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1 AUTORECLOSING - THREE-PHASE

1.1 Application

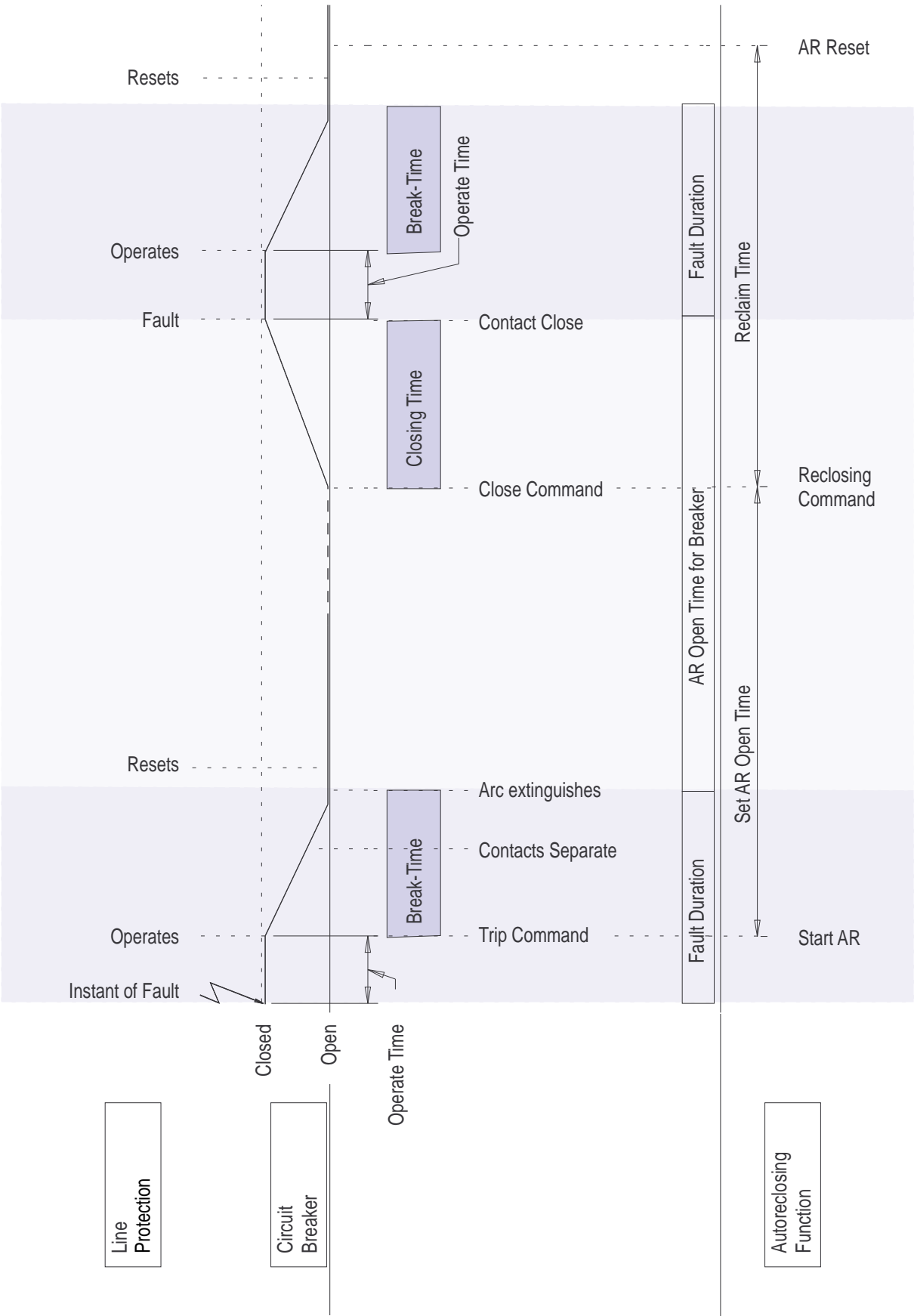
Automatic reclosing or autoreclosing (AR) is a well established method to restore the service of a power line after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by operation of line protection and line breakers, the arc de-ionises and recovers voltage withstand at a somewhat variable rate. A certain line de-ionisation time is thus necessary, but line service can then be resumed by autoreclosing of the line breakers. The length of the “dead time” is selected so as to give a good probability of fault arc de-ionisation and successful reclosing.

For the individual line breakers and autoreclosing equipment, the expression “Autoreclose open time” (AR open time) will be used.

At simultaneous tripping and reclosing at the two line ends, the “Autoreclose open time” is equal to the “dead time” of the line, but otherwise these two times may differ.

In case of a permanent fault, the line protection will trip again at reclosing to clear the fault. The operation sequence and some expressions are illustrated in Fig. 1.

The reclosing function can be set to perform 1, 2, 3 or 4 three-phase reclosing shots. The first autoreclosure open time can be set within the range 0,2-60 s to give either “High-speed autoreclosing” (HSAR), or “Delayed autoreclosing” (DAR). Autoreclosing can be performed with or without the use of synchronism check (SC) and dead line check (energization check, EC).



(X80006-1 (2))

Fig. 1 Single-shot autoreclosing at a permanent fault.

1.2 Theory of operation

The autoreclosing function in the line protection terminal co-operates first of all with the line protection functions, the trip function, the circuit-breaker and the synchronism check function. It can also be influenced by other protection functions such as shunt reactor protection through binary input (BI) signals, manual control "AR On/Off", and it can provide information to the disturbance and service report functions, event recording, indications and reclosing operation counters.

The reclosing counters can be read and reset through the MMI branch:

Service Report ARCounters

The autoreclosing is a purely logical function working with logical or binary signals, logical operations and timers.

1.2.1 Input and output signals

The input and output signals are shown in Fig. 2 below.

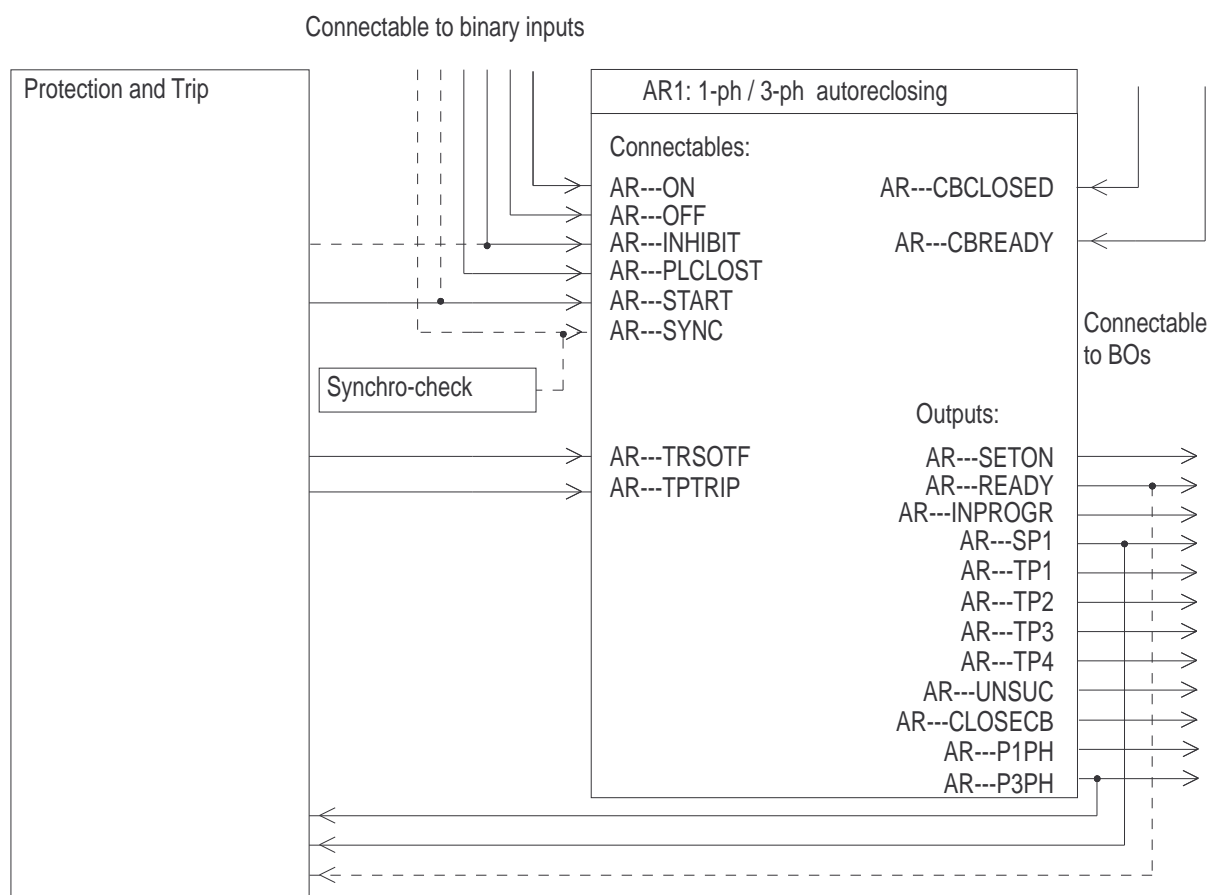


Fig. 2 Three-phase autoreclosing. Input and output signals.d

The inputs of type "connectables" can be connected by configuration to binary inputs (BIs) of the relay. The outputs are connectable by configuration to binary output relays. It is also possible to connect "connectables" and "outputs" to the free logic functions of the unit, e.g. OR-gates, and in that way add connection links.

Input signals:

AR---ON	Switches the autoreclosing "On" (at "Operation" = "Stand by")
AR---OFF	Switches the autoreclosing "Off" (at "Operation" = "Stand by")
AR---START	"Autoreclosing start" by a protection trip signal. It also makes the reclosing program continue at a repeated trip.
AR---CBCLOSED	"Circuit-breaker closed". A condition for the start of a reclosing cycle.
AR---CBREADY	"Circuit-breaker ready for a Close-Open (CO) or Open-Close-Open (OCO) operation. A condition for the start of a reclosing cycle.
AR---INHIBIT	"Inhibit autoreclosing". Interrupts and blocks autoreclosing.
AR---SYNC	"Synchronism check OK" from the internal SYNC function or an external device.
AR---PLCLOST	"Power line carrier or other form of permissive signal lost" An optional input signal at loss of a communication channel in a permissive line protection scheme. Can extend the "AR open time"
(AR---TRSOTF)	("Trip switch-onto-fault" Normally not connected)

Output signals:

AR---SETON	Indicates that the AR function is "On", i.e. operative.
AR---READY	Indicates that the AR function is ready for a new AR cycle. It is "On" and it is not started or blocked.
AR---INPROGR	"Autoreclosing in progress". Activated during the "AR open time".
AR---TP1	"Autoreclosing (three-phase), Shot 1" in progress.
AR---TP2	"Autoreclosing Shot 2" in progress.
AR---TP3	"Autoreclosing Shot 3" in progress.
AR---TP4	"Autoreclosing Shot 4" in progress.
AR---UNSUC	"Autoreclosing unsuccessful". Activated at a new trip after the last programmed shot.
AR---CLOSECB	"Close circuit-breaker" command

Further explanations under "Function" below.

1.2.2 Function and functional modules

The autoreclosing function can be controlled from the Man Machine Interface (MMI) by a parameter "Operation" to be set at "Off"/ "Stand by"/ "On".

In the "Off" mode it is made inoperative, and when set "On" the automatic reclosing is on. In the "Stand by" mode, the function can be switched "On" and "Off" by input signal pulses.

The autoreclosing function is divided into functional modules, which are shown in a simplified manner in Table 1.

One module, AR Start, controls the automatic functions "Off" ("Stand by") and "On" and the start-up of an autoreclosing cycle at a protection trip.

One module in two variants, serving to either select or not an extended "AR Open time, Shot 1" at certain conditions.

There are four reclosing programs available, for one to four autoreclosing shots.

There is a module to treat two different types of "circuit-breaker ready" signals and to use the signal from internal or external "synchronism check" function.

There is also a module for control of the output breaker closing command pulse and to drive the operate counters.

Table 1: Modules of the autoreclosing function

Autoreclosing On/Off & start	
Selection switch	Extend open time t1, Long trip signal
Selection switch	1-shot reclosing
	2-shot reclosing
	3-shot reclosing
	4-shot reclosing
Selection switch	CB Ready: CO, OCO Synch. check input
Selection switch	Close command pulsing Operate counter drivers

1.2.3 Functional logic

Start and control of the autoreclosing

Reference Fig. 3.

The automatic operation of the autoreclosing function is controlled by the parameter “operation” and the input signals as described above. When it is operative, the output AR---SETON is high (active).

The autoreclosing function is started at a protection trip via the input signal “AR---START”. At a repeated trip, this signal is also activated in order to make the reclosing program continue.

There are a number of conditions for the start to be accepted and a new cycle started. After these checks, the starting signal is latched in and the signal “Started” is activated. It can be interrupted by certain events.

AR---CBCLOSED

The circuit-breaker (CB) shall have been closed for at least five seconds to allow a new AR cycle to be started. It prevents start at closing onto a fault. It also prevents the reclosing of a breaker open at the protection trip, which is possible in a multiple breaker arrangement.

AR---CBREADY

The circuit-breaker must have its operating gear charged and ready for a Close-Open (CO) or an Open-Close-Open (OCO) cycle, to allow the start of an autoreclosing cycle. If it is not ready at start, there is little chance that it will be ready by the end of the AR open time.

AR---TRSOTF

“Trip switch-onto-fault”. This signal is normally not used. The input is left unconnected or set “low”. It is included as a possibility at particular cases: More specifically if the AR---START is not connected to a signal which appears at all trips.

This signal alone does not start reclosing. However, at a reclosing onto a permanent fault it may appear and let the function move on to “AR---UNSUC” (unsuccessful) or second-shot reclosing as programmed.

Blocking and inhibit signals may be created at other parts of the program and will interrupt the reclosing cycle or prevent reclosing. One source of such a signal is activation of input “AR---INHIBIT” in Fig. 6.

AR---READY

The output “AR ready for a new reclosing cycle” is high when the function is “On”, at rest and prepared for operation.

This signal can be used by protection function to extend the reach before reclosing, when that facility is required.

AR---UNSUC

The output “Reclosing unsuccessful” will be activated at a possible new trip after the selected number of reclosing shots, or at trip while reclosing is blocked.

The output will reset after the reclaim time.

Control of the extended "AR open time, shot 1"

Reference Fig. 4.

By setting parameter "Extended t1", this facility can either be selected or not. The purpose is to adapt the length of the "AR Open time" to the possibility of non-simultaneous tripping at the two line ends. If a "permissive" communication scheme is used, and the permissive communication channel (e.g. PLC, power line carrier) is out of service at the fault, there is a risk of sequential, non-simultaneous tripping. To ensure a sufficient line "dead time", the "AR open time" can be extended. The input signal AR---PLCLOST is checked at tripping.

Long trip signal. Under normal circumstances the trip command will reset quickly, due to fault clearing. There is a possibility of setting a maximum trip pulse duration by tTrip. At a longer trip signal, the "AR open dead time" will be extended by Extend_t1.

If Extended t1 = Off is selected, a long trip signal will interrupt the reclosing sequence in the same way as AR---INHIBIT.

Reclosing programs

There are four different reclosing programs for one to four reclosing shots. One of these is selected by the parameter Program = 1, 2, 3, or 4 shots

The programs are initiated by the start module ("Started") and influenced by some internal signals.

The program for 2-shot reclosing is used as an example for the operation. Operation: Please refer to Fig. 3, Fig. 5 and Fig. 8!

The AR function is assumed "On" and "Ready" and the breaker closed and charged.

At operation of the line protection, AR---START is received and sealed-in.

The output "AR---READY" (Ready for a new AR cycle) is reset.

The timer for shot 1 "t1", is started AR---TP1 (autoreclosing three-phase, shot 1" in process") is activated.

While any one of the timers for "AR open time" is running, the output AR---INPROGR is activated.

Immediately after start-up of the reclosing and tripping of the breaker the input (in Fig.4) AR---CBCLOSED will go "low" (and possibly also AR---CBREADY at type OCO). The signal "Started" is still kept high and the "AR Open time" timer keeps running.

At the end of the set "AR open time", t1, the TPTO (three-phase AR time-out) is activated and goes on to the output module for further checks and to give a closing command to the circuit-breaker.

Extended "AR open time", t1

This facility can be used or blocked by the parameter "Extend t1". If it is used, Should the signal AR---PLCLOST be high at the trip, e.g due to a lack of ("permissive communication channel"), the AR open time is extended by 0,4 s to allow for a sufficient line "dead time".

The second reclosing shot:

After issue of the first reclosing shot and a new trip, "Trip Int.", the timer for shot 2 (t_2) will be started and AR---TP2 indicates that it is running. At time-out T2TO is activated.

Blocking of a new reclosing cycle

A new start of a reclosing cycle is blocked for the reclaim time after the selected number of reclosing shots have been made.

Reclosing checks and "Reclaim timer"

Refer to Fig. 6.

An "AR open time" time-out signal, is received from a program module. At three-phase reclosing, a synchronism check (SC) and/or energizing check (EC), or voltage check, can be used. One may use an internal or an external synchronism check function, configured to AR---SYNC.

If reclosing without any check is preferred, the input AR---SYNC should be configured to FIXD-ON (fixed=1)

Another possibility is to set the output from the internal synchronism check function to a permanently active signal. That's done by the setting Operation = Release, and AR---SYNC is configured to SYNC---CHECKOK.

At confirmation from the synchronism check, the signal passes on.

At "CBReady" signal of type Close-Open (CO), it is checked that this signal is present to allow for reclosing.

If the breaker operate gear signal "CBReady" is of the type "Ready for an OCO-cycle", it would be too restrictive to apply that condition here.

The synchronism and energizing check is given a certain time, t_{Sync} , to appear. If it does not, or the other conditions are not fulfilled, the reclosing will be interrupted and blocked.

AR---INHIBIT

Should this input signal appear, reclosing is inhibited. There is a reset timer, t_{Inhibit} , to ensure blocking during a few seconds after the signal is removed.

The input can for instance be activated by shunt reactor protection or delayed back-up protection or breaker failure protection.

Reclaim timer

This timer defines a period from the issue of a reclosing command, after which the reclosing function is reset. Should a new tripping take place within this time, it will be treated as a continuation of the first fault.

When the signal to a closing command is given (Pulse AR), the reclaim timer is started.

There is an "AR State Control" to keep track of the actual state in the reclosing sequence.

Pulsing of CB closing command and driving the operation counters

Reference Fig. 7.

The breaker closing command, AR---CLOSECB, is made as a pulse of length, as set by the parameter "tPulse" 0,1-1 s.

For breakers without an anti-pumping function, the closing pulse cutting described below can be used.

It is selected by means of the parameter "CutPulse = On". A new tripping pulse, Trip Int, will then interrupt the pulse.

The minimum length, however, is always 50 ms.

At the issue of a reclosing command, the appropriate reclosing operation counter is also incremented.

Transient fault

After the reclosing command, the reclaim timer keeps running for the set time, tReclaim = 10 to 300 s. If no tripping takes place within this time, the autoreclosing function resets after the reclaim time. The breaker remains closed and the operating gear recharges too, AR---CBCLOSED = 1, AR---CBREADY = 1.

After the Reclaim time, the AR state control resets to the original rest state, with outputs AR---SETON = 1, AR---READY = 1, the other outputs are = 0.

Permanent fault

Refer to Fig. 3 and Fig. 8.

In a two-shot reclosing program, two reclosing operations are made. Should the fault be permanent and a trip occur again after the second reclosing, then AR---UNSUC is activated and the reclosing program will be blocked for the reclaim time.

After time-out of the reclaim time, the function will reset, but the breaker remains open (AR---CBCLOSED = 0, AR---CBREADY = 1), meaning that the reclosing function is not ready for a new reclosing function.

Other reclosing programs, particular comment

The maximum number of reclosing shots in a continued sequence at a line fault will be as selected. The operation in other respects is as outlined above.

1.3 Setting

The setting parameters are accessible through the MMI. The parameters for the autoreclosing function are found in the MMI tree under:

Settings

Functions

Group n

AutoRecloser

The parameters and their setting ranges or alternatives are shown in the appendix.

Configuration of input and output signals to the function. It is made in the MMI structure branch **Configuration**. To get the required operation of the protection terminal it is necessary to make logical connections from physical binary inputs (BIs) and from other internal functions. Output signals need also to be connected to physical binary outputs (BOs) or other functions.

Hints regarding input signals:

MMI branch:

Configuration

FunctionInputs

AutoRecloser

AR---ON and AR---OFF

may be connected to BIs for external control.

AR---START

To be connected to the protection function output for which it shall be started. It can also be connected to a BI for start from an external contact. A logical OR-gate can be used.

AR---INHIBIT

can be connected to BI e.g. for AR blocking from certain protection, such as line connected shunt reactor, transfer trip receive, back-up protection and/or breaker failure protection. In an analogous way it may be connected to an internal back-up protection function. It could also be connected to a signal for manual breaker closing, but it is not necessary, if the input AR---CBCLOSED is connected.

AR---CBCLOSED, and AR---CBREADY

shall be connected to BIs, for pick-up of the breaker signals.

AR---SYNC

If it is needed it can be connected to a BI. If neither internal nor external check shall be used, the input can be set permanently to 1 by connection to FIXD-ON.

AR---PLCLOST

Can be connected to a BI, when it is to be used.

AR---TRSOTF

Is connected to the internal line protection, distance protection, "trip switch onto fault".

Hints regarding output signals:

AR---READY

is connected to “Zone extension” of the line protection. Can also be used for indication if required.

AR---CLOSECB

Connect to a BO, output relay for breaker closing command.

(AR---P3PH)

(“Prepare 3-phase trip”. The output is in this function always activated and AR---P1PH is always low. They can be used, but that would not be necessary if protections are made for three-phase trip.)

1.4 Testing

Testing of the autoreclosing function, for instance at commissioning or after a changed configuration, can be performed with the function in co-operation with some other functions, in particular the protection and trip, as well as the synchronism check function (with energizing check).

Fig. 9 shows a suggested testing arrangement, in which the circuit-breaker is simulated by an external bistable relay (BR), for instance of type RXMVB2 or RXMVE1. There are also three manual switches, SC (Switch “Close”), ST (Switch “Trip”) and SRY (Switch “Ready”). SC and ST can be push-buttons with spring return. Should no bistable relay be at hand, it can be replaced by two self-reset auxiliary relays as in Fig. 10.

The Trip and Close circuits to the breaker and the incoming signals from the breaker are opened at a test switch or at the connecting of terminals with links.

A secondary injection relay test set is used to operate the protection function. The BR relay can be used to control the injected analogue quantities in such a way that the fault appears only when BR is picked-up, simulating a closed breaker position.

The arrangement could be made more elaborate by including simulation of the condition “Breaker charged” or AR---CBREADY for a Close-Open (CO) or Open-Close-Open (OCO) sequence. The condition AR---CBREADY at type “CO” is typically low for a recharging time of 5-10 s after a closing operation, and then, high. In the shown example it is simulated by a manual switch, SRY.

Suggested testing procedure:

1 Preparations

- 1.1 Check the settings of the autoreclosing (AR) function. The operation can be set at “Standby“ (Off).

MMI branch:

Settings

Functions

Group n

AutoRecloser

If any time settings are changed so as to speed-up or facilitate the testing, they must later be changed back to normal and a verification test must be made after this.

- 1.2 Read and note the reclosing operate counters from the MMI branch:

Service Report

ARCounters

Counters

- 1.3 Do the testing arrangements outlined above, e.g. as in Fig. 9.
- 1.4 The breaker position AR---CBCLOSED, the Trip and Closing commands, AR---CLOSECB) and other signals as well should preferably be arranged for event recording, which will provide time measurements. Otherwise, a separate timer or recorder can be used to check the “AR open time” and other times.

2 Check that the AR function works:

- 2.1 Ensure that the voltage inputs to “Synch. check” are such that they will give accepted conditions at open breaker (BR). They can, for instance, be “Live busbar and Dead line”.
- 2.2 Set the function at “On”.
- 2.3 Make a BR pick-up by a closing pulse, the SC-pulse.
- 2.4 Close SRY, “Breaker Ready” and leave it closed.

- 2.5 Inject AC quantities to give a trip and start AR.
Observe or record the BR operation. The BR relay should trip and reclose
After the closing operation, switch SRY could be opened for about 5 s, and then closed.
The “AR Open time” and the operating sequence should be checked, e.g. in the event recording.
Check the operate indications and the operate counters as well.
Should the operation not be as expected, the reason must be investigated. It could be due to an “AR Off” state or wrong program selection, or not accepted synchronism check conditions.
- 2.6 A few fault cases may be checked, for instance transient and permanent fault. The signal sequence diagrams of Fig. 10 can be of guidance for the check.

3 Check that reclosing does not take place when it is not meant to!

The number of cases can be varied according to the application. Examples of selection cases follow below.

- 3.1 “Inhibit” input signal: Check that the function is operative and that the breaker conditions are OK. Apply an input signal AR---INHIBIT and start the reclosing function. No reclosing.
- 3.2 Breaker open, closing onto a fault: Put the breaker simulating relay, BR, in open position. Close it with switch SC and start the AR within a second. No reclosing.
- 3.3 Breaker not ready: Close the breaker relay BR and see that everything except for AR---CBREADY is in normal condition, SRY open. Start the AR function. No reclosing.
- 3.4 Lack of verification from synchronism check: Check the function at non-acceptable voltage conditions. Wait for time-out, >5 s. No reclosing.
- 3.5 Operation “Standby” and “Off”: Check that no reclosing can take place with the function in “Off” state.

4 Termination of the test and restoration of the equipment to normal state

After the tests, restore the equipment to normal or desired state.

Especially the following items should be checked:

- 4.1 Reclosing operate counters: Check and record the counter contents.
(Reset if it is the user's preference.)

MMI branch:

Service report

ARCounters

Counters

Clear counters

- 4.2 Setting parameters, and Off, Standby, or On state as required.

- 4.3 Test switch or disconnected links of connection terminals.

- 4.4 Normal indications.

(If so preferred, the disturbance report may be cleared)

MMI branch:

Disturb. Report

Clear DistRep

1.5 Diagrams

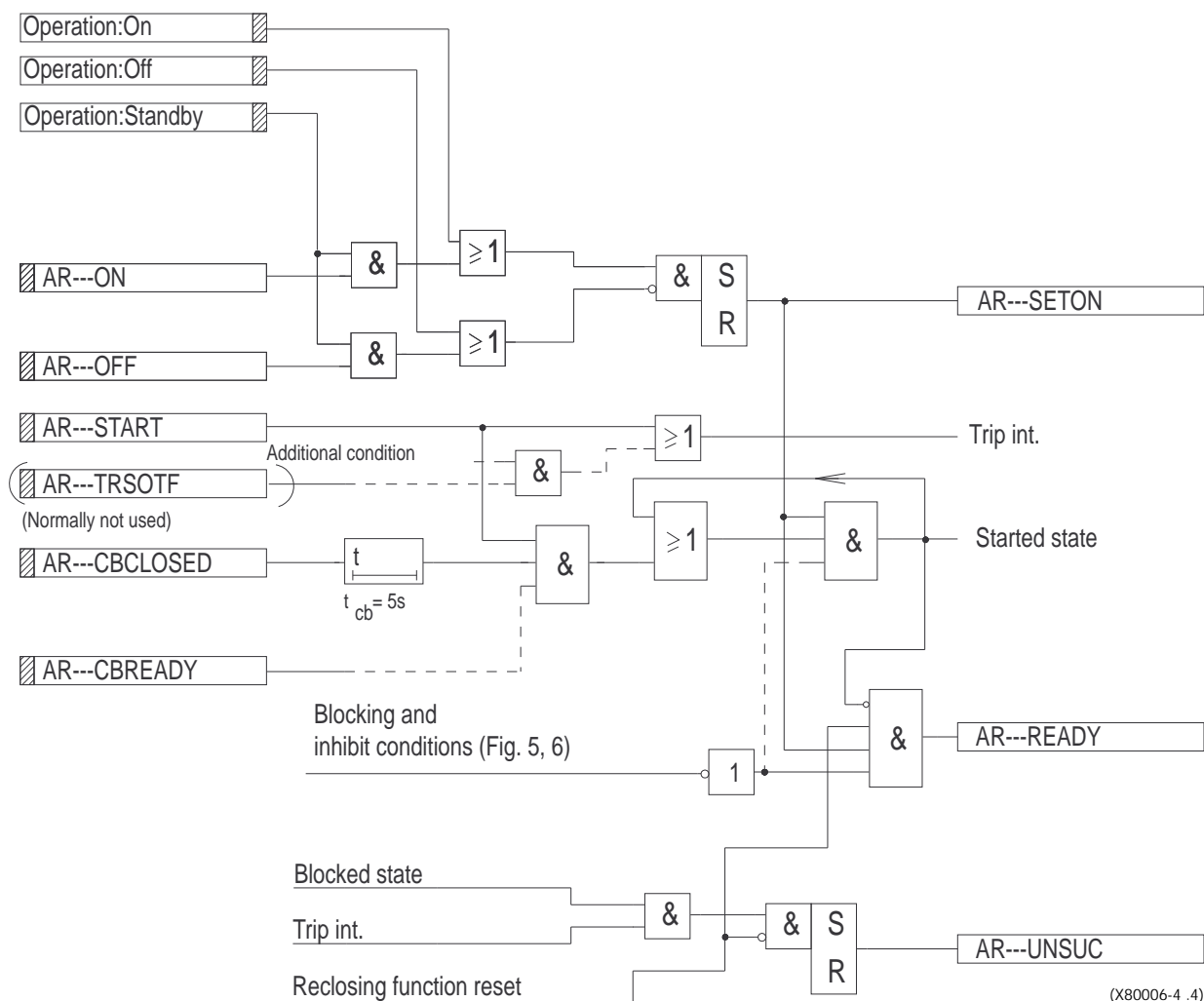
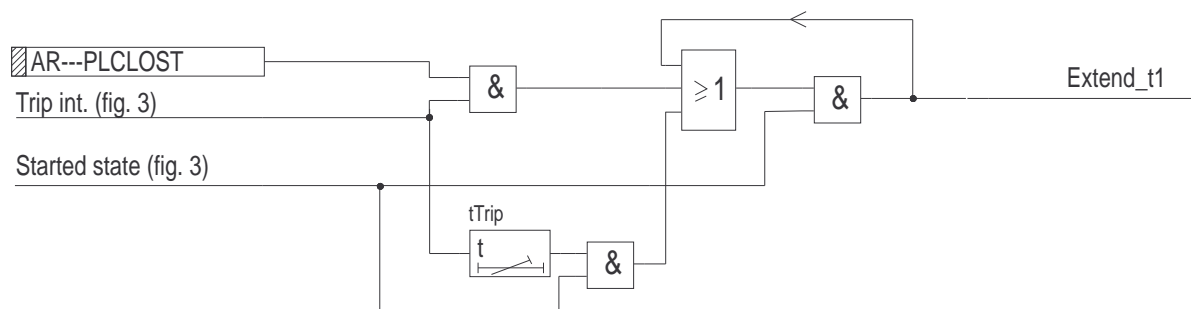
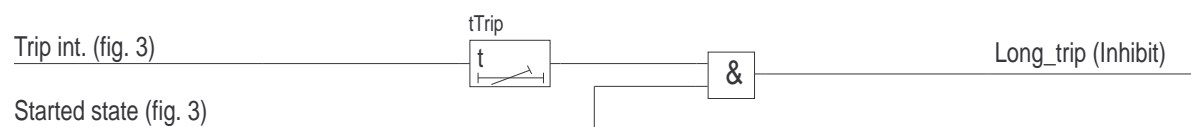


Fig. 3 Autoreclosing On/Off control and start. Simplified logic.
Details are left out.

(X80006-4 .4)



a) Extend t1=On



b) Extend t1=Off

(X80010-5 .3)

Fig. 4 Control of extended "AR open time, shot 1".

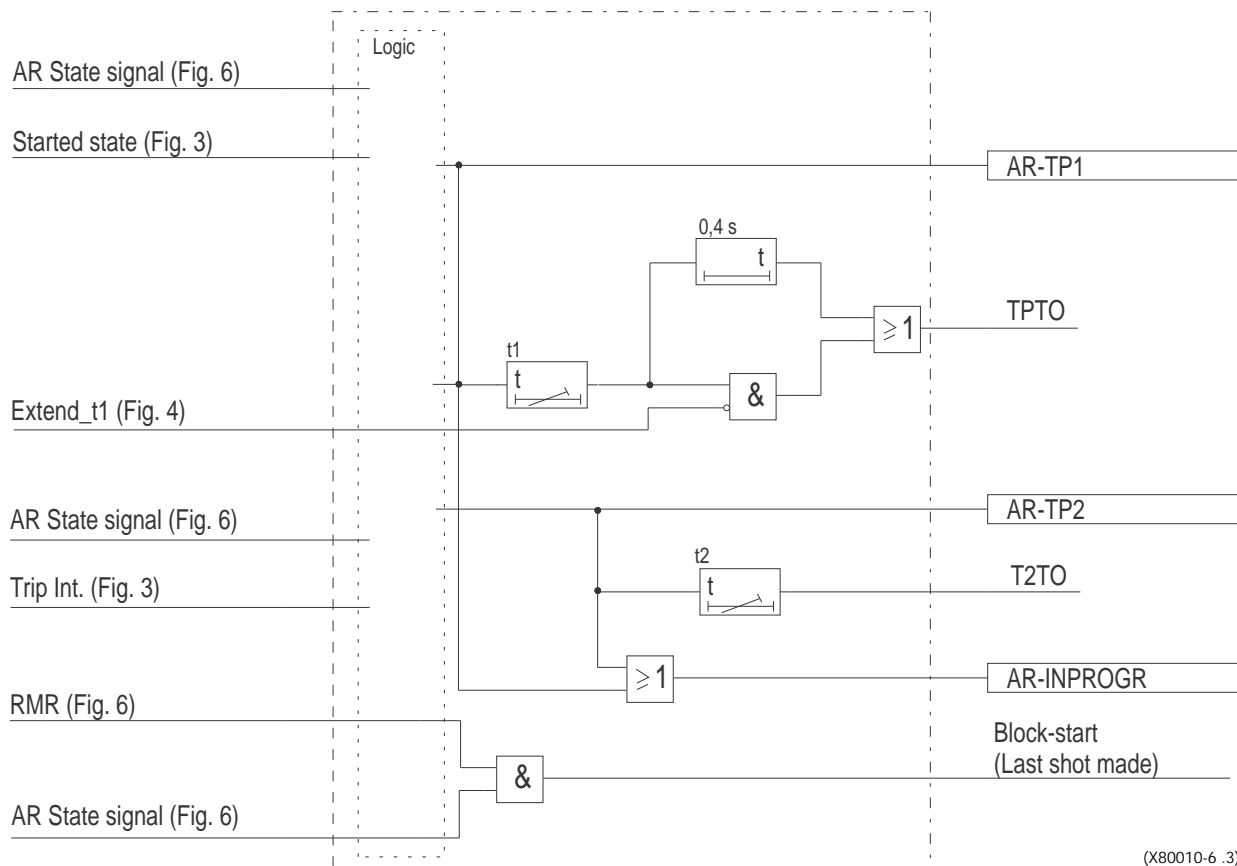
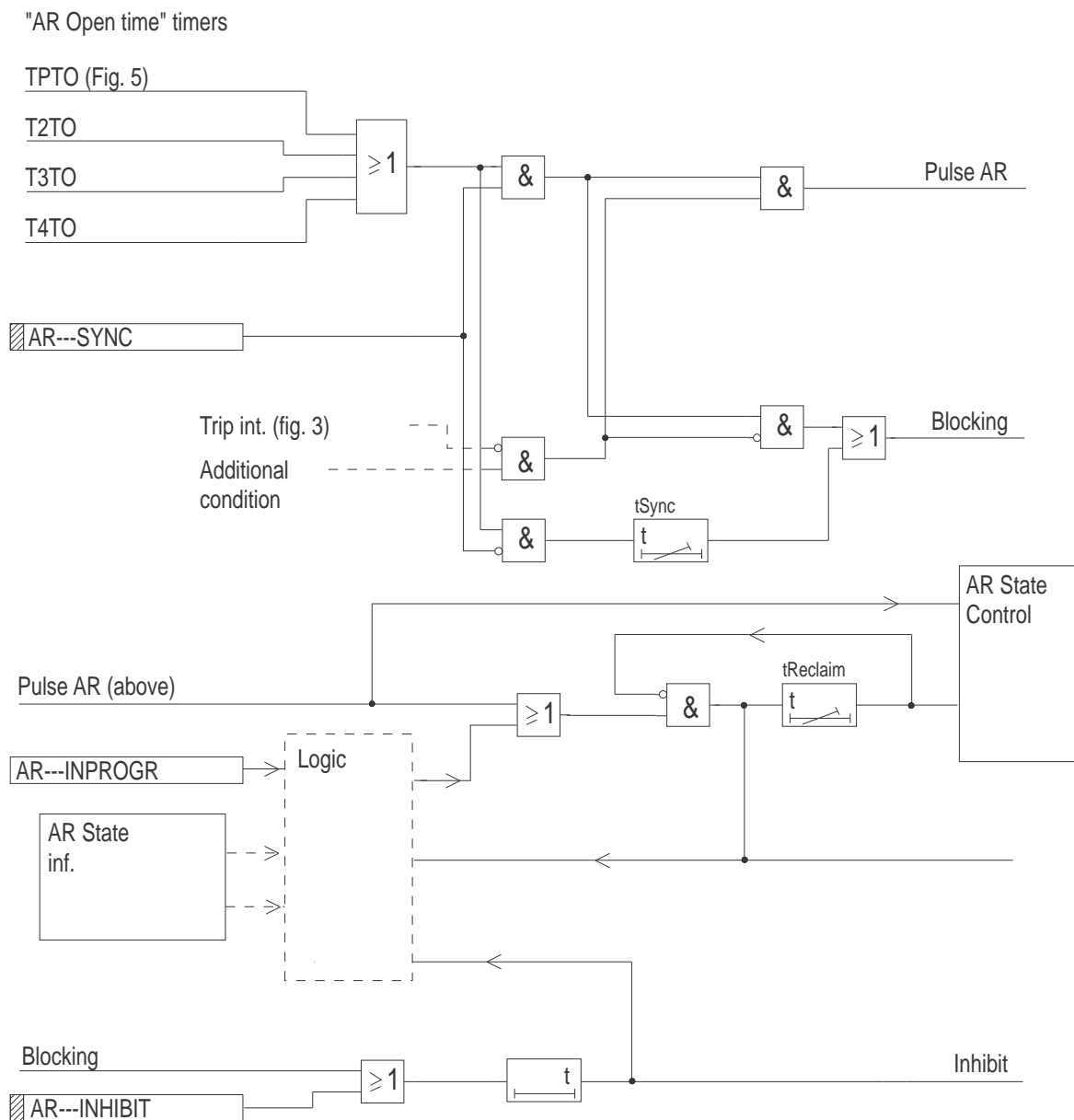
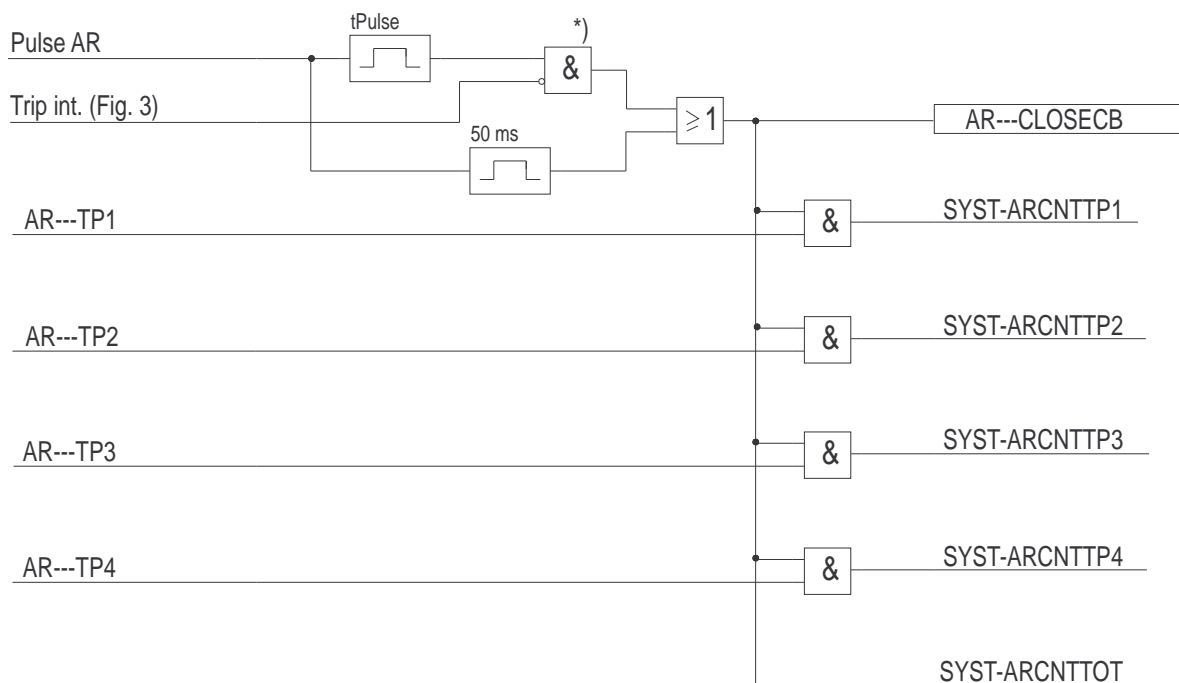


Fig. 5 Two-shot (three-phase) reclosing. Simplified logic. Details are left out.



(X80010-7.3)

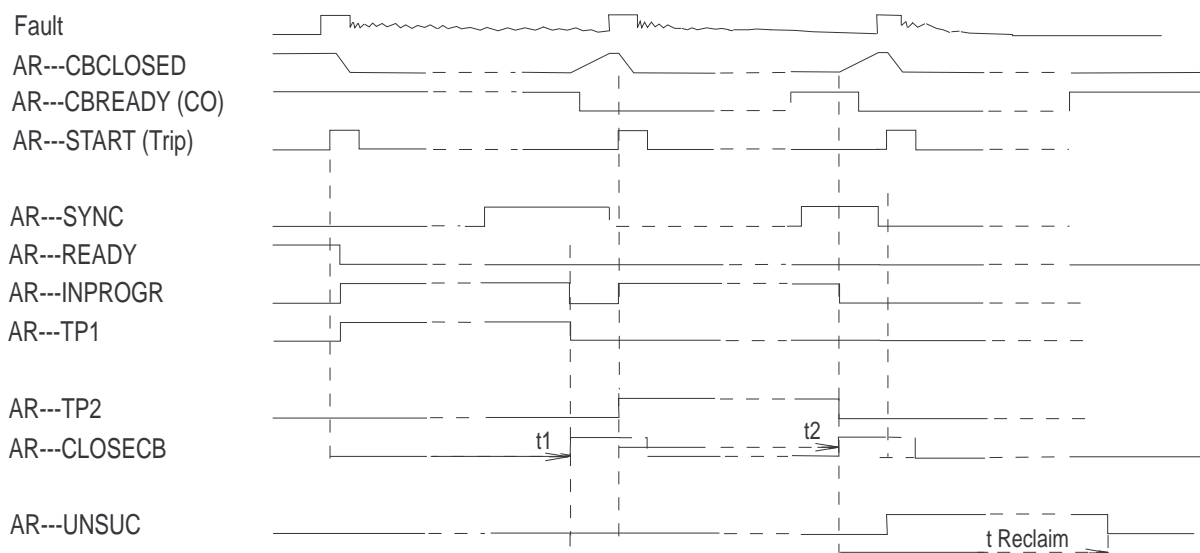
Fig. 6 Reclosing checks and "Reclaim" and "Inhibit" timers. Simplified logic. Details are left out.



*) Only if "CutPulse" = On

(X80010-8.3)

Fig. 7 Pulsing of close recommend and driving of the operation.



(X80010-9 (2))

Fig. 8 Example. Permanent fault. Two-shot reclosing.

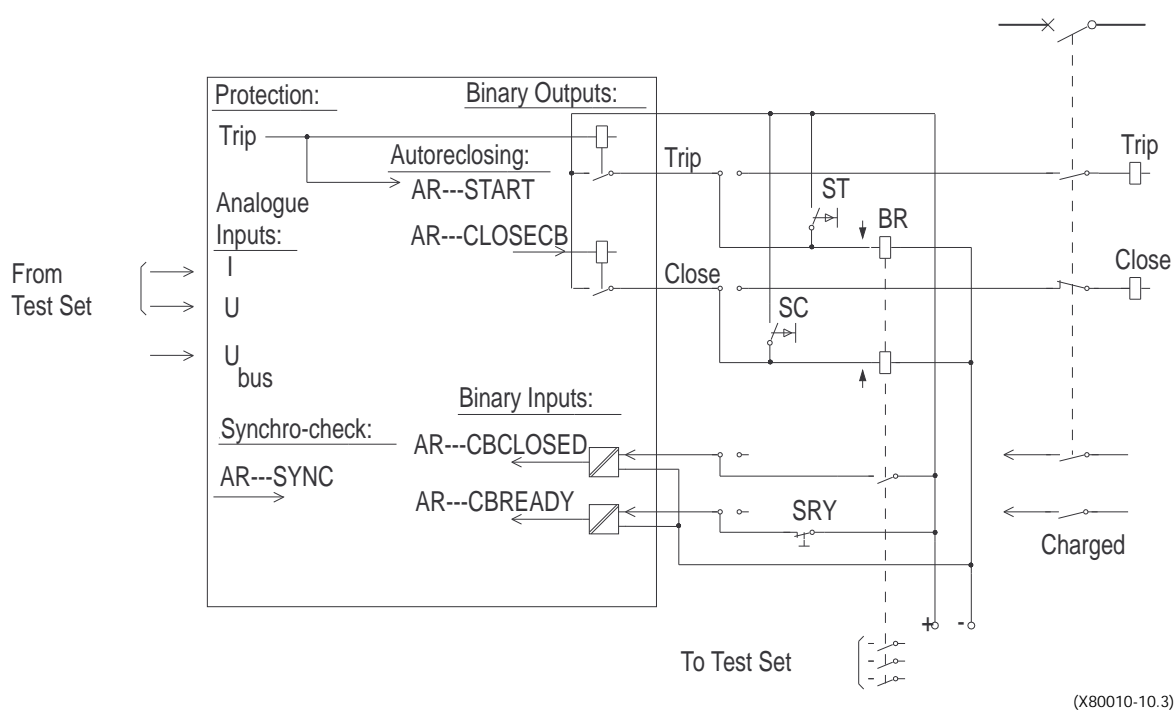
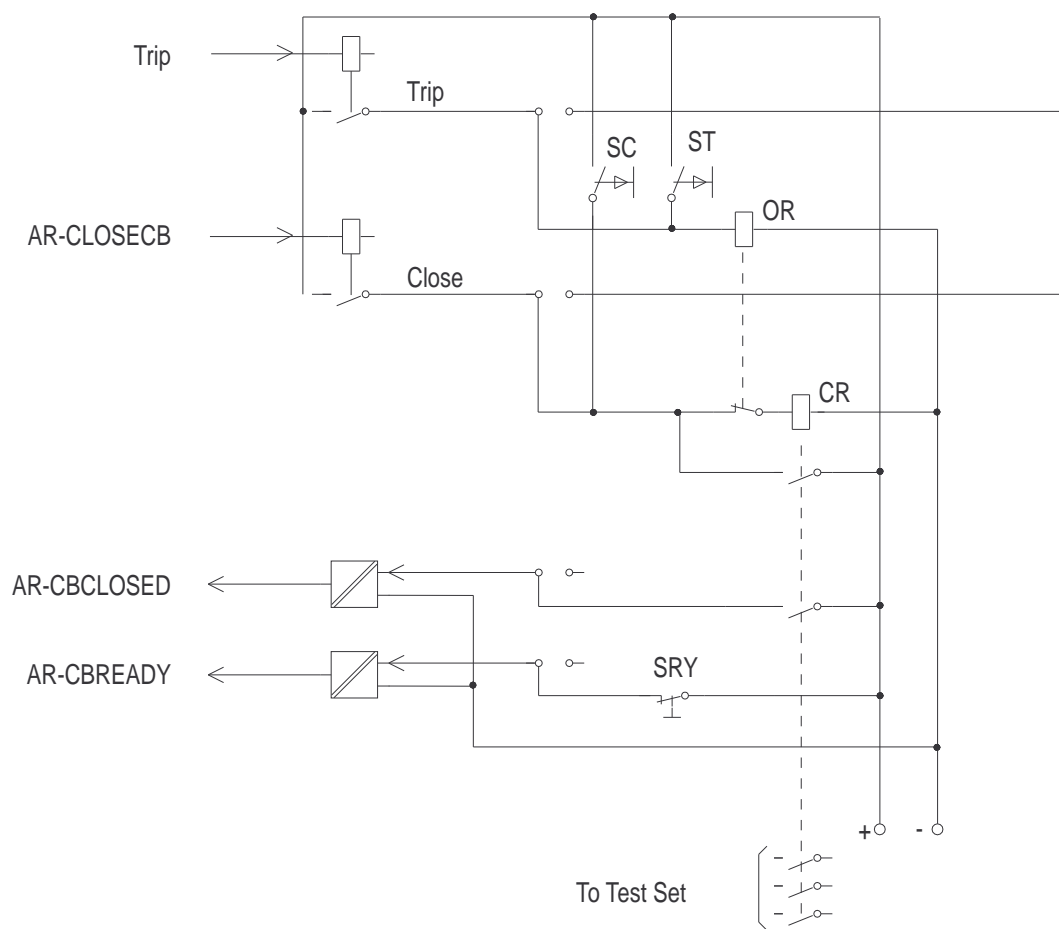


Fig. 9 Testing of auto-reclosing together with other functions.



(X80010-11.3)

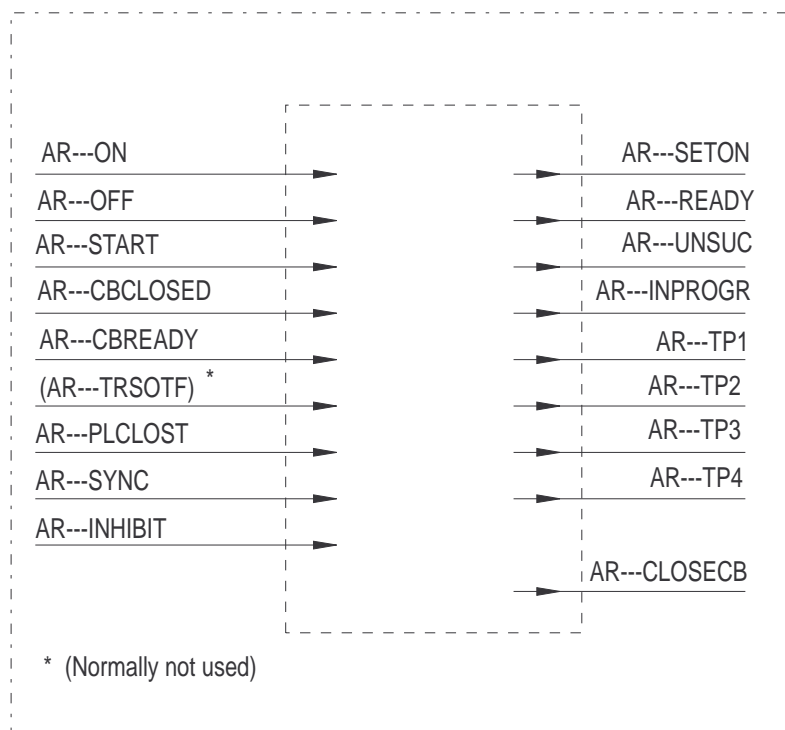
Fig. 10 Simulating breaker operation with two auxiliary relays.

1.6 Appendix**1.7 Technical data****Table 2:**

Function	Setting range
Number of autoreclosing shots	1 - 4
Number of autoreclosing programs	4
Autoreclosing open time: - shot 1 - t1 - shot 2 - t2 - shot 3 - t3 - shot 4 - t4	(0,2-60) s in steps of 0,01 s (1,0-300) s in steps of 1 s (1,0-300) s in steps of 1 s (1,0-300) s in steps of 1 s
Reclaim time - tReclaim	(10-300) s in steps of 1 s
Inhibit reclosing, reset time - tInhibit	(5-30) s in steps of 1 s
Duration of reclosing pulse - tPulse	(0,1-1,0) s in steps of 0,01 s
SC/DC time limit - tSync	(0,5-5,0) s in steps of 0,1 s
Breaker closed before start - t _{CB}	5 s fixed
Resetting of "AR Started" after reclosing - tTrip	(0,2-1,0) s in steps of 0,1 s

1.7.1 Terminal diagrams

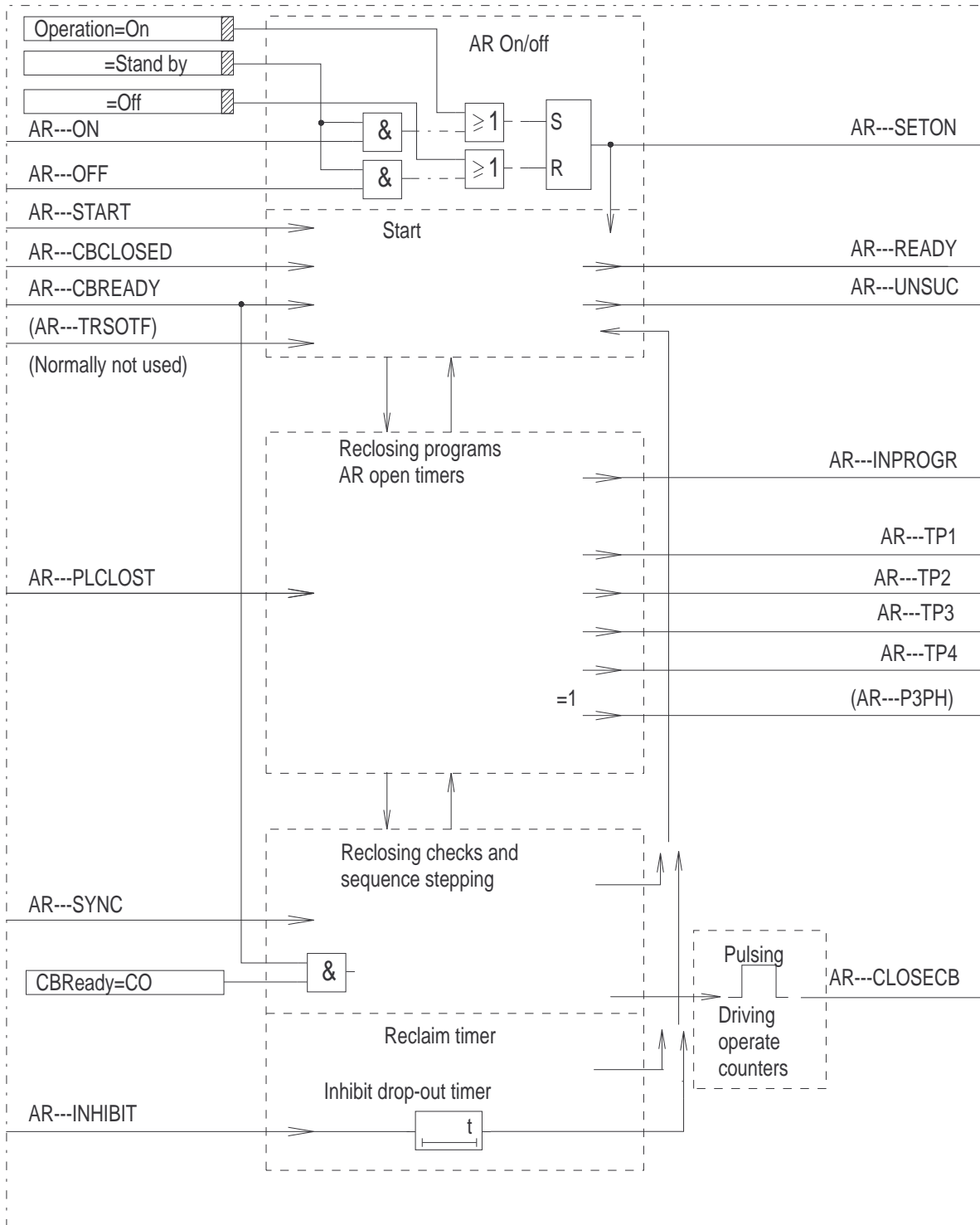
AR3 3-phase reclosing



(X80010-12.4)

Fig. 11 Simplified terminal diagram of the function.

AR3 3-phase reclosing



(X80010-13.4)

Fig. 12 Terminal diagram of the function.

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1.7.2 Signal list

CONNECTIONS:	TO:	SETTING:	DESCRIPTION:
AR---START	BI		Protection trip to autorecloser
AR---ON	BI		Enable autorecloser
AR---OFF	BI		Disable autorecloser
AR---CBREADY	BI		CB ready for operation
AR---CBCLOSED	BI		CB closed
AR---INHIBIT	BI		Inhibit autorecloser
AR---PLCLOST	BI		Carrier guard signal out
AR---SYNC	BI		Synchro-check / Energization OK
(AR---TRSOTF)	BI		Trip switch-onto-fault (normally not used)
PRODUCTION:	TO:	SETTING:	DESCRIPTION:
AR---CLOSECB	BO		Close CB command
AR---SETON	BO		Autorecloser set on
AR---INPROGR	BO		Autorecloser operation in progress
AR---READY	BO		Autorecloser prepared for reclose cycle
AR---TP1	BO		3-phase, shot 1 reclosing in progress
AR---TP2	BO		3-phase, shot 2 reclosing in progress
AR---TP3	BO		3-phase, shot 3 reclosing in progress
AR---TP4	BO		3-phase, shot 4 reclosing in progress
AR---UNSUC	BO		Autorecloser unsuccessful

1.7.3 Setting table

PARAMETER:	SETTING RANGE:	SETTING			
		ACTUAL			
		Group 1	Group 2	Group 3	Group 4
					DESCRIPTION:
Operation	Off / Standby / On				
Program	1 / 2 / 3 / 4 shots				No. of reclosing shots
Extended t1	On / Off				Extend t1
t1	0,20 - 60,00 s				Shot 1, AR open time
t2	1 - 300 s				Shot 2, AR open time
t3	1 - 300 s				Shot 3, AR open time
t4	1 - 300 s				Shot 4, AR open time
tSync	0,5 - 5,0 s				Max. time for synchron. check
tPulse	0,10 - 1,00 s				Reclose pulse duration
CutPulse	On / Off				Cut close pulse at new start
tReclaim	10 - 300 s				Reclaim time
tInhibit	5 - 30 s				Inhibit reset time
CBReady	CO / OCO				Type of CB Ready condition
tTrip	0,2 - 1,0 s				Max. duration of Trip or "Start"