High-Tech Range

MRN2- Mains decoupling Relay

C&S electric

C&S Electric Limited

(Protection & Control Division)

Contents

1. Introduction and application

The *MRN2* is a universal mains decoupling device and covers the protection requirements from VDE and most other utilities for the mains parallel operation of power stations.

- Over/ and undervoltage protection
- Over/ and underfrequency protection
- Extremely fast decoupling of generator in case of mains failure (*MRN2-1*) or
- Rate of change of frequency df/dt (*MRN2-2*)

Because of combination of three protectional functions in one device the *MRN2* is a very compact mains decoupling device. Compared to the standardly used single devices it has a very good price/performance ratio.

For applications where the single protection functions are required CSE can offer the single *MR*-relays as follows:

- *MRU1-1* four step independent over-/ and undervoltage protection (also used for generator earth fault protection)
- *MRU1-2* two step independent over-/ and undervoltage protection with evaluation of the symmetrical voltage components
- *MRF2* four step independent over/ and underfrequency protection and two step frequency gradient supervision df/dt
- *MRG2* generator mains monitor / vector surge detection

2. Features and characteristics

- Microprocessor technology with watchdog
- Effective analog low pass filter for suppressing harmonics when measuring frequency and vector surge
- Digital filtering of the measured values by using discrete Fourier analysis to suppress higher harmonics and d.c. components induced by faults or system operations
- Integrated functions for voltage, frequency and vector surge in one device.
- Voltage supervision each with two step under-/ and overvoltage detection
- Frequency supervision with three step under-/ or overfrequency (user setting)
- Completely independent time settings for voltage and frequency supervision
- Adjustable voltage threshold value for blocking frequency and vector surge measuring.
- Display of all measuring values and setting parameters for normal operation as well as tripping via a alphanumerical display and LEDs
- Storage and indication of the tripping values
- In compliance with VDE 0435, part 303 and IEC 255
- For blocking the individual functions by the external blocking input, parameters can be set according to requirement
- User configurable vector surge measurement one phase or three phase.
- Reliable vector surge measuring by exact calculation algorithm

3. Design

3.1 Connections

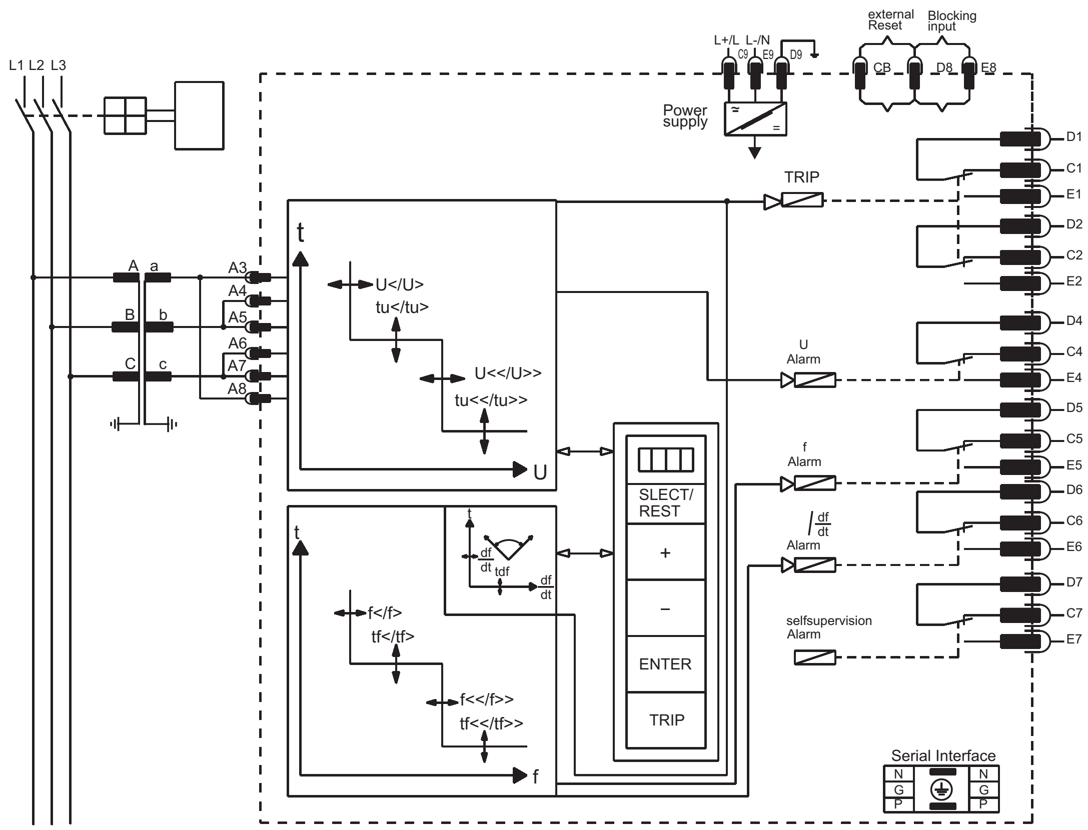


Fig. 3.1 : Connection diagram MRN2-1 and MRN2-2

3.1.1 Analog input circuits

The analog input voltages are galvanically decoupled by the input transformers of the device, then filtered and finally fed to the analog digital converter. The measuring circuits can be applied in star or delta connection (refer to chapter 4.3.1).

3.1.2 Blocking input

The blocking function can be set according to requirement. By applying the auxiliary voltage to D8/E8, the previously set relay functions are blocked (refer to 4.8 and 5.2.10).

3.1.3 Reset input

Please refer to chapter 5.4.

3.1.4 Output relays

The *MRN2* has 5 output relays. One trip relay with two changeover contacts and four alarm relays with one changeover contact.

- Tripping C1, D1, E1 and C2, D2, E2
- Indication of over-/ and undervoltage alarm C4, D4, E4
- Indication of over-/ and underfrequency alarm C5, D5, E5
- Indication of vector surge C6, D6, E6 (*MRN2-1*) or df/dt-alarm (*MRN2-2*)
- Indication self supervision (internal fault of the unit) C7, D7, E7

All trip and alarm relays are normally-off relays, the relay for self supervision is a normally-on relay.

3.2 Display

Function	Display shows	Pressed pushbutton	Corresponding LED	Type of relay
Normal operation	CSE			all types
Measured operating values	Actual measured value Min. and max. values of voltage, frequency and vector surge	<SELECT/RESET> one time for each value	L1, L2, L3, f, min, max ΔΘ df	 MRN2-1 MRN2-2
Setting values: star/delta connection	Y/DELT	<SELECT/RESET><+><->	Δ/Y	
undervoltage (low set) tripping delay of low set element	setting value in volt setting value in seconds	<SELECT/RESET><+><-> one time for each value	$U<$ $t_{U<}$	
undervoltage (high set) tripping delay of high set element	setting value in volt setting value in seconds	<SELECT/RESET><+><-> one time for each value	$U<<$ $t_{U<<}$	
overvoltage (low set) tripping delay of low set element	setting value in volt setting value in seconds	<SELECT/RESET><+><-> one time for each value	$U>$ $t_{U>}$	
overvoltage (high set) tripping delay of high set element	setting value in volt setting value in seconds	<SELECT/RESET><+><-> one time for each value	$U>>$ $t_{U>>}$	
rated frequency	setting value in Hz	<SELECT/RESET><+><->	f_N	
frequency measuring repitition	setting value	<SELECT/RESET><+><->	T	
frequency element f1 tripping delay of frequency element f1	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_1 t_{f1}	
frequency element f2 tripping delay of frequency element f2	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_2 t_{f2}	
frequency element f3 tripping delay of frequency element f3	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_3 t_{f3}	
1-of-3/3-of-3 measurement	1Ph/3Ph	<SELECT/RESET><+><->	1/3	MRN2-1
threshold for vector surge	setting value in degree	<SELECT/RESET><+><->	ΔΘ	MRN2-1
setting value df/dt measuring repitition df/dt	setting value in Hz/s setting value in seconds	<SELECT/RESET><+><-> one time for each value	df d_t	MRN2-2
Undervoltage blocking of frequency and vector surge measuring (df/dt for *MRN2-2*)	setting value in Volt	<SELECT/RESET><+><->	f, ΔΘ, df	
Slave address of serial interface	1 - 32	<SELECT/RESET><+><->	RS	
Recorded fault data: star—connection: U1, U2, U3	tripping values in Volt	<SELECT/RESET><+><-> one time for each phase	L1, L2, L3, $U<$, $U<<$, $U>$, $U>>$	
delta-connection: U12, U23, U31	tripping values in Volt	<SELECT/RESET><+><-> one time for each phase	L1, L2, L3 $U<$, $U<<$, $U>$, $U>>$	
frequency	tripping values in Hz	<SELECT/RESET><+><-> one time for each phase	f, f1, f2, f3	
rate of change of frequency	tripping value in Hz/s	<SELECT/RESET><+><->	df	MRN2-2
vector surge	tripping value in degree	<SELECT/RESET><+><-> one time for each phase	ΔΘ+L1,L2 or L3	MRN2-1
Save parameter?	SAV?	<ENTER>		
Save parameter!	SAV!	<ENTER> for about 3 s		
Software version	First part (e.g. D02-) Sec. part (e.g. 6.01)	<TRIP> one time for each part		
Manual trip	TRI?	<TRIP> three times		
Inquire password	PSW?	<SELECT/RESET>/ <+>/<->/<ENTER>		
Relay tripped	TRIP	<TRIP> or fault tripping		
Secret password input	XXXX	<SELECT/RESET>/ <+>/<->/<ENTER>		
System reset	CSE	<SELECT/RESET> for about 3 s		

Table 3.1: possible indication messages on the display

3.2.1 Parameter settings

Setting parameter	*MRN2-1*	*MRN2-2*
Δ/Y	X	X
U<	X	X
$t_{U<}$	X	X
U<<	X	X
$t_{U<<}$	X	X
U>	X	X
$t_{U>}$	X	X
U>>	X	X
$t_{U>>}$	X	X
f_N	X	X
T	X	X
f_1	X	X
t_{f1}	X	X
f_2	X	X
t_{f2}	X	X
f_3	X	X
t_{f3}	X	X
df		X
dt		X
1/3	X	
ΔΘ	X	
U_B <	X	X
RS485/ Slave	X	X

Table 3.2: Sequence of parameter setting of the two relay types

3.3 LEDs

All LEDs (except LED RS, min and max) are two-coloured. The LEDs on the left side, next to the alpha-numerical display light up green during measuring and red after tripping.

The LEDs below the push button <SELECT/RESET> are lit green during setting and inquiry procedure of the setting values which are printed on the left side next to the LEDs. The LEDs will light up red after activation of the setting values next to their right side.

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

3.4 Front plate

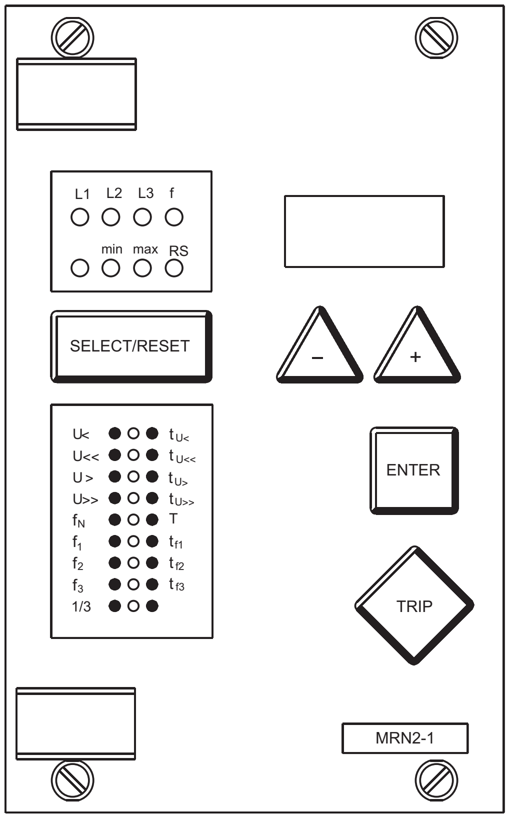


Fig. 3.2: Front plate MRN2-1

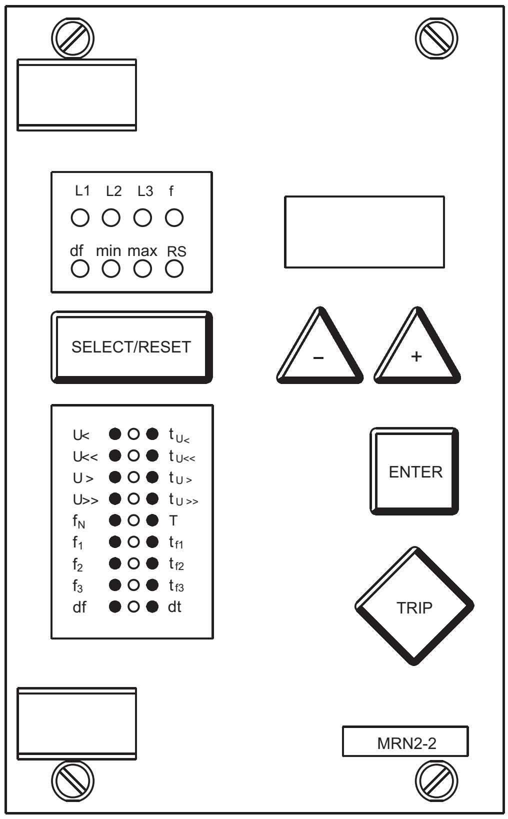


Fig. 3.3: Front plate MRN2-2

4. Working principle

4.1 Analog circuits

The input voltages are galvanically insulated by the input transformers. The noise signals caused by inductive and capacitive coupling are supressed by an analog R-C filter circuit.

The analog voltage signals are fed to the A/D-converter of the microprocessor and transformed to digital signals through Sample- and Hold- circuits. The analog signals are sampled with a sampling frequency of 16 x f_N, namely, a sampling rate of 1.25 ms for every measuring quantity, at 50 Hz.

4.2 Digital circuits

The essential part of the MRN2 relay is a powerful microcontroller. All of the operations, from the analog digital conversion to the relay trip decision, are carried out by the microcontroller digitally. The relay program is located in an EPROM (Electrically-Programmable-Read-Only-Memory). With this program the CPU of the microcontroller calculates the three phase voltage in order to detect a possible fault situation in the protected object.

For the calculation of the voltage value an efficient digital filter based on the Fourier Transformation (DFFT-Discrete Fast Fourier Transformation) is applied to suppress high frequency harmonics and d.c. components caused by fault-induced transients or other system disturbances. The microprocessor continuously compares the measured values with the preset thresholds stored in the parameter memory (EEPROM). If a fault occures an alarm is given and after the set tripping delay has elapsed, the corresponding trip relay is activated.

The relay setting values for all parameters are stored in a parameter memory (EEPROM - Electrically Erasable Programmable Read Only Memory), so that the actual relay settings cannot be lost, even if the power supply is interrupted.

The microprocessor is supervised by a built-in "watchdog" timer. In case of a failure the watchdog timer resets the microprocessor and gives an alarm signal via the output relay "self supervision".

4.3 Voltage supervision

The voltage element of MRN2 has the application in protection of generators, consumers and other electrical equipment against over/and undervoltage. The relay is equipped with a two step independent three-phase overvoltage (U>, U>>) and undervoltage (U<, U<<) function with completely separate time and voltage settings.

In delta connection the phase-to-phase voltages and in star connection the phase-to-neutral voltages are continuously compared with the preset thresholds.

For the overvoltage supervision the highest, for the undervoltage supervision the lowest voltage of the three phases are decisive for energizing.

4.3.1 Selection of star or delta connection

All connections of the input voltage transformers are led to screw terminals. The nominal voltage of the device is equal to the nominal voltage of the input transformers. Dependent on the application the input transformers can be connected in either delta or star. The connection for the phase-to-phase voltage is the delta connection. In star connection the measuring voltage is reduced by $1/\sqrt{3}$. During parameter setting the connection configuration either Y or Δ has to be adjusted.

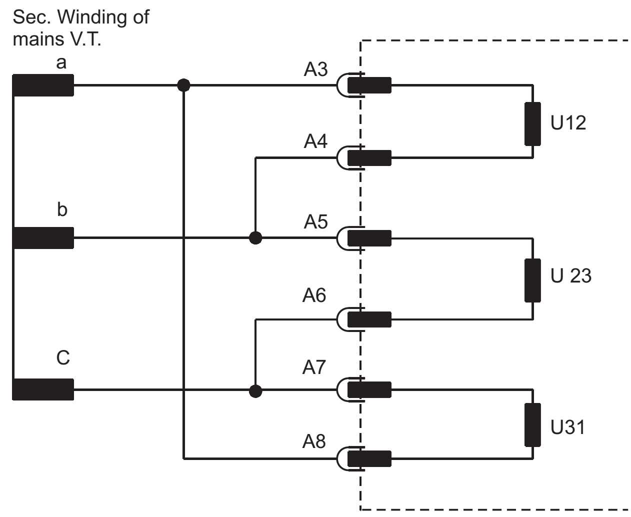


Fig. 4.1: Input v.t.s in delta connection (Δ)

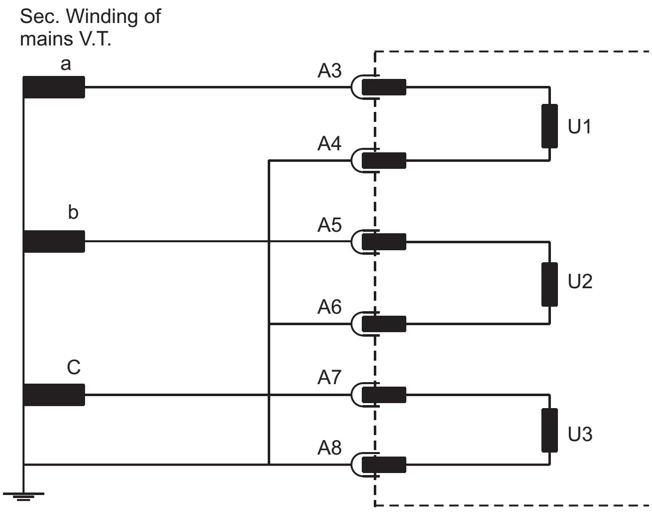


Fig. 4.2: Input v.t.s in star connection (Y)

4.4 Principle of frequency supervision

The frequency element of *MRN2* protects electrical generators, consumers or electrical operating equipment in general against over- or underfrequency. The relay has independent three frequency elements f_1 - f_3 with a free choice of parameters, with separate adjustable pickup values and delay times.

The measuring principle of the frequency supervision is based on the time measurement of complete cycles, whereby a new measurement is started at each voltage zero passage. The influence of harmonics on the measuring result is thus minimized.

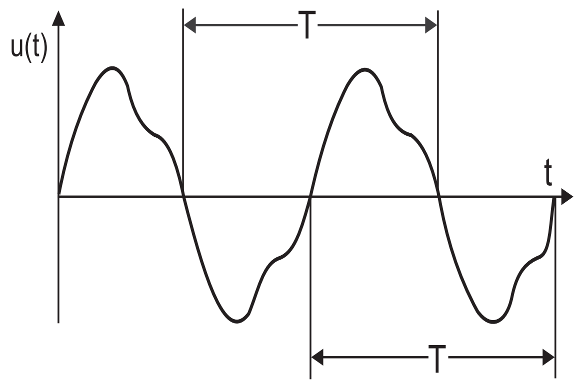


Fig. 4.3: Determination of cycle duration by means of zero passages.

In order to avoid false tripping during occurence of interference voltages and phase shifts the relay works with an adjustable measuring repetition (see chapter 5.2.3)

Frequency tripping is sometimes not desired by low measured voltages which for instance occur during alternator acceleration. All frequency supervision functions can be blocked with the aid of an adjustable voltage threshold U_B in case the measured voltage value is below this value.

4.5 Measuring of frequency gradient (*MRN2-2*)

Electrical generators running in parallel with the mains, e.g. industrial internal power supply plants, should be separated from the mains when failure in the intrasystem occurs for the following reasons:

- It must be prevented that the electrical generators are damaged when mains voltage recovering asynchrone, e.g. after a short interruption.
- The industrial internal power supply must be maintained.

A reliable criterion of detecting mains failure is the measurement of the rate of change of frequency df/dt. Precondition for this is a load flow via the mains coupling point. At mains failure the load flow changing then spontaneously leads to an increasing or decreasing frequency. At active power deficit of the internal power station a linear drop of the frequency occurs and a linear increase occurs at power excess. Typical frequency gradients during application of "mains decoupling" are in the range of 0.5 Hz/s up to over 2 Hz/s. The *MRN2* detects the instantaneous frequency gradient df/dt of each mains voltage period in an interval of one half period each. Through multiple evaluation of the frequency gradient in sequence the continuity of the directional change (sign of the frequency gradient) is determined. Because of this special measuring procedure a high safety in tripping and thus a high stabilty against transient processes, e.g. switching procedure are reached. The total switching off time at mains failure is between 60 ms and 80 ms depending on the setting.

4.6 Vector surge supervision (*MRN2-1*)

The vector surge supervision protects synchronous generators in mains parallel operation due to very fast decoupling in case of mains failure. Very dangerous are mains auto reclosings for synchronous generators. The mains voltage returning after 300 ms can hit the generator in asynchronous position. A very fast decoupling is also necessary in case of long time mains failures. Generally there are two different applications:

a) Only mains parallel operation no single operation:

   In this application the vector surge supervision protects the generator by tripping the generator circuit breaker in case of mains failure.

b) Mains parallel operation and single operation:

   For this application the vector surge supervision trips the mains circuit breaker. Here it is insured that the gen.-set is not blocked when it is required as the emergency set.

A very fast decoupling in case of mains failures for synchronous generators is known as very difficult. Voltage supervision units cannot be used because the synchronous alternator as well as the consumer impedance support the decreasing voltage.

For this the mains voltage drops only after some 100 ms below the pickup threshold of voltage supervision relays and therefore a safe detection of mains auto reclosings is not possible with this kind of relay.

Frequency relays are partial unsuitable because only a highly loaded generator decreases its speed within 100 ms. Current relays detect a fault only when shortcircuit type currents exist, but cannot avoid their development. Power relays are able to pickup within 200 ms, but they cannot prevent power to rise to short-circuit values too. Since power changes are also caused by sudden loaded alternators, the use of power relays can be problematic.

Whereas the *MRN2-1* detects mains failures within 60 ms without the restrictions described above because they are specially designed for applications where very fast decoupling from the mains is required.

Adding the operating time of a circuit breaker or contactor, the total disconnection time remains below 150 ms. Basic requirement for tripping of the generator/ mains monitor is a change in load of more than 15 - 20 % of the rated load. Slow changes of the system frequency, for instance at regulating processes (adjustment of speed regulator) do not cause the relay to trip.

Trippings can also be caused by short-circuits within the grid, because a voltage vector surge higher than the preset value can occur. The magnitude of the voltage vector surge depends on the distance between the short-circuit and the generator. This function is also of advantage to the Power Utility Company because the mains short-circuit capacity and consequently the energy feeding the short-circuit is limited.

To prevent a possible false tripping the vector surge measuring can be blocked at a set low input voltage (refer to 5.2.8). The undervoltage lockout acts faster then the vector surge measurement.

Vector surge tripping is blocked by a phase loss so that a VT fault (e.g. faulty VTs fuse) does not cause false tripping.

When switching on the aux. voltage or measuring voltage, the vector surge supervision is blocked for 5 s (refer to chapter 4.8).

Note:
In order to avoid any adverse interference voltage effects, for instance from contactors or relays, which may cause overfunctions, MRN2-1 should be connected separately to the busbar.

4.6.1 Measuring principle of vector surge supervision

When a synchronous generator is loaded, a rotor displacement angle is built between the terminal voltage (mains voltage $\underline{U}1$) and the synchronous internal voltage ($\underline{U}p$). Therefore a voltage difference $\Delta\underline{U}$ is built between $\underline{U}p$ and $\underline{U}1$ (Fig. 4.4).

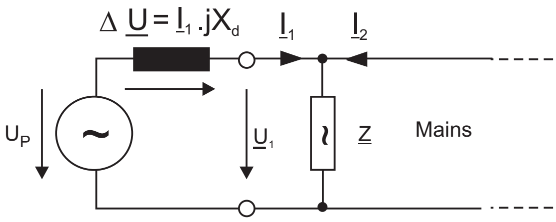


Fig. 4.4: Equivalent circuit at synchronous generator in parallel with the mains

The rotor displacement angle J between stator and rotor is dependent on the mechanical moving torque of the generator shaft. The mechanical shaft power is balanced with the electrical fed mains power, and therefore the synchronous speed keeps constant (Fig. 4.5).

In case of mains failure or auto reclosing the generator suddenly feeds a very high consumer load. The rotor displacement angle is decreased repeatedly and the voltage vector U1 changes its direction (U1 ‘) (Fig. 4.6 and 4.7).

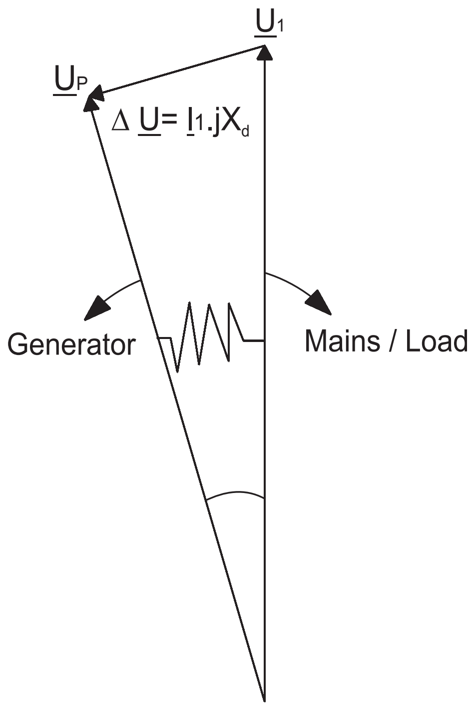


Fig. 4.5: Voltage vectors at mains parallel operation

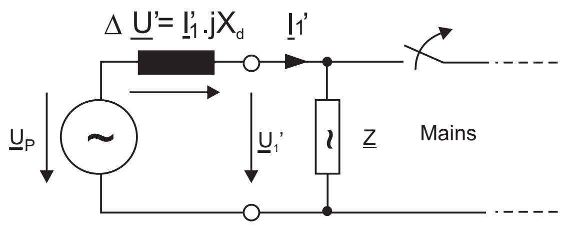


Fig. 4.6: Equivalent circuit at mains failure

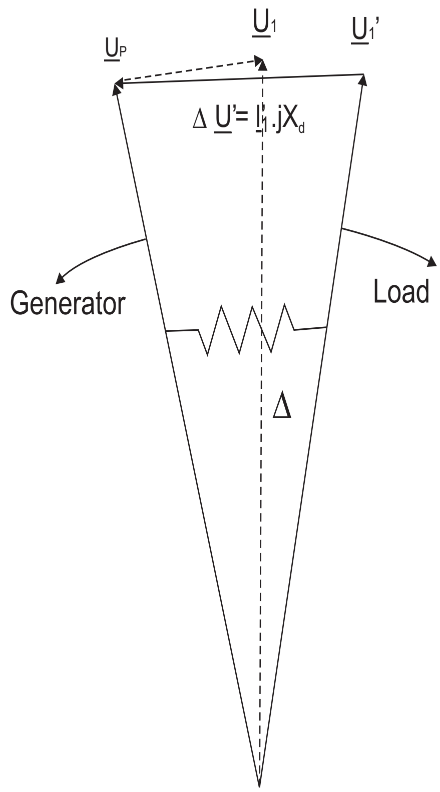


Fig. 4.7: Voltage vectors at mains failure

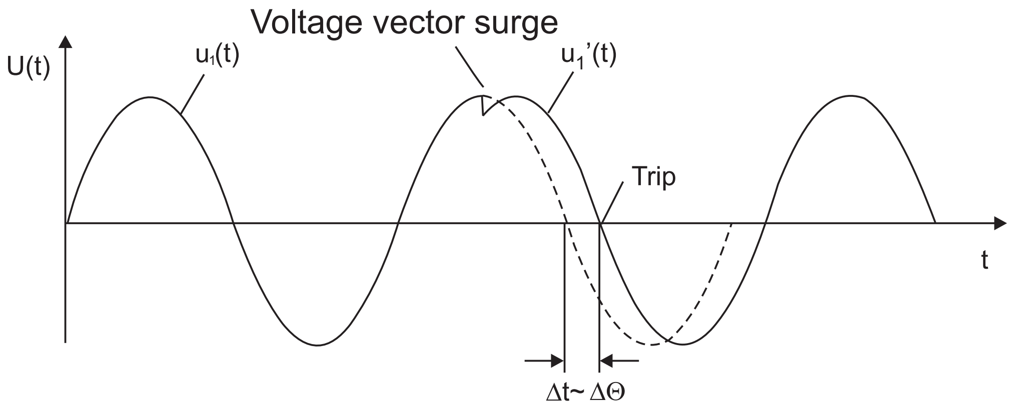


Fig. 4.8: Voltage vector surge

As shown in the voltage/time diagram the instantaneous value of the voltage jumps to another value and the phase position changes. This is named phase or vector surge.

The *MRN2-1* measures the cycle duration. A new measuring is started at each voltage zero passage. The measured cycle duration is internally compared with a quartz stable reference time and from this the deviation of the cycle duration of the voltage signal is ascertained. In case of a vector surge as shown in fig. 4.8, the zero passage occurs either earlier or later. The established deviation of the cycle duration is in compliance with the vector surge angle.

If the vector surge angle exceeds the set value, the relay trips immediately.

Tripping of the vector surge is blocked in case of loss of one or more phases of the measuring voltage.

Tripping logic for vector surge measurement:

The vector surge function of the *MRN2-1* supervises vector surges in all three phases at the same time. Tripping of the relay can be adjusted for one phase vector surge (more sensitive measurement). For this the parameter 1/3 has to be set to “1Ph”. When the parameter 1/3 is set to “3Ph”, tripping of the vector surge element occurs only if the vector surge angle exceeds the set value in all three phases at the same time.

Application hint

Although the vector surge relay guarantees very fast and reliable detection of mains failures under nearly all operational conditions of mains parallel running alternators, the following borderline cases have to be considered accordingly:

a) None or only insignificant change of power flow at the utility connection point during mains failures.

This can occur during peak lossing operation or in CHP stations (Combined Heat and Power) where the power flow between power station and the public grid may be very low. For detection of a vector surge at parallel running alternators, the load change must be at least 15 - 20 % of the rated power. If the active load at the utility connection point is regulated to a minimal value and a high resistance mains failure occurs, then there are no vector surge nor power and frequency changes and the mains failure is not detected.

This can only happen if the public grid is disconnected near the power station and so the alternators are not additionally loaded by any consumers. At distant mains failures the synchronous alternators are abruptly loaded by remaining consumers which leads directly to a vector surge and so mains failure detection is guaranteed.

If such a situation occurs the following has to be taken into account:

In case of an undetected mains failure, i.e. with the mains coupling C.B. closed, the vector surge relay reacts upon the first load change causing a vector surge and trips the mains C.B.

For detecting high resistance mains failures a minimum current relay with an adjustable trip delay can be used. A trip delay is needed to allow regulating actions where the current may reach “zero” at the utility connection point. At high resistance mains failures, the mains coupling C.B. is tripped by the minimum current relay after the time delay.

To prevent asynchronous switching on, an automatic reclosing of the public grid should be not possible during this time delay.

A further measure could be, that the load regulation at the utility connection point guarantees a minimum power flow of 15 - 20 % of rated power.

b) Short circuit type loading of the alternators at distant mains failures

At any distant mains failure, the remaining consumers cause sudden short circuit type loading of the power station generators. The vector surge relay detects the mains failure in about 60 ms and switches off the mains coupling C.B. The total switch off time is about 100 - 150 ms. If the generators are provided with an extremely fast short circuit protection e.g. able to detect di/dt, the alternators might be switched off unselectively by the generator C.B., which is not desireable because the power supply for the station is endangered and later on synchronized changeover to the mains is only possible after manual reset of the overcurrent protection.

To avoid such a situation, the alternator C.B.s must have a delayed short circuit protection. The time delay must be long enough so that mains decoupling by the vector surge relay is guaranteed.

4.7 Voltage threshold value for frequency measuring

At low measuring voltages, e.g. during generator start-up, frequency and vector surge or df/dt-measuring is perhaps not desired.

By means of the adjustable voltage threshold value U_B <, functions f_1 - f_3, df/dt or $\Delta\Theta$ are blocked if the measured voltage falls below the set value.

4.8 Blocking function

No.	Dynamic Behaviour	U</<<	U>/>>	f_1 , f_2 , f_3	$\Delta\Theta$	df/dt
1	voltage to external blocking input is applied	free programmable	free programmable	free programmable	free programmable	free programmable
2	blocking input is released	released instantaneously	released instantaneously	released after 1 s	released after 5 s	released after 5 s
3	supply voltage is switched on	blocked for 200 ms	blocked for 200 ms	blocked for 1 s	blocked for 1 s	blocked for 1 s
4	3ph measuring volt. is suddenly applied	released	released	blocked for 1 s	blocked for 5 s	blocked for 5 s
5	one or several measuring voltages are switched off suddenly (phase failure)	released	released	blocked	blocked	blocked
6	measuring voltage smaller UB < (adjustable voltage threshold value)	released	released	blocked	blocked	blocked

Table 4.1: Dynamic behaviour of MRN2 functions

Blocking function set in compliance with requirements :

The *MRN2* has an external blocking input. By applying the auxiliary voltage to input D8/E8, the requested protection functions of the relay are blocked (refer to 5.2.10).

5. Operation and settings

5.1 Adjustable parameters

The following parameters can be set by the user himself:

MRN2-1 and MRN2-2:

Δ/Y	-	changing of input transformer connection
U<	-	threshold for undervoltage
t_U <	-	tripping delay for undervoltage
U<<	-	threshold for undervoltage
t_U <<	-	tripping delay for undervoltage
U>	-	threshold for overvoltage
t_U >	-	tripping delay for overvoltage
U>>	-	threshold for overvoltage
t_U >>	-	tripping delay for overvoltage
f_N	-	rated frequency
T	-	frequency measuring repetition in periods
f_1	-	threshold for frequency element 1
t_{f1}	-	tripping delay for frequency element 1
f_2	-	threshold for frequency element 2
t_{f2}	-	tripping delay for frequency element 2
f_3	-	threshold for frequency element 3
t_{f3}	-	tripping delay for frequency element 3
U_B <	-	voltage threshold value for frequency and vector surge measuring (or df/dt)
RS	-	Slave address of the serial interface

MRN2-2 only:

df	-	threshold for rate of frequency (df/dt) in Hz/s
dt	-	measuring repetition for df/dt in periods

MRN2-1 only:

1/3	-	Vector surge tripping 1-of-3/3-of-3
$\Delta\Theta$	-	Pickup value for vector surge in degree

5.2 Setting procedure

In this paragraph the settings for all relay parameters are described in detail. For parameter setting a password has to be entered first

5.2.1 Parameter setting of over- and undervoltage supervision

The setting procedure is guided by two coloured LEDs. During setting of the voltage thresholds the LEDs U<, U<<, U> and U>> are light green. During setting of the trip delays $t_{U>}$, $t_{U>>}$, $t_{U<}$ and $t_{U<<}$ the according LEDs light up red.

Thresholds of the voltage supervision

During setting of the threshold U>, U>>, U< and U<< the displays shows the value directly in volt. The thresholds can be changed by the <+> <-> push buttons and stored with <ENTER>.

The undervoltage supervision (U< and U<<) as well as the overvoltage supervision (U> and U>>) can be deactivated by setting the threshold to "EXIT".

Tripping delay of voltage supervision

During setting of the tripping delays $t_{U<}$, $t_{U<<}$, $t_{U>}$ and $t_{U>>}$ the display shows the value directly in seconds. The tripping delay is changed via the push button <+> and <-> in the range of 0.04 s to 50 s and can be stored with the push button <ENTER>.

When setting the tripping delay to "EXIT" the value is infinite meaning only warning, no tripping.

5.2.2 Setting of nominal frequency

First the nominal frequency (50 or 60 Hz) has to be correctly set before unit *MRN2* is put into operation. All frequency functions are determined by setting the nominal frequency, i.e. whether the set frequency thresholds are evaluated as over- or underfrequency (see also chapter 5.2.4). Also the cycle duration (20 ms at 50 Hz and 16.67 ms at 60 Hz) derives from this setting which determines the minimum tripping delay for frequency elements f_1 - f_3 with an adjustable multiplier (see also chapter 5.2.5).

During setting of the nominal frequency a value in Hz is shown on the display.

5.2.3 Number of measuring repetitions (T) for frequency functions

In order to avoid false tripping of the unit at short voltage drops of the system voltage or interference voltages, *MRN2* works with an adjustable measuring repetition. When the instantaneous frequency measuring value exceeds (at overfrequency) or falls below (at underfrequency) the set reference value, the counter is incremented, otherwise the counter is decremented down to the minimum value of 0. Only when the counter exceeds the value adjusted at T, alarm is given and after the tripping delay of the frequency element has elapsed the tripping command is given. The setting range for T is between 2 - 99.

Recommendation for setting:

For short tripping times, e.g. for machine protection or for mains decoupling T should be set in the range from 2 - 5.

At precision measurements, e.g. exact measurement of the system frequency a setting of T in the range from 5 - 10 is recommended.

5.2.4 Threshold of frequency supervision

The function of the individual frequency elements can be deactivated by setting the pickup values to "EXIT". The setting value "EXIT" corresponds to the rated frequency.

5.2.5 Tripping delays for the frequency elements

Tripping delays t_{f1} - t_{f3} of the three frequency elements can independently be set from t_{fmin} - 50 s. The minimum tripping delay t_{f1min} of the relay is dependent upon the number of set measuring repetitions T (periods) and amounts to:

$$t_{fmin} = (T+1) \times 20 \text{ ms}$$

When setting the tripping delay to "EXIT" by pressing push button <+> up to the maximum setting value, the corresponding tripping relay is blocked. Pickup of the frequency element is however displayed on the front plate by the corresponding LED, an alarm relay is also activated.

5.2.6 Parameter setting of vector surge supervision (*MRN2-1*)

Both the vector surge angle $\Delta\Theta$ as well as the tripping logic concerning the vector surge have to be adjusted for a vector surge supervision.

If the tripping logic is set to 1-of-3 (= "1Ph" on the display), the relay trips as soon as the measured vector surge angle has exceeded the set value $\Delta\Theta$ in one of the three phases. This is the more sensitive adjustment when compared with the three phase tripping logic 3-of-3 (= "3Ph" on the display), where tripping occurs only if the vector surge angle exceeds the set value in all three phases.

We recommend to choose the one phase tripping logic "1Ph". Only if this adjustment is too sensitive, adjustment "3Ph" should be used.

The recommended setting of the vector surge angle $\Delta\Theta$ in a low impedance mains is 4 - 6 degrees. This setting is sufficient in most cases, because low impedance mains do not have a vector surge greater than this value. In case of an auto reclosing, this value is exceeded. In high impedance mains the setting should be 10° to 12° to avoid failure tripping when switching on or switching off big consumer loads.

The vector surge function of this device can be checked as follows:

a) Generator in isolated operation: Switching off and on of loads (approx. 20 % of the nominal generator capacity) must trip the relay. Later in normal isolated operation the tripping of the relay is inhibited.

b) In mains parallel operation switching on and switching off of consumer loads and controlling the governor of the prime mover should not trip the relay.

If possible the test described under a) and b) should be double checked by a real auto reclosing.

5.2.7 Parameter setting of frequency gradient (*MRN2-2*)

The pickup value of frequency gradient (parameter df) can be set between 0.2 to 10 Hz/s. The number of measuring repetitions (parameter dt) can be set between 2 - 64 cycles. This parameter defines the number of df/dt measurements, which have to exceed the set value, before tripping.

Setting information:

The power difference after mains failure causes a change in frequency, which can approximately be calculated as follows:

$$\frac{df}{dt} = -\frac{f_N}{T_A}\Delta P$$

with

f_N = rated frequency in Hz

T_A = inertia time constant of the generators

ΔP = per unit power deficit with reference to the rated active power of the generators

If the inertia time constant is known and a power difference given, the frequency gradient can be estimated by the above mentioned equation. At a supposed power difference of 20 % and an inertia time constant of 10 s, the frequency gradient is 1 Hz/s.

To prevent false trippings at loading, deloading or failure signals, we would recommend a setting value for dt of minimum 4 cycles.

5.2.8 Voltage threshold value for frequency and vector surge measuring (df/dt at *MRN2-2*)

Correct frequency measuring or vector surge measuring cannot be obtained if the system voltage is very low, for instance during generator start up or voltage failure. False tripping of the *MRN2* in such cases is prevented by an adjustable voltage threshold U_B. If the system voltage is below this threshold, these functions of the relay are blocked.

During adjustment of UB< LEDs f and ΔΘ or df light up in the upper display part.

5.2.9 Adjustment of the slave address

By pressing push buttons <+> and <-> the slave address can be set in the range of 1 - 32. During this adjustment the LED RS lights up.

5.2.10 Setting procedure for blocking the protection functions

The blocking function of the *MRN2* can be set according to requirement. By applying the aux. voltage to D8/E8, the functions chosen by the user are blocked. Setting of the parameter should be done as follows:

- When pressing push buttons <ENTER> and <TRIP> at the same time, message “BLOC” is displayed (i.e. the respective function is blocked) or “NO_B” (i.e. the respective function is not blocked). The LED allocated to the first protection function U< lights red.
- By pressing push buttons <+> <-> the value displayed can be changed.
- The changed value is stored by pressing <ENTER> and entering the password.
- By pressing the <SELECT/RESET> push button, any further protection function which can be blocked is displayed.
- Thereafter the menu is left by pressing <SELECT/RESET> again.

5.3 Indication of measuring values

In normal operation the following measuring values can be displayed.

Voltages (LED L1, L2, L3 green)

- In star connection all phase-to-neutral voltages
- In delta connection all phase-to-phase voltages

Frequency (LED f green + L1, L2 or L3 green; *MRN2-1*)

Vector surge (LED ΔΘ green)

Frequency gradient df/dt (LED df green; *MRN2-2*)

Min. and max. values prior to the last reset :

- Frequency (LED f + min or f + max)
- Vector surge (LED ΔΘ + min or ΔΘ + max)
- Frequency gradient (LED df + min or df + max)

5.3.1 Min./Max.- values

The *MRN2* offers a minimum/maximum storage each for the measuring values of the vector surge as well as the frequency gradient. These min./max. values are mainly used to appraise the system quality. Always the highest and lowest values of each cycle are measured and stored until the next reset.

Min./max. frequency measuring :

The *MRN2* ascertains the actual frequency from each cycle of the system voltage. These measuring values are entered into the min./max. storage. The latest entered min./max. values replace the previously stored values.

Dependent on the adjustment of dt and tripping delay, it is possible that the stored min./max. values are higher than the tripping threshold without causing a trip. The reason for this is storage of instantaneous values.

Min./Max. measuring of the frequency gradient:

The procedure described above applies also to storage of min./max. values of df/dt measurement. Since each instantaneous df/dt value is stored, high values can occur which, however, do not cause any tripping.

This can for instance happen during switching procedures where high positive and negative df/dt values occur, but they do not cause any tripping due to the special measuring method.

Min./max. vector surge measuring :

The procedure described above applies also to storage of min./max. values of vector surge measuring. Since each instantaneous $\Delta\Theta$ value is stored, also here high values are possible which, however, do not cause any tripping.

These min./max. measurements are of great advantage for long-time analysis of the grid quality.

After each reset the min./max. storages are cleared. As from this instant there is no time limit for the min./max. storage until the next reset.

5.4 Reset

All relays have 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)

Electrical 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.

6. Relay testing and commissioning

The following test instructions should 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 frequency and rated voltage of the relay correspond to the plant data on site.
- the 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 “CSE” appears on the display and the self supervision alarm relay (watchdog) is energized (Contact terminals D7 and E7 closed). It may happen that the relay is tripped because of under- voltage condition after power-on. (The message “TRIP” on the display and LED L1, L2, L3 and U< light up red). An undervoltage condition has been detected after power-on, because no input voltages are applied to the relay. In this case:

- Press the push button <ENTER>, thus entering into the setting mode. Now set the parameters U< and U<< to “EXIT” to block the undervoltage functions. After that, press the <SELECT/RESET> for app. 3 s to reset the LEDs and “TRIP” message.
- The undervoltage tripping after power on can also be eliminated by applying three phase rated voltages after power-on and reset the LED and “TRIP” message.
- Apply auxiliary voltage to the external blocking input (Terminals E8/D8) to inhibit the undervoltage functions (refer to 6.5) and press the <SELECT/RESET> for app. 3 s to reset the LEDs and “TRIP” message.

6.2 Testing the output relays

NOTE!

Prior to commencing this test, interrupt the trip circuit to the circuit breaker if tripping is not desired.

By pressing the push button <TRIP> once, the display shows 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. Pressing the <TRIP> button once more, the display shows “PSW?”. Please enter the correct password to proceed with the test. The message “TRI?” will follow. Confirm this message by pressing the push button <TRIP> again. All output relays should then be activated and the self supervision alarm relay (watchdog) be deenergized 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 Secondary injection test

6.3.1 Test equipment

- Voltmeter and frequency meter
- Auxiliary power supply
- Three-phase voltage supply unit with frequency regulation
- Timer to measure the operating time
- Switching device
- Test leads and tools

6.3.2 Example of test circuit

Figure 6.1 shows an example of a three-phase test circuit energizing the *MRN2* relay during test. The three phase voltages are applied to the relay in Y-connection.

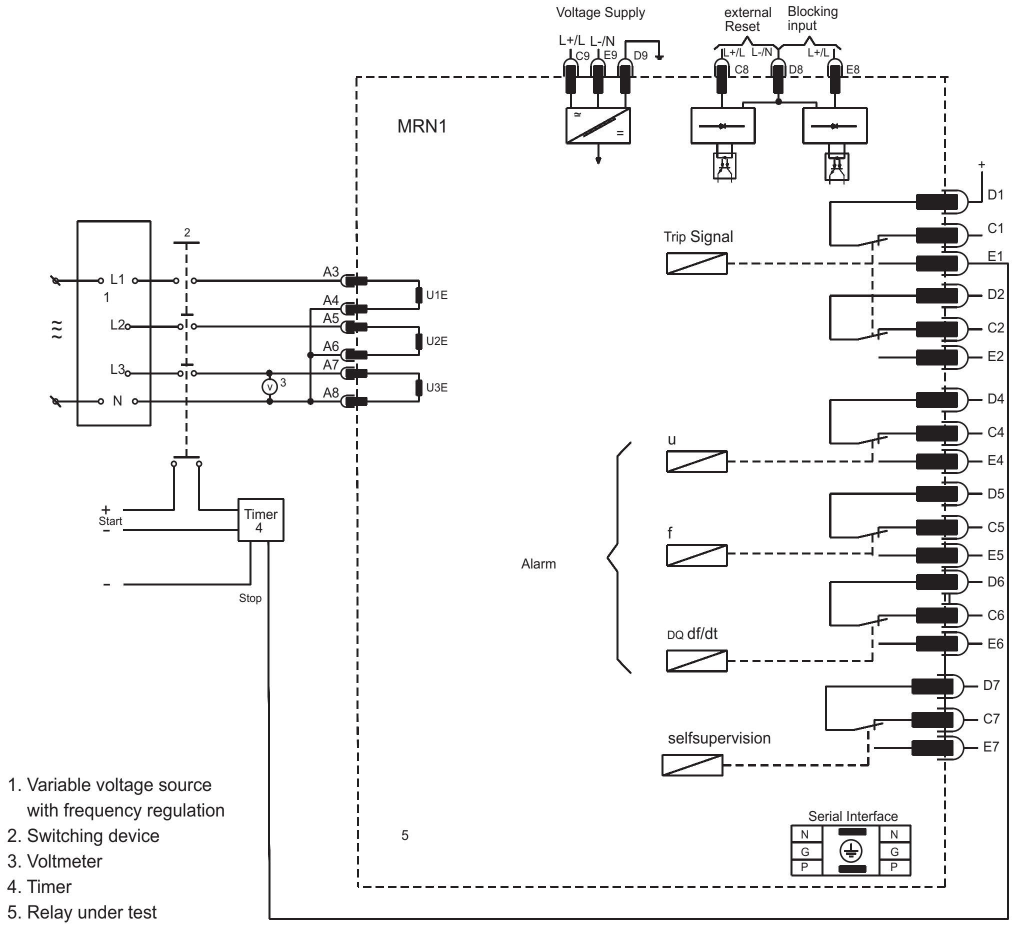


Fig. 6.1: Test circuit

For testing the vector surge function of the relay, a test circuit which can produce phase angle change (vector surge) is required to simulate mains failures (please refer to chapter 6.4.8).

For testing the df/dt function of the relay, a special test equipment is required, which produces a constant rate of change of frequency.

6.3.3 Checking the input circuits and measuring functions

Apply three voltages of rated value to the voltage input circuits (terminals A3 - A8) of the relay. Check the measured voltages, frequency and vector surge on the display by pressing the push button <SELECT/RESET> repeatedly.

The voltages are indicated on the display in volts At Y-connection:

- Phase-to-neutral voltages: LED L1, L2, L3

At Delta-connection:

- Phase-to-phase voltages: LED L1+L2, L2+L3, L3+L1

The frequency is indicated on the display in Hz: LED f (system frequency = 50.01Hz, Indication = 5001) The vector surge is indicated on the display in degrees (for *MRN2-1*): LED $\Delta\Theta$ (Indication $\Delta\Theta$ in °)

The rate of change of frequency (LED df) is indicated on the display in Hz/s (for *MRN2-2*)

Change the voltages around the rated value and check the measured voltages on the display. Change the system frequency around the rated frequency and check the measured frequency on the display.

Compare the voltage and frequency on display with the signal on voltmeter and frequency meter. The deviation for the voltage must not exceed 1% and for frequency < 0.05.

By using an RMS-metering instrument, a greater deviation may be observed if the test voltage contains harmonics. Because the *MRN2* 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.

6.3.4 Checking the operating and resetting values of the over/undervoltage functions

Note:

When the measuring voltage is connected or disconnected, vector surge tripping or df/dt tripping can occur. In order to ensure a trouble-free test procedure, the vector surge function or df/dt function of the relay have to be blocked before tests are started.

Apply three voltages with the rated value and gradually increase (decrease) the voltages until the relay starts, i.e. at the moment when the LED U> (or U<) lights up or the voltage alarm output relay (contact terminals D4/E4) is activated. Read the operating voltage indicated by the voltmeter. The deviation must not exceed 1% of the set operating value.

Furthermore, gradually decrease (increase) the voltages until the relay resets, i.e. the voltage alarm output relay is disengaged. Check that the dropout to pickup ratio for voltage is greater than 0.97 (for overvoltage function) or smaller than 1.03 (for undervoltage).

6.3.5 Checking the relay operating time of the over/undervoltage functions

To check the relay's operating time, a timer must be connected to the trip output relay contact terminals D1/E1). 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 have a deviation about 3% of the set value or < 20 ms.

6.3.6 Checking the operating and resetting values of the over/underfrequency functions

Note:

Due to frequency changes, vector surge tripping or df/dt tripping can occur during frequency tests. In order to ensure a trouble-free test procedure, the vector surge function or df/dt function of the relay have to be blocked before tests are started.

During frequency tests, each of the frequency elements should be tested separately. This makes it necessary that the other frequency elements of the relay have to be blocked by setting the frequency pickup values f_1 - f_3 to "EXIT". For testing the pickup and dropout to pickup values, the test frequency has to be increased (decreased) until the relay is engergized. This is indicated by lighting up of LEDs f_1 - f_3.

When comparing the values displayed with those of the frequency meter, the deviation must not exceed 0.05. The dropout to pickup values are ascertained by increasing (decreasing) the test frequency slowly until the output relay releases.

The dropout to pickup value for overfrequency must be > 0.99, and for underfrequency < 1.01.

6.3.7 Checking the relay operating time of the over/underfrequency functions

The operating time of the over/underfrequency functions can be tested in the similar manner as in chapter 6.4.5 for over/undervoltage functions.

6.3.8 Checking the vector surge function

With the help of an advanced relay test equipment a phase shift (vector surge) on the voltage signal can be obtained to test the vector surge function of *MRN2* relay. If there is no such testing facility available, a very simple simulation circuit may be used to test the vector surge function of the relay with a sufficient accuracy. Figure 6.2 shows the possibility to simulate a phase shift by means of a RC circuit. Closing or opening the switch S1 causes the phase angle of the input voltage to change depending on the adjustable resistor R.

The phase angle obtained may be calculated with the following formula and is almost independent on the test voltages.

In case of a 3-phase vector surge, the angle $\Delta\Theta$ can be calculated with the following formula if the parameters R_0, R and C are known:

$$\Delta\Theta = \text{arctg}\ \frac{1}{R_0 \cdot \omega \cdot C} - \text{arctg}\ \frac{1}{(R_0 + R)\ .\ \omega\ .\ C}$$

Example: $R_0 = 1$ Ohm,

$R = 363$ Ohm, $C = 3\ \mu F$

then: $\Delta\Theta = 19°$

Usually the voltage source impedance R_0 is negligible, hence R_0 may be assumed zero. Thus, with a constant C, says 3 μF (400 VAC), the value of R may be calculated using the following simplified formula:

$$\Delta\Theta\ w = 90° - \text{arctg}\ \frac{1}{R.\omega.C}$$

Note!

Using the above test circuit with single-phase vector surge, the resulting measured angle $\Delta\Theta$ is about half the value of $\Delta\Theta$ calculated for a 3-phase vector surge. To make tripping possible during a one phase test procedure, the vector surge tripping has to be set to "1Ph".

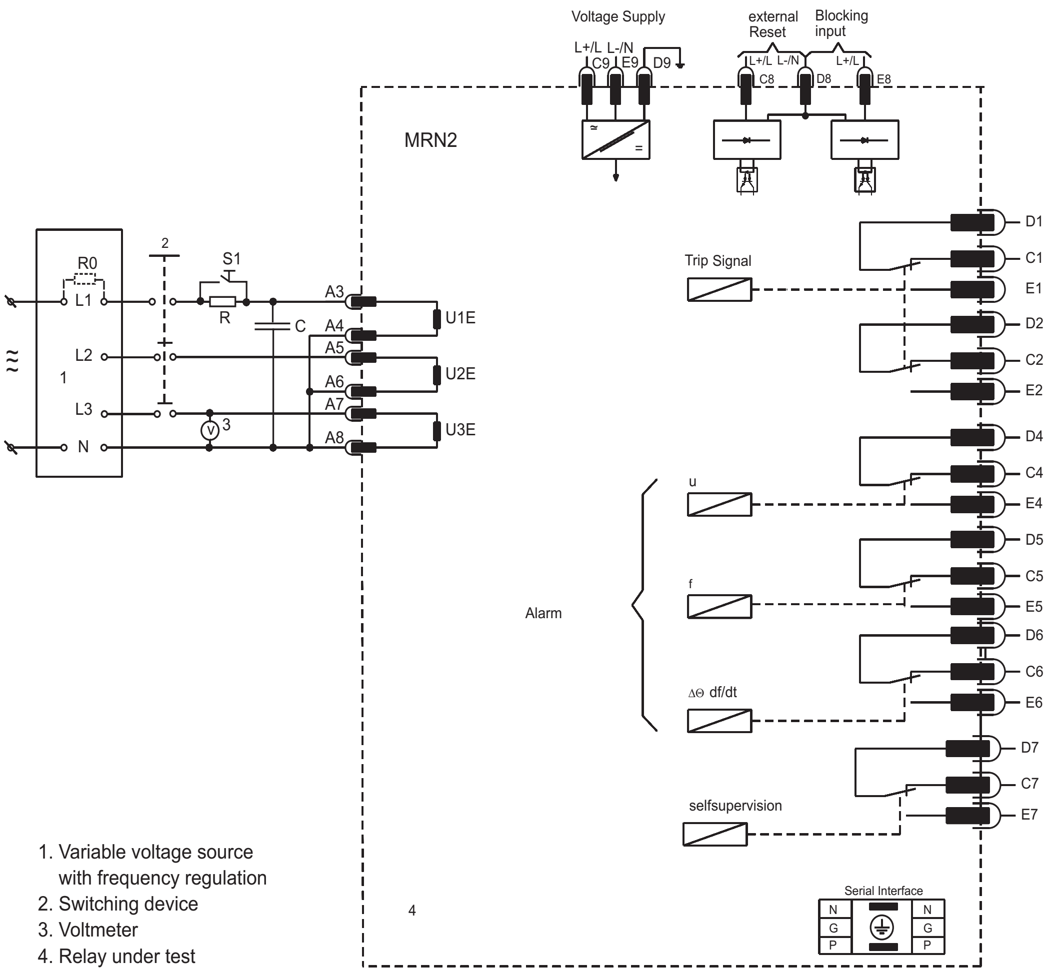


Fig. 6.2: Test circuit for the vector surge function

6.3.9 Checking the external blocking and reset functions

The external blocking input is free programmable by the user.

To test the blocking function apply auxiliary supply voltage to the external blocking input of the relay (terminals E8/D8). Inject a test voltage which could cause tripping for the testes functions. Observe that there is no trip and alarm for those functions.

Remove the auxiliary supply voltage from the blocking input. Apply test voltages to trip the relay (message "TRIP" on the display). Return the test voltages to the sound condition and apply auxiliary supply voltage to the external reset input of the relay (terminals C8/D8). The display and LED indications should be reset immediately.

6.4 Primary injection test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test described above. 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 voltages should be injected to the relay through the voltage transformers with the primary side energized.

Because of its powerful combined indicating and measuring functions, the *MRN2* relay may be tested in the manner of a primary injection test without extra expenditure and time consumption.

In actual service, for example, the measured voltage and frequency values on the MRN2 relay display may be compared phase by phase with the concerned indications of the instruments of the switchboard to verify that the relay works and measures correctly.

6.5 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 *MRN2*, this interval can be substantially longer. This is because:

- the *MRN2* relays are equipped with very wide self-supervision functions, so that many faults in the relay can be detected and signalised during service. Important: The self-supervision output relay must be connected to a central alarm panel!
- the combined measuring functions of *MRN2* relays enable supervision the relay functions during service.
- the combined TRIP test function of the *MRN2* relay allows to test the relay output circuits.

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

During a maintenance test, the relay functions including the operating values and relay tripping times should be tested.

7. Technical data

7.1 Measuring input circuits

Rated data	:	Nominal voltage U_N	100 V, 230 V, 400 V
		Nominal frequency f_N	40 - 70 Hz
Power consumption in voltage circuit	:	<1 VA	
Thermal rating	:	continuously	2 x U_N
Undervoltage lockout for frequency and vector surge measurement	:	$U<$ adjustable (5 %...100 % U_N)	

7.2 Common data

Dropout to pickup ratio	:	for $U>/U>>$: >97 %;	for $U</U<<$: <103 %
		for $f>/f>>$: >99.98 %;	for $f</f<<$: <100.02 %
Dropout time	:	60 ms	
Time lag error class index E	:	±10 ms	
Minimum operating time	:	40 ms	
Max. allowed interruption of the auxiliarxy supply without a facting the function of the device	:	50 ms	
Influences on voltage measuring:			
Aux. voltage	:	in the range $0.8 < U_H / U_{HN} < 1.2$ no additional influences measured	
Frequency	:	in the range $0.8 < f / f_N < 1.4$ (for f_N = 50 Hz) <0.15 % / Hz	
Harmonics	:	up to 20 % of the 3rd harmonic <0.1 % per percent of the 3rd harmonic up to 20 % of the 5th harmonic <0.05 % per percent of the 5th harmonic	
Influences on frequency measuring:			
Aux. voltage	:	in the range $<0.8\ U_N / U_{HN} < 1.2$ no additional influences measured	
Frequency	:	no influences	
Influences on delay time	:	no additional influences measured	

7.3 Setting ranges and steps

Function	Para- meter	Setting range	Steps	Tolerance
U</<<	U</<< $t_{U<}$ $t_{U<<}$	U_N = 100 V: 2...200 V (EXIT) U_N = 230 V: 2...460 V (EXIT) U_N = 400 V: 4...800 V (EXIT) 0.04...50 s (EXIT)	 1 V 1 V 2 V 0.02; 0.05; 0.1; 0.2; 0.5; 1.0	 ± 1 % of set value or < 0.3 % U_N ± 1 % or ± 15 ms
U>/>>	U>/>> $t_{U<}$ $t_{U>>}$	U_N = 100 V: 2...200 V (EXIT) U_N = 230 V: 2...460 V (EXIT) U_N = 400 V: 4...800 V (EXIT) 0.04...50 s (EXIT)	 1 V 1 V 2 V 0.02; 0.05; 0.1; 0.2; 0.5; 1.0	 ± 1 % of set value or < 0,3 % U_N ± 1 % or ± 15 ms
Rated frequency	f_N	f = 50 Hz / f = 60 Hz		
Frequency measuring repetition	T	2...99 (Cycles)	1	
Frequency element 1 - 3	f_1 - f_3 t_{f1} - t_{f3}	30...49.99; EXIT; 50.01...70 Hz[1] 40...59.99; EXIT; 60.01...80 Hz[2] $t_{f,min}$[3] ...50 s; EXIT	0,1; 0,01 Hz 0.02; 0.05; 0.1; 0.2; 0.5; 1.0	0.005 Hz ± 1 % or ± 20 ms
df/dt-Step df/dt-Measuring repetition	df dt	0.2...10 Hz/s (EXIT) 2...64 Periods	0.1; 0.2; 0.5 Hz/s 1	0.1 Hz/s
$\Delta\Theta$	$\Delta\Theta$	2°...22° (EXIT)	1°	± 1°
Vector surge logic	1/3	1Ph / 3Ph		
Voltage theshold for frequency measuring	U_B< (LED'f'+ $\Delta\Theta$/df)	U_N = 100 V: 5...100 V U_N = 230 V: 12...230 V U_N = 400 V: 20...400 V	 1 V 1 V 2 V	 ± 1 % of set value or < 0.3 % U_N
Serial Interface	RS	1 - 32	1	

Table 7.1: Setting ranges and steps

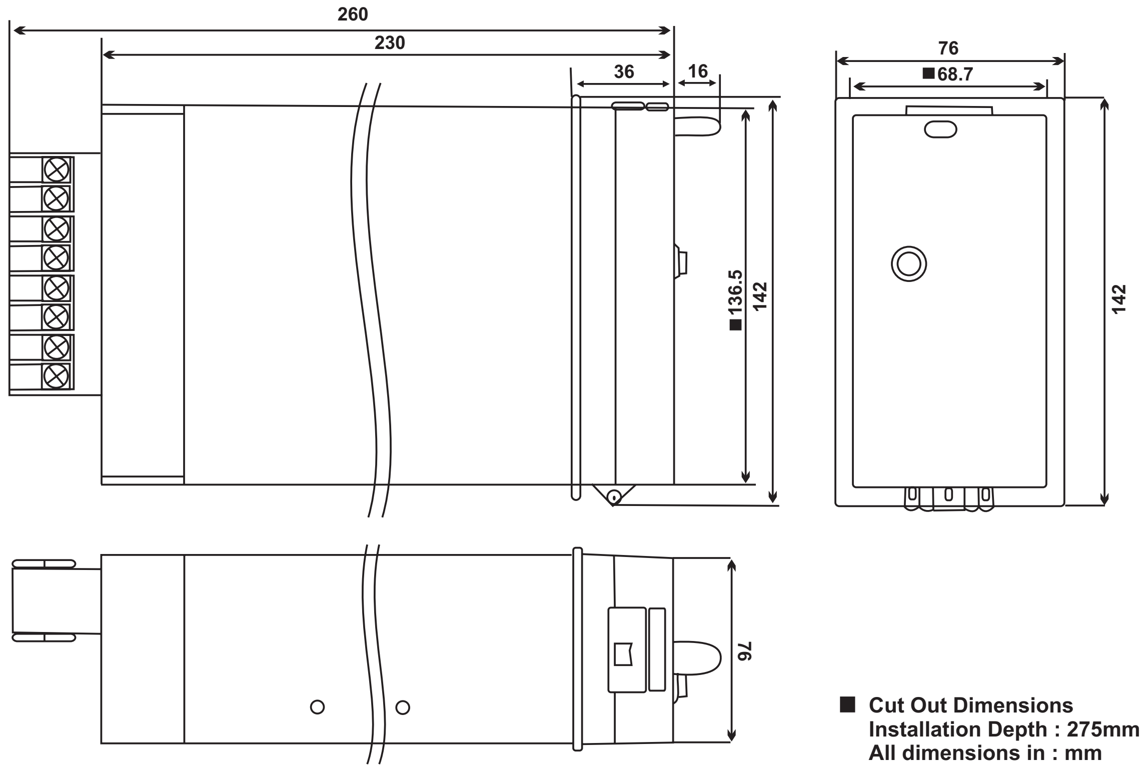
[1] At 50 Hz rated frequency
[2] At 60 Hz rated frequency
[3] $t_{f,min}$ min. time delay; $t_{f,min}$ = (T+1) x 20 ms

7.4 Output relays

Relay type	Trip relays / change-over contacts	Alarm relays / change-over contacts
MRN2	1/2	4/1

Table 7.2: Output relays

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.

9. Order form

Mains decoupling relay **MRN2-**

With voltage-, frequency and vector surge supervision		**1**				
Voltage, frequency and df/dt-supervision		**2**				
Rated voltage:	100 V		**1**			
	230 V		**2**			
	400 V		**3**			
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 RS 485					**R**	
Housing (12TE)	19"-rack					**A**
	Flush mounting					**D**

Technical data subject to change without notice!

Setting list *MRN2*

Project: ______________________________

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

Relay functions: ______________________________ Password: ______________

Function		Unit	Default settings	Actual settings
Δ/Y	input transformer connection		Y	
U<	pickup value for undervoltage element (low set)	V	90/210/360*	
t_U <	tripping delay for undervoltage element	s	0.04	
U<<	pickup value for undervoltage element (high set)	V	80/190/320*	
t_U <<	tripping delay for undervoltage element	s	0.04	
U>	pickup value for overvoltage element (low set)	V	110/250/440*	
t_U >	tripping delay for overvoltage element	s	0.04	
U>>	pickup value for overvoltage element (high set)	V	120/270/480*	
t_U >>	tripping delay for overvoltage element	s	0.04	
f_N	rated frequency	Hz	50	
T	frequency measuring repetition in periods	cycles	4	
f_1	pickup value for frequency element 1	Hz	4800	
t_{f1}	tripping delay for frequency element 1	s	0.1	
f_2	pickup value for frequency element 2	Hz	4900	
t_{f2}	tripping delay for frequency element 2	s	0.1	
f_3	pickup value for frequency element 3	Hz	5100	
t_{f3}	tripping delay for frequency element 3	s	0.1	
df	pickup value for rate of frequency (dt/dt) in	Hz/s	EXIT	
dt	measuring repetition for df/dt	periods	2	
1/3	vector surge tripping logic		1PH	
ΔΘ	pickup value for vector surge	°	2.0	
U_B <	voltage threshold value for frequency and vector surge measuring (or df/dt)	V	10/23/40*	
RS	Slave address of the serial interface		1	

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

electric

C&S Electric Limited

(Protection & Control Division)

44, Okhla Industrial Estate, New Delhi -110 020 (INDIA)
Phone : +91 11- 66602414, 30883745/54/64 Fax: +91 11- 66602413
E-mail: cspc@cselectric.co.in Web : www.cselectric.co.in

Marketing Offices :

AHMEDABAD: +91 79 30074534/35/36 FAX : +91 79 30074519 **BANGALORE:** +91 80 25586147, 25594939 FAX : +91 25584839 **BHUBANESWAR :** +91 674 2507265 FAX : +91 674 2507265 **CHANDIGARH :** +91 172 272613, 3062624 FAX : +91 172 2726153 **CHENNAI :** +91 44 39180531/32/33/34 FAX :+91 44 39180514 **DELHI** : +91 11 30838822-25 Fax :+91 11 30838826 **HYDERABAD :** +91 40 27813003 FAX : +91 40 27812987 **KOLKATA :** +91 33 22275850/51 FAX : +91 33 22275849 **MUMBAI :** +91 22 24114727/28 FAX : +91 22 24126631 **NAGPUR :** +91 712 5616651 FAX : +91 712 5616651 **PUNE :** +91 20 30283244/45 FAX : +91 20 30283245 **RAIPUR :** +91 771 320852433/34