7SR224 Recloser Controller

Overcurrent Relay

Document Release History

This document is issue **2010/05**. The list of revisions up to and including this issue is:

2008/11	First issue
2009/09	Second Issue. Updated to suit software modification
2010/04	Third Issue. Software version updated
2010/05	Fourth Issue. Document formatted due to rebrand

Software Revision History

2008/10	2435H80011R3d-2b	First issue with Loss Of Voltage Loop Automation
2009/09	2435H80011R4c-3b	Maintenance & minor LOV changes
2010/04	2435H80011R4d-4	Phase allocation and sequence, no change to this function

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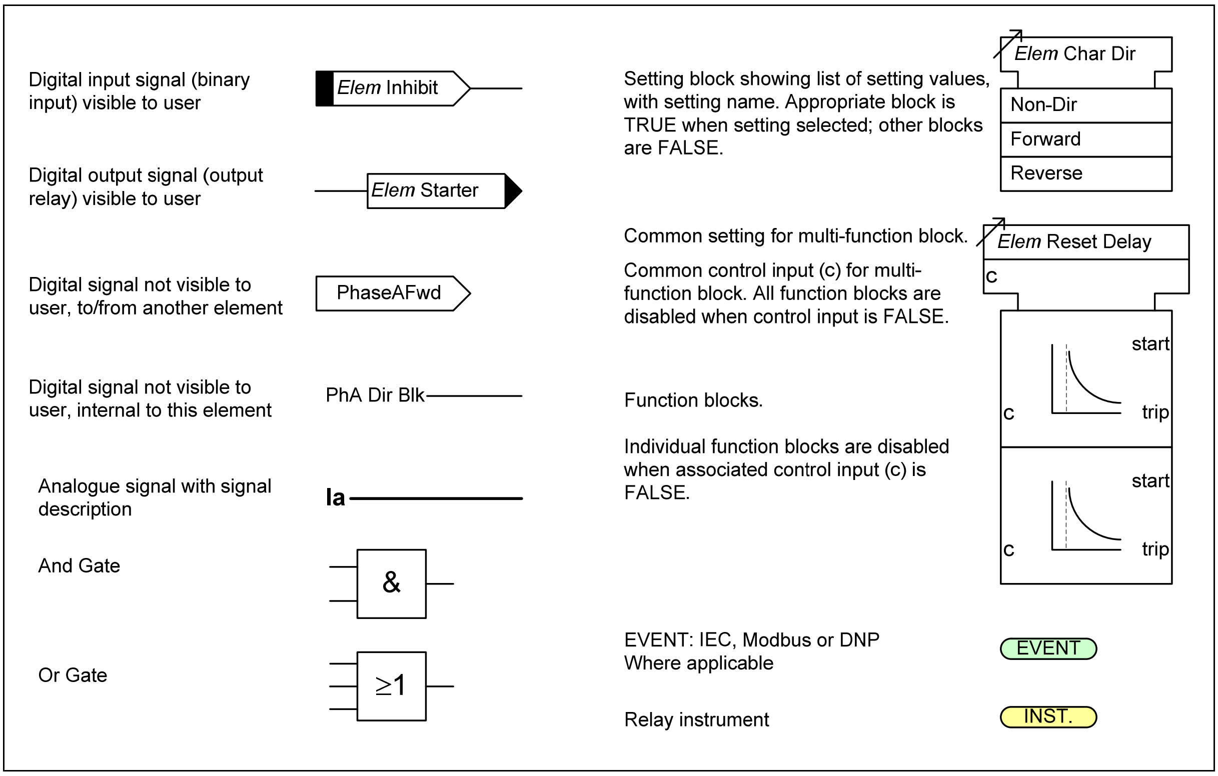
Symbols and Nomenclature

The following notational and formatting conventions are used within the remainder of this document:

- Setting Menu Location — MAIN MENU>SUB-MENU
- Setting: — ***Elem name -Setting***
- Setting value: — **value**
- Alternatives: — **[1st] [2nd] [3rd]**



1. Description Of Feature

1.1. Loss of Voltage (LOV) – Automatic Restoration Element

This additional functionality is available as an ordering option when required to suit application requirements. The LOV Automation function is applied by Reclosers at the sectioning points along a feeder and by a Normally Open Point (NOP) at the junction of two feeders, see

Figure 1, the purpose is to ensure the automatic restoration of system supply to as many customers as is possible following the lockout of a source Recloser and de-energisation of a feeder due to a permanent fault. The resultant permanent loss of supply to healthy sections of the faulted feeder can be avoided by the sequential closure of the NOP (TIE) Recloser and multiple Line Reclosers to back feed supply and isolate the faulted section. This sequence can be triggered by Loss Of Voltage to automatically and relatively quickly, restore the power to healthy sections and thus limit the disruption to Customers and minimising the Customer Minutes Lost (CML) metric. LOV Automation should be considered as a one shot automated sequence after which, the normal NOP having been closed, manual operations should be taken to clear the fault and restore the system to its normal configuration. The LOV Function described does however have the capability of reconfiguration after other permanent fault(s) occurring, after the first-fault LOV automation sequence, depending on their location within the system. However, if no manual action is to be taken the increase of load level on the back-feed feeder(s) must be considered.

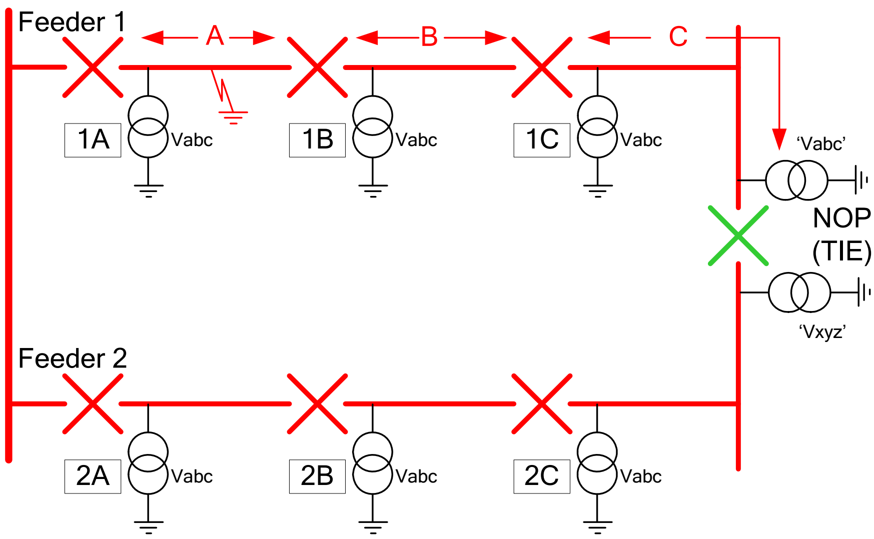


Figure 1 System Diagram showing Normally Open (TIE) Point

Reclosers in the network must be designated as one of 3 different types:

Recloser: If a LOV condition is diagnosed when the recloser is in the closed state, the controller issues a trip then subsequently recloses on restoration of voltage as part of an automated sequence to provide sectioning points along the feeder.

NOP (Tie): This device operates as a normally open point in the network which is closed automatically as part of the sequence to provide a backfeed from a different, unfaulted feeder when voltage is detected as lost.

Feeder: The controller issues a trip on detection of LOV, followed by no further action to establish a new normally open point in the network arrangement which results from the automated sequence.

The starting point is that on a normal healthy system all Reclosers A, B & C on both Feeders will be closed as shown in

Figure 1 and the NOP will be open. All Devices will have the same voltage on their upstream and downstream sides and voltage will be present on both sides of the NOP (TIE) point. It should be noted that Reclosers at different points in the system are programmed to give the optimum, different, reaction to Loss Of Voltage and that their response is not conditional on seeing fault current, only on detection of loss of voltage. An LOV sequence starts to operate due to prolonged absence of voltage which occurs when a CB or Recloser goes to Lockout after a persistent fault is isolated from the supply i.e. fault current no longer flows, following a complete but unsuccessful autoreclose sequence. The actual cause of the fault still remains but is isolated on its normal source side from the supply and from adjacent feeders by the NOP.

For a fault at the position shown on the Feeder 1- A section, the 1A CB/Source Recloser will go through a sequence of Fast plus Delayed trips to attempt to clear the fault. For a permanent fault the outcome will be that 1A goes to Lockout and Feeder 1 will be left totally dead. Feeder 1 does however have healthy sections e.g. 1B to 1C and 1C to the NOP which can be given back-feed supply from Feeder 2 if a structured restoration cycle is initiated by the automatic closure of the NOP. This is achieved as follows;- following the Lockout of the Source Recloser/CB-1A, the Line Reclosers 1B and 1C will both see permanent Loss Of voltage (LOV), (this may also have occurred temporarily, more than once during or for the whole, of the 1A recloser sequence).

1B and 1C can be set as type *Recloser* in the *LOV Automation* menu. In this case if *LOV Recloser Opening* in each is set to Enabled and they see permanent LOV on both sides for more than a user set LOV Action Delay e.g. 60 seconds, set by the user to cover a complete upstream sequence, then their LOV Elements will each take action and give a 3 pole Trip output, both 1B and 1C will therefore Trip and Lockout at about the same time.

The NOP, which is set as type *NOP (Tie)* in the *LOV Automation* menu, in example 1, will see LOV on its Feeder 1 side and will have normal system voltage available on its Feeder 2 side; if the NOP's LOV Element sees permanent LOV on either side i.e. lasting for more than a user set LOV Action Delay e.g. 75 seconds to give a grading margin to allow time for Reclosers 1A and 1B to open at, for example, 60 seconds, then the NOP LOV Element will take action and issue a NOP Close.

A type *NOP (Tie)* has separate settings for *LOV-A Action Delay* and *LOV-X Action Delay* to allow different delays to be applied for Loss of voltage action on either side of the Recloser.

For this NOP Close action the NOP Protection must be primed to perform one Fast Protection Line Check Trip & Lockout, thus, if the NOP closes onto a permanent fault or a fault appears during a set *LOV SOTF Time* (e.g. 5 seconds), on section 1C then the NOP will perform a Fast Protection Trip & Lockout. If the NOP close is successful and no fault appears, the C section of Feeder 1 will thus be back-fed. The NOP Line Check mode must be maintained as Fast Protection during its *LOV SOTF Time* but must then be changed to Delayed for the Recloser's *LOV Reclaim Time*.

Recloser 1C will now see voltage on its downstream side and if that voltage is present for the user set LOV SOTF Time e.g. 5 seconds, then 1C's LOV Element in turn will then issue a Reclose and 1C will close. Note that the 1C Protection will be primed to perform one Fast Protection Line Check Trip & Lockout, thus, if 1C closes onto a permanent fault, or a fault appears during its set *LOV SOTF Time* e.g. 5 seconds, then 1C will Fast Protection Trip and Lockout. If the Recloser close is successful the B section of Feeder 1 will thus be back-fed. The 1C Line Check mode must be maintained as Fast Protection during its *LOV SOTF Time* but must then be changed to Delayed for the Recloser's *LOV Reclaim Time*.

Recloser 1B will now see voltage on its downstream side and if that voltage is present for the user set *LOV SOTF Time* e.g. 5 seconds, then 1B's LOV Element in turn will then issue a Reclose and 1B will close. Note the 1B Protection will be primed to perform one Fast Protection Line Check Trip & Lockout thus if 1B closes onto a permanent fault, or a fault appears during its set *LOV SOTF Time* e.g. 5 seconds, then 1B will Fast Protection Trip & Lockout. If the Recloser close is successful then the A section of Feeder 1 will thus be back-fed. The 1B Line Check mode must be maintained as Fast Protection during its LOV Reclose reclaim Delay but must then be changed to Delayed for the Recloser's *LOV Reclaim Time*.

For the example shown 1B will be reclosed onto a permanent fault and will therefore perform its Fast Line Check Trip & Lockout with 1C now applying only Delayed protection. This will leave the healthy 1B and 1C sections backfed via the NOP.

As can be seen from the above, the NOP and each Recloser will close sequentially at the User set (e.g. 5 seconds) intervals and each Recloser when it Closes will be primed to perform a single Fast Protection Line Check Trip & Lockout for its Close whilst all other Reclosers/NOP have had their protection changed from Fast Protection Line Check Trip & Lockout to a Delayed Line Check Trip & Lockout; this ensures that the Recloser closing onto a faulted section will trip Fast Protection and clear the fault leaving all the other proven, unfaulted, sections energised. This mode of operation does impose a fault, which will be cleared by a single high-speed Fast-Protection Trip, onto an otherwise healthy system but it does result in 'as much of the System being maintained in-service as possible'.

If, following a Loss of Voltage and LOV Automation initiation, a type *Recloser* does not see Voltage re-appear on one side to allow the LOV Automation process to proceed, then on expiry of the *LOV Sequence Time* i.e. the LOV Automation time-allowed-to-live timer, the LOV Sequence will be terminated and the Recloser will go to Lockout.

The NOP and the Reclosers involved in the restoration sequence must have their *LOV Reclaim Time* settings set to a longer time, with grading margin > 5 secs, than the maximum time taken for the last Recloser X in the LOV Sequence to complete its LOV sequence and Reclose, tripping to clear any permanent fault which presents itself as necessary. This is necessary to ensure that the NOP and all Reclosers, which will see fault current when the last Recloser in the sequence closes, remain programmed to perform a Delayed Trip without reclose until after all Reclosers have completed their part in the Automation sequence and the system is restored unfaulted.

Once the NOP and feeder Reclosers have completed their LOV sequences and have LOV Reclaimed then they must now have co-ordinated grading to be able to deal correctly with a second fault on one of the healthy sections. This co-ordinated grading, under back-feed conditions following NOP(TIE) closure, is achieved by programming all the Reclosers in the LOV back-feed loops to be bi-directional, their settings in both directions can be co-ordinated by a Grading Study to ensure correct grading for faults fed from either the normal Forward or NOP(TIE) Closed back-feed, Reverse directions.

LOV Element has two main outputs i.e. three pole LOV Trip and three pole LOV Close these can be mapped to the existing CB Open and 79 AR Close outputs, it is not necessary to create new outputs in the output matrix, all other outputs are intended for alarm/indication purposes.

It should be noted that in a typical interconnected system at each feeder end there could be up to 3 NOP (TIE) at that node anyone of which could be closed to back feed supply to that feeder, therefore, there must be a user-set pecking order. The NOP LOV Action Delay timer User settings with grading margins e.g. 75 s - 80 s - 85 s, ensures that the optimum reconfiguration of the system occurs but with redundancy built-in to ensure that supply is restored via a third path should the first or second, choice path not be available or fails, see Figure 2 .

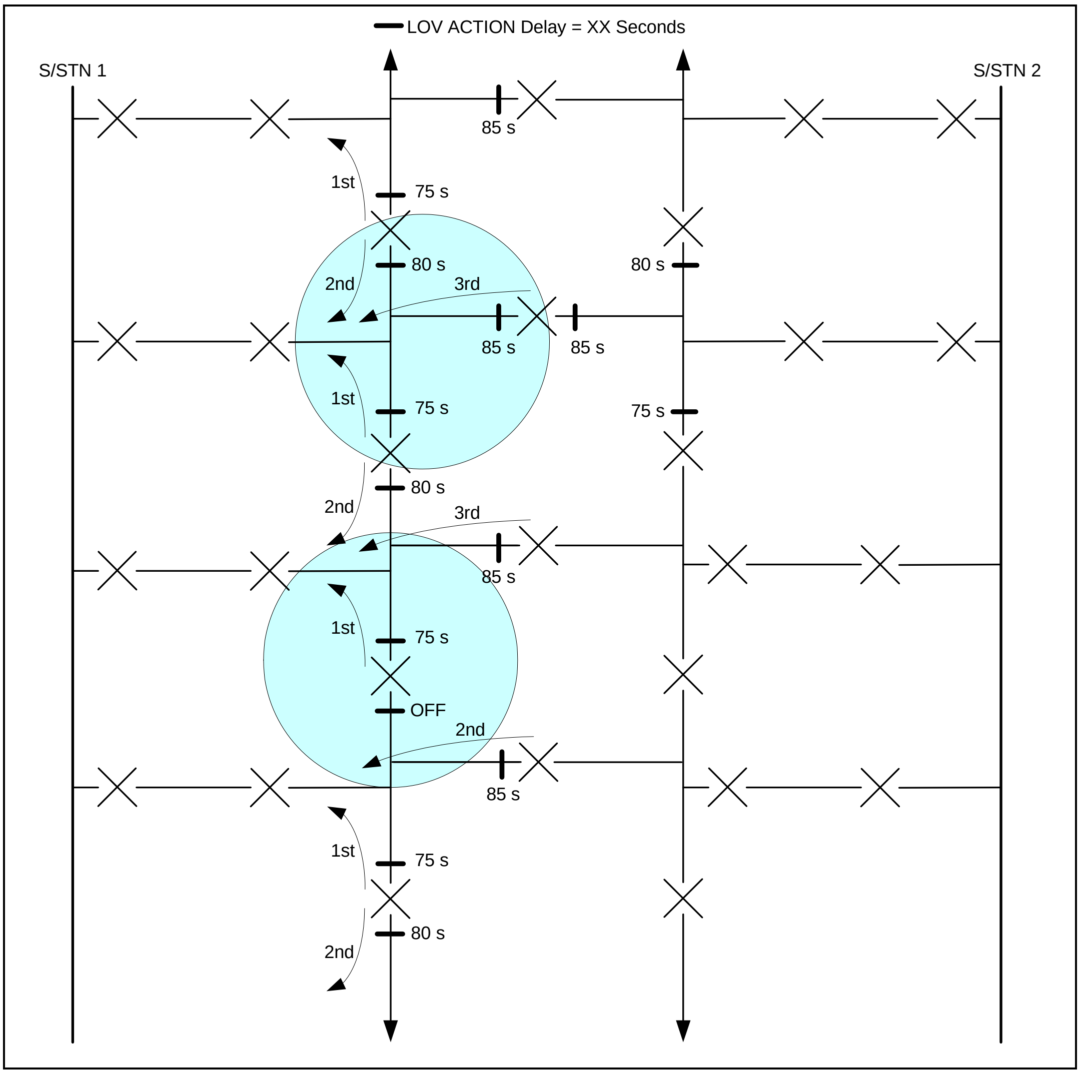


Figure 2 Typical System Interconnections showing Normally Open (TIE) Points and LOV Action Delay timer grading margins.

Loss of Voltage at the NOP on $V_A/V_B/V_C$ selects the LOVa Action Delay timer setting; Loss of voltage on $V_X/V_Y/V_Z$ selects the LOVx Action Delay timer setting.

As can be seen the result is that each Feeder can have a preferential first choice, a second choice and third choice back-feed feeder, the user can set these independently to suit his system. NOP (TIE) to Feeders from other Sub/Stations will typically always be set to third choice e.g. 85 second Action Delay time. NB the NOP LOV Automation Action Delay on either side can be set to OFF which means that the User can select NOP LOV Close so as to supply power in a single first required direction only, not a second.

The bubbles show examples of the flexibility of the grading arrangement at the node on the end of each feeder, showing how the user can select the 1st, 2nd and 3rd choice back-feed feeders for each feeder. Other arrangements can be set-up by User. Note the NOP (TIE) feeders between Sub/Stations end up with the same Action Delay time settings on both sides.

The LOV Automation function can be Enabled or Disabled, by the User setting and can be switched In/Out dynamically via any Binary Inputs, LOV can also be switched In/Out by Function Key or SCADA General Commands. LOV is automatically inhibited by Voltage Transformer Supervision if a VTS failure is detected.

For a controller with *LOV Plant Device Type* set as *Recloser* to perform its LOV Automation sequence, only the downstream voltage needs to be monitored and therefore addition primary voltage transformers are not required. Reclosers should be mounted and connected so that the standard Voltage measuring devices are on the downstream side as this voltage is monitored for voltage recovery to prompt reclosure. The controller monitors will respond to voltage restoration on either side of the recloser and therefore connections can be made to the ‘A’ or ‘X’ side.

For a NOP (TIE) to perform its LOV Automation sequence, the voltage levels on both sides of the NOP i.e. both downstream and upstream voltages, must be monitored. Voltage levels must be continuously monitored as pre-LOV memory of condition states is necessary.

An LOV close is blocked by the Block Reclose input in the same way as any autoreclose close. The setting of the Block Reclose Delay should be considered in the setting of the LOV timing.

The LOV function is set to ‘Out’ by default and must be switched ‘In’. The voltages and open/closed state of the recloser is checked when an attempt is made to switch the function ‘In’. A type Feeder or Recloser must be Closed with voltage present on at least 1 side. A type NOP(Tie) must be Open with Live voltage on both sides. This condition must be retained for the *LOV Primed Time* before the ‘primed’ staus is achieved. The device must be in the ‘primed’ state for loss of voltage to start any *LOV Action.* The enable/disable setting *LOV Primed Interlock* can be used to disable the voltage check but the relevant open/closed state is still required. The NOP(Tie) device includes a *LOV Memory Time* which provides a reset delay for the primed condition when voltage conditions of dead both sides is applied. This allows for the fact that during a fault the voltage on the unfaulted side may be depressed by the proximity of the fault.

The devices can be set to start the LOV sequence from loss of voltage on either all three phases or loss of voltage on any single phase. The single phase option can be used to restore load on a system where single pole tripping is permitted.

The LOV system can be set to operate as a single or multi-shot sequence. When selected as Single mode, the LOV Automation function will be automatically switched Out following a successful or unsuccessful LOV sequence and the *LOV In* signal must be raised by the operator before a further sequence will be executed following a subsequent loss of voltage.

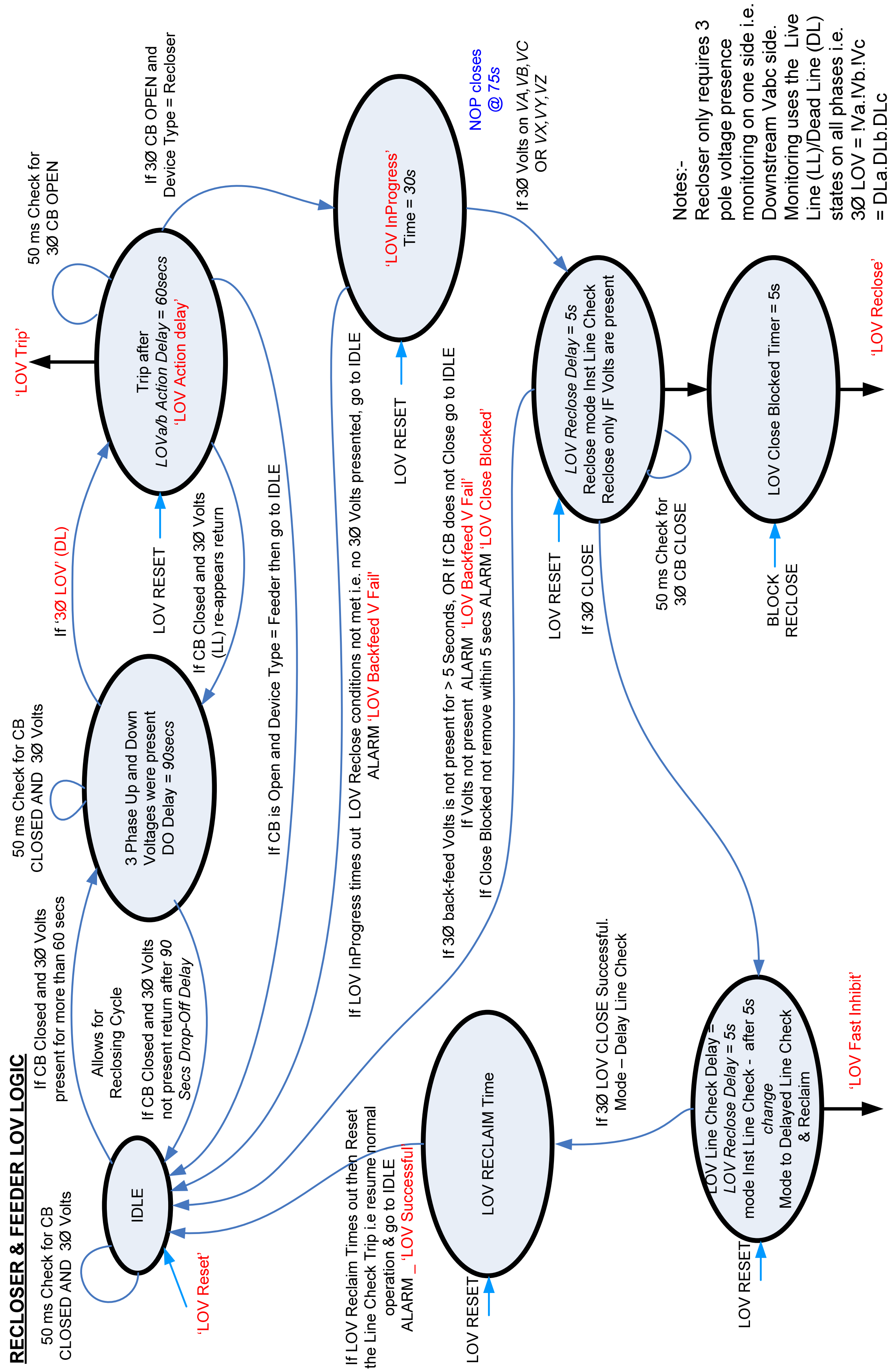


Figure 3 State Diagram for Line Recloser operation

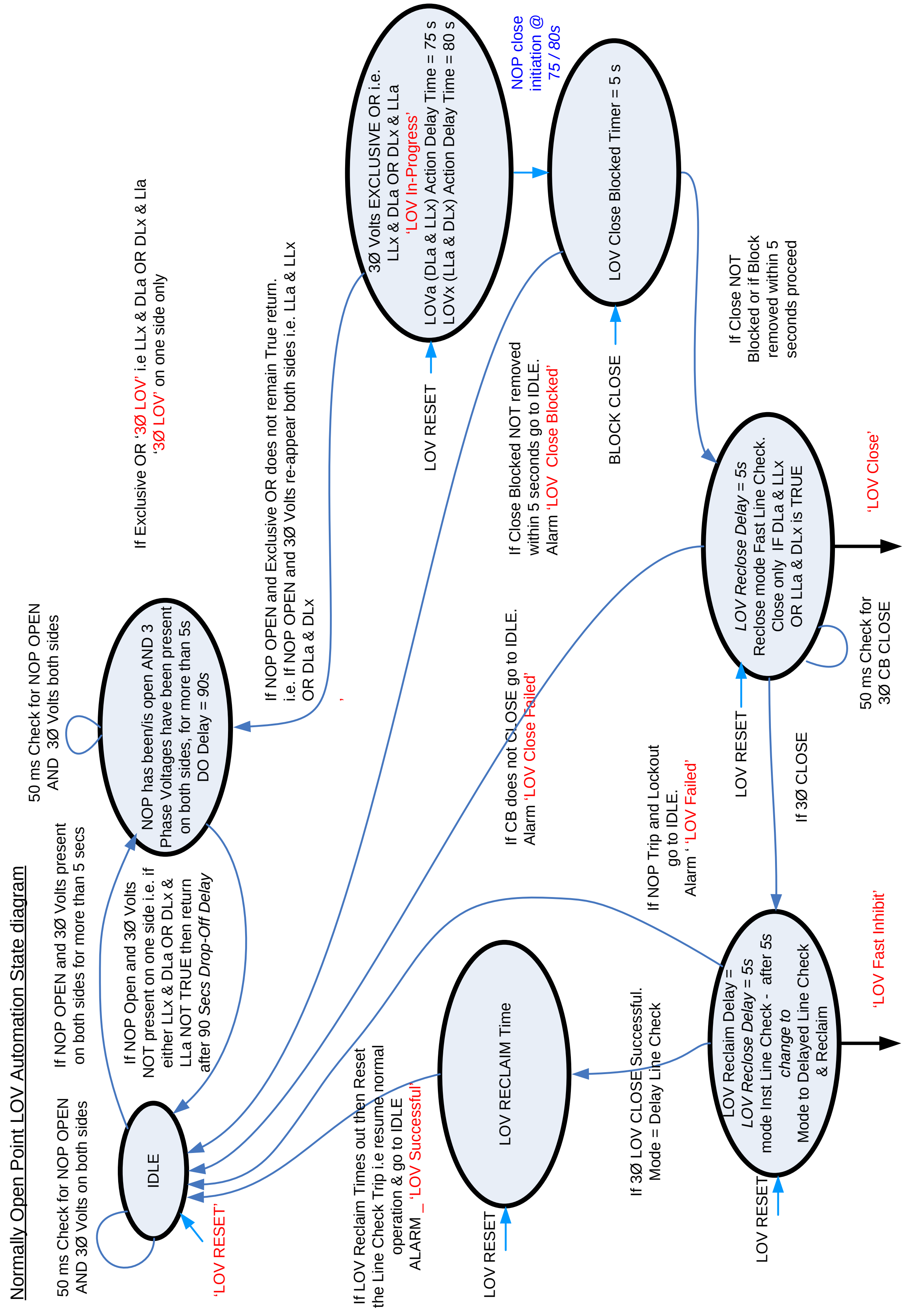


Figure 4 State Diagram for Normally Open Point

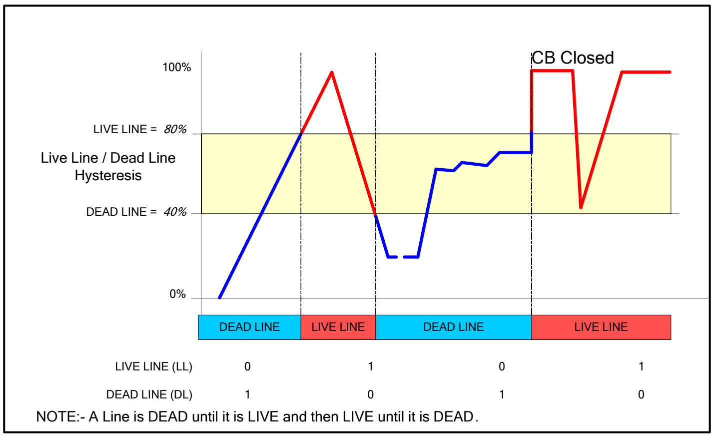


Figure 5 Live Line / Dead Line State Table Diagram

This state diagram shows how the Live Line / Dead Line states correctly mimic the response of a single electro-mechanical element with high Hysteresis. There can be no mythical *'third'* state, where a Line is neither Live nor Dead, to cause confusion. The User settable limits allow a dead line with high levels of pick-up Voltage due to mutual or capacitive coupling to remain correctly classified as a Dead Line i.e. one which can be reclosed without requiring Check Synchronising. As can also be seen the state conditions are robust allowing for severe Voltage dips caused by faults on a live line without losing the correct Live Line state indication.

1.2. Sequence Timing

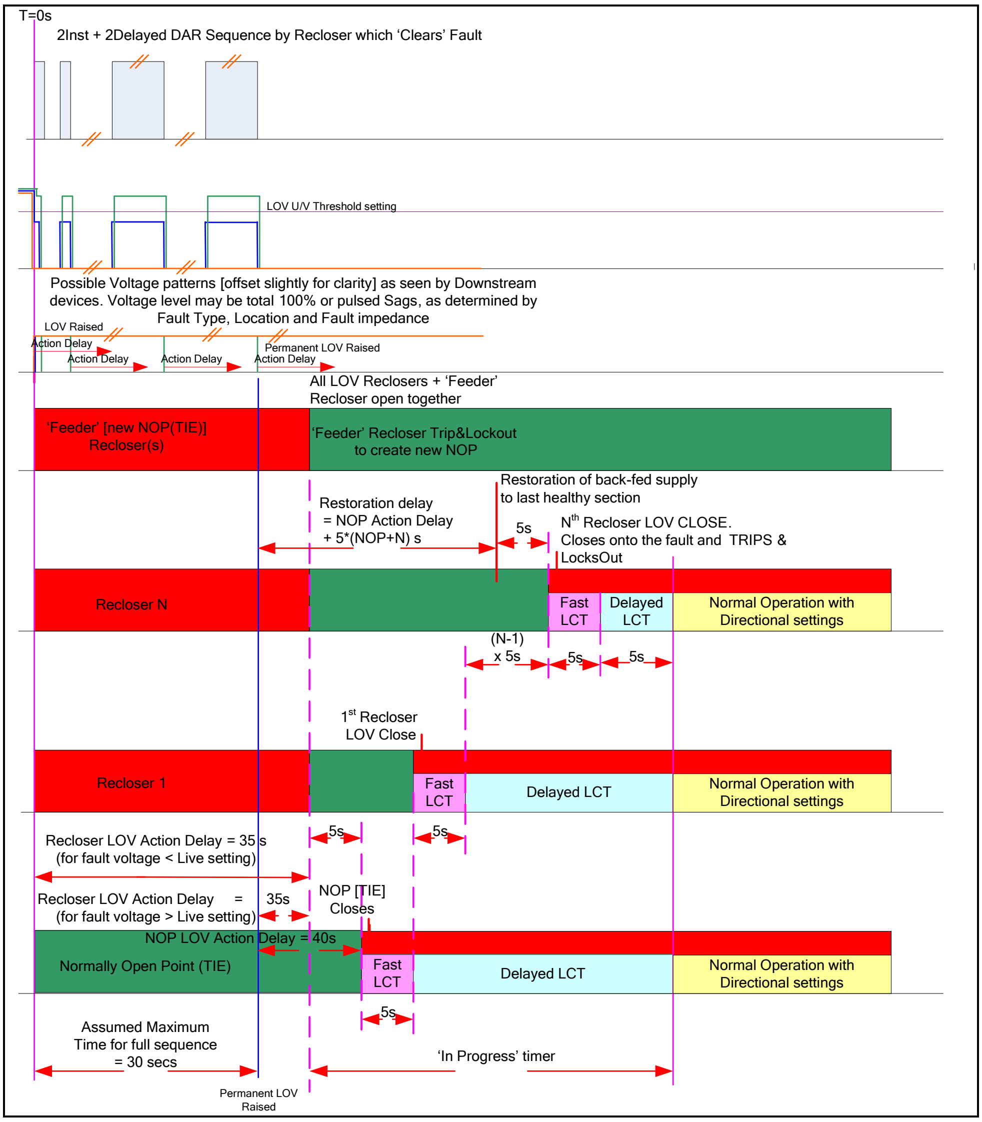


Figure 6 LOV Automation sequence showing relative timing of LOV, 'Feeder' Recloser, Line Reclosers and NOP relative timing operations.

Examples of LOV Automation Sequence Timing.

In the worst case, the LOV timing will not start until after the full multi-shot autoreclose sequence has completed due to restoration of full voltage during the recloses onto the fault. i.e. full 30 seconds sequence, a Recloser Action Delay of 35 secs, a NOP action time setting of 40 seconds and two Reclosers to the fault position, each with 5 seconds Reclose Delay, the total time from first Fault-current inception to restoration of supply to the final healthy section = 30+35+5+5 =75 seconds.

In many cases the fault voltage may remain below the Dead setting due to the low fault impedance throughout the auto sequence. The LOV timing will therefore execute during the autoreclose sequence and the LOV action will be sooner.

If the permanent LOV occurs earlier due to a shorter AutoReclose sequence, say 2 Fast + 1 Delayed =15 s, and with Recloser Action Delay of 35 seconds, a NOP action delay reduced to 36 seconds and Reclose Delay reduced to 2 seconds, then the total time = 15+36+2 = 53 s this is well below 60 s and would not count as an Interruption, therefore, the CML metric would not be increased. The majority of LOV Automation sequences could thus not count as Interruptions.

2. LOV Automation Menu

Gn LOV-A Live	Voltage above which the A Side is classed as Live.
Gn LOV-A Dead	Voltage below which the A Side is classed as Dead.
Gn LOV-X Live	Voltage above which the X Side is classed as Live.
Gn LOV-X Dead	Voltage below which the X Side is classed as Dead.
Gn LOV Automation	Selects whether the LOV Automation Element is enabled.
Gn LOV Plant Device Type	Selects the appropriate functionality for the type of device.
Gn LOV Start Option	Selects either 3P or Any pole dead for LOV starting.
Gn Primed Interlock	Allows the voltage check for correct Live voltage before allowing LOV to be switched In, to be disabled.
Gn LOV Primed Time	Time that the primed condition of correct open/closed state and live voltage has to be present for before the LOV Automation is classed as primed.
Gn LOV Recloser Opening	Select if a Recloser Type should open after LOV and reclose once voltage is restored or stay closed whilst waiting for voltage to be restored.
Gn LOV Action Delay	After Loss of Voltage for this length of time with the device in a ’primed’ state, the LOV Action starts. (Recloser & Feeder).
Gn LOV-A Action	Select whether the NOP is to operate for Loss of voltage on the A Side.
Gn LOV-A Action Delay	After the Loss of Voltage on the A Side for this length of time with the device in a ’primed’ state, the LOV action starts. (NOP).
Gn LOV-X Action	Select whether the NOP is to operate for Loss of voltage on the X Side.
Gn LOV-X Action Delay	After the Loss of Voltage on the X Side for this length of time with the device in a ’primed’ state, the LOV action starts. (NOP)
Gn LOV Sequence Time	Maximum time allowed after LOV Action Delay for a Recloser type to wait for Voltage to reappear.
Gn LOV Reclose Delay	When “Gn LOV Recloser Opening” is Enabled, the voltage must be re-established for this length of time before the Recloser will close.
Gn LOV SOTF Time	For this length of time after a recloser has been closed, due to an LOV Automation operation, all Instantaneous protections will be allowed to operate.
Gn LOV Reclaim Time	For this length of time after the *Gn LOV SOTF Time* all Instantaneous protections will be inhibited.
Gn LOV Memory Time	Length of time that NOP will remain primed for after losing voltage on both sides.
Gn LOV Operation	Selects whether the element must be switched ‘In’ again to allow another LOV operation following a successful LOV Automation operation.