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1. Introduction

1.1 Features

- Selectable underfrequency or overfrequency protection
- Selectable frequency rate of change function
- Start and trip indication in terms of output signals
- Definite-time (DT) operation
- Virtual phase-to-phase voltage measurement channels can be used instead of the corresponding analogue measurement channels

1.2 Application

This document specifies the functions of the five underfrequency or overfrequency function blocks Freq1St1, Freq1St2, Freq1St3, Freq1St4 and Freq1St5 used in products based on the RED 500 Platform. All the five stages are identical in operation.

The frequency function blocks are specially designed for applications such as generator protection, load shedding, load restoration and disconnection for island operation.

Table 1 . Protection diagram symbols used in the relay terminal

ABB	IEC	ANSI
Freq1St1	f1	81-1
Freq1St2	f2	81-2
Freq1St3	f3	81-3
Freq1St4	f4	81-4
Freq1St5	f5	81-5

For IEC symbols used in single line diagrams, refer to the manual “Technical Descriptions of Functions, Introduction”, 1MRS750528-MUM.

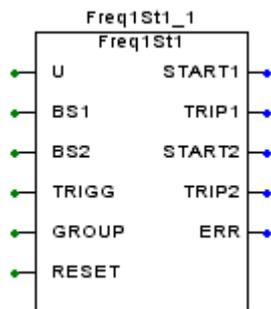


Figure 1. Function block symbol of Freq1St_, stage 1 as an example

1.3 Input description

Name	Type	Description
U	Analogue signal (SINT)	Input for measuring phase-to-phase or phase-to-earth voltage
BS1	Digital signal (BOOL, active HIGH)	Blocking signal 1 (blocks TRIP1)
BS2	Digital signal (BOOL, active HIGH)	Blocking signal 2 (blocks TRIP2)
TRIGG	Digital signal (BOOL, pos. edge)	Control signal for triggering the registers
GROUP	Digital signal (BOOL, active HIGH)	Control input for switching between the setting groups 1 and 2. When GROUP is FALSE, group 1 is active. When GROUP is TRUE, group 2 is active.
RESET	Reset signal (BOOL, pos. edge)	Signal for resetting the registers

1.4 Output description

Name	Type	Description
START1	Digital signal (BOOL, active HIGH)	Signal that indicates starting of f>/f< function
TRIP1	Digital signal (BOOL, active HIGH)	Signal that indicates tripping of f>/f< function
START2	Digital signal (BOOL, active HIGH)	Signal that indicates starting of f>/f< or df/dt function ¹⁾
TRIP2	Digital signal (BOOL, active HIGH)	Signal that indicates tripping of f>/f< or df/dt function ¹⁾
ERR	Digital signal (BOOL, active HIGH)	Signal for indicating a configuration error

¹⁾ depends on the operation mode selected

2. Description of operation

2.1 Configuration

The input and output signals of the frequency protection function block Freq1St_ is configured with the Relay Configuration Tool included in the CAP 505 Tool Box.

Frequency protection must be selected for the voltage input via the special measurements dialogue box in the configuration tool. If the frequency protection is not selected, the ERR output is activated.

Traditionally, frequency measurement is highly recommended to be based on a phase-to-phase voltage which is less dependent on the asymmetry of separate phase voltages and less sensitive to harmonics. The third harmonic, for instance, will not be present in phase-to-phase voltages. However, the function block is also able to measure the frequency reliably and accurately using a single phase-to earth voltage. The function block will check that the signal type of the U input is valid, i.e. a phase-to-phase or phase-to-earth voltage. A wrong signal type will cause a configuration error.

The output signals TRIP1 and TRIP2 of the function block can be used for frequency-based load shedding in an underfrequency situation. Some portions of the load can be reduced by disconnecting the corresponding outgoing lines from the busbar. When the remaining load is in balance with the power generation available, the power system frequency will return to its normal value.

The outputs can also be used in frequency-based load restoration. The Relay Configuration Tool is used for configuring the logic needed for load restoration after load shedding.

Please note that the task execution interval of the function block must be configured to the fastest task, i.e. 5ms ($f_n = 50$ Hz). A slower task execution interval will cause a configuration error which will force the function block to the “Not in use” mode.

2.2 Measuring mode

The actual power system frequency is measured via a sophisticated numerical method. The operation is insensitive to harmonics and the DC component.

2.3 Operation criteria

The function block Freq1St_ can be used for underfrequency ($f<$) or overfrequency ($f>$) protection. The function block operates as either underfrequency or overfrequency relays depending on whether the set operate value is above or below the rated frequency of the relay or feeder terminal.

The function block also includes a starting element that measures the rate of change of the power system frequency, so that the need for protection can be anticipated even before a major frequency change occurs. The parameter “Operation Mode” is used for setting the operation direction of the df/dt function. When the set value is indicated as “ $df/dt<$ ”, the negative rate of change of frequency is measured (the function block operates as a negative derivative function), and when the set value is indicated as “ $df/dt>$ ”, the positive rate of change of frequency is measured (the function block operates as a positive derivative function). The frequency rate of change function can also be set out of use.

The output START1 is activated when the $f</f>$ function starts. Correspondingly, START2 is activated when the $f</f>$ or df/dt function starts, depending on the operation mode used. The trip signals of both the $f</f>$ function and the df/dt function (TRIP1 and TRIP2) can be used for load shedding. The operate time of the $f</f>$ function can be set via the parameter “Operate time 1” and the operate time of both the $f</f>$ function and the df/dt function via the parameter “Operate time 2”. Active START1 and START2 signals are both indicated by steady start LEDs (yellow) and active TRIP1 and TRIP2 signals by steady trip LEDs (red) on the MMI.

The setting parameter “Operation mode” is used to select the operation mode of the function as follows:

Operation mode	Description of operation
=Not in use	The f function and the df/dt function are not in use.
= f 1 timer	TRIP1 is activated by the f function when the set operate time 1 has elapsed. The df/dt function is not in use.
= f 2 timers	TRIP1 is activated by the f function when the set operate time 1 has elapsed, and TRIP2 is activated by the f function when the set operate time 2 has elapsed. The df/dt function is not in use.
= f OR df/dt >	TRIP1 is activated by the f function when the set operate time 1 has elapsed, and TRIP2 is activated by the f function or the positive df/dt function when the set operate time 2 has elapsed.
= f AND df/dt >	TRIP1 is activated by the f function when the set operate time 1 has elapsed. TRIP2 is activated by both the f function and the positive df/dt function when the set operate time 2 has elapsed.
= f OR df/dt <	TRIP1 is activated by the f function when the set operate time 1 has elapsed, and TRIP2 is activated by the f function or the negative df/dt function when the set operate time 2 has elapsed.
= f AND df/dt <	TRIP1 is activated by the f function when the set operate time 1 has elapsed. TRIP2 is activated by both the f function and the negative df/dt function when the set operate time 2 has elapsed.

The calculation window for frequency measurement always has a length of two fundamental cycles, i.e. 40 ms at the rated system frequency 50 Hz and 33.3 ms at the rated system frequency 60 Hz. The total operate time is the sum of the start time, the additional operate delay and the operate delay of the heavy-duty output relay. The timers are cleared when the abnormal frequency situation has disappeared.

The blocking signal BS1 can be used for blocking the operation of the underfrequency and overfrequency function f . When the blocking signal BS1 is active, the DT timer 1 is frozen. In the same way, the blocking signal BS2 can be used for blocking the operation of the df/dt or f function, depending on the operation mode used. When the blocking signal BS2 is active, the DT timer 2 is frozen. Active BS1 and BS2 signals are indicated by blinking start LEDs (yellow) on the MMI.

In an undervoltage situation the function block is internally blocked. The undervoltage limit value is set according to the application.

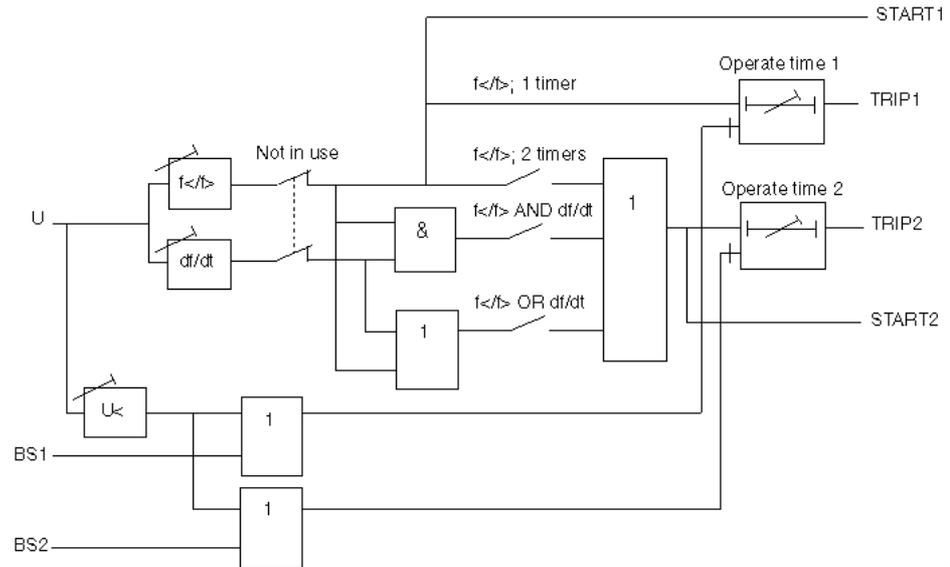


Figure 2. Simplified functional block diagram of an underfrequency and overfrequency protection function block

Note! The operate times and start times are specified for the set rated frequencies 50 Hz and 60 Hz.

Also note that the setting range of “Operate time 2” also covers up to 300.00s. However, when df/dt operation mode for TRIP2 is used, the actual setting range of “Operate time 2” is smaller due to the fact that the minimum “Start df/dt” setting is 0.2 Hz/s and the accurate operating frequency of the function block is 25...75Hz.

2.4

Setting groups

Two different groups of setting values, group 1 and group 2, are available for the function block Freq1St_. Switching between the two groups can be done in the following three ways:

- 1 Locally via the control parameter “Group selection”¹⁾ of the MMI
- 2 Over the communication bus by writing the parameter V1¹⁾
- 3 By means of the input signal GROUP when allowed via the parameter “Group selection” (i.e. when V1 = 2¹⁾).

¹⁾ Group selection (V1): 0 = Group 1; 1 = Group 2; 2 = GROUP input

The control parameter “Active group” indicates the setting group valid at a given time.

2.5

Test mode

The digital outputs of the function block Freq1St_ can be activated with separate control parameters for each output either locally via the MMI or externally via the

serial communication. When an output is activated with the test parameter, an event indicating the test is generated.

The protection functions operate normally while the outputs are tested.

2.6 START and TRIP outputs

The output signals START1 and START2 are always pulse-shaped. The minimum pulse width of the corresponding output signal is set via a separate parameter on the MMI or on serial communication. If the start situation is longer than the set pulse width, the START1 and START2 signals remain active until the start situation is over. The output signals TRIP1 and TRIP2 may be non-latching or latching. When the latching mode has been selected, the TRIP1 and TRIP2 signals remain active until the output is reset even if the operation criteria have reset.

Active START1 and START2 signals are indicated by steady start LEDs (yellow) and active TRIP1 and TRIP2 signals by steady trip LEDs (red) on the MMI.

2.7 Resetting

The TRIP output signals and the registers can be reset either via the RESET input or over the serial bus or the local MMI.

The operation indicators, latched trip signal and recorded data can be reset as follows:

	Operation indicators	Latched trip signal	Recorded data
RESET input of the function block ¹⁾		X	X
Parameter F072V013 ¹⁾		X	X
General parameter F001V011 ²⁾	X		
General parameter F001V012 ²⁾	X	X	
General parameter F001V013 ²⁾	X	X	X
Push-button C ²⁾	X		
Push-buttons C + E (2 s) ²⁾	X	X	
Push-buttons C + E (5 s) ²⁾	X	X	X

¹⁾ Resets the latched trip signal and recorded data of the function block Freq1St1. The corresponding parameters for other Freq1St_ function blocks are the following:

Freq1St2 F073V013
 Freq1St3 F074V013
 Freq1St4 F075V013
 Freq1St5 F076V013

²⁾ Affects all function blocks

3. Parameters and events

3.1 General

- Each function block has a specific channel number for serial communication parameters and events. The channels for the frequency function blocks are the following:

Function block	Channel
Freq1St1	72
Freq1St2	73
Freq1St3	74
Freq1St4	75
Freq1St5	76

- The data direction of the parameters defines the use of each parameter as follows:

Data direction	Description
R, R/M	Read only
W	Write only
R/W	Read and write

- The different event mask parameters (see section “Control settings”) affect the visibility of events on the MMI or on serial communication (LON or SPA) as follows:

Event mask 1 (FxxxV101/102)	SPA / MMI (LON)
Event mask 2 (FxxxV103/104)	LON
Event mask 3 (FxxxV105/106)	LON
Event mask 4 (FxxxV107/108)	LON

For example, if only the events E3, E4 and E5 are to be seen on the MMI of the relay terminal, the event mask value 56 (8 + 16 + 32) is written to the “Event mask 1” parameter (FxxxV101).

In case a function block includes more than 32 events, there are two parameters instead of e.g. the “Event mask 1” parameter: the parameter “Event mask 1A” (FxxxV101) covers the events 0...31 and “Event mask 1B”(FxxxV102) the events 32...63.

3.2 Setting values

3.2.1 Actual settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S1	0..6 ¹⁾	-	1	R/M	Operation mode for frequency protection
Voltage limit	S2	0.30...0.90	x Un	0.30	R/M	Undervoltage limit for blocking
Start frequency	S3	25.00...75.00	Hz	48.70	R/M	Start value for U/O frequency protection
Operate time 1	S4	0.10...300.00	s	20.00	R/M	Operate time for U/O frequency protection
Start df/dt	S5	0.2...10.0	Hz/s	10.0	R/M	Start value for frequency rate of change prot.
Operate time 2	S6	0.12...300.00	s	20.00	R/M	Timer for df/dt prot. or U/O frequency prot.

¹⁾ Operation mode
 0 = Not in use
 1 = f</f> 1 timer
 2 = f</f> 2 timers
 3 = f</f> OR df/dt>
 4 = f</f> AND df/dt>
 5 = f</f> OR df/dt<
 6 = f</f> AND df/dt<

3.2.2 Setting group 1

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S41	0..6 ¹⁾	-	1	R/W	Operation mode for frequency protection
Voltage limit	S42	0.30...0.90	x Un	0.30	R/W	Undervoltage limit for blocking
Start frequency	S43	25.00...75.00	Hz	48.70	R/W	Start value for U/O frequency protection
Operate time 1	S44	0.10... 300.00	s	20.00	R/W	Operate time for U/O frequency protection
Start df/dt	S45	0.2...10.0	Hz/s	10.0	R/W	Start value for frequency rate of change prot.
Operate time 2	S46	0.12... 300.00	s	20.00	R/W	Timer for df/dt prot. or U/O frequency prot.

¹⁾ Operation mode
 0 = Not in use
 1 = f</f> 1 timer
 2 = f</f> 2 timers
 3 = f</f> OR df/dt>
 4 = f</f> AND df/dt>
 5 = f</f> OR df/dt<
 6 = f</f> AND df/dt<

3.2.3

Setting group 2

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S71	0...6 ¹⁾	-	1	R/W	Operation mode for frequency protection
Voltage limit	S72	0.30...0.90	x Un	0.30	R/W	Undervoltage limit for blocking
Start frequency	S73	25.00...75.00	Hz	48.70	R/W	Start value for U/O frequency protection
Operate time 1	S74	0.10... 300.00	s	20.00	R/W	Operate time for U/O frequency protection
Start df/dt	S75	0.2...10.0	Hz/s	10.0	R/W	Start value for frequency rate of change prot.
Operate time 2	S76	0.12... 300.00	s	20.00	R/W	Timer for df/dt prot. or U/O frequency prot.

¹⁾ Operation mode

- 0 = Not in use
- 1 = f</f> 1 timer
- 2 = f</f> 2 timers
- 3 = f</f> OR df/dt>
- 4 = f</f> AND df/dt>
- 5 = f</f> OR df/dt<
- 6 = f</f> AND df/dt<

3.2.4

Control settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Group selection	V1	0 ... 2 ¹⁾	-	0	R/W	Selection of the active setting group
Active group	V2	0 or 1 ²⁾	-	0	R/M	Active setting group
Start pulse	V3	0...1000	ms	0	R/W	Minimum pulse width of START signals
Trip signal	V4	0 or 1 ³⁾	-	0	R/W	Selection of latching feature for TRIP outputs
Trip pulse	V5	40...1000	ms	40	R/W	Minimum pulse width of TRIP and CBFP
Reset registers	V13	1=Reset	-	0	W	Resetting of latched trip signal and registers
Test START1	V31	0 or 1 ⁴⁾	-	0	R/W	Testing of START1
Test TRIP1	V32	0 or 1 ⁴⁾	-	0	R/W	Testing of TRIP1
Test START2	V33	0 or 1 ⁴⁾	-	0	R/W	Testing of START2
Test TRIP2	V34	0 or 1 ⁴⁾	-	0	R/W	Testing of TRIP2
Event mask 1	V101	0...16383	-	255	R/W	Event mask 1 for event transmission (E0 ... E13)
Event mask 2	V103	0...16383	-	255	R/W	Event mask 2 for event transmission (E0 ... E13)
Event mask 3	V105	0...16383	-	255	R/W	Event mask 3 for event transmission (E0 ... E13)
Event mask 4	V107	0...16383	-	255	R/W	Event mask 4 for event transmission (E0 ... E13)

¹⁾ Group selection 0 = Group 1; 1 = Group 2; 2 = GROUP input

²⁾ Active group 0 = Group 1; 1 = Group 2

³⁾ Trip signal 0 = Non-latching; 1 = Latching

⁴⁾ Test 0 = Do not activate; 1 = Activate

3.3 Measurement values

3.3.1 Input data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Frequency	I1	20.00...80.00	Hz	0.0	R/M	System frequency
Rate of change	I2	-15.0...+15.0	Hz/s	0.0	R/M	Freq. rate of change
Voltage U	I3	0.0...2.0	x Un	0.0	R/M	Voltage U
Input BS1	I4	0 or 1 ¹⁾	-	0	R/M	Block signal BS1
Input BS2	I5	0 or 1 ¹⁾	-	0	R/M	Block signal BS2
Input TRIGG	I6	0 or 1 ¹⁾	-	0	R/M	Signal for triggering the registers
Input GROUP	I7	0 or 1 ¹⁾	-	0	R/M	Signal for switching between the groups 1 and 2
Input RESET	I8	0 or 1 ¹⁾	-	0	R/M	Signal for resetting the output signals and registers of Freq1St_

¹⁾ Input 0 = Not active; 1 = Active

3.3.2 Output data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Output START1	O1	0 or 1 ¹⁾	-	0	R/M	Status of start signal 1
Output TRIP1	O2	0 or 1 ¹⁾	-	0	R/M	Status of trip signal 1
Output START2	O3	0 or 1 ¹⁾	-	0	R/M	Status of start signal 2
Output TRIP2	O4	0 or 1 ¹⁾	-	0	R/M	Status of trip signal 2

¹⁾ Output 0 = Not active; 1 = Active

3.3.3 Recorded data

3.3.3.1 General

The information required for later fault analysis is recorded when the function block starts or trips, or when the recording function is triggered via the external TRIGG input.

The data of the last three events are stored in Recorded data 1...3, beginning from Recorded data 1. These registers are updated in a cyclical manner, where the values of the most recent event overwrite the oldest recorded data. If recorded data has been reset or the relay has been restarted, the first event is again stored in Recorded data 1.

Registers containing information about the voltage, frequency, etc. can be accessed over the serial communication or the local MMI of the RED 500 unit.

3.3.3.2 Date and time

The time stamp indicates the rising edge of the START1, TRIP1, START2, TRIP2 or TRIGG signals.

3.3.3.3 Duration

The duration of a start situation is recorded separately for the operate timers 1 and 2 (refer to Figure 2). The durations are recorded as percentages of the set operate times. Timers are independent from each other, i.e. if both timers are running, the highest value reached will be recorded to both durations, regardless whether a trip has been commenced by either of the timers.

3.3.3.4 Frequency and voltage values

If the function block trips, the frequency and voltage values are updated at the moment of tripping i.e. on the rising edge of the TRIP signal. At external triggering, the frequency and voltage values are updated at the moment of triggering i.e. on the rising edge of the input signal TRIGG. If the function block starts but does not trip, the values captured one fundamental cycle (20 ms at rated frequency 50 Hz) after the beginning of the start situation are recorded.

3.3.3.5 Status data

The status data of the input signals BS1, BS2 and TRIGG and the output signals START1, START2, TRIP1 and TRIP2 as well as the parameter “Active group” are recorded at the moment of tripping and triggering. The “Active group” parameter indicates the setting group valid for the recorded data.

3.3.3.6 Priority

The priority of the recording function is the following:

- 1 Tripping
- 2 Starting
- 3 External triggering,

which means that if the function has started, it will neglect an external triggering request.

3.3.3.7

Recorded data 1

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V201	YYYY-MM-DD	-	-	R/M	Recording date
Time	V202	hh:mm:ss.mss	-	-	R/M	Recording time
Start1	V203	0 or 1 ¹⁾	-	0	R/M	Status of START1
Start2	V204	0 or 1 ¹⁾	-	0	R/M	Status of START2
Duration1	V205	0.0...100.0	%	0.0	R/M	Duration of START1 situation
Duration2	V206	0.0...100.0	%	0.0	R/M	Duration of START2 situation
Trip1	V207	0 or 1 ¹⁾	-	0	R/M	Status of TRIP1
Trip2	V208	0 or 1 ¹⁾	-	0	R/M	Status of TRIP2
Frequency	V209	20.00...80.00	Hz	0.0	R/M	Meas. system frequency
Rate of change	V210	-15.0...+15.0	Hz/s	0.0	R/M	Freq. rate of change
Voltage U	V211	0.0...2.0	x Un	0.0	R/M	Meas. voltage
BS1	V212	0 or 1 ¹⁾	-	0	R/M	Status of BS1
BS2	V213	0 or 1 ¹⁾	-	0	R/M	Status of BS2
TRIGG	V214	0 or 1 ¹⁾	-	0	R/M	Status of TRIGG
Active group	V215	0 or 1 ²⁾	-	0	R/M	Active setting group

¹⁾ Status 0 = Not active; 1 = Active

²⁾ Active group 0 = Group 1; 1 = Group 2

3.3.3.9

Recorded data 3

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V401	YYYY-MM-DD	-	-	R/M	Recording date
Time	V402	hh:mm:ss.mss	-	-	R/M	Recording time
Start1	V403	0 or 1 ¹⁾	-	0	R/M	Status of START1
Start2	V404	0 or 1 ¹⁾	-	0	R/M	Status of START2
Duration1	V405	0.0...100.0	%	0.0	R/M	Duration of START1 situation
Duration2	V406	0.0...100.0	%	0.0	R/M	Duration of START2 situation
Trip1	V407	0 or 1 ¹⁾	-	0	R/M	Status of TRIP1
Trip2	V408	0 or 1 ¹⁾	-	0	R/M	Status of TRIP2
Frequency	V409	20.00...80.00	Hz	0.0	R/M	Meas. system frequency
Rate of change	V410	-15.0...+15.0	Hz/s	0.0	R/M	Freq. rate of change
Voltage U	V411	0.0...2.0	x Un	0.0	R/M	Meas. voltage
BS1	V412	0 or 1 ¹⁾	-	0	R/M	Status of BS1
BS2	V413	0 or 1 ¹⁾	-	0	R/M	Status of BS2
TRIGG	V414	0 or 1 ¹⁾	-	0	R/M	Status of TRIGG
Active group	V415	0 or 1 ²⁾	-	0	R/M	Active setting group

¹⁾ Status 0 = Not active; 1 = Active

²⁾ Active group 0 = Group 1; 1 = Group 2

3.3.4

Events

Code	Weighting coefficient	Default mask	Event reason	Event state
E0	1	1	START1 signal from f>,f< St_	Reset
E1	2	1	START1 signal from f>,f< St_	Activated
E2	4	1	TRIP1 signal from f>,f< St_	Reset
E3	8	1	TRIP1 signal from f>,f< St_	Activated
E4	16	1	START2 signal from f>,f< St_	Reset
E5	32	1	START2 signal from f>,f< St_	Activated
E6	64	1	TRIP2 signal from f>,f< St_	Reset
E7	128	1	TRIP2 signal from f>,f< St_	Activated
E8	256	0	BS1 signal of f>,f< St_	Reset
E9	512	0	BS1 signal of f>,f< St_	Activated
E10	1024	0	BS2 signal of f>,f< St_	Reset
E11	2048	0	BS2 signal of f>,f< St_	Activated
E12	4096	0	Test mode of f>,f< St_	Off
E13	8192	0	Test mode of f>,f< St_	On

4. Technical data

Operation accuracies	Underfrequency or overfrequency function ($f < / >$): ± 10 mHz Frequency rate of change function (df/dt): real $df/dt < \pm 5$ Hz/s: accuracy ± 100 mHz/s real $df/dt < \pm 15$ Hz/s: accuracy $\pm 2.0\%$ of the real df/dt Undervoltage blocking: $\pm 1.0\%$ of set value
Start time	Total start times at rated freq. $f_n = 50$ Hz: Frequency measurement: < 100 ms ¹⁾ Df/dt measurement: < 120 ms ¹⁾ Note! The operate times and start times are specified for the set rated frequencies 50 Hz and 60 Hz.
Reset time	140...1000 ms (depends on the minimum pulse width set for the TRIP output)
Operate time accuracy	$\pm 2\%$ of set value or ± 30 ms
Frequency dependence of the settings and operate times	Accuracy for the $f < / >$ function is defined in the setting range 25...75 Hz.
Configuration data	Task execution interval (Relay Configuration Tool): 5 ms at the rated frequency $f_n = 50$ Hz

1) Includes the delay of the output relay

Technical revision history	
Technical revision	Change
E	-
F	-
G	Operate time 1 and 2 upper limit changed from 120.00 s to 300.00 s