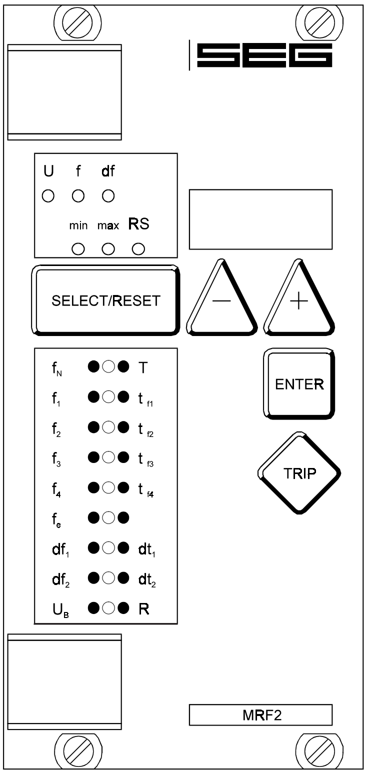
MRF2 - Frequency Relay



Contents

For additional common data of all *MR*-relays please refer to manual "*MR* - Digital Multifunctional relays".

This manual is valid for relay software version from D01_6.00 onwards

1. Introduction and Application

The *MRF2* is a universal frequency relay and contains the protective functions required by most electrical utilities for mains parallel operation of power stations:

- Four elements for over- or under frequency protection
- Two elements for frequency gradient supervision df/dt
- Fast decoupling of the generator from the grid at mains failure
- Suitable for load shedding systems

2. Features and characteristics

- Microprocessor technology with watchdog
- Effective active low pass filter for suppressing of harmonics
- Four elements for frequency supervision, alternatively for under- or overfrequency detection
- Two elements for supervision of the frequency gradient df/dt (rate of change of frequency)
- Independent separate adjustable timers
- Adjustable voltage threshold for blocking of the frequency measurement
- Display of all measuring values and setting parameters for normal operation and tripping via an alphanumerical display and LEDs
- Display of actual measuring values, storage and display of tripping values
- Minimum- and maximum measurement of the frequency gradient
- The protective functions can be assigned individually to the output relays (relay matrix)
- In compliance with VDE 0435, part 303, IEC 255
- Safe and fast mains decoupling by df/dt supervision

3. Design

3.1 Connections

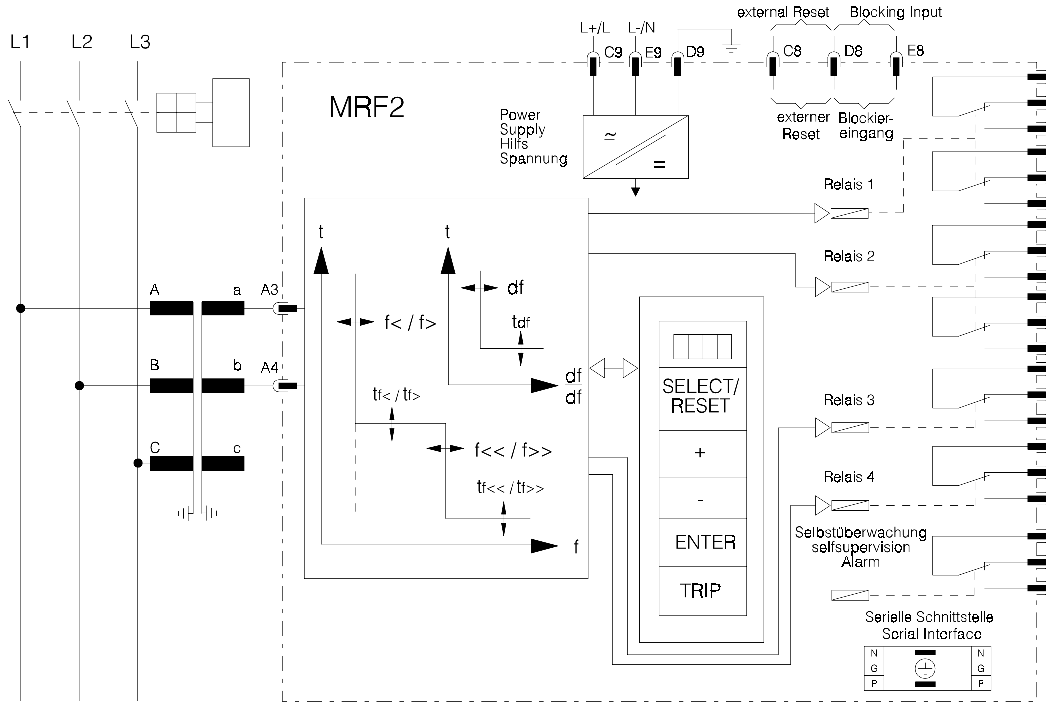


Fig. 3.1: Connection diagram MRF2

Note:
Phase voltages can also be connected to A3/A4

3.1.1 Analog inputs

The analog input voltage is galvanically isolated via the input transformer of the relay and the signal is passed through an active low pass filter. The frequency is detected from the square wave voltages which are formed via comporators. The external wiring of the measuring circuits as well as the auxiliary voltage are shown in the connection diagram.

3.1.2 Output relays

The *MRF2* has 5 output relays with change-over contacts:

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

All relays are normally off, only the self-supervision relay is normally on.

3.1.3 Blocking input

When required to inhibit the underfrequency and df/dt elements of the relay, the auxiliary voltage has to be connected to D8/E8 (please also refer to table 5.2, page 14).

3.1.4 External reset input

See chapter 5.4

3.2 Display

Function	Display indication	Required push button operation	Corresponding LED	Color of the LED
Normal operation:	│SEG			
Measured values:	meas. value of voltage	<SELECT/RESET>	U	green
	meas. value of frequency	<SELECT/RESET>	f	green
	min./max. frequency meas. values before last reset	<SELECT/RESET> one time for each value	f + (min. or max.)	green
	measuring value df/dt	<SELECT/RESET> one time for each value	df/dt	green
	min./max. meas. value of frequency gradient before last reset	<SELECT/RESET> one time for each value	df/dt + (min. or max.)	green
Setting values: Nominal frequency f_N	setting value in Hz	<SELECT/RESET><+><->	f_N	green
Measuring repetition	setting value in periods of nominal frequency	<SELECT/RESET><+><->	T	red
Frequency pickup value f_1 Tripping delay for f_1	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_1 t_{f1}	green red
Frequency pickup value f_2 Tripping delay for f_2	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_2 t_{f2}	green red
Frequency pickup value f_3 Tripping delay for f_3	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_3 t_{f3}	green red
Frequency pickup value f_4 Tripping delay for f_4	setting value in Hz setting value in seconds	<SELECT/RESET><+><-> one time for each value	f_4 t_{f4}	green red
Frequency threshold f_e for df/dt - measurement	setting value in Hz or "VARI"	<SELECT/RESET><+><->	f_e + df_1, as well as f_e + df_2	green
Pickup value df_1/dt Time difference or value of tripping timer for df_1/dt	setting value in Hz/s setting value in periods of nominal frequency	<SELECT/RESET><+><-> one time for each value	df_1 dt_1	green red
Pickup value df_2/dt Time difference or value of tripping timer for df_2/dt	setting value in Hz/s setting value in periods of nominal frequency	<SELECT/RESET><+><-> one time for each value	df_2 dt_2	green red
Blocking	EXIT	<SELECT/RESET><+><->	LED of blocked function	green
Voltage threshold for frequency measurement U_B	setting value in Volt	<SELECT/RESET><+><->	U_B	green
Assignment of output relays	1 - 4	<ENTER> + <TRIP> <SELECT/RESET><+><->	R f_1 - f_4, df_1, df_2	green red
Slave address of serial interface	1 - 32	<SELECT/RESET><+><->	RS	yellow
Stored fault values: Frequency	tripping values in Hz	<SELECT/RESET><+><->	f_1, f_2, f_3, f_4	
Rate of change of frequency	tripping value in Hz/s	<SELECT/RESET><+><->	df_1, df_2	
Save parameter?	SAV?	<ENTER>		
Save parameter!	SAV!	<ENTER> for abt. 3 s		
Software version		<TRIP> one time for each part		
Manual tripping	TRI?	<TRIP> 3 times		
Inquire password	PSW?	<SELECT/RESET>/ <+>/<->/<ENTER>		
Relay tripped	TRIP	<TRIP> or fault tripping		
Secret password	XXXX	<SELECT/RESET>/ <+>/<->/<ENTER>		
System reset	│SEG	<SELECT/RESET> für abt. 3 s		

Table 3.1: Possibilities for indications by the display

3.3 LEDs

All LEDs (except LEDs RS and min., max.) are two-colored. The LEDs left next to the alphanumerical display light up green during measurement and red at fault signals.

The LEDs below the <SELECT/RESET> push button light up green during setting and reading out the setting values printed on the left side next to the LEDs. The LEDs light up red when the setting values printed on the right side next to them are activated.

The LED marked with the letters RS lights up green during setting of the slave address for the serial interface (RS485) of the unit.

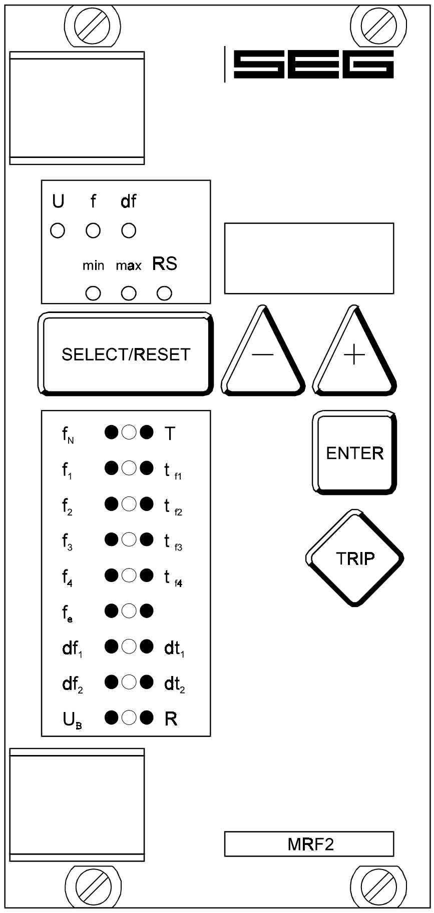


Fig. 3.2: Front plate MRF2

4. Working principle

4.1 Analog circuits

The input voltage is galvanically insulated via the input voltage transformer. The noise signals caused by the influence of inductive and capacitive couplings are then suppressed by RC-analog filter circuits. The analog voltage signals are fed to the A/D-converter of the microprocessor and then transformed into digital signals via sample- and hold-circuits. These digital values are then used for further processing. The analog signals are sampled with a sampling frequency of 16 x f_N, namely, a sampling rate of 1.25 ms for every measuring quantity (at 50 Hz). The input voltage is also passed through an analog filter for frequency measurement and is then converted into square wave signals via comparators. The frequency is determined by measuring complete cycles.

4.2 Digital part

The essential element of the protection relay is a powerful microcontroller. All functions - from the analog digital conversion to the relay tripping 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 microcontroller's CPU calculates the value of the measured voltage of the fundamental frequency. Harmonics are suppressed by an efficient digital filter based on the Fourier transformation (DFFT = Discrete Fast Fourier Transformation) When the measured voltage falls below the voltage threshold U_B, all frequency functions are blocked.

The frequency is established from the time difference of two similar voltage zero passages. The microprocessor compares continuously the frequency measured values and df/dt measuring values with the preset pickup values (setting value) stored in the parameter memory (EPROM). If a fault occurs an alarm is given and after the set tripping delay has elapsed, the corresponding tripping relay is activated.

The relay setting values for all parameters are stored in a parameter memory (EPROM - 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 failure the watchdog timer resets the microprocessor and gives an alarm signal via output relay "self supervision".

4.3 Principle of frequency supervision

Frequency relay ***MRF2*** protects electrical generators, consumers or electrical operating equipment in general against over- or underfrequency.
The relay has, independent from each other, four frequency elements f_1 - f_4 with a free choice of parameters, with separate adjustable pickup values and delay times as well as two elements for supervision of frequency gradient df/dt. With the aid of the frequency gradient sign both frequency increase and frequency decrease can be supervised.

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.

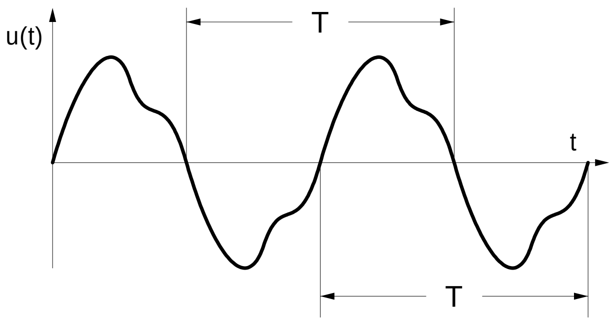


Fig. 4.1: Determination of cycle duration by means of zero passages.

In order to avoid false tripping during occurence of interference voltages and phase shifts the relay works with an adjustable measuring repetition (see chapter 5.2.2)

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

4.4 Measurement of the frequency gradient (rate of change of frequency)

Supervision of the frequency gradient df/dt is applied to the following applications:

- As additional criteria for underfrequency supervision at load shedding systems
- For fast decoupling of mains parallel electrical generators at mains failure (mains decoupling)

The df/dt elements can be set accordingly depending on the type of application .

4.4.1 Load shedding

During massive disturbances in the public electricity supply the stability of the entire grid can be endangered in case of the breakdown of several electric supply companies and the mains frequency drops rapidly because of the power deficit now.
Unit *MRF2* can be used for well-aimed load shedding in order to stabilize the mains again. Hereby the four frequency elements are set as underfrequency elements for throwing off the load.
Above this unit *MRF2* offers two special measuring elements for the mean frequency gradient df/dt. Via the rate of change of frequency the level of the power deficit can be determined and thus can cause load shedding.

The following points should be considered when applying df/dt- measurement for load shedding schemes:

- At the beginning of mains failure the frequency gradient can be very different from substation to substation and is mostly not time-constant. This depends on the power demand of the individual substations which makes it difficult to shut off the consumers selectively.
- During frequency drop in the mains power oscillations between the individual power stations can occur. Hereby the frequency gradient is not constant which means a safe decision for tripping because of the instantaneous value of the frequency gradient is not possible.

Because of the a.m. disadvantages only the mean value of the frequency gradient should be taken into consideration at load shedding systems.

The a.m. problems are excluded because the frequency gradient supervision of *MRF2* can operate acc. to this prinicple.

Measuring principle:

The df/dt function of relay *MRF2* is active only below a set frequency threshold f_e. When the measured system frequency drops under f_e, a timer is started (setting value dt in periods). When the measured system frequency drops under tripping value f_T within the time dt, *MRF2* trips immediately. The tripping value f_T results from settings df_1, f_e and dt:

$$df = \frac{f_e - f_T}{dt} \Rightarrow f_T = fe - df \cdot dt$$

If the actual frequency does not fall below f_T within dt, no tripping occures.
Only when the frequency again rises above threshold f_e, unit *MRF2* is automatically rearmed.

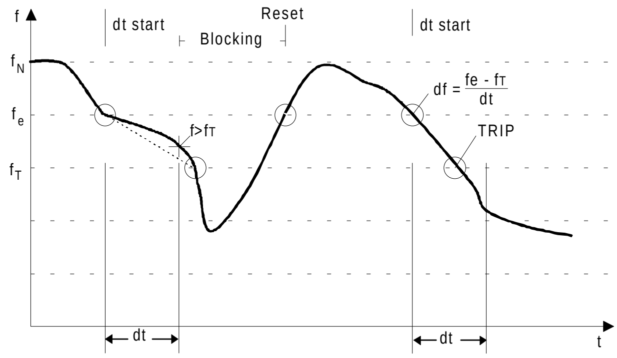


Fig. 4.2: Working principle of df/dt measurement

4.4.2 Mains decoupling of electrical generators

Electrical generators running in parallel with the mains, e.g. in captive power plants, should be separated from the mains immediately when the tie to the grid is suddenly lost as a result of a mains failure. Due to following reasons:

- It must be pervented that the electrical generators are damaged when mains voltage is recovering asynchronous, e.g. after auto reclosure.
- The captive power plant's 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 power flow via the mains coupling point. At mains failure the power flow changing then spontaneously leads to an increasing or decreasing frequency. At 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 occuring during mains failures are in the range of 0.5 Hz/s up to over 2 Hz/s. The *MRF2* 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 transients, e.g. switching transients is reached. The total tripping time at mains failure is between 60 ms and 80 ms depending on the setting.

5. Operation and settings

5.1 Setting- and measuring values

Setting values:

f_N: nominal frequency
T: measuring repetition for frequency measurement
f_1: pickup value of the first frequency element
t_{f1}: tripping delay of the first frequency element
f_2: pickup value of the second frequency element
t_{f2}: tripping delay of the second frequency element
f_3: pickup value of the third frequency element
t_{f3}: tripping delay of the third frequency element
f_4: pickup value of the fourth frequency element
t_{f4}: tripping delay of the fourth frequency element
f_{e1}: frequency threshold for df/dt-element 1
f_{e2}: frequency threshold for df/dt-element 2
df_1: pickup value for rate of change of frequency df/dt of the first frequency element
t_{df1}: differential period or value of the tripping timer for the first df/dt element
df_2: pickup value for rate of change of frequency df/dt of the second frequency element
t_{df2}: differential period or value of the tripping timer for the second df/dt element
U_B: voltage threshold for frequency measurement
RS: slave address of the serial interface
R: assignment of the output relays

Displayed measuring values:

U: system voltage in Volt
f: system frequency in Hz
df: frequency gradient in Hz/s
$f_{min/max}$: minimum and maximum value of the system frequency in Hz
$df_{min/max}$: minimum and maximum value of the frequency gradient in Hz/s

5.2 Setting procedure

Before changing a parameter a password has to be entered first (see chapter 4.4 of description "*MR*-digital multifunctional relay)

The parameter setting procedure is guided by two-colored illuminated LEDs. During setting of the frequency setting values f_N, f_1 - f_4, f_e, df_1 and df_2 the LEDs light up green. During setting of the tripping delays, differential periods or counters these LEDs light up red. The desired pickup values, nominal values and tripping delays can be adjusted by pressing push buttons <+> and <-> and stored with <ENTER>.

5.2.1 Setting of nominal frequency

First the nominal frequency (50 or 60 Hz) has to be set before unit *MRF2* is put into operation.
All frequency functions are determined by setting the nominal frequency, i.e. whether the set frequency thresholds are evaluated as over- or underfrequency (see also chapter 5.2.3). 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_4 with an adjustable multiplier (see also chapter 5.2.4).
During setting of the nominal frequency a value in Hz is shown on the display.

5.2.2 Number of measuring repetitions (T)

In order to avoid false tripping of the unit at short voltage drops of the system voltage or interference voltages, *MRF2* works with an adjustable measuring repetition. When the instantaneous frequency measuring value exeeds (at overfrequency) or falls below (at underfrequency) the set threshold 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 mains frequency a setting of T in the range from 5 - 10 is recommended.

5.2.3 Pickup values of frequency supervision

The frequency supervision of *MRF2* has four independent frequency elements. Acc. to the setting of 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_4 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". To achieve this setting the frequency setting value must be set to the adjusted nominal frequency f_N.

5.2.4 Tripping delays for the frequency elements

Tripping delays t_{f1} - t_{f4} of the four frequency elements can be set independently from t_{f1min} - 120 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.

5.2.5 Parameter for frequency gradient supervision df/dt at load shedding

Table 7.1 in chapter 7.3 shows the possible setting parameters with their setting ranges.
For the frequency gradient supervision df/dt at load shedding the following parameters are important:

f_e: frequency threshold from which the df/dt evaluation starts.
Please observe: For this application f_e must not be set to "VARI"!
df_1 and df_2: tripping value of the df/dt elements in Hz/s (see also chapter 4.4.1 "load shedding").
dt_1 and dt_2: time interval in periods of nominal frequency.

Setting example:
df/dt measurement is to be started when the frequency falls below the pickup value of f_e = 49.2 Hz. Tripping of *MRF2* is to follow when a mean frequency gradient of df_1/dt_1=1Hz/s is exceeded before the critical frequency dt_1 of 48.9 Hz is reached, this comes to a time interval df_1 to be set of:

$$dt_1 = \frac{49.2\text{Hz} - 48.9\text{Hz}}{1.0\text{Hz} / \text{s} \cdot 0.02\text{s}} = 15(\text{periods})$$

5.2.6 Parameters for frequency gradient supervision df/dt for mains decoupling

At this application threshold f_e must be set to "VARI". Parameters df_1 and df_2 are pickup values in Hz/s. Usually df_1 and df_2 are set to the same values, however with different signs
(e.g. df_1 = -2 Hz/s and df_2 = +2 Hz/s). In this way both can be detected, an unpermissible frequency increase and also a frequency decrease.
Measuring repetition counters dt_1 and dt_2 are for checking the monotony of the frequency increase or -decrease and can be set in the range from 1 - 64 cycles. For mains coupling a setting from 2 - 4 is recommended. Setting of 2 cycles corresponds to an interal evaluation of 4 measuring cycles and resulting from this a tripping delay of 2 x 20 ms = 40 ms.

The df/dt elements can be blocked when the pickup value of the frequency gradient is set to 0. The display shows "EXIT".

5.2.7 Voltage threshold for frequency measurement

At very low system voltage, e.g. during alternator start-up or voltage failure the frequency measurement cannot be done correctly. An adjustable voltage threshold U_B prevents a false tripping of the *MRF2* in such cases. When the system voltage drops below this threshold, all frequency functions of unit *MRF2* are blocked.

5.2.8 Setting of slave address

When pressing push buttons <+> and <-> the slave address can be set in the range from 1 - 32, hereby LED RS lights up.

5.2.9 Assignment of the output relays

Unit *MRF2* has five output relays. The fifth output relay is provided as permanent alarm relay for self supervision is normally on. Output relays 1 - 4 are normally off and can be assigned as alarm or tripping relays to the frequency 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. By pressing push buttons <ENTER> and <TRIP> simultaneously, the assignment mode is selected.

The relays are assigned as follows:
LEDs f_1 - f_4 are two-coloured and light up green when the output relays are assigned as alarm relays and red as tripping relays.

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

After the assignment mode has been activated, first LED R lights up red and LED f_1 lights up green. Now one or several of the four output relays can be assigned to frequency element f_1 as alarm relays. At the same time the selected alarm relays for frequency element 1 are indicated on the display. Indication "1_ _ _" means that output relay 1 is assigned to this frequency element. When the display shows "_ _ _ _", no alarm relay is assigned to this frequency element.

The assignment of output relays 1 - 4 to the frequency elements can be changed by pressing <+> and <-> push buttons. The selected assignment can be stored by pressing push button <ENTER> and subsequent input of the password. By pressing push button <SELECT/RESET>, LED f_1 lights up red. The output relays can now be assigned to this frequency element as tripping relays.

Relays 1 - 4 for the other elements are selected in the same way as described before. By repeatedly pressing of the <SELECT/RESET> push button and assignment of the relays all frequency- and df/dt elements can be assigned separately to the relays. The assignment mode can be terminated at any time by pressing the <SELECT> push button for some time (abt. 3 s). For the df/dt elements the output relays can only be assigned as tripping relay, then LEDs df1 and df2 light up red together with LED R.

Note:
- The function of jumper J2 described in general description "MR Digital Multifunctional Relays" has no function. 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				Display-indication	LED : Color
		1	2	3	4		
f_1	alarm	X				1 _ _ _	f_1: green
	tripping					_ _ _ _	f_1: red
f_2	alarm					_ _ _ _	f_2: green
	tripping		X			_ 2 _ _	f_2: red
f_3	alarm	X				1 _ _ _	f_3: green
	tripping		X			_ 2 _ _	f_3: red
f_4	alarm					_ _ _ _	f_4: green
	tripping					_ _ _ _	f_4: red
df_1/dt_1	tripping			X		_ _ 3 _	df_1: red
df_2/df_2	tripping				X	_ _ _ 4	df_2: red

Table 5.1: Example of assignment matrix of the output relay. (Default settings)

Note:
df/dt elements can only be assigned as tripping functions.

5.3 Measuring values

5.3.1 Instantaneous values

The indication of the instantaneous measuring values is described in the general description "*MR* - Digital Multifunctional Relays", chapter 4.5.1.

5.3.2 Tripping memory

The indication of the measuring values in case of a trip is described in the general description "*MR* - Digital Multifunctional Relay“, chapter 4.5.2.

5.3.3 Minimum-/maximum values

Unit *MRF2* offers each, one minimum-/maximum storage for the measuring values of the frequency and the frequency gradient. These min.-/max. storages are used mainly for the evaluation of the mains quality. Each time the largest or smallest values of each period are measured and stored until the next reset.

Min.-/max. measurement of the frequency:
Unit *MRF2* calculates from each cycle of the mains voltage the instantaneous frequency. These measuring values are written into the min.-/max.-storage. Hereby only a new minimum- or maximum value overwrites older stored values. According to the setting of T and the tripping delay it can happen that the stored min.-/max.-values are far above the tripping thresholds, but tripping does not occur. This is established by the storage of instantaneous values.

Min.-/max.-measurement of the frequency gradient
The before described is valid in the same way for storage of min.-/max. values of the df/dt measurement. Because every instananeous df/dt value is stored, high values can occur which however do not lead to tripping. This can for instance occur due to switching transients where high positive and negative df/dt values occur. Because of the special measuring procedure the relay does not trip.

Very helpful are the min.-/max.- measurements for long time study of the mains quality.

Operation:
At each reset (see chapter 5.4) the stored min.-/max.-values are deleted. From this time the min.-/max.-storage runs without time limitation until the next reset. The measuring values of the min.-/max.-storage can be called by pressing push button <SELECT> several times. Simultaneously the respective LEDs light up, for instance LEDs "f"and "min" light up at the indication of the minimum frequency.

5.4 Reset

MRF2 has the following 3 possibilities to reset the display as well as the output relays at jumper position J3 = ON.
(see also chapter 4.2 of description "*MR*-Digital Multifunctional Relays".

Manual reset
- by pressing push button <SELECT/RESET> for some time (abt. 3 secs.).

Electrical reset
- by applying aux. voltage to C8/D8.

Software reset
- software reset has the same effect as the <SELECT/RESET> push button. Please also refer here to the communication protocol of RS 485 interface.

Resetting the display is only possible when there is no pickup anymore (otherwise signal "TRIP" will still remain in the display and the relays remain activated). Resetting the relay does not change the preset parameters.

5.5 Dynamic behaviour of the relay functions

The following table shows the dynamic behaviour of the relay functions under various system conditions.

System condition/ event	Function			
	f>	f<	df/dt for load shedding	df/dt for mains decoupling
Applying auxiliary voltage	active after 1 s	active after 1 s	active after 1 s	active after 1 s
Applying auxiliary voltage to the external blocking input	not blocked	blocked	blocked	blocked
Disconneting the auxiliary voltage from the external blocking input	no influence	active after 1 s	active after 1 s	active after 1 s
Applying auxiliary voltage to the external reset input	reset of the relay	reset of the relay	reset of the relay	reset of the relay
Applying the system voltage to the frequency measuring input	active after 1 s	active after 1 s	active after 1 s	active after 1 s
Applying a voltage $<U_B$ to the frequency measuring input	blocked	blocked	blocked	blocked
Applying a voltage with a frequency $<f_e$ to the frequency measuring input	active after 1 s	active after 1 s	no tripping	no tripping
Disconnecting system voltage from the frequency measuring input	blocked	blocked	blocked	blocked
Voltage drops below U_B	blocked	blocked	blocked	blocked
Recovering of system voltage	active after 1 s	active after 1 s	active after 1 s	active after 1 s
Voltage vector surge	no tripping	no tripping	no tripping	no tripping
Short time voltage drop	no tripping	no tripping	no tripping	no tripping

Table 5.2: Dynamic behaviour of ***MRF2****-Functions*

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 voltage of the relay corresponds 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).

6.2 Testing the output relays

NOTE!
Prior to commencing this test, interrupt the tripping 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. „D01-"). By pressing the push button <TRIP> twice, the display shows the second part of the software version of the relay (e.g. „7.00". 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 deenergized one after another with a time interval of 1 second. Thereafter, reset all output relays back to their normal positions by pressing the push button <SELECT/RESET>.

6.3 Checking the set values

By repeatedly pressing the push button <SELECT>, all relay set values may be checked. Set value modification can be done with the push button <+><-> and <ENTER>.

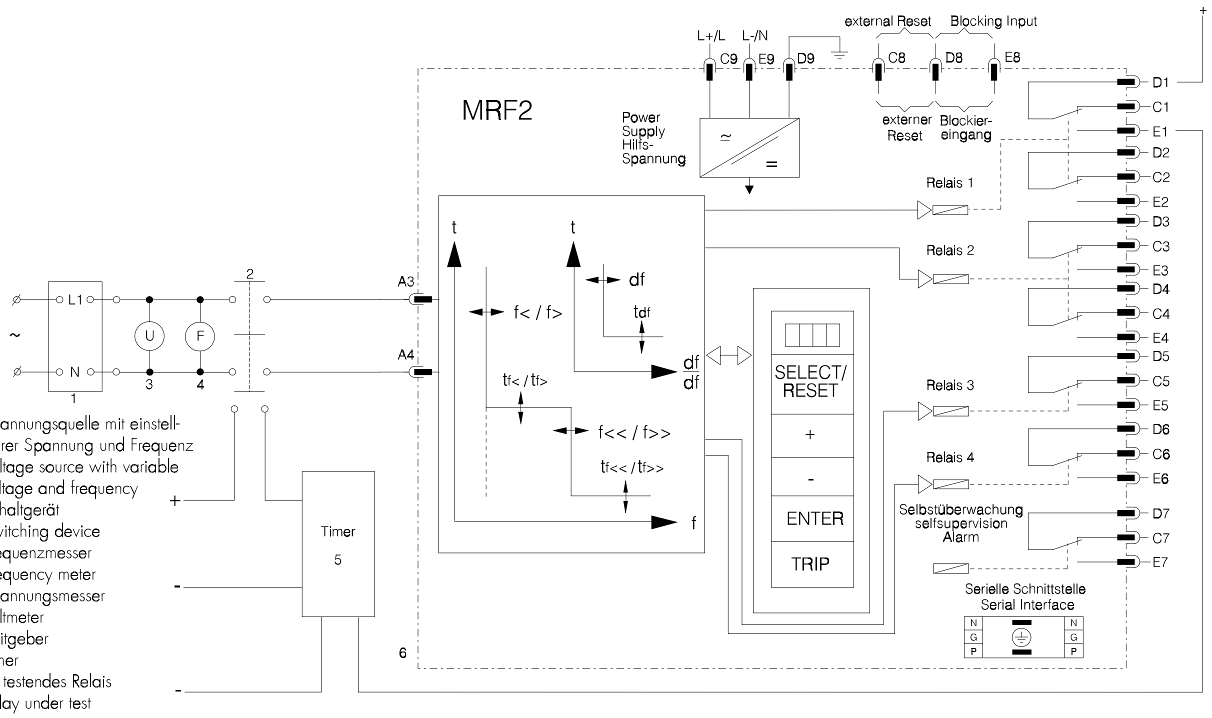
6.4 Secondary injection test

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 on the type plate
- AC voltage supply 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 class ±10 ms)
- Switching device
- Test leads and tools

6.4.2 Test circuit

For testing *MRF2* the connection of a voltage source with adjustable frequency is required. Fig. 6.1 shows a simple example of a test circuit. For checking the df/dt function a voltage source is needed which can generate a constant rate of change of frequency.



1. Spannungsquelle mit einstellbarer Spannung und Frequenz
   Voltage source with variable voltage and frequency
2. Schaltgerät
   Switching device
3. Frequenzmesser
   Frequency meter
4. Spannungsmesser
   Voltmeter
5. Zeitgeber
   Timer
6. zu testendes Relais
   Relay under test

Fig. 6.1: Test circuit

6.4.3 Checking the input circuits and measuring values

First the measuring voltage as high as the nominal voltage is to be connected to terminals A3 and A4. Then the actual measuring values of the frequency can be read by pressing push button <SELECT/RESET>. The measured frequency is indicated on the display by the simultaneous illummination of LED f as follows: 5001; corresponds to 50.01 Hz.
The rate of change of frequency is indicated on the display when LED df (indication in Hz/s) lights up. Example 3.1 corresponds to 3.1 Hz/s.

6.4.4 Checking of operating- and resetting values of the over-/underfrequency functions

Note!
During frequency test each of the four frequency elements should be checked. To guarantee a trouble-free test run the other frequency elements of the unit have therefore to be blocked at the beginning by adjusting the corresponding frequency operating values f1 - f4 to "EXIT".

To check the operating- and reset values the test frequency must be increased or decreased until the relay picks up. This is signalized when LEDs f_1 - f_4 light up. When comparing the values indicated on the display with those of the frequency meter, the deviation must not exceed more than 0.01 Hz.
The reset values are detected by increasing or decreasing the test frequency slowly till the output relay releases.
The reset value for overfrequency must be larger than 0.99 x f_N, for underfrequency it must be smaller than 1.01 x f_N.

6.4.5 Checking of operating- and resetting values of the df/dt elements

Note!
During testing the df/dt function the four frequency elements should also be checked individually. Therefore the other frequency functions must be blocked by adjusting the pickup values to "EXIT".
Frequency threshold fe and the df/dt function can, however, only be tested with a function generator which can generate a definite frequency gradient.

6.4.6 Checking the tripping delays

For checking the tripping delays t_f a voltage source is needed which changes the frequency in a defined quantity at a certain time and at the same time generates an output signal.
While checking the tripping delay a timer can be connected with the contact of the tripping relay. The timer is simultaneously started with the change of the frequency and stopped when the relay trips. Hereby the test frequencies have to be selected so that the relay detects a safe under- or overfrequency. The tripping time measured with the aid of the timer should not deviate more than 3%, or more than 20 ms (at short tripping delay), from the set tripping delay.
It is to be observed that the measured time till tripping is longer by the number of the measuring periods (T) to be evaluated than the set tripping delay.

6.4.7 Checking the external blocking- and reset functions

The external blocking input blocks the underfrequency and df/dt functions of the *MRF2*.(please refer to tab. 5.2 , page 14)

At the beginning of the test the auxiliary voltage is connected to terminals D8/E8 of the unit. Then a test frequency has to be set which normally leads to tripping of one of the frequency functions. Neither an alarm nor tripping must take place.

After this the auxiliary voltage has to be removed from the blocking input. Changing the frequency again by the same amount, the relay trips and the signal "TRIP" appears on the display. After this the test frequency must be set again to a value which does not lead to tripping. By applying auxiliary voltage to the reset input (C8/D8), the LED indication extinguishes and the display resets.

6.5 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 *MRF2* 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 *MRF2* 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.

6.6 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 *MRF2*, this interval can be substantially longer. This is because:

- The *MR*-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 *MR*-relays enable supervision the relay functions during service.
- The combined TRIP test function of the *MR*-relay allows to test the relay output circuits.

A testing interval of two years for maintenance will, therefore, be recommended.
During a maintenance test, the relay functions including the operating values and relay tripping times should be tested.

7. Technical data

7.1 Measuring input circuits

Rated data:	Nominal voltage U_N: 100 V, 230 V, 400 V Nominal frequency f_N: 50/60 Hz Operating range: 0.05...2.0 x U_N
Power consumption:	<1 VA at U_N
Thermal rating:	continuously 2 x U_N

7.2 Common data

Dropout to pickup ratio:	f>: > 99.99 % f<: < 100.02 %
Dropout time:	30 ms
Time lag error class index E:	± 10 ms
Minimum operating time:	60 ms
Max. allowed interruption of the auxiliary supply without influence to the function of the device:	50 ms
Influences on frequency measuring:	
Aux. voltage:	in the range 0.8 < U_H / U_{HN} < 1.2 no additional influences to be measured
Frequency:	no influences
Influences on delay time:	no additional influences to be measured
GL-Approbation:	98776-96HH
Bureau Veritas Approbation:	2650 6807 A00 H

For additional common data of all *MR*-relays please refer to manual "*MR* - Digital Multifunctional relays".

7.3 Setting ranges and steps

Function	Parameter	Setting range	Steps	Tolerance
Rated frequency	f_N	50 Hz/60 Hz	50 Hz/60 Hz	none
Frequency measuring repetitions	T	2…99 (periods)	1	none
Frequency element 1	f_1 t_{f1}	30…49.99; EXIT; 50.01…70 Hz[1] 40…59.99; EXIT; 60.01…80 Hz[2] $t_{f,min}$…120 s; EXIT	0.1; 0.01 Hz 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	0.005 Hz ±1% or ±20 ms
Frequency element 2	f_2 t_{f2}	30…49.99; EXIT; 50.01…70 Hz[1] 40…59.99; EXIT; 60.01…80 Hz[2] $t_{f,min}$…120 s; EXIT	0.1; 0.01 Hz 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	0.005 Hz ±1% or ±20 ms
Frequency element 3	f_3 t_{f3}	30…49.99; EXIT; 50.01…70 Hz[1] 40…59.99; EXIT; 60.01…80 Hz[2] $t_{f,min}$…120 s; EXIT	0.1; 0.01 Hz 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	0.005 Hz ±1% or ±20 ms
Frequency element 4	f_4 t_{f4}	30…49.99; EXIT; 50.01…70 Hz[1] 40…59.99; EXIT; 60.01…80 Hz[2] $t_{f,min}$…120 s; EXIT	0.1; 0.01 Hz 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	0.005 Hz ±1% or ±20 ms
Thresholds and tripping values for df/dt-element [3]	$f_e + df_1$ $f_e + df_2$	40…49.99; VARI; 50.01…60 Hz 50…59.99; VARI; 60.01…70 Hz 40…49.99; VARI; 50.01…60 Hz 50…59.99; VARI; 60.01…70 Hz	0.01; 0.1 Hz 0.01; 0.1 Hz 0.01; 0.1 Hz 0.01; 0.1 Hz	0.005 Hz 0.005 Hz 0.005 Hz 0.005 Hz
df/dt- element 1	df_1 dt_1	-10…-0.2 Hz/s; EXIT; 0.2…10 Hz/s 2…64 (periods)	0.1; 0.2; 0.5 Hz/s 1	0.1 Hz/s
df/dt- element 2	df_2 dt_2	-10…-0.2 Hz/s; EXIT; 0.2…10 Hz/s 2…64 (periods)	0.1; 0.2; 0.5 Hz/s 1	0.1 Hz/s
Voltage threshold for frequency measurement	U_B	5…100 V (U_N = 100 V) 10…230 V (U_N = 230 V) 20…400 V (U_N = 400 V)	1 V 1 V 2 V	±1% from setting value or <0.3% U_N

Table 7.1: Setting ranges and steps

[1] for setting f_N = 50 Hz
[2] for setting f_N = 60 Hz
[3] f_e setting "VARI": df/dt measurement for mains decoupling
"value": df/dt measurement for load shedding schemes

7.4 Order form

Frequency relay	***MRF2-***		
Rated voltage:	100 V	**1**	
	230 V	**2**	
	400 V	**4**	
Housing (12TE)	19"-rack		**A**
	Flush mounting		**D**

Technical data subject to change without notice!

8. Setting-list *MRF2*

Project: ______________________________ SEG job.-no.: ________________

Function group: = ____________ Location: + ______ Relay code: - ________________

Relay functions: ________________________ Password: ________________

Function		Unit	Default settings	Actual settings
f_N	nominal frequency	Hz	50	
T	measuring repitition for frequency measurement		4	
f_1	pickup value of the first frequency element	Hz	48,00	
t_{f1}	Tripping delay of the first frequency element	s	0,1	
f_2	pickup value of the second frequency element	Hz	49,00	
t_{f2}	tripping delay of the second frequency element	s	0,1	
f_3	pickup value of the third frequency element	Hz	51,00	
t_{f3}	tripping delay of the third frequency element	s	0,1	
f_4	pickup value of the fourth frequency element	Hz	52,00	
t_{f4}	tripping delay of the fourth frequency element	s	0,1	
$f_e(df_1)$	frequency threshold for df/dt-element 1	Hz	VARI	
df_1	pickup value for rate of change of frequency df/dt of the first frequency element	Hz/s	-0,2	
dt_1	differential period or value of the tripping timer for the first df/dt element	periods	4	
$f_e(df_2)$	frequency threshold for df/dt-element 2	Hz	VARI	
df_2	pickup value for rate of change of frequency df/dt of the second frequency element	Hz/s	+0,2	
dt_2	differential period or value of the tripping timer for the second df/dt element	periods	4	
U_B	voltage threshold for frequency measurement	V	10/23/40*	
RS	slave address of the serial interface		1	

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

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
f_1 alarm	X							
f_1 tripping	X							
f_2 alarm	X							
f_2 tripping	X							
f_3 alarm			X					
f_3 tripping			X					
f_4 alarm					X			
f_4 tripping					X			
df_1/dt_1 tripping							X	
df_2/dt_2 tripping							X	

Setting of code jumpers

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

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