7SG13 Delta

Protection and Control Relays

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

Pre release

2010/02	Document reformat due to rebrand
2004/07	Auto-reclose settings updated
2004/03	Performance specification updated, settings tables added
2003/02	v2 Page 1: removed invalid references
2003/01	First issue

Software Revision History

Contents

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Section 1: Introduction

1.1 Introduction

This document covers the current-based protection elements and their applications found in the Modular II range of relays, as listed below. A Diagrams and Parameters document which covers each individual model is available, which lists explicitly the functions that are provided and the manner in which they are connected.

- 25, Check synchronising
- 79, Auto-Reclose

Notes

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

- Setting: Elem *Setting name*
- Setting value: value
- Alternatives: [1st] [2nd] [3rd]

2. The purpose of this document is to describe the capabilities and functionality of Check synchronising and Auto-Reclose elements. Separate User Manual documents describe how to set up and operate the equipment: apply configuration, settings and passwords, view instruments and set default instruments, and retrieve fault data.

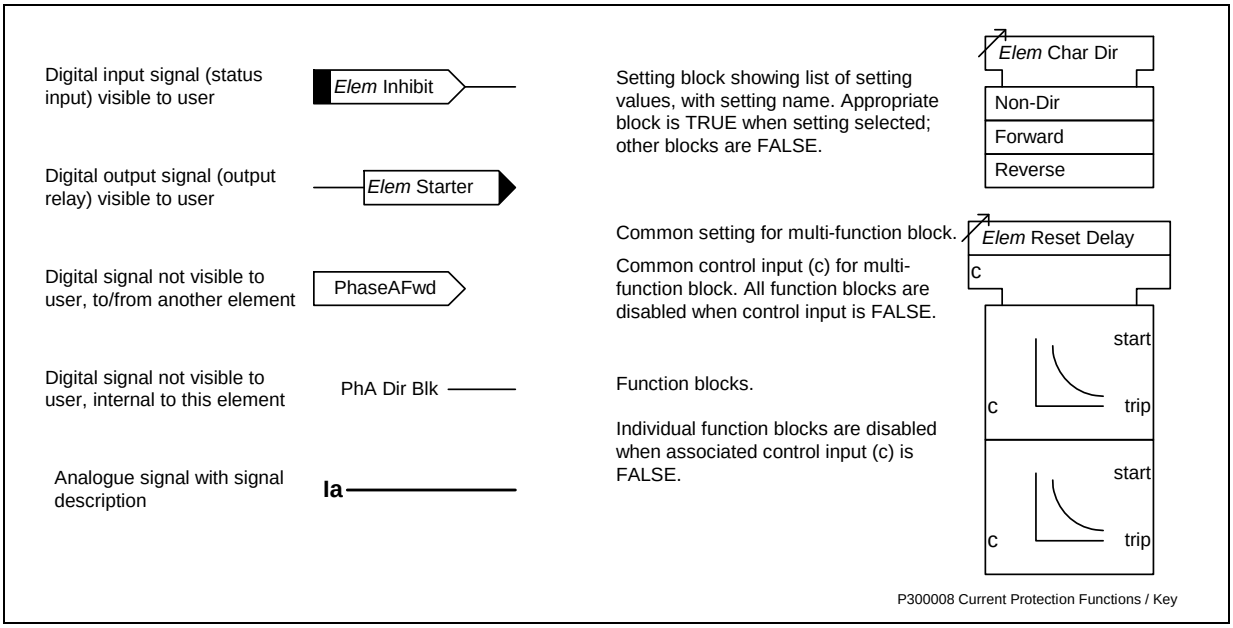


Figure 1-1 Key to Functional Block Diagrams

Section 2: Element Definitions

2.1 Auto-reclose control

Delayed Auto-Reclose (DAR) is initiated by a valid trip relay operation while the associated circuit breaker is in service.

A circuit breaker's service status is determined by its position and (where Check Synchronisation is applied) its voltage references. The circuit breaker is defined as being in service when it is closed and its voltage references are live. The in service status has a drop-off delay of 2 sec, this delay is known as the circuit memory time. This functionality prevents autoreclosing when the line is normally de-energised, or normally open.

The transition from DAR started to initiate deadtime takes place when the circuit breaker's line voltage reference goes dead; and the CB has opened; and the trip relay has reset. If any of these do not occur within the Sequence Fail time the relay will Lockout. This is provided to prevent the DAR being primed indefinitely, or the timer can be switched OFF.

Once a DAR sequence had been initiated, up to 4 unsuccessful recloses (where a closure is followed by a re-trip) may be performed before the DAR feature is locked-out. Each reclosure is preceded by a time delay (dead time) to give transient faults time to clear.

Once a CB has reclosed and remained closed for a specified time period (the Reclaim time), the DAR feature is re-initialised and a Successful Close output issued. A single, common Reclaim time is used.

A count is kept of how many recloses have been performed.

Once lockout has occurred, an alarm is issued and all further Close commands are inhibited for a specified time period (the Minimum Lockout time). A single, common lockout time is used. Lockout can be latched until reset.

There are separate dead-time settings for each of the 4 recloses.

The relay will automatically determine circuit breaker reclosure conditions. These conditions are dead line charge, dead bar charge, dead line and dead bar, unconditional close, or check sync close. If one of these conditions exists and reclosure under this condition has been pre-selected by the user then reclosure will be initiated.

When the dead line or dead bar deadtime has expired and dead line or dead bar conditions are met then the circuit breaker will be reclosed.

If the relay detects the presence of line and busbar volts and check sync reclosure has been pre-selected then the relay shall generate a check sync request prior to any reclosure. If the required check sync conditions are met then the circuit breaker will be reclosed.

Certain schemes require switching operations to be exactly coordinated by the deadtime of the autoreclose relay, whilst other scheme layouts can override the deadtime if In Sync conditions are met across the circuit breaker. The relay provides a setting to enable / disable this function, Check Sync During Deadtime.

2.1.1 Protection Trip

The Protection device which trips the CB should be connected to this input to prime and start the autoreclose sequence.

2.1.2 Protection Starter

Where the autoreclose relays are connected to overcurrent protection or a protection that includes a starter then the starter can be connected to this input. This would indicate that a reclose has closed onto a fault. Multi-shot Autoreclose sequences can be co-ordinated for adjacent relays using this input, i.e. the number of shots can be kept in step.

2.1.3 External A/R Start

An External A/R Start can be received via a status input. A separate protection device would normally initiate this.

An External A/R Start will be treated the same as a Protection A/R Start by the Relay.

2.1.4 Manual Close

An External Close Command can be received via a status input or communications. This would normally be initiated manually. It causes an instantaneous closure, over-riding any DAR sequence then in operation.

An External Close will initiate Line Check. If a fault appears on the line during the Close Pulse or the Reclaim Time with Line Check set, the Protection relay will initiate a Trip and the A/R relay will Lockout. This prevents a CB being repeatedly closed onto a faulted line.

Repeated Manual Closes are avoided by checking for Positive edge triggers. Even if the Manual Close input is constantly energised the relay will only attempt one close. No Close Pulse will be issued when the Manual Close input is reset.

Manual Closing is controlled by the following settings:

Setting	**Range**	**Default**
Manual Close DBC	Enabled / Disabled	Disabled
Manual Close DLC	Enabled / Disabled	Disabled
Manual Close DLDB	Enabled / Disabled	Disabled
Manual Close CS	Enabled / Disabled	Enabled

These combinations allow full selection of the Manual Closing process.

Manual Close resets Lockout, if the conditions that set Lockout have reset i.e. there is no trip or Lockout input present.

Manual Close cannot proceed if there is a Lockout input or Block Reclose input present.

With the Autoreclose function set to Out of Service the Manual Close control is still active.

2.1.5 In/Out Switching

The DAR feature may be switched out by changing the A/R In Service setting by a number of methods. These are either a keypad change from the front panel, or via a communication, or by an A/R OUT status input. A/R OUT status input has priority over A/R IN. If both are raised the relay will be in Out Of Service. Once the relay has been switched Out Of Service the reverse action A/R IN is required before the relay will go back In Service.

2.1.6 Overall Control

The DAR feature may be disabled by a Lockout command or by an external signal applied to a status input (A/R OUT).

If the Lockout command or A/R OUT are received while a DAR operation is in progress, the feature is immediately locked-out. An External A/R IN command can be received via a status input. This will re-enable the module.

If the Lockout command is received while a Manual Close operation is in progress, the feature is immediately locked-out.

The DAR or Manual Close feature may be paused by an external Block signal applied to a status input. This causes the feature to temporarily halt before it issues the next CB close command and can be used, for example, to delay CB closure until the CB pressure has reached an acceptable level. If the Block signal has not been removed before the end of a defined time, the Reclose Block Delay, the relay is locked-out.

A Block Reclose input active within the deadtime resets the deadtime timer.

2.1.7 CB Close Command pulse

The duration of the CB Close Command pulse will be settable to allow a range of CBs to be used. The Close pulse will be terminated if any protection Starter picks-up or a trip occurs. This is to prevent Close and Trip Command pulses existing simultaneously. A Close Onto Fault Output is given if a starter or trip picks-up in the Close Pulse. This can be independently wired to Lockout.

2.1.8 CB Failed To Open and CB Failed to Close

CB Failed To Open and CB Failed to Close features are used to confirm that a CB has not responded correctly to each Trip and Close Command. If a CB fails to operate, the DAR feature can be set to lockout.

2.1.9 CB Closed by Another Device

If, during a dead time period, the Relay detects that the CB has closed (due to an external source) it increments its Reclose count and advances to the next part of the Reclose sequence (begin Reclaim time).

2.1.10 Indications

The relay has a fully programmable output to either output contacts or LEDs, see settings sheet for complete list.

The following are included:
1. A/R In Service
2. A/R Out of Service
3. A/R In Progress
4. Successful A/R
5. Lockout

2.1.11 Trip and Reclose

This is a test function, allowing the operation of the CB to be verified.

The Trip signal should be routed directly to the Circuit Breaker. Once the CB has opened and the Trip and Reclose input is removed the DAR will wait for the first Reclose Delay and then issue a CB Close command.

A Trip and Reclose command will only be accepted if the Relay is in quiescent, or line healthy mode, i.e. no autoreclose sequences are in progress.

During the Trip and Reclose reclosure, Line Check is invoked to ensure that the CB does not repeatedly close onto a faulty line.

2.1.12 CB Close Operations

Additional DAR features are provided as an aid to maintenance.

Two counters ‘Total CB Close Count’ and ‘Delta CB Close Count’ are provided. Each counter has a User settable Alarm count. These counters can be used for Maintenance Alarms. These figures are separately re-settable by either keypad, or status input **Reset Total CB Close** or **Reset Delta CB Close**. Maximum alarm number of 999.

2.1.13 Metering

All Counters and the Status of the DAR operations are displayed in Meters under the instruments Menu.

2.1.14 Dead-time and Reclaim Timing

The Deadtime will start if a Trip has occurred and the CB is Open and the Trip and Starter have then reset and the line has gone dead. Once a trip has occurred if the CB does not open or the Trip does not reset or the starter does not reset then the DAR will Lockout. This could be due to either a CB Fail condition, which would independently notify Lockout, or the Trip or Starter relay contact failing to reset. If the line does not go dead this may signify that the remote end has failed to clear the fault, and the autoreclose will go to Lockout.

A Trip during the deadtime will result in resetting the deadtime and then restarting the deadtime when the trip resets, provided the Sequence Fail Timer has not expired.

The Reclaim time will start once the Close Pulse has timed out and the CB has closed. Lockout is alarmed if the CB is open at the end of the reclaim time.

2.1.15 Lockout

The Lockout state can be reached for a number of reasons. Lockout will occur for the following:

- at the end of the Reclaim time if the CB is in the open position.
- a protection operates during the final Reclaim time.
- if a Close Pulse is given and the CB fails to close.
- The Reclose Lockout status input is active.
- At the end of the Reclose Block Delay due to a persistent Block signal not cleared.
- At the end of the Sync Close Delay due to Synchronism not being achieved.

Once the Lockout condition has been reached, it will be maintained until reset. The following will reset lockout:

- By a Manual Close command.
- By a Reset Lockout signal, provided there is no signal present that will cause Lockout.
- At the end of the Minimum Lockout time if Reset Lockout is selected to be reset by a timer, provided there is no signal present which will cause Lockout.
- if Lockout was entered by an A/R Out signal during an Autoreclose sequence then an A/R In signal must be received before Lockout can reset.
- by the CB Closed, provided there is no signal present which will cause Lockout.

The Lockout condition has a delayed drop-off of 2s.

The Lockout condition will initiate the Lockout indication and alarm contact.

Lockout does not issue a trip signal.

Lockout indicates an abnormal system occurrence, an event that needs to be investigated. When a CB is normally open the A/R relay does not go to Lockout, but using a combination of Trip and CB In Service to start the sequence prevents A/R sequences.

2.1.16 Auto Isolation

Facilities are provided to apply auto-isolation to mesh corner or Teed feeders. An auto-isolation scheme is provided. If a trip occurs within the close pulse then auto-isolation is started if selected, the isolator should send Auto-Isolation Complete when the system is isolated, the relay will then continue with its next sequence. If Auto-Isolation Complete is not received before the end of the Auto-Isolation timer then Auto-Isolation Fail is issued, and the relay will go to Lockout.

2.1.17 Sequential Isolation

Facilities to inhibit sequential isolation are provided to enable the DAR system to stop sequential isolation if an associated DAR sequence has started. The Inhibit Sequential Isolation output is set when an A/R sequence is started and is reset at the start of the close pulse or at lockout.

2.1.18 Voltage Failure Lockout

Facilities to Lockout Autoreclose and Manual Closing if a VT Failure occurs are provided. There is a setting provided which enables and disables this feature. VT Failure is set for either:

CB Closed and Live Line and Dead Bar >> 2 sec.

Or

CB Closed and Live Bar and Dead Line >> 2 sec.

This function has been provided as a setting due to the uncertainty of isolator positions within the scheme.

Table 2-1 Typical Settings Auto-Reclose

Setting name	Range (**bold** = default)	Units	Notes
A/R In Service	In, **Out**		
Number Of Shots	**1**..4		
***Shot* Deadtime**	0.0, 0.1…**5.00**…120, 121…900	s	
CB Close Pulse	0.2, 0.3…**2.0**…20	s	
Reclaim Time	OFF, 1…**5**…600	s	
***Elem* Trip**	**Delayed**, Instant		
Line Check Trip	**Delayed**, Instant		
***Elem* TTL**	**OFF**, 1…5		
Rec Block Delay	0, 1…**60**…600	s	
Slow Open Delay	50, 60…**140**…2000	ms	
Seq Fail Timer	**OFF**, 1, 2…600	s	
Min LO Timer	0, 1…**2**…60	s	
Reset LO By Time	Enabled, **Disabled**		
Dead Bar Charge	Enabled, **Disabled**		*These settings are only available in relays with the check synchronising feature*
Dead Line Charge	Enabled, **Disabled**		
Dead L & B Charge	Enabled, **Disabled**		
Check Sync Close	**Enabled**, Disabled		
Uncondit Close	Enabled, **Disabled**		
Manual Close DBC	Enabled, **Disabled**		
Manual Close DLC	Enabled, **Disabled**		
Manual Close DLDB	Enabled, **Disabled**		

Setting name	Range (**bold** = default)	Units	Notes
Manual Close CS	**Enabled**, Disabled		
Live Line Check	**Enabled**, Disabled		
CS In Deadtime	**Enabled**, Disabled		
VT Fail Lockout	Enabled, **Disabled**		
DL Charge Delay	**0**, 1…60	s	
DB Charge Delay	**0**, 1…60	s	
Sync Close Delay	Off, 1…**30**…900	s	
Sub-menu: **Output Relays**			
Lockout	_, 1 for each output contact		
A/R Switched Out			
A/R In Progress			
Successful Close			
Line Check			
Ext Arc Start			
Sub-menu: **Status Inputs**			
A/R In	_, 1 for each status input		
A/R Out			
Extern A/R Start			
Block Reclose			
Go To Lockout			
Trip And Reclose			
Trip and Lockout			
Reset Lockout			
Manual Close			

2.1.18.1 Specification

Element Parameters

The element will take the following parameters, unless otherwise specified in the appropriate Diagrams and Parameters document.

	Parameter	**Value**
t_{cycle}	Element cycle time	20 ms
$t_{setting}$	Timer settings	Applied value

Operate Time

	Attribute	**Value**
t_{op}	Operate time following delay	$t_{setting}$, ± 1 % or ± t_{cycle}
	Repeatability	± 1 % or ± t_{cycle}

2.2 Synchronising

2.2.1 Voltage monitoring elements

2.2.1.1 Under-voltage detectors

The under-voltage detectors, if enabled, can block a close output command if either the line voltage or the bus voltage is below the under-voltage setting value. Both line and bus have their own independent settings.

2.2.1.2 Differential voltage detectors

The differential voltage detector, if enabled, can block a close output command if the difference between the line and bus voltages is greater than the differential voltage setting value.

2.2.1.3 Voltage detectors

Voltage detectors determine the status of the line or bus. If the voltages on either the line or bus are below a set threshold level they can be considered to be 'dead'. If the voltages are within a setting band around the nominal voltage they are classed as 'live'. Independent voltage detectors are provided for both line and bus.

If a voltage is in the dead band range then it will be classed as dead until it has reached the live band area. Similarly, if a voltage is live, it continues to be live until it has reached the dead band area. This effectively allows for variable amounts of hysteresis to be set. Figure 3 illustrates the voltage detector operation.

Note: the area between the dead and live zones is not indeterminate. When any voltage is applied to the relay it will ramp up the software RMS algorithm and always pass through the dead zone first.

Although a wide range is provided for live and dead voltage detector levels, these must not overlap. The relay software acts to prevent this from happening to stop unusual alarm outputs and conflicts with internal logic elements. If the user attempts to increment the dead voltage level to the live voltage level, the relay will not accept the setting. Similarly, if the live level is decremented to the dead level, the setting will not be allowed. The two voltages are displayed simultaneously on the LCD display so that this operation is clear to the user.

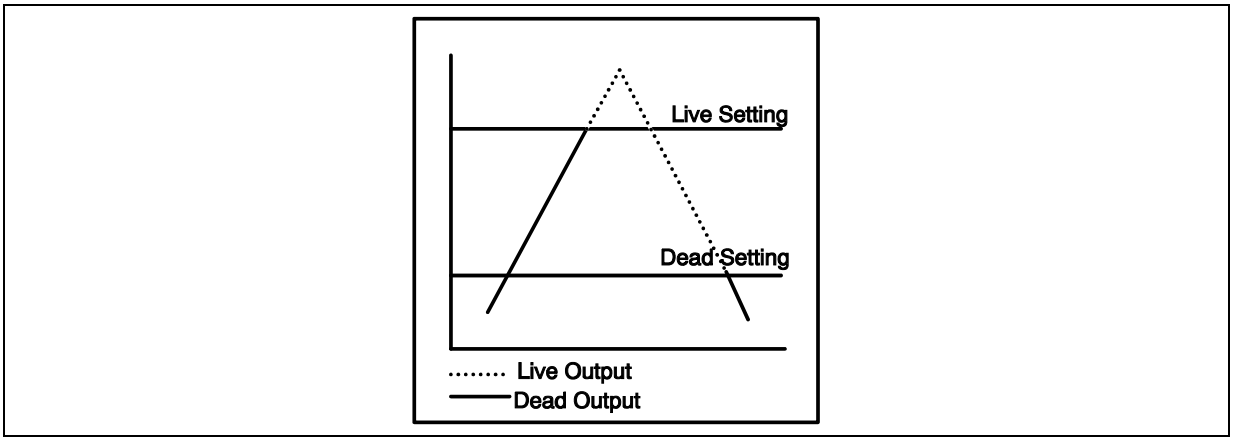


Figure 2-1 Voltage Detector Operation

2.2.1.4 Sync Override Logic

For certain switching operations, a means of bypassing the Check Synchronisation function is provided. This is provided with a separate Sync Override and a separate Manual Sync Override.

2.2.2 Check Synchronising Mode

For the relay to issue a Check Sync Close the following conditions have to be met :

CS PHASE ANGLE – the phase difference between the line and bus voltages has to be less than the phase angle setting value. Whilst within the limits the phase angle can be increasing or decreasing and the element will still issue a valid close signal.

CS SLIP FREQUENCY, [If ENABLED] – the frequency difference between line and bus has to be less than the slip frequency setting value.

CS SLIP TIMER, [If ENABLED] – the phase angle and voltage blocking features have to be within their parameters for the length of the slip timer setting. If either the phase angle or the voltage elements fall outside of their limits the slip timer is reset. If they subsequently come back in then the slip timer has to time out before an output is given. (This ensures that a close output will not be given if there is a transient disturbance on the system due to e.g. some remote switching operations).

LINE U/V DETECTOR, [If ENABLED] – the line voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

BUS U/V DETECTOR, [If ENABLED] – the bus voltage has to be above the bus under-voltage setting value and also above 5V for an output to be given.

DIFFERENTIAL VOLTAGE DETECTOR, [If ENABLED] – the difference between the line and bus voltages has to be less than the ΔV detector setting value for an output to be given.

The relay is always started in Check Synchronising mode of operation. To proceed to System Synchronisation a system split must occur.

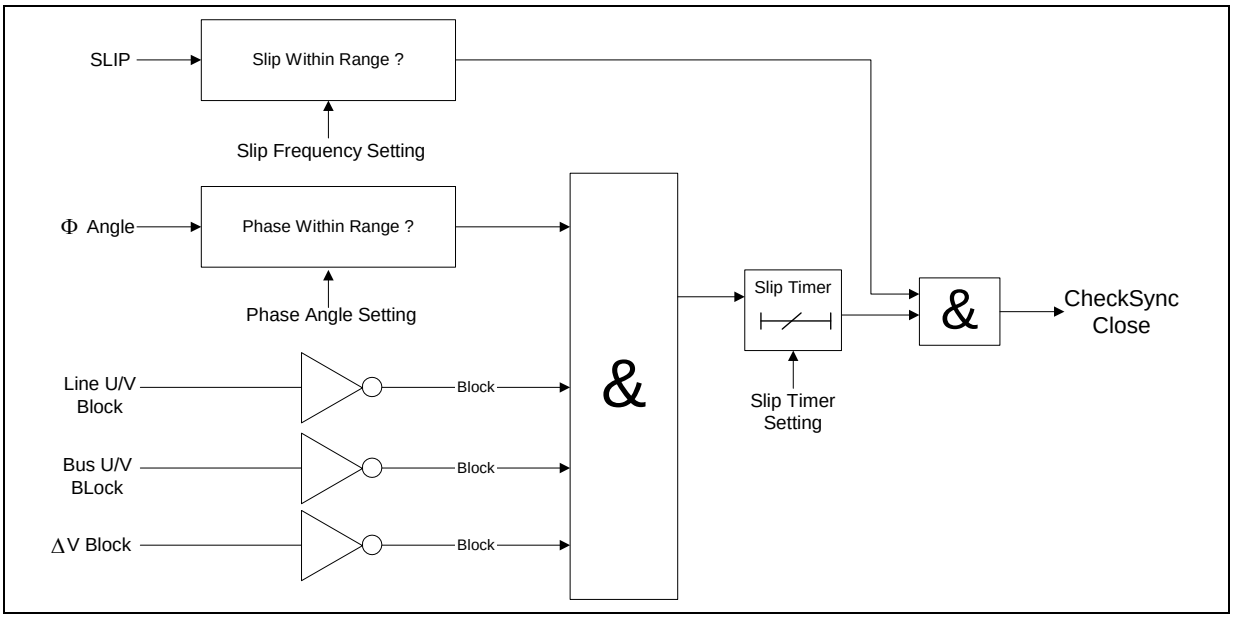


Figure 2-2 Check Sync Function

2.2.2.1 Manual Sync Override Feature

If manual closes are required to be carried out via an operator, these will be performed with Check Synchronisation unless the Manual Sync Override input is energised.

2.2.3 System Split Detector

A system split occurs where there is a loosely tied or non-parallel circuits on a power system. Under these conditions the frequencies of the voltages either side of the breaker are asynchronous and therefore high phase angle differences can occur as the frequencies slip past each other. The system split detector operates when the phase angle difference exceeds a pre-set value. The setting range for a system split is from 90°-175° step 1°.

Note : the system split setting is effectively an absolute value and therefore a split will occur at the value regardless of the direction of the frequency slip e.g. if an angle of 170° is selected, then starting from 0°, a split will occur at +170° or -170° (effectively +190°).

If a system split occurs during a Check Sync operation the following events occur:

- The Check Sync function is inhibited.
- The System Sync function is started if the setting has been set to A/R Split Action SYSTEM SYNC. If the A/R Split Action has been set to LOCKOUT, then, a system split LED indication is given. The relay will stay in this lockout mode until one of the following methods of resetting it is performed

1. The relay is reset from Lockout.
2. A status input command is received.
3. An appropriate IEC870 communications command is received.

- An event is recorded.
- The split flag can be mapped to an output relay for alarm indication.
- The system split LED will stay on for a minimum time, or can be latched using non self reset LEDs.

2.2.4 System Synchronising Mode

For the relay to issue a System Sync Close the following conditions have to be met :

SS PHASE ANGLE – the phase difference between the line and bus voltages has to be less than the phase angle setting value and the phase angle has to be decreasing before the element will issue a valid close signal.

SS SLIP FREQUENCY, [If ENABLED] – the frequency difference between line and bus has to be less than the slip frequency setting value.

SS SLIP TIMER, [If ENABLED] – the phase angle and voltage blocking features have to be within their parameters for the length of the slip timer setting. If either the phase angle or the voltage elements fall outside of their limits the slip timer is reset. If they subsequently come back in then the slip timer has to time out before an output is given. (This ensures that a close output will not be given if there is a transient disturbance on the system due to e.g. some remote switching operations).

LINE U/V DETECTOR, [If ENABLED] – the line voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

BUS U/V DETECTOR, [If ENABLED] – the bus voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

DIFFERENTIAL VOLTAGE DETECTOR, [If ENABLED] – the difference between the line and bus voltages has to be less than the ΔV detector setting value for an output to be given.

The System Synchronising operation of the relay can be started in two different ways. It is set by the 'A/R Split Action' setting which has three parameters: LOCKOUT, SYSTEM SYNC, CLOSE ON ZERO; or 'MC Split Action' setting which also has three parameters: CLOSE ON ZERO, CHECK SYNC, SYSTEM SYNC.

If the 'A/R Split Action' setting is set to:

LOCKOUT: after a split has occurred the relay will go into lockout mode

SYSTEM SYNC: the relay will only start system synchronising after a split condition has occurred. It will issue a System Sync Close automatically if the relevant parameters are met. There is also a Start System Sync input which when energised will switch the Check Synchronisation to System Sync.

CLOSE ON ZERO: the relay will only start system synchronising after a split condition has occurred. The relay will issue a close command determined by the CB close time and synchronisation parameters.

If the 'MC Split Action' setting is set to:

CLOSE ON ZERO: the relay will only start system synchronising after a split condition has occurred. The relay will issue a close command determined by the CB close time and synchronisation parameters.

CHECK SYNC: the relay will only start system synchronising after a split condition has occurred. It will issue a Check Sync Close automatically if the relevant parameters are met.

SYSTEM SYNC: the relay will only start system synchronising after a split condition has occurred. It will issue a System Sync Close automatically if the relevant parameters are met. There is also a Start System Sync input which when energised will switch the Check Synchronisation to System Sync.

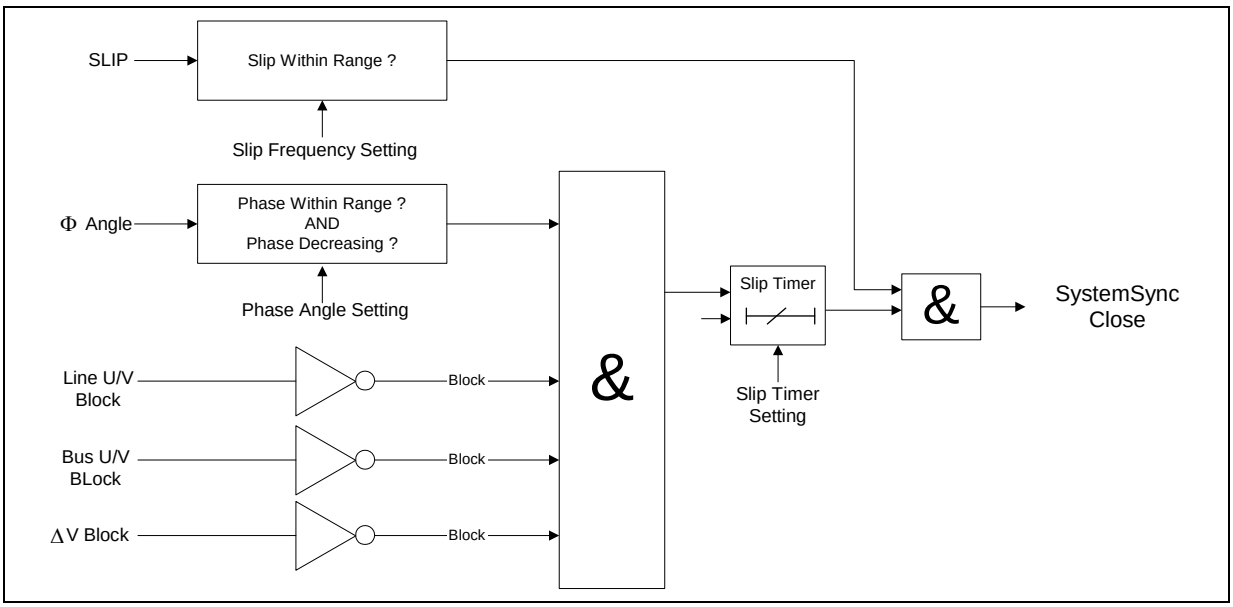
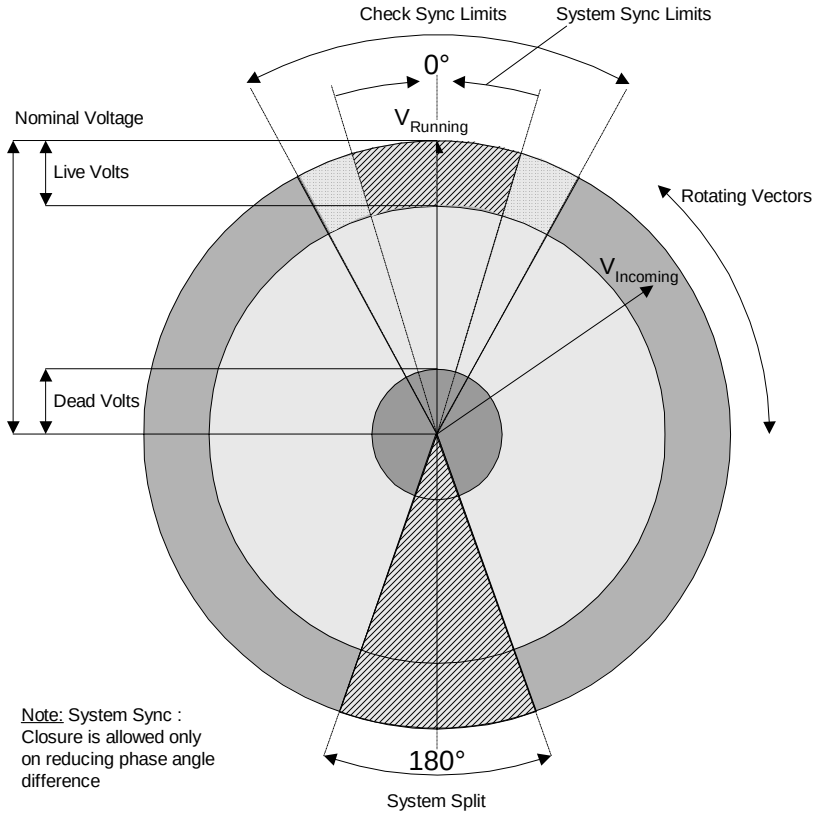


Figure 2-3 System Sync Function

Table 2-2 Typical Settings Check Sync

Setting name	Range (**bold** = default)	Units	Notes
Bus Dead | Live	5:10, 6:11…**20:90**…150:155	%	
Line Dead | Live	5:10, 6:11…**20:90**…150:155	%	
Bus Undervolts	OFF, 5,6…**90**…150	%	
Line Undervolts	OFF, 5,6…**90**…150	%	
Voltage Diff	OFF, 1…**10**…100	%	

Setting name	Range (**bold** = default)	Units	Notes
Split Angle	OFF, 95, 96…**175**	deg	
MC Split Action	**Close On Zero**, System Sync, Check Sync		
ARC Split Action	Close On Zero, System Sync, **Lockout**		
Check Sync Angle	5,6…**20**…90	deg	
Check Sync Slip	OFF, 10, 15 …**50**…2000	mHz	
Check Sync Timer	**OFF**, 0.1, 0.2…100	s	
SS / COZ Slip f	OFF, 10, 15 …**125**…2000	mHz	
CB Close Time	5,10…**60**…200	ms	
Sub-menu: **Output Relays**			
Live Line	_, 1 for each output contact		
Live Bus			
System Split O/P			
In Sync Output			
Check Sync Start			
Sync In Progress			
Dead Line Close			
Dead Bus Close			
Sub-menu: **Status Inputs**			
Sync Override	_, 1 for each status input		
Man SyncOverride			
Start SystemSync			



2.2.5 Specification

Element Parameters

The element will take the following parameters, unless otherwise specified in the appropriate Diagrams and Parameters document.

	Parameter	**Value**
t_{cycle}	Element cycle time	10 ms
f_{nom}	Nominal frequency	50 Hz
f_{cutoff}	Upper cut-off frequency	200 Hz

Reference

	Parameter	**Value**
Vn	Nominal voltage	63.5 V
Vsl	Line voltage setting	50 V
Vsb	Bus voltage setting	50 V
V_{live}	Live setting	50 V
V_{dead}	Dead setting	25 V
V_{diff}	Voltage difference setting	5 V
θ_{diff}	Phase difference	5 °
f_{slip}	Slip frequency	100 mHz
θ_{split}	Split angle	90 °
	Frequency	f_{nom}
	Ambient temperature	20 °C

Line and Bus Undervoltage Elements

	Attribute		**Value**
V_{line}	Operate level		100 % *Vsl*, ± 1 %
	Reset level		≤ 104 % V_{line}
V_{bus}	Operate level		100 % *Vsb*, ± 1 %
	Reset level		≤ 104 % V_{bus}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 1 %

Live/Dead Detector Elements

	Attribute		**Value**
$V_{live,act}$	Live operate level		100 % V_{live}, ± 1 %
	Live reset level		$V_{dead,act}$, ± 1 %
$V_{dead,act}$	Dead operate level		100 % V_{dead}, ± 1 %
	Dead reset level		$V_{live,act}$, ± 1 %
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 1 %

Voltage Difference

	Attribute	Value
V_{op}	Operate level	100 % V_{diff}, ± 2 % or ± 0.5 V
	Reset level	≥ V_{op} - 2 V and typically ≥ 90 % V_{op}
	Repeatability	± 2 %

Line and Bus Phase Angle Difference

	Attribute	Value
θ_{op}	Operate angle	θ_{diff}, - 3 °, + 0 °
	Reset angle	θ_{op}, - 0 °, + 3 °
	Repeatability	± 1 °

Slip Frequency

	Attribute	Value
f_{op}	Operate frequency	f_{slip}, - 15 mHz, + 0 mHz
	Reset angle	f_{op}, - 0 mHz, + 15 mHz
	Repeatability	± 10 mHz

Split Detector

	Attribute	Value
	Operate angle	θ_{split}, ± 1.5 °