E8 inhibits all protective functions of the *MRQ1*. This may be used during start up of the generator.

3.1.3 External reset

Please refer to 5.5

3.1.4 Output relays

The *MRQ1* has five output relays with following assigned functions:

- Trip relay: underimpedance elements 1 and 2 (two change over contacts: C1, D1, E1; C2, D2, E2)
- Alarm relay: underimpedance element 1 (one change over contact, C4, D4, E4)
- Alarm relay: underimpedance element 2 (one change over contact, C5, D5, E5)
- Trip relay: undervoltage U< (one change over contact, C6, D6, E6)
- Self-supervision alarm relay (one change over contact, C7, D7, E7)

All trip and alarm relays are working current relays, the relay for self supervision is an idle current relay.

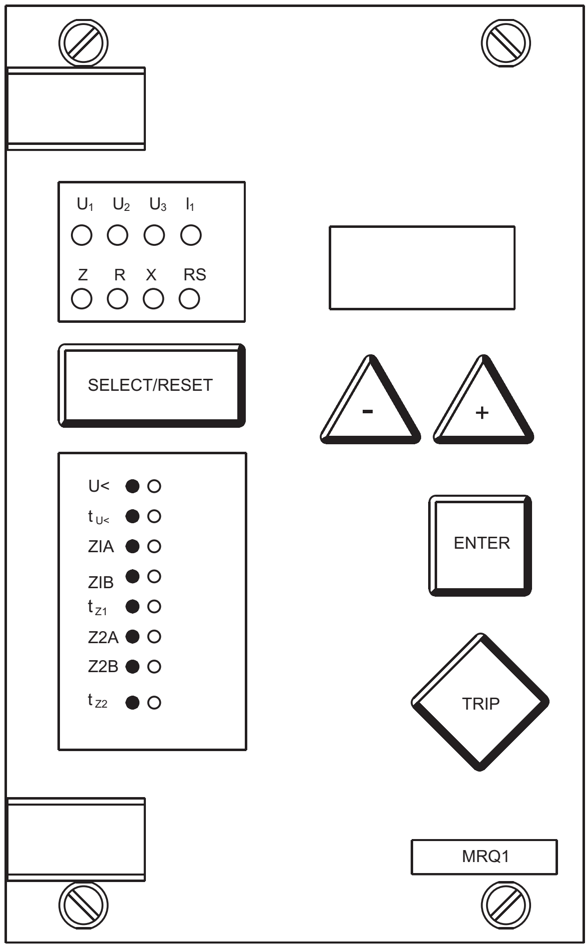


Fig. 3.2: Front plate MRQ1

The LED marked with letters RS lights up during setting of the slave address of the device for serial data communication.

3.2 Display

Function	Display shows	Pressed pushbutton	Corresponding LED
Normal operation	CSPC		
Measured operating values line-to-line voltage phase current impedance	Actual measured voltage U_{12}, U_{23}, U_{31} current L_1 impedance Z, R, X	<SELECT/RESET> one time for each value Z, R, X	U_1, U_2, U_3, I_1
Setting values: undervoltage	setting value in volt	<SELECT/RESET> <+> <->	U<
trip delay undervoltage	setting value in seconds	<SELECT/RESET> <+> <->	$t_{U<}$
Impedance setting Z_1A	setting value in %	<SELECT/RESET> <+> <->	Z_1A
Impedance setting Z_1B	setting value in %	<SELECT/RESET> <+> <->	Z_1B
trip delay impedance Z_1	setting value in seconds	<SELECT/RESET> <+> <->	t_{Z1}
Impedance setting Z_2A	setting value in %	<SELECT/RESET> <+> <->	Z_2A
Impedance setting Z_2B	setting value in %	<SELECT/RESET> <+> <->	Z_2B
trip delay impedance Z_2	setting value in seconds	<SELECT/RESET> <+> <->	t_{Z2}
Function blocking	EXIT	<+> until max. setting value	LED of blocked parameter
Slave address of serial interface	1-32	<SELECT/RESET><+><->	RS
Recorded fault data line-to-line voltages, current, impedance	Measured values at the instant of tripping	<SELECT/RESET> one time for each value	U_1, U_2, U_3, I_1, Z, R, X
measuring range overflow	max	<SELECT/RESET>	Z, R, X
blocked impedance measurement	?	<SELECT/RESET> one time for each value	Z, R, X
Save parameter?	SAV?	<ENTER>	
Save parameters !	SAV!	<ENTER> for about 3 s	
Software version	First parrt (e.g. D16-) Sec. part (e.g.5.01)	<TRIP> one time for each part	
Manual trip	TRI?	<TRIP> three times	
Inquire password	PSW?	<SELECT/RESET>/<+>/ <->/<ENTER>	
Relay tripped	TRIP	<TRIP> or after fault tripping	U_1, U_2, U_3, Z, U<, Z_1A, Z_1B, Z_2A, Z_2B
Secret password input	XXXX	<SELECT/RESET>/<+>/ <->/<ENTER>	
System reset	CSPC	<SELECT/RESET> for about 3 s	

Table 3.1: Possible indication messages on the display

3.3 LEDs

LED-designation	Colour	Mode	Meaning
U_1, U_2, U_3	green	steady	Display of the actual voltage measuring values
U_1, U_2, U_3	red	steady	U< tripped
U_1, U_2, U_3	red	flashing	U< picked up
I_1	green	steady	Display of the actual current measuring value
Z	green	steady	Display of the actual imped-ance measuring absolute value
Z	red	steady	Z< tripped
Z	red	flashing	Z< picked up
R, X	yellow	steady	Display of the actual imped-ance measuring real and imaginary value
RS	yellow	steady	Slave-address setting
U<	green	steady	U<-setting
U<	red	steady	U< tripped
U<	red	flashing	U< picked up
$t_{U<}$	green	steady	$t_{U<}$ -setting
Z_1A, Z_1B	green	steady	Z_1<-setting
Z_1A, Z_1B	red	steady	Z_1< tripped
Z_1A, Z_1B	red	flashing	Z_1< picked up
t_{Z1}	green	steady	t_{Z1} -setting
Z_2A, Z_2B	green	steady	Z_2<-setting
Z_2A, Z_2B	red	steady	Z_2< tripped
Z_2A, Z_2B	red	flashing	Z_2< picked up
t_{Z2}	green	steady	t_{Z2} -setting

Table 3.2: Possible LED indications

4. Working principle

4.1 Analog circuit

The secondary current and voltage from the main current and voltage transformers are converted into proportional voltage signals via the input transformers. High frequency disturbances are suppressed by analog RC-filters.

The analog voltage signals are fed via sample and hold circuits to the A/D-converter of the microprocessor and transformed to digital signals. The analog signals are sampled with a self adjusting sample rate of 16 times of the system frequency. The precision of the impedance measurement is, therefore, independent of variations of the system frequency in a range of 40 Hz to 70 Hz.

4.2 Digital circuit

The essential part of the ***MRQ1*** is a powerful microcontroller. All of the operations, from the analog to digital conversion up to the relay´s trip decision, are carried out by the microcontroller digitally. The relay program is located in an EPROM (Read-only-memory). With this program the microcontroller processes the analog signals and calculates the fundamental wave form of voltages and current. The algorithm uses the „Fourier-notch“ filter, excluding all frequencies except the fundamental.

4.3 Underimpedance measurement

The underimpedance elements evaluate the phase current L1 and the line to line voltage U23. The DFFT algorithm calculates the real- and imaginary values of voltage and current:

Re[]: real part

Im[]: imaginary part

$\underline{U}_{23} = \mathrm{Re}[\underline{U}_{23}] + j\ \mathrm{Im}\ [\underline{U}_{23}]$

$\underline{I}_{1} = \mathrm{Re}\ [\underline{I}_{1}] + j\ \mathrm{Im}\ [\underline{I}_{1}]$

The real and imaginary values of impedance are calculated as follows:

$$R^* = \frac{\mathrm{Re}[\underline{U}_{23}]\ \mathrm{Re}[\underline{I}_{1}] + \mathrm{Im}[\underline{U}_{23}]\ .\mathrm{Im}[\underline{I}_{1}]}{[\mathrm{Re}[\underline{I}_{1}]]^2 + [\ \mathrm{Im}[\underline{I}_{1}]]^2}$$

$$X^* = \frac{\mathrm{Im}[\underline{U}_{23}]\ .\mathrm{Re}[\underline{I}_{1}] - \mathrm{Re}\ [\underline{U}_{23}]\ .\mathrm{Im}[\underline{I}_{1}]}{[\mathrm{Re}[\underline{I}_{1}]]^2 + [\ \mathrm{Im}[\underline{I}_{1}]]^2}$$

After an angle correction follows the actual impedance phasor:

$$\underline{Z} = R + j\ X = \underline{Z}^*\ .\ e^2 = j\ (R^* + j\ X^*)$$

whereby:

$R = -\ X^*$

$X = +\ R^*$

The tripping zones of the underimpedance elements form impedance circles with their centres on the X-axis. By adjustment of two parameters per circle the tripping zones are determined:

- Z_1A/Z_2A: Distance between the upper intersection points of the circle periphery with the X-axis and the R-axis (Offset). Z_1A and Z_2A can be set in the range from -300 % > to +300 %, which define the location of the circles on the X-axis. If Z_1A or Z_2A is set to be positive, the corresponding tripping zone stretches into the positive X-region. If Z_1A or Z_2A is set to be negative corresponding tripping zone is located only in the negative x-region.
- Z_1B/Z_2B: Diameters of the impedance circles, which define the size of the circles.

The tripping zones are the areas inside the periphery of the circles. With separate adjustment of two tripping zones the optimum adaptation to the generator dynamic and steady state stability characteristics can be achieved.

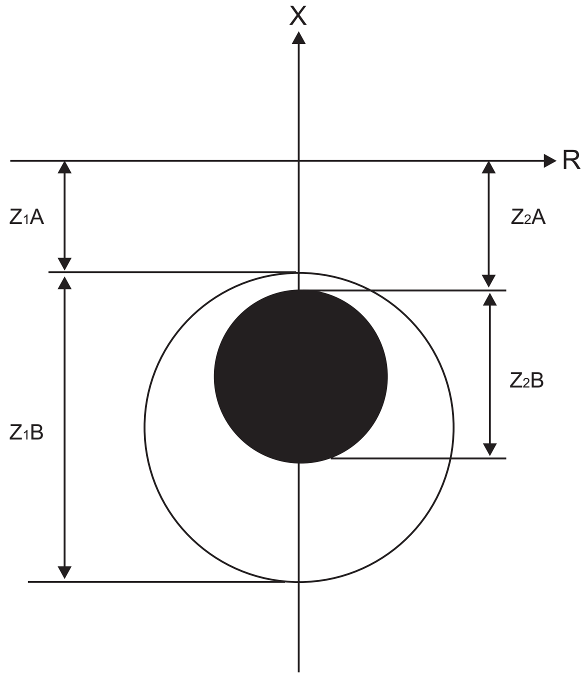


Fig.4.1: Tripping zones of the underimpedance elements

In case of missing measuring voltage, e.g. due to voltage transformer fuse failure or a near by short circuit of the generator, the detection of loss of excitation is not possible. This condition could lead to maloperation in case the trip zone includes the origin of the R-X-axis. That´s why the ***MRQ1*** automatically blocks the impedance calculation if the measuring voltage of U23 falls below 10% of Un.

4.4 Undervoltage measurement

The ***MRQ1*** provides a three phase undervoltage protection element. A collapse of the system voltage below a critical value, typically < 80 % Un, caused by a loss of excitation of the generator jeopardises the system stability seriously. Therefore the undervoltage element should trip the generator circuit breaker instantaneously (t < 0.25 s). The undervoltage element of ***MRQ1*** activates a separate output relay. The voltage setting ranges from 2 % Un to 110 % Un. The tripping time range covers 0.04 s to 50 s.

5. Operation and setting

5.1 Adjustable parameter

The user has access to the parameters listed below:

U<	-	Set point of the undervoltage element
$t_{U<}$	-	Trip delay of the undervoltage element
Z_1A	-	Offset value of impedance circle no. 1
Z_1B	-	Diameter of impedance circle no. 1
t_{Z1}	-	Trip delay of impedance element no. 1
Z_2A	-	Offset value of impedance circle no. 2
Z_2B	-	Diameter of impedance circle no. 2
t_{Z2}	-	Trip delay time of impedance element no. 2
RS	-	Slave address for remote control

5.2 Setting procedure

For parameter setting a password has to be entered first.

5.2.1 Set point for the undervoltage element (U<)

During setting of the undervoltage set point U< the display shows the actual setting in Volts. The set point may be altered by use of the buttons <+> and <-> and stored with <ENTER>. The undervoltage element is blocked, if the parameter is set to „EXIT".

5.2.2 Trip delay time delay for the undervoltage element ($t_{U<}$)

During setting of the undervoltage trip delay tU< the display shows the actual setting in seconds. The trip delay may be altered by use of the buttons <+> and <-> and stored with <ENTER>. If this parameter is set to „EXIT", the undervoltage output relay is blocked (infinite tripping time). The measurement and display for the undervoltage element is still active.

5.2.3 Impedance characteristic 1 (Z_1A/Z_1B)

The two impedance tripping zones of the ***MRQ1*** form circles in the R-X diagram. The centre of the circles is located along the X-axis. Circle no. 1 is described by two parameters: Z_1A, the distance of the circle from the R-axis and Z_1B, the diameter of the circle (ref. 4.3).

The two parameters Z_1A and Z_1B are expressed as per cent value of the calculated "nominal impedance" Z_N of the individual ***MRQ1***-relay. Z_N is defined as follow:

$$Z_N = \frac{U_{N,MRQ}}{\sqrt{3}.1_{N,MRQ}}$$

During setting of the offset value Z_1A the display shows the per cent value. This value may be altered by use of the buttons <+> and <-> in the range from-300 % to + 300 % and stored with <ENTER>. With negative values the circle lies completely in the negative X region. Positive values shift the circle into the positive X-region. Zero means that the periphery of the circle touches the R-axis with the circle in the negative region.

The diameter of the circle Z_1B may be set in the range from 0 % to 600 %. If Z_1B is set to zero, this impedance element is blocked.

5.2.4 Trip delay for impedance characteristic 1 (t_{Z1})

During setting of tripping time t_{Z1} for impedance element no.1 the display shows the actual setting in seconds. The tripping time may be altered by use of the buttons <+> and <-> and stored with <ENTER>.

5.2.5 Impedance characteristic 2 Z_2A/Z_2B)

The setting of Z_2A and Z_{2B} is similar to the setting of Z_1A and Z_1B. Please refer to 5.2.3.

5.2.6 Trip delay for impedance characteristic 2 (t_{Z2})

During setting of tripping time t_{Z2} for impedance element no. 2 the display shows the actual setting in seconds. The tripping time may be altered by use of the buttons <+> and <-> and stored with <ENTER>.

5.2.7 Slave address for remote control

The slave address may be altered by use of the buttons <+> and <-> and stored with <ENTER>.

5.3 Determination of the setting value

5.3.1 Underimpedance protection

Calculation of the setting values for the impedance tripping zones:

The settings of the impedance tripping zones have to be determined by the generator reactances X_d,and X_d, the transformer reactance X_T and the grid impedance X_N.

Knowing the above listed parameters, the secondary percentage setting values may be calculated from:

$$x_{sec}(\%) = x_{prim}(p.u.).\ \frac{I_{N,MRQ} \cdot I_{N,CT,prim} \cdot U_{N,VT,sec} \cdot U_{N,Gen}}{I_{N,CT,sec} \cdot I_{N,Gen} \cdot U_{N,MRQ} \cdot U_{N,VT,prim}}$$

Definitions:

- $x_{sec}(\%)$ - calculated secondary impedance setting of ***MRQ1*** (Z_1A, Z_1B, Z_2A or Z_2B) in percentage
- $x_{prim}(p.u.)$ - primary reactance of generator (Xd´ and X_d), transformer (X_T) and grid (X_N) in per unit
- $U_{N,Gen}$ - Generator nominal voltage in V
- $I_{N,Gen}$ - Generator nominal current in A
- $U_{N,VT,prim}$ - Primary nominal voltage of the voltage transformer in V
- $U_{N,VT,sec}$ - Secondary nominal voltage of the voltage transformer in V
- $I_{N,CT,prim}$ - Primary nominal current of the current transformer in A
- $I_{N,CT,sec}$ - Secondary nominal current of the current transformer in A
- $U_{N,MRQ}$ - Nominal voltage of the **MRQ1** in V (100V / 230V / 400V)
- $I_{N,MRQ}$ - Rated current of the **MRQ1** in A (1A/5A)

or:

$$x_{sec}(\%) = x_{prim}(p.u.)\ \frac{K_I \cdot U_{N,Gen} \cdot I_{N,MRQ}}{K_U \cdot I_{N,Gen} \cdot U_{N,MRQ}} .100(\%)$$

With the current and voltage transfer ratios:

K_I : for current

K_u : for voltage

$$K_1 = \frac{I_{N.CTprim}}{I_{N,C1.sec}} \quad \text{and } K_U = \frac{U_{N.VTprim}}{U_{N.VT.sec}}$$

Tripping time settings for the underimpedance elements:

The underimpedance protection element no.1 is usally adapted to the steady state stability characteristic of the generator. Generally, it takes at least 2 to 6 seconds to lose synchronism in case of partial loss of excitation. Hence the tripping time may be set from 0.5 s to 3 s.

The second underimpedance element provides fast clearing on loss of field and is adapted to the dynamic stability characteristic of the generator. This element should be used instantaneously or with short delay of 0.25 s to 0.5 s.

The diagrams below show examples for the relay setting:

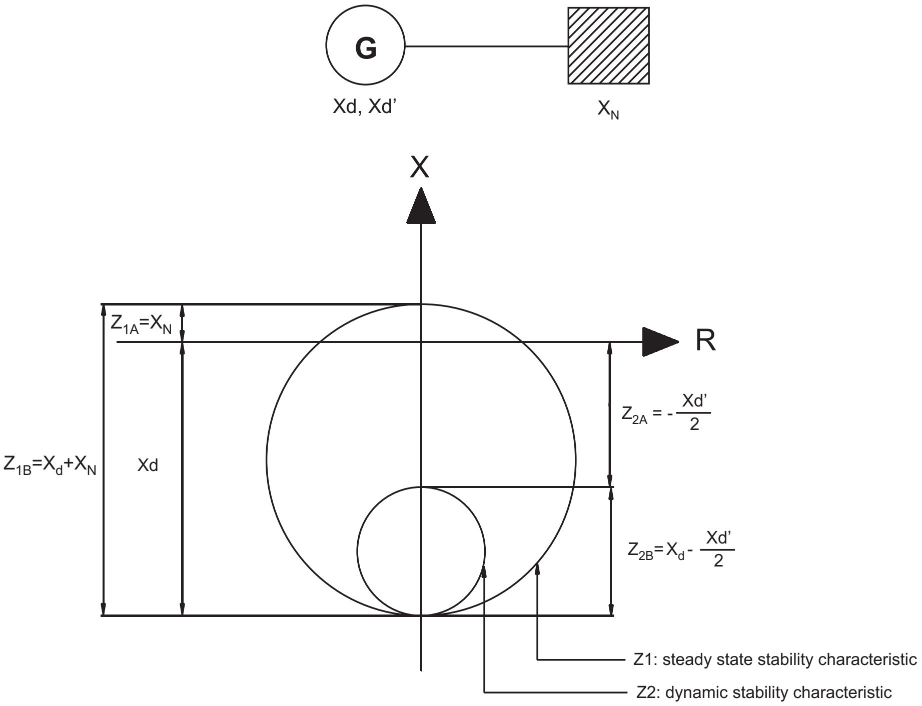


Fig. 5.1: Setting adapted to the steady state and dynamic stability characteristic

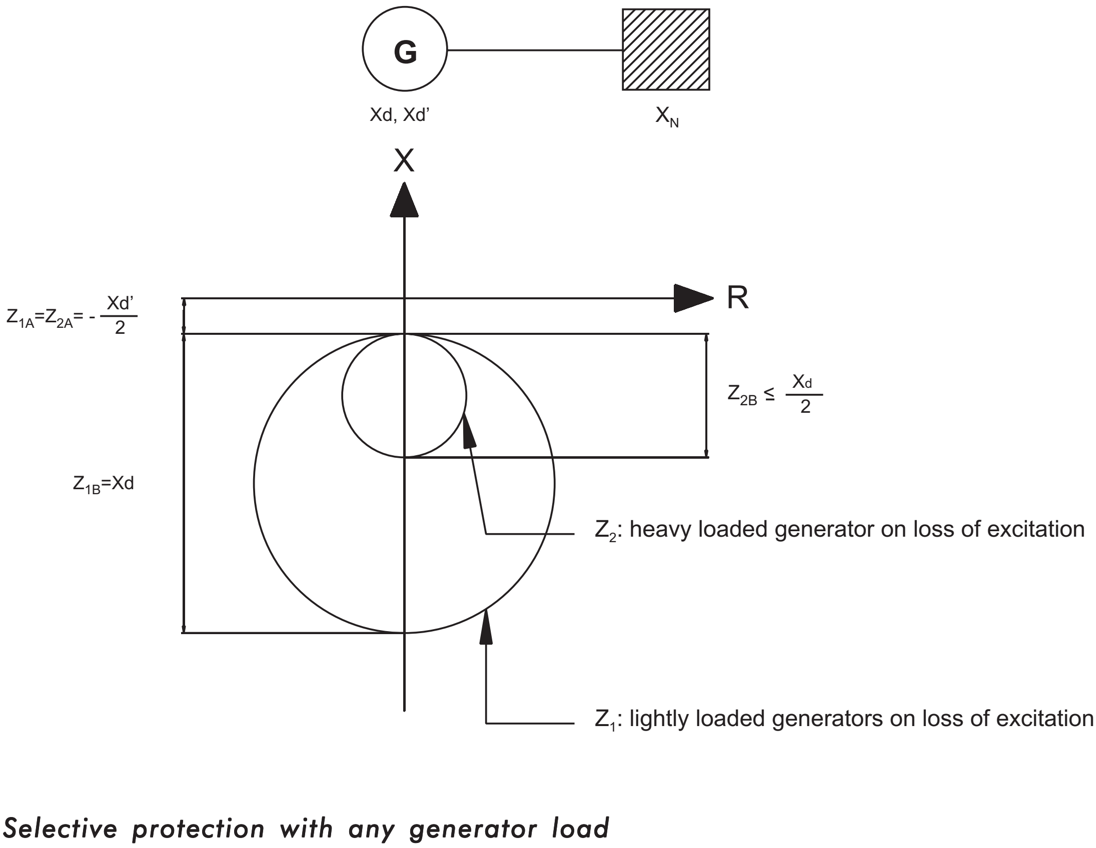


Fig. 5.2: Selective protection with any generator load

5.3.2 Undervoltage protection

The undervoltage protection element is usually set to the critical system voltage value at which the generator with loss of field jeopardises the system stability. The limit is normally about 80 % of the nominal generator voltage. The secondary set value is calculated as follows:

$$U = 0.8 \cdot \frac{U_{N,Gen}}{K_U}$$

The undervoltage trip delay should be set at 0.25 s to max. 1 s.

5.3.3 Setting example

The example below explains the setting procedure for a synchronous generator of 200 MW:

Generator parameters:

P_{Gen} = 200 MW
COSφ = 0.85
$U_{N,Gen}$ = 15.75 kV
$I_{N,Gen}$ = 8625 A
x_d = 1.9808
$x_{d'}$ = 0.2428
x_N = 0.2
K_U = 15750 V/100 V
K_I = 12000 A/5 A
$U_{N,MRQ}$ = 100 V
$I_{N,MRQ}$ = 5 A

Setting of the impedance element no. 1 (steady state stability characteristic):

$$Z_{1A}\ (\%) = x_N \cdot \frac{K_1 \cdot U_{N,Gen} \cdot I_{N,MRQ}}{K_U \cdot I_{N,Gen} \cdot U_{N,MRQ}} \cdot 100\ (\%)$$

$$Z_{1A} = 0.2 \cdot \frac{2400 \cdot 15750 \cdot 5}{157.5 \cdot 8625 \cdot 100} \cdot 100(\%) = 27.8\%$$

$$Z_{1A} = 28\ \%$$

$$Z_{1B}(\%) = x_d \cdot \frac{K_1 \cdot U_{N,Gen} \cdot I_{N,MRQ}}{K_U \cdot I_{N,Gen} \cdot U_{N,MRQ}} \cdot 100(\%) + Z_{1A}$$

$$Z_{1B}(\%) = 1.9808 \cdot \frac{2400 \cdot 15750 \cdot 5}{157.5 \cdot 8625 \cdot 100} \cdot 100(\%) + 28\%$$

$$Z_{1B} = 303.6\% = 304\%$$

Setting of the impedance element no. 2

(dynamic stability characteristic):

$$Z_{1A}(\%) = -\frac{1}{2}\ x_{d'} \cdot \frac{K_1 \cdot U_{N,Gen} \cdot I_{N,MRQ}}{K_U \cdot I_{N,Gen} \cdot U_{N,MRQ}} \cdot 100(\%)$$

$$Z_{2A} = -\frac{1}{2}\ 0.2428 \cdot \frac{2400 \cdot 15750 \cdot 5}{157.5 \cdot 8625 \cdot 100} \cdot 100(\%)$$

$$Z_{2A} = -16.9\% = -17\%$$

$$Z_{2B}(\%) = x_d \cdot \frac{K_1 \cdot U_{N,Gen} \cdot I_{N,MRQ}}{K_U \cdot I_{N,Gen} \cdot U_{N,MRQ}} \cdot 100(\%) + Z_{2A}$$

$$Z_{2B}(\%) = 1.9808 \cdot \frac{2400 \cdot 15750 \cdot 5}{157.5 \cdot 8625 \cdot 100} \cdot 100(\%) - 17\%$$

$$Z_{2B} = 258.6\% = 259\%$$

Setting of the trip delay for the impedance elements:

$t_{Z1} = 1.0$ s
$t_{Z2} = 0.25$ s

Setting of the undervoltage element:

$$U = 0.8. \frac{U_{N,Gen}}{K_U} = 0.8 . \frac{15750}{157.5} = 80V$$

Setting of the trip delay for the undervoltage element:

$t_{U<} = 0.25$ s

5.4 Indication and measuring values

The tables below list the display informations.
Please read the abbreviations as:
c: continuous
f: flashing
g: green
r: red
y: yellow

If one of the protection elements of the ***MRQ1*** picked up but did not trip, the related LED will flash slowly until the <SELECT/RESET> button is pressed for 3 s. After a trip, all measured values at the instant of tripping may be recalled by pressing the <SELECT/RESET> push button. Reset is possible by pressing the <SELECT/RESET> button for 3 s.

5.5 Reset

Unit ***MRQ1*** has the following three possibilities to reset the display of the unit as well as the output relay at jumper position J3 = ON.

Manual Reset

- Pressing the push button <SELECT/RESET> for some time (about 3 s)

External Reset

- Through applying auxiliary voltage to C8/D8

Software Reset

- The software reset has the same effect as the <SELECT/RESET> push button.

The display can only be reset when the pickup is not present anymore (otherwise "TRIP" remains in display). During resetting of the display the parameters are not affected.

Table 3: Normal operation:

Display	Unit	LED
Measured voltage value U_{12}	in V	$U_1 + U_2$ (c, g)
Measured voltage value U_{23}	in V	$U_2 + U_3$ (c, g)
Measured voltage value U_{31}	in V	$U_3 + U_1$ (c, g)
Measured current value I_1	in I/In	I_1 (c, g)
Measured impedance value	in %.	Z (c, g)
Measured impedance real value	in %.	R (c, y)
Measured impedance imaginary value	in %	X (c, y)
Remote control RS485		RS (c, y)

Pickup and trip alarms:

Cause	LED
Pickup of impedance element Z_1	Z (f, r) + Z_1A (f, r) + Z_1B (f, r)
Tripping of impedance element Z_1	Z (c, r) + Z_1A (c, r) + Z_1B (c, r)
Pickup of impedance element Z_2	Z (f, r) + Z_2A (f, r) + Z_2B (f, r)
Tripping of impedance element Z_2	Z (c, r) + Z_2A (c, r) + Z_2B (c, r)
Pickup of undervoltage element	Ux (f, r) + U< (f, r) (x: 12,23,31)
Tripping of undervoltage element	U x (c, r) + U< (c, r) (x: 12,23,31)

6. Relay Testing and commissioning

The test instructions following below help to verify the protection relay performance before or during commissioning of the protection system. To avoid a relay damage and to ensure a correct relay operation, be sure that:

the auxiliary power supply rating corresponds to the auxiliary voltage on site.

- the rated current and rated voltage of the relay correspond to the plant data on site.
- the current transformer circuits and voltage transformer circuits are connected to the relay correctly.

all signal circuits and output relay circuits are connected correctly.

6.1 Power-On

Switch on the auxiliary power supply to the relay and check that the message “CSPC” appears on the display and the self supervision alarm relay (watchdog) is energized (Contact terminals D7 and E7 closed).

6.2 Testing the output relays

NOTE!

Prior to commencing this test, always block the output circuits or interrupt in another way the output circuits which can cause the tripping of the circuit breaker if the breaker operation during this test is not desired.

By pressing the push button <TRIP> once the display shows you the first part of the software version of the relay. By pressing the push button <TRIP> twice the display shows the second part of the software version of the relay. The software version should be quoted in all correspondence. After you have got a message “PSW?” on the display by pressing the push button <TRIP> once more please enter the correct password to proceed with the test. After that the message “TRI?” will follow. Confirm this testing by means of pressing push button <TRIP> again.

All output relays should then be activated and the self supervision alarm relay (watchdog) should be deactivated one after another with a time interval of 1 second. Thereafter, reset all output relays back to their normal positions by pressing the push button <SELECT/RESET>.

6.3 Checking the set values

By repeatedly pressing the push button <SELECT> all relay set values may be checked and set value modification can be done with the push button <+><-> and <ENTER>. For detailed information about that, please refer to chapter 5.

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter, ammeter
- Phase angle meter
- Auxiliary power supply with the voltage corresponding to the rated data on the type plate
- Single-phase current supply unit (adjustable from 0 to ≥ 10xIn)
- Single-phase or three phase voltage supply unit with phase shifting (adjustable from 0 to ≥ 1.2xUn)
- Timer to measure the operating time
- Switching device
- Test leads and tools

6.4.2 Example of test circuit for MRQ1 relay

For testing field failure relays, you need both current and voltage input signals with adjustable phase shifting. Figure 6.1 shows an example of a test circuit with adjustable three-phase voltage source and a single-phase current source energizing the ***MRQ1*** relay under test. If you only have a single-phase voltage source, you can also test the under impedance function of the ***MRQ1*** by connecting the single phase voltage to the relay terminals A5/A6. For testing the field failure relay, the input voltages shall be applied to the relay with a constant value within its effective range (e.g. U=50V). The input current and phase angle shall be appropriately varied.

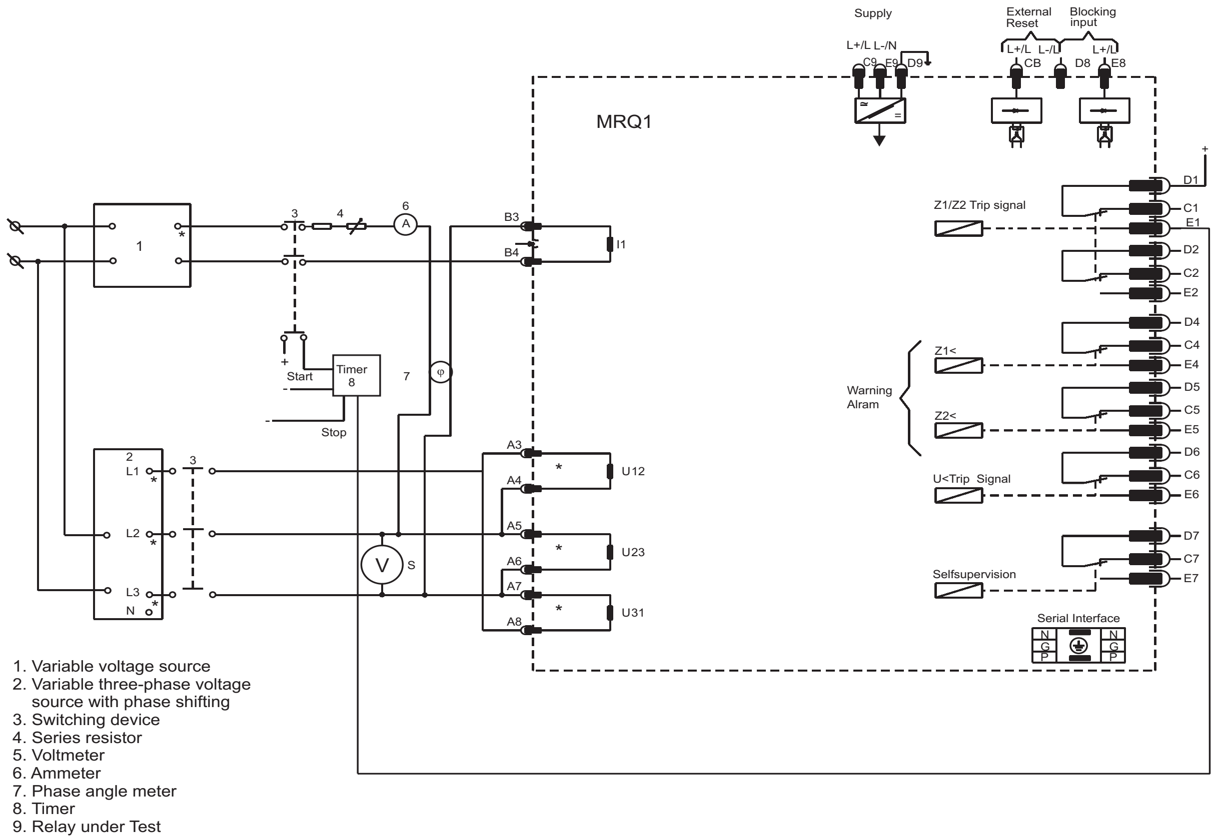


Fig. 6.1

Care must be taken as to connect the test current and test voltage to the relay in correct polarity. In Fig. 6.1 the relay and test source polarity are indicated by a * mark near the terminals.

6.4.3 Checking the input circuits and measured values

The following quantities can be measured by ***MRQ1*** and indicated on the display:

- Three phase-to-phase voltages U_{12}, U_{23}, U_{31} in volt
- Current I_{L1} related to the nominal current (x I_N)
- Impedance value Z related to the nominal impedance value (in %)
- Real part of the impedance value R related to the nominal impedance value (in %)
- Imaginary part of the impedance value X related to the nominal impedance value (in %)

The nominal impedance value is defined as follow:

$$Z_N = \frac{U_{N,MRQ}}{\sqrt{3}\ I_{N,MRQ}}$$

Inject a current of rated value (1A for In = 1A) in phase 1 (terminals B3-B4) and apply three phase-to-phase voltages in rated value (e.g. U_N=100V) to terminals A3/A4, A5/A6, A7/A8 in Δ-connection. Check the measured voltages, current and impedance on the display by pressing the push button <SELECT> repeatedly. The voltages and current to be measured in this case should have rated value (100V for U_N=100V and 1x I_N for I_N=1A). Check that the measured impedance value Z on display is 100%. The real and imaginary parts of the impedance value depend on the phase angle between the current I_{L1} and voltage U_{23} because the under impedance elements evaluate these two input quantities. Change the phase angle between the current I_{L1} and voltage U_{23}. Observe the measured impedance value and its real and imaginary parts on the display.

Compare them with the reference values given in the following table:

Impedance measurement at $U=U_N$ and $I=I_N$			
Phase angle (°)	Measured impedance on display		
	Z(%)	R(%)	X(%)
I_{L1} in phase with U_{23}	100	0	+100
I_{L1} leads U_{23} by 45°	100	+70.7	+70.7
I_{L1} leads U_{23} by 90°	100	+100	0
I_{L1} leads U_{23} by 135°	100	+70.7	-70.7
I_{L1} leads U_{23} by 180°	100	0	-100
I_{L1} lags U_{23} by 45°	100	-70.7	+70.7
I_{L1} lags U_{23} by 90°	100	-100	0
I_{L1} lags U_{23} by 135°	100	-70.7	-70.7

Compare the readings of current, voltage at indicated display of relay with the readings from the ammeter, voltmeter. The deviations of voltage and current measurement must not exceed 1% and 3% respectively. By using an RMS-metering instrument, a greater deviation may be observed if the test current and test voltage contain harmonics. Because the ***MRQ1*** relay measures only the fundamental component of the input signals, the harmonics will be rejected by the internal DFFT-digital filter. Whereas the RMS-metering instrument measures the RMS-value of the input signals. Calculate the impedance and its real and imaginary parts according to the voltage and current measurement. Compare the calculated value with the measured value on **MRQ1** display. The deviation of the impedance absolute value must not exceed ±5%. The deviation of the impedance angle must not exceed ±5°.

6.4.4 Checking the operating and resetting values of the undervoltage functions

Apply three voltages with the rated value and gradually decrease the voltages until the relay picks up, i.e. at the moment when the LED U< lights up. Read the operating voltage indicated by the voltmeter. The deviation must not exceed 1% of the set operating value. Furthermore, gradually increase the voltages until the relay resets, i.e. the LED U< is extinguished (not confused with the dim flashing LED, which means the storage of the last disturbance). Check that the resetting voltage is less than 1.03 times the operating voltage.

6.4.5 Checking the relay operating time of the undervoltage function

To check the undervoltage operating time, a timer must be connected to the undervoltage trip output relay contact (terminals D6/E6). The timer should be started simultaneously with the voltage change from sound condition to a faulty condition and stopped by the trip relay contact. The operating time measured by timer should not have a deviation more than <3% of the set value or < 20 ms.

6.4.6 Checking the underimpedance characteristics

For testing the underimpedance characteristics of ***MRQ1*** relay, three relay characteristical quantities are substantial: input voltages, input current and phase angle between them. During the testing, two of these three characteristical quantities can be set to constant values, and the other can be changed gradually as to move the measured impedance from non-tripping zone into the tripping zone.

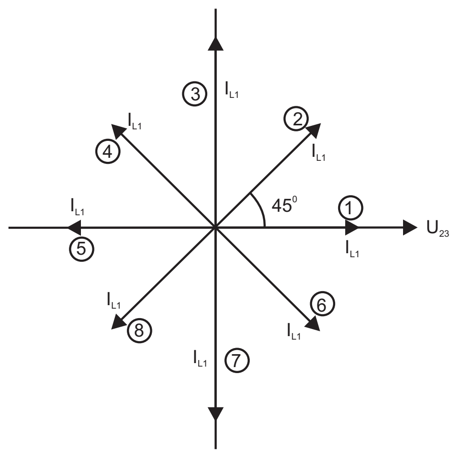
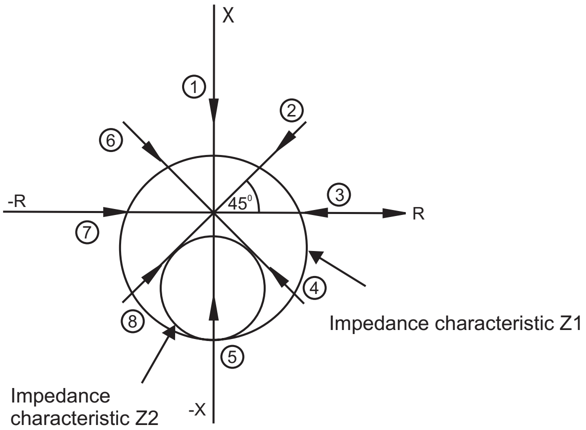


Fig. : 6.2

Phase relation between input voltage U_{23} and input current I_{L1}

Usually it is convenient to set the input voltage and the phase angle between the voltage and current to be given values, and to test the operating charactristics by means of changing the current amplitude. By selecting different phase angles, and changing the current amplitude in the same manner, you can find out operating impedance values of your relay in every direction on the RX-diagram. Fig. 6.2 and 6.3 shows various phase relations between voltage and current, as well as the corresponding impedance trajectories on the RX-plane for your reference.



6.3 Fig.

Impedance trajectories for various phase angles by changing current amplitude

6.5 Checking the external blocking and reset functions

By ***MRQ1*** relays, all relay functions will be inhibited by extern blocking input. To test the blocking function: Apply auxiliary supply voltage to extern blocking input of the relay (terminals E8/D8). Apply a test voltage and inject a test current which could cause a tripping. Observe that there is no trip and no alarm.

Remove the auxiliary supply voltage from the blocking input. Apply a test voltage and inject a test current to make the relay tripped (Message „TRIP“ on the display). Interrupt the test current and apply auxiliary supply voltage to extern reset input of the relay (terminals C8/D8). The display and LED indications should be reset immediately.

6.6 Primary injection test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test above described, with the difference that the protected power system should be, in this case, connected to the installed relays under test „on line“, and the test currents and voltages should be injected to the relay through the current and voltage transformers with the primary side energized. Since the cost and potential hazards are very high for such a test, especially if staged fault tests are intended, primary injection tests are usually limited to very important protective relays to the power system.

Because of its powerful combined indicating and measuring functions, you have still the possibilities to test the ***MRQ1*** relay in the manner of a primary injection without extra expenditures and time consumption. In actual service, for example, the measured current and voltage values on the display may be checked phase by phase and compared with the current and voltage indications of the ammeter and voltmeter. It is also possible to check the measured generator impedance value and its real and imaginary parts, Please calculate the power factor of the operating generator, and compare it with the power factor meter indication on the switch-board panel to verify that your relay works and measures correctly and to verify that the relay is connected to the power system with the correct polarity.

6.7 Maintenance

Maintenance testing is generally done on site at regular intervals. These intervals vary among users depending on many factors: e.g. the type of protective relays employed; the importance of the primary equipment being protected; the user's past experience with the relay, etc.

For electromechanical or static relays, maintenance testing will be performed at least once a year according to the experiences. For digital relays like ***MRQ1*,** this interval can be substantially longer. This is because that:

- the ***MRQ1*** relays are equipped with very wide self-supervision functions, so that many faults in the relay can be detected and signalized during the service. Important: The self-supervision output relay must be connected to a central alarm panel!
- the combined measuring functions in ***MRQ1*** relay enable supervision the relay functions during service.
- the combined TRIP test function of the ***MRQ1*** relay allows to test the relay output circuits by power system interrupt.

A testing interval of two years for maintenance will, therefore, be recommended.

During a maintenance testing, the relay functions including the operating values and relay tripping characteristics as well as the operating time should be tested.

7. Technical data

7.1 Measuring inputs

Nominal data		
Nominal voltage U_N	:	100 V; 230 V; 400 V
Rated current I_N	:	1 A; 5 A
Measuring range	:	10 x I_N
Frequency f_N	:	40 - 70 Hz
Burden of the current input:		
at I_N = 1 A	:	0.2 VA
at I_N = 5 A	:	0.1 VA
Burden of the voltage inputs	:	<1 VA/per phase at U_N
Thermal capacity of the voltage inputs	:	1.2 x U_N continuously
Current inputs withstand:		
dynamic	:	250 x I_N (one half wave)
for 1 s	:	100 x I_N
for 10s	:	30 x I_N
continuously	:	4 x I_N

7.2 Common data

Dropout to pickup ratio U<, Z<	:	< 102 %
Returning time	:	$\leq$ 30 ms
Minimum operating time	:	$\leq$ 60 ms
Influencing quantities:		
Frequency 45Hz to 65Hz	:	no influence
Auxiliary voltage	:	no influence in the specified range

7.3 Setting ranges and steps

Setting and displaying of voltage is made in Volts. Setting and displaying of current is related to the nominal current I_N of the ***MRQ1.*** Setting and displaying of the impedance values are related to the nominal values of ***MRQ1*** (pl. ref. to 4.3)

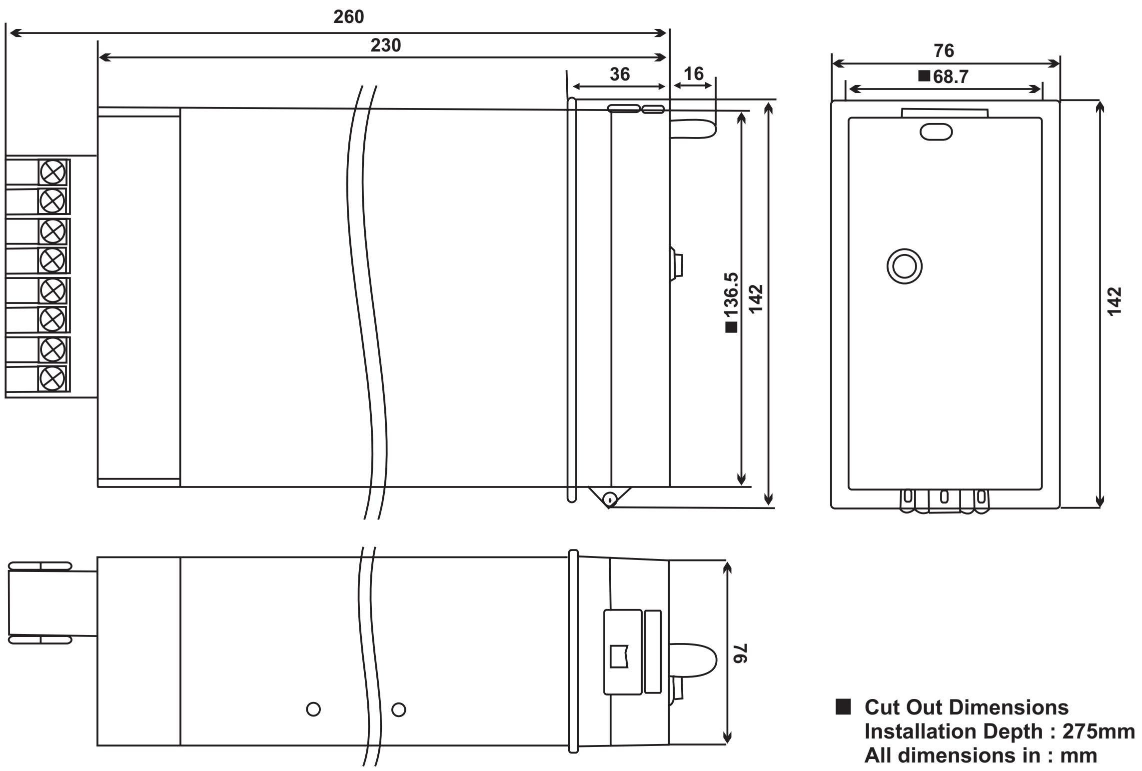
$$Z\,(\%) = \frac{U_{L2\text{-}L3}}{U_N} \cdot \frac{I_N}{I_{L1}} .100(\%)$$

$$Z\,(\%) = Z_{Sek} \, \frac{\sqrt{3} I_N}{U_N} \, .100(\%)$$

$$Z\,(\%) = \frac{Z_{Sek}}{Z_N} .100\,(\%)$$

Element	Parameter	Setting range / steps	Assigned Tolerances
U<	U< $t_{U<}$	EXIT; 2...110 V / 1V (U_N = 100V) EXIT; 5...255 V / 1V (U_N = 230V) EXIT; 10...440 V / 2V (U_N = 400V) (EXIT blocks the function) 0.04...50s; EXIT / 0.02; 0.05; 0.1; 0.2; 0.5; 1.0 (EXIT: t = ∞)	± 1 % of set value or < 0.3V whichever is higher ± 3 % or ± 20 ms whichever is higher
Z_1	Z_1A Z_1B t_{Z1}	-300 ... 300 % of Z_N / 1% 0 ... 600 % of Z_N / 1% (Z1B = 0 blocks the function) 0.04...50 s; EXIT / 0.02; 0.05; 0.1; 0.2; 0.5, 1.0 (EXIT: t = ∞)	± 5 % of set value at nominal values ± 3 % or ± 20 ms whichever is higher
Z_2	Z_2A Z_2B t_{Z2}	-300 ... 300 % of Z_N / 1% 0 ... 600 % of Z_N / 1% (Z_2B = 0 blocks the function) 0.04...50 s; EXIT / 0.02; 0.05; 0.1; 0.2; 0.5, 1.0s (EXIT: t = ∞)	± 5 % of set value at nominal values ± 3 % or ± 20 ms whichever is higher

8. Dimensional details



Please note:

A distance of 50 mm is necessary when the units are mounted one below the other in order to allow easy opening of the front cover of the housing. The front cover opens downwards.

8. Order form

Field failure relay ***MRQ1***

Current input		**I**
Rated current	1 A	**1**
Rated current	5 A	**5**
Voltage input		**U**
Nominal voltage	100 V	**1**
	200 V	**2**
	400 V	**4**
Auxiliary voltage	24 V (16 to 60 V AC/16 to 80 V DC)	**L**
	110 V (50 to 270 V AC/70 to 360 V DC)	**H**
Serial interface RS485		**R**
Housing (12TE)	19" rack	**A**
	Flush mounting	**D**

Technical data subject to change without notice!

Setting list *MRQ1*

Project: ______________________________

Function group: = ______________ Location: + ______________ Relay code: ______________

Relay functions: ______________________________ Password: ______________

Date: ______________

Function		Unit	Default settings	Actual settings
U<	Pickup of undervoltage element	V	80/190/320*	
t_U<	Tripping of undervoltage element	s	0.5	
Z_1A	Pickup of impedance element	%	20	
Z_1B	Voltage theshold for vector surge measuring	%	100	
t_{Z1}	Tripping of impedance element Z_1	s	1.00	
Z_2A	Pickup of impedance element Z_2A	%	- 10	
Z_2B	Pickup of impedance element Z_2B	%	70	
t_{Z1}	Tripping of impedance element Z_2	s	0.5	
RS	Slave address			

* Thresholds dependent on rated voltage 100 V / 230 V / 400 V

For further information, please contact :

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