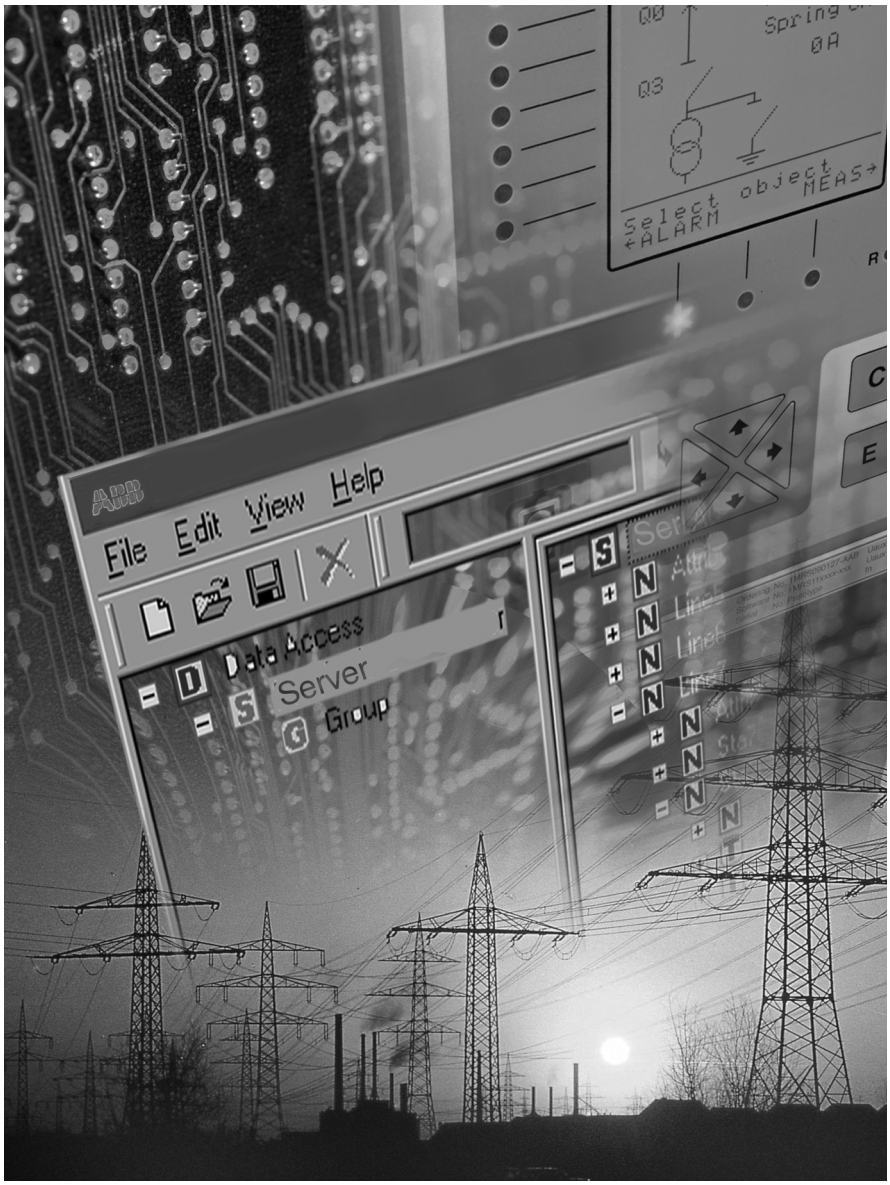
Auto-reclosing
REF542*plus*

Application and Setting Guide



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Contents

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1. Scope

This document describes the application of auto-reclosing, AR, in REF542*plus*. The auto-reclose function is primarily designed to operate with the internal feeder protection functions of REF542*plus*, for example, the directional or non-directional overcurrent protection, IDMT, directional or non-directional earth-fault protection, and distance protection. However, the auto-reclose function can also be initiated by an external protection device via a specific binary input. The number of AR shots, one to five, is selected with a setting parameter.

The different auto-reclosing modes of operation, i.e. Start and Trip Controlled and Start Controlled, are described in the document. Further, setting examples of auto-reclosing in conjunction with overcurrent and distance protection are included.

KEYWORDS: *Auto-reclosing*, *auto-reclosure*, *feeder protection*

2. Introduction

This document describes the auto-reclose (AR) function used in the feeder terminal type REF542*plus*.

The majority (about 80...85%) of medium voltage (MV) overhead line faults are arc faults which can be cleared by temporarily de-energizing the power line, whereas the rest of the faults (15...20%) can be cleared by prolonged interruptions, or eventually prove permanent. De-energizing of the faulted line for a defined period of time in order to extinguish the electric arc is performed by the AR function of a feeder terminal unit, for example, REF542*plus*. The AR function is capable of clearing most of the arc faults of open-wire overhead lines. At a permanent fault, the auto-reclose sequence ends with a final CB tripping, after which the fault spot has to be located and the fault cleared before the line can be re-energized.

The AR function of REF542*plus* can be used for auto-reclosing with any circuit breaker (CB) with three-phase auto-reclosing capability. The AR function block of REF542*plus* features five programmable AR shots, which can perform one to five successive auto-reclose shots of the desired type and duration, for instance, one high-speed and one delayed AR. When the AR is initiated by the start of a protection function, the AR function is capable of tripping the CB at reception of the protection start signal.

3. Technical implementation

The AR function features two different operation modes. The following section will describe the operation principle of these two operation modes.

3.1. Start and Trip Controlled operation mode

In the Start and Trip Controlled operation mode the time difference between the start and the trip signal of the cooperating protection function is evaluated. The AR function will only be activated, if the trip time of the cooperating protection is shorter than the setting value of the so called specified time t_{SPEC}. Therefore each AR shot can be given a different specified time setting. If the time difference between the protection start and trip signal is longer than the specified time, the AR sequence will not continue. The circuit breaker will not be re-closed. It will remain open, until closed again through a local or remote command.

Fig. 3.1.-1 illustrates a typical AR situation with one AR shot after a line fault has been detected:

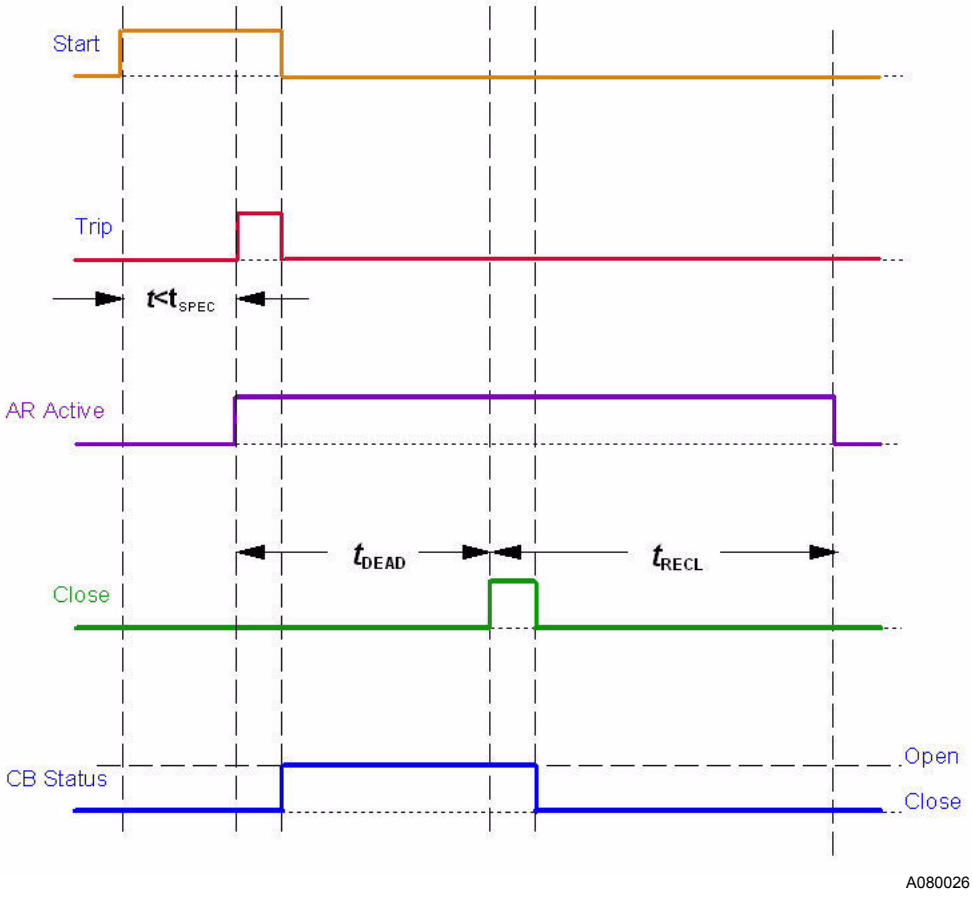

Fig. 3.1.-1 Typical AR situation with one AR shot in the Start and Trip Controlled mode of operation

As shown in the figure above, the specified time t_{SPEC} starts on the reception of the protection start signal. If the trip signal appears before the specified time t_{SPEC} has expired, the AR sequence can be continued. With the appearance of the protection trip signal, which opens the CB, the timer t_{DEAD} for the so called dead time is started. Simultaneously, the AR generates a high output signal *AR active*, which indicates that the AR sequence is running. The output signal remains high until the AR sequence has been completed.

At the end of the dead time t_{DEAD} the CB will be automatically re-closed by the AR function. The closing of the CB, in turn, starts another timer t_{RECL} for the so called reclaim time. If no other protection event occurs during the reclaim time t_{RECL}, the power system is assumed to be in normal operation state again and so the AR sequence will be completed. Consequently, the high signal of the *AR active* output turns low again.

Should the line fault still exist, the related protection function will start and generate a trip signal once the CB has reached its closed position. If the next AR shot is still possible, the AR sequence will continue, provided the time duration between the appearance of the protection trip signal and the protection start function is less than the set specified time t_{SPEC}. Otherwise, the CB will no longer be re-closed. In this case, the output signal AR active remains high, because the AR sequence has not been completed. Further, an output signal *AR failed* will be generated and the AR function will be blocked.

To get the AR function back into operation it has to be reset via the local HMI or by remote control. As a consequence, the output signal *AR failed* will disappear again, but the output signal *AR active* will still be high as the AR sequence has not been completed due to the open state of the CB. About 5 seconds after the CB has been closed again, the AR sequence will be completed. This fixed blocking time is used to avoid unwanted re-closing of the CB, should the CB be closed onto a fault when the line is re-energized. In such a case the output signal *AR active* will go low again, provided no protection start has been received during the 5 s blocking time.

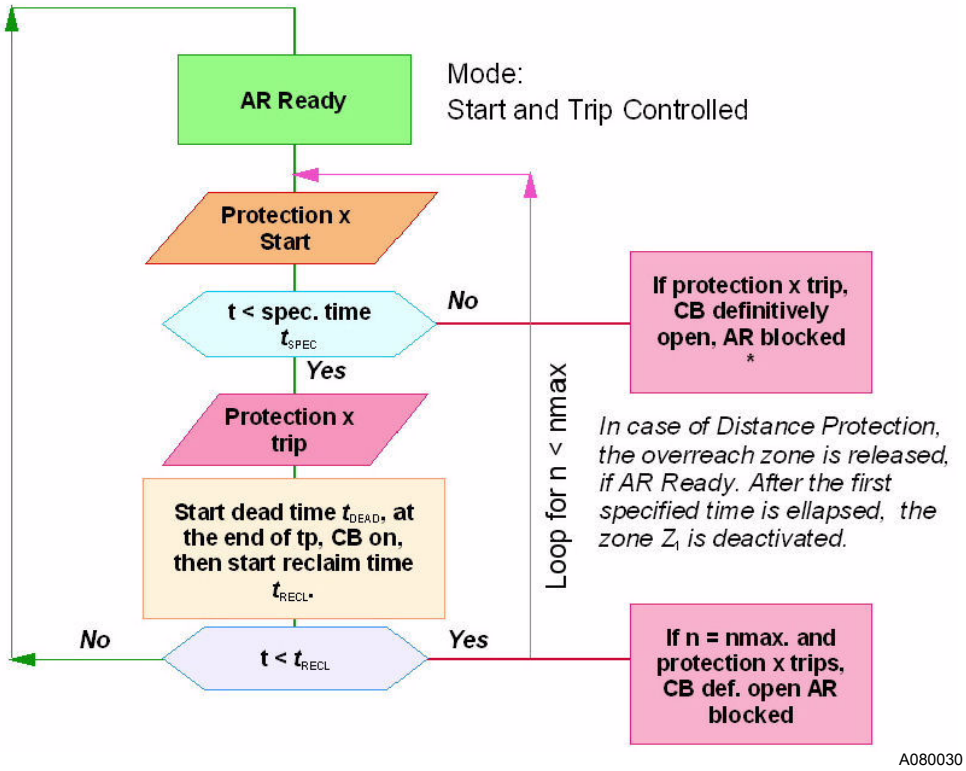

Fig. 3.1.-2 chart of start and trip controlled mode

The flow chart of the start and trip controlled mode is illustrated in Fig. 3.1.-2. The specified time t_{SPEC} is triggered by the protection start signal, provided the AR function is ready to operate. Simultaneously the indication *AR active* is generated, as the AR sequence is about to start. To open the CB before the specified time t_{SPEC} elapses, a trip signal must have been given. Only in this case, the CB will be re-closed again after the dead time has elapsed. Otherwise it will remain in the open position. Then the *AR failed* indication will be generated. At the same time the AR function is blocked. The AR function will be blocked until it is locally or remotely released and the CB is re-closed, as explained above.

The reclaim time of the AR function is used to define a successful AR sequence. Once the CB is re-closed, the reclaim time timer will start. Should another protection trip occur during the reclaim time, the AR sequence will continue. If the reclaim time has elapsed and no other protection trip has been obtained, the AR is regarded as having been successful and the AR sequence will start again from the *AR ready* status or no longer be activated. If, after the set AR shots have been carried out, a protection trip is detected during the reclaim time, the AR function will be blocked and an *AR failed* indication will be generated.

In cooperation with external distance protection, the AR function block must have some specific features. If the AR function is ready to operate, the so called overreach zone of the distance protection must be activated. The overreach zone is normally set to be about 120 to 150% of the first impedance zone. Then, when the first shot has been carried out, the overreach zone must be deactivated again. If the internal distance protection of REF542*plus* is used, no additional connection in FUPLA (FUnction plan Programming LAnguage) is needed. The connection required is

already implemented internally. If external distance protection is used, the output signal *AR active* can be used to control the activation or deactivation of the overreach scheme.

3.2. Start Controlled operation mode

In the Start Controlled operation mode an AR sequence will be initiated exclusively by the start signal of the related protection function. The tripping time (operate time) t_{OPER} for each shot can be separately delayed and it is controlled by the AR function block. The delayed tripping is needed in some applications, e.g. to burn off a tree branch from the overhead line.

Normally the first AR shot for closing the CB shall have a relatively short operate time, in the range of 30 to 100 ms. The operate time of the following shots may be longer, in the range of 1 to 10 s.

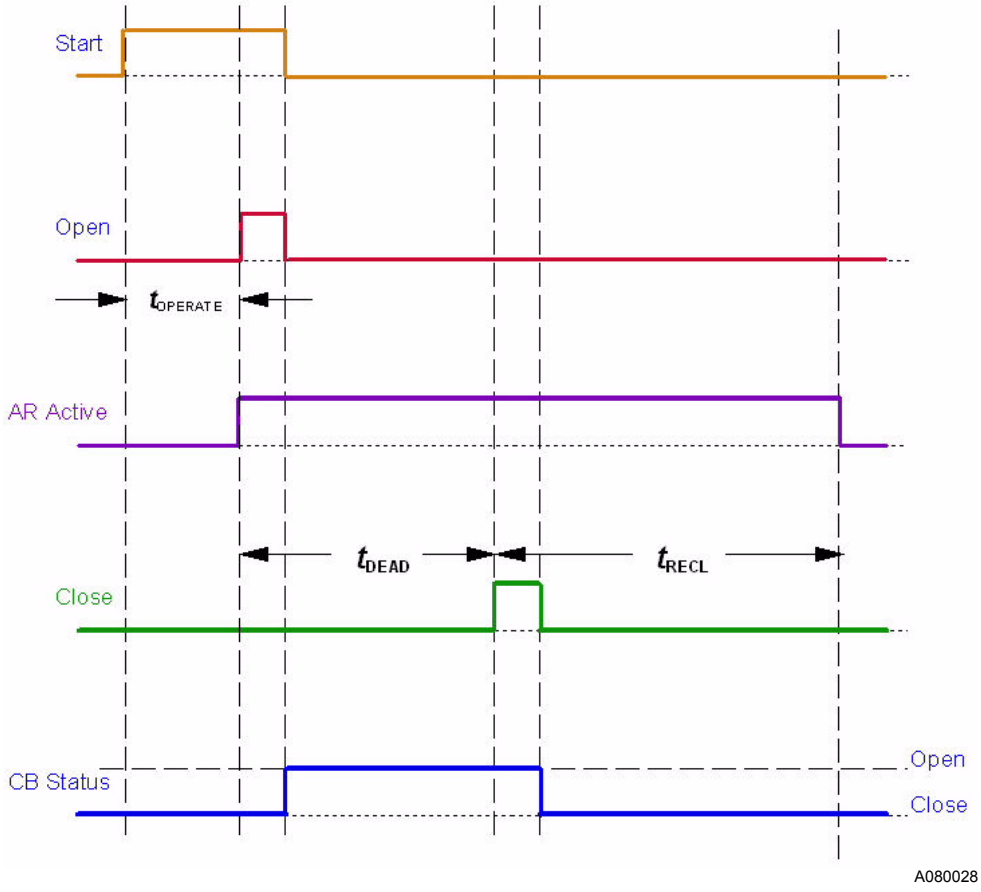

Fig. 3.2.-1 A typical AR situation with one AR shot in the Start Controlled mode.

In Fig. 3.2.-1 the AR function is activated exclusively by the start signal of the protection function. The operate time for tripping the CB in this mode is controlled by the AR function itself. The operate time t_{OPER} setting for the generation of the trip signal in the related protection function is bypassed. In other respects, the process is the same as in the setting mode explained before.

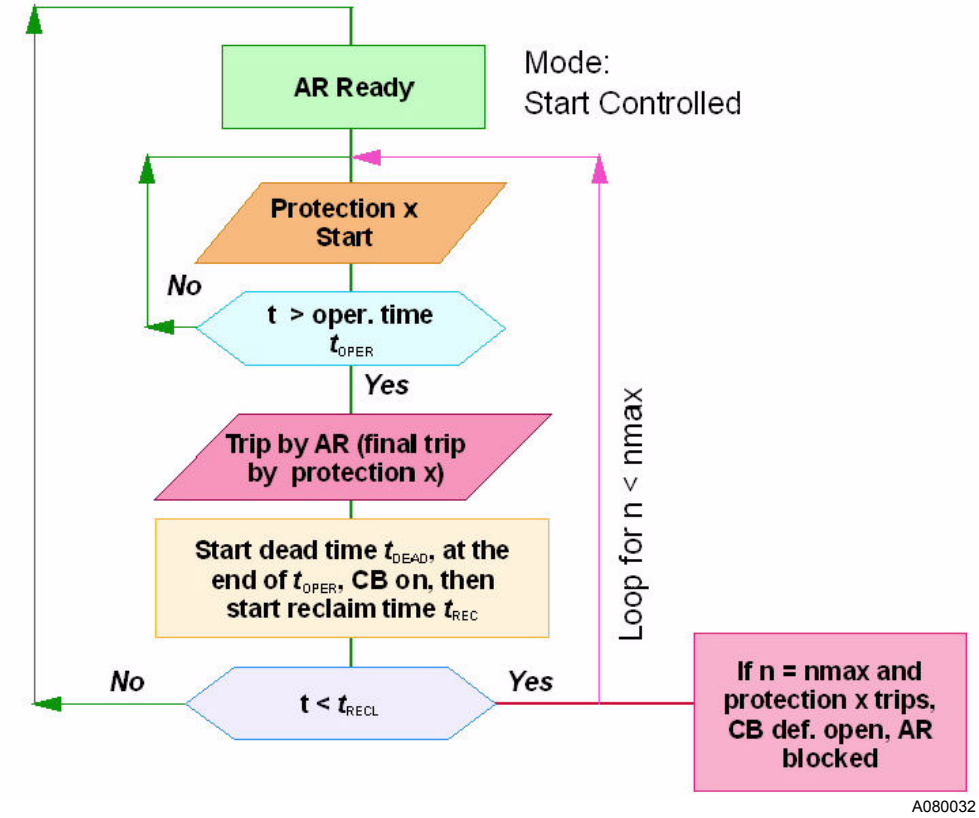

Fig. 3.2.-2 Flow chart of the Start Control mode.

To make the AR function operative again, the AR function block has to be reset via the local HMI or by remote control. As described above, the AR sequence will be ready for operation in about 5 s after the CB has been re-closed. This fixed blocking time is used to avoid unwanted reclosing of the CB, should a CB be closed onto a fault when the line is re-energized again. Then the output signal *AR active* will become low again, provided no protection start signal is obtained during the 5 s blocking time.

The flow chart of the Start Controlled mode is illustrated in Figure 3-4. Only the start signal will initiate the AR sequence. The operate time setting of each protection function block connected to the AR function block is neglected during the AR sequence, because the tripping of the CB is controlled by the AR function block. A final trip signal will be generated when the operate time of the protection elapses.

Please note that the protection maintains normal operability, when the AR function is blocked.

3.3. Design of the AR function block

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Fig. 3.3.-1 AR function block

The function block for the configuration of the AR function is shown in Fig. 3.3.-1. The input and the signals will be described in the following sections.

3.3.1. Input signals

BS: As in other protection function blocks of REF542*plus* a logical high signal, such as the BS input signal, is used to block the AR function. In this state the *AR active* output becomes high to indicate that the AR sequence is not ready for operation. To get the AR function in the ready-for-operation state again, the input signal must be low and the CB has to be in the closed position.

One SHOT: If the input is high, the setting value for the number of AR shots becomes invalid and is reduced to one single shot. Should the fault persist, the next trip signal of the related protection function will open the CB definitively and generate an *AR failed* signal, which also indicates that the AR function is blocked and a reset is needed via the local HMI or remote control.

CB OK: This input signal is used for monitoring the readiness of the CB to operate, for instance, by supervising the gas pressure of the CB breaking chamber or the status of the CB operating mechanism. If this input signal is low just before the dead time elapses, no CB re-closing will be performed. The output signals *AR active* and *AR failed* will be generated.

EX. TRIG: A logical high signal will trigger the AR function to operate or to continue operation, provided the required conditions for operation are still valid. This signal can be generated, for example, by an external protection device, the trip signal of which is routed to a binary input of REF542*plus*.

INCR: If AR is carried out by an upstream or downstream protection device with AR functionality, a high input pulse signal (rising edge) can increment the number of AR shots to synchronize the on-going AR sequence.

STOP AR: An AR sequence in progress can be stopped immediately by applying a high input signal to *STOP AR*. If the CB is open, no AR will be performed. If in closed position, the CB will be opened, provided the AR sequence is still going on. As already mentioned, the output signals *AR active* and *AR failed* will be generated.

TEST: The concerned AR sequence can be tested by using a high input signal of the corresponding duration.

3.3.2. Output signals

CLOSE CB: When high, this output signal (about 100 ms) indicates that the CB is closed by the AR function. No wiring to the specific 2-2 switch object, which is used to simulate the CB in the FUPLA, is necessary. The AR function is already wired internally to the switch object used for the simulation of the CB.

OPEN CB: When high, this output signal (about 100 ms) indicates that the CB is opened by the AR function. As mentioned above, no wiring to the specific 2-2 switch object for simulating the CB in the FUPLA is needed.

AR ACTIVE: As soon as an AR sequence is started by the related protection functions or the AR function is blocked, the output signal becomes high. The signal remains high until the AR sequence has been completed after a successful removal of the fault in the power system. A low output signal indicates that the AR function is ready for operation, which can be used, for example, to activate the overreach zone of the distance protection.

AR FAILED: If the AR sequence cannot be continued or the power system fault still persists after the set number of shots has been accomplished, a high output signal will be generated. The AR function is blocked and has to be reset from the local HMI or by remote control.

SHOT 1: A high signal on this output (duration about 100 ms) indicates that the 1st AR shot has been initiated.

SHOT 2: A high signal on this output (duration about 100 ms) indicates that the 2nd AR shot has been initiated.

SHOT 3: A high signal on this output (duration about 100 ms) indicates that the 3rd AR shot has been initiated.

SHOT 4: A high signal on this output (duration about 100 ms) indicates that the 4th AR shot has been initiated.

SHOT 5: A high signal on this output (duration about 100 ms) indicates that the 5th AR shot has been initiated.

3.3.3. Setting parameters

The setting parameters for the AR function are shown when the AR function block is opened. Fig. 3.3.3.-1 shows the General sheet for setting the AR function. The operation mode can be selected to be either Start and Trip Controlled or Start Controlled mode of operation.

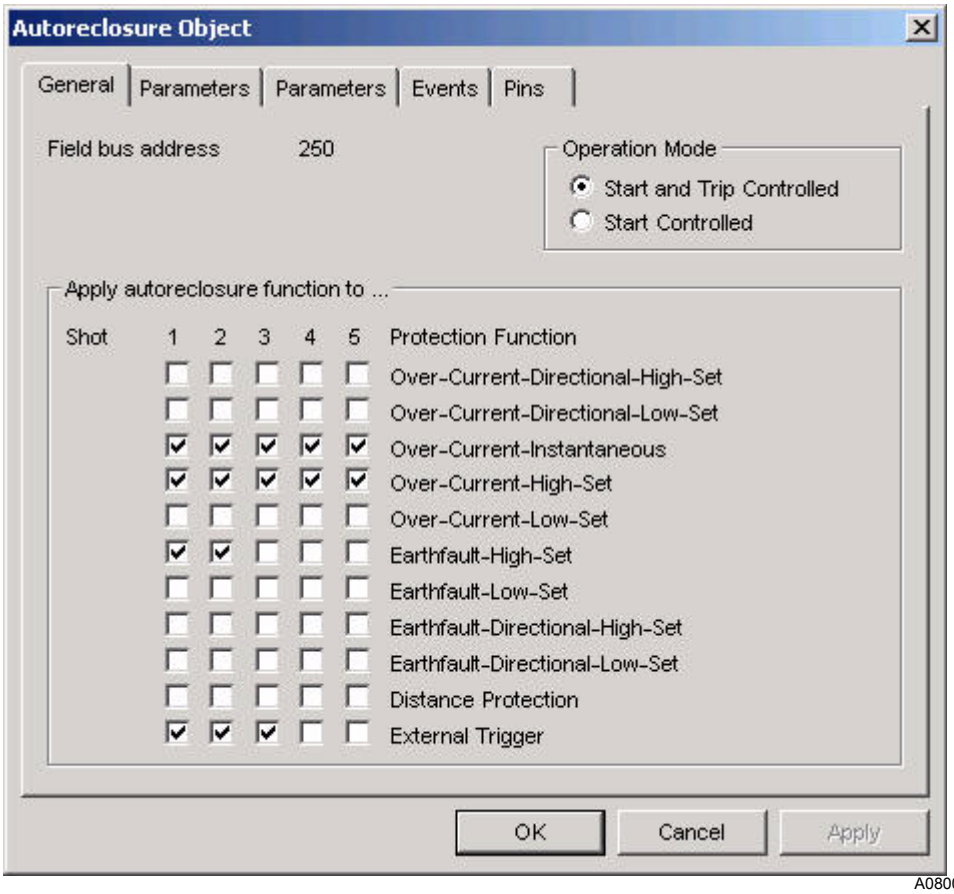

Fig. 3.3.3.-1 General sheet for setting the AR function

Furthermore, there is a checklist for the selection of the protection functions to be involved in the AR process. If the protection function is not checked in the list, the start and the subsequent trip will not be considered in the AR function and will not lead to a reclosing of the CB. As shown in the Fig. 3.3.3.-1, the high-set earth-fault protection is only considered for the 1st and the 2nd shot. If the high-set earth-fault protection generates another trip signal after the second re-closing of the CB, the CB will no longer be reclosed. If however, the CB is tripped again by the instantaneous overcurrent protection and the high-set overcurrent protection function or an external trigger signal the CB will continue to be reclosed.

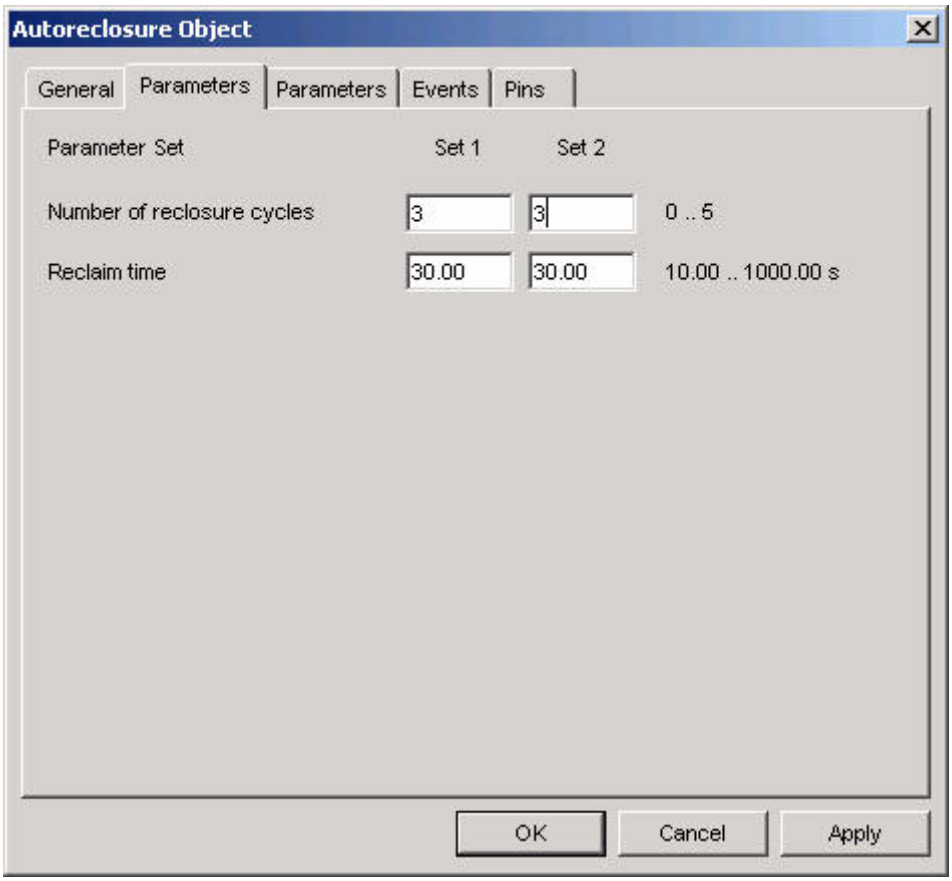

Fig. 3.3.3.-2 Parameter sheet for setting the AR function

The number of shots and the reclaim time are set in the sheet shown in Fig. 3.3.3.-2.

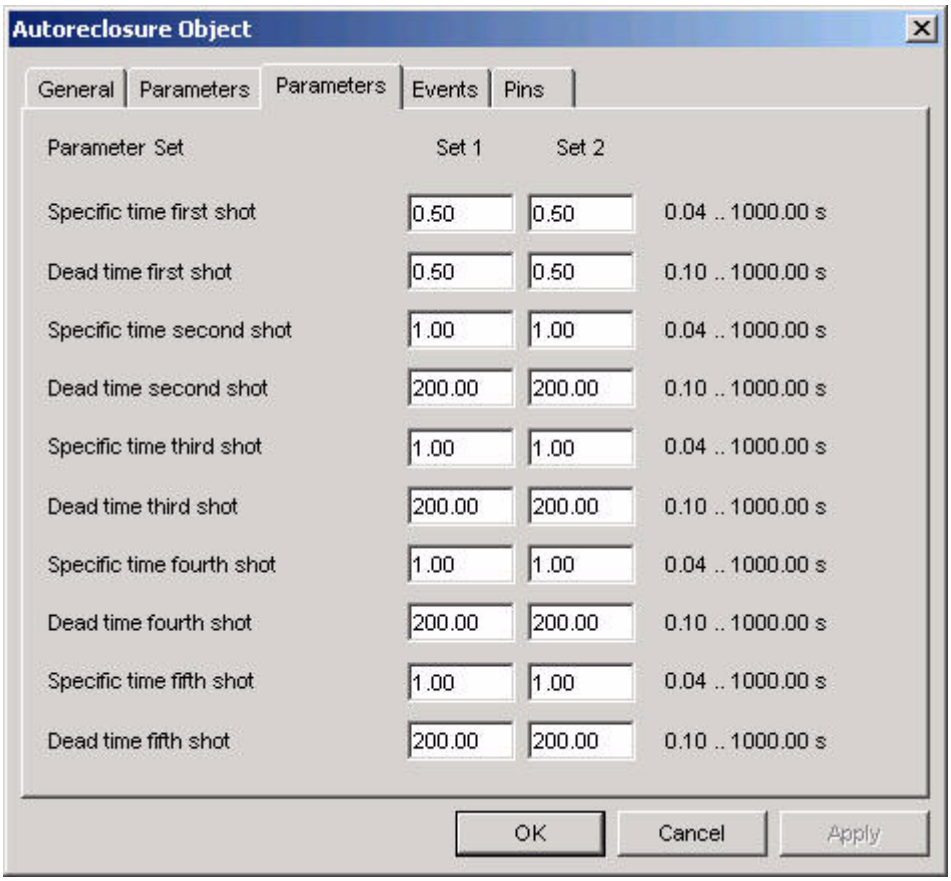

Fig. 3.3.3.-3 Parameters for setting the timers for the separate AR shots

Fig. 3.3.3.-3 shows the sheet for setting the specific time for monitoring the AR permission and the dead time for each AR shot. These setting parameters are valid for the Start and Trip Controlled mode of operation.

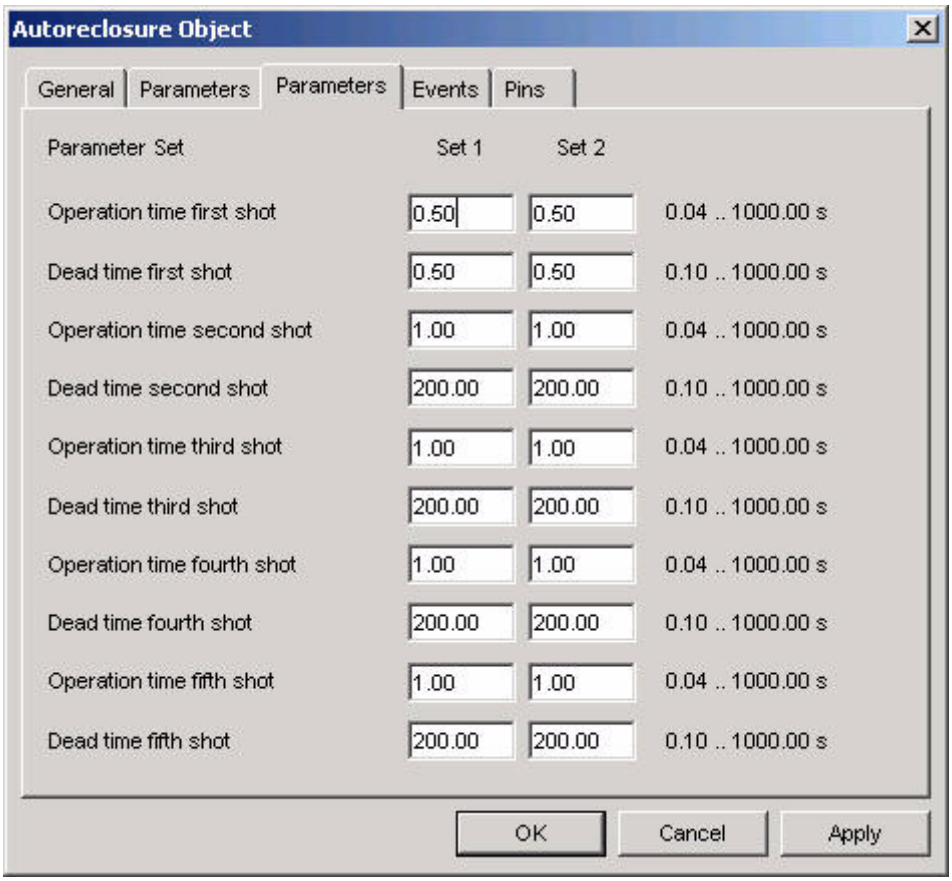

Fig. 3.3.3.-4 Parameters for setting the timers for the separate AR shots

If the Start Controlled operation mode is selected, the sheet shown in Fig. 3.3.3.-4 for setting the timer for the separate AR shots will appear.

4. Setting example

4.1. AR in conjunction with distance protection

Auto-reclosing is generally used in conjunction with distance protection of overhead lines. In this application certain cooperation is required between the AR function and the distance protection. Fig. 4.1.-1 shows the reach of impedance zone Z_1 of the distance protection (DP installed in station A for the protection of the line between station A and station B. The figure also shows the overreach zone ZOV.

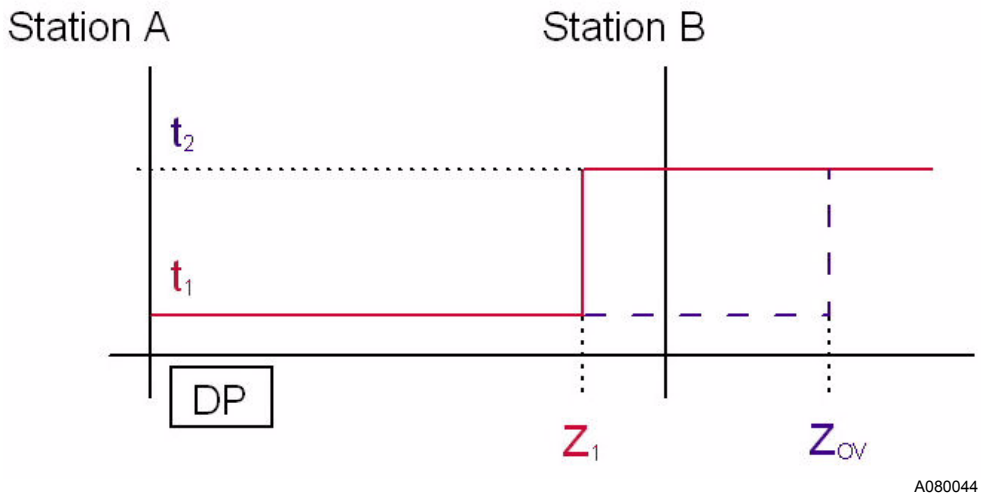

Fig. 4.1.-1 Reach of the first impedance zone Z_1 and overreach zone Z_{OV}

For selectivity reason the reach of the first impedance zone Z_1 of the distance protection is normally set to cover 85 to 90% of the length of the line. The related fast operate time is named t1. As a consequence, a fault located near the line end or just behind station B can only be tripped by the protection system of the second impedance zone, with a operate time t2 according to the remote backup protection scheme.

To increase the chances for a successful AR sequence, the fault mentioned above has to be isolated as fast as possible. The shorter the operate time is, the faster the arc is extinguished. Even in the case of a failure of the CB next to the fault spot, the fault must be rapidly isolated from the system. This again requires that the power supply to the fault spot must be temporarily disconnected by the AR function.

Distance protection easily fulfils this requirement. The distance protection can provide the so called overreach zone Z_{OV}. This zone must be activated, if the AR function is ready to operate. After the fault has been cleared, the overreach zone Z_{OV} must be deactivated again. The distance protection can work normally again with the related impedance zones. If the fault still persists after the first AR cycle, it will be cleared using to the normal settings of the impedance zones, as shown in the scheme for the coordination of the time discrimination by the related impedance zone. The faulty line will be disconnected by the selective protection scheme applied.

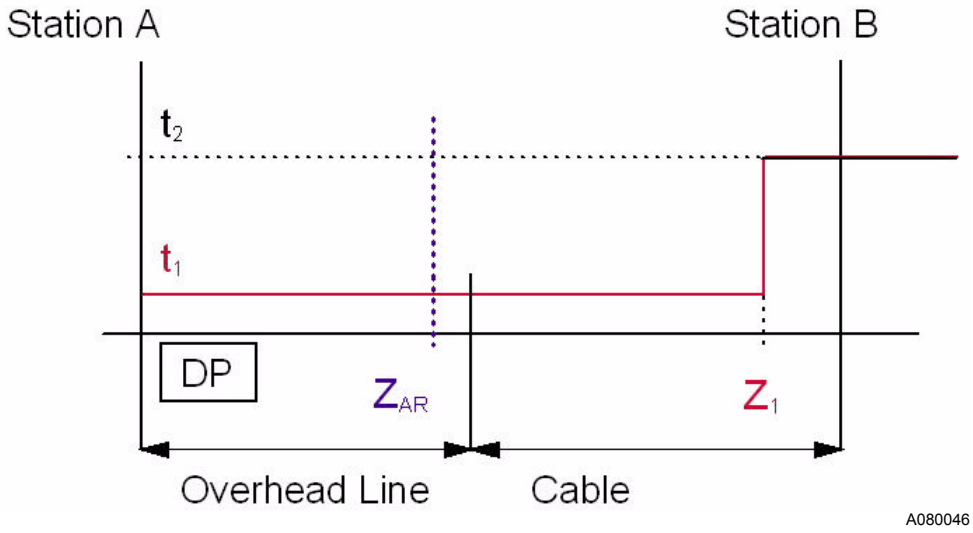

Fig. 4.1.-2 Combined overhead line and cable feeder between station A and B

The MV line between station A and station B can be a composed overhead line and a cable feeder. In Fig. 4.1.-2 the line protected by the distance protection scheme located in station A is both a combined overhead line and cable feeder. In this case AR can be carried out only if the fault occurs in the initial overhead line section. For faults located in the second section consisting of a cable feeder, no AR will be performed. This kind of cooperation between AR and distance protection is offered by REF542*plus*.

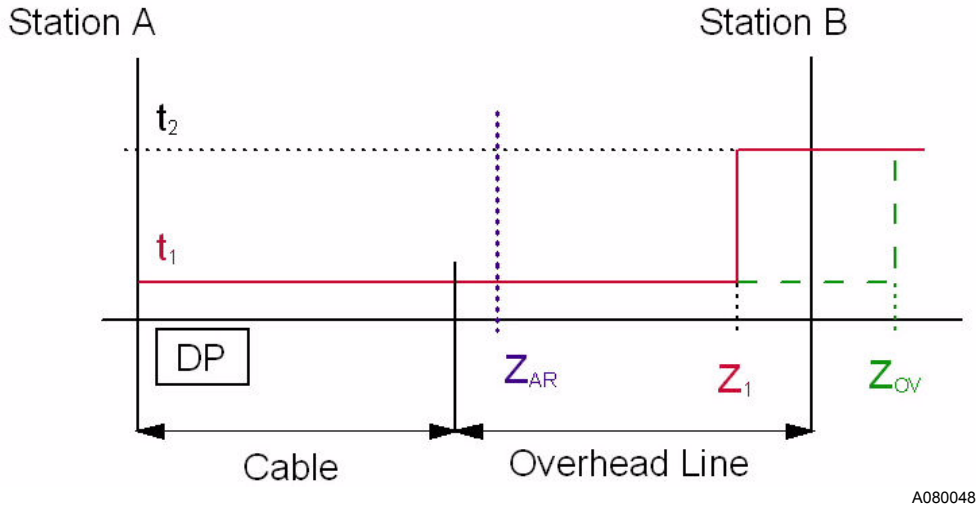

Fig. 4.1.-3 Combination cable and overhead line feeder between station A and B

In the opposite arrangement shown in Fig. 4.1.-3, the blocking of AR must also be possible if a fault occurs in the initial cable line section. On the other hand, AR must be performed, if the fault is in the overhead line section.

NOTE: To obtain the functionality described above, it is necessary to set the distance protection as mentioned in the corresponding application note.

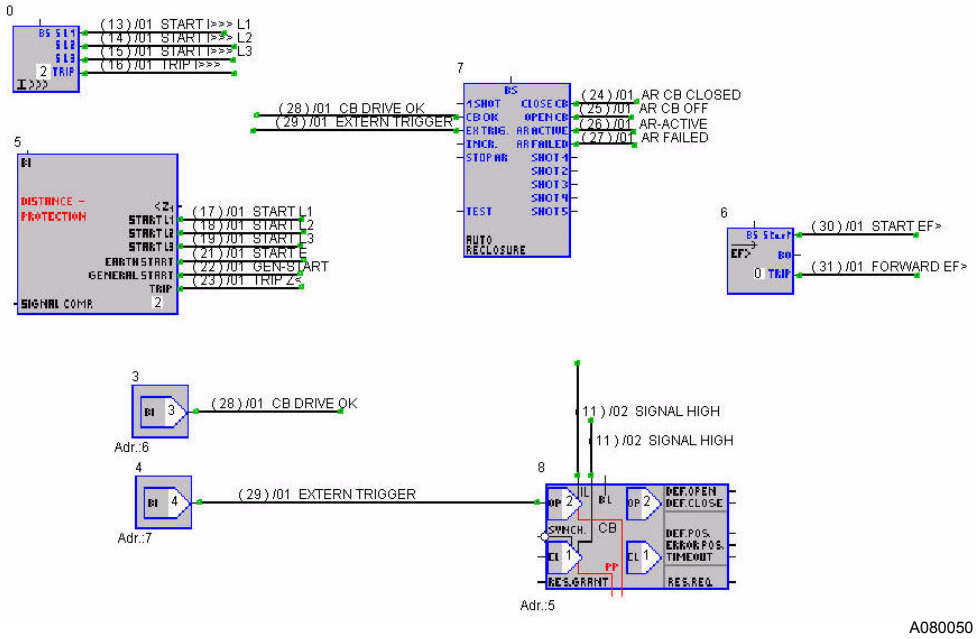

Fig. 4.1.-4 Example of AR configuration in conjunction with distance protection

A configuration example for the combination of distance protection and AR is illustrated in Fig. 4.1.-4. The overcurrent protection provides back up protection for the distance protection so no separate back-up protection needs to be considered. The settings of the AR function can be seen in the following figures.

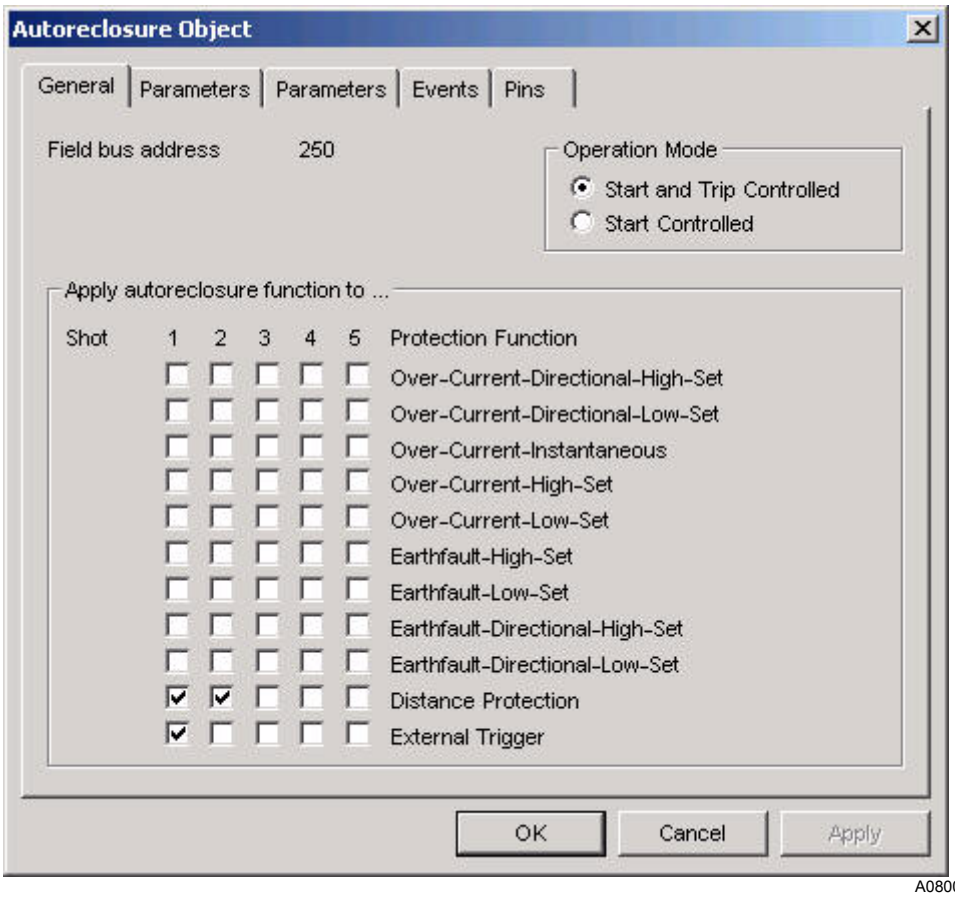

Fig. 4.1.-5 Setting of the operation mode and initiation of AR

In this example the operation mode of the distance protection is Start and Trip Controlled. The AR functions are initiated by the integral distance protection of REF542*plus* and by an external trigger signal applied on a defined binary input.

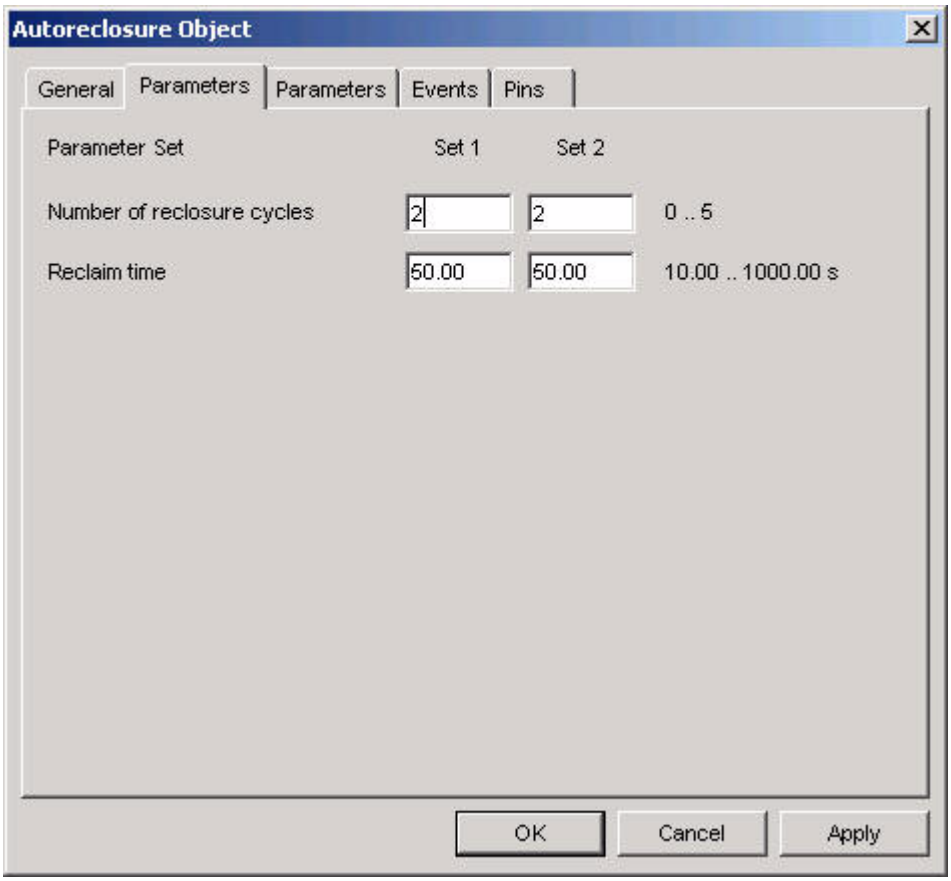

Fig. 4.1.-6 Setting of the number of shots and reclaim time

According to Fig. 4.1.-6 above the AR function will perform up to 2 AR shots. The reclaim time for the AR function is 50 s. When this time has elapsed, the AR function will be ready for operation, provided no additional fault has been detected meanwhile.

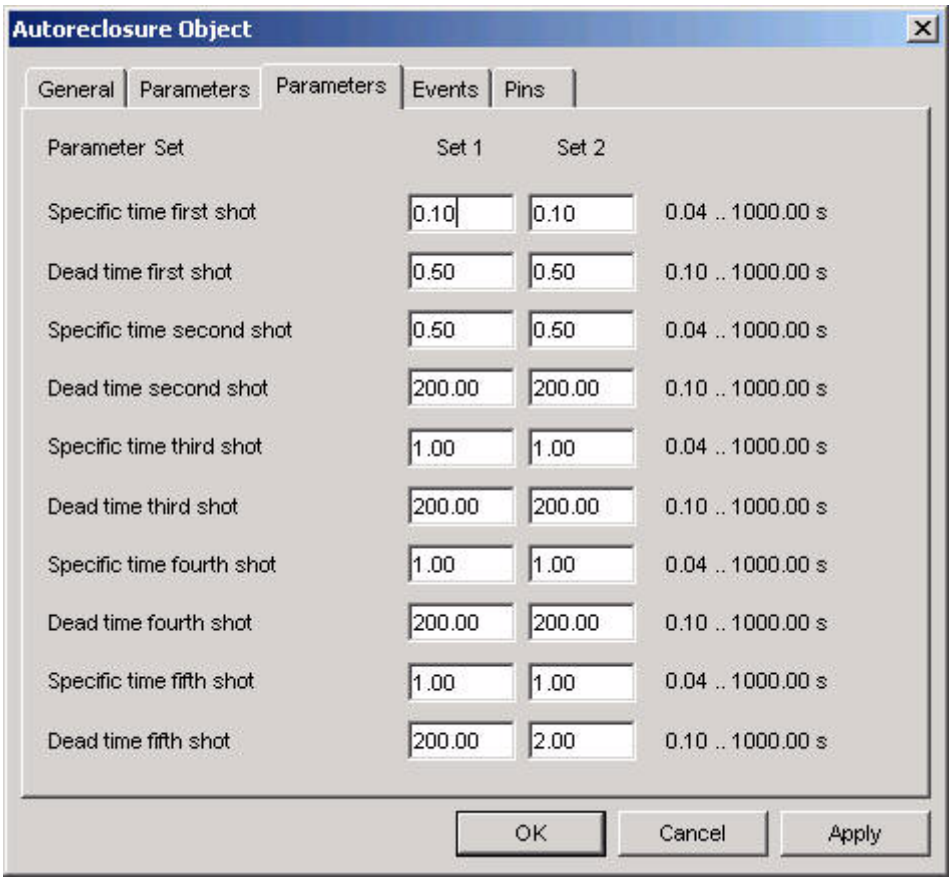

Fig. 4.1.-7 Setting of of the specific time and dead time for the separate AR shots

According to Fig. 4.1.-7 above, the first AR shot will be initiated by a fault occurring in the first impedance zone or in the overreach zone with a trip time less than 0.1 s. Otherwise no AR will be performed. The dead time for the first AR is set to be 0.5 s. When the CB has been re-closed, the next shot will be initiated only under the condition that

- the reclaim time has not elapsed and
- the trip time of the distance protection is less than 0.5 s.

The dead time of the CB to be re-closed in this second shot is 200 s. The other setting parameters on this sheet are not considered, as the number of AR shots is limited to two.

4.2. AR in conjunction with overcurrent protection

This application example shows the setting of the AR function in conjunction with overcurrent protection. The configuration of REF542*plus* is shown in Fig. 4.2.-1 below.

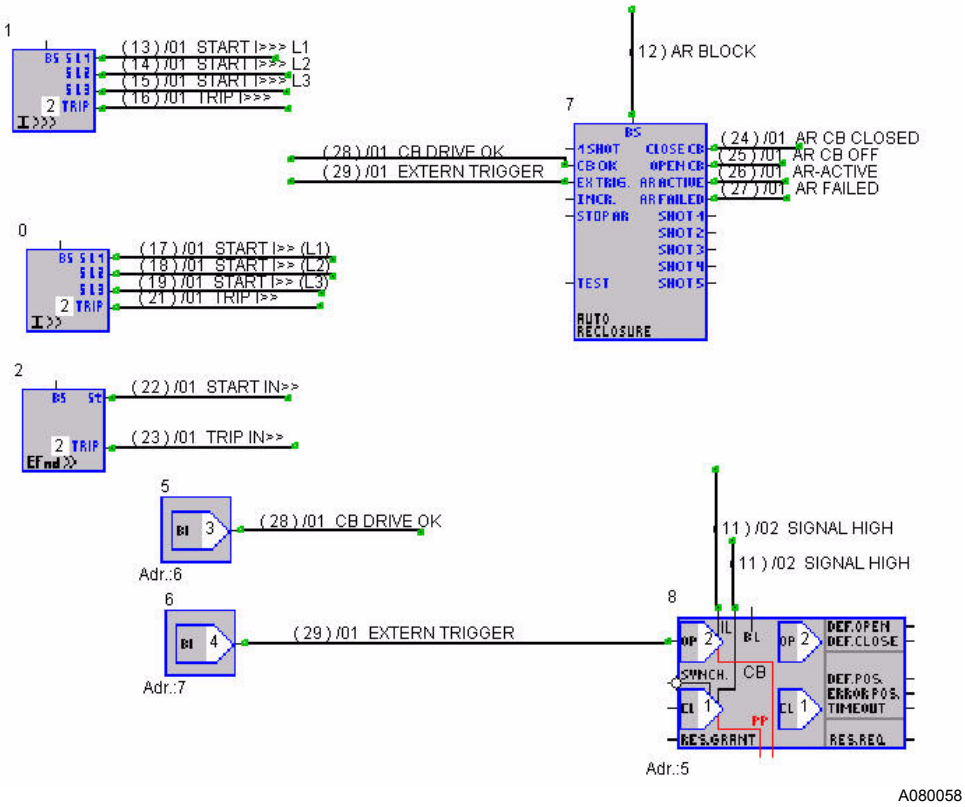

Fig. 4.2.-1 Configuration of AR in conjunction with overcurrent protection functions.

The operate times of the protection functions in the applications are as follows:

- Instantaneous overcurrent protection: 30 ms
- High-set overcurrent protection: 500 ms
- High-set earth-fault protection: 250 ms

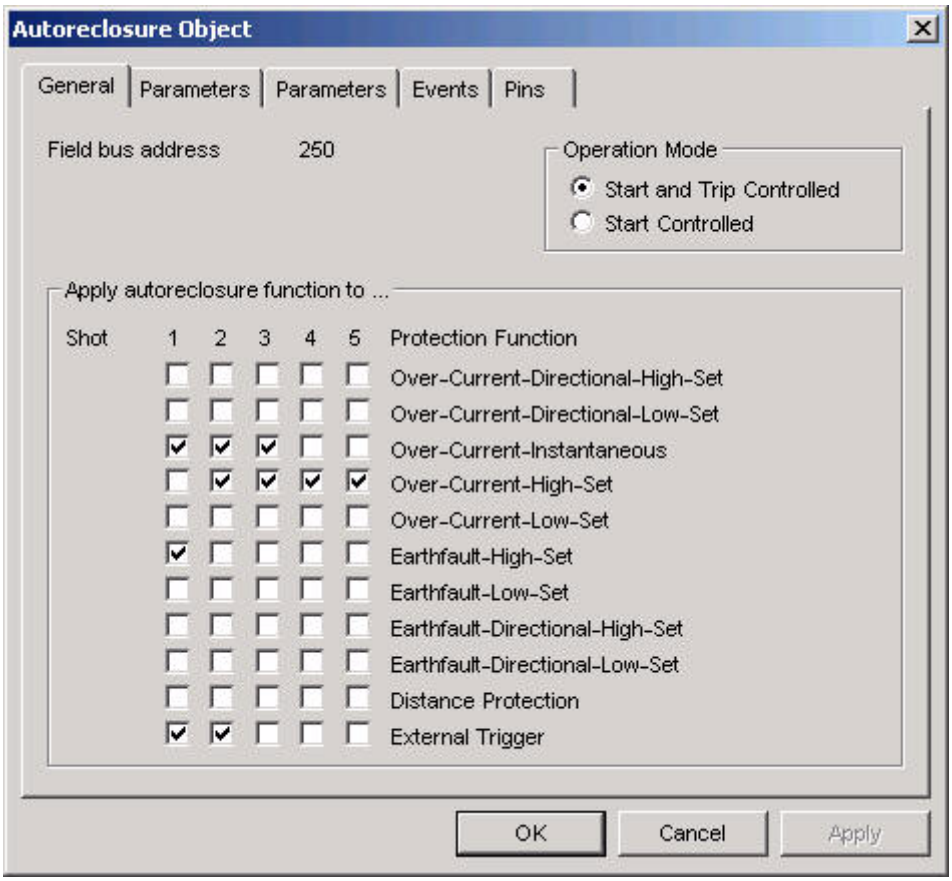

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Fig. 4.2.-2 Setting of the operation mode and initiation of AR

As indicated in Fig. 4.2.-2, the AR sequence will not be initiated by the high-set overcurrent protection because it is not checked for the first shot. If just the high-set overcurrent protection operates, there will be no AR.

The mode of operation selected here is the Start and Trip Controlled mode. The number of shots is limited to 3 as shown in Fig. 4.2.-3. The AR shall be initiated according to the corresponding selection list.

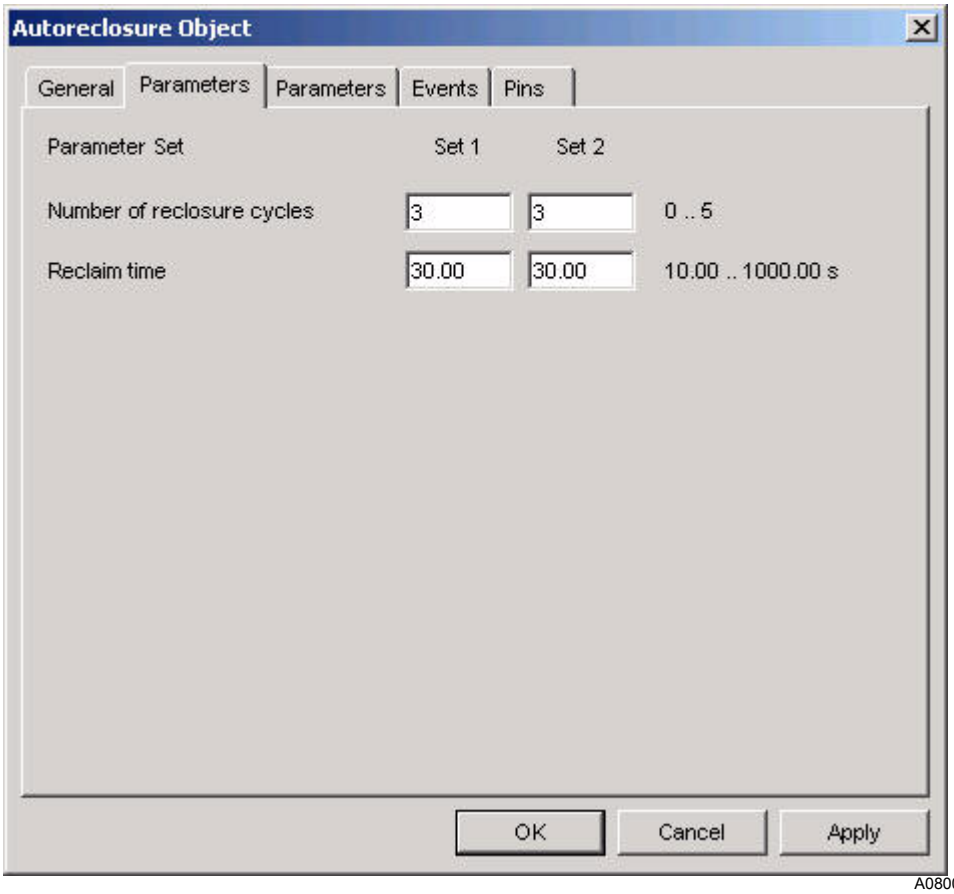

Fig. 4.2.-3 Setting of number of shots and reclaim time

Fig. 4.2.-3 shows the number of AR shots and the reclaim time set. Since the number of shots is limited to three, AR shot 4 and 5 will not be initiated by the high-set overcurrent protection as seen in the list in Fig. 4.2.-2.

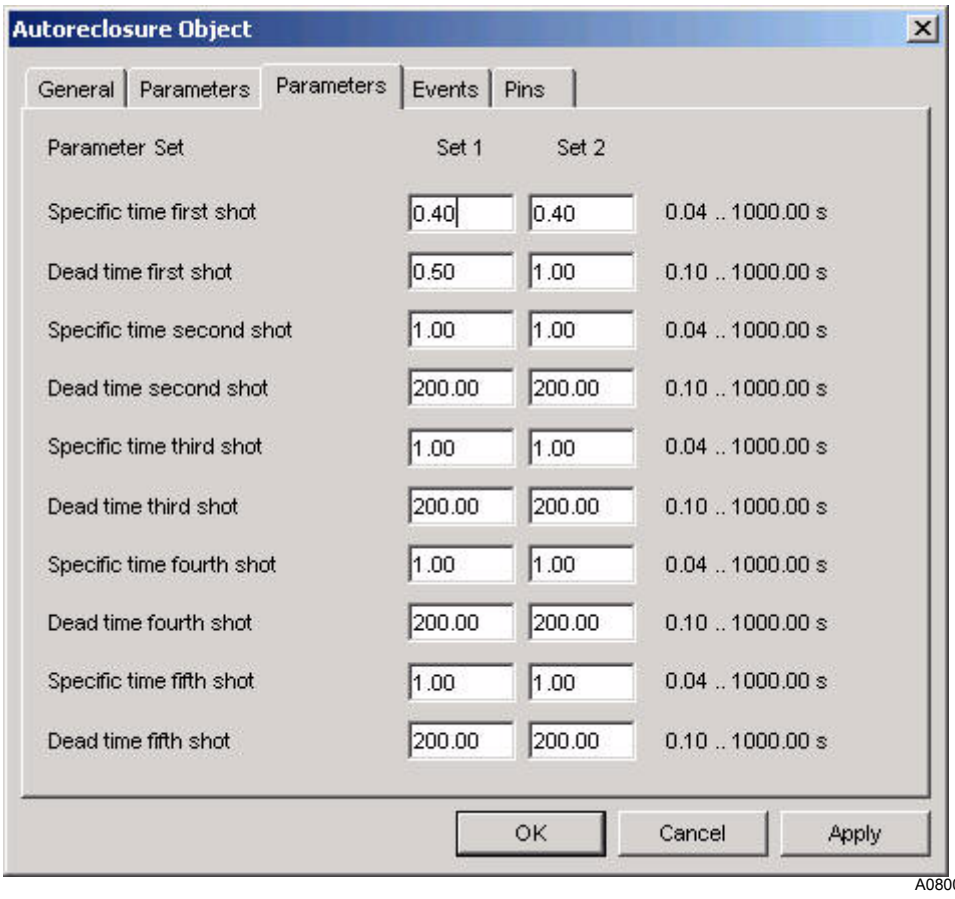

Fig. 4.2.-4 Setting of the specific time and dead time for the AR shots

Fig. 4.2.-4 shows the timer setting. The specific time for the first shot is limited to 0.4 s, so merely tripping by the instantaneous overcurrent protection and the high-set earth-fault protection will be accepted. According to the list in Fig. 4.2.-2, also a CB trip by an external trigger signal will initiate AR shot 1 and AR shot 2. Once the CB has been reclosed by AR shot 2, a new external trip signal will stop the AR sequence and generate an *AR FAILED* indication.

5. Summary

The AR function of REF542*plus* can be used for auto-reclosing of any CB designed for three-phase auto-reclosing. The AR function block provides five programmable AR shots, which can be used for one to five successive auto-reclose shots of desired type and duration, for example, one high-speed and one delayed AR. When the AR is initiated by the start of a protection function, the AR function is capable of tripping the CB, if the fault still persists after the last set AR shot has been carried out.

The operation modes described in the document are:

- Start and Trip Controlled
- Start Controlled

Examples of an AR application in combination with distance protection and an AR application in combination with overcurrent protection using the Start and Trip controlled operation mode are also included in this application note.

6. References

1MRS755871: REF542*plus*, Configuration Tool manual

1MRS755860: REF542*plus*, Protection Functions, Configuration and Settings

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