Inrush3
Three-Phase Transformer Inrush and Motor Start-Up Current Detector

Contents

1. Introduction

1.1 Features

- Fast output signal for stabilizing the protection stages in a transformer inrush or at motor start-up
- Transformer inrush detection
- Motor start-up detection
- Current measurement with conventional current transformers or Rogowski coils
- Single-phase, two-phase or three-phase operation

1.2 Application

This document specifies the function of the three-phase transformer inrush and motor start-up detection function block Inrush3 used in products based on the RED 500 Platform.

The function block Inrush3 can be used for doubling the set start current of overcurrent protection in a transformer magnetizing inrush situation or at motor start-up, or for blocking (stabilization) overcurrent protection in a transformer magnetizing inrush situation.

Table 1 . Protection diagram symbols used in the relay terminal

ABB	IEC	ANSI
Inrush3	**3I2f>**	**68**

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

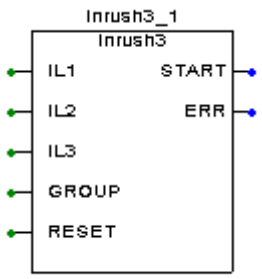

Figure 1. Function block symbol of Inrush3

1.3 Input description

Name	Type	Description
IL1	Analogue signal (SINT)	Input for measuring phase current I_{L1}
IL2	Analogue signal (SINT)	Input for measuring phase current I_{L2}
IL3	Analogue signal (SINT)	Input for measuring phase current I_{L3}
GROUP	Digital signal (BOOL, active high)	Control input for switching between the setting groups 1and 2. When GROUP is FALSE, group 1 is active. When GROUP is TRUE, group 2 is active.
RESET	Reset signal (BOOL, pos. edge)	Input signal for resetting the registers of Inrush3

1.4 Output description

Name	Type	Description
START	Digital signal (BOOL, active high)	Output signal for stabilization
ERR	Digital signal (BOOL, active high)	Signal for indicating a configuration error

2. Description of Operation

2.1 Configuration

Phase currents can be measured using conventional current transformers or Rogowski coils. A special dialogue box of the Relay Configuration Tool included in the Cap 505 Tool Box, is used for selecting and configuring the measuring devices and signal types for analogue channels. Digital inputs are configured in the same programming environment (the number of selectable analogue inputs, digital inputs and digital outputs depends on the hardware variant).

When the analogue channels and digital inputs have been selected and configured in the dialogue box, the inputs and outputs of the function block can be configured on a graphic worksheet of the configuration tool. The phase currents I_{L1}, I_{L2} and I_{L3} are connected to the corresponding IL1, IL2 and IL3 inputs of the function block. Digital inputs are connected to the boolean inputs of the function block and in the same way, the outputs of the function block are connected to the output signals.

Note! When the function block Inrush3 is used, the 2nd harmonic restraint must be selected for the channels connected to the IL_ inputs of the function block from the special measurements dialogue box of the configuration tool, regardless of whether the transformer inrush mode or the motor startup mode is used.

2.2 Measuring mode

There are two operation modes available. The measuring mode depends on the operation mode selected.

2.2.1 Transformer inrush mode

In transformer inrush mode, the operation is based on the ratio between the digitally filtered second harmonic phase current and the fundamental frequency phase current:

- operation is insensitive to the DC component
- the suppression of harmonics for the fundamental frequency calculation is at least -50 dB at $f = k \times f_n$, where k = 2, 3, 4, 5,...
- the suppression of harmonics for the second harmonic calculation is at least -50 dB at $f = k \times f_n$, where k = 1 or 3, 4, 5,...

2.2.2 Motor start-up mode

In motor start-up mode, the operation is based on momentary values and consecutive peak-to-peak values of phase currents. Harmonics are not suppressed.

2.3 Operation criteria

The setting parameter “Operation mode” is used for selecting the operation mode. There are two modes available: the transformer inrush mode and the motor start-up mode.

2.3.1 Transformer inrush mode

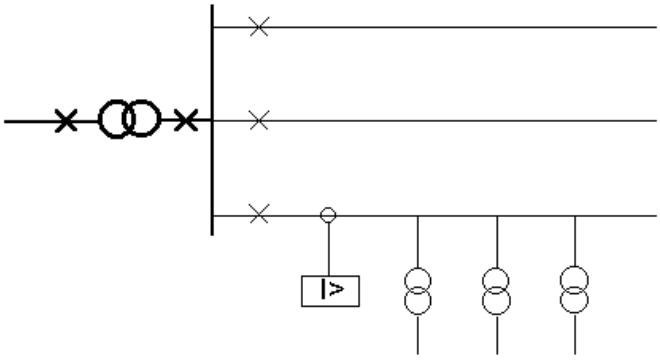

Figure 2. The function block Inrush3 can be used for blocking overcurrent protection at transformer magnetizing inrush

Transformer inrush detection is based on the traditional principle: the output signal START is activated once the numerically derived ratio I_{2f}/I_{1f} between the amplitudes of the second harmonic and the fundamental frequency current in one phase exceeds the value set for the “Ratio I2f/I1f>“ parameter.

The signal START can be activated only if the amplitude of the fundamental frequency current of the corresponding phase is above 3% I_n. A control parameter[1] is used for setting the minimum pulse width of the output signal START. However, the signal START remains active until the ratio I_{2f}/I_{1f} drops below the value set for the “Ratio I2f/I1f>“ parameter in all phases, i.e. until the inrush situation is over, even if the start pulse timer has elapsed earlier.

[1] “Start pulse”

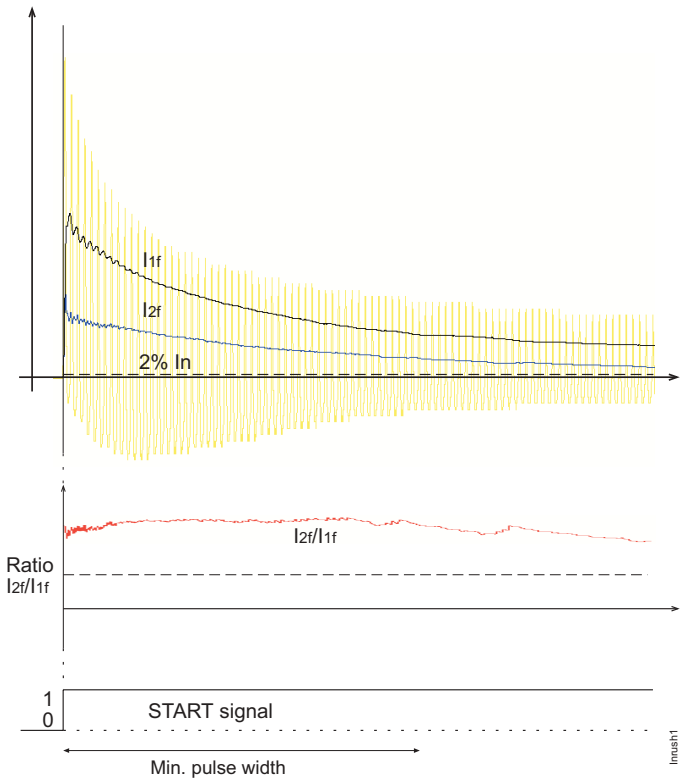

Figure 3. Functionality of the transformer inrush mode

2.3.2 Motor start-up mode

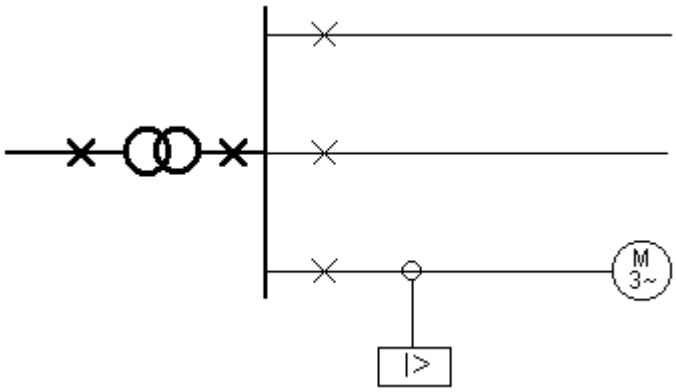

Figure 4. The function block Inrush3 can be used for blocking overcurrent protection at motor start-up

The motor start-up is defined as a situation in which the initial three phase currents stay below 5.0% I_n for about 60 ms, i.e. the motor is at standstill, and in which the value of at least one phase current rises from 5.0 % I_n above the set start current within the set rising time. If a phase current exceeds the set current level within the set time, the START signal is immediately set to TRUE, i.e. the START output can be activated before the set rising time has elapsed.

A control parameter “Start pulse” is used for setting the minimum pulse width of the output signal START. However, the START signal remains active until all the three phase currents fall below 0.9 x Start current and remain below that level for about 150 ms, i.e. until the start-up situation is over, even if the START pulse timer has elapsed earlier.

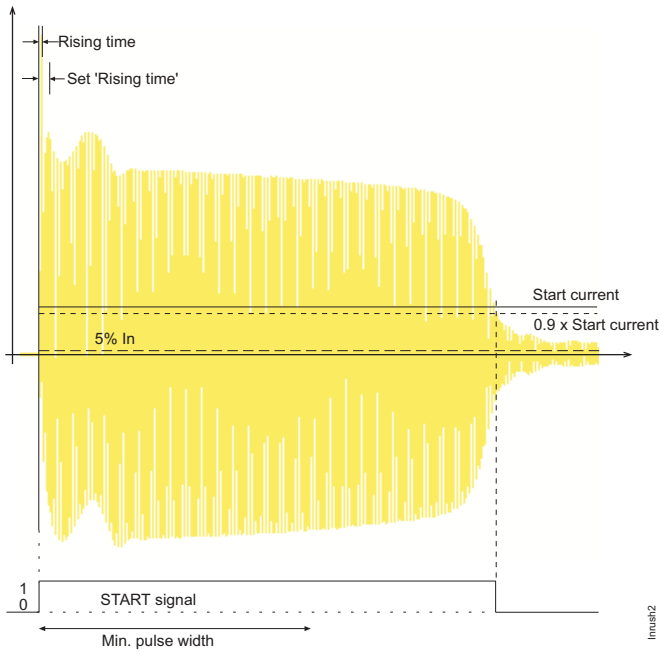

Figure 5. Functionality of the motor start-up mode

2.4 Setting groups

Two different groups of setting values, group 1 and group 2, are available for the function block. 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 V2[1)]

3 By means of the input signal GROUP when allowed via the parameter “Group selection” (i.e. when V2 = 2[1)]).

[1)] Group selection (V2): 0 = Group 1; 1 = Group 2; 2 = GROUP input

The control parameter “Active group” indicates the setting group valid at a given time. The settings that are active can be read from the “Actual settings” view.

2.5 Test mode

The digital outputs of the function block 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 output

A separate parameter on the MMI or via the serial communication is used for setting the minimum pulse width of the output signal START.

2.7 Resetting

The TRIP output signal 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 F034V013 [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 particular function block.
[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 channel for Inrush3 is 34.
- 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 ... 2 [1)]	-	1	R/M	Selection of operation mode
Ratio I2f/I1f>	S2[2)]	5 ... 50	%	15	R/M	Blocking limit I_{2f}/I_{1f}
Start current	S3[3)]	0.10 ...5.00	x In	0.10	R/M	Motor start current

[1)] Operation mode 0 = Not in use; 1 = Inrush mode; 2 = Start-up mode
[2)] Active only in transformer inrush mode
[3)] Active only in motor start-up mode

3.2.2 Setting group 1

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S41	0 ... 2 [1)]	-	1	R/W	Selection of operation mode
Ratio I2f/I1f>	S42[2)]	5 ... 50	%	15	R/W	Blocking limit I_{2f}/I_{1f}
Start current	S43[3)]	0.10 ...5.00	x In	0.10	R/W	Motor start current

[1)] Operation mode 0 = Not in use; 1 = Inrush mode; 2 = Start-up mode
[2)] Active only in transformer inrush mode
[3)] Active only in motor start-up mode

3.2.3 Setting group 2

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S71	0 ... 2 [1)]	-	1	R/W	Selection of operation mode
Ratio I2f/I1f>	S72[2)]	5 ... 50	%	15	R/W	Blocking limit I_{2f}/I_{1f}
Start current	S73[3)]	0.10 ...5.00	x In	0.10	R/W	Motor start current

[1)] Operation mode 0 = Not in use; 1 = Inrush mode; 2 = Start-up mode
[2)] Active only in transformer inrush mode
[3)] Active only in motor start-up mode

3.2.4 Control settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Rising time	V1[4]	20...60	ms	20	R/W	Rising time for phase currents
Group selection	V2	0...2 [1]	-	0	R/W	Selection of the active setting group
Active group	V3	0 or 1 [2]	-	0	R/M	Active setting group
Start pulse	V4	0...1000	ms	0	R/W	Minimum pulse width of signal START
Reset registers	V13	1=Reset	-	0	W	Resetting of registers
Test START	V31	0 or 1 [3]	-	0	R/W	Testing of START
Event mask 1	V101	0...15	-	3	R/W	Event mask 1 for event transmission (E0 ... E3)
Event mask 2	V103	0...15	-	3	R/W	Event mask 2 for event transmission (E0 ... E3)
Event mask 3	V105	0...15	-	3	R/W	Event mask 3 for event transmission (E0 ... E3)
Event mask 4	V107	0...15	-	3	R/W	Event mask 4 for event transmission (E0 ... E3)

[1] Group selection 0 = Group 1; 1 = Group 2; 2 = GROUP input
[2] Active group 0 = Group 1; 1 = Group 2
[3] Test START 0 = Do not activate; 1 = Activate
[4] Active only in motor start-up mode

3.3 Measurement values

3.3.1 Input data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Current IL1	I1	0.00...60.00	x In	0.00	R/M	Phase current I_{L1}
Current IL2	I2	0.00...60.00	x In	0.00	R/M	Phase current I_{L2}
Current IL3	I3	0.00...60.00	x In	0.00	R/M	Phase current I_{L3}
Input GROUP	I4	0 or 1 [1]	-	0	R/M	Signal for switching between the groups 1 and 2
Input RESET	I5	0 or 1 [1]	-	0	R/M	Signal for resetting the registers

[1] Input 0 = Not active; 1 = Active

3.3.2 Output data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Output START	O1	0 or 1 [1)]	-	0	R/M	Status of start signal

[1)] Output 0 = Not active; 1 = Active

3.3.3 Recorded data

The registers are triggered when an inrush or start-up situation is detected. The time stamp indicates the moment of detection, i.e. the moment when the second harmonic content of the current in one phase exceeds the value set for the “Ratio I2f/I1f>“ parameter or when a phase current exceeds the set start current when a motor start-up situation is detected.

When the set “Ratio I2f/I1f>“ is exceeded in one phase or when the value of at least one of the phase currents rises from 5.0 % I_n above the set start current in less time than the set “Rising time”, the function block starts calculating the average of each phase current I_{L1}, I_{L2} and I_{L3}, and the minimum value of the ratio I_{2f}/I_{1f} in each phase. The average currents and the minimum values of I_{2f}/I_{1f} will be updated when the START signal resets. The values of the phase currents I_{L1}, I_{L2} and I_{L3} are recorded as multiples of the rated current I_n. The recorded I_{2f}/I_{1f} ratios are percentage values.

The duration of the transformer inrush situation is defined as the time during which the set I2f/I1f value is exceeded. The duration of a motor start-up situation is defined as the time from the moment when the first phase current exceeds 5.0% I_n until all three currents fall below 0.9 x Start current and remain below that value for about 50 ms. The duration is updated when the START signal resets.

The data of three last operations (operation 1...3) are recorded and the values of the most recent operation always replace the data of the oldest operation.

3.3.3.1 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
Duration	V203	0.0...60.0	s	0.0	R/M	Duration of start situation
Average IL1	V204	0.00...60.00	x In	0.00	R/M	Average value of I_{L1}
Average IL2	V205	0.00...60.00	x In	0.00	R/M	Average value of I_{L2}
Average IL3	V206	0.00...60.00	x In	0.00	R/M	Average value of I_{L3}
Min. I2f/I1f L1	V207	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L1}
Min. I2f/I1f L2	V208	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L2}
Min. I2f/I1f L3	V209	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L3}
Active group	V210	0 or 1 [1)]	-	0	R/M	Active setting group

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

3.3.3.2 Recorded data 2

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V301	YYYY-MM-DD	-	-	R/M	Recording date
Time	V302	hh:mm:ss.mss	-	-	R/M	Recording time
Duration	V303	0.0...60.0	s	0.0	R/M	Duration of start situation
Average IL1	V304	0.00...60.00	x In	0.00	R/M	Average value of I_{L1}
Average IL2	V305	0.00...60.00	x In	0.00	R/M	Average value of I_{L2}
Average IL3	V306	0.00...60.00	x In	0.00	R/M	Average value of I_{L3}
Min. I2f/I1f L1	V307	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L1}
Min. I2f/I1f L2	V308	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L2}
Min. I2f/I1f L3	V309	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L3}
Active group	V310	0 or 1 [1)]	-	0	R/M	Active setting group

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

3.3.3.3 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
Duration	V403	0.0...60.0	s	0.0	R/M	Duration of start situation
Average IL1	V404	0.00...60.00	x In	0.00	R/M	Average value of I_{L1}
Average IL2	V405	0.00...60.00	x In	0.00	R/M	Average value of I_{L2}
Average IL3	V406	0.00...60.00	x In	0.00	R/M	Average value of I_{L3}
Min. I2f/I1f L1	V407	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L1}
Min. I2f/I1f L2	V408	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L2}
Min. I2f/I1f L3	V409	0.0...100.0	%	0.0	R/M	Minimum I_{2f}/I_{1f} of I_{L3}
Active group	V410	0 or 1 [1)]	-	0	R/M	Active setting group

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

3.3.4 Events

Code	Weighting coefficient	Default mask	Event reason	Event state
E0	1	1	START signal from Inrush3 stage	Reset
E1	2	1	START signal from Inrush3 stage	Activated
E2	4	0	Test mode of Inrush3 stage	Off
E3	8	0	Test mode of Inrush3 stage	On

4. Technical Data

Operation accuracies	At the frequency f/f_n = 0.95...1.05: current measurement: ±2.5% of set value or ±0.01 x I_n. ratio I2f/I1f measurement: ±5.0% of set value		
Start time	f/f_n = 0.95...1.05	internal time	< 32 ms
		total time[1)]	< 40 ms
Configuration data	Task execution interval (Relay Configuration Tool): 10 ms at the rated frequency f_n = 50 Hz		

[1)] Includes the delay of the signal relay

Technical revision history	
Technical revision	**Change**
B	-
C	- default value of V31 = 0
D	- data type of events E0 and E1 changed to single indication