

STATIC VAR COMPENSATORS FOR CONNECTION TO 275 KV AND 400KV SYSTEMS

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PURPOSE AND SCOPE

This specification defines National Grid's functional and performance requirements for Static Var Compensators (SVC) for connection to the National Grid system at 400 kV and 275 kV.

It does not include the switchgear connections to the HV system, which are specified separately in TS 2.2.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 Introduction

National Grid requires Static Var Compensators (SVCs) in order to provide reactive power to the 400 kV or 275 kV systems. This reactive power is primarily required for voltage control purposes and a fast speed of response is required to enable dynamic voltage control during the post fault recovery period.

1.2 Overall

An essential feature of the SVC is that once operational, it can be relocated and be ready for operation at any other National Grid substation within 6 months (26 weeks) of final de-energisation at the first site. Of particular importance are the requirements for minimal foundations and the ability to relocate the SVC at minimal cost to National Grid in terms of labour, constructional costs and asset write-off costs. The SVC will be required to fit on sites having different sizes and shapes and therefore the use of standard modules is encouraged.

The SVC connection voltage at the first site will be specified in the Substation Design Specification (SDS). Any additional requirements for the SVC to be designed to enable subsequent relocation to a National Grid substation with a different connection voltage to the first site shall be specified in the SDS (see also clause 1.5).

Any requirement for facilities to enable the operation of any shunt branches separately (i.e. depleted mode operation) is detailed in the SDS.

Clause 1.11.3 details the maximum levels of harmonic voltage that the Supplier shall assume will be pre-existing on the National Grid system. The range of system impedances for harmonics of order 2 to 100 are detailed in the SDS and these take into account a range of possible system connection points and the requirement for different connection voltages (if applicable) to enable the SVC to be relocated to a new site without any modifications to harmonic filtering arrangements.

Civil, structural and building engineering works shall comply with Design Handbook 10 and TS 3.10.x series of documents. Specific requirements for civil, structural and building engineering works etc is detailed in the SDS. Oil containment shall comply with TS 2.20.

Equipment identification (e.g. labelling, etc) shall be provided in accordance with TS 2.1.

All schematic diagrams shall be submitted to National Grid. All technical reports, component specifications and other technical documentation shall be written in English and submitted to National Grid during the contract stage.

1.3 Extent of Supply

The Supplier shall supply the following:

- a) All equipment necessary to enable the connection of the SVC to the National Grid system at the system connection point including the HV step-down transformer, the HV (i.e. 275 kV or 400kV) circuit breakers, disconnectors, earthing switches, HV busbars and support insulators and separate HV current and voltage transformers.
- b) All SVC component equipment including any LV switchgear, surge arresters, protection and control equipment, auxiliary equipment, cooling, alarm and indication equipment (including connections into existing substation equipment as necessary and connection to National Grid's Remote Terminal Unit).

- c) All enclosures to house the SVC equipment and facilitate transportation.
- d) Any specialised test equipment required for the routine servicing or replacement of parts.
- e) All earthing connections to the supplied equipment.
- f) A model of the SVC control system as defined in clause 2.1.6.

In addition to the above, the Supplier shall provide a list of spare parts predicted as being required during the first five years of operation and additionally over the design lifetime of the SVC. Fixed price quotations for these spares shall also be provided by the Supplier.

1.4 Site Details

1.4.1 Space Limitations

The SVC shall be designed to occupy and enable subsequent relocation to any of the site areas and layouts detailed in the SDS.

The Supplier shall provide general layout drawings of all SVC configurations to verify the compliance of his design with the specified land area requirements.

1.4.2 Foundations

The foundations will consist of one or more flat concrete slabs, as required. The Supplier shall provide details of the civil requirements, including those necessary to relocate the SVC to all site areas and layouts detailed in the SDS.

1.4.3 Other Site Layout Details

The design of the SVC shall take into account all aspects of safety associated with construction, commissioning, operation, maintenance (including any mid-life refurbishment), decommissioning and disposal. Provision shall be made to allow all work to be carried out in a manner which is safe. Safe access and egress for any foreseeable activity shall be provided. This will include, for example, the provision of suitable and sufficient measures to permit access to smoke detectors, ventilation equipment, light fittings and any other items requiring maintenance or replacement that might be located at height.

Access shall be prevented to parts that might represent a hazard (due to voltage, temperature, mechanical movement, etc). Activities involving working at height or manual handling shall be eliminated by design where reasonably practicable. Where not reasonably practicable to eliminate such activities, the Supplier shall propose a safe system of work to be agreed with National Grid and provide associated risk assessments and method statements.

The layout of the SVC shall be such as to allow suitable access for maintenance, repair or replacement of all primary plant using a mobile elevated work platform (MEWP) or similar equipment. Access shall be possible without the need to remove any structural member or support, including insulators, main connections, busbars, fences or any other normally fixed equipment. It shall be possible to replace failed components such as capacitors units or thyristors while minimising outage requirements. Suppliers shall confirm their compliance with this requirement by supplying detailed layout drawings in their Tender.

Adequate provision shall be made to facilitate the safe handling of items of equipment. Items of equipment that may be subject to removal during maintenance or repair shall be provided with lifting lugs. Items of equipment requiring regular replacement or exchange (e.g. deioniser resin containers) shall be provided with permanently installed lifting facilities.

- 1.4.4 Safety clearances shall conform with the requirements of TS 2.1 unless the equipment concerned is fenced off and access prevented (by an interlocking scheme to the approval of National Grid) whenever the equipment is de-energised but unearthed. It shall be possible to walk within the SVC compound without danger while the equipment is both isolated from the National Grid system and earthed. Therefore cables, pipework etc shall not be surface laid without prior agreement by National Grid; similarly cables, pipework or supporting structures shall not be placed less than 2 metres above the ground without prior agreement by National Grid. Access to the plant during in-service operation is not required.

1.4.5 Site and Plant Safety Hazards

The Supplier is reminded that the design of the SVC must comply with the requirements of UK legislation. The Supplier's attention is drawn to the provisions of the Health and Safety at Work Act, Construction (Design and Management) Regulations, Electricity at Work Regulations, Manual Handling Operations Regulations, Work at Height Regulations and the Workplace (Health, Safety and Welfare) Regulations.

Suppliers shall declare all safety hazards relating to the equipment Tendered. This 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, oil leaks, etc).

1.4.6 Land Area Premium

Any premium applied by National Grid for Tender assessment purposes applicable to designs where the actual land area requirement of the SVC is less than the maximum permissible land area will be detailed in the SDS. In such cases, in Tendering a compact design the Supplier shall take due regard of the implications of this on the maintainability of the SVC and the availability criteria specified in clause 2.4.

1.5 Requirements for Portability

It shall be possible to transport the SVC from one substation to another using a number of road-going vehicles. All such vehicles shall fall within the Department of Transport Special Types General Order (STGO) Category 3 that applies at the time of contract placement while carrying the required load. Although there is no legal restriction on the travelling height of loads, because of physical obstructions such as bridges, the travelling height shall not exceed 5 metres.

It shall be possible to relocate the SVC from one site to another within a maximum timescale of six months (26 weeks). This relocation time comprises the time period between final de-energisation at the first site and the completion of recommissioning at the new site. It assumes the same connection voltage, immediate availability of circuit outages and pre-prepared foundations at the new site.

The SVC shall be designed such that following a relocation no redesign of the SVC is required other than "parameterisation". Where specified in the SDS, the procurement of a further suitable step-down transformer shall permit relocation to a connection voltage different to that of the first site. The Supplier shall provide National Grid with the transformer specification to enable the procurement of this transformer by a third party.

The Supplier shall demonstrate by the submission of drawings and other supporting documentation as required that their design of SVC can be relocated to all of the site layouts detailed in the SDS. Indicative instructions for the complete relocation of the SVC to the site layouts specified in the SDS to justify the relocation timescales and costs quoted in Appendix J shall also be provided by the Supplier. Included in the submission shall be a detailed breakdown of redesign costs, asset write-off costs, manpower, vehicle, time and overall costs associated with the relocation process. The details of any vehicle requiring permission and/or escort to use the United Kingdom road system shall also be stated in the Tender.

The Supplier shall assume that each relocation shall involve transporting the SVC over 200 km of which 15 km is on B roads, 25 km is on single carriageway A roads and 160 km is on dual carriageway or motorway.

Fully detailed relocation instructions shall be provided at the contract stage to enable relocation to be performed by a third party.

The costs of relocating the SVC to the different site areas detailed in the SDS will be taken into account by National Grid at the Tender assessment stage. Details of the method of assessment will be provided in the SDS.

For Tender appraisal purposes National Grid may reduce the Tender price should it be possible to relocate the SVC more quickly than the specified time of six months (26 weeks). The value of this premium and its method of calculation will be specified in the SDS. Should such a premium apply, and if the Supplier declares a relocation timescale less than 26 weeks, a detailed method statement and appropriate guarantees shall be provided by the Supplier with their Tender submission to justify the declared relocation timescales.

1.6 Control System Requirements

The primary requirement of the SVC is that it will support system voltage following circuit outages particularly in the period immediately following a fault, as well as in response to network voltage variations caused by the daily load cycle.

Steady state control action shall be based upon independent measurement of each of the three system phase voltages and the use of the average magnitude to determine SVC output (the averaged voltage signal shall be known for the purposes of this specification as the "controlled system voltage"). Should one of these three system phase voltage signals become unavailable during service due to the loss of a VT signal, then the controlled system voltage shall be derived from the averaged outputs of the remaining two VTs. Similarly, should a further system phase voltage become unavailable during service due to the loss of the VT signal, then the controlled system voltage shall be derived from the output of the sole remaining VT. The loss of any of the three system phase voltages shall be alarmed. When any defective VT signal is restored, then the average of all healthy signals shall again be used as the controlling voltage signal.

The SVC shall be capable of operation in the following two modes, either mode of operation being selectable at any of the control points listed in clauses 1.7.2, 1.7.3, and 1.7.4.

- a) Target Voltage Mode - In this mode the SVC current shall respond in proportion to the deviation of the HV system voltage from the preselected "target voltage" (see also clause 2.1.5). The SVC current shall be inversely proportional to the slope setting.
- b) Constant Mvar Mode - This mode is an extension of target voltage mode and should be identical in operation as far as fast and/or large system voltage changes are concerned. However, in this mode an overriding and slow acting control loop adjusts the Mvar output to equal a "Target Mvar" setting. The SVC can thus still react rapidly to sudden changes in system voltage, its output returning steadily to the target Mvar value over a time period settable by National Grid (at the local control point only, see clause 1.7.2) following the sudden voltage change. Should the National Grid system voltage vary outside adjustable preset limits, the Constant Mvar control mode shall be abandoned and an automatic change to Target Voltage Mode shall take place in order to allow the SVC to control the abnormal system voltage. This change of operating mode shall be alarmed to alert the system operator to a change of control mode possibly arising from an abnormal system condition (see clause 1.7.4 (c)). The preset system voltage limits shall be adjustable (at the local control point only, see clause 1.7.2) between 0.93 and 1.07 pu, with a resolution of 0.01 pu. Change of operating mode from Target Voltage Mode back to Constant Mvar Mode shall be achieved by operator intervention only.

The control system shall be so arranged to cater for any depleted operating mode requirements of clause 1.2 if specified by National Grid.

The Supplier shall provide a "Damping Input Terminal" to allow the SVC to be used to control oscillations on the National Grid system. National Grid shall be responsible for the derivation of the signal to be presented at this terminal. Clause 2.3 specifies how the SVC shall respond to this signal.

Limitation of steady state operation will normally be achieved by operator action. To facilitate this an excess Mvar indication shall be provided to show that the SVC is operating above a preset limit for longer than a preset time.

This excess Mvar indication shall be single stage with reset differential. The operating level shall be adjustable, at all control points, over the full Mvar range of the SVC. The time shall be adjustable at the local control point only, in the range 1 to 10 minutes in 1 minute steps. The reset differential shall be adjustable at the local control point only, over the range 1 to 15 Mvar.

The Supplier shall detail the control strategies employed during single and two phase faults. Additionally, where the SVC control system incorporates a three phase current balancing mechanism, the Supplier shall provide details of its method of operation and the maximum tolerable level of negative phase sequence voltage on the supply system for which the mechanism can operate.

1.7 Control Interface and Alarm Scheme

1.7.1 General

The SVC control system shall be compliant with the relevant sections of NGTS 2.7 and the documents listed therein.

The SVC control system shall be capable of supporting a serial interface to the existing site Substation Control System.

The SVC shall be capable of being controlled from three points as listed below. However, only one control point shall be capable of carrying out control functions at any given time but it shall be possible to view the plant status, control targets and other SVC parameters from the two other control points.

1.7.2 Local Control Point

The local control point shall be in the SVC control and protection equipment room and shall provide all control facilities when the other two control points are out of service. This control point shall be fully instrumented and fitted with all indications and grouped alarms necessary to operate the plant.

It shall be fitted with a two position selector switch enabling the control functions to be carried out either at the local control point (indicated as "local" on the selector switch) or at an alternative control point (indicated as "Remote/Substation" on the selector switch).

1.7.3 Substation Control Point (Standby Control Point)

A dedicated control interface (e.g. PC based with keyboard and VDU) shall be supplied located at the existing substation control point. It shall be capable of being linked to the SVC over a distance of up to 2 km (e.g. via a serial link).

The substation control point for the SVC shall be relocatable to another substation without disruption to the operation of the existing HV substation.

This control point shall be equipped with the following indications and associated controls:

- a) Starting sequence in progress.
- b) Stopping sequence in progress.
- c) Target voltage setting (resolution 1 kV, changeover from maximum to minimum settings to take one minute or less).
- d) Constant Mvar setting (resolution 5 Mvar).
- e) Preset Mvar limit setting with its associated alarm (see clause 1.6).
- f) Control mode selected.
- g) Control point selected.
- h) Full mimic of the compensator up to and including the high voltage busbar selectors, and including thyristor status indications (blocked/de-blocked).
- i) Indication of compensator parameters (e.g. temperatures, primary voltage, current and reactive power) and the details of other indications required shall be agreed with National Grid.
- j) Enable/disable damping input.
- k) Any other controls and indications that the Supplier considers necessary for the control of the SVC.

This control point shall have a selector switch which allows the SVC to be controlled either from the substation (indicated as "Substation" on the selector switch) or from the remote control point (indicated as "Remote" on the selector switch). This selector shall only be effective if the selector switch referred to in clause 1.7.2 is set to the "Remote/Substation" position.

1.7.4 Remote Control Point (National Grid Control Centre)

This control point is to be used for the majority of control operations. An abbreviated range of controls, indications and alarms is required at this control point; these are detailed below:-

The Supplier shall provide a facility to interface the SVC controls, indications and alarms to the existing SCS on site.

a) Controls Required at the Remote Control Point :

These involve controls required to start and stop the compensator, change control mode, selection of the control point, enable and disable the damping input, allow operation when any branch of the SVC is inoperable (if provided), set the Target Voltage (maximum steps 1 kV) and the Target Mvar (maximum steps 5 Mvar).

b) Indications Required at the Remote Control Point :

All the controls mentioned above must be provided with matching double point indications to indicate that the desired action has been executed. In addition, single point indications are required as follows:

- (i) SVC in local or substation control (i.e. not controlled by the Remote Control Point)

- (ii) SVC active (i.e. valves conducting)
 - (iii) SVC branch(es) unavailable (if applicable)
 - (iv) any indications required to inform the operator of the progress of the start/stop operations.
- c) Alarms Required at the Remote Control Point :
- (i) SVC Trip relay operated
 - (ii) Failure of SVC remote control facility
 - (iii) Constant Mvar mode overridden (see clause 1.6 (b))
 - (iv) Preset Mvar Limit exceeded (see clause 1.6)
 - (v) SVC transformer gas and oil actuated relay alarm
 - (vi) Grouped alarms (e.g. capacitor out of balance, etc.)

1.7.5 Alarm Scheme

Contacts shall be fitted to each item of plant and all protection and control equipment (see TS 3.24.91) as appropriate to indicate the equipment status (open/closed, blocked/de-blocked, tripped etc) and the presence of any alarm condition. This requirement includes the feedback of data from each level of each thyristor valve. Additionally, each item of equipment that produces an alarm shall be fitted with a manually resettable flag (mechanical or LED), in order to indicate the item of equipment which is faulted. The flag (even if of the LED type) must continue to give a correct indication after loss and subsequent reinstatement of power. All flags must be visible and capable of being reset without opening cubicle doors.

The alarm information is required in four further locations as listed below, and hence the initiating alarm contact shall be wired to a multiplying relay. The contacts shall be wired from this relay to the following points:

a) The Local Control Point

Since control of the SVC will be required from this point from time to time, a grouped representation of the alarms and an audible warning system is required.

b) The Substation Control Room (Standby Control Point)

A grouped alarm system which permits full operation of the SVC and information relevant to the operator is required. An audible warning system is also required.

A full data logger for all SVC alarms in the ungrouped state shall be supplied by the Supplier

c) The Remote Control Point (see clause 1.7.4 (c) above)

All alarm handling schemes shall comply with NGTS 3.7.4; event logging shall be to NGTS 3.7.5.

d) Remote Interrogation

The SVC control system shall be provided with a communication interface suitable for remote interrogation over Ethernet and PSTN connection.

1.8 Control Equipment Hardware

The control equipment shall comply with the requirements of the relevant sections of NGTS 2.7 and TS 3.24.15 and their associated level 3 specifications.

The control equipment shall be designed to operate from secure d.c. supplies.

All control points shall be powered by a secure means of supply. The Man Machine Interface (MMI) shall normally be powered by a single positive earthed 48 V d.c. supply whose characteristics are defined in TS 2.12 and TS 3.12.4. However, suitable alternative arrangements for powering the MMI (e.g. through an inverter system, 230 V a.c. supply with UPS, etc) will be considered.

All connections to the control equipment interface shall be via suitable connectors to maximise the relocatability of the SVC and its associated equipment.

Reliability and availability requirements for control systems forming part of an overall SVC scheme are included within the overall SVC reliability and availability figures defined in clause 2.4.

1.9 Protection

The SVC protection systems, including protection of the compensator transformer, shall comply with the requirements of TS 3.24.77, 3.24.78 and TS 3.24.91. For SVC designs that fall outside the scope of TS 3.24.91 (for example those that employ voltage or current source converter technologies), the general requirements of TS 2.24 shall be applied and the Supplier shall provide a full submission at the Tender stage detailing the protection schemes proposed for National Grid consideration.

1.10 Insulation Co-ordination

1.10.1 Insulation Co-ordination - General

The SVC shall be capable of withstanding the transient and temporary overvoltage conditions as defined in TS 1 as well as any surges generated by the operation of the SVC including tripping of the SVC circuit breaker followed immediately by re-energisation and tripping of the circuit-breaker. The completed assembly, including any surge arresters, must comply with the requirements of TS 1, TS 2.1 and TS 2.3.

In addition the SVC shall be able to withstand either of the following sequences occurring on the National Grid grid system :

- a) A double exponential full wave of 1200 kV peak (400 kV system) or 1050 kV (275 kV system) with 8/50 μ s waveshape, followed by a temporary overvoltage on the primary side of the compensator transformer of 1.45 pu for a duration of 1 s linearly decaying to 1 pu over 5 s. The SVC shall be capable of being tripped and then immediately re-energised and tripped following the above sequence.
- b) A chopped double exponential wave of 1750 kV peak (400 kV system) or 1300 kV (275 kV system) with 1.2/50 μ s waveshape chopped at 10 μ s, followed by a temporary overvoltage on the primary side of the compensator transformer of 1.45 pu for a duration of 1 s linearly decaying to 1 pu over 5 s. The SVC shall be capable of being tripped and then immediately re-energised and tripped following the above sequence.

The Supplier shall submit an insulation co-ordination report covering the entire SVC installation. As a minimum, the report shall describe the performance of the SVC under energisation conditions and its response to Rated Lightning Impulse Withstand Voltage (RLIWV) and Rated Switching Impulse Withstand Voltage (RSIWV) as defined in TS 1 and the sequences of (i) and (ii) above. Additionally where surge arresters and earthing

capacitors are included in the installation to limit overvoltages and to satisfy the requirements for insulation co-ordination, the report shall demonstrate the adequacy of their ratings.

1.10.2 Insulation Co-ordination - Primary Side

The means of achieving insulation co-ordination on the primary side of the compensator transformer shall be detailed in the Tender submission. If surge arresters are used for this purpose, they shall comply with TS 3.2.3.

1.10.3 Insulation Co-ordination - Secondary Side

a) The electrical clearances applied to the secondary side of the compensator transformer shall meet the requirements of TS 2.1 for the rated secondary voltage selected by the Supplier or the next highest rated secondary voltage should the selected secondary voltage not correspond directly to one of the nominal system voltages quoted in TS 2.1. However, if equipment is installed in a vermin proof enclosure or incorporates an insulated oversheath, the phase to phase and phase to earth clearances listed in BS 7354 are acceptable, but for equipment housed within vermin proof enclosures satisfying clause 1.10.3 b) below, the internal clearances can be determined by type tests to BS EN 60694.

b) Where a physical barrier (such as a GRP container wall) is introduced between high voltage conductors and areas accessible by personnel, one of the following requirements shall be met:-

- (i) The clearance between the high voltage conductors and the physical barrier shall comply with the safety distances specified in TS 2.1
- (ii) The clearance between the high voltage conductors and the physical barrier shall comply with the minimum basic electrical clearance specified in TS 2.1.
- (iii) The equipment configuration shall be subject to type and route tests to BS EN 60694.

Additionally, if option (ii) or (iii) above is followed, the barrier shall be capable of carrying the appropriate fault current. This capability shall be demonstrated to National Grid.

c) The electrical withstand voltages required for the secondary side of the compensator transformer are listed in Table 1 below. Where the selected secondary voltage does not correspond directly to one of the Um values quoted in Table 1, the electrical withstand voltages shall be those for the next highest value of Um. Lower withstand voltages may be proposed where surge arresters are employed subject to the submission of insulation co-ordination studies and acceptance of these by National Grid.

Highest voltage for equipment, Um (kV rms.)	Rated lightning impulse withstand voltage (kV peak)	Transformer minimum induced overvoltage withstand voltage (kV peak)	Transformer minimum applied voltage withstand (kV rms.)	Switchgear rated power frequency dry withstand to earth (kV rms.)	Corresponding National Grid nominal system voltage (kV rms.)
72.5	325	132 #	140 *	140	66
36	170	66 #	70 *	70	33
24	150	44 #	50 *	50	22
17.5	125	32 #	44 *	38	-
12	95	22 #	38 *	28	11

Table 1 - Required Insulation Withstand Voltages

Induced voltage to correspond to primary winding test but in any case not less than $2 \times$ nominal voltage

* Fully insulated winding assumed

Note - Reference should be made to BS EN 60694 and BS EN 60517 for withstand voltages for longitudinal insulation for switchgear, disconnectors, etc.

All surge arresters connected at the secondary voltage shall have a minimum energy absorption capability equivalent to at least line discharge Class 3 unless Supplier's insulation co-ordination studies indicate for a higher energy absorption class. All surge arresters shall comply with the test requirements of BS EN 60099-4.

The protective level of the surge arresters shall be such that the Rated Lightning Impulse Withstand Voltage (RLIWV) and Rated Switching Impulse Withstand Voltage (RSIWV) of the secondary side insulation is a factor of at least 1.25 and 1.15 respectively of the highest possible relevant surge arrester residual voltage.

1.10.4 Convertor Assembly d.c. Insulation Co-ordination

For SVCs employing voltage or current source convertor technology, the Supplier shall provide a full design submission demonstrating the suitability of the insulation co-ordination system applicable to the d.c. convertor system.

1.11 Component Equipment Items

1.11.1 General

All SVC component equipment items shall comply with the general conditions specified in TS 1, TS 2.1, TS 2.2 and BS EN 60694 for the selected voltage and current ratings. Full account of any allowances for harmonics as detailed in clause 1.11.3 below shall be taken by the Supplier in selecting the voltage and current ratings of all component equipments. Individual plant items shall also comply with the relevant British, International and TS Level 3 specifications listed in Section 1 and the additional requirements detailed below.

1.11.2 External Insulation

Unless otherwise specified in the SDS, the minimum creepage distance of all external porcelain insulation shall be based on IEC 60815 values as follows for the selected equipment rated voltages:

For equipment mounted in the vertical/upright position, pollution class III

For equipment mounted in any other spatial orientation, pollution class IV

Polymeric insulation may be accepted subject to National Grid evaluation.

However, where necessary this creepage distance shall be increased to take into account the allowances for harmonics as detailed in clause 1.11.3 below and the factor k_d in accordance with IEC 60815 clause 5.3.

Porcelain insulator fittings shall comply with IEC 60273.

The selected insulator configurations and supporting steelwork shall not result in insulation failure due to heavy wetting conditions.

The requirements for resistor insulation are detailed separately in TS 3.11.2.

1.11.3 SVC Equipment Rating

All components of the SVC shall be rated taking into account the following parameters:-

- a) Any harmonics generated by the SVC itself.
- b) The supply system harmonic impedance loci ("rating" conditions) for the 400 kV and 275 kV systems which are detailed in the SDS.
- c) The maximum continuous fundamental frequency voltage on the HV system (refer to TS 1).
- d) The levels of pre-existing harmonic voltage distortion on the system.

In respect of item (d) above, the root sum square of all harmonics pre-existing at the HV connection point shall be taken as 4% of the nominal fundamental voltage, the maximum third harmonic as 1.8%, the maximum fifth harmonic as 3%, the maximum seventh harmonic as 1.5% and individual maxima of all other harmonics as 1% of the nominal fundamental voltage. The Supplier shall assume that the above levels of pre-existing distortion are represented as voltage sources behind the harmonic impedances as seen from the HV busbar, and therefore the open circuit voltages are the values quoted above prior to the connection of the SVC.

The Supplier shall assume that the supply system at each harmonic exhibits the value of impedance that results in the greatest harmonic contribution to rating of the particular SVC component under consideration due to both pre-existing voltage distortion and harmonics generated by the SVC itself.

- e) System frequency variations and durations in accordance with the following table:-

System frequency (Hz)	Duration
47.0 - 47.5	20 seconds
47.5 – 49.0	90 minutes
49.0 - 51.0	Continuous
51.0 - 51.5	90 minutes
51.5 - 52.0	15 minutes

It shall be assumed that following the frequency excursions outside the range 49.0 – 51.0 Hz detailed above, that the system frequency stabilises to a value between 49.0 – 51.0 Hz. No consideration therefore need be given to consecutive frequency excursions outside the range 49.0 – 51.0 Hz.

- f) The maximum level of negative phase sequence component of phase voltage existing on the National Grid system. Suppliers should assume a continuous value of 1.5% negative phase sequence voltage for rating purposes, although short duration peaks of 2% for up to 20 minutes may occur.

Suppliers shall supply details of their SVC sub-component rating methodology to demonstrate compliance with the parameters (a) to (d) above.

1.11.4 Thyristor Valves (including GTO thyristor/IGBT based valves and other devices)

- a) General

All thyristor valves, whenever used and of whatever type, shall comply in general with the applicable sections and principles of BS EN 60146 and IEC 60747 Part 6.

Impregnants, where used, shall not contain PCB or other toxic or hazardous materials. All site and safety hazards shall be declared as per the requirements of clause 1.4.5.

It shall be possible to exchange thyristors and other discrete power semiconductor assemblies with the minimum disassembly of any power or water cooling circuit and with the minimum dismantling of any overall converter module (if supplied). Special tools required for the replacement of these parts shall be provided under the contract. Points for attaching earthing devices for the control of trapped charge, induced voltages or inadvertent re-energisation of the valves should be provided.

The in-service failure of any single SVC valve component shall not prevent the continued operation of the SVC at any point on its continuous operating characteristic. Should a fault occur, the control system will automatically notify the existence of the fault and log the date and time of its occurrence. A clear indication of the fault location shall also be provided. The Supplier shall provide full details as to how this requirement for redundancy will be implemented and how the voltage stresses applicable to the non-bypassed components are affected.

The purpose and configurations of semiconductor snubber and associated circuits shall be summarised by the Supplier in their Tender submission. A more detailed design report covering all aspects of the valve design shall be provided by the Supplier at the contract stage.

Any control or fibre optic cabling must be protected from inadvertent contact by personnel. The cabling must also be adequately protected from vermin damage.

b) Thyristor Valve Cooling

The cooling plant shall be arranged to minimise the auxiliary power requirements of the SVC throughout its entire continuous operating characteristic and during periods whilst the SVC is shutdown.

Any coolant passing through outdoor heat exchangers shall have a freezing point below the minimum possible ambient temperature defined in TS 1 clause 3.2.2 (minus 25 °C outdoor applies).

An indicative report shall be provided by the Supplier detailing the required flow rates, pressures, temperatures, number of external coolers in operation and other parameters as appropriate in respect of the cooling system relating to the float Mvar condition (i.e. zero Mvars) and also the Mvar value which corresponds to maximum cooling load. This information shall be calculated assuming the maximum ambient temperature external to the thyristor valves given in TS 1 clause 3.2. Indicative cooling plant ratings shall also be provided at the Tender stage.

Evidence shall be provided by the Supplier to demonstrate that any coolant mixture used in the cooling circuit is fully 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. As a minimum, data sheets and other supporting documentation (e.g. compatibility test evidence demonstrating non-corrosion performance, etc.) shall be provided to confirm compliance with this requirement. The cooling design shall ensure that no cross contamination of separate cooling sub-systems (e.g. a pure water system to a water/glycol mixture system) is possible. The growth of algae and other harmful bacteria within the cooling system must be prevented.

The Supplier is reminded that, depending on the design, the valve cooling system or a part thereof may be required to comply with the Pressure System Safety Regulations 2000. The Supplier is responsible for assessing whether the regulations do apply and if not, should state why the regulations do not apply. If the regulations do apply, the

Supplier shall produce a Written Scheme of Examination (WSE) and ensure that the WSE is in place before the valve cooling system is put into operation for the first time.

Sufficient on-site coolant storage shall be provided, either in expansion tanks or in supplementary tanks to ensure a 6 month standby for normal operating losses.

Any spillage or losses of coolant which may contain a pollutant or contaminant must be appropriately contained to allow proper disposal. Any coolant losses should be minimised and shall not require operator intervention (e.g. topping up) any more frequently than once every 2000 hours of operation.

Evaporative coolers are not permitted.

The average annual cost of components and labour resources for replacing all components in the valve cooling system scheduled to be replaced periodically (such as exchangeable resin cylinders, if used) shall be stated at the Tender stage.

Redundancy shall be provided to ensure that the SVC can continue in operation throughout its entire continuous operating characteristic at maximum ambient temperature with a pump (primary and secondary), fan, 3 way valve or heat exchanger (as applicable) out of service. It shall be possible to safely gain access and perform work on any redundant component with the remaining component in service. All redundant equipment must be provided with a means of local isolation for maintenance purposes in accordance with National Grid Safety Rules and the Electricity at Work regulations.

To maximise lifetime and cooling plant availability the apportionment of running hours between the cooling system rotating plant shall be controlled automatically by the control system. The criteria used by the Supplier to achieve the pump rotation optimisation shall be stated at the Tender stage. 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 comprises one or more item of equipment that is only required to operate infrequently or at certain times of the year (such as a chiller/refrigeration unit utilised when the ambient temperature is relatively high), the Supplier shall detail the provision made in the cooling plant design to 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 as deemed necessary.

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 must be stored/logged before resetting.

c) Valve Protection

The requirements of TS 3.24.91 shall be satisfied. Additionally:-

(i) Protective Firing of Valves

Where the protection of the compensator is achieved by additional protective valve firing pulses, these additional pulses shall be counted and the total number of pulses recorded in a manner that can be read while the compensator is on load. Additionally there shall be an alarm, recorded on the data processor, to indicate the period during which these pulses have been produced.

(ii) Overvoltage Protection of Thyristor Switched Capacitor Banks

If a thyristor switched capacitor shunt branch is provided, and if over-voltage protection of this shunt branch is achieved by firing of the thyristor valve, then the thyristor valve protection shall be arranged such that over-stressing of the capacitors or transients on the National Grid HV system do not occur if the protection operates. Supporting evidence shall be provided at the Tender stage.

(iii) Protective Stopping of Valve Firing Pulses

When the protection of the compensator is achieved by stopping valve firing pulses being sent from the control equipment, then each period of operation of the protective equipment shall be alarmed.

(iv) Cooling Controller Protection

The supply to any separate controller associated with the cooling plant shall be supervised. Upon loss of the supply to the cooling controller the SVC circuit breaker shall be opened.

d) Valve System Insulation Co-ordination

Insulation co-ordination shall be in accordance with BS EN 60071-1 and BS EN 60071-2.

e) Series Switching Device Connection Issues

It is probable that semiconductor devices will be connected in series in order to meet voltage rating requirements. The Supplier shall indicate the means by which the voltage ratings of components, thyristor levels, etc, have been devised taking account of the voltage rating capabilities of the semiconductor devices, the redundancy requirements detailed in clause 1.11.4 (a) above, component equipment manufacturing tolerances and the effects of variations in the performance characteristics of individual semiconductor devices.

Where gate turn-off thyristors (GTOs), insulated gate bipolar transistors (IGBTs) or similar devices with turn-off capability are supplied and connected in series, the means by which the satisfactory turn-on and turn-off performance of the series string will be achieved shall be detailed by the Supplier. This shall include details of the effects of component equipment manufacturing tolerances and the effects of variations in the performance characteristics of individual semiconductor devices (e.g. turn-on and turn-off delays, etc).

f) Thyristor Valve Availability

The minimum requirements for overall SVC availability are specified in clause 2.4. Within these values, the availability figures specific to the thyristor valves (including associated cooling plant) shall be 99.5% (excluding planned maintenance) and 99% (including planned maintenance) respectively. These figures assume a 2 day annual outage for thyristor valve and cooling plant maintenance.

A statistical availability study shall be supplied by the Supplier with the Tender submission (in addition to that requested in clause 2.4) demonstrating compliance with the above requirement. The source of component failure rate statistics shall be included with this submission. Particular attention should be drawn to the make up and performance of the components of the thyristor valve cooling system and the associated pumps, transducers, controllers, etc.

With National Grid's assistance, the Supplier shall monitor the availability of the thyristor valve equipment over a period of five years following take-over of the SVC by National Grid. At this point a report shall be presented to National Grid demonstrating

that the valves have met the specified availability figures of 99.5% and 99% respectively (as defined above). Where the actual availability performance is measured to be less than specified, a penalty shall apply. The nature and value of this penalty will be detailed in the SDS.

1.11.5 Disconnectors and Earth Switches

Where disconnectors are used on the LV side of the compensator transformer they shall be triple pole and shall comply with BS EN 60129 and the general requirements of TS 3.2.2.

Triple pole earth switches, complete with manual operating mechanisms shall be provided to earth each separate section of conductor including the main LV busbars. The earth switches shall comply with BS EN 60129 and the general requirements of TS 3.2.2.

1.11.6 LV Busbars, Connectors and Clearances

LV busbars and connectors and their safety clearances shall conform to TS 2.1 unless the equipment concerned is fenced off and access prevented (by an interlocking scheme to the approval of National Grid) whenever the equipment is unearthed. They shall be suitably rated to match the full capabilities of the SVC.

1.11.7 Capacitors

a) A.C. Filter/TSC Capacitors

Where supplied, a.c. capacitors and associated equipment shall comply with the requirements of TS 3.11.1.

The required capacitor voltage rating (U_n) shall be determined according to the procedure detailed in Appendix M.

In determining the capacitor(s) maximum continuous voltage (Appendix M item 5), the contribution due to the maximum system fundamental frequency voltage shall be added arithmetically to the worst case resonant harmonic contribution derived from the application of the criteria detailed in clause 1.11.3. This voltage shall then be added arithmetically to the root sum square (rss) of the remaining "resonant" contributions (derived under conditions consistent with the worst case "resonant" harmonic contribution).

The Supplier shall base the rated voltage (U_n) of the capacitors on the maximum continuous voltage defined above, and on the effects of any transient over-voltages. The rated voltage (U_n) of the capacitors Tendered in the Tender shall not be less than the maximum continuous fundamental frequency component that may occur under any condition (Appendix M, item 1(ii)). The maximum system fundamental frequency voltage used for these calculations shall be derived from that specified in TS 1 clause 4.2. If the capacitor rated voltage (U_n) is less than the maximum continuous voltage of Appendix M item 5, the Supplier shall provide a report justifying the selection of the U_n value.

The protective system shall match the capability of the capacitors and shall have full regard for the harmonic content of the current.

b) A.C. High Frequency Earthing Capacitors

Where supplied, a.c. high frequency earthing capacitors shall comply with the requirements of BS 7578 or TS 3.11.1 as applicable.

c) D.C. Capacitors

Where supplied, d.c. capacitors shall comply with BS EN 61071. Suppliers shall provide full details with their Tender submission of the methodology used in determining the choice of d.c. capacitor rating and resultant stress levels including the effects of any harmonics.

Where d.c. capacitors are installed in a cabin or housing, Suppliers shall demonstrate that their mounting arrangement and cooling facilities are suitable for the chosen capacitor environmental temperature category and rated voltage.

It shall be possible to replace individual capacitors without the need to dismantle d.c. buswork. For maintenance purposes, a suitable method shall be provided to enable the short-circuiting, discharging and connecting to earth of the d.c. capacitors and d.c. buswork.

The capacitors shall be of self-healing type, so designed to ensure minimal energy release should a fault occur within the capacitor unit.

1.11.8 Compensator Transformer

a) General

The HV compensator transformer shall comply with the relevant requirements of TS 2.3. The neutral ends of the HV windings shall be directly earthed.

b) Transformer Cooling

Cooling of the compensator transformer shall be as specified in TS 2.3, except as follows:

No ONAN rating is required. As a result of a step load change from float to maximum rated SVC output, no part of the winding shall exceed the temperature attained when operating at full rated output.

The operation of fans and pumps shall be completely automatic but a manual override facility shall be provided to allow the operation of each component of the cooling system separately or in combination.

The SVC must be capable of maximum rated power with any one fan or pump out of commission.

1.11.9 Earthing Transformer

An earthing transformer shall earth the secondary side of the compensator transformer. It may also be used to provide the SVC auxiliary supplies (see clause 1.13). The neutral end of the HV windings of the earthing transformer shall be solidly earthed unless the Supplier can justify why this should not be the case and an alternative means of earth fault protection is provided.

The earthing transformer shall comply in general with the requirements of BS EN 60076.

1.11.10 Reactors

Where oil filled reactors are provided they shall comply with the relevant parts of TS 2.3. Where dry type reactors are supplied they shall comply with TS 3.3.2. Where reactors not falling within the general scope of either TS 2.3 or TS 3.3.2 are provided, the Supplier shall provide full details of the specifications to which these reactors are designed and tested.

1.11.11 Other Transformers/Wound Components

Transformers and other wound components not covered by clauses 1.11.8, 1.11.9 and 1.11.10 above shall comply with the appropriate sections of BS EN 60076.

1.11.12 Current Transformers

Current transformers shall comply with the requirements of BS EN 60044-1 and shall be suitably rated to match the full capabilities of the SVC. CT transformation ratios, outputs, and accuracy classes within the SVC scheme shall be selected by the Supplier to meet the requirements of the specific CT application. Full details of all the CTs being Tendered shall be provided by the Supplier.

Test and isolation facilities for CT secondary circuits shall be provided and agreed with National Grid.

1.11.13 Voltage Transformers

Voltage transformers shall comply with the requirements of BS EN 60044-2. VT transformation ratios, outputs, and accuracy classes within the SVC scheme shall be selected by the Supplier to meet the requirements of the specific VT application. Full details of all the VTs being Tendered shall be provided by the Supplier.

Test and isolation facilities for VT secondary circuits shall be provided and agreed with National Grid.

Three single phase, high accuracy wound voltage transformers of the relevant rated voltage will be installed. These will be connected, one per phase, to the load (i.e. transformer) side of the HV circuit breaker and their secondary outputs will be available for compensator control purposes.

In addition an existing lower accuracy, single phase signal representing nominal busbar voltage (i.e. source side of circuit breaker) will be made available if required.

1.11.14 Bushings

All bushings shall comply with TS 3.2.7.

1.11.15 Outdoor Insulators

Outdoor insulators shall comply with the requirements of TS 3.2.9 accommodating the minimum creepage distances specified in clause 1.11.2 of this specification. They shall be tested in accordance with TS 3.2.9 and BS EN 60168 as applicable.

1.11.16 Optical Fibres

All fibres and cables supplied shall comply with BS EN 60794.

Fibres when installed and terminated shall allow sufficient spare length to permit at least three re-terminations at each end of the fibre, unless otherwise agreed by National Grid. This extra length shall be available within the termination cubicle.

1.11.17 Cables

Cables, where supplied, shall comply with the relevant sections of BS 6622. Continuous extruded metallic sheath cables shall be provided with an extruded insulation screen. Particular attention is drawn to BS 6622 in respect of the requirements for earthing of armour and/or screens.

Where multiple cables per phase are required, the Supplier shall ensure that the current rating of any cable is not exceeded under any continuous operating condition due to current sharing effects.

1.11.18 Resistors

Air insulated resistors, where supplied, shall comply with TS 3.11.2.

1.12 Equipment Fire Protection

Fire protection and control, including limitation of fire risk shall comply with TS 3.1.3.

Unless otherwise agreed by National Grid, all cables used shall comply with BS 6724 regarding the level of smoke emitted during combustion and the concentration of acid gas emitted during combustion.

The Supplier shall show, to the approval of National Grid, that the walls and roof, both internal and external, of any buildings used have been tested in accordance with the procedure set out in BS 476 Part 7 (surface spread of flame) and the results of these tests shall be within the limits defined for a classification of Class 1 (see BS 476 Part 7 Table 2).

1.13 Auxiliary Supplies

The SVC shall be self-sufficient for its a.c. power requirements, except for start up and shut down, when a changeover system, to be supplied as part of the SVC contract, may be employed to connect to the existing substation supplies. The requirements of the changeover system will be specified in the SDS. The quality of supply provided by this alternative source of supply is described in Section 4 of TS 2.12.

The overall supervision of the auxiliary supply system shall be carried out by the compensator alarm and data processing system.

48 V d.c. and 110 V d.c. power supplies, where used, shall comply in general with TS 3.12.4.

1.14 Earthing System

All switchgear and compensator equipment, structures and enclosures shall be connected to the existing substation as specified in TS 2.1 and associated specifications.

1.15 Ferroresonance

Before any SVC equipment is connected to the National Grid system, the Supplier shall demonstrate by computer modelling that there is no risk of sustained linear resonance or ferroresonance on any plant supplied by the SVC Supplier under any system operating condition detailed in TS 1 and in this specification during any commissioning or foreseeable operating condition. Any method of detection and suppression of ferroresonance incorporated into the SVC design shall be subject to separate evaluation and testing.

2 PERFORMANCE REQUIREMENTS

2.1 Compensator Rating

2.1.1 Continuous Rating - Normal System Conditions

Continuous and controllable operation shall be possible according to the operating characteristic detailed in Appendix A. The Mvar output capability and the design points defining the operating characteristic of Appendix A are specified in the SDS.

No negative tolerance on the specified Mvar range is permissible, and the effects of worst case tolerances for individual components (e.g. transformers, capacitors and reactors), supply system frequency variations (normal conditions, i.e. 49.5 - 50.5 Hz continuously), and the relevant environmental conditions stated in TS 1 clause 3.2.2 (minus 25 °C outdoor) must be taken into account in the design. Full calculations that demonstrate that these requirements are satisfied by the design Tendered shall be provided with the Tender submission.

Such continuous operation shall be achievable over the outside ambient air temperature range defined in TS 1 clause 3.2.2 (minus 25 °C outdoors). These are to be taken as free air temperatures for the site and include no allowance for solar gain, self-heating effects or the proximity of other plant.

2.1.2 Short Term Capability and Rating

a) General

Suppliers shall declare the short time capability of the SVC in the capacitive range.

In the inductive range the SVC shall be rated for continued operation at 1.3 per unit primary voltage for one second following and followed by operation at the maximum inductive capability. For voltages exceeding this magnitude and duration it is expected that control action will reduce compensator loading in preference to a protective trip. The short time capability of the SVC in the inductive range shall be declared by the Supplier.

b) Requirements During Low Voltage Disturbances

- (i) For system voltages between the minimum continuous SVC operating voltage and 0.8 pu, the SVC shall continue generating Mvars for at least 20 minutes. After this 20 minute period the SVC output can be reduced to zero Mvars but the main SVC circuit-breaker shall not be opened.
- (ii) For system voltages between 0.8 pu and 0.4 pu, the SVC shall continue generating Mvars for at least 1.5 seconds. The SVC circuit-breaker shall not open at any time that the system voltage is above 0.4 pu.

c) For system voltages below 0.4 pu the SVC shall perform as follows:-

- for occurrences lasting less than 0.5 seconds the SVC shall be capable of generating Mvars in accordance with pre-excursion control set points and targets immediately the system voltage returns to, or exceeds, 0.4 pu.
- for occurrences lasting between 0.5 seconds and 1 hour the SVC circuit-breaker shall not open; it shall be capable of generating Mvars in accordance with pre-excursion set points and targets within 1 minute of the system voltage returning above 0.4 pu.
- for occurrences lasting more than 1 hour the SVC is permitted to open its circuit-breaker if it would be unsafe to re-apply voltage to the SVC; this condition shall be alarmed.

Any premium applied by National Grid at the Tender assessment stage due to the enhanced Mvar generation performance of the SVC at low system voltages when compared to the Mvar generation capability of an equivalent constant impedance device will be detailed in the SDS.

2.1.3 Operation with Depleted Cooling Capacity

If any particular Mvar output is not attainable due to the unavailability of cooling plant in excess of that required to fulfil the requirements of all other clauses of this specification, the SVC shall temporarily adjust its operating target so that the nearest Mvar output that is safely and practically attainable is provided. This condition shall raise an alarm. Once operation at the original target is again possible, the SVC shall automatically return to operation at that original target. The Supplier shall provide an indication of the control strategy employed during such an event.

2.1.4 Slope Characteristic

The slope characteristic shall be adjustable over the range 2% to 10% voltage change (with 1% resolution) from the nominal voltage for a compensator current change relating to full rated output as detailed in the SDS. This performance shall be available over the full range of target voltage adjustment.

Unless otherwise specified, the voltage-current characteristic of the SVC shall be continuous and smoothly variable (i.e. not stepped) throughout the complete controllable Mvar range for any target voltage or slope setting.

For contracts where a non-continuous (i.e. stepped) voltage-current is acceptable (refer to SDS) the maximum step shall not exceed 30 Mvar based on an HV system voltage of 0.9 pu, unless otherwise specified in the SDS. The Supplier shall ensure that sustained switching instability will not occur at the extremes of short circuit level detailed in clause 2.1.6 of this specification.

2.1.5 Float Condition

The float condition or target voltage shall be variable over the range 0.95 to 1.05 per unit system voltage (261 to 289 kV for 275 kV system, 380 to 420 kV for 400 kV system).

2.1.6 Speed of Response

Over the required dynamic Mvar range detailed in the SDS, the SVC shall respond to changes of system voltage (either minor variations, steps or major disturbances e.g. faults) such that the 0-90% rise time of SVC current is less than 100 ms for all system conditions quoted in TS 1 and in this specification. The settling time shall be less than 200 ms, with all oscillations greater than 1% of full load current having ceased 500 ms after the disturbance. The minimum short-circuit levels at both 275kV and 400kV shall be taken as 4000MVA and the maximum at 275kV and 400kV shall be taken as 19000 MVA and 43600 MVA respectively. The above performance shall be maintained for this range of short-circuit levels. Any adverse effects on the SVC design resulting from Mvar overshoot shall be taken into account by the Supplier in the SVC design.

Suppliers should note that the short-circuit levels quoted above relate to compliance with the performance requirements of this specification. Lower short-circuit levels may exist as the result of abnormal system conditions, and Suppliers shall therefore declare the minimum short-circuit level for safe operation of the SVC.

Should the SVC characteristic be stepped (see clause 2.1.4), it shall be capable of altering its output within its range from any value within its range to any other value within its range without performing incremental steps. No constraints on the frequency of such switching operations, such as may arise from the use of mechanically switched elements, are permissible.

To enable the study of the power system transient and dynamic behaviour under small and large disturbances, including the correct behaviour of the SVC, a model representing the transfer function block diagram for the SVC control system shall be supplied. The model

shall be suitable for balanced, r.m.s., positive phase sequence system behaviour, excluding the effects of electromagnetic transients, harmonic and sub-harmonic frequencies.

The model required shall correctly represent the overall performance of the SVC over its entire voltage operating range including that which is inherent to the SVC and that which is achieved by the use of an “external” control system providing either continuous or stepwise control.

The overall structure of the model shall include:

- a) The measurement module.
- b) The Target Voltage Mode module.
- c) Any supplementary control signal modules such as Constant Mvar Mode or Power Oscillation Damping Control.
- d) Any blocking, de-blocking and protective trip features that are part of the model.
- e) Any other information required to model the SVC behaviour under small and large power system disturbances to meet the model functional requirement described above.

The model shall display all the transfer functions and their parameters, any non wind-up logic and signal limits.

When incorporated into a standard power system dynamic solution analysis program, the model should be capable of reproducing the SVC steady state and dynamic performance as specified in clauses 2.1.1, 2.1.2, 2.1.4, 2.1.5 and 2.1.6.

2.1.7 SVC Start Up

As a minimum requirement the SVC shall be capable of generating its full Mvar range within one minute of initial energisation of the compensator transformer. Reference is made to clause 1.13 regarding the use of a changeover system, to be supplied as part of the SVC contract, that may be employed to connect to the existing substation supplies during start up.

The Supplier shall state the performance of the SVC following initial energisation of the compensator 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 compensator transformer.

2.1.8 Performance During System Frequency Excursions

Clause 1.11.3(e) provides details of the frequency excursions outside the range 49.0 - 51.0 Hz for which the SVC plant is required to be rated. It should be noted by Suppliers that unless otherwise specified the SVC performance requirements detailed in section 3 of this specification are only required to be achieved for normal system frequency conditions of 49.5 - 50.5 Hz. However, the SVC must remain connected to the National Grid system for the system frequency variations and durations defined in clause 1.11.3(e) without damage to the SVC or associated equipment as a result of the operation of the SVC under those conditions.

Outside of the normal continuous frequency range of 49.5 to 50.5 Hz, the SVC shall continue to be able to generate Mvar output for the system frequencies and time durations specified in clause 1.11.3(e). In the capacitive Mvar range (if supplied), any decrease in Mvar output in the frequency range 47 to 49.5 Hz shall be no more than pro-rata with frequency, and any increase in Mvar output in the range 49.5 to 52 Hz shall be at least pro-rata with frequency. In the inductive Mvar range (if supplied), any increase in Mvar output in the frequency range

47 to 50.5 Hz shall be at least pro-rata with frequency, and any decrease in Mvar output in the range 50.5 to 52 Hz shall be no more than pro-rata with frequency.

Suppliers shall declare the performance of the SVC for the conditions of system frequency outside the normal 49.5 - 50.5 Hz range for each of the envelopes defined in clause 1.11.3(e). This shall include a description of the manner in which the SVC is controlled, details of the performance and rearrangement of auxiliary supplies (if implemented), details of the harmonic performance of the SVC (where applicable) and the Mvar generation capability of the SVC under those conditions.

2.1.9 Performance During Conditions of Phase Unbalance

The SVC shall fulfil all performance requirements of this specification under conditions of 1% continuous negative phase sequence component of phase voltage.

2.2 Limitation of Harmonic Voltages and Currents

The SVC equipment shall be designed to limit the harmonic voltages it causes at the HV side of the compensator transformer to conform to the following criteria. The criteria shall apply for all possible loadings of the SVC over the entire Mvar range taking into account the characteristics of the a.c. system (described in TS 1 and this specification) and the specified range of harmonic impedances for 400 kV and 275 kV systems detailed in the SDS ("performance" conditions), but neglecting any resulting individual harmonic voltage that is below 0.1%:-

Maximum root-sum-square total harmonic distortion	0.25%
Maximum 3rd harmonic voltage distortion	0.10%
Maximum 5th harmonic distortion	0.15%

These limits are in percentages of the nominal fundamental frequency voltage, and apply to an SVC of dynamic rating 150 Mvar. The acceptance limits shall be scaled pro-rata to the actual dynamic rating specified in the SDS (e.g. for a device of 225 Mvar dynamic range, the maximum rss total harmonic distortion is 0.375%). These limits apply to the vectorial contribution to the harmonic levels which occurs when the SVC operates in a mode which generates its maximum levels of harmonic distortion compared with the levels measured when the SVC is connected but not generating harmonic distortion.

Additionally, the following requirements regarding the maximum permissible harmonic voltage magnification at the HV point of connection of the SVC shall apply:

Harmonic order	Maximum permissible harmonic voltage magnification at the HV point of connection due to resonance between the SVC and the harmonic system impedance
2	3.5
3	1.2
4	1.0
5	1.0
6 - 100	1.0

It shall be assumed that the supply system harmonic impedance (performance conditions) as detailed in the SDS at each harmonic exhibits the value of impedance that results in the greatest magnification factor.