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Technical
Specification

Automatic Reactive Switching for HV and LV Shunt Reactive Plant

NGTS 3.24.42
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AUTOMATIC REACTIVE SWITCHING FOR HV AND LV SHUNT REACTIVE PLANT

FOREWORD

This Specification is a functional specification within the Substation Information, Control and Protection (SICAP) suite of technical specifications. It shall be called up and applied by appropriate station level specifications.

1 SCOPE

This Specification describes the functional and performance requirements for Automatic Reactive Switching (ARS) systems for National Grid's shunt MSCs, reactors connected at HV 400 kV, 275 kV, 132 kV or lower voltage as specified in NGTS 1.

Figures in Appendix D show the block diagram and overview structure of this ARS system at a substation.

2 REFERENCES

This Specification makes reference to, or should be read in conjunction with the following documents:

NGTS 3.24.4 Hardware Platform
NGTS3.24.69 Quality of Supply
NGTS3.24.72 Operational Metering Summator

3 ABBREVIATIONS AND DEFINITIONS

ARS:	Automatic Reactive Switching.
Busbar:	A length of conductor in a substation to which circuits (including transformers) are connected.
Busbar group:	A busbar or a group of connected busbars.
Controlled Plant:	Reactive plant under ARS control.
HMI:	Human Machine Interface.
HVARs:	The ARS or a function module to control HV shunt reactive plant (comprising HV MSCs and HV reactors).
HV MSC:	The MSC connected to the busbar at 275 kV or above.
HV Reactor:	The reactor connected to the busbar at 275 kV or above.
Inhibit:	To temporally suspend a defined function. Release of the inhibit condition will permit suspended function to proceed, if it is still required.
Lockout:	To stop or prevent a defined function from functioning. The prevented function normally is not automatically recoverable when the lockout condition clears. It can only be re-enabled by users through Human-Machine Interface.
LVARS:	The ARS or a function module to control LV shunt reactive Plant (comprising LV MSCs and LV Reactors).
LV MSC:	The MSC connected to the busbar or transformer secondary/tertiary at 132 kV or below.
LV Reactor:	The reactor connected to the busbar or transformer secondary/tertiary at 132 kV or below.
LV Reactive Plant:	General term for LV MSCs and LV Reactors.
MSC:	Mechanically Switched Capacitor.

Plant:	In this document, plant refers to heavy current equipment at a substation, such as power transformers, Switchgear, Voltage/Current Transformers.
RCP:	Remote Control Point. This is normally at the National Grid Control Centre but may be at a manned control point.
Reactive Plant:	Refers to shunt MSCs or reactors in this document.
SCP:	Substation Control Point. A facility on site, providing full centralised control and monitoring facilities for the whole site. To be used for maintenance roles and for operation of the site in the event of loss of remote facilities.
SCS:	Substation Control System.
SICAP:	Substation Information Control and Protection. The SICAP strategy specifies the future requirements for Substation Information Control and Protection system of National Grid Company.
SGT:	Supergrid Transformer, which is used in National Grid Transmission System.
Switchgear:	General name for a disconnector or circuit breaker.

4 GENERAL FUNCTIONAL REQUIREMENTS

- 4.1** The Automatic Reactive Switching (ARS) system shall monitor and control the 400/275 kV system voltage by switching shunt reactive plant at a substation.

Informative: The reactive plant includes Mechanically Switched Capacitors (MSCs), and reactors. The reactive plant may be connected to HV busbars, HV feeders, HV mesh corners, LV busbars, the LV or tertiary (TV) of a supergrid transformer (SGT).

- 4.2** The ARS system shall be capable of controlling up to 4 HV reactive plant and an unspecified quantity of other reactive plant at a site.

Informative: A substation can have various permutations of HV/LV/Tertiary connected reactive plant.

- 4.3** The ARS system shall include the functions of HVARS, LVARS and Co-ordination. The HV and the LVARS shall control the HV and LV reactive plant respectively. The co-ordination function shall co-ordinate the switching operations within an ARS system.

- 4.4** Each item of the HV plant shall have its own dedicated HVARS module to enable the HV MSC be re-locatable. All LV reactive plant shall be controlled by either a centralised LVARS module or by a dedicated one for each item of the plant.

Informative: the overview structure of such an ARS system is shown in Figure 2.

- 4.5** It shall be possible to configure this ARS system into a LVARS or HVARS system where a site has only LV or HV reactive plant.

Informative: Either centralised or distributed control structure may be used to implement this ARS system. For the centralised structure, all the HVARS, LVARS and co-ordination modules will reside within a one cubicle. Where for the distributed structure, each of the functional modules may have its own cubicle.

- 4.6** All the HVARS and LVARS functions shall comply with the functional requirements in this section. The specific requirements for LVARS, HVARS and their Co-ordination are specified in section 5, 6, 7.

Substation Size and Topology

- 4.7** The ARS system shall be capable of handling substation topologies with the maximum sizing limits defined in the table C1 of Appendix C for HV, LV and tertiary taken concurrently.

Informative: Substation topology refers to the electrical connectivity among the plant within a substation. It will generally conform to a double busbar or mesh configuration, although there are some non-standard substation layouts within Nation Grid system. Substation Layout and Plant Ratings will be specified in the contract document for a specific contract.

- 4.8** The ARS system shall be capable of handling the elements/plant and their associated attributes as specified in the table C2 of Appendix C.
- 4.9** The ARS system shall be capable of handling connection paths containing up to eight switchgear in series. It shall be possible for a connection path to be defined which contains no switchgear. Any given switchgear shall be capable of being in more than one connection path.

Informative: A connection path is the link between a plant item and an associated busbar. A connection path can be formed through switchgear and transformers as well as other plant items.

Control Points and Facilities

- 4.10** There shall be 3 main control points for an ARS system. These are the local control point (LCP), Substation Control Point (SCP) and Remote Control Point (RCP). A selection facility shall be provided to enable control to be switched from the LCP to the SCP/RCP, see Figure1.

Informative: For an ARS system with a distributed structure, a Module Control Panel (MCP) may be needed for each HVARS or LVARS Module.

- 4.11** When one control point is selected, control from other control points shall be inhibited.
- 4.12** The ARS shall provide the following control functions as specified in the table below. These functions shall be available at appropriate control points of an ARS system.

Control Functions	Actions	Control Points
Auto Control OFF	No ARS functions available.	RCP, SCP, LCP HVARS and LVARS MCPs*
Auto Control ON	Protection, Coarse Voltage Control and Manual Control modes available for the ARS system.	RCP, SCP, LCP HVARS and LVARS MCPs*
Fine Voltage Control ON/OFF	Fine Voltage Control made available/unavailable (for LVARS) provided Auto Control is ON.	RCP, SCP, LCP LVARS MCP*
Raise Volts by LV Plant	This control will request the Manual Control Mode to switch a reactor Out or LV MSC In as appropriate.	RCP, SCP, LCP LVARS MCP*
Lower Volts by LV Plant	This control will request Manual Control Mode to switch a LV MSC Out or reactor In as appropriate.	RCP, SCP, LCP LVARS MCP*
Raise Volts by HV Plant (Per HV Plant)	Requests EMS/Manual Mode Raise Volts by switching out/in each item of HV Reactor/MS	RCP, SCP, LCP HVARS MCP*
Lower Volts by HV Plant (Per HV Plant)	Requests EMS/Manual Mode Lower Volts by switching out/in each item of HV MSC/Reactor	RCP, SCP, LCP HVARS MCP*
Voltage Targets 1 - 5	These controls shall enable the operator to select one of five HV voltage targets	RCP, SCP, LCP HVARS and LVARS MCPs*
Plant (ID) Selected (Per Plant)	This control allows the user to select/deselect each item of controlled reactive plant for automatic control.	RCP, SCP, LCP HVARS MCP*

*For the ARS system with a distributed structure only, see Clause 4.5 and Clause 4.10

- 4.13** The selected control functions shall be indicated at all the control points.
- 4.14** When an ARS is powered-up, it shall be set to Auto Control and Fine Voltage Control "Off", and adopt a target voltage preset in database.
- 4.15** It shall be possible to select to one of the five pre-set voltage targets for the ARS system. The target voltages shall be settable in the range of $\pm 10\%$ of HV nominal system voltage.

Input and Output Signals

- 4.16** The operating position of all the monitored circuit breakers and disconnectors shall be sensed as double point inputs indicating open or closed or discrepancy position (ie Do not Believe It "DBI").
- 4.17** The ARS system shall provide separate open and close control pulses to operate the controlled plant's circuit breakers.
- 4.18** The output for both the open and close controls shall be provided by 2 normally open voltage free contacts, which are closed to provide a pulse of up to 2 seconds duration.

Informative: Control output requirements are given in NGTS 3.24.4.

- 4.19** All control outputs shall incorporate a check mechanism following the principle of NGTS 3.24.4, which ensures a secure operating sequence is followed. The control system shall monitor all control outputs and controlled plant position status and alarm any malfunction.
- 4.20** The ARS system shall provide the following analogue outputs for recording by System Monitoring Equipment (NGTS 3.24.69) and the substation control point interface equipment:-
- (a) HV Voltage (Average HV group voltage) (2 Outputs)
 - (b) Target Voltage (1 Output)
 - (c) Raise/Lower HV Volts (1 Output)
- 4.21** Each analogue output channel shall be capable of driving a 0 to 22 mA constant current analogue output channel that can be scaled with an $Mx + C$, characteristic.

Control Principles

- 4.22** The ARS system shall assign to each item of controlled reactive plant (called controlled Plant hereinafter) the status of either Available or Unavailable for control. Each item of the controlled plant shall be marked Available for automatic control if the following conditions are met as appropriate:-
- (a) The controlled plant disconnector is CLOSED.
 - (b) Where several plant items are connected via a common circuit breaker (ie they form a "set") the common circuit breaker is CLOSED.
 - (c) LV reactive plant has a live closed electrical path from LV to HV (excluding the controlled circuit breaker).
 - (d) TV reactive plant that has a live closed electrical path direct from TV to HV (Paths via LV connections shall not be included).
 - (e) HV plant has a live path to HV (excluding the controlled circuit breaker).
 - (f) None of the conditions specified in Clause 4.23.
- 4.23** Each item of controlled plant shall be marked Unavailable for automatic control if any of the following conditions are met as appropriate:-
- (a) A controlled plant Lockout condition has been detected.
 - (b) An unrequested switching operation of a controlled plant has been detected - operation of circuit breaker under ARS control is not initiated by the ARS (except for the condition specified in Clause 4.75).
 - (c) A Plant under ARS control fails to respond to a switching request by ARS.

- 4.24** When controlled Plant is made unavailable for the conditions specified in 4.23, this plant can only become available again if the user resets the ARS plant unavailable condition. An indication shall be made for each item of Controlled Plant to indicate its availability status. If plant is not selected for automatic control then lockout and unrequested operations shall be ignored.
- 4.25** Plant shall only be under ARS Control if the plant is Available and Selected for Auto Control.
- 4.26** Where a switchgear position returns a DBI (Don't Believe It) for a pre-set DBI Confirmation Time (DBICT, refer Appendix A), then a DBI alarm shall be raised and ARS system shall be switched to Auto Control "Off" for all controlled plant.
- 4.27** While a plant DBI is being confirmed, the plant position status shall maintain its existing Open/Closed status until the DBI condition has been confirmed.
- 4.28** A selective facility shall be available to override the DBI status for a switchgear. This facility shall be achieved via monitoring/diagnostic facilities or the LCP/SCP as appropriate. When DBI override is set for a switchgear, ARS system shall treat the status of the switchgear as open regardless of its actual state, and an indication "DBI Override" shall be illuminated at the LCP and RCP.
- 4.29** All the events and faults associated with or affecting the ARS function shall be logged.
- 4.30** The ARS system shall provide a count of the number of ARS operations of each circuit breaker under ARS control. This data shall be stored internally and accessed via the diagnostic facility. It shall be possible to reset the counter by using an appropriate monitoring/diagnostic facilities.
- 4.31** The ARS system shall provide the following modes of operation listed in order of control priority:-

ARS Modes of Operation	Operating Function	Related Module
Protection	Monitors and protects the HV busbars to which the HV reactive plant are connected, from over-voltage.	HVARS
	Monitors and protects the LV busbars to which the LV reactive plant are connected from over-voltage.	LVARs
Coarse Voltage Control	Fast switching of HV reactive plant to correct large HV voltage variations.	HVARS
	Fast switching of LV reactive plant to correct large HV voltage variations.	LVARs
Fine Voltage Control	Slow switching of LV reactive plant to maintain the voltage within set limits of user selected target voltage.	LVARs
HV Plant EMS/Manual Control	Actions requested by operator to raise/lower the HV system volts by switching the HV reactive plant.	HVARS
LV Plant Manual Control	Actions requested by operator to raise/lower the HV system volts by switching the LV reactive plant.	LVARs

- 4.32** When voltage target Changes, the new target shall ramp to the new target at a preset rate (Voltage Target Ramp Rate "VTRR", refer Appendix A). However, the indication of the voltage target change shall take effect immediately at all the control points.

Informative: This ramping function is to avoid the fast reactive switching due to the voltage target change.

- 4.33** If the ARS issues a circuit breaker control request and the plant fails to respond the ARS shall make the plant unavailable and raise an alarm "External Fault".
- 4.34** The ARS facility shall, where possible, evenly distribute switching actions between the same type of reactive plant (i.e. MSCs or reactors) at the same voltage level.

- 4.35** The ARS system shall be capable of recognising the connectivity between the reactive plant and the HV system by detecting the HV or LV groupings. The reactive plant shall only be switched to control the HV system if the plant is connected or has a path to a live HV system.

Informative: A substation is capable of being subdivided into a number of separate HV and LV groups. An HV/LV group is defined as a part of HV/LV substation, in which plant (including busbars) are electrically connected internally, and separated externally from other parts of substation. Where there are both HV and LV splits, the substation may be split into two or more independent systems (system split). Plant within an independent system is electrically connected via either LV or HV system, and separated from other independent systems. See Figure 5 in Appendix D.

- 4.36** If the substation is electrically split at HV and LV to form two or more independent systems, the ARS system shall be able to recognise the situation and form an LVAR system for each independent system (control group). Each of the LVAR systems shall be capable of controlling each control group independently.
- 4.37** If the ARS equipment fails due a power failure or non-hardware fault, the ARS shall be capable of automatically restarting without the need for manual intervention when the fault or failure clears. When the equipment restarts it shall not place the controlled plant under automatic control.
- 4.38** When a switching operation by the ARS system is initiated, the indication "Switching in Progress" shall be produced until the switching operation is completed or cancelled.
- 4.39** Switching operations shall be cancelled if the requested switching operation is not possible or is not completed within a pre-set time of the control being accepted " Switching Complete Time (SCT)".
- 4.40** If a switching request by the ARS system is cancelled or not accepted, a "Switching Incomplete" indication shall be set for 5 Second and if set, the "Switching in Progress" indication shall be automatically reset after the 5 Second period.
- 4.41** When reactive switching is initiated by Fine Voltage Control Mode or Manual Control Mode, an output "Breaker Operation Warning" shall be provided in form of clear contact. This output shall be set for 5 seconds before the actually switching is carried out.
- 4.42** The ARS system shall monitor its ability to function correctly. Any detectable hardware or software failure shall cause the "ARS Faulty" alarm and the ARS system shall suspend some or all automatic control function as appropriate.
- 4.43** "External fault" Alarm shall be generated when the following situations occur:
- (a) Plant DBI;
 - (b) Unrequested plant operation;
 - (c) Plant Lockout;
 - (d) Plant fails to respond,
 - (e) Analogue Error

Voltage Measurements

- 4.44 The ARS system shall monitor the voltage, if available, at the following points as shown in the table:

Voltage Measurement Points	Required by
HV Reactive plant Connection Point	HVARS
Busbars at HV Substation	HVARS, LVARS
Feeders at HV Substation	HVARS, LVARS
Transformer HV connection point.	HVARS, LVARS
Busbars at LV Substation	LVARS
Feeders at LV Substation	LVARS
Transformer LV connection point.	LVARS
Transformer Tertiary connection point.	LVARS

- 4.45 The power system voltage inputs to the ARS system shall be supplied from Capacitive Voltage Transformers (CVTs) or Wound Voltage Transformers (WVTs) with an output of 63.5 V rated secondary. Only single-phase voltage measurement shall be used for the ARS system. A balanced load and voltage shall be assumed at all times.
- 4.46 All voltage measuring transducers (if applicable) shall be full range 4 - 20 mA true rms in accordance with NGTS 3.24.72. When a voltage transducer's output is below 3 mA or above 21 mA, this transducer shall be marked as faulty and an alarm raised if the condition persists for more than 2 s. During the confirmation period the suspect analogue shall be ignored. The alarm shall clear when the transducer input returns to the range 4 - 20 mA.
- 4.47 Outputs from faulty transducers shall not be used until the fault is cleared.
- 4.48 The measurement process shall incorporate smoothing to minimise the impact of 50 Hz ripples on transducer signals.
- 4.49 If a voltage transformer is connected to busbar via a circuit breaker, connectivity shall be checked before the voltage measurement is used for ARS.
- 4.50 Validity checks shall be performed on each voltage input. A voltage input shall be classified as "live" if its level is greater than a pre-set value "LIVE%" of the nominal system voltage. The voltage is "dead" if its level is less than a pre-set value "DEAD%" of the nominal system voltage.
- Informative: The setting ranges for those parameters are given in Appendix A.*
- 4.51 A voltage input shall be treated as invalid if its value stays between the pre-set value of "Live" and "dead" for a pre-set period of time "Voltage DBI time (VDBIS)". This invalid voltage input shall not be used.
- 4.52 If there are no valid voltage measurements available for an HV busbar/group (see Clause 4.35) for a pre-set period of time "HV group dead time (HVDS)", then an alarm "No HV Voltage" shall be generated, and the HVARS or LVARS associated with the group shall be locked out.

- 4.53** The ARS system shall measure the HV, LV or tertiary voltage steps that occur following switching of reactive plant. These include:
- (a) Measured LV voltage step by LVARS (MLVVS).
 - (b) Measured TV Voltage Step by LVARS (MTVVS).
 - (c) Measured HV Voltage Step by LVARS (MHVVS1).
 - (d) Measured HV Voltage Step by HVARS (MHVVS2).
- 4.54** Voltage step measurements taken within 2s after an ARS switching operation shall not be used in determining the measured voltage step.
- 4.55** The minimum and maximum limits shall be applied to those measured voltage steps to avoid registering spurious values. If a measured value is Lower/higher than its minimum/maximum, it shall be reset to the minimum/maximum values as appropriate.

Informative: There are also other conditions for resetting the measured voltage step values to their minimum and maximum limits as specified in the clauses below.

Voltage Measurement- Measured LV Voltage Step

- 4.56** The Measured LV Voltage Step (MLVVS) shall be used by LVARS Protection Mode for calculating deadbands.
- Informative: MLVVS can be multi-valued to cover situations where the LV part of a substation is split into two or more LV groups, each containing controllable reactive plant.*
- 4.57** Where there are two or more groups of LV reactive plant or busbar groups, the MLVVS shall be derived separately for each group so that the thresholds for the LVARS Protection Mode, Delta LV Inhibit can be calculated separately for each LV group.
- 4.58** The MLVVS shall be updated each time the ARS system undertakes an LV/TV switching operation from any ARS control mode including Manual Control Mode. It shall not be updated for HV switching operations.
- 4.59** Preset upper and lower limits (MLVVSmax, MLVVSmin) shall be applied to MLVVS. The MLVVS shall be reset to its lower limit for each of the following transitions:-
- (a) When Auto Control is selected.
 - (b) When Fine Voltage Control is selected.
 - (c) The LV busbar changes from a split busbar to a solid busbar condition.
- 4.60** When a LV busbar becomes split, the last value of MLVVS shall be carried over to each side of the split. The value of MLVVS for each LV group will then be updated independently for LV MSC or reactor switching on either side of the split.

Voltage Measurement -Measured TV Voltage Step

- 4.61** The Measured TV Voltage Step (MTVVS) shall be derived from the tertiary voltage.
- 4.62** Upper and lower limits (MTVVSmax, MTVVSmin) shall be applied to MTVVS to avoid registering spurious values, see Appendix A.
- 4.63** The MTVVS shall be derived separately for each SGT tertiary or its busbar with compensation plant connected. It shall only be updated when a switching operation takes place on that plant. It shall be reset to its lower limit for the same conditions as the MLVVS, including LV re-coupling.
- 4.64** Where tertiary plant exists without its own voltage measurement, the LVARS shall treat the plant as being connected to the LV feeder of the SGT. Protection Mode shall then make use of the LV voltage measurements to estimate of the tertiary voltage level.

Voltage Measurement - Measured HV Voltage Step by LVARs

- 4.65** The Measured HV Voltage Step (MHVVS1) is the change in HV voltage that occurred when the last LV or tertiary connected MSC or reactor was switched.

Informative: MHVVS1 will be used to calculate deadbands by Coarse and Fine Voltage Control Modes for LVARs (see Section 5 LVARs). The value of MHVVS1 should be scaled according to the Mvar rating of the next item of LV reactive plant to be switched.

- 4.66** Upper and lower limits (MHVVS1max, MHVVS1min) shall be applied to MHVVS1. The MHVVS1 shall be reset to its lower limit value (MHVVS1min)

- (a) When Auto Control is selected; or
- (b) When Fine Voltage Control is selected.

- 4.67** If the substation is electrically split at HV and LV to form 2 ARS control groups, the value of MHVVS1 shall be carried over to both systems. If two ARS control groups join then the value of MHVVS for the combined control group shall be set to the minimum value for MHVVS1. HV/LV splits which do not cause a new ARS control group to be formed shall be ignored.

Voltage Measurement - Measured HV Voltage Step by HVARs

- 4.68** The Measured HV Voltage Step (MHVVS2) is the change in HV voltage that occurred when the last HV reactive plant was switched.

Informative: MHVVS2 will be used for calculating the deadbands for HVARs (see section 6).

- 4.69** Upper and lower limits (MHVVS2max, MHVVS2min) shall be applied to MHVVS2. The MHVVS2 shall be reset to its lower limit value (MHVVS2min) when Auto Control is selected.

- 4.70** If the substation is electrically split at HV into 2 HVARs control groups, the value of MHVVS2 shall be carried over to both systems. If two HVARs control groups join, then the value of MHVVS for the combined control group shall be set to the minimum value for MHVVS2.

Lockouts and Inhibits

- 4.71** For each item of controlled plant, the ARS system shall have a Lockout input which when active will immediately make the plant unavailable for control. Lockout must be active for a minimum time of 100 ms to be recognised by the ARS.

- 4.72** The plant shall only be made available for control once the Lockout condition has been reset and the plant item has been selected for control via the ARS system.

- 4.73** For each item of controlled plant, the ARS shall have an Inhibit input which when active will prevent control of the associated circuit breaker. When the Inhibit condition resets, control of the plant is automatically reinstated after 2 seconds time delay.

- 4.74** Where when the ARS receives the Lockout and Inhibit inputs for a controlled plant at the same time, the lockout function shall take priority.

- 4.75** Following "an unrequested plant operation", if the Inhibit condition for the plant is established within a pre-set period of time "unrequested plant operation Delay (UPOD)", the plant item shall not be made unavailable for control, see Clause 4.23.

Informative: This requirement is for the co-ordination with power system protection tripping scheme.

Human-Machine Interface

- 4.76** The Human Machine Interface (HMI) shall be provided for an ARS system. The control facilities and the alarms/indications detailed in Appendix B shall be displayed on the HMI.