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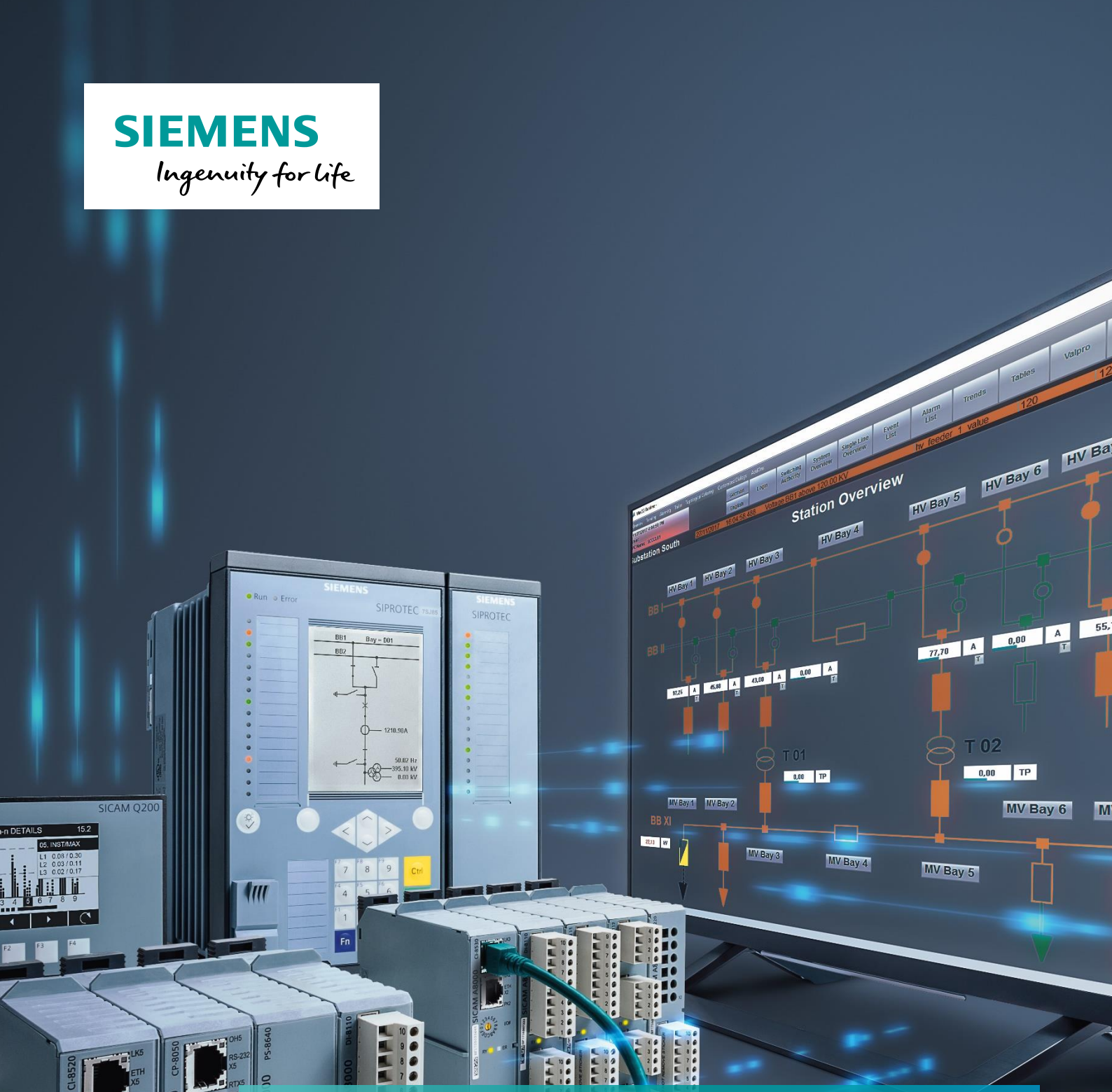

Point-on-Wave Closing with Transformer - Basics

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SIPROTEC 5 Application

Point on Wave Closing with Transformer - Basics

APN-071, Edition 1

Content

1 Point-on-Wave Closing with Transformer - Basics

1.1 Introduction

On large transformers the in-rush current during energization is detrimental to the power system and the service life of the transformer. By timing the close command in each phase of the circuit breaker it is possible to minimize the in-rush current and the transient overvoltage.

The functionality used for this purpose in SIPROTEC 5 is the Point on Wave (PoW) switching.

- Inrush current: reduced
- Voltage transients: reduced
- Maintenance intervals: increased

This application note will demonstrate the PoW function in SIPROTEC 5 devices, only the Close Command is considered in this application note in terms of the Point-on-Wave function.

1.2 Possible Device Types and Device Applications

The Point-on-Wave switching function can be applied in the following SIPROTEC 5 device types: 6MD86, 7SJ85, 7SA87, 7SD87, 7SL87, 7VK87, 7UT85, 7UT86, 7UT87, 6MU85, 7UM85.

3 different device applications are possible:

- Stand-alone point-on-wave (PoW) switching device, via the device type 6MD86
- Bay-control function and point-on-wave switching in one device, via the device type 6MD86
- Protection, bay-control function, and point-on-wave switching in one device, via the preceding listed devices

Additional function points must be considered for the Point-on-Wave Switching function. For each switching direction (closing or opening) one IO209 extension module with high-speed relays is required as well optionally a IO212 for fast measuring- transducer inputs. IO212 offers 8 fast measuring-transducer inputs, 3 of which are required for the reference contacts if applicable.

In case of non-Siemens circuit breakers, this function is carried out via the 52a auxiliary contact of the circuit breaker, which is connected to normal device binary inputs, for example, available in the 1/3 base module. No IO212 is required for this .

1.3 Timing

For the transformer closing, the PoW function has predefined timing. This timing is based on the flux that will be induced in the transformer core due to the closing of the pole (prospective flux) in relation to the flux that is already present prior to closing of the pole (remnant and/or dynamic flux). In this application remnant flux is not considered.

The timing of the 3 poles for closing with PoW can be checked in the settings (a modification is not required:

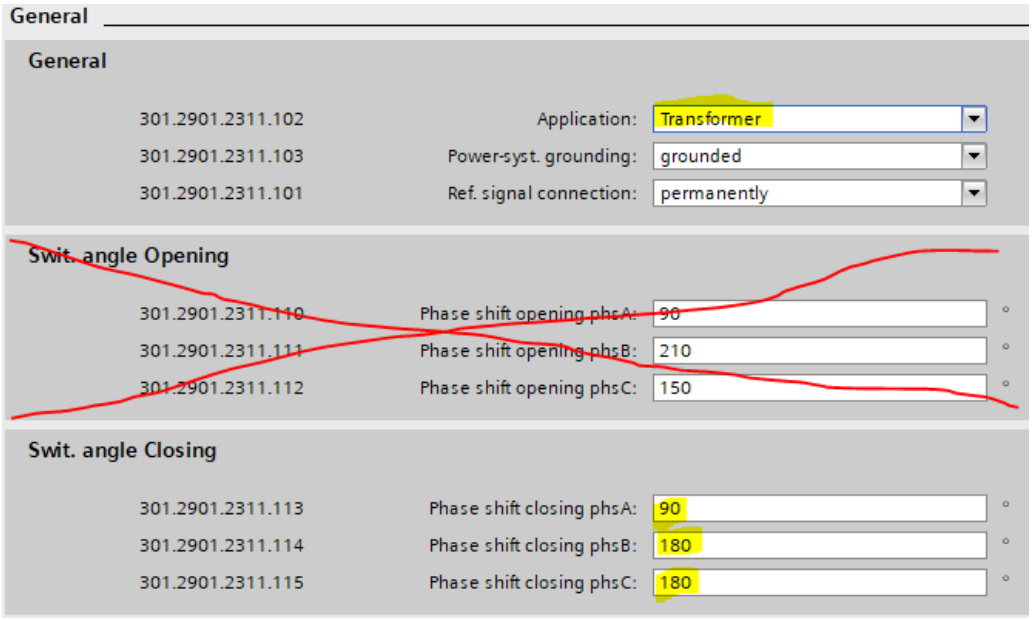


Figure 1: Timing of PoW closing - transformer

The switching angle at closing always refers to the reference voltage which is the Phase A voltage. The first phase will be A which closes at 90°; this is at the peak of the phase A voltage. The phase B and C follow with closing when the reference voltage is at 180° which is at the zero-crossing subsequent to 90°.

1.4 Circuit Breaker

During closing the circuit breaker will go through the following stages (figure is copied from PoW manual description):

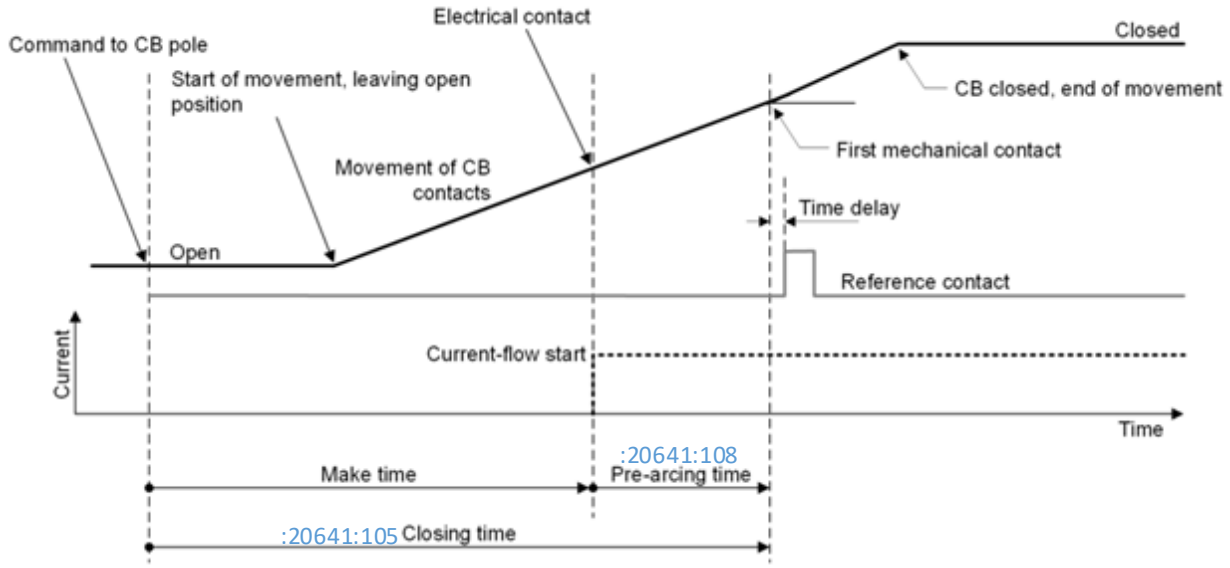


Figure 2: Timing of Circuit Breaker Closing

The PoW function must be set with the relevant circuit breaker data:

CB data

301.2901.20641.105	CB closing time phsA:	8.2	ms
301.2901.20641.106	CB closing time phsB:	13.0	ms
301.2901.20641.107	CB closing time phsC:	13.4	ms
301.2901.20641.108	CB pre-arcing time phsA:	0.4	ms
301.2901.20641.109	CB pre-arcing time phsB:	0.1	ms
301.2901.20641.110	CB pre-arcing time phsC:	0.1	ms
301.2901.20641.115	CB correction time phsA:	2.00	ms
301.2901.20641.116	CB correction time phsB:	-2.00	ms
301.2901.20641.117	CB correction time phsC:	0.00	ms

Figure 3: Circuit Breaker settings

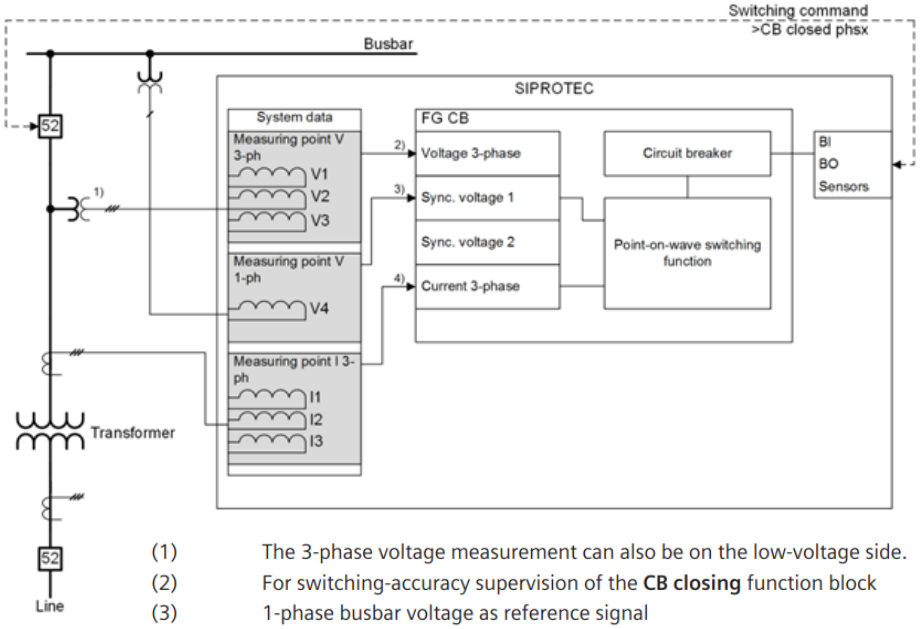
The above CB settings are for a CB model and are therefore not typical for real circuit breaker. The correction times set in the screenshot above adapt for deviation reference contact (auxiliary contact), i.e. the difference between the reference contact and the primary CB contact.

Parameter	Descripting	Setting
_:105 CB closing time phs A	Time between make of close contact in relay and first mechanical contact closing in CB	Set this to the specified "t_c" of the circuit breaker
_:108 CB pre-arcing time phs A	Time between first electrical contact in the CB and first mechanical contact closing in CB	Set this to the specified pre-arc time of the circuit breaker.
_:115 CB correction time phs A	During commissioning small deviations from the specified closing time may be determined and set here	Set to the deviation from the set closing time as discovered during commissioning

The above table describes the CB timing settings for Phase A. The Phase B and C settings are set in the same manner.

1.5 Connection

The transformer will be connected as follows:



(1) The 3-phase voltage measurement can also be on the low-voltage side.
(2) For switching-accuracy supervision of the **CB closing** function block
(3) 1-phase busbar voltage as reference signal
(4) For switching-accuracy supervision of the **CB opening** function block and for recording of the inrush current

Figure 4: Transformer connection diagram

The phase selective close commands must be routed via high speed contacts (IO 209 Module). The bus voltage (Phase A) will be used as reference voltage: i.e. the voltage that controls the PoW closing commands.

Note that the busbar voltage, single phase connection must be assigned to Vsync 1 of the circuit breaker:

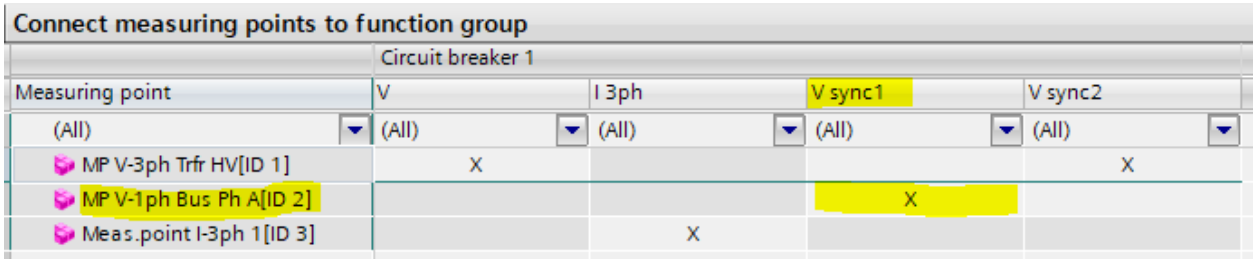


Figure 5: Assignment of Measuring points

The following settings allow the configuration of supervision boundaries for the reference voltage:

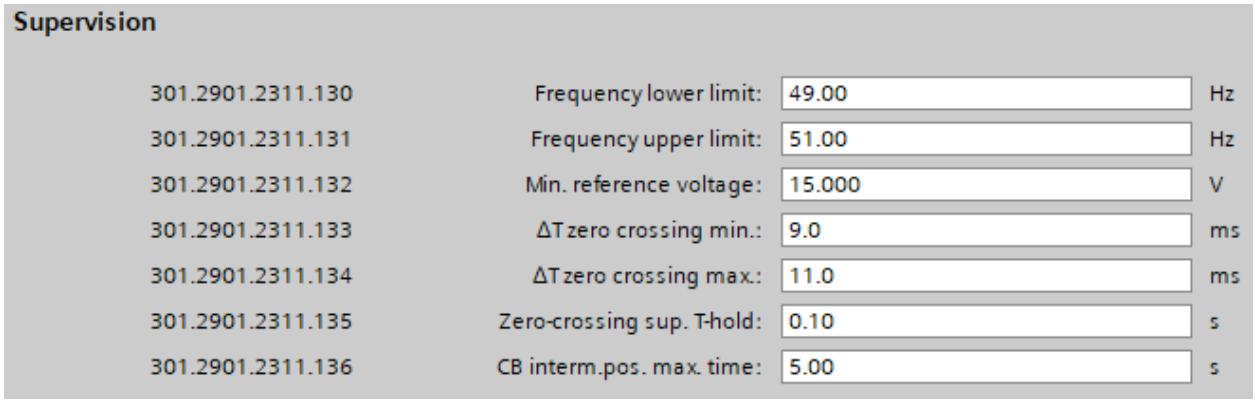


Figure 6: Setting of supervision boundaries

For this application at 50 Hz, the default settings are applied. The ΔT of the zero crossings checks the interval between successive zero crossings. Expected is 10 ms at 50 Hz. The holding time delays the drop out once a ΔT outside the set boundaries has been detected. Refer to the manual for more details.

Must the close command be processed when PoW closing is not possible?

When the reference voltage is not present or disturbed a controlled PoW closing is not possible. From an operational point of view, it may however be desirable to still process the close commend (3 pole). This can be set with the following parameter:

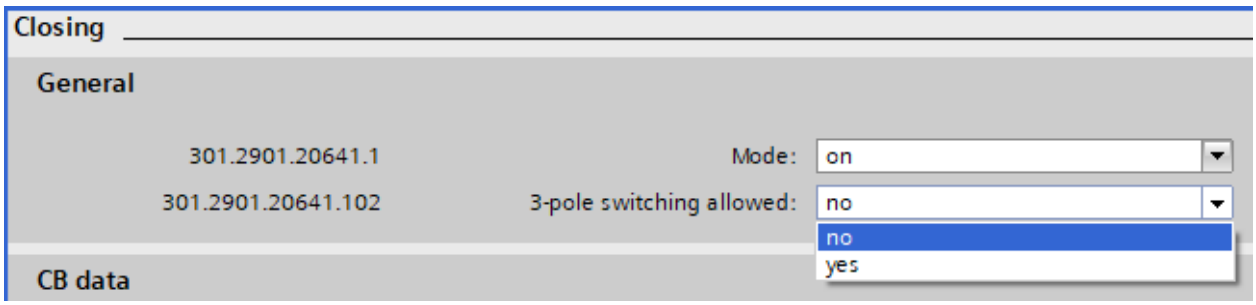


Figure 7: Closing 3-pol when PoW is not possible

Set _:102 3-pole switching allowed = yes to allow 3 pole closing when PoW is not possible.

During the PoW closing relevant information should be routed to the operational log. It may be advisable to trigger a fault record in order to check the operation. If a fault record is triggered the PoW signals can be routed to the "Fault Log" which will be opened together with the fault record. In this manner the data can be processed more easily. The following CFC block can be used to trigger the fault record:

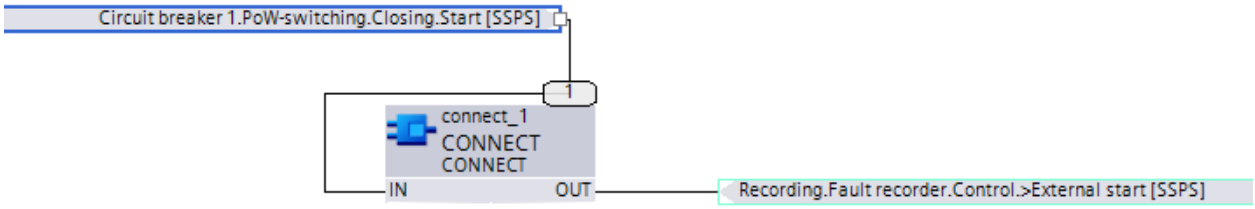


Figure 8: CFC logic for triggering Fault Record with PoW closing

The following settings allow the configuration of the boundaries of the PoW closing. When exceeded a corresponding indication is provided (checks correct response of Circuit Breaker).

Swit.accuracy sup.

301.2901.20641.114	Maximum allowed time:	0.30	s
301.2901.20641.129	Clos. time: allowed diff. :	3.0	ms
301.2901.20641.130	Make time: allowed diff.:	3.0	ms
301.2901.20641.144	Make-time detection via:	voltage	
301.2901.20641.135	Make-time detec. V> phsA:	40.000	V
301.2901.20641.136	Make-time detec. V> phsB:	40.000	V
301.2901.20641.137	Make-time detec. V> phsC:	40.000	V
301.2901.20641.138	Threshold: V too high:	120.000	V
301.2901.20641.139	Threshold: I too high:	2.000	A

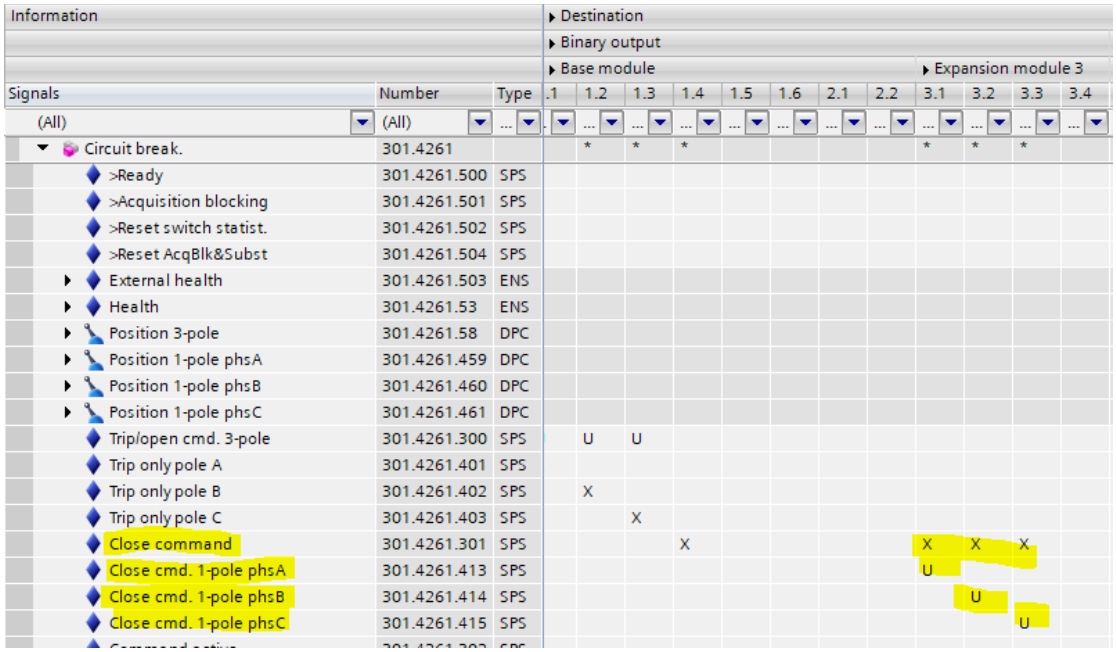
Figure 9: Settings of switching accuracy supervision

For more details on the above settings refer to the manual. In this application with closing of a transformer the "Make-time detection" is fixed via "voltage". When the 1st pole closes there will be induced voltage in the other 2 phases; this is not used for closing detection. When these poles close there will be a significant jump. (refer to Figure 14 Fault Record) For a rated secondary Ph-Ph voltage of 100 V the setting of 40 V is approximately 50% of the peak instantaneous voltage – this is OK, in some cases an increase may be advisable.

If the PoW closing works correctly there will be very little transient overvoltage. The threshold "V too high" sets the boundary. If a Voltage exceeds this threshold (instantaneous) a corresponding alarm is initiated. The current threshold is not relevant here as the voltage is used for the PoW closing of transformers.

1.6 Routing Matrix

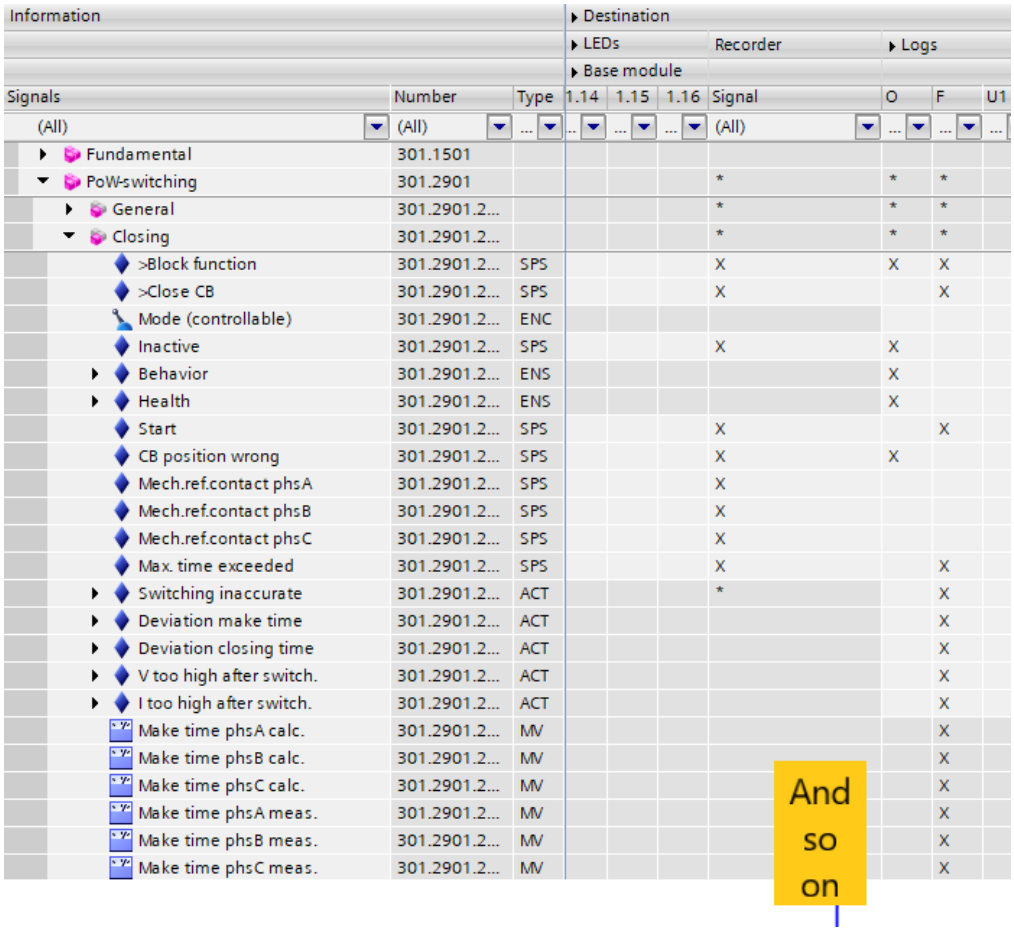
Apart from the standard signal routing (CB auxiliary contacts, tripping etc.) the PoW closing requires the routing of the high-speed contacts of the IO 209 Module:



Information			Destination											
			Binary output											
			Base module								Expansion module 3			
Signals	Number	Type	.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	3.1	3.2	3.3	3.4
(All)	(All)													
Circuit break.	301.4261			*	*	*					*	*	*	
>Ready	301.4261.500	SPS												
>Acquisition blocking	301.4261.501	SPS												
>Reset switch statist.	301.4261.502	SPS												
>Reset AcqBlk&Subst	301.4261.504	SPS												
External health	301.4261.503	ENS												
Health	301.4261.53	ENS												
Position 3-pole	301.4261.58	DPC												
Position 1-pole phsA	301.4261.459	DPC												
Position 1-pole phsB	301.4261.460	DPC												
Position 1-pole phsC	301.4261.461	DPC												
Trip/open cmd. 3-pole	301.4261.300	SPS		U	U									
Trip only pole A	301.4261.401	SPS												
Trip only pole B	301.4261.402	SPS		X										
Trip only pole C	301.4261.403	SPS			X									
Close command	301.4261.301	SPS				X					X	X	X	
Close cmd. 1-pole phsA	301.4261.413	SPS									U			
Close cmd. 1-pole phsB	301.4261.414	SPS										U		
Close cmd. 1-pole phsC	301.4261.415	SPS											U	

Figure 10: Routing of PoW closing to high speed contacts (IO209)

As the closing triggers a fault record via CFC in this application, the PoW signals should be routed to the Fault Log and Recorder:



Information			Destination					
			LEDs			Recorder	Logs	
			Base module					
Signals	Number	Type	1.14	1.15	1.16	Signal	O	F	U1
(All)	(All)					(All)			
Fundamental	301.1501								
PoW-switching	301.2901					*	*	*	
General	301.2901.2...					*	*	*	
Closing	301.2901.2...					*	*	*	
>Block function	301.2901.2...	SPS				X	X	X	
>Close CB	301.2901.2...	SPS				X		X	
Mode (controllable)	301.2901.2...	ENC							
Inactive	301.2901.2...	SPS				X	X		
Behavior	301.2901.2...	ENS					X		
Health	301.2901.2...	ENS					X		
Start	301.2901.2...	SPS				X		X	
CB position wrong	301.2901.2...	SPS				X	X		
Mech.ref.contact phsA	301.2901.2...	SPS				X			
Mech.ref.contact phsB	301.2901.2...	SPS				X			
Mech.ref.contact phsC	301.2901.2...	SPS				X			
Max. time exceeded	301.2901.2...	SPS				X		X	
Switching inaccurate	301.2901.2...	ACT				*		X	
Deviation make time	301.2901.2...	ACT						X	
Deviation closing time	301.2901.2...	ACT						X	
V too high after switch.	301.2901.2...	ACT						X	
I too high after switch.	301.2901.2...	ACT						X	
Make time phsA calc.	301.2901.2...	MV						X	
Make time phsB calc.	301.2901.2...	MV						X	
Make time phsC calc.	301.2901.2...	MV						X	
Make time phsA meas.	301.2901.2...	MV						X	
Make time phsB meas.	301.2901.2...	MV						X	
Make time phsC meas.	301.2901.2...	MV						X	

And so on

Figure 11: Routing of PoW signals to Fault Log and Recorder

1.7 Commissioning

Once the settings are applied, the 1st closing operation must be recorded and evaluated. In the log below the relevant time values for analysis are provided. These can be used to check the correct close timing of the circuit breaker (Figure 2 above).

Time stamp	Relative time	Fault n	Entry nu	Functions structure	Name	Value
		...	(...	(All)	(All)	(All)
19.02.2020 11:07:40.131 (3...		16		Fault log		
19.02.2020 11:07:40.131	00:00:00:00.000		1	Recording:Fault recorder:Control	Fault number	16
19.02.2020 11:07:40.131	00:00:00:00.000		2	Circuit breaker 1:PoW-switching:Closing	Start	on
19.02.2020 11:07:40.131	00:00:00:00.000		3	Line 1:Process monitor:Closure detec.	Closure	on
19.02.2020 11:07:40.184	00:00:00:00.053		4	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsA	on
19.02.2020 11:07:40.184	00:00:00:00.053		5	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsC	on
19.02.2020 11:07:40.184	00:00:00:00.053		6	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsB	on
19.02.2020 11:07:40.222	00:00:00:00.091		7	Circuit breaker 1:PoW-switching:Closing	Clos. time phsA calc.	8.380 ms
19.02.2020 11:07:40.222	00:00:00:00.091		8	Circuit breaker 1:PoW-switching:Closing	Clos. time phsB calc.	12.480 ms
19.02.2020 11:07:40.222	00:00:00:00.091		9	Circuit breaker 1:PoW-switching:Closing	Clos. time phsC calc.	12.880 ms
19.02.2020 11:07:40.222	00:00:00:00.091		10	Circuit breaker 1:PoW-switching:Closing	V max. phsA	334.48 kV
19.02.2020 11:07:40.222	00:00:00:00.091		11	Circuit breaker 1:PoW-switching:Closing	V max. phsB	326.98 kV
19.02.2020 11:07:40.222	00:00:00:00.091		12	Circuit breaker 1:PoW-switching:Closing	V max. phsC	327.00 kV
19.02.2020 11:07:40.222	00:00:00:00.091		13	Circuit breaker 1:PoW-switching:Closing	Clos. time phsA meas.	9.175 ms
19.02.2020 11:07:40.222	00:00:00:00.091		14	Circuit breaker 1:PoW-switching:Closing	Clos. time phsB meas.	12.575 ms
19.02.2020 11:07:40.222	00:00:00:00.091		15	Circuit breaker 1:PoW-switching:Closing	Clos. time phsC meas.	12.975 ms
19.02.2020 11:07:40.222	00:00:00:00.091		16	Circuit breaker 1:PoW-switching:Closing	Δ closing time phsA	0.795 ms
19.02.2020 11:07:40.222	00:00:00:00.091		17	Circuit breaker 1:PoW-switching:Closing	Δ closing time phsB	0.095 ms
19.02.2020 11:07:40.222	00:00:00:00.091		18	Circuit breaker 1:PoW-switching:Closing	Δ closing time phsC	0.095 ms
19.02.2020 11:07:40.222	00:00:00:00.091		19	Circuit breaker 1:PoW-switching:Closing	Make time phsA calc.	7.980 ms
19.02.2020 11:07:40.222	00:00:00:00.091		20	Circuit breaker 1:PoW-switching:Closing	Make time phsB calc.	12.380 ms
19.02.2020 11:07:40.222	00:00:00:00.091		21	Circuit breaker 1:PoW-switching:Closing	Make time phsC calc.	12.780 ms
19.02.2020 11:07:40.222	00:00:00:00.091		22	Circuit breaker 1:PoW-switching:Closing	Make time phsA meas.	7.832 ms
19.02.2020 11:07:40.222	00:00:00:00.091		23	Circuit breaker 1:PoW-switching:Closing	Make time phsB meas.	12.357 ms
19.02.2020 11:07:40.222	00:00:00:00.091		24	Circuit breaker 1:PoW-switching:Closing	Make time phsC meas.	12.757 ms
19.02.2020 11:07:40.222	00:00:00:00.091		25	Circuit breaker 1:PoW-switching:Closing	Δ make time phsA	-0.148 ms
19.02.2020 11:07:40.222	00:00:00:00.091		26	Circuit breaker 1:PoW-switching:Closing	Δ make time phsB	-0.023 ms
19.02.2020 11:07:40.222	00:00:00:00.091		27	Circuit breaker 1:PoW-switching:Closing	Δ make time phsC	-0.023 ms
19.02.2020 11:07:40.222	00:00:00:00.091		28	Circuit breaker 1:PoW-switching:Closing	Start	off
19.02.2020 11:07:40.280	00:00:00:00.149		29	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsA	off
19.02.2020 11:07:40.280	00:00:00:00.149		30	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsC	off
19.02.2020 11:07:40.285	00:00:00:00.154		31	Circuit breaker 1:Circuit break.	Close cmd. 1-pole phsB	off
19.02.2020 11:07:40.430	00:00:00:00.299		32	Line 1:Process monitor:Closure detec.	Closure	off

Figure 12: Fault Log of PoW close sequence

The information from this 1st closing operation are entered in Excel:

Pole	Set Clos. Time	Set Pre arc Time	Calc. Make Time	Meas. Clos. Time	Meas. Make Time
A	8,380	0,400	7,980	9,175	7,832
B	12,480	0,100	12,380	12,575	12,357
C	12,880	0,100	12,780	12,975	12,757

The calculated make time is the set closing time – set Pre-arc time.

The measured make time is obtained by monitoring the measured voltage.

The measured closing time is obtained by monitoring the auxiliary contact.

A comparison of the set and measured values allows checking that the application is working as expected.

The above results are shown in the following graph for easy comparison:

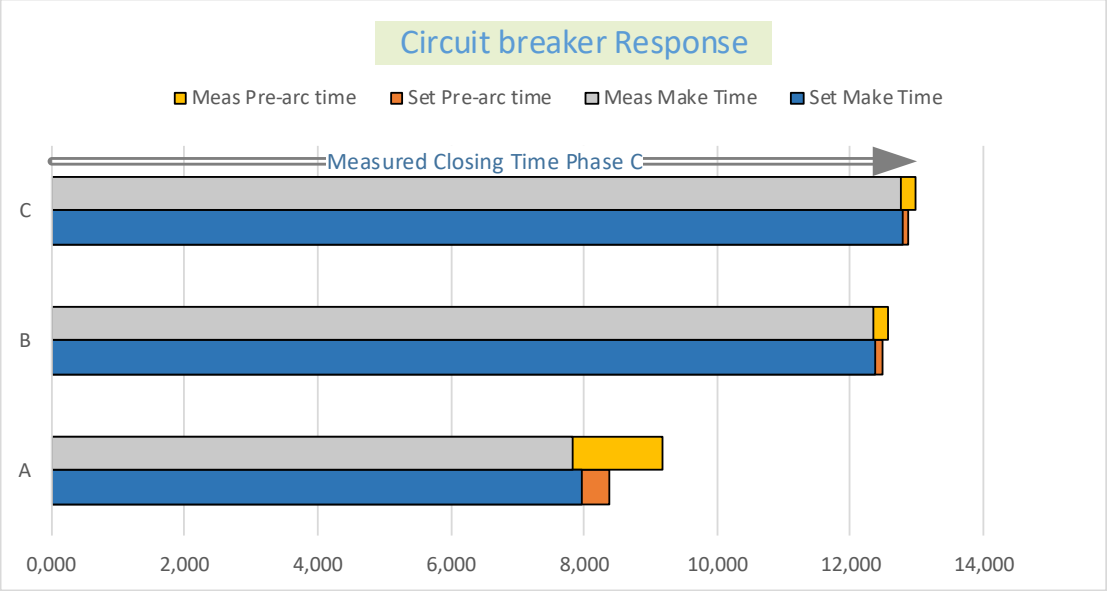


Figure 13: Set and measured CB operating times

The set and measured values have a good correlation so that the application can be considered as working as correctly.

A further method of checking the PoW closing is by analyzing the fault record:

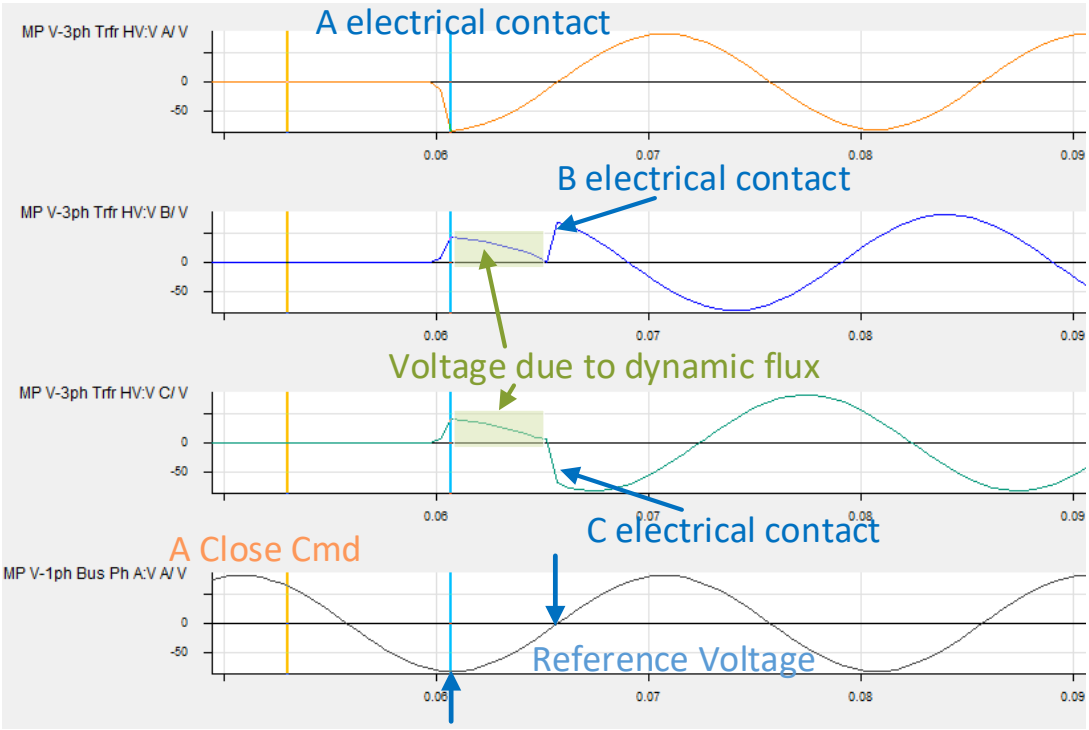


Figure 14: Fault record of CB closing sequence

The record confirms the correct initial electrical contact in phase A at the negative voltage peak of the reference voltage. Subsequently the phases B and C measure a voltage opposite to phase A and with half the magnitude; this is due to the dynamic flux. At the zero crossing of the reference voltage the phases B and C have initial electrical contact.

Based on the results from the fault log and the record, the correct operation of the PoW closing can be confirmed. If there is a significant deviation, the CB must be checked, and the settings adjusted accordingly.

1.8 Conclusion

The Point-on-wave switching function in SIPROTEC 5 is used to reduce increased electrodynamic and dielectric loads which are caused by non-optimal switching of circuit breakers in the network. In extreme cases, these loads reduce the reliability and life of the equipment installed in the network or lead to unnecessary opening operations by the protection device. To avoid effects such as over-voltages and inrush currents, this function can control the closing and opening instants of circuit breakers.

This basic example demonstrated how PoW closing on a transformer can be applied and checked. It shows all the key steps required in the implementation. Additional features such as adapting the timing to environmental conditions or the consideration remnant flux are not covered. Further information covering these aspects is planned.

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