

PROTECTION & CONTROL FOR A STATIC COMPENSATOR - STATCOM

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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	10
4 INTERFACE REQUIREMENTS	16
5 PERFORMANCE REQUIREMENTS.....	18
6 TEST REQUIREMENTS	18
7 FORMS AND RECORDS	18
PART 2 - DEFINITIONS AND DOCUMENT HISTORY	19
8 DEFINITIONS	19
9 ACRONYMS	19
10 AMENDMENTS RECORD	20
11 IMPLEMENTATION.....	20
PART 3 - GUIDANCE NOTES AND APPENDICES	21
12 REFERENCES	21
APPENDIX A - AN EXAMPLE OF A STATCOM PROTECTION ZONE ARRANGEMENT	24
APPENDIX B - FUNCTION INTEGRATION ARRANGEMENT	25
APPENDIX C - AN EXAMPE OF V-I OPERATIONAL CHARACTERISTICS OF A STATCOM.....	29
APPENDIX D - SITE SPECIFIC DATA TO BE INCLUDED IN THE ENQUIRY DOCUMENTATION ...	30
APPENDIX E - SCHEDULES OF DATA TO BE SUPPLIED BY THE SOLUTION PROVIDER.....	31

PURPOSE AND SCOPE

This Technical Specification (TS) defines the functional, performance and testing requirements for the Protection and Control (P&C) systems of a Static Compensator (STATCOM) for connection to the National Grid Electricity Transmission (NGET) system.

This document shall be read in conjunction with TS 2.32 for a STATCOM, as well as the relevant policy and specification documents as listed in the Reference section.

PART 1 – FUNCTIONAL AND PERFORMANCE REQUIREMENTS

1 GENERAL REQUIREMENTS

1.1 General

- 1.1.1 The STATCOM shall be equipped with a P&C system designed to operate satisfactorily under normal and abnormal conditions.
- 1.1.2 The P&C system of a STATCOM shall be designed to ensure that no single failure may cause a fault to remain connected to the primary system. To implement this, the P&C system shall have full redundancy in all vital parts as appropriate. This shall be supported by a design report and associated documentation which shall be provided at the Tender Stage.

- 1.1.3 The protection shall be as independent as possible from the control functions such that control failure shall not limit the functionality of the protection, and vice versa. The protection shall always remain active and shall be fed by two, separate and independent power supplies.
- 1.1.4 The STATCOM shall be divided into several separately protected and overlapping zones as illustrated in Figure A.1 (See Appendix A). A protection function shall only act upon a specific type of fault within a designated zone and shall be stable to other types of disturbances or faults external to the relevant zone.
- 1.1.5 Where P&C functions are integrated within the same Intelligent Electronic Device (IED), the design shall satisfy the requirements for normal operation, maintenance and failure modes. The Solution Provider shall declare the integration arrangement in Table B.1 (See Appendix B).
- 1.1.6 The P&C functions detailed within this Specification shall co-ordinate with primary device(s) e.g. Surge Arresters as appropriate.
- 1.1.7 All P&C functions for a STATCOM shall be co-ordinated with, and have no adverse effects on other systems connected to the transmission network, including but not limited to:
- a) Alternating Current (AC) and Direct Current (DC) protection schemes
 - b) Flexible AC Transmission Systems (FACTS)
 - c) High Voltage Direct Current (HVDC) Systems
 - d) Tripping and intertripping arrangements
 - e) Operational Tripping Schemes (OTS)
 - f) Delayed Automatic Reclosing (DAR) schemes
 - g) Over-loading requirements etc.

1.2 Engineering Interface

- 1.2.1 An Engineering interface shall be provided by the P&C system for setting configuration, commissioning, diagnostic and other engineering purposes. Software/Firmware versions shall be clearly identifiable within the interface.
- 1.2.2 The configuration and settings philosophy shall follow the principles defined in PS(T) 10.
- 1.2.3 A change management process shall be provided and followed to control the version changes of configuration within the Engineering interface.
- 1.2.4 Software for interrogation of all P&C devices shall be provided to NGET users.

1.3 Hardware and Accommodation

- 1.3.1 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 TS 3.24.04, TS 3.24.15, TS 3.24.03 and TS 2.19.

1.4 Spares, Maintenance, Refurbishment and Replacement

- 1.4.1 Unless separately specified in the Enquiry Documentation, spares, maintenance, post-delivery support, refurbishment and replacement requirements for the STATCOM P&C system shall comply with TS 2.32 and other relevant NGET existing policies.

- 1.4.2 A Failure Mode, Effects and Criticality Analysis (FMECA) shall be performed on the STATCOM P&C solution offered by the Solution Provider. The FMECA shall highlight failure modes with their probabilities and severity of consequences to demonstrate where effort and design considerations have been directed to minimise any potential consequences of a failure or to identify where further effort may be required in the detailed design stage. The FMECA shall be used to support the STATCOM reliability, availability and maintenance study.

Informative : The P&C FMECA may be performed in conjunction with the FMECA for the complete STATCOM solution as reference in TS 2.32.

- 1.4.3 All electronic circuits and devices shall be easily accessible for maintenance and testing purposes.
- 1.4.4 All the P&C equipment that requires 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.
- 1.4.5 The Solution Provider shall supply fully documented method statements for the maintenance and replacement procedures for the P&C equipments/system.
- 1.4.6 Suitable space shall be provided in the STATCOM relay room to enable replacement equipment to be built and installed off-line which will minimise the future outage requirements. This shall be supported through the provision of a replacement methodology and relay room layout drawings etc.

1.5 Type Registration

- 1.5.1 The STATCOM P&C system shall be type registered as per UKBP TP183. Further guidance is provided in TS 2.32 with respect to Type Registration of the whole STATCOM solution.

1.6 Quality Assurance

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

2 PROTECTION FUNCTIONS

2.1 Typical Protection Zone Arrangement of a STATCOM System

- 2.1.1 For the purposes of this Specification, a typical STATCOM is assumed to consist of the following primary components in accordance with TS 2.32:

- a) Converter transformer
- b) Phase reactor
- c) AC/DC converter
- d) Low Voltage (LV) connection busbar
- e) AC filter where required
- f) Earthing/auxiliary transformer.

Informative: The AC filter may be of manufacturer dependent design.

- 2.1.2 Except where otherwise specified in the Enquiry Documentation, the following dedicated protection zones for these primary components shall be separated from, but overlapped with neighbouring zone(s) and those ones for other immediately connected plant as appropriate:

- a) Converter transformer zone
- b) STATCOM zone
- c) LV connection busbar zone
- d) AC filter zone where required
- e) Earthing/auxiliary transformer zone.

Informative: An entire protection scheme can be considered for the phase reactor and the converter in a same protection zone – the STATCOM zone.

- 2.1.3 The Solution Provider shall provide supporting documentation describing their design, testing and operational methodology.

2.2 Converter Transformer Zone Protection

- 2.2.1 The protection function arrangements of all converter transformer types shall be provided as per TS 3.24.08 and TS 3.24.91 (For details, see Table B.1).

- 2.2.2 On operation, the protection shall:

- a) Block STATCOM valves where appropriate
- b) Trip the associated Circuit Breaker (CB)
- c) Initiate Circuit Breaker Fail (CBF) protection
- d) Generate an alarm.

2.3 STATCOM Zone Protection

- 2.3.1 Main Protection

A single main protection shall be provided by an overall unit protection in accordance with TS 3.24.65. The protection shall be responsive to both phase-to-phase and phase-to-earth faults on the reactor, the converter as well as the connections between phase reactor and converter.

If a biased differential principle is used, the protection shall comply with the requirements of IEC 60255-13.

- 2.3.2 Phase Reactor Protection

- a) Reactor Overcurrent Protection

The overcurrent protection capable of both inverse time and definite time characteristics shall be provided as per TS 3.24.38.

- b) Reactor Thermal Overload Protection

The reactor thermal overload protection shall be provided as per TS 3.24.78.

- c) Mechanical Protection

Where an oil filled reactor is used, a gas and oil actuated relay shall be provided as per TS 2.3 to protect against gas accumulation, loss of oil and oil surge.

- d) On operation, the protection shall:

- Block STATCOM valves where appropriate

- Trip the associated CB(s)
- Initiate CBF protection
- Generate an alarm.

2.3.3 Converter Protection

Informative: The converter within a STATCOM typically consists of semiconductor-based valves with turn-on/off capabilities, DC capacitors and other auxiliary components. All the converters with three-phase two-, three- and multi-level valve topologies can be deployed for a STATCOM application. According to Draft BS EN 62927, the STATCOM valves based on different valve topologies can be divided into two categories:

- *STATCOM valves of the ‘Switch’ type (see Draft BS EN 62927 Figure A.2 to Figure A.4). The valves of this type function as controllable switches with only “on” and “off” states. The DC capacitors are completely separated from the valves so that the valves for each phase have to share with a common DC energy storage source which consists of a set of DC capacitors. The DC capacitors should charge/discharge simultaneously for AC/DC power conversion. The protection of such DC capacitors can be independent from valve protection.*
- *STATCOM valves of the “Controllable voltage source” type (see Draft BS EN 62927 Figure A.5). A DC capacitor becomes an integral part of a valve submodule. Those half or full-bridge valve sub-modules are commonly used for multi-level valve topologies such as Chain-link and Modular Multi-level Converter (MMC). The distributed multiple DC capacitors are co-ordinated via STATCOM control system to charge/discharge in the logical sequences for AC/DC power conversion. For such topologies, the DC capacitor protection may be integrated into valve protection as an entire converter protection scheme.*

a) Valve Overvoltage Protection

Valve overvoltage protection shall be provided to prevent any potential overvoltage across the STATCOM valve.

Where the valves of a “Controlled voltage source” are used, a DC voltage balance control mechanism shall be applied for balancing the DC voltage on each valve submodule in series connections so as to avoid unexpected abnormal voltages and current distortions.

On operation, the protection shall take into account the following actions, but not limited to:

- Controlled limitation of the valve voltage
- Block STATCOM valves
- Trip the associated CB(s)
- Generate an alarm.

b) Valve Overcurrent Protection

The valve overcurrent protection as per TS 3.24.38 shall be provided to protect STATCOM valves against potential overcurrent through them.

On operation, the protection shall take into account the following actions, but not limited to:

- Controlled limitation of the instantaneous and RMS converter currents
- Block STATCOM valves
- Trip the associated CB(s)
- Generate an alarm.

c) Valve Thermal Overload Protection

Where required, the valve thermal overload protection shall be provided to protect STATCOM valves (including valve junctions) from thermal overloading.

On operation, the protection shall take into account the following actions, but not limited to:

- Block STATCOM valves
- Apply Full Cooling where appropriate
- Trip the associated CB(s) where necessary
- Generate an alarm.

d) DC Capacitor Overvoltage Protection

Where protective devices/functions for DC capacitors are designed to be partly or fully integrated into the valve protection as an entire converter protection scheme, the Solution Provider shall provide its solution(s) to NGET for evaluation and agreement.

Where the DC capacitor overvoltage protection is separately designed, it shall be provided to protect the DC capacitors against potential overvoltage across a DC capacitor.

On operation, the protection shall take into account the following actions, but not limited to:

- Controlled limitation of the DC-side voltage of a STATCOM
- Block STATCOM valves
- Trip the associated CB(s)
- Generate an alarm.

e) DC Capacitor Overcurrent Protection

Where the DC capacitor overcurrent protection is separately designed, it shall be provided as per TS 3.24.38 to protect DC capacitors against potential overcurrent through the DC capacitors.

On operation, the protection shall take into account the following actions, but not limited to:

- Controlled limitation of the current through the DC capacitors
- Block STATCOM valves

- Trip the associated CB(s)
- Generate an alarm.

Informative: The DC capacitors of the 'Self-healing' type shall be provided for all the STATCOMs in accordance with TS 2.32.

2.4 Valve & Ancillary System Protection

Informative: The protective zone for these protection functions is normally within the STATCOM zone.

The valve & ancillary system protection also called Valve Based Electronics (VBE) shall be provided to detect and clear faults associated with equipment failure that may cause the operation of STATCOM to be compromised, harm the STATCOM valves or compromise the integrity of the main components of the STATCOM equipment, such as failure of STATCOM valves and Cooling Plant.

2.4.1 Valve Unit Protection

All the components in the STATCOM valve units shall be monitored to ensure the number of failed components do not exceed the redundancy level to affect normal performance of the STATCOM.

If the number of failed components exceeds a pre-set limit (as recommended by the Solution provider and agreed by NGET), the protection shall:

- a) Block STATCOM valves
- b) Trip the associated CB(s)
- c) Generate an alarm.

2.4.2 Valve Cooling Plant Failure Protection

The Valve Cooling Plant failure protection shall be provided to detect the Cooling Plant failure for the STATCOM valves.

On operation, the protection shall:

- a) Block STATCOM valves
- b) Trip the associated CB(s) as necessary
- c) Generate an alarm.

Informative: When Cooling Plant failure is detected, a trip of the local CB(s) may be considered to avoid further complications.

Informative: Where the cooling plant has built-in redundancy, a single plant item failure shall not cause a reduction of rating or performance of the STATCOM. As a result, this shall not be regarded as a failure of the valve cooling system. Under these circumstances, only a cooling plant failure alarm shall be generated.

2.5 LV Connection Busbar Zone Protection

2.5.1 A numerical busbar protection shall be provided as per TS 3.24.34. The protection shall be responsive to both phase-to-phase and phase-to-earth faults on the LV connection busbar.

On operation, the protection shall:

- a) Block STATCOM valves where appropriate
- b) Trip the associated CB(s)
- c) Initiate CBF protection
- d) Generate an alarm.

2.6 AC Filter Zone Protection

Informative: The AC filter usually comprises capacitors, reactors as well as resistors and other equipment.

2.6.1 Main Protection

A single main protection shall be provided by an overall unit protection as per TS 3.24.65. The protection shall be responsive to both phase-to-phase and phase-to-earth faults on the AC filter.

If a biased differential principle is used, the protection shall comply with the requirements of IEC 60255-13.

2.6.2 Capacitor Excessive Root Mean Square (RMS) Overcurrent Protection

The 3-phase capacitor excessive RMS overcurrent protection shall be provided as per TS 3.24.77.

2.6.3 Capacitor Overvoltage Protection

The capacitor overvoltage protection shall be provided as per TS 3.24.77.

2.6.4 Capacitor Out-of-balance Protection

The capacitor out-of-balance protection shall be provided as per TS 3.24.77.

2.6.5 Reactor Thermal Overload Protection

The reactor thermal overload protection shall be provided as per TS 3.24.78.

2.6.6 Resistor Thermal Overload Protection

Where resistors are used, the resistor thermal overload protection shall be provided as per TS 3.24.78.

2.6.7 Resistor Open Circuit Protection

Where resistors are used, the resistor open circuit protection shall be provided as per TS 3.24.11.

2.6.8 On operation, the protection shall:

- a) Block STATCOM valves
- b) Trip the associated CB(s)
- c) Initiate CBF protection
- d) Generate an alarm.

2.7 Earthing/Auxiliary Transformer Protection Zone

2.7.1 Main Protection

Where the earthing/auxiliary transformer is not included in the zone of the converter transformer overall unit protection or LV connection busbar protection, the Restricted Earth

Fault (REF) protection shall be provided for the HV winding of the earthing/auxiliary transformer in accordance with TS 3.24.91 as appropriate.

Where applicable, the neutral voltage displacement relay shall be provided. It shall be duplicated and an appropriate Voltage Transformer (VT) with an open delta LV shall be required.

2.7.2 Back-up Protection

The unrestricted earth fault protection shall be provided as per TS 3.24.38 and TS 3.24.91.

2.7.3 Mechanical Protection

A gas and oil actuated relay shall be provided for the earthing/auxiliary transformer as per TS 2.3.

2.7.4 On operation, the protection shall:

- a) Block STATCOM valves where appropriate
- b) Trip the local CB(s)
- c) Initiate CBF protection
- d) Generate an alarm.

2.8 Converter Blocking Fail Protection

The converter blocking fail protection shall be provided to cater for the failure of blocking STATCOM valves.

On operation, the protection shall:

- a) Trip the associated CB(s)
- b) Generate an alarm.

2.9 Circuit Breaker Fail Protection

The CBF protection shall be provided as per TS 3.24.39 for CB(s) associated with the STATCOM.

On operation, the protection shall:

- a) Trip other CBs connected to the same busbar or mesh corner
- b) Initiate the Direct Transfer Trip (DTT) send functions of each feeder connected to the same busbar as per TS 3.24.39
- c) Initiate the DTT send functions of each transformer and feeder connected to the same mesh corner where appropriate as per TS 3.24.06
- d) Generate an alarm.

2.10 Voltage Transformer Gas and Oil Actuated Protection

Where a wound oil-filled voltage transformer is used for the STATCOM, it shall be provided with a gas and oil actuated relay as per TS 2.3.

On operation, the protection shall:

- a) Block STATCOM valves where appropriate
- b) Trip the associated CB(s)
- c) Initiate CBF protection
- d) Generate an alarm.

2.11 Tripping Arrangements

2.11.1 Tripping System

Two separately energised independent tripping systems shall be provided for all the protection functions specified in this Specification.

The tripping systems shall be designated to operate from 110V DC battery systems specified in TS 3.12.04.

Each tripping system shall be provided with a separately protected supply fed from different battery systems.

High burden self-resetting trip relay(s) shall be provided for each tripping system.

The outputs of all protections shall operate both tripping systems.

Operation of the tripping systems from the protections shall be conditioned by auxiliary switches on the appropriate primary disconnectors to inhibit tripping when the protected STATCOM is disconnected from the transmission network.

2.11.2 Trip Outputs

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

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

Where required, the protection system shall also provide outputs as per TS 3.24.91 for initiation of:

- a) Disconnector sequential isolation where required
- b) Trip relay reset
- c) STATCOM control system.

3 CONTROL FUNCTIONS

3.1 General

- 3.1.1 A control system shall be provided for a STATCOM with Supervisory Control and Data Acquisition (SCADA) functions and automatic control functions as appropriate that enable the STATCOM to function appropriately under steady-state, transient and dynamic operating conditions.