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400 kV and 220 kV Static Synchronous Compensator (STATCOM)

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Contents

1 INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This Functional Specification is applicable for use in offshore wind transmission links delivered by the Customer as Contestable Works, to be owned and operated by EirGrid.

The following specification outlines the general requirements for the design, procurement, construction and commissioning of static synchronous compensators (STATCOM's) for use in onshore compensation compounds (OCC) that will be owned and operated by EirGrid.

This specification should be read in association with the project specific contestable works pack and project documentation and all other relevant functional specifications as issued by EirGrid.

For the purpose of this specification the term Customer shall refer to Offshore Wind Power Developers, responsible for the design and build of assets to be handed over to EirGrid.

The purpose of this STATCOM functional specification is to ensure that STATCOMs supplied by the Customer shall comply with EirGrid's requirements and the latest industry standards and practices.

The document 'STATCOM Technical Schedule' OTS-SSS-416 sets out the particular technical requirements of this application. Note that most parameters of the Technical Schedule shall be completed during the design by Customer in consultation with EirGrid.

1.2 DEFINITION OF STATCOM

A static synchronous compensator (STATCOM) is a reactive power regulating device based on the voltage sourced converter (VSC) used to maintain AC system voltages and to enhance the stability of the AC system. The basic function of the STATCOM is to provide dynamic reactive support in order to help control the system voltage. An advantage of a STATCOM is its ability to provide rated capacitive reactive current when the voltage is low.

The STATCOM system consists of a range of physical components consisting of reactors, capacitor banks, power transformers, auxiliary transformers, AIS MV busbars, cooling equipment and Voltage Source Converter (VSC) technology.

The VSC equipment shall be housed in a conventional building or suitable metal containers appropriately sized to cater for operation and maintenance activities for the equipment's design life.

The control building (and other relevant civil and structural works) shall be built in accordance with EirGrid's Substation Civil and Building Works specification OFS-SSS-417.

1.3 UTILISATION OF STATCOM

STATCOMs may be required for the following applications subject to design review, risk assessment and review by EirGrid and any conditions listed herein:

1. Provision of the following requirements.
    a. Voltage Control/Regulation at Grid Interface Point (GIP)

b. Fault Ride Through

c. Harmonic Performance

2. Support of power system stability.

1.4 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AIS	Air Insulated Switchgear
CT	Current Transformer
DC	Direct Current
EMC	Electromagnetic Compatibility
EU	European Union
FAT	Factory Acceptance Test
FACTS	Flexible AC Transmission Systems
FVT	Factory Verification Tests
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
HVDC	High Voltage Direct Current
IEC	International Electro-technical Committee
IGBT	Insulated Gate Bipolar Transistor
IP	Ingress Progression
LV	Low Voltage
LVAC	Low Voltage Alternating Current
P&C	Protection & Control
PLC	Power Line Carrier
rms	root mean square
SAT	Site Acceptance Tests
STATCOM	Static Synchronous Compensator
SCADA	Supervisory Control And Data Acquisition
TARGET VOLTAGE	Defined as the target voltage the system is trying to keep the voltage as close as possible to.
TAO	Transmission Asset Owner
US	United States
UV	Ultra Violet
VBE	Valve Based Electronics
VSC	Voltage Source Converter
VT	Voltage Transformer
SSCI	Sub-Synchronous Control Interaction

1.5 LEGISLATION

Equipment offered shall be compliant with the provisions of the latest applicable versions of all relevant Irish legislation and directives of the European Union.

These include the following or latest versions/ amendments as appropriate:

SI No. 132	Safety signs regulations 1995 (implements EEC Directive 92/58)
SI No. 291	Safety, Health and Welfare at Work (Construction) Regulations
SI No. 299	Safety, Health and Welfare at Work (General Application) Regulations 2007
SI No. 445	Safety, Health and Welfare at Work (General Application) (Amendment) Reg. 2012
Reg (EC) No 1907/2006	Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
Reg (EC) No 1272/2008	Classification, Labelling and Packaging of Substances and Mixtures (CLP)
Reg (EU) No 517/2014	Fluorinated greenhouse gases and repealing regulation (EC) No 842/2006
Reg (EU) 2015/2068	Format of labels for products and equipment containing fluorinated greenhouse gases
Reg (EU) 2015/2065	Format for notification of the training and certification programmes of the Member States
Reg EU 2015/2066	Minimum requirements and the conditions for mutual recognition for the certification of natural persons carrying out installation, servicing, maintenance, repair or decommissioning of electrical switchgear containing fluorinated greenhouse gases or recovery of fluorinated greenhouse gases from stationary electrical switchgear
Directive 2011/65/EU	Restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS)
Directive 2012/19/EU	Waste electrical and electronic equipment (WEEE)
Directive 2014/30/EU	Harmonisation of the laws of the Member States relating to electromagnetic compatibility
ECE/TRANS/275	Vol. I and II ("ADR 2019") European Agreement Concerning the International Carriage of Dangerous Goods by Road
Directive 2013/35/EU	Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)
ICNIRP	International Commission on Non-Ionizing Radiation Protection (ICNIRP)

Equipment shall carry the CE Mark in accordance with Directive 768/2008/EC and the EU Construction Products Regulation (No. 305/2011 – CPR) and adequate documentation to demonstrate full compliance should be retained.

In order to prove compliance, the equipment shall carry the CE Mark in accordance with Direction 768/2008/EC and the EU Construction Products Regulation (No. 305/2011 – CPR) where required.

The proposed STATCOM shall comply with the EirGrid requirements at the GIP as specified in OFS-GEN-021.

The Grid Code is the technical document which establishes the rules governing the operation, maintenance and development of the transmission system and sets out the procedures for governing the actions of all transmission system users.

1.6 National International and Other Applicable Standards

Except where otherwise stated in the functional specification, materials shall be designed, manufactured, tested and installed according to relevant IEC and/or EN standards.

Where available, the Irish adaptation of European standards (IS EN version), including any national normative aspects shall be applied.

Where no IEC standard or EN standard has been issued to cover a particular subject then an international or British Standard shall be applied. The latest edition and amendments shall apply in all cases.

The equipment shall comply with the latest editions of the international standards, codes and normative references indicated below, and the latest editions of the standards that they reference.

1.7 International Standards

Number	Title
IEC 60060	High Voltage Test Techniques - Series
IEC 60068	Environmental testing - Series
IEC 60071-1	Insulation co-ordination - Part 1: Definitions, principles and rules
IEC 60071-2	Insulation co-ordination - Part 2: Application guide
IEC 60076-1	Power transformers - Part 1: General
IEC 60076-2	Power transformers - Part 2: Temperature rise for liquid immersed transformers
IEC 60076-3	Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-4	Power transformers - Part 4: Guide to lightning impulse and switching impulse testing - Power transformers and reactors
IEC 60076-5	Power transformers - Part 5: Ability to withstand short-circuit
IEC 60076-6	Power transformers - Part 6: Reactors
IEC 60076-8	Power transformers - Part 8: Application guide

Number	Title
IEC 60076-10	Power transformers - Part 10: Determination of sound levels
IEC 60099-1	Surge Arresters Part 1: Non-linear resistor type gapped arresters for AC systems
IEC 60099-3	Surge Arresters Part 2: Artificial pollution testing of surge arresters
IEC 60099-4	Surge Arresters Part 4: Metal-oxide surge arresters without gaps for AC systems
IEC 60146-1-1	Semiconductor Converters – General requirements and line commutated converters Part 1-1: Specification of basic requirements
IEC 60146-1-3	Semiconductor Converters – General requirements and line commutated converters Part 1-3: Transformers and Reactors
IEC 60146-2	Semiconductor Converters – General requirements and line commutated converters Part 2: Self-commutated semiconductor converters including direct DC converters
IEC 60168	Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 kV
IEC 60255	Measuring relays and protection equipment - Series
IEC 60270	High-voltage test techniques - Partial discharge measurements
IEC 60273	Characteristics of Indoor and Outdoor Post Insulators for System with nominal voltages greater than 1000 V
IEC 60437	Radio interference test on high-voltage insulators
IEC 60507	Artificial Pollution Tests on High-Voltage ceramic and glass insulators to be used on AC systems
IEC 60529	Degrees of Protection Provided by Enclosures (IP Code)
IEC 60551	Determination of transformer and reactor sound levels
IEC 60549	High voltage fuse for external protection of shunt capacitors
IEC 60721-2-6	Classification of environmental conditions - Part 2: Environmental conditions appearing in nature. Earthquake vibration and shock
IEC 60747-6	Semiconductor devices Part 6: Thyristors
IEC 60747-9	Semiconductor devices discrete devices Part 9: Insulated-gate bipolar transistors (IGBTs)
IEC 60794-1-1	Optical fibres General
IEC 60794-1-2	Optical fibres General Specification basic optical cable test procedures
IEC/TS 60815	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Series
IEC 60865	Short circuit currents – Calculation of Effects
IEC 60871-1	Shunt Capacitors for AC. power systems having a rated voltage above 1000 V - Part 1: General
IEC 60871-2	Shunt Capacitors for AC power systems having a rated voltage above 1000 V - Part 2 Endurance testing

Number	Title
IEC 60871-3	Shunt Capacitors for AC power systems having a rated voltage above 1000 V - Part 3: Protection of shunt capacitors and capacitor banks
IEC 60871-4	Shunt Capacitors for AC power systems having a rated voltage above 1000 V - Part 4: Internal fuses
IEC 60943	Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals
IEC 61000-4-1	Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series
IEC 61071	Capacitors for Power Electronics
IEC 61462	Composite hollow insulators – Pressurized and un-pressurized insulators for use in electrical equipment with rated voltage greater than 1000 V – Definitions, test methods, acceptance criteria and design recommendations
IEC 61642	Industrial a.c. networks affected by harmonics - Application of filters and shunt capacitors
IEC 61869	Instrument transformers – Series
IEC 61936-1	Power installations exceeding 1 kV AC - Part 1: Common rules
IEC 61954	Static VAR compensators (SVC) - Testing of thyristor valves
IEC 62199	Bushings for DC application
IEC 62927	Voltage sourced converter (VSC) valves for static synchronous compensator (STATCOM) - Electrical Testing.
IEC 17A/1085/CD	High-voltage switchgear and controlgear - Part 1: Common specifications for alternating current switchgear and controlgear
IEC 62474	Material declaration for products of and for the electro technical industry
IEC 62751-1	Power losses in voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) systems - Part 1: General requirements
IEC 62751-2	Power losses in voltage sourced converter (VSC) valves for high voltage direct current (HVDC) systems - Part 2: Modular multilevel converters
IEC TR 62757	Fire prevention measures on converters for high-voltage direct current (HVDC) systems, static var compensators (SVC) and flexible ac transmission systems (FACTS) and their valve halls
IEC 22F/380/CD	Voltage sourced converter (VSC) valves for static synchronous compensator (STATCOM) - Electrical testing
IEC TR 60757	Fire prevention measures on converters for high-voltage direct current (HVDC) systems, static var compensators (SVC) and flexible ac transmission systems (FACTS) and their valve halls
IEC/TS 60815-1	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions. Definitions, information and general principles
IEC/TS 60815-2	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions. Ceramic and glass insulators

Number	Title
IEC/TS 60815-3	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions. Polymer insulators for a.c. systems
IEC/TR 61000-3-6	Electromagnetic compatibility (EMC). Limits. Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems
IEEE 519	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
IEEE Standard 18	Standard for Shunt Power Capacitors
IEEE Standard 1531	IEEE Guide for Application and Specification of Harmonic Filters.
EN ISO 3746	Acoustics – determination of sound power levels and sound energy levels of noise sources using sound pressure – survey method using and enveloping measurement surface over a reflecting plane.
EN ISO 9614	Acoustics – determination of sound power levels of noise sources using sound intensity – Series
ET:103: 2015	National Rules for Electrical Installations Power installations exceeding 1 kV AC.
IEC ISO 3746	Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane

1.8 OTHER RELEVANT STANDARDS

Number	Title
EN ISO 9001	Quality Management Systems
CIGRE Technical Brochure 144	Static synchronous Compensator
CIGRE Technical Brochure 074	Electric Power Transmission and the Environment: Fields, Noise and Interference. Cigré. Working Group 36.01 (Corona and Field Effects)
CIGRE Technical Brochure 663	Guidelines for the procurement and testing of STATCOMS
CIGRE Technical Brochure 717	Protocol for reporting operational performance of FACTS
International Commission on Non-Ionizing Radiation Protection	Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz) Health Phys. 74 (4): 494-522; 1998.

EU Council Recommendation of 12 July 1999	on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC)

Where a particular subject is not covered by one of the above standards then a recognised national standard shall apply.

This specification shall take precedence in case of conflict between it and any of the listed standards.

In addition, there shall be compliance with the provisions of all relevant Directives of the European Communities relating to work equipment, i.e. in regard to safety of personnel who operate and maintain the equipment, in regard to Electromagnetic Compatibility (EMC) of the equipment (Directive 2004/108/EC) and in regard to 'the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)' (Directive 2004/40/EC).

2 Health And Safety

Please refer to Health and Safety requirements as outlined in EirGrid Safe by Design Methodology XDS-SDM-00-001-R0.

It is the responsibility of the customer to produce a suitable & sufficient design risk assessment.

A register of the hazards shall be submitted and shall include those hazards associated with the physical arrangement of the equipment (e.g. trip/fall hazards) which may pose a danger during off-load maintenance access, and those associated with the in-service operation of the equipment (e.g. stray magnetic fields, high temperatures, fluid leaks, presence of dangerous voltages).

The risk assessment must ensure that the design is safe and without risk to health when properly used by a person at a place of work, taking into account the initial installation, time based inspection, time based maintenance requirements, operation activities, decommissioning and future extension of the switchgear.

Any additional control measures deemed applicable shall be mutually agreed with EirGrid.

3 Service Conditions

Service conditions shall be as set out in the EirGrid OFS-SSS-400 Onshore Compensation Compound General Requirements specification.

The proposed STATCOM supplier shall have:

- At least 4 years' experience in the design and installation of the relevant voltage/current range (or higher) of the STATCOM as specified herein and is in use in at least one EU utility.
- As an alternative to such experience within the EU, similar experience with British, Swiss, Japanese, Australian, Korean or US/Canadian utility would be considered.

If the design team and production facilities proposed are relocated then the combined time of both plants would be considered as long as the new facilities have substantially the same workforce and equipment as the existing facilities.

3.1 Clearance From Live Parts

Clearances from live parts shall be as set out in the latest revision of the EirGrid Onshore Station General Requirements functional specification OFS-SSS-400 and Grid Code.

The Customer shall design ensure maximum safety of personnel during operation, maintenance, repairing/replacement and decommissioning.

The general layout of the VSC plant shall be such as to permit sufficient clearance for accessibility, necessary maintenance activities and replacement of VSC components. The Customer shall supply fully documented method statements for the maintenance and replacement procedures for the system.

Suitable space shall be provided in the relay room to enable replacement equipment to be built and installed off-line which will minimise future outage requirements.

Access gates or panels to low level mounted HV AIS equipment (bottom of insulator <2300 mm above ground, and >1 kV) e.g. HV capacitor banks, SVC, HV reactors etc. shall be secured using fixing bolts at minimum of 2 no. fixing points and shall not be secured with a lock; so that to access to the mini compound one or two section of the minicompound fence have to be removed.

3.2 Site & Environmental Data

The customer shall design and demonstrate mechanical adequacy to deal with the following loading effects (electrical and mechanical):

- Wind and ice loading.
- Forces due to expansion and contraction due to ambient temperature and load variations.
- Electromagnetic forces including those arising from short circuit or fault conditions.

Functional requirements with respect to environmental conditions are as set out in EirGrid functional specification OFS-SSS-400, Onshore Compensation Compound General Requirements.

Environmental conditions according to OFS-SSS-400, including effects of solar gain and wind speeds, shall be considered by the overall design.

A 40-year design life in a marine/coastal environment is required. Please refer to sections on corrosion protection for further detail.

4 Scope Of This Specification

This functional specification is applicable to the complete STATCOM assembly up to, and including, the main coupling transformer at the Grid Interface Point. For avoidance of doubt, any primary equipment connected on the HV side of the STATCOM coupling transformer is outside the scope of this functional specification and standard EirGrid specifications shall apply.

This functional specification applies to all primary/secondary equipment including, but not limited to, the following:

- Power transformer
- MV switchgear
- Capacitor banks
- Reactors
- STATCOM units
- LVAC supply systems
- Interfaces with site LVAC supply systems for start-up.
- DC supply systems
- Protection systems
- STATCOM Control systems
- STATCOM VSC
- Interfaces with substation SCADA
- Cooling system

5 POWER SYSTEM CHARACTERISTICS

5.1 GENERAL

The equipment shall be suitable for installation and connection to the Transmission system at the Grid Interface Point. The specific design parameters for the GIP are specified in EirGrid Onshore Interface Point Network Functionality Requirement Specification OFS-GEN-021 and the Project Specific Technical Schedules.

Site specific requirements, such as connection voltage, system strength, X/R ratios and harmonic characteristics, are provided by EirGrid on a project-by-project basis and are contained in Project Specific Technical Schedules. Some system parameters specifically dealing with requirements for STATCOM design have also been specified in this section.

The Customer shall propose a STATCOM configuration that meets both the performance requirements detailed in this specification and those detailed in the Project Specific Technical Schedules. It is up to the Customer to propose the best suited configuration and design of STATCOM system that fits the project requirements and the requirements specified in OFS-GEN-021.

5.2 SYSTEM FREQUENCY

The STATCOM design shall remain stable and comply with the rated, maximum continuous and minimum continuous frequency ranges and the excursions detailed below in Table 1.

The STATCOM should operate within its given characteristics and remain connected during rate of change of the transmission frequency of values up to and including 1 Hz per second as measured over a rolling 500 milliseconds period.

Following a system frequency excursion outside the range 49 – 50 Hz detailed in Table 1, system frequency shall stabilise to a value between 49 – 50 Hz. System frequency variations and durations shall be in accordance with Table 1

Table 1 - System Frequency

System frequency (Hz)	Duration
51.5 – 52	STATCOM to operate and remain connected for 60 min
51 – 51.5	STATCOM to operate and remain connected for 90 min
49 – 51	Continuous operation
47.5 – 49	STATCOM to operate and remain connected for 90 min
47.0 – 47.5	STATCOM to remain connected for 30 seconds each time the frequency is below 47.5 Hz.

5.3 GENERAL

The Customer shall propose a STATCOM configuration that meets both the performance requirements detailed in this specification and the project specific requirements detailed in Project Specific Technical Schedule. It is up to the Customer to propose the best suited configuration and design of STATCOM system that fits the project requirements.

5.4 STATCOM PERFORMANCE REQUIREMENTS

5.4.1 CONTINUOUS AND SHORT TIME CURRENT RATINGS

The STATCOM and its components shall be designed to withstand the specified continuous rated current, available emergency overloads during, and post power system faults specified in this document. The above ratings and required performances shall align with the requirements set out in Project Specific documentation which shall be based on calculations and design demonstrated by the Studies mentioned in OFS-GEN-005.

The effects of worst-case tolerances for individual components (e.g. transformers, capacitors and reactors), supply system frequency variations and the relevant environmental conditions stated in this document and in Project Specific documentation, shall be taken into account in the design.

The rated output of the STATCOM shall align with in the Project Specific documentation to be developed by the Customer. The STATCOM shall be capable of varying the output continuously over the full required leading and lagging reactive power range. This rated output shall be continuously available and controllable at the Grid Interface Point in accordance with the operating characteristics detailed in OFS-GEN-021. The design points defining the

operating characteristics are either outlined in OFS-GEN-021 or to be agreed with EirGrid during the design.

A study report with full calculations which demonstrates that these requirements are satisfied shall be provided as outlined further in Appendix A.

5.4.2 VOLTAGE AND REACTIVE OUTPUT RATING

When the transmission system voltage deviates from the normal operating range, special control strategies shall be implemented which override the normal control modes.

The Customer shall provide the STATCOM's capability to provide the maximum current injections (either lagging or leading). An example of an operating characteristic that should be provided is shown in the figure below.

Figure 1 STATCOM reactive current operating characteristic Illustration only (not to scale)

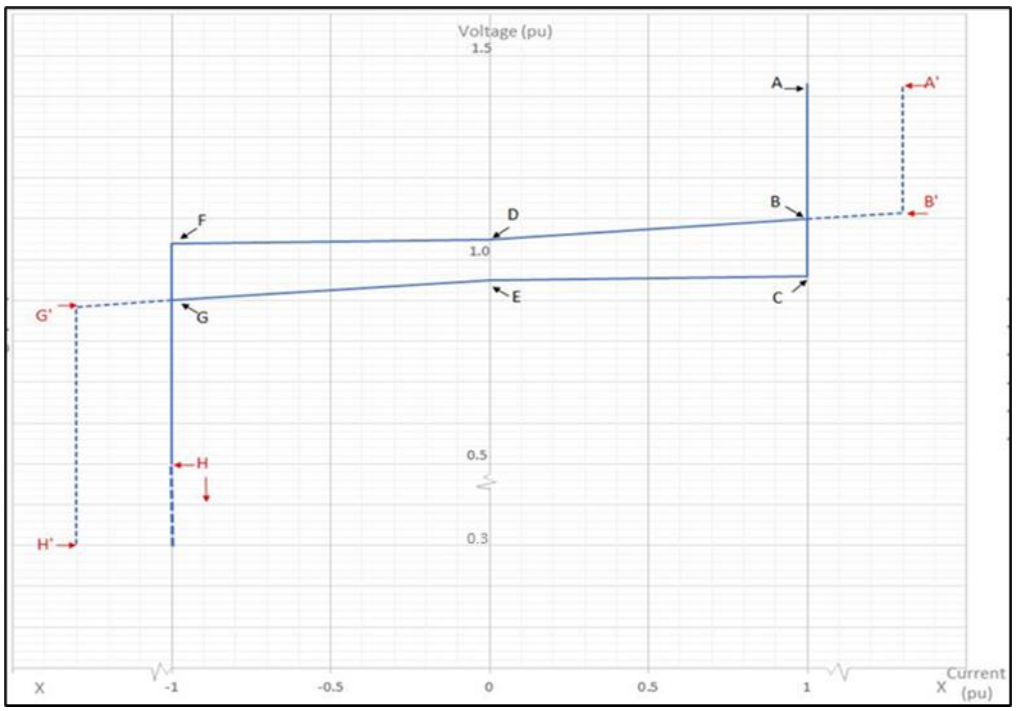

Table 2 - Minimum Duration of Maximum Current Injection (Either Lagging or Leading)

Voltage ranges (p.u.) at the Grid Interface Point[1]	Reference to the operating characteristics design points[2]	Minimum duration of maximum current injection
1.32 - 1.43	BB'A'A	80 ms
1.21 – 1.32	BB'A'A	500 ms
1.1 – 1.21	BB'A'A	1 s
1.1 – 0.9	BCFG	Continuous operation
0.9 – 0.7	GH	20 min
0.7 – 0.3	GH	2 s
0.9 – 0.3	HH'G'G	800 ms

Note that the required values for each design point **BDFGECB** as shown in the operating characteristic diagram above are detailed in the Project Specific Technical Schedules along with minimum required operating times. A sample of values is shown in the table above. Points **A and H *minimum*** values are also stated in the Project Specific Technical Schedules. Contractors may offer values in excess of these minimum requirements, such as those described with dotted lines.

1. The area (BDFGECB) is the required operating region of the STATCOM and provided in the Project Specific Technical Schedules for all locations of installation
2. The voltage de-block design point H, or minimum operating voltage design point shall be advised by the Contractor for their particular design. Point G is the inductive transient current rating design point. Point C is the capacitive transient current rating design point. The V-I Characteristics shall comply with transient inductive voltage rating of;
    a. Line AC - the values as defined in the Project Specific Technical Schedules

[1] The durations defined in Table 2 aim to provide post fault support for sufficient periods to incorporate the time required by automated systems to function and to enable Control Room manual switching on the transmission system for post fault management

[2] The operating characteristic diagram is shown in the Project Specific Technical Schedule

OR

b. Line A'B' - values offered by the Contractor for their particular design over and above the minimum as defined by line AC.

3. The scope of the V-I curves shall be confirmed by real time operational conditions. The Slope characteristics shall be adjustable over the range 1% to 10% voltage change (with 1% resolution)

4. In the event of voltages exceeding the magnitudes as listed in the Project Specific Technical Schedules, in either the inductive or capacitive range, the Contractor shall state the capabilities of the STATCOM and describe the control actions that shall be taken.

5. The actual short time capabilities of the STATCOM, as designed by the Customer, in both the inductive and capacitive capabilities shall be stated by the Customer.

Note that the voltage refers to the GIP. The minimum durations of maximum current injection aim to provide post fault support for sufficient periods to incorporate the time required by automated systems to function and to enable Control Room manual switching of the transmission HV network for post fault management.

5.4.2.1 REQUIREMENTS DURING HIGH VOLTAGE DISTURBANCES:

a) In the leading (inductive) range the STATCOM shall meet the minimum short time Operating Characteristic requirements as specified in the Project Specific Technical Schedules, following and followed by operation at the maximum continuous inductive capability. The Customer shall advise the actual capabilities of their design in excess of these minimum requirements.

b) For voltages exceeding the magnitude in Table 2, the customer shall describe the recommended action the STATCOM shall take. For these circumstances (transient over voltages) a control action is preferred to a protective trip.

c) The short time capability of the STATCOM in the inductive range shall be declared by the Customer.

5.4.2.2 REQUIREMENTS DURING LOW VOLTAGE DISTURBANCES

a) For periods beyond the minimum defined period as per Operational Characteristic, the STATCOM output may be reduced to zero MVAr but the main STATCOM circuit breaker shall not be opened for at least 1 hour. The Customer shall describe the recommended action the STATCOM shall take.

b) The STATCOM shall be capable of generating MVAr in accordance with pre-excursion set points and targets within 500 ms of the system voltage returning above the voltage point at which the STATCOM de-blocks. This voltage point is defined in Project Specific Technical Schedule.

c) The Customer shall declare the short time capability of the STATCOM in the capacitive range.

5.4.3 FAULT RIDE-THROUGH

The STATCOM shall meet the fault ride-through requirements as outlined in Table 1 of this specification. The STATCOM shall be demonstrated (through the design and testing phase as part of the Reactive Power Control test) to operate and remain connected to the transmission system during and subsequent to voltage disturbances at the Grid Interface Point.

The minimum trip delay for the STATCOM, from 0.3 p.u retained voltage down to complete loss of the transmission system voltage (including loss of AC auxiliary supplies) shall exceed 3 s. This shall be provided for via the STATCOM independent 220 V DC battery supplies.

The main STATCOM HV circuit breaker shall not open for HV network voltages above the voltage de-block point as advised by the Customer which shall be at a minimum as per the parameters defined in the Project Specific Technical Schedules except for internal fault protection operation.

For low voltages, lower than the minimum voltage de-block point as defined in Project Specific Technical Schedule (0.5 p.u. or lower value as offered by the Customer), lasting more than 1 hour, the STATCOM is permitted to open its circuit-breaker if it would be unsafe to re-apply voltage to the STATCOM; this condition shall be alarmed back to the SCADA system.

5.4.4 SPEED OF RESPONSE

Over the required dynamic MVAr range that shall be detailed in the Project Specific Technical Schedule, the STATCOM shall respond to step changes of system voltage such that a 90 % of the STATCOM current shall be achieved in less than 50 ms. This response will include the time taken by the STATCOM to measure the change in system voltage.

In addition to the speed of the step change in current, the response shall have;

- A settling time less than 200 ms, such that oscillations greater than 1 % of step change in current ceased 200 ms after the disturbance.
- First overshoot and undershoots no more than 5 % of the step change in current

This requirement is for all system conditions quoted in this document and in the Project Specific Technical Schedule. The Customer shall indicate the actual response and validate this in FAT and SATs.

5.4.5 STATCOM CONTROL STRATEGIES

The STATCOM shall be designed to contribute to control of Transmission System Voltage by continuous modulation of reactive output by means of a continuously acting control scheme.

Two principle control strategies shall be implemented for the output control of the STATCOM.

- Voltage control mode
- Reactive power mode

It shall be possible to change between the two strategies, with negligible transients seen in the reactive output from the STATCOM.

In some cases, there may be a requirement for additional control functionality. These requirements shall be detailed in Project Specific Technical Schedule.

5.4.6 STATCOM START UP

As a minimum requirement the STATCOM shall be capable of generating its full MVAr range within one minute of initial energisation of the STATCOM assets.

The Customer shall state the performance of the STATCOM following initial energisation of the coupling transformer. This shall include a description of the manner in which the various auxiliary loads are connected, how the auxiliary supplies are reconfigured and how the automatic start up sequence operates following energisation of the coupling transformer.

This information is required for inclusion in the Station operating instruction.

5.4.7 PERFORMANCE DURING PHASE UNBALANCE

The STATCOM shall fulfil all performance requirements of this specification under conditions of minimum 2 % continuous negative phase sequence component of phase voltage.

5.5 HARMONIC PERFORMANCE & RATING

5.5.1 EQUIPMENT RATING

The design of the STATCOM installation shall address the effects of harmonics, as detailed in this specification and Project Specific Technical Schedule. Harmonic content shall be taken into consideration when selecting the appropriate ratings of all components. Factors to be evaluated shall include, but not be limited to the following:

a) Any harmonics generated by the STATCOM

b) The supply system harmonic impedance loci (“rating” conditions) for the HV system (as detailed in Project Specific Technical Schedule)

c) The maximum continuous fundamental frequency voltage on the HV system

d) EirGrid Planning levels, as per IEC 61000-3

Specific requirements shall comply with parameters outlined in Project Specific Technical Schedule. Component tolerances shall be considered, when designed to meet this requirement.

The TSO will monitor the harmonic contributions of the Offshore connection by monitoring the harmonic contribution pre and post connection to the system as part of the Power Quality Performance test as listed in Performance Verification and Acceptance Test section of the specification.

5.5.2 EQUIPMENT PERFORMANCE

The STATCOM equipment shall be designed to meet the Harmonic Voltage Distortion Gain requirements at the HV side of the coupling transformer as specified in Project Specific Technical Schedule.

The following shall be provided in Project Specific Technical Schedule:

- System harmonic impedances (“performance” conditions loci) seen from the relevant AC substation busbar
- The level of existing harmonic voltage distortion (“performance” conditions) at the relevant AC substation busbar
- The maximum allowable Harmonic Voltage Distortion Gain from operation of the STATCOM

Any predicted exceedance of the specified gains shall be mitigated by the Customer (by installation of harmonic filters or other suitable measures). These mitigations shall form part of the STATCOM installation.

5.5.3 ACTIVE FILTERING

Any harmonic filtering requirement can be met with either active filters or passive filters. Harmonic voltage distortion limits will be provided in the Project Specific Technical Schedule and the Customer can choose the any of the mitigation methods above to meet those requirements.

5.6 VOLTAGE FLUCTUATIONS

Customers shall ensure that their connection to the Transmission System does not result in the level of fluctuation of the supply Voltage on the Transmission System at the GIP exceeding limits set out below. Any necessary data will be exchanged between both parties and the exchange of data shall not be unreasonably withheld.

- **Voltage Flicker**
  Customers shall take responsibility for limiting Voltage Flicker caused by their Plant and the corresponding transmission assets installed by the customers for connection into the transmission system to remain within the maximum permissible Voltage Flicker limits at the GIP as allocated to them by the TSO or, as a minimum, those defined in Table 5 of IEC/TR 61000-3-7.
- **Rapid Voltage Change**
  Customers shall ensure that the disturbance levels introduced by their Offshore PPMs, transmission assets installed for their connection, and/or corresponding Apparatus at GIP do not promote rapid Voltage changes exceeding those specified in the below table[3] or alternative limit allocated to them by the TSO during normal system operation.

Table 3 Rapid Voltage Change

Type of Rapid Change	$\frac{\Delta U}{U_N}$ Limit (%)	Timeframe

[3] Table describes both +/-5% and +/-3%

Temporary Voltage Depression	5	Must recover to nominal **Voltage** in 3 Seconds
Step Change	3	One Cycle

The Customers can be connected to the Transmission System provided that the required studies have been completed by the Customers to show compliance and have been reviewed by the TSO. Following consultation with the TSO, a conditional connection may be allowed to Customers where modelling of the connection shows a breach of the limits to be marginal or only occurring during contingencies as defined by the TSO. This may allow the Customers to verify that the installation is compliant by monitoring, or to implement a mitigation solution.

The Customers Allocated Harmonic Distortion Limits will be issued in the Project Specific Technical Schedules and any special conditions pertaining to power quality will be referenced in the Connection Agreement. These are subject to verification of compliance by the TSO and through an on-going monitoring programme.

In the event that a Customer causes any limits to be breached, the TSO shall be entitled to require the Customers to take such steps as the TSO reasonably considers to be necessary in order to prevent such breach from continuing and the Customers shall comply with the TSO's instructions without delay.

5.7 TELEPHONE & RADIO INTERFERENCE

5.7.1 TELEPHONE INTERFERENCE

In addition to the requirements outlined in OFS-SSS-400, the design of the STATCOM shall be such that it will not cause any objectionable interference with radio, television or communication mediums in the vicinity, either by direct radiation or by transmission through the cable/conductor to which the STATCOM may be connected. The assessment shall consider the case when the STATCOM is energised at full rated voltage and delivering any load up to the continuous maximum rating.

5.7.2 RADIO INTERFERENCE

The STATCOM shall be demonstrated to comply with European Council Directive 89/336/EEC on electromagnetic compatibility with respect to the limitation of radio frequency emissions.

5.8 AUDIBLE NOISE

5.8.1 PROTECTION OF HEARING

The STATCOM shall comply with chapter 1 of Part 5 of the Safety, Health and Welfare at Work (General Application) Regulations 2007 S.I. No. 299 of 2007 as amended from 12 November 2007 by the Safety, Health and Welfare at Work (General Application) (Amended) Regulations 2007 (S.I. No. 732 of 2007) which sets down the minimum requirements for the protection of workers from the health risks associated with noise in the workplace.

The level of audible noise inside the STATCOM building/enclosure should not exceed 70 dB(A) in areas where personnel are permitted during STATCOM operation.

5.8.2 Environmental Noise

The maximum permissible level shall be stated either at a sensitive receptor critical to noise disturbance, e.g. a residential house, or at a defined position.

The design of the STATCOM shall take into account all reasonably practicable noise mitigation measures in order to reduce the noise generated from the STATCOM and its associated equipment to comply with Table 4. This shall take into account at least the following:

a) Coupling transformer noise enclosure;

b) Air-cored reactor sound shields;

c) Power electronic valve cooling incorporating fans for the outdoor air cooler banks and the use of noise barriers with appropriate placement to utilise attenuation from inherent features like buildings;

d) Power electronic valve cooling room which incorporates sound proof doors, walls and silenced ventilation intakes/extracts etc.; and

e) Building HVAC equipment intakes and extracts which are silenced and the control system arranged to minimise the impact at the receiver, e.g. the first extractor fans to operate for increasing temperature shall be located away from the receiver.

The noise levels of transformers shall be measured in accordance with IEC 60076-10. The noise level shall be for sound pressure level at 2 m away from the principal radiating surface with all forced air cooling equipment in service.

Where no other specification is given, the following limits shall apply:

Table 4 Permissible Sound Levels

Location	Sound Pressure dB(A)
Station Fence	50 or as per Planning Permission limits

5.8.3 Noise Assessment

Where environmental noise is identified outside the limits, a noise model shall be developed for the proposed STATCOM equipment using an industry standard noise modelling package. The noise studies shall include;

a) Tables of raw sound power data to enable independent noise modelling;

b) Tables of equipment operating modes and associated sound powers;

c) Details of proposed acoustic mitigation and insertion loss;

d) Incorporation of site layout and equipment design including heights and dimensions of principal noise sources;

e) Details of the source input data used;

f) Tables of contributions at residential receivers;

g) Details of key assumptions made in the noise modelling;

h) A statement specifying whether or not a dB penalty for tonality has been applied (and if so, at source or at receiver) in accordance with BS 4142:2014; and

i) Clear noise contour maps with contours to below background.

The noise model shall consider float, full output, any lifetime load profile detailed in Project Specific Technical Schedule as operational scenarios for the equipment and any operating points that the Customer considers to be more onerous for Environmental Noise.

Design of the proposed STATCOM equipment shall aim to achieve an acceptable (below background) assessment level at the most sensitive receivers.

The noise performance data required for air-cored reactors shall be determined in accordance with BS EN ISO 3746 or BS EN 9614.

In the event that the noise assessment determines that some or all of the noise mitigation methods are not necessary at first, the design of the STATCOM shall allow these mitigation methods to be installed in the future. This is especially pertinent in respect of air-cored reactor sound shields. Additionally, the design and layout of any mitigation methods shall be consistent with safe operation and maintenance.

5.9 LOSS EVALUATION

The design of the STATCOM shall be optimized to minimize losses over a lifetime of the asset. A loss report shall be supplied as outlined in Appendix A – Phase 1 to demonstrate the Customers calculations and compliance with the following requirements.

Losses shall be calculated in accordance with the principles of EN 62751-1 and EN 62751-2. Separate values shall be given for both no load and load related losses.

The Customer shall state the losses for each group of equipment, which shall include all STATCOM components up to the main HV bus connection. The equipment may include, but are not limited to:

1. Transformers;
2. Interphase Magnetics (e.g. phase reactors);
3. VSC Converters;
4. Capacitor banks;
5. Control and protection equipment; and
6. Cooling and Auxiliary equipment.

The loss report shall include a graph of the loss in kW against MVAr output for the entire output range of the STATCOM (including all transformers). This shall be based on a target voltage of 1 p.u., a slope setting of 5 %, at rated frequency (50 Hz), an ambient air temperature of 20°C and component tolerances which give the worst case losses. All hysteresis effects, any increased losses due to the switching of power electronic devices and all auxiliary plant loads shall be included. The losses of all components with a loss greater than 1 kW shall be considered. Capacitors forming part of the STATCOM shall be considered as single lumped components and the losses in any external capacitor fuses shall be identified separately.

The declared Tendered losses shall be further subdivided into two categories as follows:

- **Measured losses**: Those losses which can be verified by test measurements either in works or at site at which the STATCOM is installed.
- **Calculated losses**: Those losses which can only be proven by calculation and cannot be further verified by testing. No re-evaluation of the calculated losses shall be allowed following contract placement except where justified by the Customer and agreed by the TSO.

Full details of the calculation methods used to derive both the ‘calculated’ and the ‘measured’ losses, and the proposed means by which measured losses are to be established shall be provided as outlined in Appendix A – Phase 1.

The lifetime costs of the proposed equipment shall be considered as part of the overall economics of the proposed solution. This will include an annual capitalised value of the losses in € for the STATCOM. The anticipated operation and monetary value of the losses of the STATCOM will be provided in the form of a duty cycle graph and table as defined in the Losses section of the Project Specific Technical Schedule.

5.10 STATCOM AVAILABILITY & RELIABILITY

The installation shall be designed to have an operational lifespan of the following:

- The STATCOM primary equipment and associated civil works shall have a minimum design life of 40 years.
- The protection and control systems associated with the STATCOM shall have a minimum design life of 25 years.
- The power electronic devices shall have a minimum design life of 25 years.

A minimum of maintenance shall be required during this time. Any components the customer considers to be unable to meet this life expectancy shall be listed in the deviations schedule in document Project Specific Technical Schedule as well as the reason for non-compliance.

The Customer may propose additional design life where it demonstrates an overall cost benefit and complies with Reliability, Availability and Maintainability requirements.

- The overall availability shall exceed 98%. (“overall” includes scheduled, forced outages and any outages associated with any burn-in and warranty periods).

The Customer shall provide details of their proposed approach to facilitate the design life of the STATCOM installation including features permitting the replacement of components such as protection and control, power electronic systems or devices with the minimum of down time for the STATCOM installation. Should this include mid-life refurbishment, the scope of such refurbishment shall be provided along with details of how the required outage shall be minimised.

The Customer shall supply a detailed reliability, availability and maintenance (RAM) study demonstrating compliance with this requirement inclusive of primary, secondary and auxiliary system performance. The Customer shall identify the consequences of unreliability in their STATCOM design and propose mitigation measures to maintain availability until the next scheduled outage. Further, the Customer shall provide a statistical availability study demonstrating compliance with the power electronic valve availability requirement. This study shall include the source of the component failure rate statistics and consider the configuration and performance of the components of the valve cooling system and the associated pumps, transducers, controllers, etc.

A sufficient level of redundancy shall be provided to achieve the availability requirements as outlined above. The statistical availability study shall include any necessary mitigation measures where appropriate to achieve these availability requirements and to prevent potential downtime which may be anticipated during the early phase (burn-in) of the asset.

Consideration shall be given to minimising outage requirements for operation and maintenance (including any mid-life refurbishment or replacement) activities through, for example, provision of redundancy of critical systems and components and appropriate positioning of components to which access may be required.

Following energisation of the equipment, the Customer shall monitor the reliability and availability of the STATCOM equipment. Before the asset is handed over to EirGrid the Customer shall provide a report demonstrating compliance with the availability figures. Where the availability figures are measured to be less than specified, the Customer agree the action required with EirGrid and shall rectify the shortfalls.

6 STATCOM PROTECTION AND CONTROL REQUIREMENTS

The STATCOM shall be equipped with a Protection and Control system designed to operate satisfactorily under normal and abnormal conditions.

The Protection and Control system of a STATCOM shall be designed to ensure that no single failure may cause a fault to remain connected to the primary system.

Refer to OFS-GEN-016 specification and its Appendix for further details of protection and control requirements. In general, STATCOM protection shall follow OEM requirements and recommendations that shall be submitted to EirGrid for review.

This shall be supported by a Protection and Control system design report and associated documentation which shall be provided by the Customer for EirGrid review as outlined in Appendix A – Phase 1.

6.1 STATCOM PROTECTION

The STATCOM protection system shall be co-ordinated with the Onshore Compensation Compound protection system and have no adverse effects on other systems connected to the transmission system. Refer also to OFS-GEN-016 specification.

The Customer shall provide a protection co-ordination study in order to demonstrate any interface protection requirements with the network protection which will include the STATCOM protection settings. The Customer shall engage with EirGrid post contract award in order to harmonise settings in line with the network protection relays.

The STATCOM protection 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.

Two sets of protection shall be provided namely main protection and backup protection. Main protection and backup protection shall be independent devices to prevent the loss of a complete protection system on a single device malfunction. The backup protection shall differ from the main protection in the measuring and protection principles, where possible.

Each of the two sets of protection shall be supplied from two independent DC supplies and two independent Current transformer cores.

Main protection shall be protection devices which isolate the respective zone in the shortest possible time. Maximum Clearance time (including CB operating time) to be less than 100 mS. Back-up protection should be protection time graded with the main protection.

All the protection equipment that requires regular inspection and/or maintenance shall be listed in the Phase 1 submission, together with fully documented method statements and recommended inspection/maintenance intervals to achieve the required service life.

It shall be possible to remove any single protection system from service without leaving any section of the STATCOM unprotected or endangering the STATCOM plant.

Suitable space shall be provided in the relay room to enable replacement equipment to be built and installed off-line which will minimise future outage requirements.

All protection interfacing with the connecting Substation with respect to interface trips, CBF starts, alarms and signals will be proposed during detailed design stage when the STATCOM supplier is confirmed and shall be reviewed and agreed with EirGrid.

6.2 CONTROL AND MONITORING

6.2.1 GENERAL CONTROL SYSTEM REQUIREMENTS

The control system shall be designed as appropriate to enable the STATCOM to function under steady-state, transient and dynamic operating conditions.

The Customer shall provide details of the STATCOM control and monitoring system as outlined in Appendix A – Phase 1.

The STATCOM shall have an HMI which shall communicate with SCADA, SCS and provide a centralised (local) operator control of the STATCOM functions. All human interface operations necessary for the control and monitoring of the STATCOM shall be provided at this point.

The HMI display shall include diagrams of all STATCOM components in the display system, and shall indicate status, alarms, voltages, currents, etc. The HMI shall provide complete diagnostics on alarm and trip indications as required and discussed in this specification.

The Customer shall define the control methodology employed to manage the loss of any of the three system phase voltage signals and the behaviour of the STATCOM control system during unbalance conditions and single or two phase faults.

The Customer shall provide sufficient redundancy and reliability such that a single failure of any part of the control system including measurement transformers will not result in the incorrect performance or reduced availability of the STATCOM.

Duplicated control systems shall be used. Only one control system shall be in service at a time. An automatic changeover function shall be provided to switch between the main and hot standby system when a fault is detected in the in-service system.

The STATCOM protection operation or failure shall annunciate through the SCADA system.

Any additional protection requirements such as disturbance/data recording, PMU, time synchronisation will be outlined in the project specific protection specification.

6.2.2 CONTROL POINTS (LOCATIONS)

The STATCOM shall normally be unmanned and operated from transmission SCADA, SCS.

There shall be at least two selectable control points for the STATCOM:

1. The Local Control Point is located in proximity of the STATCOM equipment where the specific plant and associated functions can be locally operated.
2. EirGrid transmission SCADA (remote). Refer to OSP-GEN-015 specification. STATCOM control system shall interface with transmission SCADA. .

The control system shall have a control arbitration mechanism to ensure that only one control point has control authority (active) to operate a plant item or function at a time. Selected control points shall be clearly annunciated at all the control points.

It shall be possible to select between the different control strategies / modes (voltage control mode and reactive power mode) from all the above defined Control points. For each control mode, it shall be possible, to select the set point (control target/reference) of which the range will be specified.

Project specific Protection and Control requirements and signal lists will outline the control commands, alarms and signals that the Customer shall provide to the transmission SCADA.

Spare capacity (software and hardware) of each type of signal shall be provided for in the STATCOM control system for potential future signalling.

6.2.3 STATCOM INTERFACE REQUIREMENTS

A facility shall be provided whereby the local HMI features and functions shall be accessible from remote. A remote user shall be able to view screens and change STATCOM parameter settings as necessary.

Relevant subset STATCOM functionalities (including operation and monitoring functions) shall be integrated into transmission SCADA, Substation Control Station. The subset shall be sufficient to enable transmission SCADA operators to control, operate and monitor all STATCOM systems.

A detailed proposal of signals to be interfaced between transmission SCADA and STATCOM controls shall be submitted by Customer to EirGrid for review.

6.2.4 INTERLOCKING

The STATCOM shall provide outputs to the substation interlocking system to ensure safe operation of other substation switchgear. The interface interlocking requirements will be proposed by Customer and submitted to EirGrid for review.

7 MAIN STATCOM COMPONENTS REQUIRED FUNCTIONS AND FEATURES

The Customer shall select and propose the nominal operating voltage for the low voltage side of the step-down transformer, in order to optimize the design of the STATCOM. The proposal will be submitted to EirGrid for review.

All substances used shall be classified in accordance with European Community SI on Hazardous Substances Regulations. Safety Data Sheets shall be submitted where appropriate.

7.1 POWER ELECTRONIC CONVERTER

The valves shall comply with the applicable sections and general principles of BS EN 60146-1 and BS IEC 60747-9.

The solid-state switching devices shall be assembled into discrete power electronic modules which can be rapidly exchanged with the minimum disturbance to current-carrying connections and the water cooling circuit. Any requirement for dismantling other parts of the overall valve assembly shall be minimised. Any special tools required for the replacement of these parts shall be provided to EirGrid.

The in-service failure of any single valve component shall not prevent the continued operation of the STATCOM at full rated MVAr capacity. If a fault occurs, the control system shall immediately identify its existence and (where appropriate) adjust the control strategy to mitigate the impact of that of the fault and log the date and time of its occurrence. An indication of the fault location shall be provided in the control system.

The Customer shall provide information on how the redundancy is to be implemented (including details on the number of integrated redundant valve modules capable of seamless change over on valve failure) and demonstrate that the voltage stresses applicable to the non-bypassed components are within acceptable limits.

A sufficient level of redundancy shall be provided to achieve 99.5 % availability (excluding planned maintenance) and allow valves to operate for a period of three years between scheduled maintenance. This requirement drives the level of valve redundancy needed in the STATCOM.

A detailed design report covering all aspects of the valve design, including protection functions, shall be provided by the Customer at the design stage.

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.

The STATCOM valve hall/housing and any other associated outdoor enclosures/connections shall be designed to allow normal operation under the full range of environmental conditions specified in OFS-SSS-400 Onshore Compensation Compound General Requirements. Particular attention shall be paid to the temperature ranges, level of salinity in the air, humidity levels and the risk of condensation developing inside the housings/enclosures. The design shall ensure that moisture ingress is limited to a level which will not cause damage to valve components (either immediate or long term) or lead to a flashover of any insulation.

Where HVAC is employed to control the climate in the valve accommodation the performance, operation and maintenance shall be included in the overall STATCOM reliability/availability assessment for the required 99.5% availability requirement. Redundancy shall be provided where HVAC is critical to STATCOM operation.

The Customer shall demonstrate that the design of the valve and its enclosure meets the recommendations of IEC/TR 62757 and follows best practice in managing the risk of fire.

7.2 CONVERTER COOLING SYSTEM

The converter valves shall, unless otherwise agreed, be water cooled. A closed cooling system shall be provided to circulate water through the valves and then through external cooler banks. The cooling system shall be sized to permit the STATCOM to operate continuously at the worst-case operating point under all environmental conditions specified in OFS-SSS-400. Unless otherwise agreed, dry-type coolers shall be used and chillers or evaporative coolers shall not be accepted.

The cooling plant shall be designed to minimise auxiliary power consumption of the STATCOM over its normal duty cycle. The plant should automatically shut down when the STATCOM is taken out of service.

The cooling plant shall be accessible for routine inspections, without the need to isolate and earth the primary plant.

Isolation valves shall be provided at locations accessible from ground level and external to any enclosure. These valves shall be lockable.

Vent valves shall be provided at the highest point and drain valves at the lowest point of the cooling system to enable fluids to be drained from the system prior to any intrusive access or maintenance and to facilitate refilling.

The cooling fluid in the external cooling circuit shall not freeze when exposed to the minimum ambient temperature specified in OPS-SSS-400. To achieve this, pipework may be thermally insulated or the cooling fluid may be treated with an additive to prevent the risk of freezing. The coolant mixture used in the cooling circuit shall be compatible with the pipework and all other materials into which it will come into contact for all conditions of temperature, pressure and flow rate that will be experienced in service. Data sheets and other supporting documentation shall be provided, on request, to confirm compliance with this requirement.

Where the valves are designed to be cooled by deionised water, the cooling design shall ensure that no cross contamination of the separate cooling sub-systems (e.g. a deionised water system to a water/glycol mixture system) is possible.

The growth of algae and bacteria within the cooling system must be inhibited.

External piping shall be manufactured from stainless steel and shall be designed to minimise leakage.

The Customer shall provide a design report detailing the required flow rates, pressures and resulting temperatures in respect of the cooling system under float conditions (i.e. zero MVAr transfer) and also the MVAr transfer corresponding to maximum thermal losses. As part of the design report the Customer shall assess the necessity of a bund for containment of potential spillages.

This information shall be calculated based on the minimum number of cooler banks in service and the maximum specified ambient temperature

Depending on the design, the valve cooling system or a part thereof may be required to comply with regulations relating to the design and operation of pressure systems. The Customer is responsible for assessing whether the regulations apply and defining maintenance and examination requirements.

Any spillage or losses of coolant which may contain a pollutant or contaminant must be contained to allow proper disposal.

Coolant losses during operation shall be minimised and shall not require operator intervention (e.g. topping up) any more frequently than once every 2200 hours (~3 month) of operation.

Redundancy shall be provided to ensure that the STATCOM can continue in normal operation, at maximum ambient temperature, following failure of a pump (primary or secondary), a three-way valve or a heat exchanger. All redundant equipment must be provided with a means of local isolation for maintenance purposes.

To maximise lifetime and cooling plant availability the apportionment of running hours between rotating plant (fans and pumps) shall be automatically assigned by the control system. Changeover between cooling pumps shall be achieved in a smooth manner enabling

the cooling plant to continue in operation without reduction in performance whilst the changeover is occurring.

Where the cooling plant includes items of equipment that are only required to operate infrequently or at certain times of the year, the cooling plant design shall ensure that such components will satisfactorily operate when required following a long duration of inactivity. It is expected that this will take the form of some periodic running under automatic control.

Instrumentation for coolant flow pressure, temperature and conductivity shall remain within calibration for a minimum period of two years and shall be arranged to be fail safe. Transient indications and alarms associated with these devices shall be stored / logged before resetting.

Once the cooling system, cross-site pipework and connections to the valve have been installed and assembled on site, the fully assembled system shall be subjected to an over pressure test to prove the system.

7.3 REACTORS

The following requirements apply to air cored reactors used between the VSC converter and the STATCOM MV busbar, to provide fixed inductive elements to the STATCOM system and for tuning harmonic filters.

7.3.1 VOLTAGE/POWER RATING

The Customer shall provide a design study to demonstrate how the voltage and power rating of the reactors has been determined. The ratings shall be defined in accordance with IEC 60076-6, Power transformers - Part 6: Reactors.

The ratings shall consider the full range of specified system operating parameters (max/min voltage, frequency range, harmonic distortion) as well as the continuous and short term operating range of the STATCOM.

The dielectric performance of the reactor shall be demonstrated by dielectric type/routine tests in accordance with IEC60076-3.

7.3.2 INRUSH AND DISCHARGE CURRENT

The design study shall also consider the inrush and discharge currents arising from normal operation of the STATCOM and from contingency events (i.e. equipment faults). The reactors shall be designed to withstand these temporary currents without damage.

7.3.3 TEMPERATURE RISE LIMIT

The temperature rise of the reactor windings shall not exceed the limits specified in IEC 60076 (all parts). Temperature rise tests shall be carried out to verify this performance.

The temperature rise of the reactor supporting structures shall not exceed 30°C if they are accessible during normal operation or 50°C otherwise.

7.3.4 MAGNETIC FIELD CLEARANCES

The design shall comply with guidelines from the International Commission on Non-Ionising Radiation Protection (ICNIRP) for time-varying fields. For public exposures this will be in terms of EU Recommendation 1999/519/EC2.

Measurement of magnetic characteristics under normal operating conditions, as stated in EirGrid standard OFS-SSS-400, Compensation Compound General Requirements, shall be conducted.

Suitable magnetic clearance distances shall be provided from the installed reactor to all metallic objects. Closed metallic loops shall be excluded from the immediate vicinity of the reactor. The customer recommended magnetic clearances shall be shown on the reactor data sheet and on equipment layouts.

The Customer shall provide magnetic field contour plots covering all points external to the STATCOM footprint area at which the magnetic field exceeds 100 µT.

7.3.5 TOLERANCES

The customer shall meet the tolerance values set out in in Project Specific Technical Schedule.

7.4 AC AND DC CAPACITORS

7.4.1 DC CAPACITORS

DC capacitors installed in the power electronic modules shall comply with BS EN 61071. The Customer shall provide a design study to justify the choice of DC capacitor rating and resultant stress levels including the effects of any harmonics.

7.4.2 AC CAPACITORS – DESIGN AND CONSTRUCTION

AC capacitors installed shall comply with applicable IEC standards as outlined in this specification.

7.4.2.1 STEADY-STATE VOLTAGE

The voltage rating of the capacitor units shall be defined in accordance with IEC 60871-1. The Customer shall provide a design study to demonstrate how the voltage rating of the capacitors has been determined. The ratings shall consider the full range of specified system operating parameters (max/min voltage, frequency range, harmonic distortion) as well as the continuous and short term operating range of the STATCOM.

7.4.2.2 LIGHTNING IMPULSE

Capacitors shall be subjected to a lightning impulse test as set out in Section 5, of IEC 60871-1.

7.4.2.3 RATED POWER FREQUENCY CURRENT

The rated power frequency and harmonic current spectrum shall be sufficient to meet the requirements of the application which shall be defined in the Customer design study.

7.4.2.4 INRUSH AND DISCHARGE CURRENT

Inrush transient currents shall be limited to the values set out in Section 27.6.2 Transient overcurrent's, of IEC 60871-1.

Capacitors shall be able to withstand the inrush current (amplitude and frequency) resulting from normal operation and contingency events of the STATCOM.

Capacitor fuses shall be able to carry the number of inrush current surges due to switching, during the life of the capacitor. The peak value of the inrush current shall not exceed 100 times the rated (r.m.s.) current.

Capacitors shall comply with Section 27.6.2, Transient overcurrent's and Section 22 Safety requirements for container connections of IEC 60871-1.

The capacitor banks and individual capacitors shall comply with the discharge times set out in IEC 60871-1.

7.4.2.5 INSULATION REQUIREMENTS

The insulation levels of the capacitor installation shall be defined in the Customer design study and EirGrid specification OFS-SSS-400 Compensation Compound General Requirements together with appropriate electrical clearances.

7.4.2.6 CAPACITOR ELEMENT TOPOLOGY

The Customer shall provide details of the proposed capacitor bank element topology including how the requirement for unbalance protection shall be met.

7.4.2.7 FUSING REQUIREMENTS: INTERNAL/EXTERNAL FUSED CAPACITORS

Capacitors fitted with internal fuses shall conform to IEC 60871-4 and have been tested in accordance with Section 5 of this standards.

External fuses, where used, shall comply with IEC 60871-3, section 5 External fuses.

7.5 POWER TRANSFORMERS

The Customer shall provide a design study to demonstrate how the rated parameters of the coupling transformer have been determined.

The transformer shall comply with the requirements outlined in IEC 60076 (all parts).

7.6 CIRCUIT BREAKERS

This specification excludes circuit-breakers on the HV side of the coupling transformer.

The Customer shall provide a design study to demonstrate how the rating of the circuit-breakers on the MV side of the coupling transformer has been determined.

7.7 DISCONNECTORS AND GROUNDING SWITCHES

This specification excludes disconnectors and grounding switches on the HV side of the coupling transformer.

The Customer shall provide a design study to demonstrate how the rating of the disconnectors/grounding switches on the MV side of the coupling transformer has been determined.

7.8 AUXILIARY POWER SUPPLIES

The Customer shall supply adequate details of auxiliary power requirements. Auxiliary power supplies of STATCOM shall be communicated with and integrated into the integrated SCADA and SCS for the offshore wind plant transmission system.

Full details of the auxiliary power rating requirements shall be provided for the STATCOM. This shall define the loading at float condition, at full output and in any other state which defines the maximum capacity.

Protection and control power supplies shall consist of two independent redundant 220V DC supplies. 220V DC supplies for STATCOM systems shall be taken from main OCC 220V DC Battery Charger systems. Customer can also propose an alternative DC supply solution to EirGrid for acceptance.

LVAC and D.C. supply systems shall comply, as appropriate, with EirGrid specifications:

- OFS-SSS-403 Auxiliary Power Supplies;
- OFS-SSS-405 Station 220V DC and 230/400V AC Distribution Boards
- OFS-SSS-404 220V Lead Acid Batteries and Chargers.

8 ENGINEERING STUDIES

8.1 PRE-MANUFACTURING ENGINEERING AND DESIGN VERIFICATION STUDIES AND STATCOM MODELS

8.1.1 DESIGN STUDIES

A summary of the study requirements to be performed by the Customer is provided in Appendix A.

During the detailed design of the STATCOM, the Customer shall provide copies of design studies to determine the ratings and configuration based on the requirements of this specification and Project Specific Technical Schedule.

These studies shall include, but not be limited to

a) Steady-state load flow (inc. voltage step change) and dynamic studies

b) Insulation Coordination studies

c) Switching (EMTP) studies

d) Temporary and Dynamic Overload Rating studies

e) Operating control modes

f) Electrical and Audible Noise studies

g) Reliability, Availability and Performance studies

h) Loss and Loss Evaluation studies

i) Flicker

j) EMC report (to identify any requirement for a Power Line Carrier (PLC) filter)

8.1.2 Sub-Synchronous Control Interaction Studies

The customer shall provide the detailed models including descriptions of the control system to enable EirGrid to carry out these studies.

The study shall demonstrate that the performance of the control system, in relation to dynamic devices in close electrical proximity, does not exhibit unacceptably damped oscillatory behaviour.

Where SSCI is identified as a potential risk, suitable countermeasures shall be recommended by EirGrid and agreed with the Customer.

8.1.3 Harmonic Studies

The Customer shall carry out suitable modelling and network analysis and provide the details of Harmonic current and voltage studies to highlight any potential overheating conditions that may occur.

System harmonic voltage studies should use the data provided in Project Specific Technical Schedule. These studies shall demonstrate anticipated compliance levels at the HV node. This shall be submitted to EirGrid for review as a report.

Particular attention shall be made to any nearby HVDC terminal, STATCOM, HF filters or SVC installations. The pre-existing background Harmonics shall be defined in Project Specific Technical Schedule.

8.1.4 Statcom Models For Power System Analysis

Suitable models shall be provided to facilitate the following studies during detail design stage:

- **Load Flow Analysis:**

An accurate model representation of the STATCOM for balanced and unbalanced 50 Hz load flow studies shall be provided in both PSS/E and Power Factory formats. The models shall capture the correct representation of the STATCOM steady-state operating characteristics under all possible control modes.

- **RMS Dynamic Analysis:**

An accurate model representation for RMS time domain simulations (dynamics studies) shall be provided in PSS/E, Power Factory and Powertech's TSAT formats. The models shall capture the key components of the STATCOM and the control loops to accurately reproduce the dynamic behaviour of the device over its entire operating range. A Laplace diagram with full description of the blocks shall also be provided.

- **Small Signal Stability:**

An accurate model for modal analysis/eigenvalue calculation shall be provided in Power Factory format.

- **EMT Analysis:**

A full model with complete representation of the power electronic devices, protection, functionality and control strategies shall be provided in ATP/EMTP and PSCAD formats. In addition, a "faster" average model version (where the power electronic converters are replaced with equivalent voltage sources designed to maintain the balance of power) shall be provided in ATP/EMTP and PSCAD formats.

- **Harmonics:**

A detailed frequency domain model of the STATCOM capturing its frequency dependant behaviour (passive Z(f)) and active harmonic emissions at all operating points/modes shall be provided in Power Factory format.

Each of the above models must be accompanied by detailed documentation explaining the model structure and use. Project specific parameters must be identified. A validation report must also be provided for each model.

9 MISCELLANEOUS ITEMS

9.1 EARTHING

Earthing arrangements shall be in compliance with EirGrid's functional specification OFS-SSS-407.

The Customer shall discuss with the STATCOM manufacturer requirement for a special earthing system (i.e. open loops requirements) and prepare a report for EirGrid review.

Where required, an earthing transformer shall be used to earth the secondary side of the transformer. The primary winding of the earthing transformer shall be directly earthed unless the customer can justify using an alternative means of earth fault protection. STATCOM auxiliary supplies may also be provided from the earthing transformer (to be decided during detailed design).

If the earthing system of any of the STATCOM components are isolated from one another the open connection shall be protected against over-voltages.

9.2 SUPPORTING STEEL WORK

All supporting steelwork and access platforms where required shall be supplied and shall be designed for fixing to the foundations.

Refer to OFS-SSS-419 for further details.

9.3 FOUNDATIONS AND LOADING

The housing and mounting arrangements for the STATCOM shall be included in the Customer detailed design and issue to EirGrid for review.

Any outdoor components installed within the station boundary and not on concrete foundations shall have their bases sealed with a covering to tarmac.

The customer shall supply a mechanical loading report and foundation drawings as part of detailed design and prior to delivery of the STATCOM.

The loading report shall include:

- Mechanical loads during operation and installation.
- Electromagnetic forces include those arising from fault or short time loading conditions
- Wind and ice conditions.
- Forces due to expansion and contraction due to both ambient temperature and load variation.

The customer shall indicate how long after award of contract they will supply the mechanical loading report and foundation drawings.

9.4 CORROSION PROTECTION

Corrosion of both ferrous metals, aluminium and aluminium alloys is a particular problem in Ireland.

Experience has shown that because of high humidity, extreme precautions are necessary, to prevent the aggressive ingress of moisture between flange plates, around gaskets and O-rings, at insulator/flange interfaces, etc. All necessary precautions shall be taken to prevent this. Tactile 506 type grease or equivalent should be used if required. This level of attention shall also be paid to all devices bought from sub-suppliers.

The Customer shall state clearly the corrosion protection applied to all aluminium or aluminium alloy parts. This corrosion protection shall be suitable for the site environmental conditions.

Any aluminium or aluminium alloy exposed to the environmental conditions shall be of a suitable grade for the environment and this grade shall be listed by the Customer in the Corrosion Protection Schedule. The Customer shall draw attention to all exposed points in their equipment at which aluminium or aluminium-alloy parts are in contact with or in close proximity to other metals, and shall state clearly in the Corrosion Protection Schedule the protection employed at each point to exclude air and moisture.

The Customer shall confirm that all paint systems employed for corrosion protection of steel parts meet or exceed the requirements of ISO 12944-5 (Corrosion Protection of Steel Structures), to provide high durability (minimum of 15 years) coating with category C5-M corrosion protection, suited to environments with high condensation, pollution and salinity as per ISO 12944-2.

Minimum requirements for the painting and corrosion protection systems for Hot Dip Galvanised Steel are as follows:

- Hot dip galvanising of steel shall be fully compliant with the requirements of EirGrid's specification OFS-SSS-420 Hot-dip galvanising of iron and steel articles other than wire".
- Paint system for hot-dip-galvanised steel surfaces shall meet or exceed the requirements of Paint System A7.13 of ISO 12944-5, to provide high durability (minimum of 15 years) coating with category C5-M corrosion protection, suited to environments with high condensation, pollution and salinity as per ISO 12944-2.

The process for painting hot-dip galvanised steel is detailed below:

Table 5 Table Process for Painting Hot-Dip Galvanised Steel

Process	Materials	Minimum Requirements
Clean	Appropriate solvents or other cleaning agents	A grease / oil free substrate
Sweep blast	Aluminium oxide or other inert abrasive medium	A light texture on the zinc layer with no more than 3 % of the zinc removed by the process
Priming	As per Paint System A7.13 of ISO 12944-5	As per Paint System A7.13 of ISO 12944-5
Undercoating	As per Paint System A7.13 of ISO 12944-5	As per Paint System A7.13 of ISO 12944-5
Finish coating	As per Paint System A7.13 of ISO 12944-5	As per Paint System A7.13 of ISO 12944-5

The minimum requirements acceptable to EirGrid for individual items are as follows:

a) Hot-Rolled Steel, Mechanism Boxes, Marshalling Cabinets, Fasteners larger than 12 mm Diameter and pipes:

   i. Hot dip galvanising, in accordance with EirGrid Specification; and

   ii. Painting system as per painting and corrosion protection for Hot Dip Galvanised Steel stated above.

b) Smaller Fasteners, Cable Clips and any nonferrous material or stainless steel of suitable grade for the environmental conditions stated in EirGrid OFS-SSS-400 Onshore Compensation Compound General Requirements specification.

c) As a minimum all exposed non-stainless ferrous parts, including supporting steel work for STATCOM, kiosks, nuts and bolts, shall be hot-dip-galvanised to comply with EirGrid specification, OFS-SSS-420.

9.5 TESTING OF STEEL CORROSION PROTECTION

The painting and corrosion protection system shall be type tested as per ISO 12944-6.

In addition the following type and routine tests shall be carried out where not covered by ISO 12944-6:

- The required tests of appearance on the painting and corrosion protection system for hot dip galvanised steel are detailed below and shall be carried out as part of type and routine tests.

Table 6 Painting and Corrosion Protection System Tests

Test Method	Gloss	Colour	General Appearance
ISO 2813	80 $^{+/-}$ 10 Units @ 60 ^{o}		
ISO 7724		ΔE CIELAB of not more than 1.5 under D65 light source from the master chip.	
Viewed in clear north light with the unaided eye at a distance of 2m.			The coating shall be of smooth uniform appearance, with no inclusions, voids, or other blemishes, which mar the surface.

- The required type and routine tests of performance characteristics on the painting and corrosion protection system for hot dip galvanised steel are detailed below:

Table 7 Type Tests

Type Tests				
Test	**Method**	**Requirements**		
480 HOUR SALT SPRAY	ISO 9227	MAXIMUM ADHESION LOSS AT SCRIBE	BLISTERING REMOTE FROM SCRIBE	OTHER DEFECTS
		2 mm	None	None
480 HOUR HUMIDITY	ASTM D 2247	BLISTERING	COLOUR CHANGE	OTHER DEFECTS
		None	None	None
SOLVENT RESISTANCE RUB TEST	ASTM D 4752	CORROSION	BLISTERING	OTHER DEFECTS
		None	None	None
1,000 HOURS UVA ARTIFICIAL WEATHERING	ISO 4892-3	MAXIMUM COLOUR CHANGE	MAXIMUM LOSS OF GLOSS @ 60^{0}	OTHER DEFECTS.
		ΔE = < 2.6	< 25 %	None
ROUTINE TESTS				
TEST	METHOD	REQUIREMENTS		
Initial adhesion. Cross Hatch Test	ISO 2409 ASTM D 3359	MINIMUM RATING		
		0		
Hardness Test	ASTM D 3363	MINIMUM RATING		

Type Tests				
Test	**Method**	**Requirements**		
		0		
DIRECT IMPACT	ASTM D 2794	FAILURE AT 56 INCH / LB		

9.6 ELECTROMAGNETIC COMPATIBILITY (EMC)

Attention should be given to the design of the earthing system and to the layout of the STATCOM and its components to reduce the risk of EMC problems, in regard to safety of personnel who operate and maintain the equipment, in respect of the Directive 2004/108/EC and Directive 2004/40/EC for the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)'.

9.7 PADLOCKING

All items which require padlocking shall be provided with a hole, approximately 7 mm diameter for accepting padlocks with a shackle diameter of 30 mm, shackle length of 23 mm and 6.3 mm diameter cross-section for this padlocking.

9.8 LABELS AND MARKINGS

9.9 EQUIPMENT NAMEPLATES AND LABELLING

The equipment shall be labelled so that each component and each piece of main equipment may be identified. Each individual STATCOM component shall be provided with a name plate bearing information as specified by relevant IEC Publication. Individual equipment nameplates shall contain the actual current, voltage, resistance, inductance, capacitance, CT ratio ratings of the equipment.

All labels printed shall survive the equipment's anticipated lifespan and shall be clear and indelibly printed in English. The labels shall be engraved and resistant to UV light. The labelling shall also include EirGrid's designations as required.

The following indications shall be supplied as minimum:

a) Each STATCOM component connection shall be clearly labelled to indicate its function and connection point.

b) Each phase of the STATCOM bays shall be identified with appropriate phase reference at each point where it may be accessed.

c) Each STATCOM component shall be labelled and referenced to its identification code contained in the customer's drawings.

All labelling shall be subject to review by EirGrid to confirm clarity and understanding of all texts.

Addition labelling requirements are outlined in OFS-SSS-402 Control and Protection Cabinets and Marshalling Kiosks.

10 Testing And Commissioning

10.1 Testing Of Components

Tests shall be carried out in accordance with the appropriate IEC publications and OEM recommendations, unless stated otherwise. Customer shall submit ITPs (inspection and test plans) and testing / commissioning procedures to EirGrid for review.

Type tests shall be performed on one of each type to be delivered. Type tests are not required if the Customer provides type test reports for the specific equipment, provided the type tests are fully applicable to the specific equipment.

All equipment must be subjected to and pass the specified type tests at an accredited testing laboratory in accordance with the relevant IEC Publication, and the test certificates or reports obtained shall be submitted to EirGrid for review.

EirGrid may wish to witness type, routine and special tests, or visit the factory during the manufacture of the STATCOM

All functional testing shall be executed and recorded on the Plant and Materials installed during the commissioning, under normal and possible fault conditions.

10.2 Statcom Testing

Inspection and test requirements consist of testing at works (type and routine tests), factory acceptance tests (FAT) for main components and all sub-systems, commissioning tests, performance verification and acceptance tests, as well as extended performance acceptance tests. The Customer shall develop and submit the Inspection and Test Plans (ITP) to EirGrid for review and comments, the FAT report following successful completion of the FAT and all test reports following completions of all commissioning tests, in accordance with the requirements of this specification.

The Customer shall provide the following for EirGrid review:

1. Inspection and Test Plans
2. Specific Test Plans and Procedures (FAT, type, routine),
3. Site Acceptance Test Plan and Procedures,
4. Commissioning Test Plan and Procedures,
5. Performance Verification and Acceptance Test Plan

10.3 Testing Responsibilities

The Customer shall perform all testing including the performance verification and acceptance tests. All tests that require connection of the STATCOM to EirGrid's system (STATCOM HV bus) may be witnessed by EirGrid. Energised system testing shall be kept to a minimum.

The Customer shall provide commissioning and specific STATCOM energisation procedures as part of the Commissioning Test Plan to EirGrid for review.

The Customer shall provide all necessary labour and test equipment / material to perform all tests and inspections that are the Customer's responsibility.

10.4 INSPECTION AND TEST PLAN (ITP)

The Inspection and Test Plan shall be in accordance with OEM recommendations, EirGrid's Requirements and shall cover all aspects of testing and inspections. The preliminary and detailed ITP shall be submitted to EirGrid and shall include a schedule of all pre-commissioning and commissioning tests. All plant and material forming part of the STATCOM shall be included in the ITP.

Test and inspection plans and procedures shall be developed and submitted to EirGrid for review.

The Customer shall provide Declaration of Fitness for all STATCOM components that have been commissioned.

10.5 GENERAL TEST REQUIREMENTS

All equipment must be subjected to and pass the specified routine tests in the factory of manufacture before delivered to site.

All equipment must be subjected to and pass the specified type tests at an accredited testing station in accordance with the relevant IEC Publication, and the test certificates or reports obtained shall be submitted for review. Separate type tests may not be required on items of equipment that are of the same design, insulation class and comparable rating. Existing type test reports may be accepted if the equipment tested was identical to the equipment offered, the equipment is to be under the same or less stresses than the equipment already tested and the relevant equipment standards have not changed. A comprehensive report describing the past tests and how they can be applied to the new equipment shall be provided.

However, the valves shall be fully type tested for each project.

All the type tests prescribed in the relevant IEC Publication shall be have been made on STATCOM components. These tests shall have been carried out at a recognised and accredited testing facility.

Certificates/Reports containing full details of type tests shall be issued to EirGrid for review.

Full details of any modifications (no matter how minor) which have been made to the STATCOM since the full set of type test was carried out shall be submitted together with the reports on the tests which were carried out to prove the modification.

The acceptance of any equipment may be made conditional on further tests being performed at an accredited testing station and EirGrid may witness such tests. The equipment available for type tests shall be identical in all respects to those to be supplied to EirGrid.

In the event of a type test failure, EirGrid shall not be charged for any additional type tests.

All of the routine tests prescribed in the relevant IEC Publication shall be made on each assembled unit before shipment.

In addition, routine tests on the first fully assembled bay shall include verification of the IP rating and operational tests before shipment. EirGrid shall witness these tests.

Measurement of insulator creepage on a representative sample shall be included in the test results.

Routine tests for STATCOM designs shall be in accordance with IEC 61954, BS EN 62927 (IEC 22F/380/CD)

As outlined in CIGRE Technical Brochure 663, the following type test shall be carried out as a minimum requirement where applicable:

10.5.1 Power Transformers

If a power transformer is used to connect the STATCOM to the power system, this transformer should be tested according to the relevant standard such as IEC 60076 and the manufacturer's standards.

10.5.2 DC Capacitors

All DC capacitors shall be tested according the relevant standard such as IEC 61071 and the manufacturer's standards..

10.5.3 AC Capacitors Testing

All AC capacitors tests shall be carried out in accordance with IEC 60871-1 and the manufacturer's standards..

10.5.3.1 Routine Tests

a) Capacitance measurement (see Section 7)

b) Measurement of the tangent of the loss angle (tan S) of the capacitor (Section 8)

c) Voltage test between terminals (Section 9)

d) AC voltage test between terminals and container (Section 10)

e) Test of internal discharge device (Section 11)

f) Sealing test (Section 12);

g) Discharge test on internal fuses (Section 5.1.1 of IEC 60871-4:1996)

10.5.3.2 TYPE TESTS

a) Thermal stability test (Section 13)

b) Lightning impulse voltage test between terminals and container (Section 15.2)

c) Overvoltage test (Section 16)

d) Short-circuit discharge test (Section 17)

e) Disconnecting test on internal fuses (Section 5.3 of IEC 60871-4:1996)

10.5.4REACTORS

The type test on the reactor must be in accordance with IEC 60076-6 Section 8. The customer shall provide test results as follows for the proposed reactors. These shall be carried out as indicated.

10.5.4.1 ROUTINE TESTS

The Customer shall provide the following routine test results:

a) Measurement of winding resistance (Clause IEC 60076-1:2011)

b) Measurement of inductance (Clause 9.10.5, IEC 60076.6: 2008)

c) Measurement of loss and quality factor (Clause 9.10.6, IEC 60076.6: 2008)

d) Winding overvoltage test (Clause 9.10.7, IEC 60076.6: 2008)

10.5.4.2 TYPE TESTS

The Customer shall provide reports for the following type tests:

a) Temperature rise test (Clause 9.10.8, IEC 60076.6: 2008)

b) Lightning impulse test (Clause 9.10.9, IEC 60076.6: 2008)

10.5.5OTHER TESTS

Other STATCOM equipment such as AC breakers, AC capacitors, disconnectors, arresters, MV switchgear, DC and LV AC distribution, controls, SCADA interfaces and communications, cooling system shall be tested according to the relevant standards and OEM recommendations.

Some equipment such as the inrush resistor and discharge resistor are customer dependent and a type test procedure shall be discussed with the customer.

10.6 TYPE TESTS

All the type tests prescribed in the relevant IEC Publication shall have been made on STATCOM components. These tests shall have been carried out at a recognised and accredited testing station. Type Testing shall also include relevant tests outlined in ‘Testing of Painting and Corrosion Protection’ section 19 above.

Certificates/Reports containing full details of type tests shall be included in the submission.

Full details of any modifications (no matter how minor) which have been made to the STATCOM since the full set of type test was carried out shall be submitted together with the reports on the tests which were carried out to prove the modification.

The acceptance of any equipment may be made conditional on further tests being performed at an accredited testing station and EirGrid may witness such tests. The equipment available for type tests shall be identical in all respects to those to be supplied to EirGrid.

In the event of a type test failure, EirGrid shall not be charged for any additional type tests.

10.7 SPECIAL TYPE TESTS

EirGrid may elect to have any of the following type tests performed:

10.7.1 VALVE TESTS

The customer shall fully type test the valves for each project. The relevant valve type testing standard for the proposed semiconductor valves shall be consulted. These standards shall include but not be limited to

- IEC 60146-1-1:2009 Semiconductor converters - General requirements and line commutated converters - Part 1-1
- IEC 62927: Voltage sourced converter (VSC) valves for static synchronous compensator (STATCOM) - Electrical Testing.

A list of all tests to be performed including on all auxiliary plant and material associated with the valve shall be submitted to EirGrid for review and comment. The Customer shall provide test reports of all type tests.

10.7.2 RADIO INTERFERENCE TEST

The customer shall demonstrate compliance with ‘EN-standard ENV 50121-5, Railway Applications EMC; Fixed Power Supply Apparatus’, and with European Council Directive 89/336/EEC on electromagnetic compatibility with respect to the limitation of radio frequency emissions.

10.7.3 AUDIBLE NOISE TEST

The STATCOM shall comply with chapter 1 of Part 5 of the Safety, Health and Welfare at Work (General Application) Regulations 2007 S.I. No. 299 of 2007 as amended from 12 November 2007 by the Safety, Health and Welfare at Work (General Application) (Amended) Regulations 2007 (S.I. No. 732 of 2007) which sets down the minimum requirements for the protection of workers from the health risks associated with noise in the workplace.

The customer shall carry out audible noise tests to EN ISO 3746, EN 9614 as agreed with EirGrid and demonstrate that the level of audible noise inside the STATCOM building/enclosure does not exceed 70 dB(A) in areas where personnel are permitted during STATCOM operation.

10.7.4 IMPULSE VOLTAGE TEST

A complete STATCOM may be subjected to impulse voltage tests at the prescribed insulation withstand levels. The test assembly shall include at least one item of each component of STATCOM.

Tests shall be carried out in accordance with IEC 61954, BS EN 62927 (IEC 22F/380/CD) and CIGRE Technical Brochure 144.

10.8 ROUTINE TESTS

All of the routine tests prescribed in the relevant IEC Publication shall be made on each assembled unit before shipment. Routine Testing shall also include relevant tests outlined in 'Testing of Painting and Corrosion Protection' section 19 above.

In addition, routine tests on the first fully assembled bay shall include verification of the IP rating and operational tests before shipment. EirGrid may witness these tests.

Measurement of insulator creepage on a representative sample shall be included in the test results.

Routine tests for DC capacitor units shall be in accordance with IEC 60171.

Routine tests for STATCOM designs shall be in accordance with IEC 61954, BS EN 62927 (IEC 22F/380/CD).

10.9 QUALITY ASSURANCE

The customer shall provide evidence of the Quality Management System used for the development, management and testing of Hardware platforms / Software functions. This shall include but not be limited to, the demonstration of a quality controlled method for raising software non-conformances during development, implementation and testing of software functions with a clear and accountable audit trail for such items to be addressed and closed out.

The customer shall demonstrate how the pre-FAT or Factory Verification Tests (FVT) documentation is developed for a specific project and how this is used to develop the FAT documentation, indicating the clear links between the Functional requirements, detailed design specifications and the testing documentation.

The customer shall provide SAT results and commissioning documentation for function and accuracy check of all protection for all STATCOM components (including the grid connected transformer). This shall include secondary cabling, by secondary current and voltage injection during the pre-commissioning phase.

The customer shall provide a protection co-ordination study in order to demonstrate any interface protection and control requirements with the OCC protection system that may be specified in the project specific Protection Specification.

10.10 REAL TIME SIMULATIONS (RTS)

To Verify The Dynamic Performance Of The STATCOM Hardware And Software Against The critical network conditions and different types of disturbances identified during the design, RTS analysis and tests shall be carried out.

The customer shall perform factory system tests using the RTS to demonstrate the proper operation of the control and protection system by connection of the actual plant to a real time simulator and material to be supplied. The test scope and procedures for RTS shall be submitted to EirGrid for review and acceptance.

An adequate representation of EirGrid's power system under static and dynamic conditions to which the STATCOM will be connected, shall be used for the tests/studies. The Customer shall provide information on the simulator studies, at least 26 weeks before the commencement of the RTS studies.

EirGrid reserves the right to appoint a representative or consultant to inspect and attend the simulator study tests. The Customer shall give EirGrid adequate notice in writing of the date of commencement of the simulator tests (minimum 4 weeks). The Simulator Study Results report shall be submitted 3 weeks after completion the tests / studies.

10.11 Tests After Erection

The customer shall test the complete STATCOM after full erection as per IEC and OEM recommended tests.

These tests shall include Partial Discharge measurements.

If the STATCOM is connected by cable then site HV tests may be required depending on the scale of the site assembly. The level of testing to be carried out after erection shall be subject to EirGrid agreement.

The necessary plant to carry out the prescribed test must be provided by the Customer for the duration of the test.

No changes to the equipment shall occur on site without agreement in advance with EirGrid. Any proposed changes to the technical records provided prior to equipment delivery must be communicated clearly to EirGrid and agreed in advance.

10.12 Performance Verification And Acceptance Tests

The following tests shall be performed at the site on the fully assembled STATCOM with the STATCOM operating and connected to the transmission system. These tests are required in order for the customer to validate the operation of the STATCOM and its impact on the transmission system.

The Customer shall issue a report analysing the STATCOMS performance in the tests outlined below.

Additionally, the Customer shall validate the model provided during the design phase by confirming that the design model matches the final control parameters installed (for fault ride through and voltage control mode etc).

The Customer shall confirm that the simulated curves provided during the design phase match those that are measured through testing.

The following shall be carried out as minimum:

- Reactive Power Control
    - Voltage control mode test
    - Reactive power mode test
    - Transferring between modes
    - Speed of response
- Reactive Power Capability (operating range test)
    - Leading capability
    - Lagging capability
- STATCOM redundancy test
    - Redundancy of the STATCOM converter within design range.
    - Redundancy of the STATCOM controller inputs and power supplies.
- STATCOM overload test
- AC system fault test
- System control tests from local HMI
- Transmission SCADA interfaces and remote functional tests, including End-to-End tests.
- Trial Operation
    - STATCOM start-up test
    - Measurement of Audible Sound
    - Power Quality / Harmonics Measurements
    - Performance monitoring during normal operation

11 INSTALLATION

While installation is the responsibility of the Customer, EirGrid requires a copy of the installation instructions be provided. The instructions shall be in English and shall cover all aspects of equipment installation up to and including putting into service. The Customer shall ensure that the information supplied is clear and specific to the equipment being provided.

11.1 ERECTION AND MAINTENANCE

11.2 MAINTENANCE LAYOUT

The plant shall be arranged to give safe personnel access to maintenance staff when the plant is not energised. The layout shall be designed to minimise the impact of maintenance on the availability of the STATCOM.

For indoor and outdoor mounted components platforms or catwalks with handrail shall be provided where necessary. A catwalk serving two or more operating positions shall have two stairways to the operating floor.

The general layout of the plant shall be such as to permit replacement or maintenance of any sub-components of the plant. Fixed platforms or catwalks shall have removable sections to permit replacement or maintenance of any sub-components if required. The layout shall also allow for the provision of vehicular access for maintenance purposes if required.

The general layout of the plant shall be such as to permit replacement of any complete STATCOM components by crane or other suitable lifting machinery. Access arrangements shall be subject to review by EirGrid.

Lifting eyes shall be provided on all STATCOM components and also on removable catwalk sections which cannot be lifted safely by other means.

The exact location and layout of the STATCOM on site will be agreed with EirGrid taking into account the physical constraints of the site and the system constraints in de-commissioning any existing equipment.

To ensure safety of personnel during maintenance:

- All parts of main circuits to which access is required shall be capable of being earthed.

Provision shall be made for carrying out primary injection tests on all current transformers.

Provision shall be made to allow component testing according to the maintenance procedure.

11.3 Special Tools And Equipment

The Customer shall provide all special tools or equipment required for maintenance of the STATCOM system. This special tools shall include any hoists, jigs, gauges, templates, meters, etc.

11.4 Spare Parts

The Customer, in consultation with the manufacturers of all parts of the STATCOM system, shall list the those spare parts which they recommend should be held by EirGrid for operation and maintenance. All such spare parts, their type and quantity and any additional requirements shall be agreed with EirGrid.

All recommended spare parts shall be provided with a description of their function and complete installation instructions and associated drawings.

11.5 Maintenance Instructions

The Customer shall provide a complete set of maintenance instructions (O&M). The instructions shall be complete, in English and contain all associated instructions and drawings pertaining to the continuing maintenance of the equipment throughout its lifecycle.

12 COMPLIANCE WITH SPECIFICATION

All deviations from the requirements of this specification shall be listed in the “Deviations Schedule” included in the Technical Schedule.

Should EirGrid determine that the offer does not comply with this specification or any part of it, EirGrid reserve the right to reject the proposal.

13 DOCUMENTATION

All documents and communication shall be in English.

13.1 TO BE SUBMITTED DURING DESIGN

- Fully completed copy of the SCHEDULES attached to this Specification including Deviations from Specification, quoting relevant section numbers of this specification.
- Fully detailed Type Test Certificates/Reports.
- Full technical particulars, detailed electrical connection diagram including internal wiring, detailed physical drawings, technical literature, photographs, catalogues, technical pamphlets, reference list, recommended spare parts, etc. to enable full assessment of the offer.
- Details of corrosion protection and associated type test details.
- Details of routine, type and special tests to which all units will be submitted before dispatch.
- Storage, Installation and Maintenance instructions.
- Statement of acceptance of warranty requirements.
- Any other data or information necessary to fully describe the STATCOM.
- Reference list for equipment similar to the proposed STATCOM including details of quantities already in service, location and contact person.
- Service experience to date including defects history.
- A short description of the Quality Control philosophy including sampling techniques, statistical parameters etc. plus tests carried out on raw materials employed.
- Factory production experience of STATCOM in general and specific STATCOM proposed under this specification.
- Service Experience as required in this specification.

13.2 TO BE SUBMITTED DURING DETAILED DESIGN

13.2.1 DESIGN DOCUMENTS AND DRAWINGS

Primary and secondary design documents and drawings to be submitted during project detail design stage shall include:

- Outline dimensioned drawings of complete equipment.
    - arrangement complete with fittings
    - arrangement for transport and shipping
    - Schematic diagrams of the complete STATCOM showing enclosures and components including CT wiring and terminations
    - A three dimensional model in REVIT or equivalent of the physical layout of the STATCOM and all its components.
- Data sheets and FAT reports for complete equipment and for all individual components including weight of all units.
- Single line diagrams, wiring diagrams, schematics, bill of materials.
- Lifting and handling studies
- Recommendation for installation, operation and maintenance, including list of tools and equipment required e.g. test equipment.
- All technical documents (e.g. Navisworks / AutoCAD 3D models of equipment, drawings, instruction manuals, etc.) shall also be provided in electronic format and drawings shall be delivered via Internet e-mail in one of the following formats:
    - MicroStation .dgn – compatible with latest version MicroStation
    - AutoCAD .dwg – latest release
    - Misc.dxf – compatible with latest version MicroStation

13.2.2 DESIGN REPORTS

The Customer shall provide the following design reports for EirGrid review prior to manufacture of the STATCOM:

- Control system report
- Ratings report: HV plant on MV side of coupling transformer
- Earthing arrangements on MV side of coupling transformer
- Insulation co-ordination report

13.3 TEST PROGRAMME

The Customer shall submit a proposed test programme or inspection and test plan (ITP) and test procedures to EirGrid for review prior to commencement of the tests. EirGrid is expected to witness a number of inspections, tests.

13.4 TECHNICAL RECORDS

At hand-over 3 copies of the technical record folder of the STATCOM shall be supplied in hardcopy and on USB/CD. This folder shall include:

- Guaranteed rated values and characteristics i.e. the Project Specific Technical Schedules that accompany the submission, modified where necessary.
- Detailed physical and electrical drawings.
- Detailed installation, operation and maintenance instructions.
- Certificates relating to the insulating material.
- Summary of type tests, routine tests and special tests, with copies of the Test Certificates.
- Full details of all auxiliary equipment including FAT reports.

14 TRAINING

The Customer shall submit a training plan which shall describe in detail how the Customer proposes to train EirGrid staff for operation of future EirGrid assets.

Training requirements will be detailed further in OFS-GEN-009 - Operation and Maintenance General Specification.

15 Appendix A: Studies And Reports To Be Provided By The Customer

Studies and reports shall be performed as detailed below and in accordance with the requirements outlined in this specification.

15.1 Phase 1 – Outline Design

The Customer shall provide studies and reports to demonstrate that the STATCOM can meet the performance requirements of this specification and Project Specific Technical Schedule. These studies/ reports shall include but are not limited to:

a) Load flow Studies - the objective of the studies are to determine and demonstrate the STATCOM design characteristics such as: Steady-state and short-term STATCOM ratings, reactive power flows under normal and abnormal system conditions and also to demonstrate operating characteristics as detailed in Section 1.1.

b) Harmonic performance of the device (Section 8)

c) Loss Evaluation report (Section 1.1)

d) Acoustic noise performance including modelled values at sensitive receptors (Section 1.1)

e) Reliability , availability , maintenance and safety studies (Section 1.1)

f) Whole life costing - estimates based on the losses, spare parts, maintenance. (Section1.1)

g) Protection, Control and monitoring report describing the design philosophy. (Section 6)

15.2 Phase 2 - Detailed Design Studies

Studies and reports to be provided during detailed design This stage will confirm or re-evaluate the estimates and assumptions made in the FEED. The values and findings will form design parameters for manufacture and testing requirements including type or factory testing.

Transient Stability Studies shall be carried out to determine the impact of the STATCOM on electromechanical performance of the power system in response to a number of contingencies over a range of operating conditions, to determine the stability and damping of electromechanical oscillations (0.1-5 Hz) following the contingencies.

a) STATCOM transient ratings

b) transient response and damping of the power system.

c) Interaction of the STATCOM with other power system components.

d) Identify critical system conditions and contingencies

e) To identify enhancement to power transfer limits, transient stability and system damping performance provided by the STATCOM.

f) Demonstrate control modes, control parameters and control limits.

g) STATCOM operation and system protection detailed design report.

h) Small disturbance studies shall be carried out to assess the performance of the STATCOM in relation to other active devices within the local network.

i) Identify any interaction modes between the various control devices in the system

j) The possibility of low frequency oscillations due to lack of damping,

k) measures for providing damping will be demonstrated.

l) effect of STATCOM POD controller on the system damping, and the controller phase requirements.