MANUAL

HighTECH Line | PROTECTION TECHNOLOGY MADE SIMPLE

MRN3-3 | MAINS DECOUPLING RELAY WITH DF/DT AND PROGRAMMABLE UNDERVOLTAGE CHARACTERISTICS

MAINS DECOUPLING RELAY WITH DF/DT

AND PROGRAMMABLE UNDERVOLTAGE CHARACTERISTICS

Original document

English

Revision: A

Contents

1 Introduction and Application

The mains decoupling relay *MRN3-3* has been designed for the use under special conditions, especially to be found at wind parks.
If power generating systems are due to comply with the GridCodes, i.e. if they shall not immediately disconnect from the grid in case of a mains failure, but support it, instead, the *MRN3-3* will be the optimal relay. Its' function is to supervise mains voltage and mains frequency in compliance with the GridCodes, the grid connection rules and the operator guidelines.

For this reason, the distinction between short-distance or long-distance errors is an elementary fact. As per the requirements of the e-on grid connection rules (version dd. 20.08.03) and the VDN guideline "EEG power generating plants at high and maximum voltage systems", in addition to the standard protection functions, the *MRN3-3* provides the voltage time characteristics which are necessary to distinguish between short distance and long distance errors. Normal voltage collapse shapes at mains failures are taken into account by these characteristics, that allow selective disconnection of systems only there, where it is absolutely required for operation.

If, in the event of a failure, the systems are to be connected to the grid for a longer period, they will support the mains voltage and thus avoid large-area breakdowns that could no more be compensated by the interconnected network's primary control reserve.

Thanks to the presence of two independent characteristics, it is possible to distinguish between short-term or permanent interruption, each according to the type of error.

In the event of a failure, the fault sequence can be recorded by an oscilloscope.

Within this error scenario, the *MRN3-3* with its characteristics hat have been applied for the first time in protection technique - is of enormous use for the accurate identification and analysis of the grid state - as demanded by the rules.

General Note:
For further technical data and detailed descriptions, please refer to our "*MR* - Digital Multifunctional Relays".

2 Features and Characteristics

- Microprocessor technology with watchdog,
- effective analogue 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 df/dt supervision in one device,
- two parameter sets,
- two free programmable under voltage limit curves with each 5 definition points,
- three voltage supervision steps with under or over voltage function that can be freely parameterised,
- frequency supervision with three step under-/or over frequency function (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,
- display of measuring values as primary quantities
- Storage of the pickup- and tripping values of three failure events (voltage fail-safe),
- recording of up to four fault occurences with time stamp
- to block the individual functions by the external blocking input, parameters can be set according to requirement,
- reliable vector surge measuring by exact calculation algorithm,
- suppression of indication after an activation (LED flash),
- Direct connection 690 V (linked).
- free assignment for output relays,
- display of date and time,
- in complience with VDE 0435, part 303 and IEC 255,
- serial data exchange via RS485 interface possible; alternatively with SEG RS485 Pro-Open Data Protocol or Modbus Protocol.

3 Design

3.1 Connections

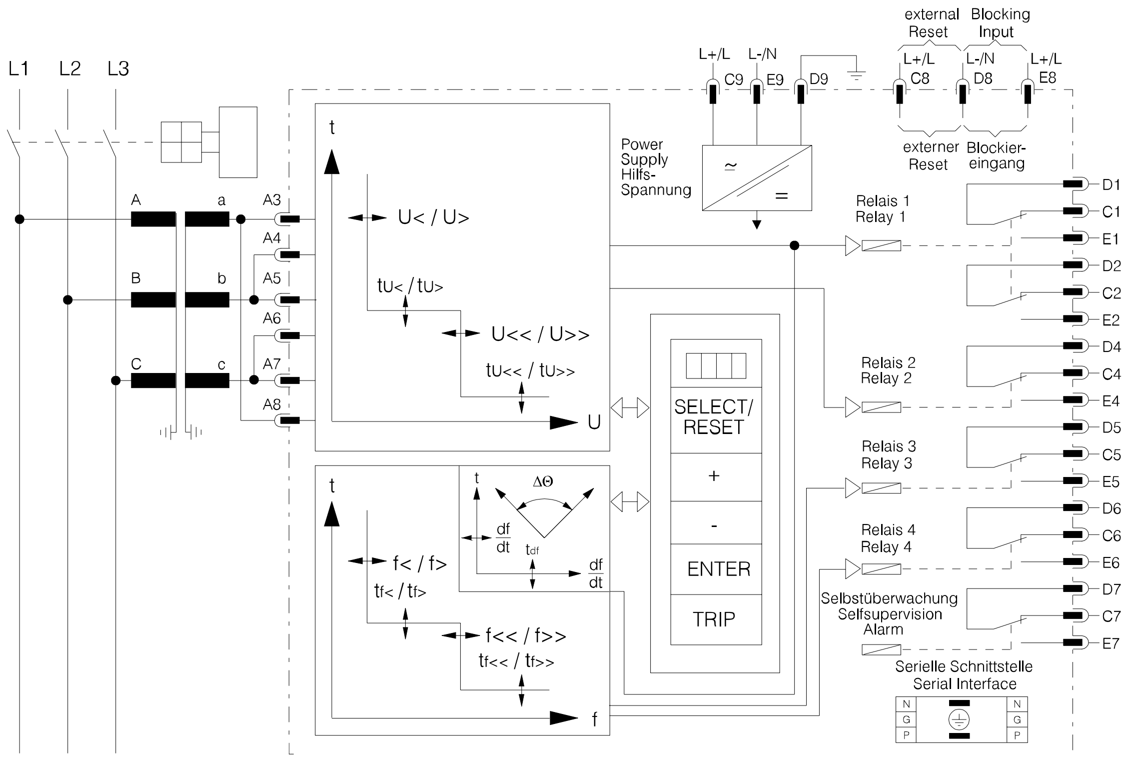

Figure 3.1: Connection diagram MRN3-3

3.1.1 Analogue input circuits

The analogue input voltages are galvanically decoupled by the input transformers of the device, then filtered and finally fed to the analogue 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 5.7.1).

3.1.3 Reset input

Please refer to chapter 5.9.1.

3.1.4 Output relays

The *MRN3-3* is equipped with 5 output relays. Apart from the relay for self-supervision, all protective functions can be optionally assigned:

- Relay 1: C1, D1, E1 and C2, D2, E2
- Relay 2: C3, D3, E3 and C4, D4, E4
- Relay 3: C5, D5, E5
- Relay 4: C6, D6, E6
- Relay 5: Signal self-supervision (internal failure of the unit) C7, D7, E7

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

3.1.5 Fault recorder

The *MRN3-3* has a fault value recorder which records the measured analogue values as instantaneous values.
The instantaneous values

U_{L1}; U_{L2}; U_{L3} for star connection
or U_{12}; U_{23}; U_{21} for delta connection

are scanned at a raster of 1.25 ms (at 50 Hz) and 1.041 ms (at 60 Hz) and saved in a cyclic buffer. It is possible to store 1 - 8 fault occurrences with a total recording time of 18 s (with 50 Hz) and 15 s (with 60 Hz) per channel.

Storage division

Independent of the recording time, the entire storage capacity can be divided into several of disturbance events with a shorter recording time each. In addition, the deletion behaviour of the fault recorder can be influenced.

No writing over*

If 2, 4 or 8 recordings are chosen, the complete memory is divided into the relevant number of partial segments. If this max. number of fault event has been exceeded, the fault recorder block any further recordings in order to prevent that the stored data are written over. After the data have been read and deleted, the recorder is ready again for further action.

Writing over

If 1, 3 or 7 recordings are chosen, the relevant number of partial segments is reserved in the complete memory. If the memory is full, a new recording will always write over the oldest one.

Thus, the fault recorder can be adjusted to record the following data/parameters:

Number of recorded faults	Recorded length of time	
	50 Hz	60Hz
1*	20 s	16.66 s
1	10	8.33 s
2*	10 s	8.33 s
3	5 s	4.16 s
4*	5 s	4.16 s
7	2.5 s	2.08 s
8*	2.5 s	2.08 s

When there is no more storage capacity left, the LED FR starts flashing.

The memory part of the fault recorder is designed as circulating storage. In this example 7 fault records can be stored (written over).

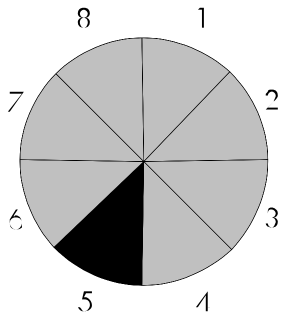

Figure 3.2: Division of the memory into, for example, 8 segments

Memory space 6 to 4 is occupied.
Memory space 5 is currently being written in

Since memory spaces 6, 7 and 8 are occupied, this example shows that the memory has been assigned more than eight recordings. This means that No. 6 is the oldest fault recording and No. 4 the most recent one.

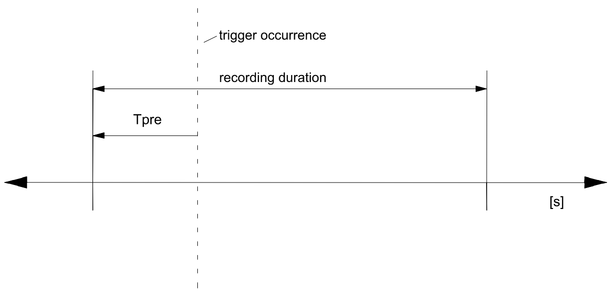

Figure 3.3: Basic set-up of the fault recorder

Each memory segment has a specified storage time which permits setting of a time prior to the trigger event.

Via the interface RS485 the data can be read and processed by means of a PC (HTL/PL-Soft4). The data is graphically edited and displayed. Binary tracks are recorded as well, e.g. activation and trip.

3.2 Order of parameter settings

3.2.1 System parameters

Setting parameter		Unit	Range
L1, L2, L3	Transmission ratio of the voltage transformers		SEK, 1.01...6500
Δ/Y	Input voltage correction depending on the input voltage transformer connection		Y = star DELT = Delta
fN	Adjustment of the rated frequency	Hz	50/60
ΔΘ/df	Selection vector surge or df/dt function		dPhi/dfdt
	LED flashing after excitation	FLSH	FLSH/NOFL = flashing NOFL = no flashing
P2	Parameter set change-over switch/Assignment of digital inputs Set1 = parameter set 1 Set2/2 = parameter set 2 FR = External triggering B = External blocking R = External Reset		SET 1 SET2 B_S2 R_S2 B_FR R_FR S2_FR (refer to chapter 5.3.5)

3.2.2 Protection parameters

Setting parameters		Unit	Range
Char1+U<Start	Start point of the limit curve 1	V	1–200/1–460/4–800*
Char1	Symmetrical, asymmetrical or general fault		SYM; ASYM, ALL
Char1	Under voltage limit curve 1		warn = Display shows no „TRIP" trip = Display shows „TRIP"
Char1+U<1	1. Char. point_value 1 (voltage value)	V	1* - <= U<Start 2* - <= U<Start
Char1+U<1+t>	1. Char. point_value 2 (not parameterisable)	s	0s fixed
Char1+U<2	2. Char. point_value 1 (voltage value)	V	>= U<1–200*/>=U<1–460*/ >=U<1–800*
Char1+U<2+t>	2. Char. point_value 2 (time value)	s	> U<1+t> - 60s
Char1+U<3	3. Char. point_value 1 (voltage value)	V	>= U<2–200*/ >=U<2–460*/>=U<2–800*
Char1+U<3+t>	3. Char. point_value 2 (time value)	s	> U<2+t> - 60s
Char1+U<4	4. Char. point_value 1 (voltage value)	V	>= U<3–200*/ >=U<3–460*/>=U<3–800*
Char1+U<4+t>	4. Char. point_value 2 (time value)	s	> U<3+t> - 60s
Char1+U<5	5. Char. point_value 1 (voltage value)	V	>= U<4–200* and >= U<Start–200*/ >= U<4–460* and >= U<Start–460*/ >=U< 4–800* and >= U<Start–800*
Char1+U<5+t>	5. Char. point_value 2 (time value)	s	> U<4+t> - 60s
Char1+tR	Release time after voltage recovery 1	s	0.06 – 1.00s
Char2+U<Start	Start point the limit curve 2	V	1–200/1–460/4–800*
Char2	Under voltage limit curve 2		warn = Display shows no „TRIP" trip = Display shows „TRIP"
Char2	Symmetrical, asymmetrical or general fault		SYM; ASYM, ALL
Char2+U<1	1. Char. point_value 1 (voltage value)	V	1* - <= U<Start 2* - <= U<Start

Setting parameters		Unit	Range
Char2+U<1+t>	1. Char. point_value 2 (not parameterisable)	s	0s fixed
Char2+U<2	2. Char. point_value 1 (voltage value)	V	>= U<1–200*/ >=U<1–460*/>= U<1–800*
Char2+U<2+t>	2. Char. point_value 2 (time value)	s	> U<1+t> - 60s
Char2+U<3	3. Char. point_value 1 (voltage value)	V	>= U<2–200*/ >=U<2–460*/>= U2–800*
Char2+U<3+t>	3. Char. point_value 1 (time value)	V	> U<2+t> - 60
Char2+U<4	4. Char. point_value 1 (voltage value)	V	>= U<3–200*/ >=U<3–460*/>=U3–800
Char2+U<4+t>	4. Char. point_value 2 (time value)	s	> U<3+t> - 60s
Char2+U<5	5. Char. point_value 1 (voltage value)	V	>= U<4–200* and >= U<Start–200*/ >= U<4–460* and >= U<Start–460*/ >= U<4–800* and >= U<Start–800*
Char2+U<5+t>	5. Char. point_value 2 (time value)	s	> U<4+t> - 60s
Char2+tR	Release time after voltage recovery 1	s	0.06 – 1.0
U1	Function of the 1st voltage element		U< = undervoltage U> = overvoltage
U1	Pick-up value for the 1st voltage element	V	1–200/1–460/4–800*
tU1 (U1+t>)	Tripping time for the 1st voltage element	s	0,04 - 290
U2	Function of the 2nd voltage element		U< = undervoltage U> = overvoltage
U2	Pick-up value of the 2nd voltage element	V	1–200/1–460/4–800*
tU2 (U2+t>)	Tripping time of the 2nd voltage element	s	0.04 - 290
U3	Function of the 3rd voltage element		U< = undervoltage U> = overvoltage
U3	Pick-up value of the 3rd voltage element	V	1–200/1–460/4–800*
tU3 (U3+t>)	Tripping time of the 3rd voltage element	s	0,04 - 290
T	Frequency measuring repetition in periods	periods	2 - 99
f_1	Pickup value for frequency element 1	Hz	30–70 or 40–80
t_{f1} (f_1+t>)	Tripping delay of the 1st frequency element	s	$t_{fmin.}$ -290
f_2	pickup value for frequency element 2	Hz	30–70 or 40–80
t_{f2} (f_2+t>)	Tripping delay of the 2nd frequency element	s	t_{fmin} -290
f_3	Pick-up value for frequency element 2	Hz	30–70 or 40–80
t_{f3} (f_3+t>)	Tripping delay of the 3rd frequency element	s	t_{fmin} -290
$\Delta\Theta$	Pick-up value for the vector surge function		2–22
1-3	Vector surge tripping logic		1Pha/3Pha
df	pickup value for rate of change of frequency (dt/dt) in	Hz/s	0.2 - 10
dt	measuring repetition for df/dt	periods	2 - 64
U_B	voltage threshold value for frequency and df/dt element	V	5-100/12—230/20–400
RS	Slave address of the serial interface		1 - 32
RS	**Baud-Rate of the serial interface		1200 - 9600
RS	**Parity check*		even/odd/no

* Dependent on the rated voltage Un=100V/Un=230V/Un=400V/Un=690V

** Only at Modbus protocol

3.2.3 Parameter related to the fault recorder

Setting parameter		Unit	Range
FR	Number of records		1 x 20/1 x 16.66* 1 x 10/1 x 8.33 2 x 10/2 x 8.33 3 x 5/3 x 4.11 4 x 5/4 x 4.11 7 x 2.5/7 x 2.04 8 x 2.5/8 x 2.04
FR	Storage of record, in case of event		P_UP = with excitation TRIP = with trip A_PI = stop of all failures TEST = test record
FR	Period before trigger event	s	0.05s – maximal recording time

**50Hz or 60Hz*
Table 3.1: Parameter setting

3.3 LEDs

All LEDs (except LED FR, P2 and RS, min. and max.) are two-coloured. The LEDs on the left side, next to the alphanumerical display light up green during measuring and red during fault message.

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 parameterising 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.

The LED marked with the letters FR is alight while the fault recorder is being adjusted.

3.4 Front plate

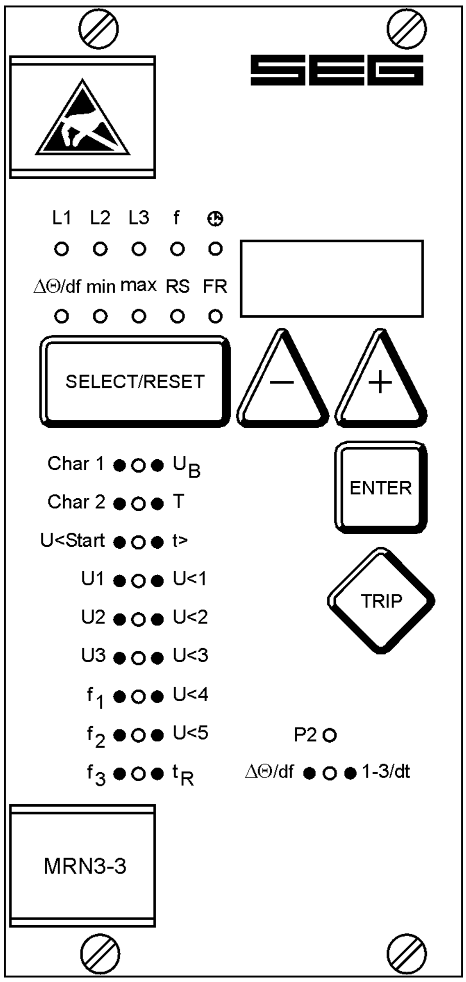

Figure 3.4: Front plate ***MRN3-3***

4 Working Principle

4.1 Analogue circuits

The input voltages are galvanically isolated by the input transformers. The noise signals caused by inductive and capacitive coupling are suppressed by an analogue R-C filter circuit.

The analogue voltage signals are fed to the A/D-converter of the microprocessor and transformed to digital signals through Sample- and Hold- circuits. The analogue 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 ***MRN3-3*** relay is a powerful microcontroller. All of the operations, from the analogue 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 occurred 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 supervision element of ***MRN3-3*** is used to protect generators, consumers and other electrical equipment from over-/and undervoltage.
The relay is equipped with a 3-step voltage supervision unit with pre-selectable under- or over voltage function 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 of 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.

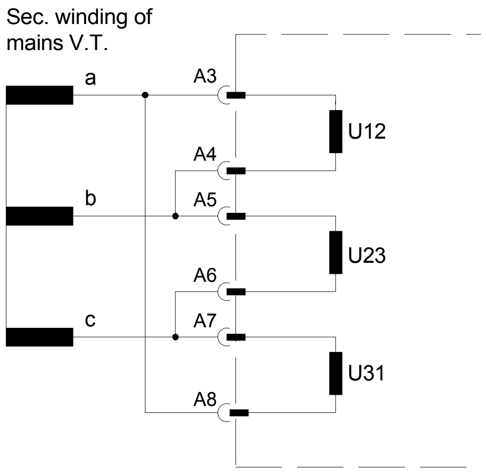

Figure 4.1: Input v.t.s in delta connection (Δ)

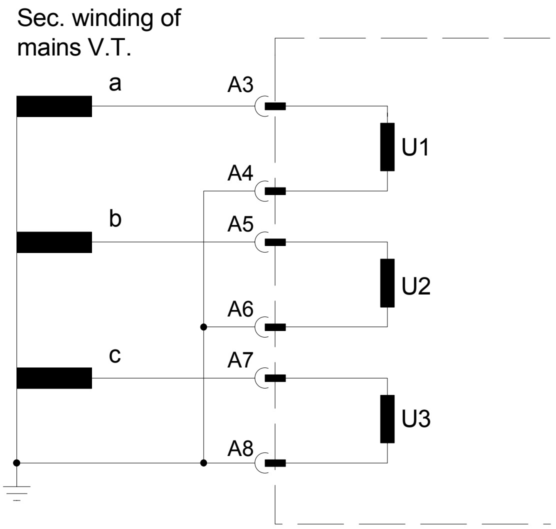

Figure 4.2: Input v.t.s in star connection (Y)

4.4 Principle of frequency supervision

The frequency element of *MRN3-3* protects electrical generators, consumers or electrical operating equipment in general against over- or underfrequency.
The relay has three independent frequency elements f_1 - f_3 with individually adjustable parameters with separate adjustable pickup values and delay times.

The measuring principle of the frequency supervision is based in general 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.

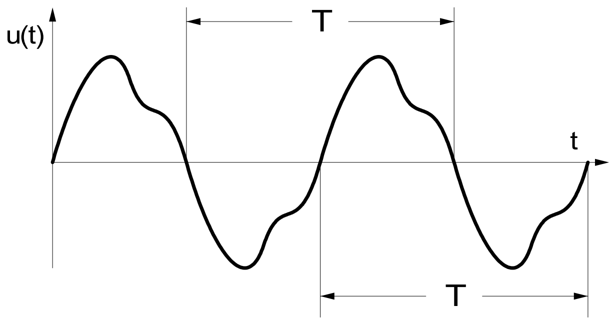

Figure 4.3: Determination of cycle duration by means of zero passages.

In order to avoid false tripping during occurrence of interference voltages and phase shifts the relay works with an adjustable measuring repetition. (refer to chapter 5.4.6)

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 voltages value is below this value.

4.5 Measuring of frequency gradient

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 in case of asynchronous mains voltage recovering, 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 *MRN3-3* 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 stability 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

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 isolated 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 just required to operate 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 reason 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, as well, are partially unsuitable because only a highly loaded generator measurably decreases its speed within 100 ms. Current relays detect a fault only when short-circuit type currents exist, but cannot avoid their development. Rate of change of power supervision 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 rate of change of power supervision can be problematic.

The *MRN3-3* detects mains failures within 60 ms without the restrictions described above because it was 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 supervision unit is a change in load of at least 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 5.4.10). 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, *MRN3-3* should be connected separately to the busbar.

4.7 Measuring principle of vector surge supervision

When a synchronous generator is loaded, a rotor displacement angle is build between the terminal voltage (mains voltage) U1 and the synchronous internal voltage (Up). Therefore a voltage difference ΔU is built between Up and U1 (Fig. 4.4).

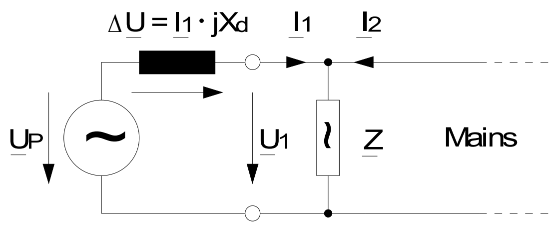

Figure 4.4: Equivalent circuit at synchronous generator in parallel with the mains

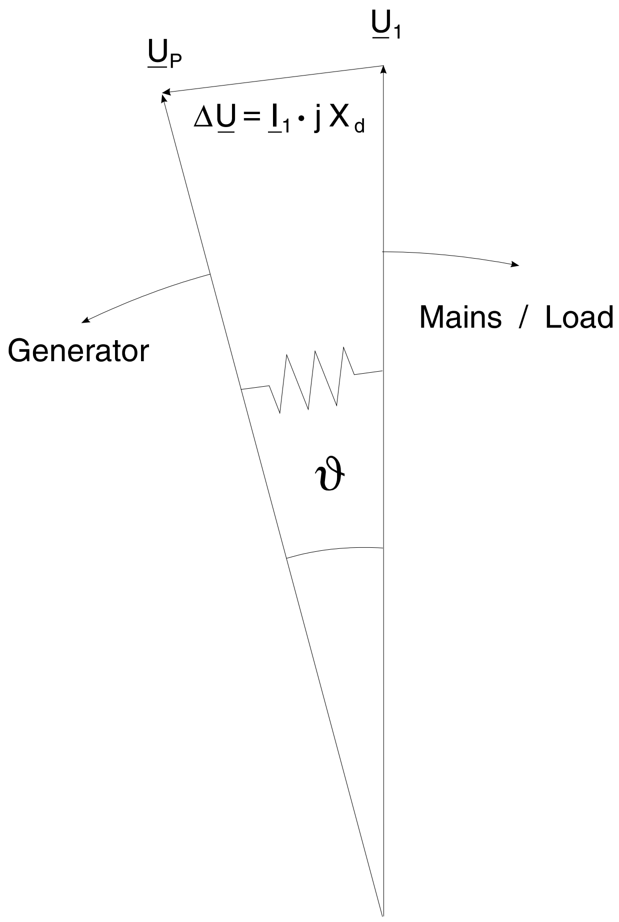

Figure 4.5: Voltage vectors at mains parallel operation

The rotor displacement angle ϑ between stator and rotor is depending 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 is maintained constant (Fig. 4.5).

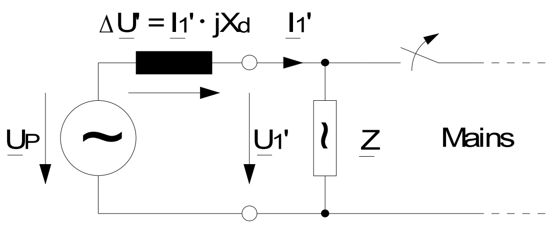

Figure 4.6: Equivalent circuit at mains failure

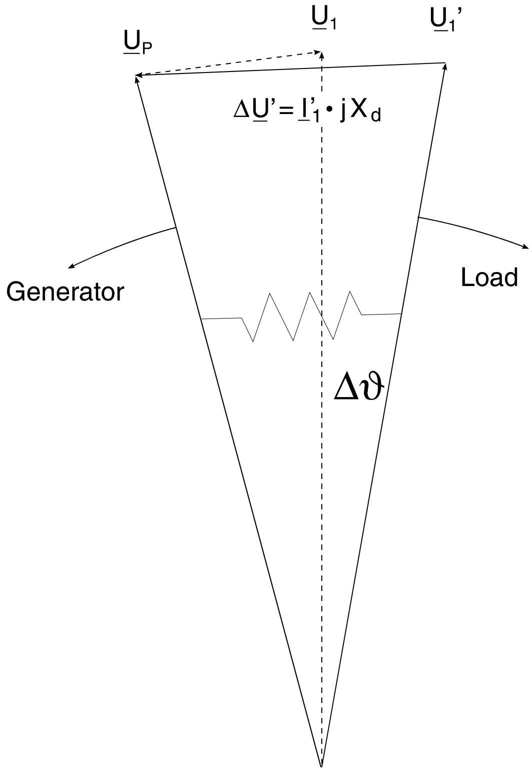

Figure 4.7: Change of the rotor displacement angle at sudden generator load

In case of mains failure or auto re-closing the generator suddenly feeds a very high consumer load. The rotor displacement angle suddenly increases and the voltage vector $\underline{U}_1$ changes its direction ($\underline{U}_1$') (Fig. 4.6 and 4.7).

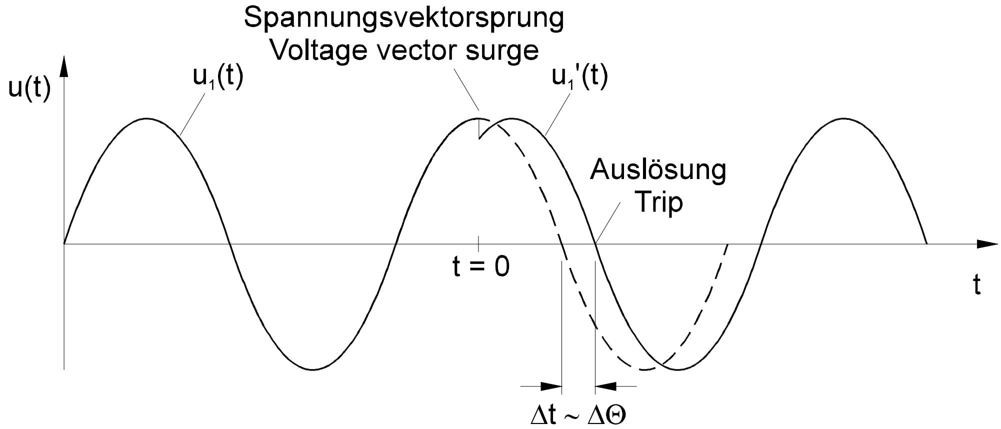

Figure 4.8: Voltage vector surge

As shown in the 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 *MRN3-3* 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 *MRN3-3* supervises vector surges in all three phases at the same time. Tripping of the relay can be adjusted for an 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 lopping 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 to design the load regulation at the utility connection point as to guarantee a minimum power flow of 15 - 20% of the generators' 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. Thus, 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.

4.8 Voltage threshold value for frequency- df/dt measuring

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

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

4.9 Blocking function

No.	Dynamic Behaviour	U</<<	U>/>>	f_1, f_2, f_3	ΔΘ	df/dt
1	voltage to external blocking input is applied	can be set acc. to requirement	can be set acc. to requirement	can be set acc. to requirement	can be set acc. to requirement	can be set acc. to requirement
2	blocking input is released	Instantaneously released	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 5s	blocked for 1 s
4	3ph measuring volt. is suddenly applied	released	released	blocked for 1 s	blocked for 5s	blocked for 5 s
5	one or several measuring voltages are suddenly switched off (phase failure)	released	released	blocked	blocked	blocked
6	measuring voltage smaller U_B< (adjustable voltage threshold value)	released	released	blocked		blocked

*Table 4.1: Dynamic behaviour of **MRN3-3** functions*

Blocking function set according to requirements:

The *MRN3-3* 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 5.7.1).

5 Operation and Settings

5.1 Display

Function	Display shows	Pressed pushbutton	Corresponding LED
Normal operation	|SEG		
Measured operating values	Actual measured value Min. and max. values of voltage, frequency and vector surge and df/dt	<SELECT/RESET> one time for each value	L1, L2, L3, f, min, max $\Delta\Theta$/df
Transformer ratio of the CT's	(SEK) 1.01–6500=prim	<SELECT/RESET><+><->	L1, L2, L3
Setting values: star/delta connection	Y/DELT	<SELECT/RESET><+><->	Δ/Y
Selection vector surge or df/dt	dPhi/dfdt	<SELECT/RESET><+><->	$\Delta\Theta$/df
Parameter set change-over switch/ext. triggering of FR	SET1, SET2, B_S2, R_S2, B_FR, R_FR, S2_FR	<SELECT/RESET><+><->	P2
Switch-over LED flash No LED flash	FLSH NOFL	<SELECT/RESET><+><->	
Starting point of the limit curve 1	Setting value in Volt	<SELECT/RESET><+> <-> one time for each value	Char1+U<Start
Selection symmetrical, asymmetrical or general fault	SYM/ASYM/ALL	<SELECT/RESET><+><->	Char1
Under voltage limit curve 1 Function	warn/trip	<SELECT/RESET><+><->	Char1
1. Char. point_value 1 (U<1) 1. Char. point_value_2	Setting value in Volt Setting value in seconds	<SELECT/RESET><+><-> set to 0s (fixed)	Char1+U<1
2. Char. point_value 1 (U<2) 2. Char. point_value_2 (tU<2)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char1+U<2 Char1+U<2+t>
3. Char. point_value 1 (U<3) 3. Char. point_value_2 (tU<3)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char1+U<3 Char1+U<3+t>
4. Char. point_value 1 (U<4) 4. Char. point_value_2 (tU<4)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char1+U<4 Char1+U<4+t>
5. Char. point_value 1 (U<5) 5. Char. point_value_2 (tU<5)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char1+U<5 Char1+U<5+t>
Permissible release time for undervoltage limit curve 1	Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char1+tR
Starting point of the limit. curve 2	Setting value in Volt	<SELECT/RESET><+><-> one time for each value	Char2+U<Start
Selection symmetrical, asymmetrical or general fault	SYM/ASYM/ALL	<SELECT/RESET><+><->	Char2
Under voltage limit curve 2 Function	warn/trip	<SELECT/RESET><+><->	Char2
1. Char. point_value 1 (U<1) 1. Char. point_value_2	Setting value in Volt Setting value in seconds	<SELECT/RESET><+><-> set to 0s (fixed)	Char2+U<1
2. Char. point_value 1 (U<2) 2. Char. point_value_2 (tU<2)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char2+U<2 Char2+U<2+t>
3. Char. point_value 1 (U<3) 3. Char. point_value_2 (tU<3)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char2+U<3 Char2+U<3+t>
4. Char. point_value 1 (U<4) 4. Char. point_value_2 (tU<4)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char2+U<4 Char2+U<4+t>
5. Char. point_value 1 (U<5) 5. Char. point_value_2 (tU<5)	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char2+U<5 Char2+U<5+t>
Permissible release time for undervoltage limit curve 1	Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	Char2+tR
Function of the 1st voltage element	U</U>	<SELECT/RESET><+><->	U1
Voltage threshold value U1 Tripping time delay tU1	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	U1 U1+t>
Function of the 2nd voltage element	U</U>	<SELECT/RESET><+><->	U2
Voltage threshold value U2 Tripping time delay tU2	Setting value in Volt Setting value in seconds	<SELECT/RESET><+> <-> one time for each value	U2 U2+t>
Function of the 3rd voltage element	U</U>	<SELECT/RESET><+><->	U3

Function	Display shows	Pressed pushbutton	Corresponding LED
Voltage threshold value U1 Tripping time delay tU1	Setting value in volt Setting value in seconds	<SELECT/RESET> <+> <-> one time for each value	U3 U3+t>
rated frequency	setting value in Hz	<SELECT/RESET><+><->	f_N
frequency measuring repitition	setting value	<SELECT/RESET><+><->	T
frequency element f_1 tripping delay of frequency element f_1	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_1 f_1+t>
frequency element f_2 tripping delay of frequency element f_2	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_2 f_2+t>
frequency element f_3 tripping delay of frequency element f_3	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	F_2 f_3+t>
1-OFF-3/3-OFF-3 Vector surge tripping	1Ph/3Ph	<SELECT/RESET><+><->	1-3/dt
Pick-up value for Vector surge	Setting value in degree	<SELECT/RESET><+><->	ΔΘ/df
df/dt pick-up value df/dt measuring repetition	Setting value in Hz/s Setting value in cycle	<SELECT/RESET><+><-> one time for each value	ΔΘ/df 1-3/dt
Blocking	EXIT	<+> until max. setting value	LED of blocked parameter
Blocking of a protection step via digital input	BLOC/NO_B	<SELECT/RESET><+><->	LED of the blocking protection function
Relay assignment	_ _ _ _ / 1_ _ _ 1 2 3 4	<SELECT/RESET><+><->	LED of the assigned protective function
Voltage threshold value for the frequency, vector surge and df/dt measurement	setting value in Volt	<SELECT/RESET><+><->	f, ΔΘ, df
Slave address of serial interface	1 - 32	<SELECT/RESET><+><->	RS
Baud-Rate [1)]	1200-9600	<SELECT/RESET> <+><->	RS
Parity-Check [1)]	even odd no	<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, U1, U2, U3
delta-connection: U12, U23, U31	tripping values in Volt	<SELECT/RESET><+><-> one time for each phase	L1, L2, L3, U1, U2, U3
frequency	tripping values in Hz	<SELECT/RESET><+><-> one time for each phase	f, f_1, f_2, f_3, f_{min}, f_{max}
rate of change of frequency	tripping value in Hz/s	<SELECT/RESET><+><->	ΔΘ/df
Vector surge angle at tripping	tripping value in degree	<SELECT/RESET><+><->	ΔΘ + L1, L2 or L3
Enquiry failure memory	FLT1; FLT2…..	<-><+>	L1, L2, L3, U1, U2, U3, f_1, f_2, f_3, ΔΘ/df
Save parameter?	SAV?	<ENTER>	
Save parameter!	SAV!	<ENTER> for about 3 s	
Trigger signal for the fault recorder	TEST, P_UP, A_PI, TRIP	<SELECT/RESET> <+><->	FR
Number of fault occurrences at 50 Hz	1=20; 2=10; 3=5; 4=5; 7=2; 8=2	<SELECT/RESET> <+><->	FR
Number of fault occurrences at 60 Hz	1=16; 2=8; 3=4; 4=4; 7=2; 8=2	<SELECT/RESET> <+><->	FR
Display of date and time	Y=99, M=10, D=1, h=12, m=2, s=12	<SELECT/RESET> <+><->	◷
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	⎮SEG	<SELECT/RESET> for about 3 s	

[1)] *only Modbus*

Table 5.1: Possible indication messages on the display

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 (please refer to 4.4 of description "*MR*-Digital Multifunctional Relays").

5.3 System parameters

5.3.1 Display of residual voltage U_E as primary quantity (U_{prim}/U_{sec})

The residual voltage can be shown as primary measuring value. For this parameter the transformation ratio of the VT has to be set accordingly. If the parameter is set to "sec", the measuring value indicated on the display is shown as rated secondary voltage.

Example:
The voltage transformer used is of 10 kV/100 V. The transformation ratio is 100 and this value has to be set accordingly. If still the rated secondary voltage should be shown, the parameter is to be set to 1.

5.3.2 Δ/Y – Switch over

Depending on the mains voltage conditions, the input voltage transformers can be operated in delta or Y connection. The appropriate made can be selected via the <+> and the <-> keys and it is stored with <ENTER>.

5.3.3 Setting of nominal frequency

For proper functioning it is necessary to first adjust the rated frequency (50 or 60 Hz).

For this a distinction has to be made between the settings v = 50 Hz/f = 50 Hz or v = 60 Hz/f = 60 Hz The difference lies in the method of voltage measuring. With the setting "v" = 50/60 Hz voltage measuring is independent of the existing frequency. This means, the voltage value can be correctly measured between 30 Hz and 80 Hz without adverse effects from the frequency.

With the setting "f" = 50/60 Hz the measured voltage value is influenced by the frequency (see table 5.2).

This difference in settings is required for the fault recorder. If the fault recorder is to be used, the setting must be f = 50 Hz or f = 60 Hz.
The different designations "f" or "v" have no influence on any of the other functions.

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 5.4.4). 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 5.4.5).
During setting of the nominal frequency a value in Hz is shown on the display.

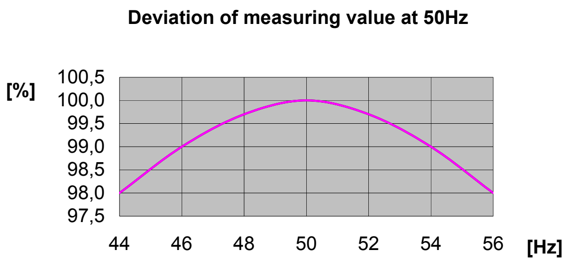

Figure 5.1: Median influence at f = 50 Hz

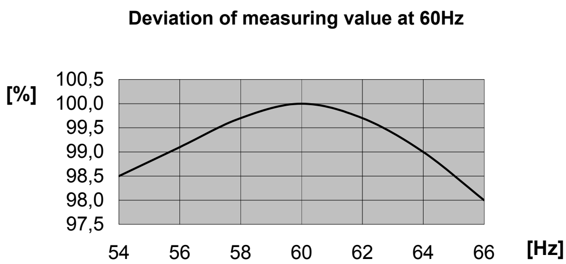

Figure 5.2: Median influence at f = 60 Hz

Setting	v = 50	f = 50	v = 60	f = 60
Rated frequency	50 Hz	50 Hz	60 Hz	60 Hz
Influence on voltage measurement	none	0.5..1%/Hz (see figure 5.1)	none	0.5..1%/Hz (see figure 5.2)
Fault recorder	Recording distorted**	Recording correct***	Recording distorted**	Recording correct***
Influence on all other functions	none	none	none	none

Table 5.2: Deviation of measured value at 50 Hz or 60 Hz

* Setting is important for differentiation between over- and underfrequency
** Sample rate is variably adjusted to the momentarily measured frequency. 16 samples are always measured in one period.
*** Sample rate setting is fixed to 50 Hz or 60 Hz. 16 samples per 20 ms or 16.67 ms are always measured.

5.3.4 Display of the activation storage (FLSH/NOFL)

If after an activation the existing current drops again below the pickup value, e.g. U1 (provided, this step was parameterised as under voltage step), without a trip has been initiated, LED U< signals that an activation has occurred by flashing fast. The LED keeps flashing until it is reset again (push button <RESET>). Flashing can be suppressed when the parameter is set to NOFL.

5.3.5 Parameterswitch/external trigger for the fault recorder

By means of the parameter-change-over switches it is possible to activate two different parameter sets. Switching over of the parameter sets can either be done by means of software or via the external inputs RESET or blocking input. Alternatively, the external inputs can be used for Reset or blocking and for the triggering of the fault recorder.

Software-parameter	Blocking input used as	RESET input used as
SET1	Blocking input	RESET input
SET2	Blocking input	RESET input
B_S2	Parameter switch	RESET input
R_S2	Blocking input	Parameter set switch
B_FR	External triggering of the fault recorder	Reset input
R_FR	Blocking input	External triggering of the fault recorder
S2_FR	Parameter switch	External triggering of the fault recorder

Figure 5.3: Function of digital inputs

With the settings SET1 or SET2 the parameter set is activated by software. Terminals C8/D8 and D8/E8 are then available as external reset input or blocking input.

With the setting B_S2 the blocking input (D8, E8) is used as parameter-set change-over switch. With the setting R_S2 the reset input (D8, E8) is used as parameter-set change-over switch. With the setting B_FR the fault recorder is activated immediately by using the blocking input. On the front plate the LED FR will then light up for the duration of the recording. With the setting R_FR the fault recorder is activated via the reset input. With the setting S2_FR parameter set 2 can be activated via the blocking input and/or the fault recorder via the reset input. The relevant function is then activated by applying the auxiliary voltage to one of the external inputs.

With the setting R_FR the fault recorder is activated via the reset input. With the setting S2_FR parameter set 2 can be activated via the blocking input and/or the fault recorder via the reset input.
The relevant function is then activated by applying the auxiliary voltage to one of the external inputs.

Important note:
When functioning as parameter change over facility, the external input RESET is not available for resetting. When using the external input BLOCKING the protection functions must be deactivated by software blocking separately (refer to chapter 5.7.1).

5.4 Protection parameter

5.4.1 Setting parameters for under voltage characteristics

For the under voltage detection, the ***MRN3-3*** has two under voltage characteristics (limit curves) that can be independently set and that each provide 5 characteristic definition points. All individual setting points are defined by two parameters: one voltage value (1) (in Volt) and a time-value (2) (in seconds).
Both characteristics can be optionally defined to either provide a warning or a tripping function. The difference lies in the varying display indication. In case of warning, the display retains unchanged, for tripping, the abbreviation « TRIP » will be indicated.
For characteristic setting point 1, only the value 1, i.e. the voltage will be adjusted since excitation of the step always starts as soon as the failure occurs. A fault incident is detected when the voltage is below the threshold value U<start and it will be stopped as soon as the voltage range U<5 had been exceeded.

At the moment when the voltage falls below the threshold value U<start, the ***MRN3-3*** will initiate the tripping timer. The present voltage is compared with the adjusted characteristic after expiry of each one measuring cycle*. If the voltage at time x is below the appropriate characteristic value, the ***MRN3-3*** relay will trip. When the U<Start parameter is set to EXIT, the characteristic is out of service and all relevant setting values will be faded out.

* One measuring cycle is 20 ms at 50 Hz and it takes 16.66 ms at 60 Hz.

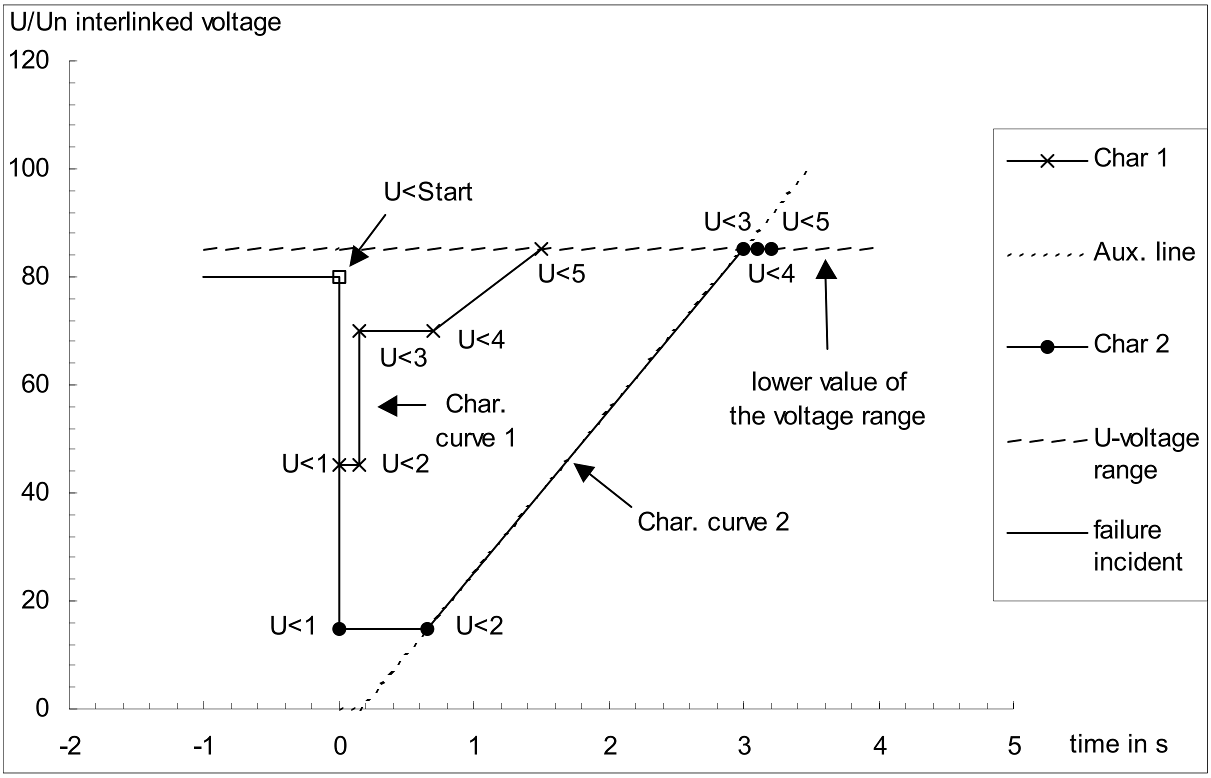

Figure 5.4: Trend of two-characteristics

5.4.2 SYMmetrical, ASYMmetrical or GENEral faults*

Besides the warning and tripping function the U-characteristic has a further special feature. As for the tripping criterion it can be selected whether the characteristic should react to a symmetrical an asymmetrical or a general fault. Thus it is possible to parameterize whether the fault should occur as a single-phase, two-phase or three-phase one. If the condition of the characteristic is not met, it will be blocked.

Symmetrical fault:
A symmetrical fault has occurred if all three phases are below the starting point.
Asymmetrical fault:
An asymmetrical fault has occurred if one or two phases are below the starting point.
General fault:
A general fault has occurred if one phase is below the starting point.

If the tripping time of one of the two characteristics has elapsed at the instant of a fault, then the *MRN3-3* decides what kind of fault it is.

Parameter settings:
SYM means symmetrical fault: If this function is assigned to an under-voltage characteristic and the *MRN3-3* detects an asymmetrical fault, then tripping of this characteristic will be blocked.
ASYM means asymmetrical fault: If this function is assigned to an under-voltage characteristic and the *MRN3-3* detects a symmetrical fault, then tripping will be blocked.
ALL means general fault: If this function is assigned to an under-voltage characteristic and the *MRN3-3* detects a fault, then the relay trips.

As soon as a voltage dip is recognized either as asymmetrical, or symmetrical or general fault it will be considered accordingly until it is switched off or has recovered automatically. When the voltage has recovered automatically it might happen that a symmetrical fault is detected as an asymmetrical one due to a slight time delay. But blocking of a characteristic is only neutralized when all three phases are above the U-voltage range and the tR time has elapsed. In case one, two or all three phases are dropping below the U- voltage range when the tR time is still running then the relay trips, provided the tripping conditions are met.

Example:
If a fault has been recognised as a symmetrical one, the relay trips only when within the tR time of the symmetrical characteristic all three phases drop below the threshold of the U-voltage range.

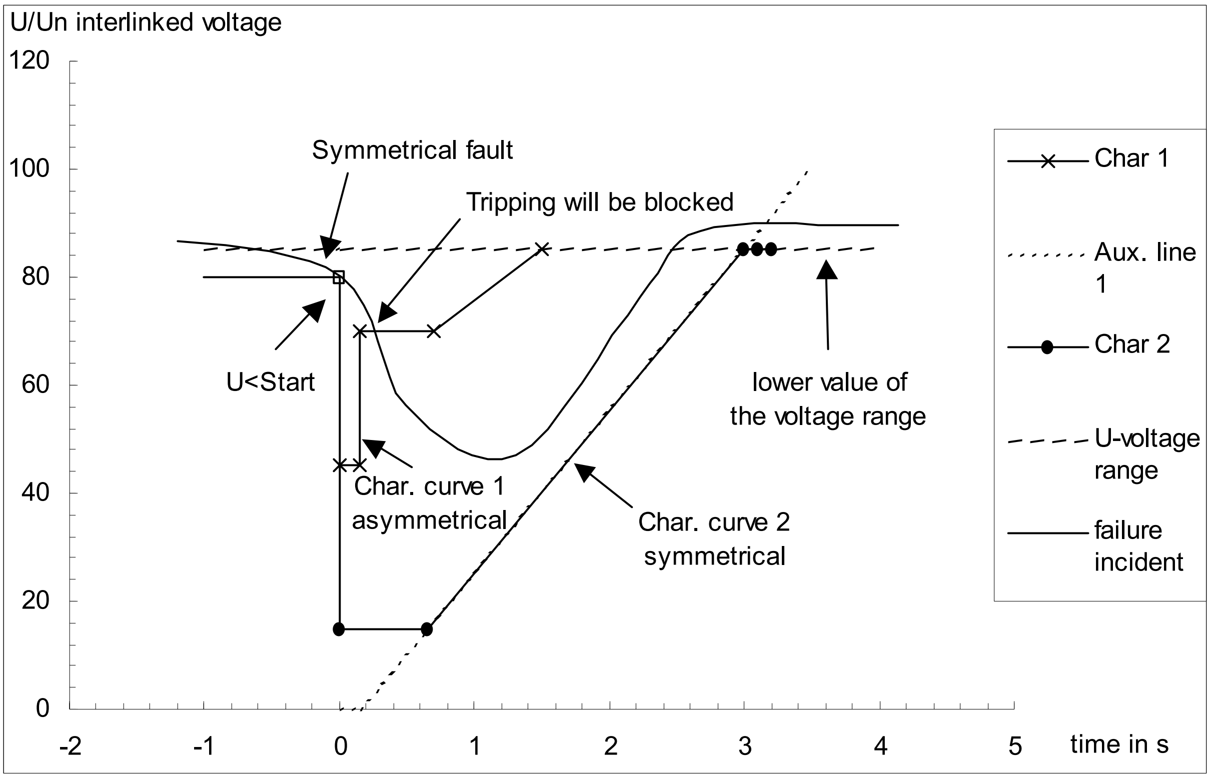

Figure 5.5: Possible voltage shape of a symmetrical fault

* GENEral, the display shows ALL See chapter 5.1

5.4.3 Permissible release time for the under voltage characteristic curve

The end of the failure incident is detected on condition that the voltage had been above the voltage range for at least the period of setting value t_R. The characteristic value calculation is interrupted then and any new falling below the starting threshold will be defined as a new failure incident. The adjustable value is indicated in green by LEDs Char1 or Char2 and value t_R marked accordingly, in red.

5.4.4 Plausibility check of the voltage characteristic

The setting points are not independent from each other. It is therefore recommended to parameterise them in ascending order, which, in fact, agrees with the unit's pre-adjusted parameter sequence. This, for example, means that follow-up times can only be higher than preceding ones. Voltage-related values, however, are depending on their function. If, for example, the factory set value of U<1 is higher than the value of U<Start that has to be adjusted, U<1 will automatically be set to the same value when U< is adjusted.
(See chapter 3.2.2: Order of parameter setting or chapter 7.3: Protection parameters.)

5.4.5 Parameter setting of the voltage functions

The function of the additional voltage elements is determined by means of a separately adjusted value, that either parameterizes the related function as overvoltage (U>) or as under voltage (U<). The adjustable parameters are indicated by LEDs flashing in two colors. When setting the voltage pick-up values U1, U2 and U3, the LEDs U1, U2 and U3 will flash in green, at setting of the related pick-up delay times t_{U1}, t_{U2} and t_{U3}, the LED t> additionally flashes in red.

Pick-up values of the voltage supervision
When adjusting the pick-up values U1, U2 and U3, the values on the display are indicated in Volt. By setting the pick-up values to "EXIT", each individual step can be deactivated.

Tripping delay of the voltage supervision
When adjusting the tripping delay time tU1 (U1+t>), tU2 (U2+t>) and tU3 (U3+t>), the value on the display is indicated in seconds. The tripping delay time can be adjusted from 0.04s to 290s and the set values be stored via push-button <ENTER>.

When the tripping delay time was set to "EXIT", it is indefinite, i.e. there will be warning only, no tripping.

5.4.6 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, *MRN3* 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.

5.4.7 Threshold of the frequency supervision

The frequency supervision of *MRN3* has three frequency elements independent from each other. Acc. to setting the pickup value above or below the nominal frequency, these elements can be used for over- or under frequency supervision.

Dependent on the preset nominal frequency f_N the pickup values from 30 Hz up to 70 Hz at f_N = 50 Hz and from 40 Hz to 80 Hz at f_N = 60 Hz can be set. During setting of the pickup values f_1 - f_3 the display shows the values in Hz. A value of for instance 49,8 Hz is indicated with "4980".

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 f_N.

5.4.8 Tripping delays for the frequency elements

Tripping delays t_{f1} - t_{f3} of the three frequency elements can be set independently from t_{f1min} - 290 s. The minimum tripping delay t_{f1min} of the relay depends upon the number of set measuring repetitions T (periods) and amounts to:

T	$t_{f,min}$
2….49	(T+1)·20 ms
50….69	(T - 49)·50 ms + 1 s
70….99	(T - 69)·100 ms + 2 s

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 assigned alarm relay is also activated. This setting applies to 50 Hz and 60 Hz.

5.4.9 Parameter setting of vector surge supervision or frequency rate of change df/dt

By the parameter for selecting the vector surge function or df/dt supervision it is defined which of the two functions is active. (See chapter 4.5 and 4.6)

Parameter setting of the vector surge supervision
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 high performance mains with low impedance 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, however, this value is considerably exceeded. In high impedance mains the setting should be 10° to 12° to avoid false 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.

Threshold for the vector surge supervision
When the pickup value of the vector surge supervision is set, a value in angular degree is indicated at the display. The pickup value requested can be adjusted by pushbuttons <+> and <-> in the range of 2° to 22°. LED $\Delta\Theta$ lights up red during this procedure.

Parameter setting for the frequency rate change
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:

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

with
f_N = rated frequency in Hz
T_A = inertia constant at rated torque
ΔP = per unit power deficit with reference to the rated active power of the generator

If the inertia constant is known and a power difference given, the frequency gradient can be estimated by the a.m. 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.

5.4.10 Voltage threshold value for frequency and vector surge measuring (df/dt)

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 *MRN3-3* 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 U_B< LEDs f and ΔΘ or df light up in the upper display part.

5.4.11 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 in the upper display part.

5.4.12 Setting of Baud-rate (applies for Modbus Protocol only)

Different transmission rates (Baud rate) can be set for data transmission via Modbus Protocol.
The rate can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

5.4.13 Setting of parity (applies for Modbus Protocol only)

The following three parity settings are possible :

- "even" = even
- "odd" = odd
- "no" = no parity check

The setting can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

5.5 Adjustment of the fault recorder

The *MRN3-3* is equipped with a fault recorder (see chapter 3.1.5). Three parameters can be determined.

5.5.1 Number of the fault recordings

The max. recording time is 20 s at 50 Hz or 16.66 s at 60 Hz.
The number of max. recordings requested has to be determined in advance. There is a choice of 1, 2, 3, 4, 7 or 8 recordings and dependent on this the duration of the individual fault recordings is defined, i.e.

1 recording for a duration of 20 s (with 50 Hz)
(16.66 s with 60 Hz)
1*/2 recordings for a duration of 10s (with 50 Hz)
(8.33s with 60 Hz)
3*/4 recordings for a duration of 5 s (with 50 Hz)
(4.16 s with 60 Hz)
7*/8 recordings for a duration of 2.5 s (with 50 Hz)
(2,08 s with 60 Hz)

* is written over when a new trigger signal arrives

If the respective partition was defined as not being overwriteable and the maximal number of recorded disturbance events was assigned, the LED FR starts flashing (refer to chapters 3.1.5 and 5.9.3).

Caution:
If the fault recorder is used, the frequency should be set to f = 50 Hz or f = 60 Hz (see chapter 5.3.3).

5.5.2 Adjustment of trigger occurences

There is a choice between four different occurrences:

P_UP (PickUP)	Storage is initiated after recognition of a general activation.
TRIP	Storage is initiated after a trip has occurred.
A_PI (After Pickup)	Storage is initiated after the last activation threshold was fallen short of.
TEST	Storing is immediately activated by simultaneous actuation of the keys <+> and <->. During the recording time the display shows "Test".

5.5.3 Pre-trigger time (T_{pre})

By the time T_{pre} it is determined which period of time prior to the trigger occurrence should be stored as well. It is possible to adjust a time between 0.05s and the max. recording interval (2.5; 4,5; 10 or 20s with 50 Hz and 2.08; 4.16; 8.33 or 16.33 s with 60 Hz). With keys <+> and <-> the values can be changed and with <ENTER> be saved.

5.6 Adjustment of the clock

When adjusting the date and time, LED 🕒 lights up. The adjustment method is as follows:

Date :	Year	Y=00
	Month	M=00
	Day	D=00
Time :	Hour	h=00
	Minute	m=00
	Second	s=00

The clock starts with the set date and time as soon as the supply voltage is switched on. The time is safe-guarded against short-term voltage failures (min. 6 minutes).

Note:
The window for parameter setting is located behind the measured value display. The parameter window can be accessed via the <SELECT/RESET> key.

5.7 Additional functions

5.7.1 Setting procedure for blocking of the protection functions and assignment of output relays

The blocking function of the *MRN3-3* 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 Char1 lights green.
- 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.
- If the <SELECT/RESET> key is actuated again, the blocking menu is left and the assignment mode is accessed.

Function	Description	Display	LED
Char1	Undervoltage step 1	BLOC	green
Char2	Undervoltage step 2	BLOC	green
U1	Voltage step 1	BLOC	green
U2	Voltage step 2	NO_B	green
U3	Voltage step 3	NO_B	green
f1	Frequency step 1	BLOC	green
f2	Frequency step 2	BLOC	green
f3	Frequency step 3	NO_B	green
$\Delta\Theta$	Vector surge	BLOC	green
df/dt	Frequency changing rate	BLOC	green

Table 5.3: Blocking function for two parameter sets

Assignment of the output relays:
Unit *MRN3-3* has five output relays. The fifth output relay is provided as permanent alarm relay for self supervision and it is normally on. Output relays 1 - 4 are normally off and can be assigned as alarm or tripping relays to the protection functions which can either be done by using the push buttons on the front plate or via serial interface RS485. The assignment of the output relays is similar to the setting of parameters, however, only in the assignment mode.

The assignment mode can be reached only via the blocking mode.
By pressing push button <SELECT/RESET> in blocking mode again, the assignment mode is selected.

The LEDs Char1, Char2, U1, U2, U3, f1, f2, f3 and $\Delta\Theta$/df light up **green** when the output relays are assigned as **alarm relays** and LED t> **red** as **tripping relays**.

Definition:
Alarm relays are activated at pickup.
Tripping relays are only activated after elapse of the tripping delay.

After the assignment mode has been activated, first LED Char1 lights up green. Now one or several of the four output relays can be assigned to under voltage characteristic 1 as alarm relays. At the same time the selected alarm relays for under voltage characteristic 1 are indicated on the display. Indication "1_ _ _" means that output relay 1 is assigned to this step. When the display shows "_ _ _ _", no alarm relay is assigned to this under voltage element. The assignment of output relays 1 - 4 to the current elements can be changed by pressing <+> and <-> push buttons. The selected assignment can be stored by pressing push button <ENTER> and subsequent entry of the password. By pressing push button <SELECT/RESET>, LED Char1 lights up green and t> lights up red. The output relays can now be assigned to this element as tripping relays.

Relays 1 - 4 are selected in the same way as described before. By repeatedly pressing of the <SELECT/RESET> push button and assignment of the relays all elements can be assigned separately to the relays. The assignment mode can be terminated at any time by pressing the <SELECT/RESET> push button for some time (approx. 3 s).

Note:
- The function of jumper J2 described in general description "MR Digital Multifunctional Relays" does not apply for *MRN3-3*. For relays without assignment mode this jumper is used for parameter setting of alarm relays (activation at pickup or tripping).

A form is attached to this description where the setting requested by the customer can be filled-in. This form is prepared for telefax transmission and can be used for your own reference as well as for telephone queries.

Relay function		Output relays 1	2	3	4	Display-Indication	Corresponding LED
Char1	cycle running					_ _ _ _	Char1 green
Char1	tripping/warning		X			_ 2 _ _	Char1 green t> red
Char2	cycle running			X		_ _ 3 _	Char2 green
Char2	tripping/warning	X				1 _ _ _	Char2 green t> red
U1	alarm				X	_ _ _ 4	U1 green
U1+t>	tripping	X				1 _ _ _	U1 green t> red
U2	alarm				X	_ _ _ 4	U2 green
U2+t>	tripping	X				1 _ _ _	U2 green t> red
U3	alarm				X	_ _ _ 4	U3 green
U3+t>	tripping	X				1 _ _ _	U3 green t> red
f1	alarm				X	_ _ _ 4	f1 green
tf1	tripping	X				1 _ _ _	f1 green t> red
f2	alarm				X	_ _ _ 4	f2 green
tf2	tripping	X				1 _ _ _	f2 green t> red
f3	alarm				X	_ _ _ 4	f3 green
tf3	tripping	X				1 _ _ _	f3 green t> red
ΔΘ	tripping					1 _ _ _	ΔΘ/df green
df/dt	tripping	X				1 _ _ _	ΔΘ/df green

Table 5.3: Example of assignment matrix of the output relays (default settings).

5.8 Indication of measuring and fault values

5.8.1 Measuring indication

In normal operation the following measuring values can be displayed.

- Voltages (LED L1, L2, L3 green)
- All phase-to-neutral voltages in star connection
- All phase-to-phase voltages in delta connection
- Frequency (LED f green)
- Vector surge in all three phases (LED ΔΘ/df green + L1, L2, or L3 green) or
- Frequency change df/dt (LED df green)

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

- Frequency (LED f + min or f + max)
- Vector surge(LED ΔΘ/df + min or df/ΔΘ + max) or
- Frequency change(LED ΔΘ/df + min or ΔΘ/df + max).

5.8.2 Min./Max.- values

The *MRN3-3* 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 mains quality. Always the highest and lowest values of each cycle are measured and stored until the next reset.

Min./max. frequency measuring:
The *MRN3-3* 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 T 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.
* Reset function see chapter 5.9.1

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

Min./max. vector surge measuring :
The procedure described above applies also to storage of min./max. values of vector surge measuring. Since each instantaneous ΔΘ 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.

As to operation :
After each reset (ref. 5.9.1) the min./max. storage units are cleared. As from this instant there is no time limit for the min./max. storage until the next reset.
By repeatedly pressing the <SELECT/RESET> push button, the measuring values of the min./max. storage can be queried. The respective LEDs light up at the same time; e.g. during minimum frequency is displayed, LEDs "f" and "min" light up.

5.8.3 Unit of the measuring values displayed

The measuring values can optionally be shown in the display as a multiple of the "sec" rated value (x In) or as primary current (A). According to this the units of the display change as follows:

Indication as	Range	Unit
sec. voltage	000V – 999V	V
primary voltage	.000 – 999V 1K00 – 9K99 10K0 – 99K9 100K – 999K 1M00 – 3M00	V KV KV KV MV

Table 5.5: Displayed units

5.8.4 Indication of fault data

All faults detected by the relay are indicated on the front plate optically. For this purpose, the four LEDs (L1, L2, L3, f) and the four function LEDs (U1,U2,U3, f1, f2, f3 und df/dt) are equipped at *MRN3-3*. Not only fault messages are transmitted, the display also indicates the tripped protection function. If, for example an overcurrent occurs, first the respective phase LED will light up and also, for example LED U1, provided, this step was previously parameterised as over voltage function. After tripping the LEDs are lit permanently.

5.9 Fault memory

When the relay is energized or trips, all fault data and times are stored in a non-volatile memory manner. The *MRN3-3* is provided with a fault value recorder for max. three fault occurrences. In the event of additional trippings always the oldest data set is written over.

For fault indication not only the trip values are recorded but also the status of LEDs. Fault values are indicated when push buttons <-> or <+> are pressed during normal measuring value indication.

- Normal measuring values are selected by pressing the <SELECT/RESET> button.
- When then the <-> button is pressed, the latest fault data set is shown. By repeated pressing the <-> button the last but one fault data set is shown etc. For indication of fault data sets abbreviations FLT1, FLT2, FLT3, ... are displayed (FLT1 means the latest fault data set recorded). At the same time the parameter set that is active at the occurrence is shown.
- By pressing <SELECT/RESET> the fault measuring values can be scrolled.
- By pressing <+> it can be scrolled back to a more recent fault data set. At first FLT3, FLT2, ... are always displayed.
- When fault recording is indicated (FLT1 etc), the LEDs flash in compliance with the stored trip information, i.e. those LEDs which showed a continuous light when the fault occurred are now blinking to indicate that it is not a current fault. LEDs which were blinking during trip conditions, (element had picked up) just briefly flash.
- If the relay is still in trip condition and not yet reset (TRIP is still displayed), no measuring values can be shown.
- To delete the trip store, the push button combination <SELECT/RESET> and <->, has to be pressed for about 3s. The display shows "wait".

Recorded fault data:

Measuring	Displayed value	Corresponding LED
Voltage	L1; L2; L3; L1/L2; L2/L3; L3/L1	L1; L2; L3
Frequency	f; f min f max	f; min; max
Frequency changing rate	df	df
Vector surge	$\Delta\Theta$	$\Delta\Theta$/df
Time stamp Date: Time:	 Y = 99 M = 03 D = 10 h = 17 m = 21 s = 14	 ◷ ◷ ◷ ◷ ◷ ◷

5.9.1 Reset

All relays offer the following three possibilities to reset the display of the unit as well as the output relay at jumper position J3=ON.

Manual Reset
- By 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 (see also communication protocol of RS485 interface)

Automatical Reset
- At each excitation of a protection function

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.

5.9.2 Erasure of fault storage

To delete the trip store, the push button combination <SELECT/RESET> and <->, has to be pressed for about 3s. The display shows "wait".

5.9.3 Erasure of disturbance recorder

By repeated setting of the parameter "number of recorded events", it is possible to delete data of the disturbance recorder. The LED FR will then expire (refer to chapter 5.5.1).
Alternatively, it is also possible to clear the memory space of the disturbance recorder by means of the software "HTL/PL-Soft4".

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

NOTE!
Prior to switch on the auxiliary power supply, be sure that the auxiliary supply voltage corresponds to the rated data on the type plate.

Switch on the auxiliary power supply to the relay and check that the message "ISEG" 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 U1 light up red). In case that undervoltage condition has been detected after power-on, because no input voltages were applied to the relay. In this case:

- press the push button <ENTER>, thus entering into the setting mode. Now set the parameters for the under voltage characteristics Char1+U<1; Char2+U<1 and the pick-up value of the first voltage level U1 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.
- By means of an appropriate parameterisation, the under voltage function Char1 and Char2 as well as the parameterised voltage step U1 as under voltage step can be blocked (refer to 5.7.1). Apply auxiliary voltage to the external blocking input (terminals E8/D8) to inhibit the undervoltage functions and press the <SELECT/RESET> for app. 3 s to reset the LEDs and "TRIP" message.

6.2 Testing the output relays and LEDs

PLEASE 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 (e.g. „D07-“). By pressing the push button <TRIP> twice, the display shows the second part of the software version of the relay (e.g. „1.00“. 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 deenergised 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/RESET>, all relay set values may be checked. Set value modification can be done with the push button <+><-> and <ENTER>. For detailed information about that, please refer to chapter 4.3 of the description "MR – Digital multifunctional relays".

As relay input energizing quantities, three phase voltages should be applied to ***MRN3-3*** relay input circuits. Depending on the system conditions and the voltage transformer used, three voltages can be connected to the relay input circuits with either star or delta connection. In case of a star connection the phase-to-neutral voltage will be applied to the voltage input circuits, while the phase-to-phase voltages will be connected to the voltage input circuits in case of a delta connection. The voltage input connection must be set as a parameter, and should correspond with the actual voltage input connection:

Star connection:	Phase-to-neutral voltages will be measured and evaluated.
Delta connection:	Phase-to-phase voltages will be measured and evaluated.

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter and frequency meter with class 1 or better,
- auxiliary power supply with the voltage corresponding to the rated data indicated on the type plate,
- three-phase voltage supply unit with frequency regulation (Voltage: adjustable from 0 to 2 x U_N; Frequency: adjustable from 40 - 70 Hz),
- timer to measure the operating time (accuracy ±10 ms),
- switching device and
- Test leads and tools

6.5 Example of test circuit

For testing of the *MRN3-3* relay, a three phase voltage source with adjustable voltage and frequency is required. Figure 6.1 shows an example of a three-phase test circuit where three phase voltages are applied to the relay in Y-connection.

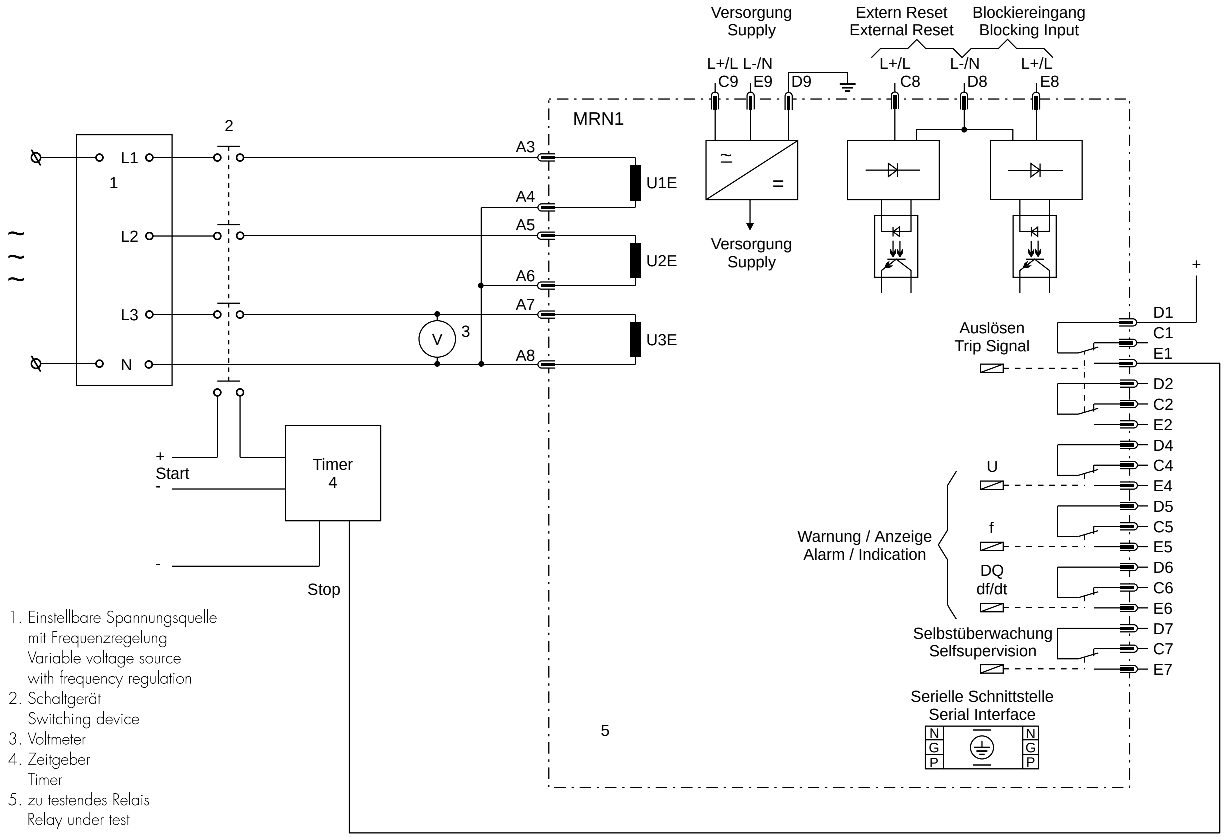

Figure 6.1: Three-phase test circuit

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 6.5.6).

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

6.5.1 Checking the input circuits and measuring values

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 or df/dt on the display by pressing the push button <SELECT/RESET> repeatedly. The displayed measuring voltages (shown in Volt) are dependent on the wiring of the input voltage converters and the set transformation ratio.

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 angle is indicated by lighting up of LED ΔΘ (Display in °) plus L1, L2 or L3.
The rate of change of frequency (LED df) is indicated on the display in Hz/s .

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 <0.01 Hz.

By using an RMS-metering instrument, a greater deviation may be observed if the test voltage contains harmonics. Because the ***MRN3-3*** 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.

6.5.2 Checking the operating and reset ting values of the over-/undervoltage functions

Note:
When the measuring voltage is connected or disconnected vector surge or df/dt tripping can occur. In order to ensure a trouble-free test procedure, vector surge 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 U1 (or U2) lights up or the voltage alarm output relay (contact terminals D4/E4) is activated.

(Ex-works default setting of U1 is under voltage; for U2 it is over voltage).

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 U1 (U2) is disengaged. Check that the dropout to pickup ratio for voltage is greater than 0.99 (for overvoltage function) or smaller than 1.01 (for undervoltage).

6.5.3 Checking the tripping delay of the over-/undervoltage functions

To check the tripping relay, a timer must be connected to the trip output relay contact (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.

6.5.4 Checking the operating and reset ting values of the over-/underfrequency functions

Note:
Due to frequency changes, vector surge or df/dt - tripping can occur during frequency tests. In order to ensure a trouble-free test procedure, the vector surge 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 energised. 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 0.01 Hz. 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.

6.5.5 Checking the tripping delay of the over-/underfrequency functions

The tripping delay of the over/underfrequency functions can be tested in the similar manner as in chapter 6.5.3 for over/undervoltage functions.

6.5.6 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 *MRN3* 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:

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

Example: R_0 = 1 Ohm, R = 363 Ohm, C = 3 μF

then: $\Delta\Theta \cong 19°$

Usually the voltage source impedance R_0 is negligible, hence R_0 may be assumed zero. Thus, the value of R may be calculated using the following simplified formula:

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

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".

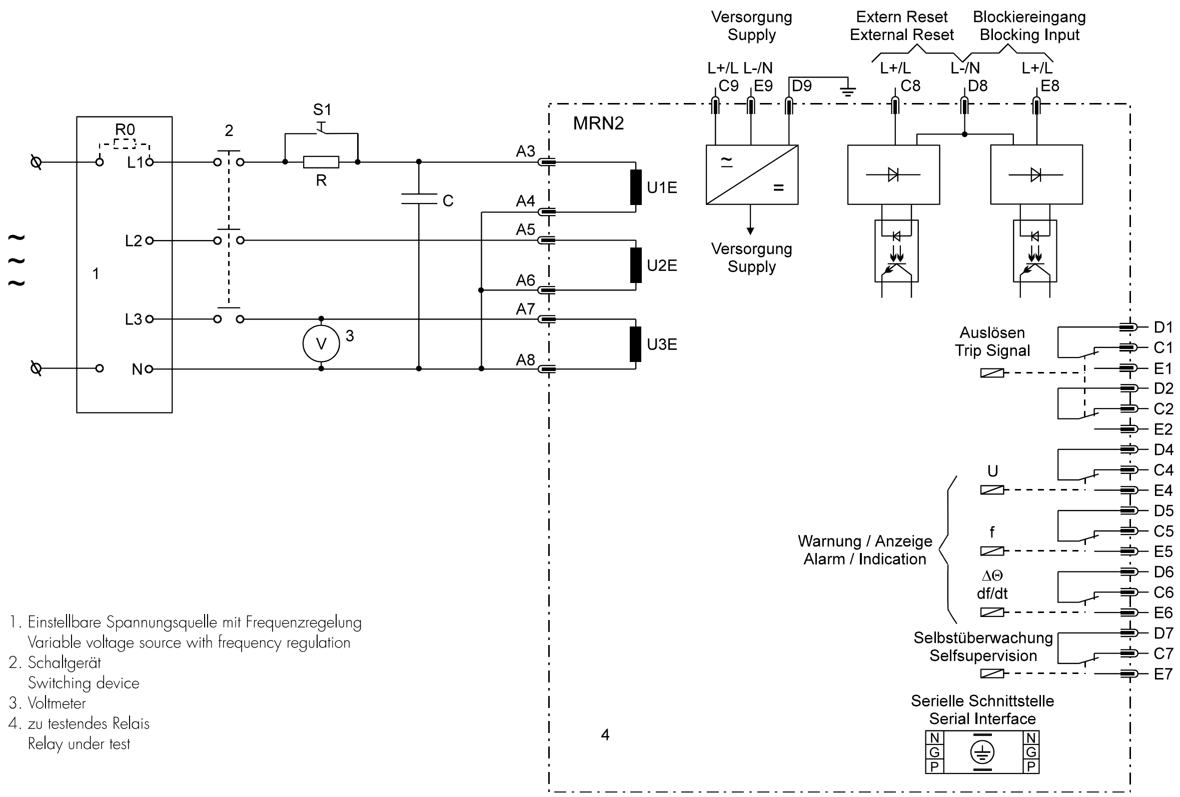

Figure 6.2: Test circuit for the vector surge function

6.5.7 Checking the tripping and reset values of the df/dt stages

The df/dt function can only be tested with a frequency generator which is capable of producing a defined linear frequency gradient. The step speed of the frequency generator must be < 10 ms. The tripping value of the frequency gradient can be tested with the following setting values.

Set all frequency stages to "EXIT"
df = 0.5 Hz/s, dt = 10, f_N = 50 Hz,
U_B = 40 % of Un

First of all a measuring voltage is applied the value of which must be higher than the voltage threshold for frequency measuring and the df/dt measuring. After 5 s the df/dt supervision is released (refer to chapter 4.7). The frequency generator should now run through a frequency ramp from 50 Hz to 48.6 Hz within 2.0 s which corresponds to a frequency-change speed of – 0.7 Hz/s. If the frequency change during the set time dt = (T+1') x 20 ms is greater than the set trip value df, tripping will take place. In this case that means after 120 ms with a permissible tolerance of +/- 20 ms. Tripping will also take place if the frequency ramp from 50 Hz to 51.4 Hz within 2 s (+0.7 Hz/s). If the frequency ramp is set from 50 Hz to 49.4 Hz within 2 s (0.3 Hz/s), there must not be any tripping.

6.5.8 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.

6.6 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. Since the cost and potential hazards are very high for such a test, primary injection tests are usually limited to very important protective relays in the power system.

Because of its powerful combined indicating and measuring functions, the *MRN3-3* 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 *MRN3-3* 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.

6.7 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 *MRN3-3*, this interval can be substantially longer. This is because:

- The *MRN3-3* 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 *MRN3-3* relays enable supervision of the relay functions during service.
- The combined TRIP test function of the *MRN3-3* 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, 690 V
	Nominal frequency f_N	40 - 70 Hz
	Measuring range:	0 – 2xUn (100V, 230V, 400V)
	Measuring range:	0 – 1,16xUN (690V)
	Measuring accuracy:	1% of the measuring value or 0.3% of the nominal value
Power consumption in voltage path:	<1 VA	
Thermal rating of the voltage path:	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:	U>/U>>:>99% or –0.003 U/U_N U</U<<:<101% or +0.003 U/U_N f>:>99,96% f>:< 100.04%
Dropout time:	60 ms
Time lag error class index E:	±10 ms
Minimum operating time:	40 ms
Max. allowed interruption of the auxiliary 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 to be measured
Frequency:	in the range $0.8 < f/f_N < 1.4$ (for f_N = 50 Hz) <0.15%-1%/Hz of the parameter set f = 50 Hz or f = 60 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 to be measured
Frequency:	no influences
Influences on delay time:	no additional influences to be measured

7.3 Setting ranges and steps

7.3.1 System parameter

Function	Para-meter	Setting range	Steps/Range	Tolerance
Transformer ratio	U_{prim}/U_{sek}	(SEC) 1.01...6500	0.01 (1,01...2,00) 0.02 (2,00...5,00) 0.05 (5,00...10,0) 0.1 (10,0...20,0) 0.2 (20,0...50,0) 0.5 (50,0...100) 1.0 (100...200) 2.0 (200...500) 5.0 (500...1000) 10 (1000...2000) 20 (2000...5000) 50 (5000...6500)	
Switch group	Δ/Y	Δ = Delta/Y = Star		
Rated frequency	f_N	f = 50 Hz / f = 60 Hz v = 50 Hz/v = 60 Hz		
Selection vector surge or df/dt function	ΔΘ/df	dPhi/dfdt		
LED blinking at pick-up		FLSH/NOFL		
Parameter set switch/external trigger for TR	P2/FR	SET1/SET2/B_S2/R_S2/B_FR/ R_FR/S2_FR		

7.3.2 Protection Parameter

Function	Para-meter	Setting range	Steps/Range	Tolerance
Function of the characteristic	Char 1/ Char 2	warn/trip		
Voltage characteristics Char1/ Char2	U<Start	Un = 100 V (EXIT) 1...200 V Un = 230 V (EXIT) 1...460 V Un = 400 V (EXIT) 4...800 V Un = 690 V (EXIT) 4...800 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
	U<1	Un = 100 V 1...<= U<Start Un = 230 V 1...<= U<Start Un = 400 V 2...<= U<Start Un = 690 V 2...<= U<Start	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
	U<2	Un = 100 V >= U<1...200 V Un = 230 V >= U<1...460 V Un = 400 V >= U<1...800 V Un = 690 V >= U<1...800 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
	tU<2 (U<2+t>)	0,06...60s	0.02 (0.06...1.00) 0.05 (1.00...2.00) 0.1 (2.00...5.00) 0.2 (5.00...10.0) 0.5 (10.0...20.0) 1 (20.0...50.0) 2 (50.0...60)	±1% related to the measured value of voltage resp. ±30 ms (see EN60255-3 + rounding error* and frequency influence**)
	U<3	Un = 100 V >= U<2...200 V Un = 230 V >= U<2...460 V Un = 400 V >= U<2...800 V Un = 690 V >= U<2...800 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N

* If parameter U>Start is set to « EXIT » all follow-up parameters of the characteristic will be faded out.

Protection parameter **(continuation)**

Function	Parameter	Setting range	Step	Tolerance
	tU<3 (U<3+t>)	> tU<2…60s	0.02 (0.06…1.00) 0.05 (1.00…2.00) 0.1 (2.00…5.00) 0.2 (5.00…10.0) 0.5 (10.0…20.0) 1 (20.0…50.0) 2 (50.0…60)	±1% related to the measured value of voltage resp. ±30 ms (see EN60255-3 + rounding error* and frequency influence**)
	U<4	Un = 100 V >= U<3…200 V Un = 230 V >= U<3…460 V Un = 400 V >= U<3…800 V Un = 690 V >= U<3…800 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
Voltage characteristic Char1/Char2	tU<4 (U<4+t>)	> tU<3…60s	0.02 (0.06…1.00) 0.05 (1.00…2.00) 0.1 (2.00…5.00) 0.2 (5.00…10.0) 0.5 (10.0…20.0) 1 (20.0…50.0) 2 (50.0…60)	±1% related to the measured value of voltage resp. ±30 ms (see EN60255-3 + rounding error* and frequency influence**)
	U<5	Un = 100 V >= U<1…200 V >= U<4…200 V Un = 230 V >= U<1…460 V >=U<4…460 V Un = 400 V >= U<1…800 V >= U<4…800 V Un = 690 V>= U<1…800 V >= U<4…800 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
	tU<5 (U<5+t>)	> tU<4…60s	0.02 (0.06…1.00) 0.05 (1.00…2.00) 0.1 (2.00…5.00) 0.2 (5.00…10.0) 0.5 (10.0…20.0) 1 (20.0…50.0) 2 (50.0…60)	±1% related to the measured value of voltage resp. ±30 ms (see EN60255-3 + rounding error* and frequency influence**)
Release time of the undervoltage characteristic Char1/Char2	tR	0.06…1.00s	0.02	±1% or 30 ms

*Rounding error :
Additional to the time error, related to EN60255-3, this error has to be taken into account.

The minimal resolution of characteristic slope is 1V/32s. This equals to 0.03125V/s
The maximal resolution is 1V/0.005s (200V/s)

Range	Additional error of time setting
dU/dt > 10V/s	±1%
dU/dt > 1V/s <= 10V/s	±2%
dU/dt > 0.5V/s <= 1V/s	±4%
dU/dt > 0.25V/s <= 0.5V/s	±7%
dU/dt < 0.25V/s	±60%

**Frequency influence
When the ***MRN3-3*** is adjusted to f = 50 Hz or f = 60 Hz and the instantaneous frequency deviates from the rated frequency, the measured voltage (refer to chapter 5.3.3) will reduce. As a consequence, it may happen that the voltage characteristics' tripping time shortens proportionally at the same ratio of a lower voltage measured.

Protection parameter **(continuation)**

Function	Parameter	Setting range	Step	Tolerance
Function of the voltage steps		U< (Under voltage function)/ U> (Over voltage function)		
Voltage stages U1 – U3	U1 U2 U3	Un = 100 V 1…200 V (EXIT) Un = 230 V 1…460 V (EXIT) Un = 400 V 4…800 V (EXIT) Un = 690 V 4…800 V (EXIT)	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N
	tU1 (U1+t>) tU2 (U2+t>) tU3 (U3+t>)	0.04…300s (EXIT)	0.02 (0.04…1.00) 0.05 (1.00…2.00) 0.1 (2.00…5.00) 0.2 (5.00…10.0) 0.5 (10.0…20.0) 1 (20.0…50.0) 2 (50.0…100) 5 (100…..200) 10 (200…..290)	±1% or 30ms
Frequency measuring repetition	T	2…99 (periods)	1	
Frequency element 1 - 3	$f_1 - f_3$	30…49.99; EXIT; 50.01…70 Hz[1] 40…59.99; EXIT; 60.01…80 Hz[2]	0.01 (30.0…48.0) 0.1 (48.0…52.0) 0.01 (52.0…70.0) 0.01 (40.0…58.0) 0.1 (58.0…62.0) 0.01 (62.0…80.0)	0.04 Hz ±1% or ±20 ms
	(f_1+t> - f_3+t>)	$t_{f,min}$[3]…290 s; EXIT	0.02 (0.06 1.00) 0.05 (1.00…2.00) 0.1 (2.00…5.00) 0.2 (5.00…10.0) 0.5 (10.0…20.0) 1.0 (20.0…50.0) 2.0 (50.0…100) 5.0 (100….200) 10.0 (200….290)	
df/dt-Step	df	0,2…10 Hz/s (EXIT)	0.1 (0.2…1.0) 0.2 (1.0…5.0) 0.5 (5.0…10.0)	0.1 Hz/s
df/dt-Measuring repetition	dt	2 64 periods	1	±2 periods
Vector surge tripping	1/3	1Ph/3Ph		
$\Delta\Theta$	$\Delta\Theta$	2°…22° (EXIT)	1°	±1°
Voltage threshold for frequency measuring	U_B<	U_N = 100 V: 5…100 V U_N = 230 V: 12…230 V U_N = 400 V: 20…400 V U_N = 690 V: 20…400 V	1 V 1 V 2 V 2 V	±1% from setting value or 0.3% of U_N

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 (see chapter 5.4.8)

4) only Modbus

7.3.3 Interface parameter

Function	Parameter	Modbus-Protocol	RS485 Pro Open Data Protocol
RS	Slave-Address	1 - 32	1 - 32
RS	Baud-Rate*	1200, 2400, 4800, 9600	9600 (fixed)
RS	Parity*	even, odd, no	"even Parity" (fixed)

Table 7.1: Interface parameter

*only Modbus Protocol

7.3.4 Parameters for the fault recorder

Function	Parameter	Adjustment example
FR	Number of recordings	1 x 20 s; 1*/2 x 10 s; 3*/4 x 5 s; 7*/8 x 2.5 s (50 Hz) 1 x 16.66 s; 1*/2 x 8.33 s, 3*/4 x 4.16 s, 7*/8 x 2.08 s (60 Hz)
FR	Saving of the recording at the occurrence	P_UP; TRIP; A_PI; TEST
FR	Pre-trigger-time	0.05 s – 20.0 s

Table 7.2: Parameters for the fault recorder

* is written over when a new trigger signal arrives

7.4 Output relays

Relay type	Trip relays/change-over contacts	Alarm relays/change-over contacts
MRN3-3	2/2	3/1

Table 7.3: Output relays

8 Order form

Mains decoupling relay **MRN3-**	**3**			
with voltage back up function according to VDN/e.on voltage (2 flexible voltage time characteristics, 3 standard steps Frequency (3 steps) df/dt-supervision (1 step) and vector surge (1 step)				
Rated voltage — 100 V (Utilities Substation/main substation) 230 V (direct connection without transformers 400 V (direct connection without transformers) 690 V (direct connection without transformers)		**1** **4** **7**		
Housing (12TE) — 19"-rack Flush mounting			**A** **D**	
RS 485 — optionally with Modbus protocol				***** **-M**

* Please leave box empty if option is not desired

Technical data subject to change without notice!

Setting list *MRN3-3*

Project: ______________________________ SEG job.-no.: ______________________

Function group: = ______________ Location: + ________ Relay code: - ______________________

Relay functions: ______________________________ Password: ______________________

Date: ______________________

All settings must be checked at site and should the occasion arise, adjusted to the object/item to be protected.

Setting of the parameters

System parameter

Function		Unit	Default settings	Actual settings
U_{prim}/U_{sek}	Voltage transformer ratio	X	SEK	
Δ/Y	input transformer connection		DELT	
f_N	Rated frequency	Hz	f=50	
$\Delta\Theta/df$	Selection vector surge or df/dt		dfdt	
	LED blinking after pick-up		FLSH	

Protection parameter

Function		Unit	Default settings	Actual settings	
	Voltage limit curve 1		Set1/Set2	Set1	Set2
U<Start	Start point of the characteristic curve 1	V	85/195/340/586*		
Char 1	Selection symmetric or asymmetric fault		ALL		
Char 1	Function of characteristic 1		warn		
U<1	1. Char. point_value 1	V	45/104/180/310*		
	1. Char. point_value 2 (not changeable)	s	- / -		
U<2	2. Char. point_value 1	V	45/104/180/310*		
U<2+t>	2. Char. point_value 2	s	0,16		
U<3	3. Char. point_value 1	V	70/161/280/482*		
U<3+t>	3. Char. point_value 2	s	0,18		
U<4	4. Char. point_value 1	V	70/161/280/482*		
U<4+t>	4. Char. point_value 2	s	0,70		
U<5	5. Char. point_value 1 (U-voltage band)	V	85/195/340/586*		
U<5+t>	5. Char. point_value 2 (End time)	s	1,50		
tR	Permissible release time for characteristic curve 1	s	0,10		
	Voltage limit curve 2				
U<Start	Start point of the characteristic curve 2	V	85/195/340/586*		
Char 2	Selection symmetric or asymmetric fault		ALL		
Char 2	Function of characteristic 2		trip		
U<1	1. Char. point_value 1	V	15/34/60/104*		
	1. Char. point_value 2 (not changeable)	s	- / -		
U<2	2. Char. point_value 1	V	15/34/60/104*		
U<2+t>	2. Char. point_value 2	s	0,66		
U<3	3. Char. point_value 1	V	85/195/340/586*		
U<3+t>	3. Char. point_value 2	s	3,00		

* Settings depending on the rated voltage 100 V/230 V/400 V or 690 V

Function		Unit	Default settings	Actual settings	
			Set1/Set2	Set1	Set2
U<4	4. Char. point_value 1	V	85/195/340/586*		
U<4+t>	4. Char. point_value 2	s	3.00		
U<5	5. Char. point_value 1 (U-voltage band)	V	85/195/340/586*		
U<5+t>	5. Char. point_value 2 (End time)	s	3.00		
tR	Permissible release time for characteristic curve 2	s	0.10		
U1	Function of the 1st voltage step		U<		
U1	Pick-up value for the 1st voltage step	V	85/195/340/586*		
U1+t>	Tripping time for the 1st voltage step	s	5		
U2	Function of the 2nd voltage step		U>		
U2	Pick-up value for the 2nd voltage step	V	110/253/440/760*		
U2+t>	Tripping time for the 2nd voltage step	s	1.00		
U3	Function of the 3rd voltage step		U>		
U3	Pick-up value for the 3rd voltage step	V	120/276/480/800*		
U3+t>	Tripping time for the 3rd voltage step	s	0.10		
T	Measuring repetition for frequency measuring	Periods	4		
f_1	Pick-up value for the 1st frequency step	Hz	48.00		
f_1+t>	Tripping delay of the 1st frequency step	s	0.1		
f_2	Pick-up value for the 2nd frequency step	Hz	47.50		
f_2+t>	Tripping delay for 2ndfrequency step	s	0.1		
f_3	Pick-up value for the 3rd frequency step	Hz	51.50		
f_3+t>	Tripping delay for 3rd frequency step	s	0.1		
$\Delta\Theta$	Pick-up value for vector surge	0	not active		
1/3	Vector surge tripping logic		not active		
df	Pick-up value for rate of change of df/dt	Hz/s	0.2		
dt	Measuring repetition for df/dt	Periods	4		
U_B	Voltage threshold for frequency measuring	V	10/23/40/68*		

* Settings depending on the rated voltage 100 V/230 V/400 V or 690 V

Fault recorder

Function		Unit	Default settings	Actual settings
FR	Number of recordings		4	
FR	Saving of the recording at the occurrence		TRIP	
FR	Time prior to trigger impulse	s	0.05	
🕓	Year setting	year	Y=00	
🕓	Month setting	month	M=00	
🕓	Day setting	day	D=00	
🕓	Setting of the hour	hour	h=00	
🕓	Setting of the minute	minute	m=00	
🕓	Setting of the second	second	s=00	

Parameter for serial interface

Function		Unit	Default settings	Actual setting
RS	Slave address of the serial interface		1	
RS	**Setting of the Baud-Rate		9600	
RS	**Parity check		even	

** only Modbus protocol

Assignment of the output relays

Function	Relay 1		Relay 2		Relay 3		Relay 4	
	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings
Char. 1 cycle running								
Char. 1 trip/alarm			X					
Char. 2 cycle running					X			
Char 2 trip/alarm	X							
U1 alarm							X	
U1+t> tripping	X							
U2 alarm							X	
U2+t> tripping	X							
U3 alarm							X	
U3+t> tripping	X							
f1 alarm							X	
f1+t> tripping	X							
f2 alarm							X	
f2+t> tripping	X							
f3 alarm							X	
f3+t> tripping	X							
df/dt tripping	X							

Blocking function

	Default settings				Actual settings			
	Blocking		Not blocking		Blocking		Not blocking	
Parameter set	P1	P2	P1	P2	P1	P2	P1	P2
Char1	X	X						
Char2	X	X						
U1	X	X						
U2			X	X				
U3			X	X				
f1	X	X						
f2	X	X						
f3			X	X				
df/dt	X	X						

Setting of code jumpers

Code jumper	J1		J2		J3	
	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings
Plugged						
Not plugged	X		No function		X	

Code jumper	Low/High-range for Reset input		Low/High-range for blockage input	
	Default settings	Actual settings	Default settings	Actual settings
Low=plugged	X		X	
High=not plugged				

All settings must be checked at site and should the occasion arise, adjusted to the object/item to be protected.

This technical manual is valid for
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MRN3-3-M: D57-1.00

HighTECH Line

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