

STATIC VAR COMPENSATOR BAY FUNCTIONS

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PURPOSE AND SCOPE

This Specification describes the functional and performance requirements for the protection of 400 kV and 275 kV SVCs.

The detailed requirements for back-up protection for SVCs are specified in TS 3.24.38 Back-up Protection.

The requirements for devices for mechanical protection, including gas and oil actuated relays, and oil winding temperature instruments are specified in TS 2.3 Power Transformers and Reactors. This Specification only specifies their function within the SVC electrical protection system.

The requirements for the protection of HV connections associated with the SVC are specified in TS 3.24.65 Overall Protection.

The requirements for the trip relay resetting schemes are specified in TS 3.24.87 Trip Relays and Trip Relay Resetting.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 Functional Requirements

For the purposes of this Specification the SVC should be considered as comprising the following primary components:

- a) Static Compensator Transformer (SCT).
- b) Earthing/Auxiliary Transformer.
- c) LV Connections.
- d) Thyristor Switched Capacitors (TSC) comprising capacitors, reactors and resistors where appropriate.
- e) Thyristor Controlled Reactors (TCR).
- f) Filter Bank(s) comprising capacitors, reactors and resistors where appropriate.

The SVC protection system shall comprise main protection, back-up protection and mechanical protection devices, as appropriate, for each of the above primary components, as described in Sections 1.1.1 to 1.1.6 respectively.

These protection devices shall operate into two independent tripping systems as described in Section 1.1.7 to provide a complete protection system, as shown in Appendix A.

Each of the above items 1.1a-f shall be considered as separate protected zones and it shall be possible to identify the location of primary phase and earth faults by the operation of the zone main protection(s).

A typical arrangement of the interconnections of the SVC protection system with associated plant, equipment and other protection systems within the substation is given in TS 2.24.

For alternative SVC arrangements, differing from those specified above, the outline protection requirements are given in Section 1.5.

1.1.1 Static Compensator Transformer

a) Main Protection

Two main protections driven from a common current transformer circuit shall be provided. At least one main protection shall be provided by an overall unit protection relay which is responsive to both phase to phase and phase to earth faults on the transformer and its associated connections. The other main protection shall, as a minimum, be sensitive to earth faults on both HV and LV windings.

If a biased differential principle is used, the protection must comply with the requirements of IEC 255-13.

The primary operating current for earth faults shall be set as per PS(T) 010. The protection shall not give an unwanted operation under any normal operating conditions or external fault conditions, and shall remain stable for all inrush or outrush transients, and harmonics generated by the SVC.

b) Back-up Protection

Back-up protection shall be provided in accordance with TS 3.24.38 and shall consist of the following:

- HV 3-phase overcurrent protection
- HV 3-phase instantaneous high set overcurrent protection

These shall be supplied from a three phase set of current transformers located adjacent to the HV circuit-breaker(s).

c) Mechanical Protection

- Gas and Oil Actuated Protection

Gas and oil actuated relays specified in TS 2.3 shall be provided to protect each separate main tank associated with the transformer against loss of oil and oil surge.

- Winding Temperature Protection

Winding temperature instruments, specified in TS 2.3 shall be provided to protect the HV and LV windings from winding over-temperature.

1.1.2 Earthing/Auxiliary Transformer

a) Main Protection

Where the earthing/auxiliary transformer is not included in the zone of protection of the Static Compensator Transformer overall protection or the LV Connections overall protection, the HV winding of the earthing/auxiliary transformer shall be separately protected against earth faults by a restricted earth fault relay.

b) Back-up Protection

In order to provide back-up earth fault protection to the TCR, TSC, Filter and LV Connections, unrestricted earth fault protection specified in TS 3.24.38 shall be provided. The protection shall be energised from a current transformer located on the HV neutral-earth connection of the earthing/auxiliary transformer.

c) Mechanical Protection

The earthing/auxiliary transformer shall be provided with a gas and oil actuated relay to protect against loss of oil and oil surge.

1.1.3 LV Connections

An overall unit main protection responsive to both phase faults and earth faults shall be provided to protect the LV Connections, in accordance with the requirements specified in TS 3.24.65, although only a single A.C. fault detection relay is required. CT buswire supervision is only required for high impedance relays. The TSC, TCR and Filter Bank branch LV Connections protection current transformer secondary wiring shall be shorted and disconnected from the LV Connections buswiring, via auxiliary switches or repeat relay contacts associated with the respective disconnectors. Where a high impedance scheme is applied this would need to be duplicated.

The setting range shall be 10%-30% of the available earth fault current.

The LV Connections protection zone should overlap the Static Compensator Transformer overall protection and the TCR, TSC and Filter Bank branch overall unit protections.

1.1.4 Thyristor Switched Capacitor

a) Main Protection

A single main protection shall be provided by an overall unit protection relay which is responsive to both phase-to-phase and phase-to-earth faults on the TSC.

If a biased differential principle is used, the protection shall comply with the requirements of IEC 255-13.

The unit protection shall include in its zone of protection the thyristor valve and overlap the LV Connections protection zone.

The protection shall be stable for all inrush or outrush transients, and harmonics generated by the SVC and flowing into the SVC equipment from the supply system. It shall not give unwanted operation under normal operating conditions or external fault conditions.

The setting range shall be 10%-30% of the available earth fault current at the TSC terminals.

b) Back-up Protection

Back-up protection shall be provided in accordance with TS 3.24.38 and shall consist of a three-phase definite time overcurrent protection.

c) Capacitor Excessive RMS Overcurrent Protection

Three-phase excessive RMS overcurrent protection shall be provided for all capacitor banks forming part of the TSC in accordance with TS 3.24.77.

d) Capacitor Overvoltage Protection

Capacitor overvoltage protection shall be provided for all capacitor banks forming part of the TSC in accordance with TS 3.24.77.

e) Capacitor Out-of-Balance Protection

Capacitor out-of-balance protection shall be provided for all capacitor banks forming part of the TSC in accordance with TS 3.24.77.

f) Reactor Thermal Overload Protection

Reactor Thermal Overload Protection shall be provided in accordance with TS 3.24.78.

g) Resistor Thermal Overload Protection

Resistor Thermal Overload Protection shall be provided in accordance with TS 3.24.78.

h) Resistor Open Circuit Protection

Where resistors are employed, resistor open circuit protection shall be provided. The protection shall be able to detect resistor open circuit and high resistance fault conditions and shall give a trip output after a time delay. The protection shall be

stable for inrush or outrush transients and harmonics and shall not give an unwanted operation under any normal operation conditions or external fault conditions.

The setting range of the time delay shall be 0.1 s - 5 s in steps of 0.1 s.

i) Other Protection

Protection trip output(s) shall be provided from the TSC thyristor cooling/control scheme according to the design of the particular scheme supplied.

1.1.5 Thyristor Controlled Reactor

a) Main Protection

Main protection is to be provided, as described for the Thyristor Switched Capacitor in Section 1.1.4a.

b) Reactor Thermal Overload Protection

Reactor Thermal Overload Protection shall be provided in accordance with TS 3.24.78.

c) Back-up Protection

Back-up protection shall be provided in accordance with TS 3.24.38 and shall consist of a three- phase EIDMT overcurrent protection.

d) Other Protection

- Protection trip output(s) shall be provided from the TCR thyristor cooling/control scheme according to the design of the particular scheme supplied.
- Where oil filled reactors are used, suitable gas and oil actuated protection shall be provided as specified in TS 2.3.

1.1.6 Filter Bank

a) Main Protection

Main protection is to be provided, as described for Thyristor Switched Capacitor in Section 1.1.4a.

b) Capacitor Excessive RMS Overcurrent Protection

Three-phase excessive RMS overcurrent protection shall be provided for all capacitor banks forming part of the filter(s) in accordance with TS 3.24.77.

c) Capacitor Overvoltage Protection

Capacitor overvoltage protection shall be provided for all capacitor banks forming part of the filter(s) in accordance with TS 3.24.77.

d) Capacitor Out-of-Balance Protection

Capacitor out-of-balance protection shall be provided for all capacitor banks forming part of the filter(s) in accordance with TS 3.24.77.

e) Reactor Thermal Overload Protection

Reactor Thermal Overload Protection shall be provided in accordance with TS 3.24.78.

f) Resistor Thermal Overload Protection

Resistor Thermal Overload Protection shall be provided in accordance with TS 3.24.78.

g) Resistor Open Circuit Protection

To be provided as Section 1.1.4h where applicable.

1.1.7 Protection System

Two separately energised independent tripping systems shall be provided. Each tripping system shall operate the HV circuit breaker(s), via high burden electrically reset latching trip relay(s) or equivalent. as specified in TS 3.24.87.

The following SVC protections shall be arranged to energise the trip relay(s) of the first tripping system:

- a) SCT biased differential protection.
- b) SCT main gas and oil actuated protection.
- c) Earthing transformer gas and oil actuated protection.
- d) Earthing transformer earth fault protection.
- e) LV connections overall protection.
- f) TSC overall protection.
- g) TSC capacitor excessive RMS overcurrent protection.
- h) TSC capacitor overvoltage protection.
- i) TSC reactor thermal overload protection (where applicable).
- j) TSC resistor thermal overload protection (where applicable).
- k) TCR overall protection.
- l) TCR reactor thermal overload protection (where applicable).
- m) TCR reactor gas and oil actuated protection (where applicable).
- n) Filter overall protection.
- o) Filter capacitor excessive RMS overcurrent protection.
- p) Filter reactor thermal overload protection (where applicable).
- q) Filter resistor thermal overload protection (where applicable).

The following SVC protections shall be arranged to energise the trip relay(s) of the second tripping system:

- a) SCT HV restricted earth fault protection.
- b) SCT LV restricted earth fault protection.
- c) SCT HV winding circulating current protection.
- d) SCT winding temperature.
- e) Earthing transformer restricted earth fault protection.
- f) TSC overcurrent protection.
- g) TSC capacitor out-of-balance protection.
- h) TSC resistor open circuit protection (where applicable).
- i) TSC thyristor control/cooling.
- j) TCR overcurrent protection.
- k) TCR thyristor control/cooling.
- l) Filter capacitor overvoltage protection.
- m) Filter capacitor out-of-balance protection.
- n) Filter resistor open circuit protection (where applicable).

All protections will trip both trip systems on the HV Circuit Breakers

Where electrical protection, other than fuses, is provided on the LV side of the Earthing/Auxiliary Transformer then this shall trip into the SVC second tripping system.

Where gas and oil actuated protection is fitted to oil filled reactors or resistors, then it shall trip into the SVC first tripping system via the appropriate TSC, TCR and Filter Bank disconnector auxiliary switches.

Typical tripping logic diagrams for the first and second tripping systems for an SVC protection system are shown in Appendix A and B.

The HV connections between the HV circuit-breaker(s) and the static compensator transformer shall be protected by an HV connections protection system as specified in TS 3.24.65.

The HV high set overcurrent protection and HV overcurrent protection shall be connected to trip into the first and second tripping systems, respectively, of the HV connections protection system.

Where a wound VT is provided within the zone of the HV connections, then its gas/oil surge detection device shall be connected to trip into the first tripping system of the HV connections protection system. See TS 3.2.5.

1.2 Inputs

1.2.1 Power Supply

The tripping systems shall be designed to operate from a 110 V (nominal) D.C. battery specified in TS 3.12.4. Each tripping system shall be provided with a separately fused supply fed from different batteries where a 110v change over system is employed it shall be located in a cubicle which is separate from any Protection Relays panels and Control Cubicles

If an auxiliary energising supply is required, the protection equipment shall be designed to operate from a 110 V (nominal) D.C. battery as specified in TS 3.12.4. This auxiliary supply shall be taken from the tripping system supply to which the protection is connected and the failure of any single protection system will not cause the SVC to trip..

1.2.2 Current Transformers

The requirements for current transformers (CTs) at 400 kV, 275 kV and 132 kV are specified in TS 3.2.4. At lower voltages the requirements shall be in accordance with IEC 60044-1.

Details of other current transformer arrangements acceptable to National Grid are given in TS 2.1 and TS 2.24.

1.2.3 Contact Initiations

The protection system shall be provided with inputs from the auxiliary switches of the TSC, TCR and Filter Bank disconnectors.

1.2.4 D.C. Initiations

The protection system shall be provided with an input to receive a D.C. signal for trip relay reset (110 V D.C.).

1.3 Outputs

1.3.1 Trip Outputs

The trip relays of each tripping system shall be provided with output contacts for initiation of the following:

- a) Tripping the local HV circuit-breaker(s).
- b) Circuit-breaker fail protection.

1.3.2 Additional Outputs

The protection system shall be provided with outputs for initiation of the following:

- a) Disconnector sequential isolation (where required).
- b) Trip relay reset.
- c) SVC Control System.

1.3.3 Alarm Outputs

Protection operation or failure shall be annunciated through the substation alarm and event logging system.

The following protection alarm outputs shall be provided:

- a) Protection operated alarm for each electrical and mechanical protection.
- b) Trip relay operated indication (where required).
- c) Protection supply supervision alarm for each fused supply (refer to TS 2.24).
- d) Capacitor excessive RMS overcurrent stage 1.
- e) Capacitor overvoltage stage 1 and 2.
- f) Capacitor out-of-balance stage 1 and 2.
- g) Reactor thermal overload stage 1 and 2.
- h) Resistor thermal overload stage 1 and 2.

The following plant alarms associated with the protection shall be provided:

- a) SCT main gas alarm.
- b) SCT winding temperature alarm.
- c) Earthing transformer gas alarm (where required).
- d) TCR reactor gas alarm (where required).

If the protection equipment is of the static (analogue or digital) type, an alarm output of equipment inoperative shall be provided for the loss D.C. auxiliary energising supply and internal failures of the equipment.

1.3.4 Fault Recorder

Operation of SVC protection trip relays shall trigger, and be recorded on, a fault recorder. Refer to TS 3.24.71.

1.4 Operator Interface

The protection system shall be provided with the following, where appropriate, in accordance with TS 2.24:

- a) Setting Facilities.
- b) Indication Facilities.
- c) Isolation and Test Facilities via Test/Normal Switches and Trip Test Switches on all main protections.
- d) Informative Interface

1.5 Protection of Alternative SVC Arrangements

For SVCs using arrangements other than that described in Section 1.1, such as Voltage Source Converter (VSC) based SVCs (i.e. STATCOM), the protection of the static compensator transformer and associated connections to the SVC devices shall be in line with that described below for various transformer winding options.

Protection for the SVC device shall be specified by the contractor, based on the recommendation of the SVC manufacturer and submitted to National Grid for assessment and agreement.

1.5.1 Double Wound Static Compensator Transformer Arrangement

The following protections shall be provided:

- a) Static Compensator Transformer main, backup and mechanical protections as specified in Section 1.1.1.
- b) Earthing/auxiliary transformer main, backup and mechanical protection as specified in Section 1.1.2.
- c) LV connections protection, as specified in Section 1.1.3 (where LV connections are provided).

1.5.2 Multi-Wound Static Compensator Transformer Arrangement

The following protections shall be provided:

- a) Static Compensator Transformer main, backup and mechanical protections as specified in Section 1.1.1. The biased differential protection provided shall be capable of protecting three or more windings. LV restricted earth fault protection shall be provided separately for each LV winding.
- b) Earthing/auxiliary transformer main, backup earth fault and mechanical protections as specified in Section 1.1.2 where earthing transformers are fitted to delta LV windings.
- c) LV backup earth fault protection shall be provided for star windings by a definite time unrestricted earth fault relay energised from a current transformer located on the neutral-earth connection of the star winding.
- d) LV overcurrent protection shall be provided by a three phase definite time overcurrent relay energised from a current transformer located on the LV connections to each SVC device.

2 PERFORMANCE REQUIREMENTS

The performance requirements for SVC protections are specified below. LV connections overall protection and back-up protection performance requirements are given in the appropriate TS Level 3 Specifications.

2.1 General

The protection shall perform correctly in accordance with the requirements of this Specification for the range of power system conditions specified in TS 1 and TS 2.11 for the SVC equipment, and the range of environmental conditions specified in TS 2.24 and TS 3.24.15. In addition, the performance of the protection shall not be adversely affected by the worst conditions of transformer magnetising current, current transformer saturation, SVC inrush or outrush currents and harmonics.

2.2 Overall Unit Protection

2.2.1 Accuracy

The assigned error shall not be greater than 5%.

2.2.2 Resetting

The resetting time of the protection shall be no greater than 50 ms.

2.2.3 Drop Off/Pick Up Ratio

The drop off/pick up ratio of the protection shall not be less than 70%.

2.2.4 Operating Time

Operating time of the protection shall not exceed 30 ms at a fault current multiple of twice times setting.

2.2.5 Thermal Rating

The protection shall be capable of withstanding an unbalance current of 30% of rated current to cater for the condition of open circuit transformers under load conditions at maximum setting.

2.3 Capacitor Excessive RMS Overcurrent Protection

The assigned error of the RMS overcurrent pick up and operating time shall not be greater than 5% over the range 45 Hz to 1550 Hz. Where a VSC (STATCOM) is employed, the required operating frequency range is 45 Hz - 2450 Hz.

The resetting time of the protection shall be no greater than 50 ms.

The drop off/pick up ratio of the protection shall be sufficiently high to prevent sustained operation of the protection after inrush/outrush conditions, typically 80%.

2.4 Capacitor Overvoltage Protection

The assigned error of the overvoltage pick up and operating time shall not be greater than 5% over the range 45 Hz to 1550 Hz. Where a VSC (STATCOM) is employed, the required operating frequency range is 45 Hz - 2450 Hz.

The resetting time of the protection shall be no greater than 50 ms.

The drop off/pick up ratio of the protection shall be sufficiently high to prevent sustained operation of the protection after inrush/outrush conditions, typically 80%.

2.5 Capacitor Out-of-Balance Protection

The assigned error shall not be greater than 5%.

The resetting time of the protection shall be no greater than 50 ms.

The drop off/pick up ratio of the protection shall be sufficiently high to prevent sustained operation of the protection after inrush/outrush conditions, typically 80%.

2.6 Reactor and Resistor Thermal Overload Protections

The assigned error of the protection shall not be greater than 5%.

The drop off/pick up ratio of the protection shall not be less than 80%.

2.7 Resistor Open Circuit Protection

The assigned error of the protection shall not be greater than 5%.

The drop off/pick up ratio of the protection shall be sufficiently high to prevent sustained operation of the protection after inrush/outrush conditions, typically 80%.

2.8 Earthing Transformer Earth Fault Protection

Refer to TS 3.24.38.

2.9 Timing Relays

External timing relays shall comply with IEC 255-1-00. The assigned error of the timing relays shall not be greater than 5%.

3 TEST REQUIREMENTS

3.1 General

Tests stated in IEC 255-6, IEC 255-8 (for thermal overload protection), IEC 255-13 (for biased protection) and IEC 255-1-00 shall be carried out on the protection equipments in order to demonstrate that they meet the requirements specified in Section 2.

3.2 Environmental Tests

The protection equipments shall be demonstrated to meet the appropriate environmental test requirements specified in TS 2.24.

3.3 Protection Characteristics

The characteristics of the overall unit protection system and its accuracy shall be demonstrated. Two types of characteristic presentation that could be used (if appropriate to the principle of operation) are as follows:

a) Bias Characteristic

This is a plot of differential current against bias current at the margin of operation. This would be variable according to setting.

b) Polar Characteristic

This is a polar plot of the ratio of the currents at the relaying points at the margin of operation. This would be variable according to setting and current magnitude.

3.4 Conjunctive Tests with Current Transformers

Tests shall be carried out to determine the limits of stability and operating time during transient saturation of an equivalent CT. To obtain maximum flux in the CT, three faults shall be applied at the point-on-wave which produces maximum offset of the current waveform before reversing the point-on-wave and applying a further three faults.

4 NATIONAL GRID TYPE REGISTRATION

Only protection relays and products that are Type Registered by National Grid against this specification will be accepted under the Contract (See TS 1).

Where a particular protection relay or product offered is not National Grid Type Registered, then the Supplier shall obtain registration by confirming that the equipment complies with the requirements stated in this specification, using the self certification statement and compliance checklist provided by National Grid (See TS 1).

Any non-compliance and associated application limitation(s) shall be declared on the appropriate compliance checklist.

5 INTEGRATION TABLE

Informative: The following tables should be read in conjunction with the diagrams shown in Appendix A. Each table entry refers to a connection on the drawing to which it relates e.g. the table headed Sheet 3 MP1 refers to drawing MP1-Sheet 3. On that drawing is shown a connection number 'MP1 2' and labelled 'CB Trip 1 & 2' which is the tripping signal to the circuit breaker's Trip Circuit 1 & Trip Circuit 2 (shown on Sheet CB) and is initiated by the 'MP 1 operated' output. In the table this is described in line Spec Ref, which shows both the connection number (sheet ref) and label. It also shows under 'Other Ref', the connection number when it arrives at sheet CB.

5.1 Sheet 3 MP1

Spec Ref	This Sheet Ref	Other Sheet Ref	Label	Initiations	Comments
5.1.1	MP1 1	CB 1	CB TRIP 1 & 2	MP 1 Operated	TRIP output to the SVC circuit breaker – via Trip Circuit 1 & Trip Circuit 2.
5.1.2	MP1 2	BB 9 or CBF 10	START CBF	MP 1 Operated	TRIP output to initiate the CB fail function.
5.1.3	MP1 3	IM 8	FR TRG	MP 1 Operated	TRIP output to trigger the fault recorder.
5.1.4	MP1 4	CB 17	SVC disc closed	SVC disconnecter closed	Closed position indication from the SVC disconnecter if required.
5.1.5	MP1 5	CB 7	CT		Input from 3 phase measurement/protection current transformers.
5.1.6	MP1 6	CB 8	VT		Input from 3 phase SVC VT (if required by the Capacitor Protection)
5.1.7	MP1 A1	SCS A4	EVENTS/ALARMS/INDICATIONS		The alarms and indications are described in TS 3.24.65 and TS 3.24.77

5.2 Sheet 4 MP2

Spec Ref	This Sheet Ref	Other Sheet Ref	Label	Initiations	Comments
5.2.1	MP2 1	CB 2	CB TRIP 1 & 2	MP 2 Operated	TRIP output to the SVC circuit breaker – via Trip Circuit 1 & Trip Circuit 2.
5.2.2	MP2 2	BB 9 or CBF 10	START CBF	MP 2 Operated	TRIP output to initiate the CB fail function.
5.2.3	MP2 3	IM 9	FR TRG	MP 2 Operated	TRIP output to trigger the fault recorder.
5.2.4	MP2 4	CB 17	SVC disc closed	SVC disconnecter closed	Closed position indication from the SVC disconnecter if required.
5.2.5	MP2 5	CB 6	CT		Input from 3 phase measurement/protection current transformers.
5.2.6	MP2 6	CB 9	VT		Input from 3 phase SVC VT (if required by the Capacitor Protection)
5.2.7	MP2 A1	SCS A5	EVENTS/ALARMS/INDICATIONS		The alarms and indications are described in TS 3.24.77 and TS 3.24.78