

PROTECTION AND CONTROL FOR SERIES COMPENSATION BAYS

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TABLE OF CONTENTS

PURPOSE AND SCOPE.....	1
PART 1 – FUNCTIONAL AND PERFORMANCE REQUIREMENTS	1
1 GENERAL REQUIREMENTS	1
2 PROTECTION FUNCTIONS	3
3 CONTROL FUNCTIONS	12
4 INTERFACE REQUIREMENTS	19
5 PERFORMANCE REQUIREMENTS.....	20
6 TEST REQUIREMENTS	21
7 FORMS AND RECORDS	21
PART 2 - DEFINITIONS AND DOCUMENT HISTORY	21
8 DEFINITIONS	21
9 ACRONYMS	21
10 AMENDMENTS RECORD	22
11 IMPLEMENTATION.....	22
PART 3 - GUIDANCE NOTES AND APPENDICES	23
12 REFERENCES	23
APPENDIX A - INTEGRATION TABLE.....	25
APPENDIX B – TYPICAL ARRANGEMENTS OF SERIES COMPENSATION BAYS	27

PURPOSE AND SCOPE

This specification defines the functional and performance requirements for the protection and control of 400kV and 275kV Series Compensation (SC) Bays including the Fixed Series Capacitors (FSC) and the Thyristor Controlled Series Capacitors (TCSC). Typical arrangements of SC bays connected to National Grid transmission network are shown in Appendix B.

This document shall be read in conjunction with the Technical Specification for Series Compensation Bay as defined in TS 2.30. The impact of SCs on the protection and control of the compensated and adjacent circuits will be dealt with in a separate Technical Guidance (TGN) document.

PART 1 – FUNCTIONAL AND PERFORMANCE REQUIREMENTS

1 GENERAL REQUIREMENTS

1.1 General

Each SC bay shall be equipped with a control and protection system designed to operate satisfactorily under normal as well as abnormal conditions.

The protection and control of a SC shall be designed to ensure that no single failure may cause a fault to remain connected to the primary system. To implement this, independent and duplicated systems shall be considered by the Solution Provider as appropriate.

Where a TSCS is used, a duplicated (dual lane) system shall be considered for the protection and control functions to achieve a required availability. The dual lane system shall consist of an in-service lane and a hot-standby lane with a manual and an automatic changeover facility, and shall allow operational and/or maintenance activities, including the updating of any software or exchange of hardware within the hot standby lane while the other lane is in service.

The de-energisation, testing and re-energisation of the hot standby lane shall not cause a protection operation or disturbance to the operation of the in-service lane or series capacitor installation in general.

The protections shall be as independent as possible from the control functions and, such that control failures shall not limit the functionality of these protections, and vice versa. The protections shall always remain active and shall be powered by the two separate, independent power supplies.

Where protection and control functions are integrated within a same Intelligent Electronic Device (IED), the design shall satisfy the requirements for normal operations, maintenance as well as failure modes. Supplier(s) shall declare the integration arrangement in Table 1 of Appendix A.

The electronic protection and control functions specified in this document shall co-operate with primary protection devices such as MOV, Spark Gap, as appropriate.

All the protection and control functions for a SC shall be co-ordinated with, and have no adverse effects on those ones for the compensated feeder(s) and rest of connected AC network, including but not limited to AC and DC protection schemes, Flexible AC Transmission Systems (FACTS), Tripping and Intertripping arrangements, Operational Tripping Schemes (OTS), Delay Auto Re-close (DAR) schemes, over-loading requirements, etc.

1.2 Engineering Interface

Engineering interface shall be provided within a SC protection and control system for the setting configuration, commissioning, diagnostic and other engineering purposes. Software/Firmware version shall be clearly identifiable within the interface.

Auditoria shall be provided for version changes of configuration within the engineering interface.

1.3 Hardware and Accommodations

All the hardware, cubicles and other General Arrangements associated with the required functions in this specification shall comply with the relevant electrical, environmental and ancillary requirements in TS3.24.4, TS3.24.15, TS2.19.

1.4 Spares, Maintenance, Refurbishment and Replacement

Unless separately specified in the Contract, spares, maintenance, refurbishment and replacement requirements for SC protection and control systems shall comply with National Grid existing policies, particularly PS(T)12.08, PS(T)12.09, PS(T)12.10, PS(T) 024, PS(T) 035 and PS(T) 066.

All electronic circuits and devices, including those located on the platform, shall be easily accessible for maintenance and testing purposes.

Where appropriate, a test apparatus that simulates signals transmitted from the platform shall be provided to enable testing and Maintenance work to be performed on the ground level.

All protection and control equipment that require regular inspection and/or maintenance shall be listed in the Tender submission, together with the recommended inspection/maintenance intervals to achieve the required service life.

The Solution Provider shall supply fully documented method statements for the maintenance and replacement procedures for the protection and control equipment/system that may be located both on and off the capacitor platform.

1.5 Type Registration

SC protection and control systems shall be type registered in accordance with National Grid Transmission Procedure TP183 – Type Registration.

1.6 Quality Assurance

All the software/firmware version control and configuration parameter settings shall be managed as per TP107.

2 PROTECTION FUNCTIONS

The protection functions for a SC bay shall include Main Protection, Back up protection, Mechanical protection.

The SC bay shall have its own dedicated protection zone, which shall be separated from, but overlapped with those ones for the compensated circuit and other immediately connected plant as appropriate.

Informative: Triggering the spark gap and/or closing the bypass switch may also be initiated by the operation of SC protections to minimise the potential Transient Recovery Voltage (TRV) on the line CB(s). This will be confirmed by the Contract.

2.1 Main Protection

Main protection functions required for a SC bay shall comprise Overall protection, Capacitor protections, Damping Network protections, MOV protections, Spark gap protections, Trigger circuit supervision, Platform protections, Sub-harmonic protection, as well as additional protection functions for the TCSC where applicable.

Informative: All the main protection functions can be called up and applied separately as appropriate and necessary.

2.2 Overall Protection

An overall protection shall be provided for a SC in accordance with NGTS 3.24.65. The protection shall be responsive to both phase and earth faults. The protection shall be provided with self-supervision and CT supervision functions.

The setting range of the protection shall include 10 % - 50 % of the rated current of SC.

If the overall protection is of high impedance type, duplicated overall protection driven from common current transformers shall be provided for 400 kV and 275 kV SCs.

The operation of the overall protection shall

- a) Trigger Spark Gap and/or Close bypass switch as necessary,
- b) Trip the local line CB
- c) Send DTT to trip the remote CB of the compensated line,

- d) Lockout SC Automatic Functions (see Section 3.2) where applicable
- e) Generate an alarm

2.3 Capacitor Protections

Capacitor protection functions shall be provided as per NGTS 3.24.77 for each capacitor segment(s), within a SC installation. Each shall comprise excessive RMS overcurrent protection, Overvoltage protection and Out-of-balance protection unless the Contractor can demonstrate that the capacitor bank is adequately protected by alternative protection functions. The Solution provider shall declare how the capacitor protections are applied to each capacitor bank.

The operation of the above protections shall

- a) Trigger Spark Gap and/or Close bypass switch as necessary,
- b) Trip the local line CB,
- c) Send DTT to trip the remote CB of the compensated line,
- d) Lockout SC Automatic Functions (see Section 3.2) where applicable
- e) Generate an alarm.

Informative: Capacitor over-voltage protection here is a backup for the over-voltage protection provided by MOV.

Where the discharge current which occurs due to the short circuit of a capacitor unit is of sufficient magnitude to cause unacceptably high voltages on the secondary wiring of the out-of-balance protection, effective means of limiting this voltage shall be employed.

2.4 Damping Network Reactor Open Circuit Protection

The Reactor Open Circuit Protection shall be provided for each reactor to detect reactor open circuit conditions.

The protection shall be stable for inrush or outrush transients and harmonics and shall not give an unwanted operation under any normal operating conditions.

The supplier shall declare the method of measurement employed by the Reactor Open Circuit Protection.

The operation of the above protections shall generate an alarm.

2.5 MOV Protections

MOV protections shall include MOV overload protections and MOV failure protection.

2.5.1 MOV Overload Protections

The MOV overload protection shall be provided to protect the MOV from high energy injection overload as well as thermal overload. A typical MOV overload protection shall include three functions:

- Short time MOV energy protection
- High MOV current protection

- High MOV temperature protection

On operation, the above protections shall

- Trigger the spark gap
- Close the bypass switch
- Generate an Alarm
- Initiate DARI where applicable

Informative: The protection systems shall properly determine the energy absorbed by the MOV during system faults. The energy can be calculated as the integral of the dissipated power in the MOV. The current is typically readily available from a CT in the MOV branch. The voltage across the MOV, is usually not measured but can be estimated from the MOV U-I characteristic.

a) MOV short time energy protection

MOV short time energy protection also known “MOV energy rate of rise protection” shall prevent high energy absorption over a short time period which may cause hotspots in the metal oxide discs.

Informative: This protection complements the MOV high current protection for internal line faults. It also provides protection against high energy absorption due to faults external to the compensated line exceeding those specified in the duty cycles, thus save the energy accumulation capability of the MOV for external fault conditions.

The setting is usually based on the maximum energy accumulation due to the external fault duty cycle with some margin in order to avoid bypassing of the series capacitor for external faults.

b) MOV high current protection

MOV high current protection shall be provided to reduce unnecessary energy absorption for heavy internal faults. The setting shall be above the maximum external fault current.

Triggering of the spark gap and initiation of closure of the bypass switch shall be instantaneous based upon current magnitude.

c) MOV high temperature protection

MOV high temperature protection shall be provided to prevent damage to the MOV discs due to overheating.

Informative: The maximum design temperature (approximately 180-200 °C) could be reached during a period of successive transmission line faults or long term overload conditions.

The thermal model for the protection shall include the ambient temperature which can be used in the simulation of the overheating as well as the cooling process. Steady state load current on the series compensated line (to calculate the resulting voltage across the MOV) shall be used in the model. The cooling characteristic of the MOV shall be part of the thermal model for the protection.

2.5.2 MOV Imbalance Protection

Where appropriate, MOV imbalance protection should be provided to detect the unbalanced loading conditions between the parallel strings of MOV units. The protection shall have two stage settings,

On operation the protection shall

At stage -1,

- a) Generate an alarm

At stage -2,

- a) Trigger the spark gap and close the bypass switch
- b) Lockout SC Automatic Functions (see Section 3.2) where applicable
- c) Generate an alarm

2.5.3 MOV Failure Protection

The MOV failure protection shall be provided to detect MOV failure condition(s).

On operation, the protection shall

- a) Close the bypass switch
- b) Lockout SC Automatic Functions (see Section 3.2) where applicable
- c) Generate an alarm

Informative: One possible implementation of a MOV failure protection is to use the ratio between the MOV current and the line current and initiate a series capacitor bypass if a pre-set ratio is exceeded.

2.6 Spark Gap Protections

The spark gap protections shall include the spark gap mal-operation protection and the spark gap trigger circuit supervision functions.

Informative: the spark gap failed protection is specified as a back-up protection in Clause 2.8.3.

2.6.1 Spark gap mal-operation protection

The spark Gap Mal-operation Protection shall be provided to detect unwanted operation of the spark gap. On operation, the protection shall

- a) Close the bypass switch
- b) Lockout SC Automatic Functions (see Section 3.2) where applicable
- c) Generate an alarm.

2.6.2 Spark Gap trigger circuit supervision

The trigger circuit supervision shall be provided to detect faults in the spark gap trigger circuit. In case of redundant systems, faults in both circuits shall operate the protection function. On operation, the protection shall

- a) Close the bypass switch
- b) Lockout SC Automatic Functions (see Section 3.2) where applicable
- c) Generate an alarm.

Informative: The trigger circuit normally comprises of: a trigger capacitor, a trigger transformer and a thyristor switch (where applicable)

2.7 Platform Protections

2.7.1 Flashover to platform protection

The flashover to platform protection shall be provided to detect a flashover from any of the platform mounted equipment to the platform. On operation, the protection shall

- a) Close the bypass switch
- b) Trip the local line CB
- c) Send DTT to trip the remote CB of the compensated line
- d) Lockout SC Automatic Functions (see Section 3.2) where applicable
- e) Generate an alarm.

Informative: This function is usually implemented by measuring the current from a current transformer connecting one side of the primary plant to the platform.

2.7.2 Platform to ground fault

The platform to ground fault protection shall be provided to detected and clear earth faults on the platform. On operation, the protection shall

- a) Trigger the spark gap and close the bypass switch as necessary
- b) Trip the local line CB,
- c) Send DTT to trip to the remote CB of the compensated line
- d) Lockout SC Automatic Functions (see Section 3.2) where applicable
- e) Generate an alarm

2.8 Backup Protection

Backup protection functions shall comprise Feeder Circuit Breaker Fail (CBF) protection as well as Bypass Switch Fail (BSF) protection and Spark Gap Fail (SGF) Protection.

2.8.1 Circuit Breaker Fail (CBF) protection

Circuit breaker fail (CBF) protection shall be provided for the SC local line circuit breaker as per see NGTS 3.24.39. On operation CBF protection shall

- a) Trip other CBs connected to the same busbar or mesh corner.
- b) Initiate the DTT send functions of each transformer and feeder connected to the same mesh corner where appropriate (see NGTS 3.24.6).
- c) Lockout SC Automatic Functions (see Section 3.2) where applicable

2.8.2 Bypass Switch Fail (BSF) Protection

The bypass switch failure protection shall be provided to detect a faulty bypass switch. If the bypass switch failed to close after a pre-set period of time, the protection shall

- a) Trip the local line CB (optional for a manual operation of the bypass switch)
- b) Send DTT to trip the remote CB of the compensated line (optional for a manual operation of the bypass switch)
- c) Lockout SC Automatic Functions (see Section 3.2) where applicable
- d) Generate an alarm

2.8.3 Spark Gap Fail (SGF) Protection

The spark gap failure protection shall be provided to detect failure of Spark Gap operations. If the spark gap failed to close after a triggering signal is issued for a pre-set period of time, the protection shall

- a) Re-initiate the closing of the bypass switch
- b) Lockout SC Automatic Functions (see Section 3.2) where applicable
- c) Generate an alarm

2.9 Mechanical Protection

2.9.1 Voltage Transformer Gas and Oil Actuated Protection

Where a wound oil-filled voltage transformer is used for the SC, it shall be provided with a gas and oil actuated relay (see NGTS 2.3) to protect against gas accumulation, loss of oil and oil surge. On operation, Mechanical protection function shall

- a) Trip the local line CB.
- b) Send DTT to trip the remote CB of the compensated line
- c) Initiate CBF protection where appropriate.
- d) Lockout SC Automatic Functions (see Section 3.2) where applicable
- e) Generate an alarm

2.10 Additional Protections for TCSC banks

Informative: The protection functions specified in this section are additional to those specified for FSC and only applicable to the TCSC.

2.10.1 Thyristor overvoltage protection

Thyristor overvoltage protection shall be provided to prevent potential overvoltage across a thyristor valve caused by the thyristor valve being blocked. On operation, the protection shall

- a) Order thyristor firing,
- b) Close the bypass switch
- c) Lockout the TCSC
- d) Generate an alarm

Informative: the protection can either be implemented as an indirect thyristor valve overvoltage protection that uses the thyristor current derivative or a direct overvoltage protection that uses the voltage across the thyristors.

2.10.2 Thyristor valve overcurrent

Overcurrent protection capable of both DTOC and IDMT characteristics as per NGTS 3.24.38 shall be provided to protect TCSC thyristor valves. On the operation, the protection shall

- a) Order thyristor firing,
- b) Close the bypass switch
- c) Lockout the TCSC
- d) Generate an alarm

2.10.3 Thyristor thermal overload protection

Thyristor thermal overload protection shall be provided to protect TCSC thyristor valves (including Thyristor junctions) from thermal overloading.

Informative: The protection calculates the energy dissipated in the thyristor and then calculates the average temperature of the silicon.

There shall be two settings for the thyristor temperature level:

- a) At level 1, an alarm will be initiated and the maximum reactance reference will be limited until the thyristor temperature has decreased below a release level.
- b) If the thyristor temperature increases above the level 2 (trip) the protection shall
 - Close the bypass switch
 - Lockout the TCSC
 - Generate an alarm