Dual autoreclosure scheme with distance protection for the El Furrial 230 kV substation

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Jesús W. Bolívar, PLC Services S.A.

Introduction

SUMMARY

The autoreclosure scheme implemented on the 21/21N/67N primary and secondary protection (implemented by two UR-series D60 relays) of the 230 kV lines in the El Furrial substation is intended to be totally redundant. This means both protections initiate their 79 function algorithms for specific faults that allow a reclosure shot. Even when both protections initiate their 79 algorithm, only one of them will execute the reclosure. This is achieved using the AR RIP (autoreclose reclose-in-progress) FlexLogic™ operand to pause the 79 algorithm on the secondary protection.

If the primary protection successfully executes its reclosure sequence, it sends a reset signal to secondary protection by means of the AR CLOSE BKR1 FlexLogic™ operand. On the other hand, if the primary protection is unable to initiate its sequence because of an internal failure, a unit not programmed, or a power down condition, the secondary protection will take charge of the reclosure. The possible failure to close the breaker by the primary protection once the AR CLOSE BKR1 signal is issued will also be considered.

THE D60 AUTORECLOSURE PROGRAMS

The UR-series D60 Line Distance Relay has four autoreclosure programs available for its 79 algorithm. These are indicated in the following table:

TABLE 1. D60 autoreclosure programs

MODE	AR MODE	FIRST SHOT		SECOND SHOT	
		SINGLE-PHASE FAULT	MULTI-PHASE FAULT	SINGLE-PHASE FAULT	MULTI-PHASE FAULT
1	1 and 3 POLE	1 POLE	3 POLE	3 POLE or Lockout	3 POLE or Lockout
2	1 POLE	1 POLE	LO	3 POLE or Lockout	3 POLE or Lockout
3	3 POLE-A	3 POLE	LO	3 POLE or Lockout	Lockout
4	3 POLE-B	3 POLE	3 POLE	3 POLE or Lockout	3 POLE or Lockout

According to EDELCA's (the substation's owner) engineering staff, reclosure shots are allowed on either two or three-phase faults depending on dispatch and control center orders, and are always allowed for single-phase faults.

According to the above table, the most suitable autoreclosure program would be #4. Although this program allows reclosures for every kind of fault, the initiation of the 79 algorithm can be restricted by a FlexLogic™ equation containing the fault types on which the desired reclosure is initiated. This is accomplished by the FlexLogic™ operands of the phase select or distance elements.

For the tests in this technical note, the USER 1, USER 2, and USER 3 control pushbuttons were programmed to enable the reclosure as the dispatch and control center demands. The configuration for these buttons are detailed in the following sections.

Test Preparation

EQUIPMENT USED DURING THE TESTS

The following equipment was used during the tests.

- UR-series D60 Line Distance Relay for primary protection
  model number: D60-H00-HCH-F8G-H6P-M6K-P6C-U6D-WXX
  firmware revision: 4.0x
- UR-series D60 Line Distance Relay for secondary protection
  model number: D60-H00-HCH-F8G-H6P-M6K-P6C-U6D-WXX
  firmware revision: 4.0x
- Double coil relay to emulate a close coil and trip coil circuit of a breaker.
- Relay test system FREJA 300
- Laptop computer running the EnerVista UR Setup software for programming the D60 relay

PRE-TEST SETUP

The following steps were performed before the functional tests were carried out:

1. The following signals were wired from the primary to the secondary protection:

   – pause signal: issued by the AR RIP FlexLogic™ operand
   – reset signal: issued by the AR CLOSE BKR1 FlexLogic™ operand
   – lockout signal: issued by the AR LO FlexLogic™ operand

2. The following signals were wired from the secondary to the primary protection:

   – reset signal: issued by the AR CLOSE BKR1 FlexLogic™ operand
   – lockout signal: issued by the AR LO FlexLogic™ operand

3. The current inputs of both D60 relays were wired in series with the current outputs of the FREJA 300 relay test system, and the D60 voltage inputs were wired in parallel with the voltage outputs of the FREJA 300 relay test system to simultaneously simulate a fault on both relays and simultaneously allow the initiation of the 79 function algorithm on both relays.

4. Both D60 relays were wired to a GPS device to synchronize their time and dates. This guarantees a reliable analysis of the event record and oscillography files.

5. The autoreclose program most suitable for the applications of our client relies on the reclose program 4 (see Table 1 on page 2).

6. Since EDELCA requested for the possibility for reclosure on two-phase or three-phase faults in addition to single-phase faults, it was necessary to develop FlexLogic™ that could handle this situation with the user-programmable control pushbuttons:

   – RESET button: programmed to reset all latched conditions
   – USER 1 button: programmed to inhibit reclosure for two-phase faults
   – USER 2 button: programmed to inhibit reclosure for three-phase faults
   – USER 3 button: programmed to clear the USER1 and USER2 selections

   The programmed control pushbuttons are located on LED panel 1 as shown below:

   The non-volatile latches were programmed with the following settings. They are used to select the conditions on which the 79 function is blocked, and will be described later in this document.

Save | Restore | Default

PARAMETER	LATCH 1	LATCH 2
Function	Enabled	Enabled
Type	Set Dominant	Set Dominant
Set	CONTROL PUSHBUTTON 1 ON	CONTROL PUSHBUTTON 2 ON
Reset	CONTROL PUSHBUTTON 3 ON	CONTROL PUSHBUTTON 3 ON
Target	Self-reset	Self-reset
Events	Disabled	Disabled

7. The D60 was programmed with data from an existing line. The reclosure settings for the primary and secondary protection is shown in the following sections.

Primary protection settings

AUTORECLOSE SETTINGS

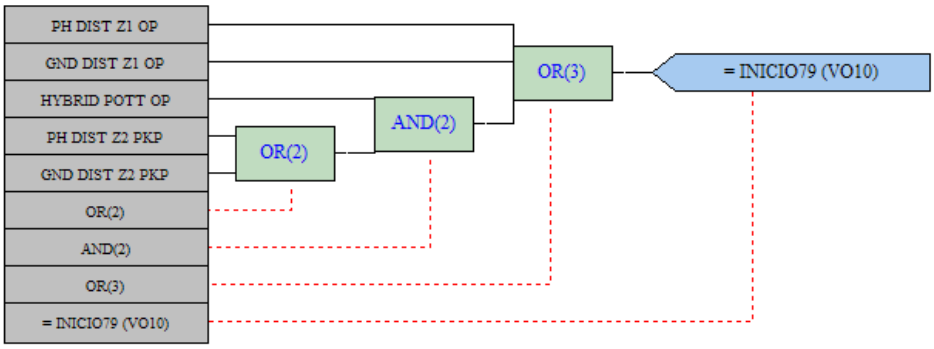
The reclosure settings for the primary protection is shown below:

SETTING	PARAMETER
Function	Enabled
Mode	3 Pole - B
Max Number Of Shots	1
Block BKR1	OFF
Close Time BKR1	0.02 s
BKR Man Close	Remote I/P 3 ON
Blk Time Upon Man Cls	10.00 s
1-P Init	OFF
3-P Init	Inicio79 On (VO10)
3-P TD Init	OFF
Multi P Fault	OFF
BKR 1 Pole Open	OFF
BKR 3 Pole Open	52bMXX5 On(H8a)
3-P Dead Time 1	0.10 s
3-P Dead Time 2	0.20 s
Extend Dead T1	OFF
Dead T1 Extension	0.50 s
Reset	Reset79 On (VO13)
Reset Time	0.30 s
BKR Closed	52bMXX5 Off(H8a)
Block	Block79 On (VO14)
Pause	OFF
Inc Seq Time	0.50 s
Block BKR2	OFF
Close Time BKR2	0.10 s
Transfer 1 to 2	No
Transfer 2 to 1	No
BKR1 Fail Option	Continue
BKR2 Fail Option	Continue
1-P Dead Time	1.00 s
BKR Sequence	1
Transfer Time	4.00 s

URD60Principal | Settings: Control Elements

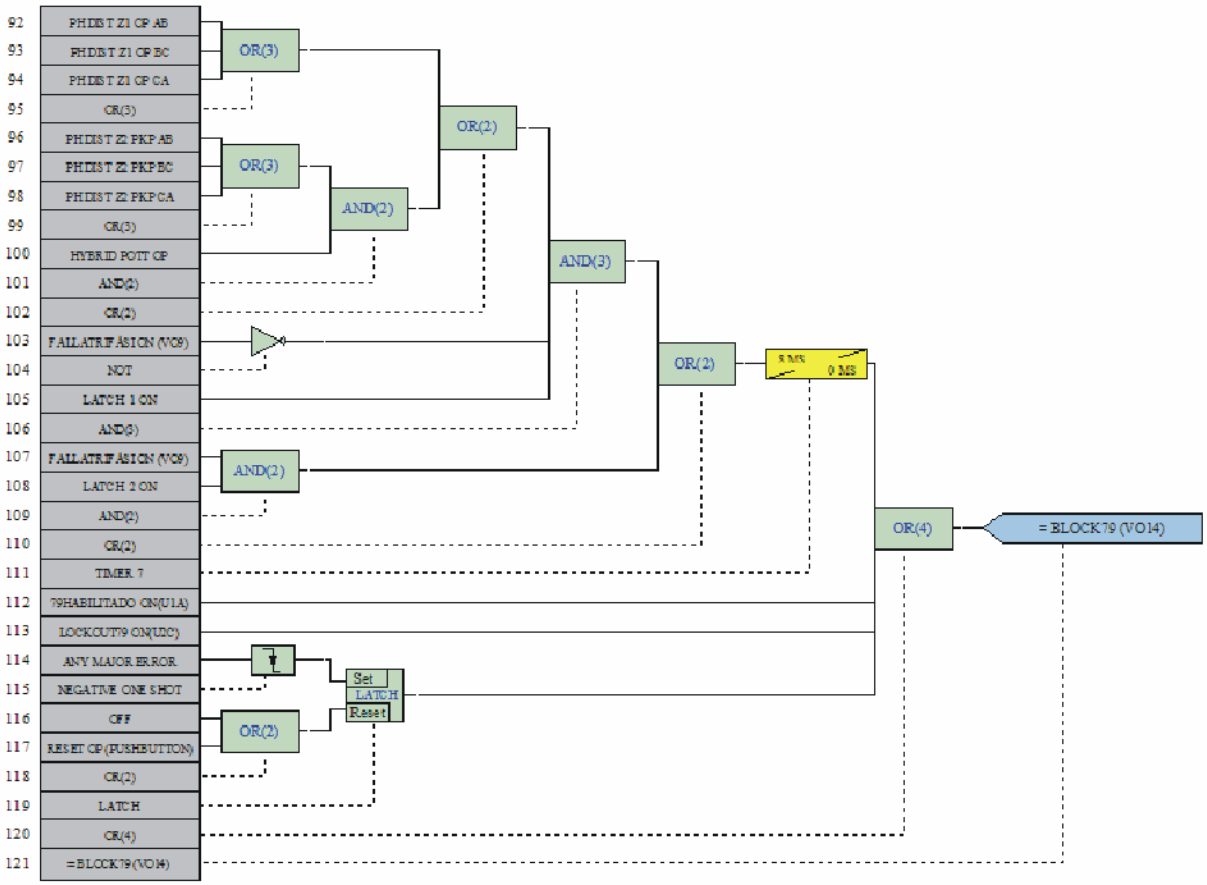
The two D60 relays (primary and secondary protection) were each connected to a UR-series C60 Breaker Management Relay through a local area network (LAN). The BKR MAN CLOSE signal issued by Remote Input 3 comes from this C60 relay, which simulates the manual close of a breaker through the use of a control switch.

As seen in the 79 settings, the 3P-INIT signal is issued by Virtual Output 10 (VO10). This output is achieved using the following FlexLogic™:



ALLOWING FOR TWO- AND THREE-PHASE FAULTS

As requested by the customer, reclosures are allowed on instantaneous faults, such as Zone 1 faults and on the Hybrid POTT scheme with Zone 2 pickups. At this point, the 79 function will progress for single and multi-phase faults. The goal is to allow the 79 function to be executed for two- or three-phase faults in addition to single-phase faults (or even for single phase faults only). This is accomplished through the BLOCK79 signal issued by Virtual Output 14 (VO14):



This FlexLogic™ is programmed as follows:

FLEXLOGIC ENTRY	TYPE	SYNTAX
View Graphic	View	View
FlexLogic Entry 92	Protection Element	PH DIST Z1 OP AB
FlexLogic Entry 93	Protection Element	PH DIST Z1 OP BC
FlexLogic Entry 94	Protection Element	PH DIST Z1 OP CA
FlexLogic Entry 95	OR	3 Input
FlexLogic Entry 96	Protection Element	PH DIST Z2 PKP AB
FlexLogic Entry 97	Protection Element	PH DIST Z2 PKP BC
FlexLogic Entry 98	Protection Element	PH DIST Z2 PKP CA
FlexLogic Entry 99	OR	3 Input
FlexLogic Entry 100	Protection Element	HYBRID POTT OP
FlexLogic Entry 101	AND	2 Input
FlexLogic Entry 102	OR	2 Input
FlexLogic Entry 103	Read Virtual Outputs On	FallaTrifási On (VO9)
FlexLogic Entry 104	NOT	1 Input
FlexLogic Entry 105	Protection Element	LATCH 1 ON
FlexLogic Entry 106	AND	3 Input
FlexLogic Entry 107	Read Virtual Outputs On	FallaTrifási On (VO9)
FlexLogic Entry 108	Protection Element	LATCH 2 ON
FlexLogic Entry 109	AND	2 Input
FlexLogic Entry 110	OR	2 Input
FlexLogic Entry 111	TIMER	Timer 7
FlexLogic Entry 112	Contact Inputs On	79Habilitado On(U1a)
FlexLogic Entry 113	Contact Inputs On	Lockout79 On(U2c)
FlexLogic Entry 114	Protection Element	ANY MAJOR ERROR
FlexLogic Entry 115	NEGATIVE ONE SHOT	1 Input
FlexLogic Entry 116	Off	OFF
FlexLogic Entry 117	Protection Element	RESET OP (PUSHBUTTON)
FlexLogic Entry 118	OR	2 Input
FlexLogic Entry 119	LATCH	Set/Reset
FlexLogic Entry 120	OR	4 Input
FlexLogic Entry 121	Write Virtual Output[Assign]	= Block79 (VO14)

This logic is reviewed step-by-step below:

1. Lines 92 to line 106 allow two-phase faults to be blocked for reclosure by means of Control Pushbutton 1 and Latch 1. Virtual Output 9 (VO9) at line 103 indicates if a three-phase fault has occurred. The phase select operands were not used for this indication since they last only a few milliseconds, even if their cause remains active. Instead, the more secure phase distance operands were used.
2. Lines 107 to 110 allowing three-phase faults to be blocked for reclosure by means of Control Pushbutton 2 and Latch 2.
3. When a three-phase fault occurs, the AB, BC and CA distance operand flags do not appear simultaneously. As such, an 8 ms pickup timer is programmed in line 111. Without this pickup timer, the blocking targets could be misled; for example; a three phase-fault could be interpreted by VO14 as a two-phase fault and later change to a three-phase fault.
4. Line 112 corresponds to a control switch with inverted logic that disables the 79 function through a digital input of the relay.
5. Line 113 is related to Contact Input U2C and corresponds to the AR LO flag received from the secondary protection.
6. Lines 114 to 120 are very important: Suppose the primary protection goes out of service and the secondary protection takes control of the 79 function. However, if the primary protection returns to service before the reclose is completed by the secondary protection, a swinging pattern can occur. To avoid this swinging pattern

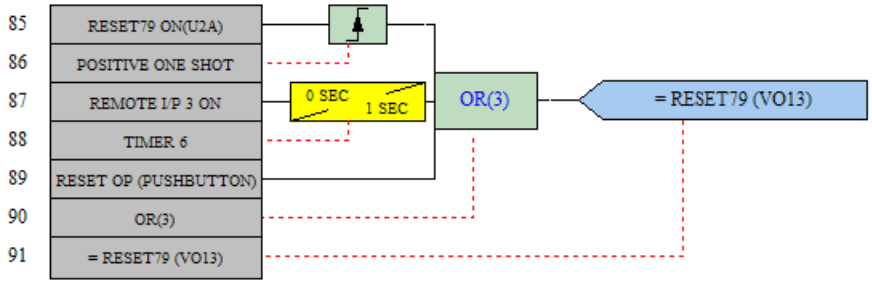
once the primary protection returns to service, its 79 function will remain blocked until the secondary protection completes the reclose.

NOTE

Control Pushbuttons 1 and 2 could also be programmed on VO10 instead of VO14. In this case, the user-programmable pushbuttons inhibition would be carried out on the reclosure initiation.

ISSUING THE RESET SIGNAL

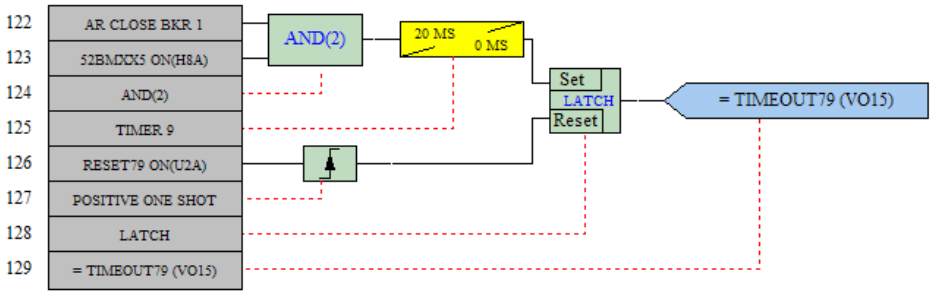
According to the primary protection 79 function, the RESET signal is issued by Virtual Output 13 (VO13) via the following FlexLogic™:



Line 85 indicates the RESET signal wired from the secondary protection. Line 87 represents the manual close signal sent by the C60 relay from the LAN.

CONDITIONING THE PAUSE, RESET AND LOCKOUT SIGNALS

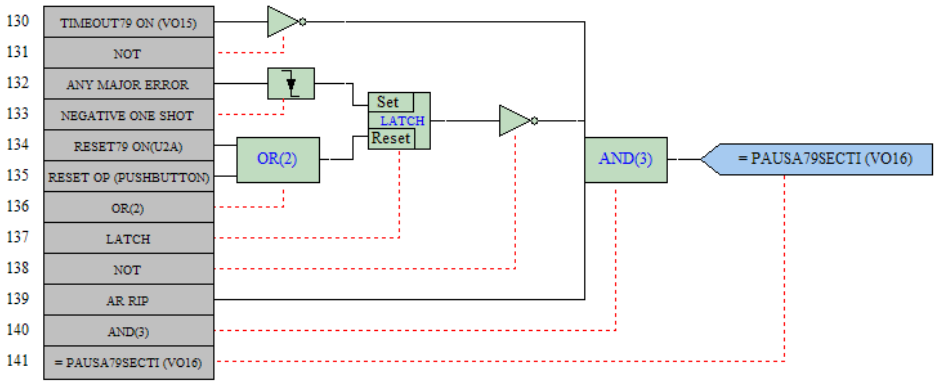
Suppose that something has happened with the Close Coil circuit. Although it might not be a relay problem, the 79 function will go to Lockout state if the breaker fails to close, and no reclosure would be executed by either relay. To avoid this situation, the following logic was created to condition the PAUSE, RESET and LOCKOUT signals sent to the secondary protection:



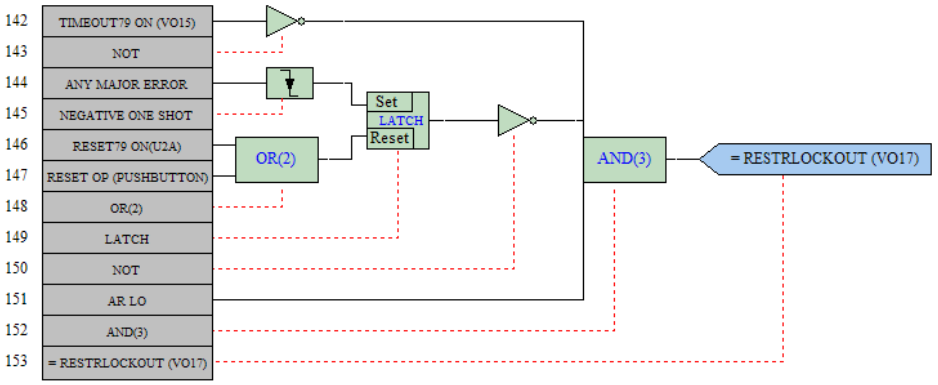
Since the **AR CLSE BKR 1** setting latches until the breaker closes or the scheme goes to reset or lockout, the success of the reclosure is verified through the breaker open status (52BMXX5 ON signal) and the 20 ms timer. TIMER 9 has a direct relation with the **CLOSE TIME BKR1** setting. This timer should be programmed slightly over the real time employed by the breaker to be closed. For example, our tests indicate that the double-coil relays have a response time of 15 to 18 ms; as such, a 20 ms time for the **CLOSE TIME BKR1** setting was implemented through TIMER 9.

Once Virtual Output 15 (VO15) was created, the Pause, Lockout and Reset signals to be sent to the secondary protection were conditioned as follows.

The pause signal (PAUSA79SECTI) is issued by the AR RIP operand. The 3-port AND gate ensures it will not be sent to the secondary protection if there is a problem with the close coil path or the primary protection is returning to service from an internal failure condition.



The lockout signal (RESTRLOCKOUT) is issued by the AR LO operand. The 3-port AND gate ensures it will not be sent to the secondary protection if there is a problem with the close circuit or the primary protection is returning to service from an internal failure condition.



The reset signal is sent to the secondary protection only if a successful reclosure is achieved.

Secondary protection settings

AUTORECLOSE SETTINGS

The autoreclose settings for the secondary protection is shown below:

SETTING	PARAMETER
Function	Enabled
Mode	3 Pole - B
Max Number Of Shots	1
Block BKR1	OFF
Close Time BKR1	0.02 s
BKR Man Close	Remote I/P 3 ON
Blk Time Upon Man Cls	10.00 s
1-P Init	OFF
3-P Init	Inicio79 On (VO10)
3-P TD Init	OFF
Multi P Fault	OFF
BKR 1 Pole Open	OFF
BKR 3 Pole Open	52bMXX5 On(H8a)
3-P Dead Time 1	0.10 s
3-P Dead Time 2	0.20 s
Extend Dead T1	OFF
Dead T1 Extension	0.30 s
Reset	Reset79 On (VO13)
Reset Time	0.30 s
BKR Closed	52bMXX5 Off(H8a)
Block	Block79 On (VO14)
Pause	Pausa79 On(U2a)
Inc Seq Time	0.50 s
Block BKR2	OFF
Close Time BKR2	0.10 s
Transfer 1 to 2	No
Transfer 2 to 1	No
BKR1 Fail Option	Continue
BKR2 Fail Option	Continue
1-P Dead Time	1.00 s
BKR Sequence	1
Transfer Time	4.00 s

URD60Secundario | Settings: Control Elements

The secondary protection FlexLogic™ has several differences from that of the primary protection. For instance, the logic for the Virtual Output 14 (VO14) no longer monitors if the protection is coming back in service after an internal failure, since there is no other device to which to pass the 79 function. The reset signal (VO13) and lockout signals remain the same and are sent without any other condition. There is no pause signal from the secondary protection towards the primary protection.

BREAKER SETTINGS

The secondary protection breaker settings are shown below:

PARAMETER	BREAKER 1
Function	Enabled
Push Button Control	Disabled
Name	M305
Mode	3-Pole
Open	OFF
Close	OFF
Phase A/3-Pole	52bMXX5 Off(H8a)
Phase B	OFF
Phase C	OFF
External Alarm	OFF
Alarm Delay	0.000 s
Manual Close Recal Time	0.000 s
Out Of Service	OFF
UCA XCBR PwrSupSt 0	OFF
UCA XCBR PresSt	OFF
UCA XCBR TrpCoil	OFF

Test Cases

OVERVIEW

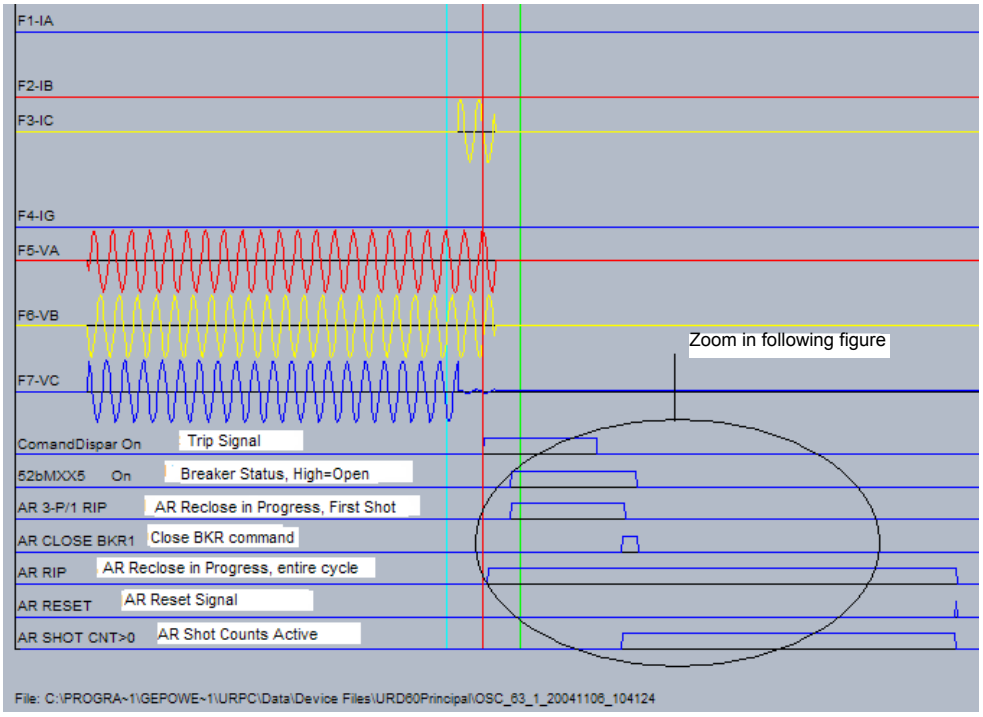
Consider the following six cases covered during the tests:

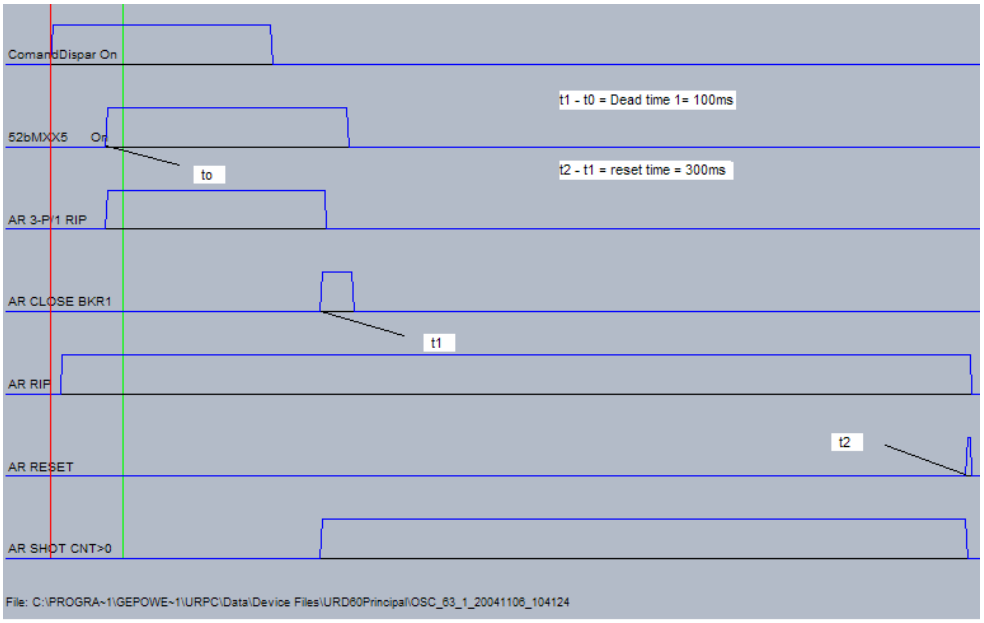
- **CASE 1**: Both protections are in service, a fault occurs and the autoreclosure algorithm is allowed to initiate. The primary protection executes the autoreclosure function and then resets the paused secondary protection.
- **CASE 2**: The primary protection is out of service, a fault occurs and the autoreclosure algorithm is allowed to initiate, the secondary protection executes the autoreclosure function. The primary protection takes no action.
- **CASE 3**: Both protections are in service and initiate the autoreclosure function, during the reclosure's progress the primary protection fails to close the breaker (due to the loss of the Close Coil voltage or the interruption of the Close Coil circuit). The secondary protection takes over and executes the autoreclosure function, and will reset the lockout condition on the primary protection generated by its closure failure.
- **CASE 4**: Both protections in service, the maximum number of shots is reached.
- **CASE 5**: Programmable autoreclosure initiation verification. The USER programmable pushbuttons were configured or programmed to select the type of faults that are allowed to initiate the autoreclosure function.
- **CASE 6**: Both protections initiate the autoreclosure function, during the process the primary protection has an internal mayor error and goes out of service, the secondary protection takes over and executes the reclosure even though the primary protection recovers from its internal error.

The oscillography and events displays for cases 1 through 6 are indicated in the following sections.

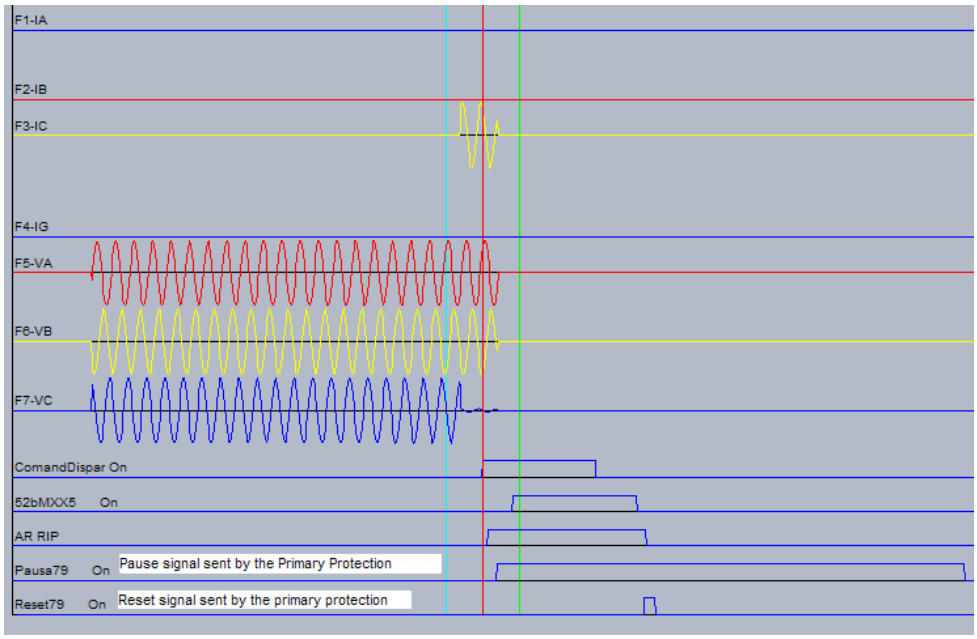
CASE 1

The oscillography for primary protection for Case 1 is shown in the two figures below.





The secondary protection oscillography for Case 1 is shown below.



CASE 2

The event record for primary protection for case 2 is shown below. No oscillography was triggered.

File Name: C:\PROGRA~1\GEPOWE~1\URPC\Data\Device Files\URD60Principal\EVT_63_20041106_112156.EVT

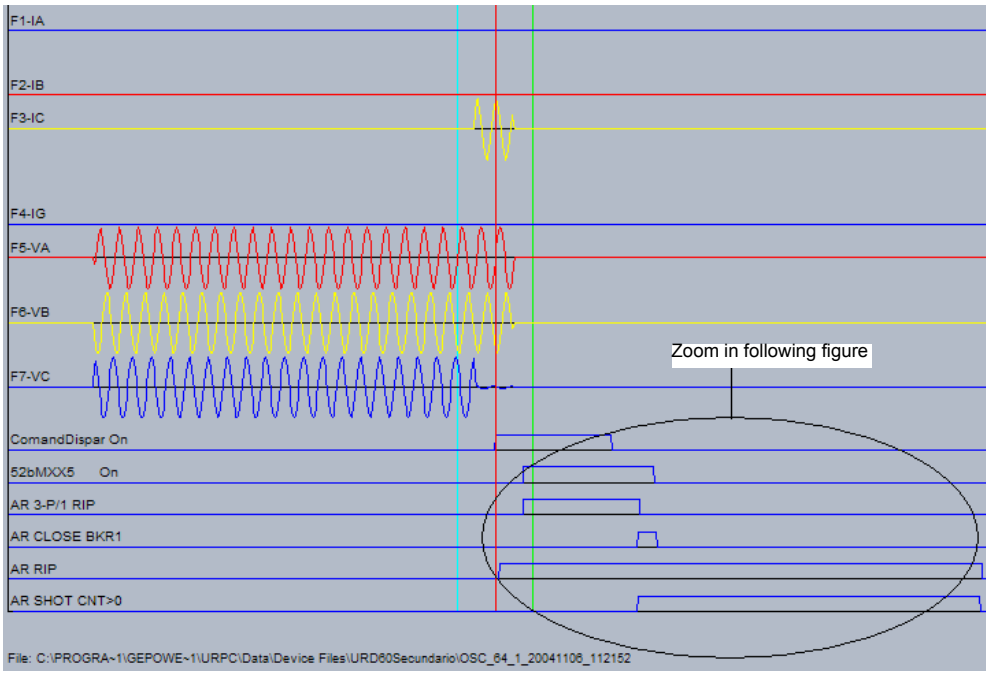
Date / Time of Last Clear: Saturday, November 06, 2004 11:21:56

Events Since Last Clear: 15 Shown Number of Events: 15

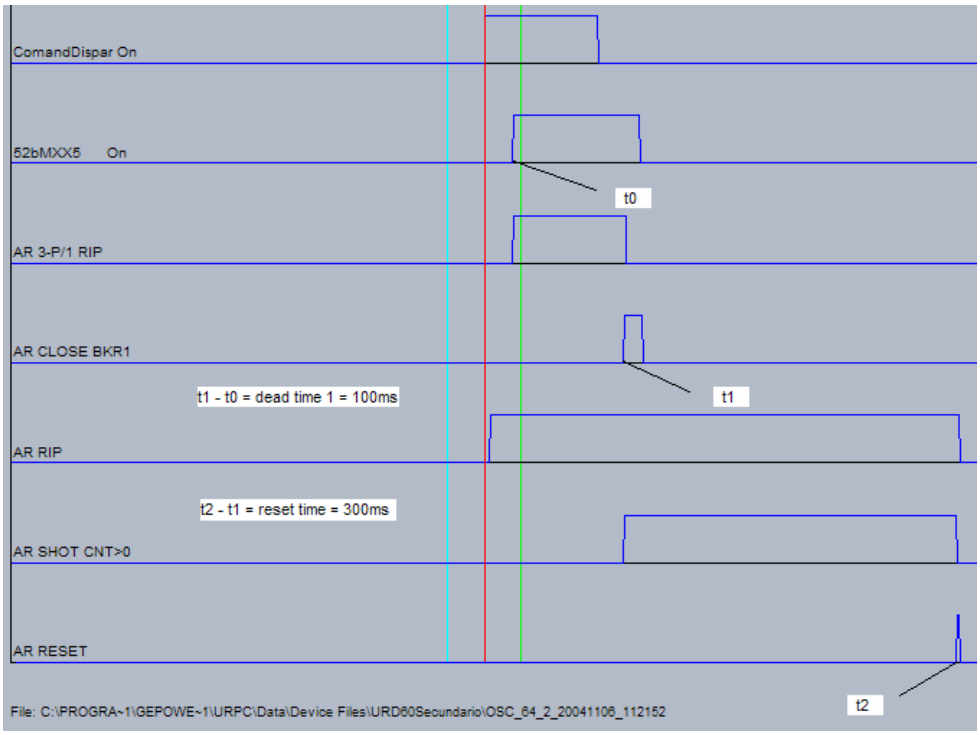
0 days 0 h : 0 m : 0.010010 s

Event Number	Date/Time	Cause	Data
15	Nov 06 2004 11:22:34.375881	Reset79 Off	
14	Nov 06 2004 11:22:34.365871	52bMXX5 Off	
13	Nov 06 2004 11:22:34.364652	Reset79 Off	
12	Nov 06 2004 11:22:34.362569	Reset79 On	
11	Nov 06 2004 11:22:34.358875	Reset79 On	
10	Nov 06 2004 11:22:34.251833	52bMXX5 On	
9	Nov 06 2004 11:22:28.125160	RELAY OUT OF SERVICE	
8	Nov 06 2004 11:22:28.125160	UNIT NOT PROGRAMMED	
7	Nov 06 2004 11:22:15.535713	Reset79 Off	
6	Nov 06 2004 11:22:15.535713	AR RESET	
5	Nov 06 2004 11:22:15.535713	RESET OP(OPERAND)	
4	Nov 06 2004 11:22:15.533631	Reset79 On	
3	Nov 06 2004 11:22:15.533631	RESET OP(PUSHBUTTON)	
2	Nov 06 2004 11:21:58.911649	OSCILLOGRAPHY CLEAR	
1	Nov 06 2004 11:21:56.908925	EVENTS CLEARED	

The secondary protection for Case 2 is shown below.

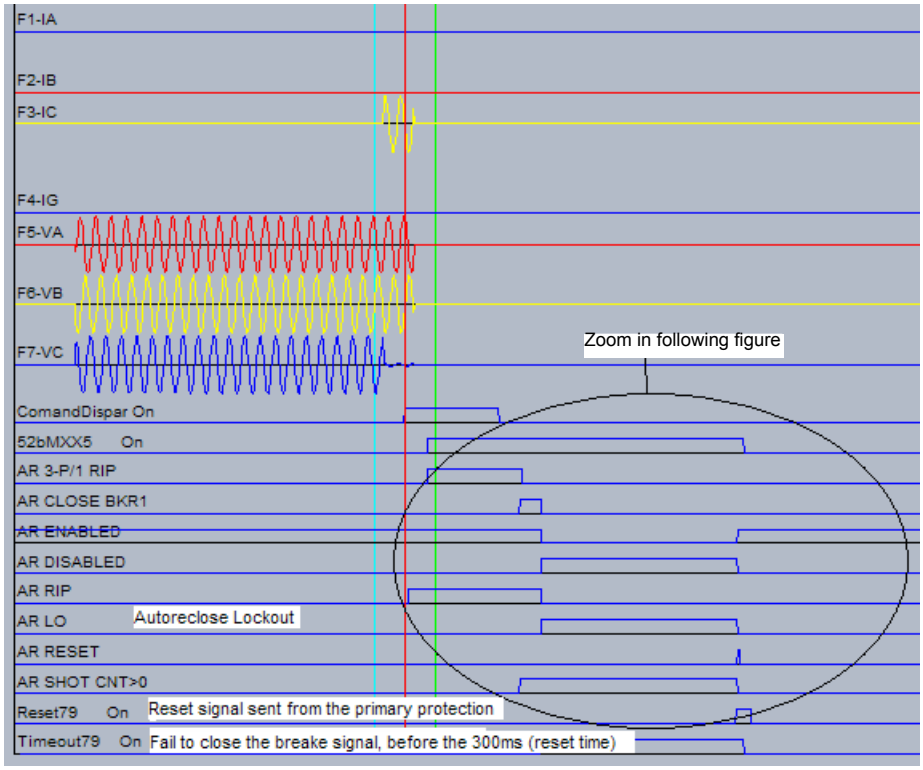


The following figure illustrates a close-up view of the reclosure FlexLogic™ operands for secondary protection.

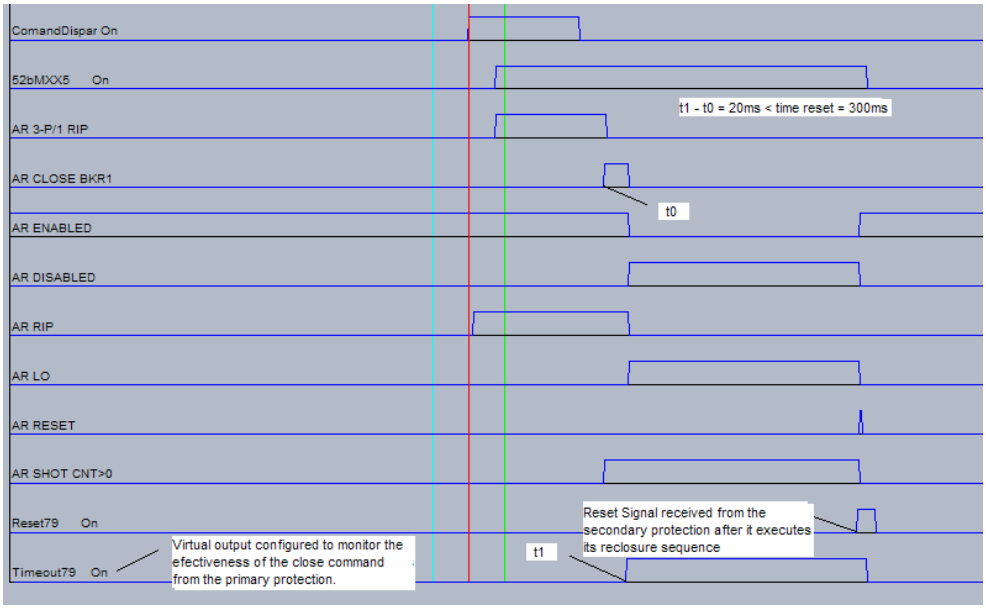


CASE 3

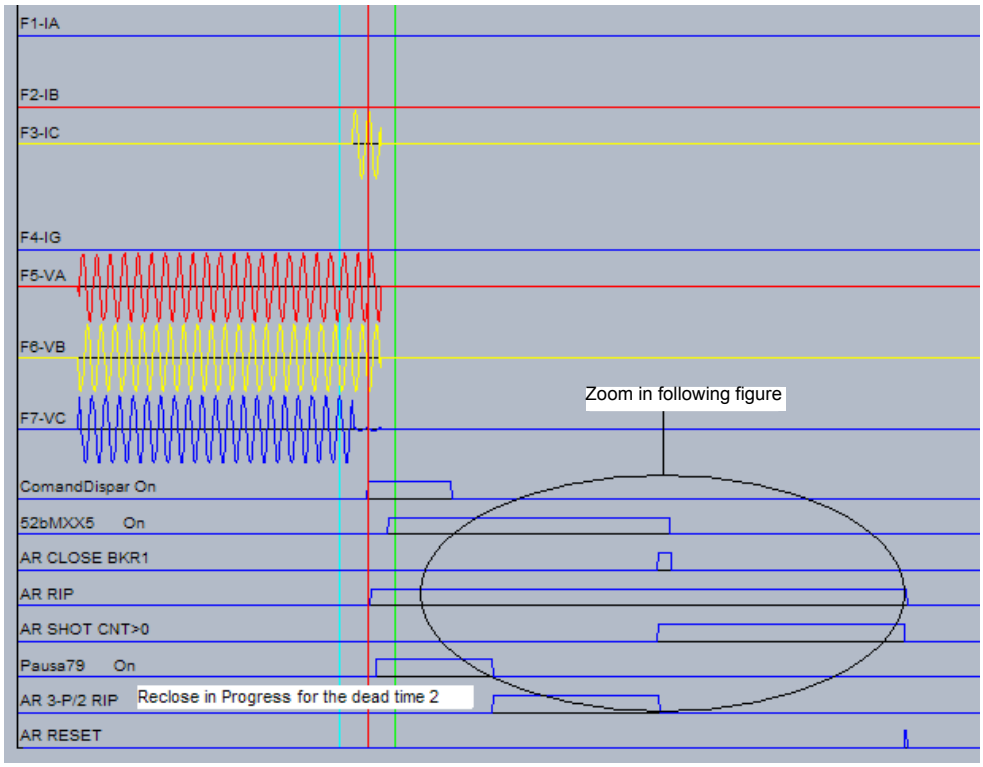
The primary protection oscillography for Case 3 is shown below.



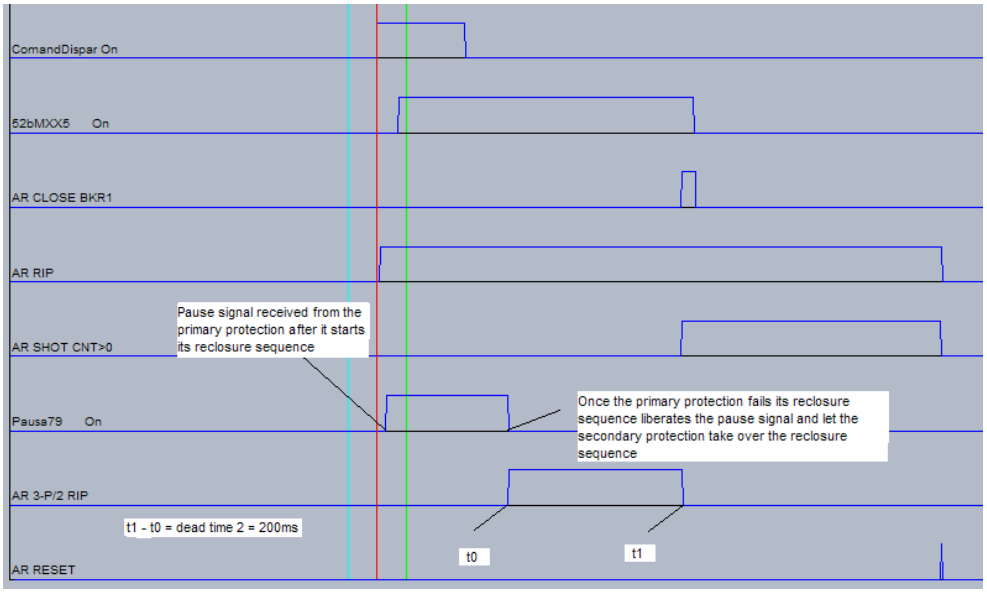
The following figure illustrates a close-up view of the reclosure FlexLogic™ operands for primary protection Case 3.



The secondary protection oscillography for Case 3 is shown below.

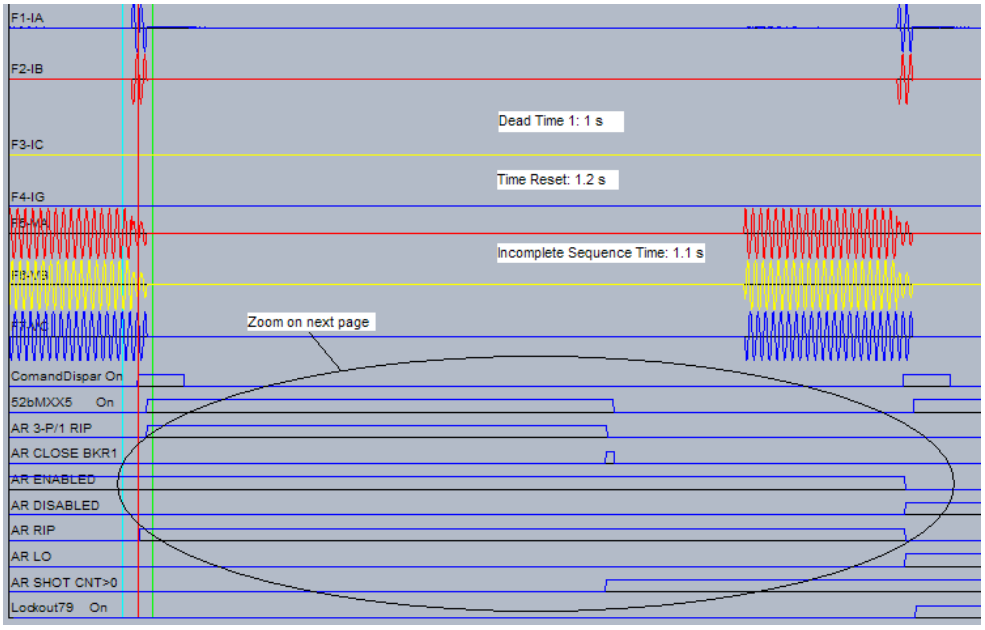


The following figure illustrates a close-up view of the reclosure FlexLogic™ operands for secondary protection Case 3.

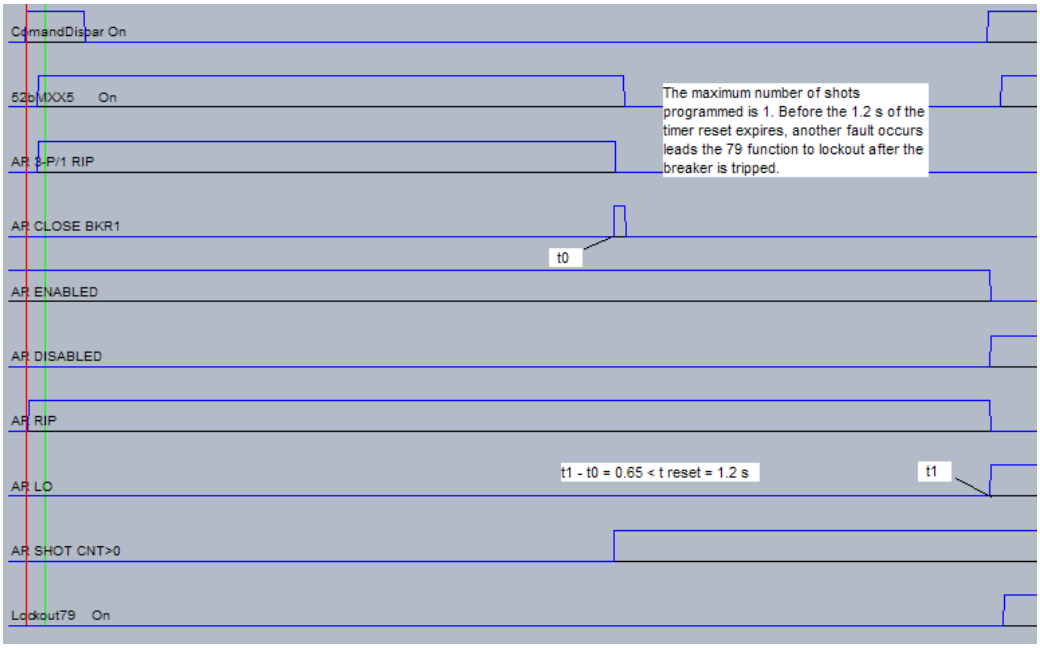


CASE 4

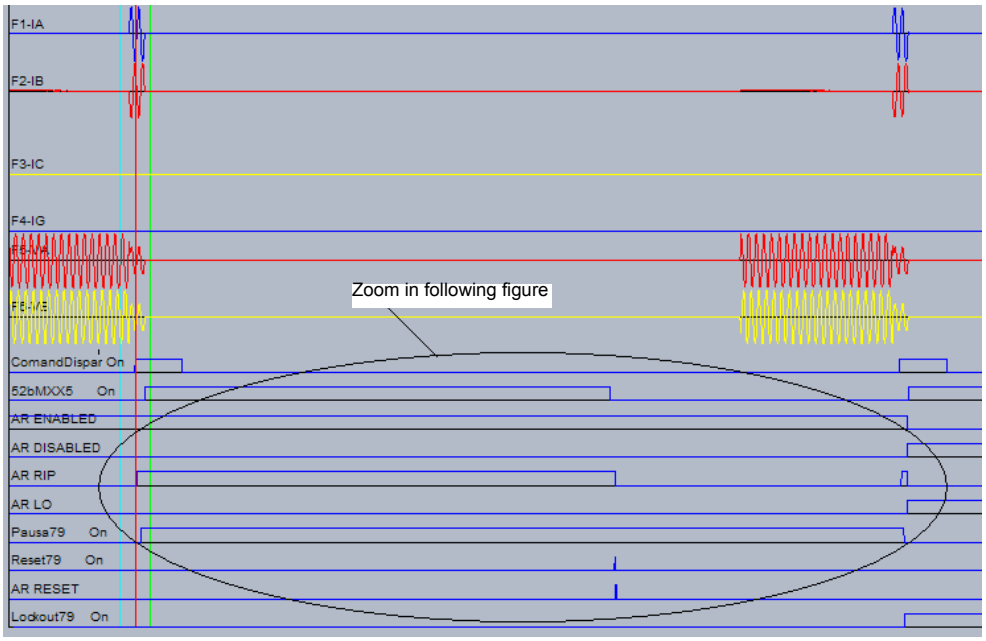
The primary protection oscillography for Case 4 is shown below.



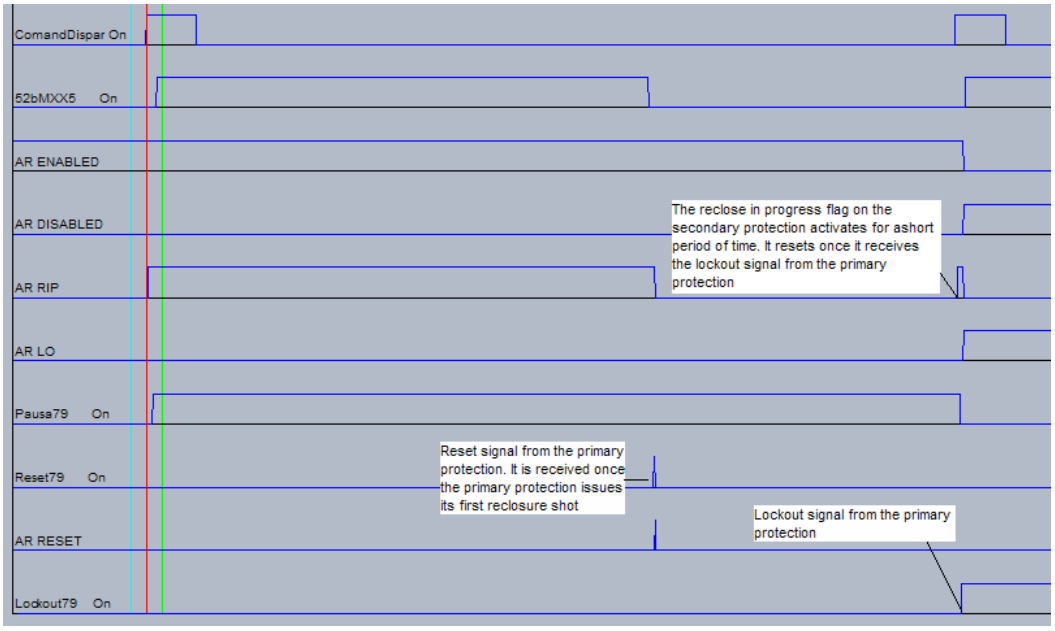
The following figure illustrates a close-up view of the reclosure FlexLogic™ operands for primary protection for Case 4.



The secondary protection oscillography for Case 4 is shown below.

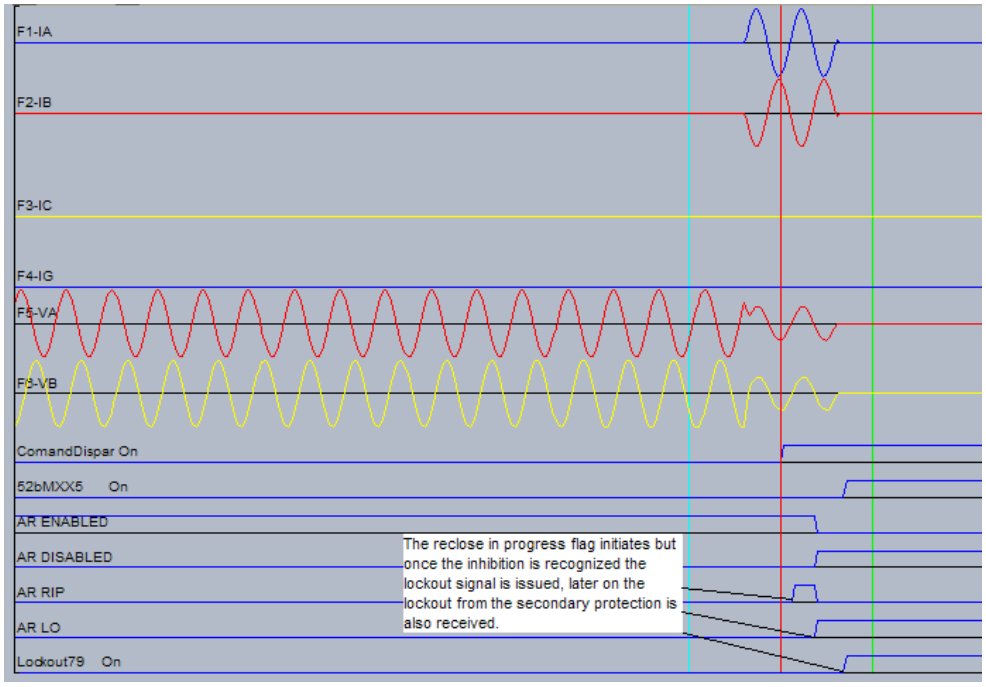


The following figure illustrates a close-up view of the reclosure FlexLogic™ operands for secondary protection for Case 4.

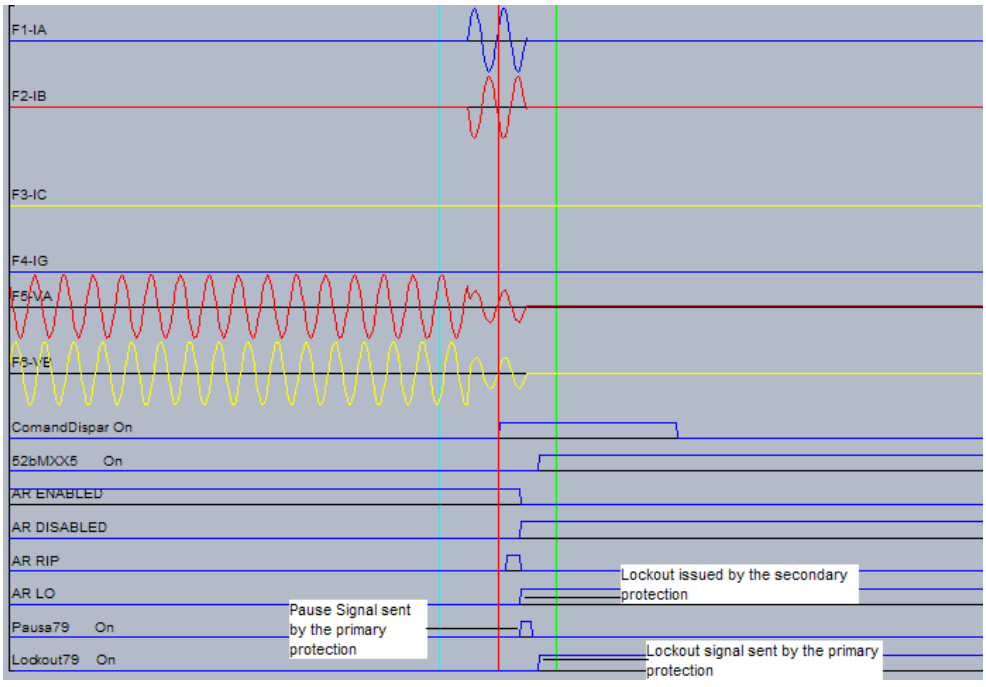


CASE 5

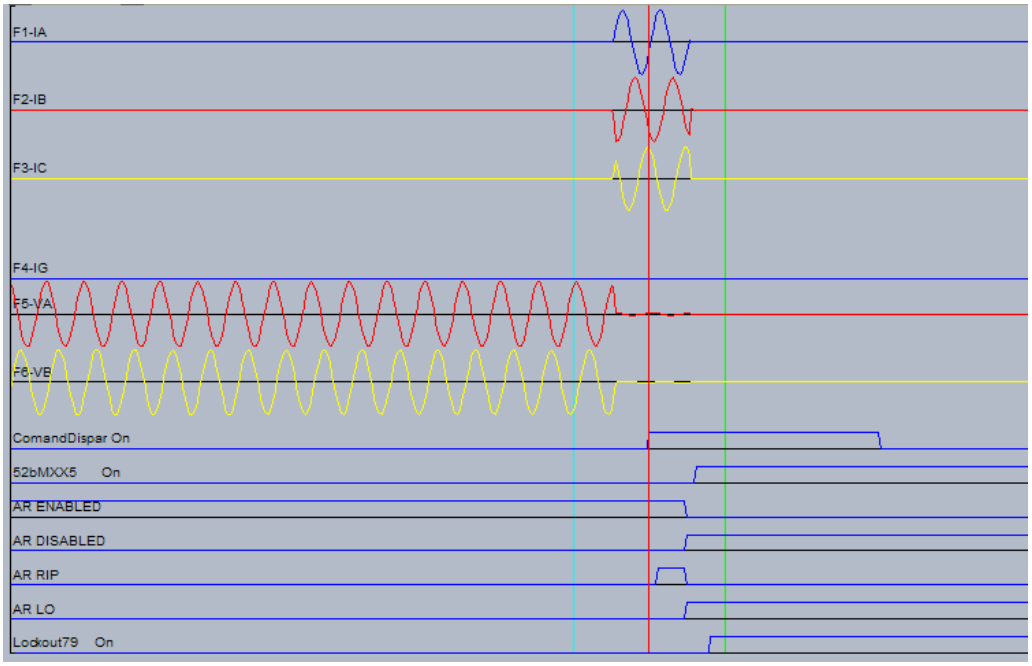
The primary protection oscillography for Case 5 is shown below (two-phase fault, control pushbutton 1 activated).



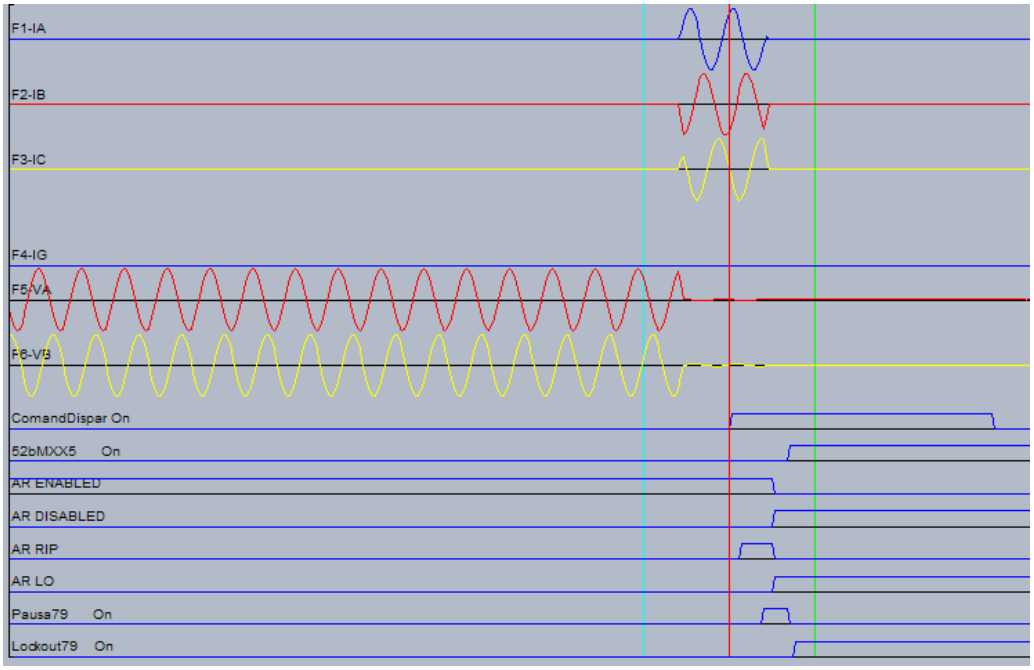
The secondary protection oscillography for Case 5 is shown below (two-phase fault, control pushbutton 1 activated).



The primary protection oscillography for Case 5 is shown below (three-phase fault, control pushbutton 2 activated).

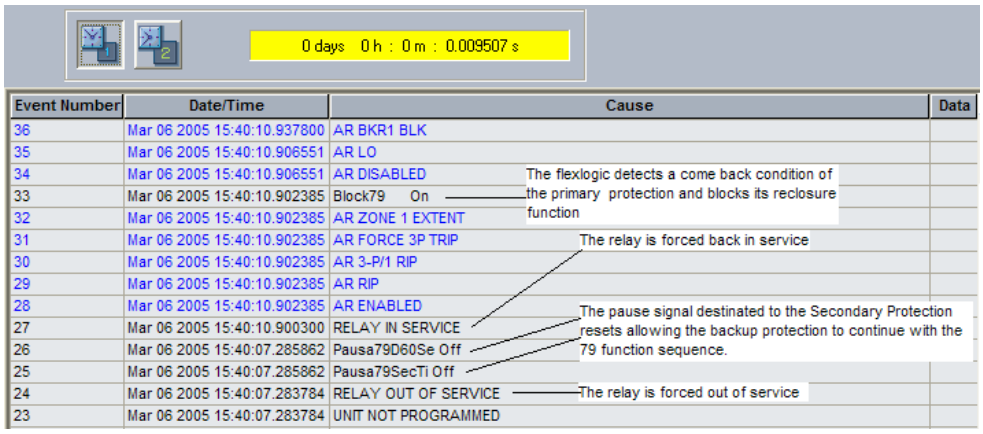


The secondary protection oscillography for Case 5 is shown below (three-phase fault, control pushbutton 2 activated).



CASE 6

The primary protection event record for Case 6 is shown below.



0 days 0 h : 0 m : 0.009507 s

Event Number	Date/Time	Cause	Data
36	Mar 06 2005 15:40:10.937800	AR BKR1 BLK	
35	Mar 06 2005 15:40:10.906551	AR LO	
34	Mar 06 2005 15:40:10.906551	AR DISABLED	
33	Mar 06 2005 15:40:10.902385	Block79 On	
32	Mar 06 2005 15:40:10.902385	AR ZONE 1 EXTENT	
31	Mar 06 2005 15:40:10.902385	AR FORCE 3P TRIP	
30	Mar 06 2005 15:40:10.902385	AR 3-P/1 RIP	
29	Mar 06 2005 15:40:10.902385	AR RIP	
28	Mar 06 2005 15:40:10.902385	AR ENABLED	
27	Mar 06 2005 15:40:10.900300	RELAY IN SERVICE	
26	Mar 06 2005 15:40:07.285862	Pausa79D60Se Off	
25	Mar 06 2005 15:40:07.285862	Pausa79SecTi Off	
24	Mar 06 2005 15:40:07.283784	RELAY OUT OF SERVICE	
23	Mar 06 2005 15:40:07.283784	UNIT NOT PROGRAMMED	

The flexlogic detects a come back condition of the primary protection and blocks its reclosure function

The relay is forced back in service

The pause signal destinated to the Secondary Protection resets allowing the backup protection to continue with the 79 function sequence.

The relay is forced out of service

Although the relay returns from being out-of-service and retakes the 79 function, it remains blocked so the secondary protection can proceed with the reclosure.

The secondary protection event record for Case 6 is shown below.

Event Number	Date/Time	Cause	Data
30	Mar 06 2005 15:40:17.650434	RecierreM305 Off	
29	Mar 06 2005 15:40:17.567106	Res79D60Prin Off	
28	Mar 06 2005 15:40:17.561549	52bMXX5 Off	
27	Mar 06 2005 15:40:17.548356	Res79D60Prin On	
26	Mar 06 2005 15:40:17.548356	Recierre305 On	
25	Mar 06 2005 15:40:17.548356	RecierreM305 On	
24	Mar 06 2005 15:40:17.548356	AR SHOT CNT>0	
23	Mar 06 2005 15:40:17.548356	AR CLOSE BKR1	
22	Mar 06 2005 15:40:07.548757	AR 3-P/2 RIP	
21	Mar 06 2005 15:40:07.546048	Pausa79 Off	
20	Mar 06 2005 15:40:03.525999	DisparoM305 Off	
19	Mar 06 2005 15:40:03.525999	ComandDispar Off	
18	Mar 06 2005 15:40:03.459324	Inicio79 Off	
17	Mar 06 2005 15:40:03.459324	PH DIST Z3 DPO AB	
16	Mar 06 2005 15:40:03.459324	PH DIST Z2 DPO AB	
15	Mar 06 2005 15:40:03.459324	PH DIST Z1 DPO AB	
14	Mar 06 2005 15:40:03.441152	52bMXX5 On	
13	Mar 06 2005 15:40:03.432649	Pausa79 On	
12	Mar 06 2005 15:40:03.428059	AR RIP	
11	Mar 06 2005 15:40:03.425975	FAULT RPT TRIG	
10	Mar 06 2005 15:40:03.423893	DisparoM305 On	
9	Mar 06 2005 15:40:03.423893	OSCILLOGRAPHY TRIG'D	

The secondary protection executes its closure with success.

The primary protection fails and resets its pause signal, allowing the secondary continue with the reclosure sequence by meaning of the AR 3-P/2 RIP flag.

The secondary protection initiates its reclosure sequence but its paused by the primary protection.

Once the fault occurs and the primary protection initiates its reclosure, the secondary protection is paused. After primary protection fails and the pause signal is deactivated, the secondary protection continues its reclosure despite the recovery of primary protection.