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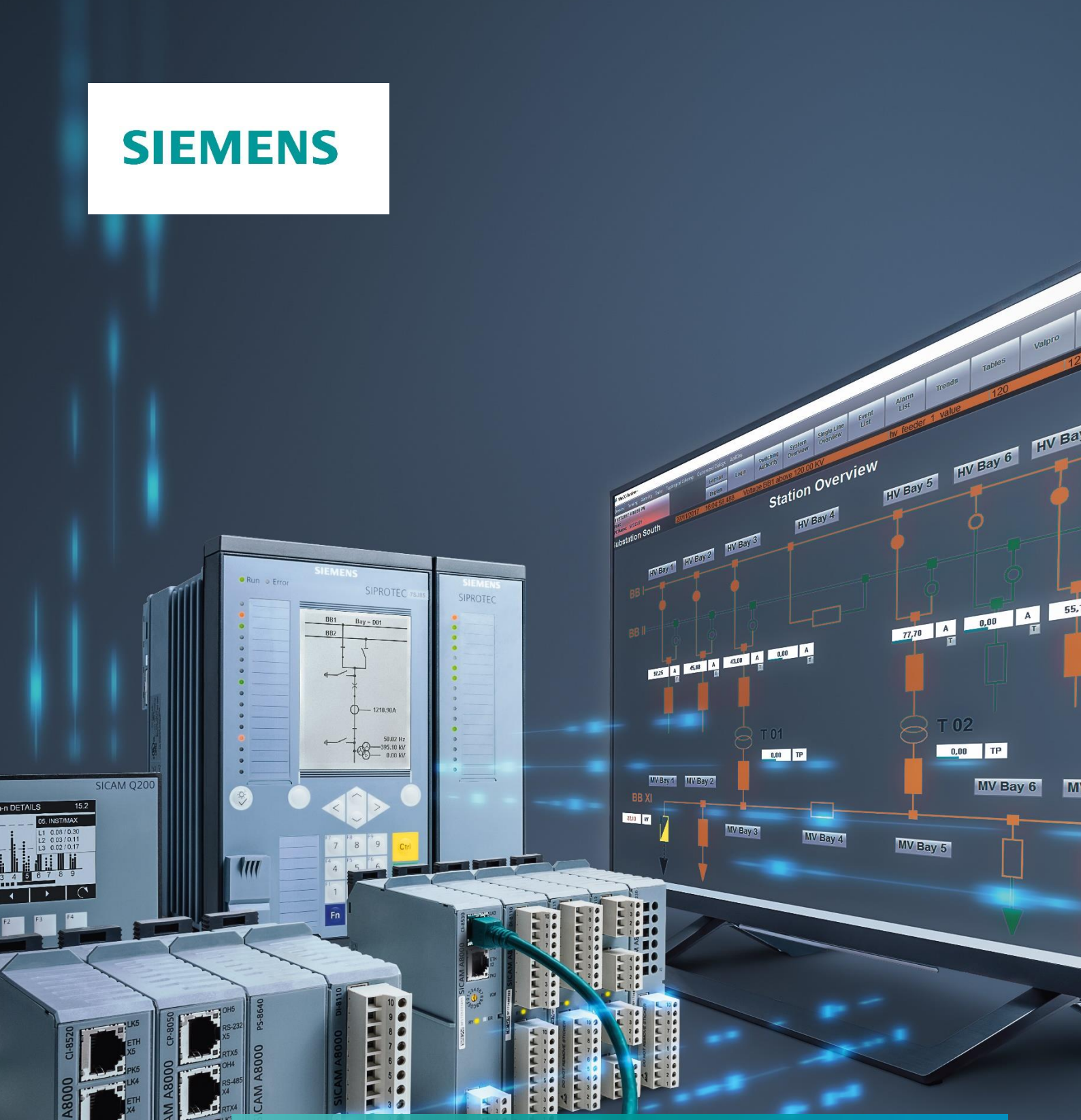

SIPROTEC 5

Secondary Arc Detection for better Auto Re-Closure (APN-086)

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SIPROTEC 5 Application

Secondary Arc Detection for better Auto Re-Closure

APN-086, Edition 1

Content

1 Secondary Arc Detection for better Auto Re-Closure

1.1 Introduction

The application of single pole auto re-closure on over-head lines (OHL) has proven its effectiveness in transmission and sub-transmission networks over many years. In practice approximately 80% of all single pole trips can be successfully re-closed. The remainder are either not arc faults or the fault arcs did not extinguish fast enough. This application note will describe how the application of auto re-closure with secondary arc detection, on the one hand, prevents re-closure onto not extinguished faults and, on the other hand, allows faster re-closing when secondary arcs have extinguished in a short time.

1.2 Single Pole Dead Time Classification

For the further explanations a classification of single pole dead times, based on the state of the faulted line, into the following categories is done.

1. Transient arc fault: Secondary arc extinguished during the set maximum dead time
2. Sustained arc fault: Secondary arc does not extinguish during set maximum dead time
3. No arc faults: After CB opens there is no secondary arc; fault is off immediately
4. Metallic fault: No secondary arc detected, and open pole voltage is below defined threshold

It is desired to have re-closure only for type 1 and type 3 conditions. For type 2 and type 4 the auto re-close should couple the single pole trip to a 3-pole trip. It is optional for the user if a subsequent 3-pole auto re-close cycle is done or not.

1.3 Secondary Arc

The secondary arc is detected by means of the measured voltage during the 1-pole open condition. The pre-requisite for this function is therefore that the voltage transformers are located on the line side of the circuit breaker.

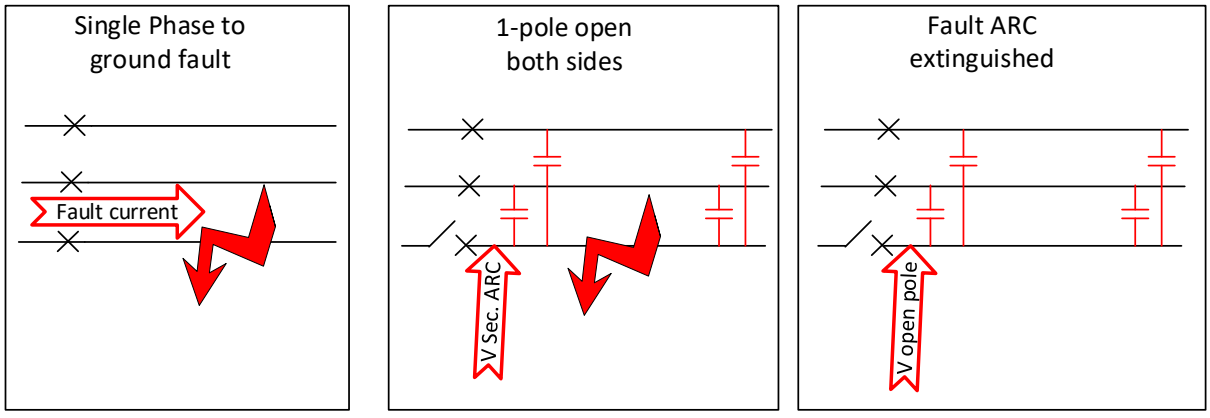


Figure 1: The 3 stages of a 1-pole fault with transient arc fault (Type 1)

a) During the 1st stage, the fault current is flowing via the circuit breaker that is closed and the fault arc. This fault arc condition is the primary arc. The protection then issues the trip command and the circuit breaker then initiates the single pole trip.

b) During the 2nd stage the circuit breaker is now open single pole and current is flowing via the ph-ph capacitance of the line from the healthy phases onto the faulted phase and the secondary arc. This arc

condition is called the secondary arc. The SAD function measures the voltage on the line side voltage transformers and recognizes the secondary arc condition.

c) At the 3rd stage the secondary arc has extinguished. The voltage on the open pole is a sinusoidal fundamental component value due to the capacitive coupling with the healthy phases.

The recording below shows the above 3 stages during a real fault on 400 kV:

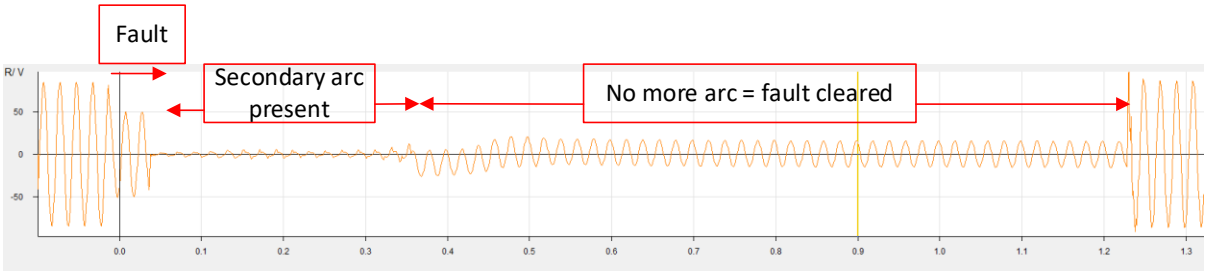


Figure 1: Example single pole trip with transient secondary arc

In the example above the re-closure is successful because the transient secondary arc was extinguished after approximately 300 ms dead time. The actual reclosure took place with a classic dead time setting of 1200 ms. With the SAD function the re-closure could have been done with a shorter effective dead time of approximately 500 ms. This would have reduced the negative impact of the single pole dead time on the system stability and general stress of plant due to unbalanced conditions.

1.4 Implementing secondary arc detection auto reclosure (SAD)

The SAD method for auto re-close can be applied in the following cases:

1. Single pole tripping by the circuit breakers is possible (and required)
2. The voltage transformers are located on the line side of the circuit breaker
3. Voltage measuring point (3ph) must be assigned to FG Circuit Breaker
4. A function group FG Line must be configured.

In the Function Group circuit breaker check if there is a standard 79 Auto re-closing function applied. It must be deleted and replaced by the 79 SAD auto re-close function from the library.

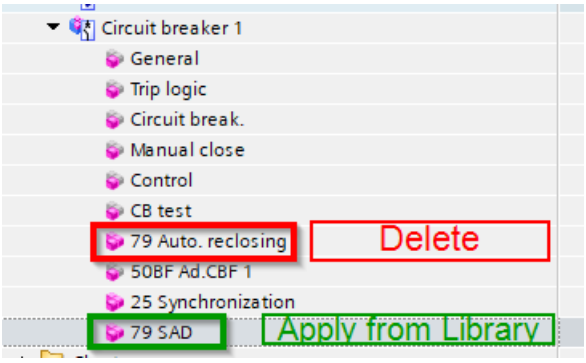


Figure 2: Replace standard 79 Auto re-close with SAD Reclose from Library

After adding the 79 SAD to the function group circuit breaker the settings are applied.

Make sure that a function group line (FG Line) is configured.

1.4.1 General settings

The general settings are identical to those of the standard 79 auto re-close. No further attention is given to these in this application note.

1.4.2 SAD Cycle

The SAD cycle is always the 1st cycle. Optionally further cycles may be applied for faults that are tripped 3-pole or for single pole faults that are coupled 3-pole after the 1 pole dead time.

The setting options of the SAD cycle are shown below:

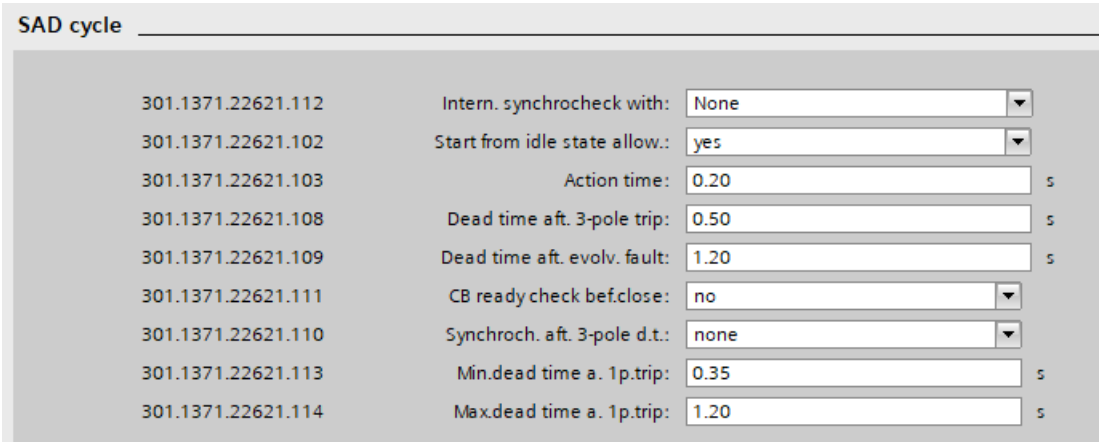


Figure 3: Default settings of the SAB cycle

:112 Internal synchro-check with:

This is relevant for 3 pole re-closing after an evolving fault dead time if this function is used or a 3-pole cycle if this is applied. Select here the sync check source (internal or external) that applies for re-close after such 3-pole trips.

:102 Start from idle state allowed

This setting is available in all cycles and must be set to yes for the SAD as the SAD cycle will always be the first cycle. Only for cycles that run strictly after a preceding cycle must this setting be set to “no”.

:103 Action time

This is the action time as used in all cycles. It must be set shorter than the operate delay of the slowest protection stage that is permitted to start this auto re-close cycle. For this example, we assume that the SAD cycle will only be started by Zone 1 of distance protection and 85-21. The setting of 200 ms is longer than the time between pick-up and operate for these functions. A zone 2 operate on the other hand, with a Zone 2 time of 250ms or 300 ms, will be longer than the set time. The Zone 2 and other stages with similar or longer operate delays will therefore not start the SAD cycle because the action time will expire before they operate. Subsequent cycles with longer action times may then be configured for such operates.

:108 Dead time after 3-pole trip

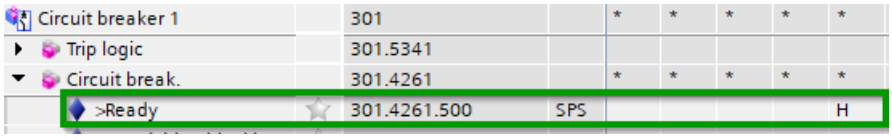
The protection and tripping logic will determine if the trip is a single pole or 3-pole trip. In the event of 3-pole trips this setting will determine if this cycle will re-close or not. If this cycle must re-close then set the desired dead time here. In this case a 3-pole dead time of 500 ms is set. If no 3-pole reclosing is desired by this cycle, then change this setting to infinity “oo”.

:109 Dead time after evolving fault

Only when under the general settings the parameter ":109 Response to evolving faults" is set to "start evolving fault dead time" will this parameter be required. In that case set here the desired 3-pole dead time that is required after a 1-pole dead time is coupled 3-pole due to an evolving fault detection.

:111 CB ready check before close

The readiness of the CB may be determined via a binary input:



If this binary input is configured the AR cycle dead time may be extended until the ready condition is present. Make allowance for this extension of the dead time under the relevant general settings. In applications where the readiness must be present before the cycle is started set the corresponding parameter under general settings. In this application the readiness is not checked before the cycle releases the close command, therefore the setting of "no".

:110 Synchrocheck after 3-pole dead time

Here the stage of the internal sync check is set when an internal sync check was set as described under heading ":112 Internal synchro-check with:" above.

:113 Minimum dead time after 1-pole trip

In some cases, the SAD function may establish after a very short time that a re-close is permitted because the secondary arc is off. This may be too short for the circuit breaker mechanism. Set here the minimum dead time (the shortest permissible single pole dead time) for the SAD cycle.

:113 Maximum dead time after 1-pole trip

In cases where the secondary arc does not extinguish, the SAD cycle will extend the dead time. To prevent too long single pole open conditions, set here the maximum permissible single pole dead time. The SAD function will terminate the dead time after this time and, if set under general, a 3-pole trip will be issued. If further cycles are configured that allow 3-pole re-closure then these will apply after the 3-pole trip.

1.5 Testing the function

The actual tests that are done with the SAD cycle depend on what the tester wants to establish. For an acceptance test on site it is sufficient to do a function test with injection of a single-phase fault and dead time using for example a state sequence test module. More interesting test can be done if records of real faults with secondary arc are available. Here the detection of the presence and absence of secondary arc and the corresponding response of the SAD cycle can be checked. Such tests are not required on site or for factory acceptance.

1.6 State Sequencer for site acceptance

1.6.1 Test 1; successful AR

The following sequence is configured as example for a simple test of the SAD re-close cycle:

	1			2			3			4		
Name	Pre-Fault			AG Fault			A pole open no volt			A pole open 5 V		
V A-N	57,74 V	0,00 °	50,000 Hz	5,000 V	0,00 °	50,000 Hz	0,000 V	180,00 °	50,000 Hz	5,000 V	180,00 °	50,000 Hz
V B-N	57,74 V	-120,00 °	50,000 Hz	57,74 V	-120,00 °	50,000 Hz	57,74 V	-120,00 °	50,000 Hz	57,74 V	-120,00 °	50,000 Hz
V C-N	57,74 V	120,00 °	50,000 Hz	57,74 V	120,00 °	50,000 Hz	57,74 V	120,00 °	50,000 Hz	57,74 V	120,00 °	50,000 Hz
I A	1,000 A	0,00 °	50,000 Hz	10,00 A	-75,00 °	50,000 Hz	0,000 A	-75,00 °	50,000 Hz	0,000 A	-75,00 °	50,000 Hz
I B	1,000 A	-120,00 °	50,000 Hz	1,000 A	-120,00 °	50,000 Hz	1,000 A	-120,00 °	50,000 Hz	1,000 A	-120,00 °	50,000 Hz
I C	1,000 A	120,00 °	50,000 Hz	1,000 A	120,00 °	50,000 Hz	1,000 A	120,00 °	50,000 Hz	1,000 A	120,00 °	50,000 Hz
I N	0,000 A	300,00 °	50,000 Hz	9,789 A	99,34 °	50,000 Hz	1,000 A	360,00 °	50,000 Hz	1,000 A	360,00 °	50,000 Hz
CMC Rel	3 Ausgänge aktiv			3 Ausgänge aktiv			2 Ausgänge aktiv			2 Ausgänge aktiv		
Trigger		1,000 s			100,0 ms			400,0 ms			2,600 s	

Figure 4: Example sequence to test SAD re-close: step up voltage during dead time

In the above sequence, the fault condition is an AG fault that will be inside a typical Zone 1 forward set zone (approximately 0.25 Ω secondary). This may have to be adapted depending on the application. The fault duration is fixed at 100 ms, this also may be modified – do not exceed the set "start signal supervision time" – typically set to 130 ms.

The auxiliary contacts are output (if required).

The maximum dead time in the sequence is set to 3000 ms. The applied voltage on the open pole A is initially zero and then stepped up to 5 V after 400 ms during the dead time. This corresponds to no secondary arc so that the close command should arrive when the voltage is stepped up (100ms later).

Time stamp	Relative time	Fault	Entry numb	Functions structure	Name	Value
		(All)	(All)	(Custom filter...)	(All)	(All)
05.03.2021 16:48:12.035 ...		3		Fault log		
05.03.2021 17:52:28.210 (45)		4		Fault log		
05.03.2021 17:52:28.2...	00:00:00:00.003		6	Circuit breaker 1:79 SAD:General	79 state	trip by prot.
05.03.2021 17:52:28.2...	00:00:00:00.003		7	Circuit breaker 1:79 SAD:General	In progress	on
05.03.2021 17:52:28.2...	00:00:00:00.003		8	Circuit breaker 1:79 SAD:SAD cycle	Cycle running	on
05.03.2021 17:52:28.3...	00:00:00:00.119		17	Circuit breaker 1:79 SAD:General	79 state	fault disap.
05.03.2021 17:52:28.3...	00:00:00:00.119		18	Circuit breaker 1:79 SAD:General	79 permits 1-pole trip	off
05.03.2021 17:52:28.3...	00:00:00:00.119		19	Circuit breaker 1:79 SAD:General	Dead t. aft.1pole trip	on
05.03.2021 17:52:28.8...	00:00:00:00.602		21	Circuit breaker 1:79 SAD:General	Actual reclose cycle	0
05.03.2021 17:52:28.8...	00:00:00:00.602		22	Circuit breaker 1:79 SAD:General	79 state	CB closed
05.03.2021 17:52:28.8...	00:00:00:00.602		23	Circuit breaker 1:79 SAD:General	Not ready	on
05.03.2021 17:52:28.8...	00:00:00:00.602		24	Circuit breaker 1:79 SAD:General	Reclaim time running	on
05.03.2021 17:52:28.8...	00:00:00:00.602		25	Circuit breaker 1:79 SAD:General	Dead t. aft.1pole trip	off
05.03.2021 17:52:28.8...	00:00:00:00.602		26	Circuit breaker 1:79 SAD:General	Cls.cmd after 1p.1.cyc	on
05.03.2021 17:52:28.8...	00:00:00:00.602		27	Circuit breaker 1:79 SAD:General	Cyc1 1p AR	3
05.03.2021 17:52:28.8...	00:00:00:00.602		28	Circuit breaker 1:79 SAD:General	Close cmd. indication	on
05.03.2021 17:52:28.8...	00:00:00:00.602		30	Circuit breaker 1:79 SAD:SAD cycle	Stage release prot.	off
05.03.2021 17:52:28.9...	00:00:00:00.702		32	Circuit breaker 1:79 SAD:General	Cls.cmd after 1p.1.cyc	off
05.03.2021 17:52:28.9...	00:00:00:00.702		33	Circuit breaker 1:79 SAD:General	Close cmd. indication	off
05.03.2021 17:52:31.8...	00:00:00:03.602		35	Circuit breaker 1:79 SAD:General	Actual reclose cycle	1
05.03.2021 17:52:31.8...	00:00:00:03.602		36	Circuit breaker 1:79 SAD:General	79 state	successful

Figure 5: Fault Log – Successful re-close due to voltage recovery in dead time (5 V in phase A after 400 ms).

Check in the Fault Log (signals must be routed to Fault Log) that the close command is released approximately 500 ms after start of the dead time. In the log above close command released at 602 ms which is approx. 500ms after the dead time started (119 ms).

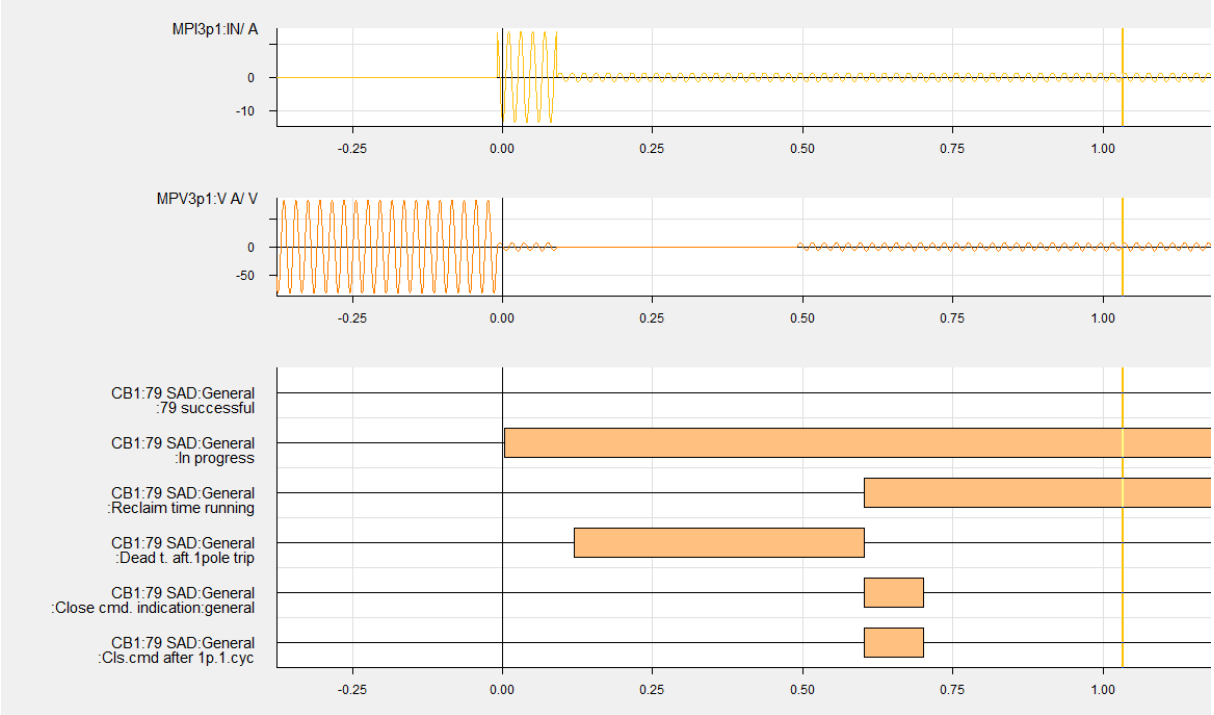


Figure 6: Voltage step up to 5 V secondary in dead time - successful re-close

1.6.2 Test 2: Metallic Fault – No re-close

The following sequence is applied to simulate a metallic fault condition.

Tabellenansicht: State Sequencer.seq

	1			2			3		
Name	Pre-Fault			AG Fault			A pole open		
V A-N	57,74 V	0,00 °	50,000 Hz	5,000 V	0,00 °	50,000 Hz	0,000 V	180,00 °	50,000 Hz
V B-N	57,74 V	-120,00 °	50,000 Hz	57,74 V	-120,00 °	50,000 Hz	57,74 V	-120,00 °	50,000 Hz
V C-N	57,74 V	120,00 °	50,000 Hz	57,74 V	120,00 °	50,000 Hz	57,74 V	120,00 °	50,000 Hz
I A	1,000 A	0,00 °	50,000 Hz	10,00 A	-75,00 °	50,000 Hz	0,000 A	-75,00 °	50,000 Hz
I B	1,000 A	-120,00 °	50,000 Hz	1,000 A	-120,00 °	50,000 Hz	1,000 A	-120,00 °	50,000 Hz
I C	1,000 A	120,00 °	50,000 Hz	1,000 A	120,00 °	50,000 Hz	1,000 A	120,00 °	50,000 Hz
I N	0,000 A	300,00 °	50,000 Hz	9,789 A	99,34 °	50,000 Hz	1,000 A	360,00 °	50,000 Hz
CMC Rel	3 Ausgänge aktiv			3 Ausgänge aktiv			2 Ausgänge aktiv		
Trigger		1,000 s			100,0 ms			3,000 s	

Figure 7: Test

The fault condition is the same as in the "Test !", only that the voltage in the open pole remains at zero during the entire dead time – metallic fault.

Read log entries | Delete | Show values as: primary

Time stamp	Relative time	Fault	Entry numb	Functions structure	Name	Value
		. (All)	(All)	(Custom filter...)	(All)	(All)
05.03.2021 16:48:12.035 ...		3		Fault log		
05.03.2021 16:48:12.0...	00:00:00:00.003		6	Circuit breaker 1:79 SAD:General	79 state	trip by prot.
05.03.2021 16:48:12.0...	00:00:00:00.003		7	Circuit breaker 1:79 SAD:General	In progress	on
05.03.2021 16:48:12.0...	00:00:00:00.007		8	Circuit breaker 1:79 SAD:SAD cycle	Cycle running	on
05.03.2021 16:48:12.1...	00:00:00:00.119		17	Circuit breaker 1:79 SAD:General	79 state	fault disap.
05.03.2021 16:48:12.1...	00:00:00:00.119		18	Circuit breaker 1:79 SAD:General	79 permits 1-pole trip	off
05.03.2021 16:48:12.1...	00:00:00:00.119		19	Circuit breaker 1:79 SAD:General	Dead t. aft.1pole trip	on
05.03.2021 16:48:13.3...	00:00:00:01.317		21	Circuit breaker 1:79 SAD:General	Actual reclose cycle	0
05.03.2021 16:48:13.3...	00:00:00:01.317		22	Circuit breaker 1:79 SAD:General	79 state	unsuccessful
05.03.2021 16:48:13.3...	00:00:00:01.317		23	Circuit breaker 1:79 SAD:General	Not ready	on
05.03.2021 16:48:13.3...	00:00:00:01.317		24	Circuit breaker 1:79 SAD:General	3-pole operate by 79	on
05.03.2021 16:48:13.3...	00:00:00:01.317		25	Circuit breaker 1:79 SAD:General	In progress	off
05.03.2021 16:48:13.3...	00:00:00:01.317		26	Circuit breaker 1:79 SAD:General	Dead t. aft.1pole trip	off
05.03.2021 16:48:13.3...	00:00:00:01.317		27	Circuit breaker 1:79 SAD:General	Block. by max. cycles	on
05.03.2021 16:48:13.3...	00:00:00:01.317		29	Circuit breaker 1:79 SAD:SAD cycle	Cycle running	off
05.03.2021 16:48:13.3...	00:00:00:01.317		30	Circuit breaker 1:79 SAD:SAD cycle	Stage release prot.	off
05.03.2021 16:48:13.3...	00:00:00:01.326		31	Circuit breaker 1:79 SAD:SAD cycle	No close: metallic flt.	on
05.03.2021 16:48:13.4...	00:00:00:01.367		40	Circuit breaker 1:79 SAD:General	3-pole operate by 79	off
05.03.2021 16:48:13.4...	00:00:00:01.376		41	Circuit breaker 1:79 SAD:SAD cycle	No close: metallic flt.	off
05.03.2021 16:48:13.8...	00:00:00:01.817		42	Circuit breaker 1:79 SAD:General	Actual reclose cycle	1

Figure 8: Fault Log – Metallic Fault

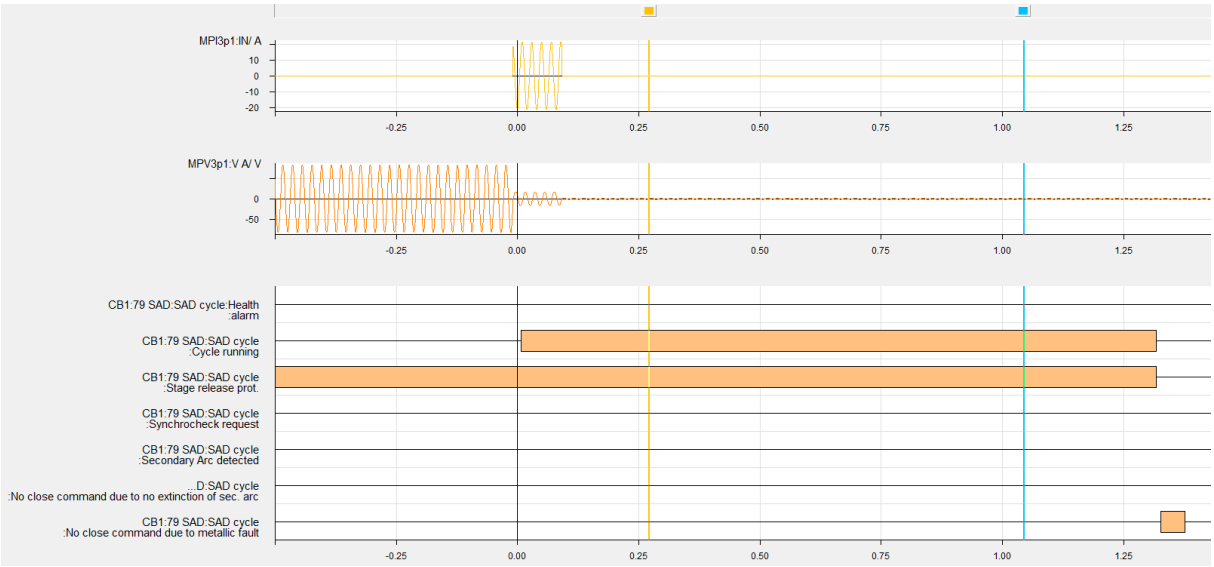


Figure 9: Recording of Metallic Fault Test

The output signals shown depend on which signals are routed to the fault log and the record.

1.7 Conclusion

The SAD re-close function can be applied with very Ismall difference to the classic re-close function. It will provide a significantly improved single pole re-close performance:

1. Shorter average dead times
2. No re-close onto metallic single pole faults
3. No re-close onto secondary arcs that do not extinguish.

This will reduce stress of circuit breakers and other primary plant and improve the power system quality overall.

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