

SERIES COMPENSATION BAY FOR CONNECTION TO 275 KV AND 400 KV SYSTEMS

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PURPOSE AND SCOPE

This Technical Specification (TS) defines National Grid's functional, performance and testing requirements for Series Compensation (SC) for connection on the National Grid (NG) transmission system at 275 kV and 400 kV. This includes Fixed Series Capacitors (FSC) and Thyristor Controlled Series Capacitors (TCSC). Typical arrangements of SC bays for connection to the NG Transmission system are shown in Appendix A.

The detailed Protection and Control (P&C) requirements for the SC bay are defined separately in TS 3.24.88.

This specification is by reference to the relevant British and International standards and specifications.

Where a requirement in a National Grid Technical Specification exceeds or is more onerous than that of the British or International standard, the most onerous condition shall be considered appropriate.

To prevent duplication, where a requirement is already defined within an existing TS, reference is made to that TS and the requirement may not be re-stated within this TS.

PART 1 – PROCEDURAL

1 GENERAL

This section defines the environmental service conditions, power system conditions and main characteristics to which any SC installation shall comply.

1.1 Environmental Conditions

- 1.1.1 The SC design shall comply with the environmental requirements of TS 1.

Informative : National Grid TS 1 specifies the normal and abnormal environmental conditions, including Ingress Protection (IP) rating, maximum and minimum operating temperatures, ice coating and pollution class, in which SC equipment shall be expected to operate at its specified current, voltage and frequency ratings.

- 1.1.2 The platform mounted SC components shall be designed for an outdoor installation with the exception of any Thyristor valves which may be mounted in a dedicated weather proof housing.

- 1.1.3 The SC design shall comply with the mechanical loading requirements of TS 3.1.4.

Informative : TS 3.1.4 specifies the dead, wind, ice and short circuit mechanical loadings to be considered.

- 1.1.4 The environmental conditions for the P&C equipment are specified in TS 3.24.88.

1.2 Power System Characteristics

- 1.2.1 The SC design shall comply with the normal and abnormal power system conditions defined in TS 1.

Informative : The Solutions Provider's attention is drawn to document 'CI 01 – Technical and Operational Characteristics of the Transmission System' which provides historical background information of the power system requirements as set out in TS 1.

- 1.2.2 System Voltage

The SC design shall comply with the nominal, maximum continuous, minimum continuous and short term maximum system voltages for plant and equipment specified in TS 1.

- 1.2.3 System Frequency

The SC design shall remain stable and comply with the rated, maximum continuous and minimum continuous frequency ranges specified in TS 1 (and Grid Code CC6.1.2 and CC.6.1.3) and the excursions detailed below.

Following a system frequency excursion outside the range 49 - 51 Hz detailed in TS 1, system frequency shall stabilise to a value between 49 - 51 Hz.

No consideration therefore need be given to consecutive system frequency excursions outside the range 49 - 51 Hz. It shall be assumed that the above incidents will occur as defined in Table 1;

System frequency (Hz)	Occurrence
47.0 - 49.0	Once every five years
51 - 52.0	Once every five years (excluding islanding)

Table 1 : Occurrence of Frequency excursions

- 1.2.4 Short Circuit Rating

TS 1 specifies the short circuit rating for plant and equipment and the associated fault clearance times. Any deviation from these requirements shall be specified in the Enquiry Document.

The minimum short circuit level for each location where series compensation is to be installed shall be specified in the Enquiry Document.

Solution Providers shall note that such minimum short-circuit levels relate to compliance with performance requirements of this specification; lower short-circuit levels may exist as the result of abnormal system conditions and Solution Providers shall declare the minimum short-circuit level for safe operation, including switching of the SC.

1.2.5 Insulation Levels

TS 1 specifies the standard insulation levels for power frequency, switching impulse and lightning impulse withstand voltages.

Further details for insulation co-ordination and creepage are given in clause 5 of this specification.

1.3 Main Series Compensation Characteristics

1.3.1 Percentage Compensation

The required percentage of compensation for each installation shall be specified in the Enquiry Document.

1.3.2 Mvar Rating

The required Mvar rating for each installation shall be specified in the Enquiry Document.

1.3.3 Continuous Current Rating

TS 1 specifies the nominal continuous current ratings for plant and equipment. Clause 6.2 of this specification provides further details.

1.3.4 Short Term Rating

TS 2.1 specifies the short term ratings (overload factors) for plant and equipment. Clause 6.2 of this specification provides further details.

1.3.5 The Fault Duty Cycle

The Fault Duty Cycle shall be specified in the Enquiry Document.

Informative : A typical Fault Duty Cycle is defined in BS EN 60143-2:1994 clause 3.4.

1.3.6 Number of Segments/Switching Steps

This requirement shall be specified in the Enquiry Document.

1.3.7 Segment/Switching Step reactance split (if more than one segment)

This requirement shall be specified in the Enquiry Document.

1.4 Site and Plant Safety Hazards

Informative : UK legislation requires the Solution Provider to declare all safety hazards relating to the equipment offered.

1.4.1 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 or other relevant hazards.).

1.5 Workplace Noise

- 1.5.1 In normal operation of the facility, it shall not be necessary for any person to work in, or enter an area on a regular basis, where the steady state or peak noise levels exceed the relevant exposure action values specified in The Control of Noise at Work Regulations 2005.
- 1.5.2 The Solution Provider shall identify any areas that are to be designated as Hearing Protection Zones.

1.6 Installation Layout

- 1.6.1 The equipment shall be designed to occupy the minimum land area required to permit adequate space for maintenance access and egress in a safe manner for activities at ground level and on the platform.
- 1.6.2 The design of the foundation rebar within the magnetic field generated by the SC reactor(s) shall avoid closed loops to reduce heating and corrosive effects. Further details are given in TS 3.10 and Design Handbook (DH) 10, clause 2.13.6.
- 1.6.3 The design of the platform and other metallic components on the platform shall take in to consideration the magnetic field effects of the SC reactor(s) that may be mounted on or off the platform.
- 1.6.4 Safety clearance distances shall comply with the requirements of TS 2.1 clause 5.101 unless the equipment is fenced off and access is prevented by a suitable interlocking scheme whenever the equipment is either;
- (i) energised, or
 - (ii) de-energised and unearthed.
- 1.6.5 Where the equipment is fenced off, access for inspection or operation of all ground mounted equipment (ie marshalling kiosks, bypass switch, disconnector/earth switch mechanism cabinets, protection & control and cooling plant) shall be possible from outside the compound to prevent the need to isolate and earth the series capacitor in order to access these items.
- 1.6.6 Where the equipment is fenced off, the access gates to the installation's compound shall be designed to allow access by any prescribed plant or vehicles (such as a Mobile Elevated Work Platform (MEWP)) required for inspection, maintenance or repair activities.
- 1.6.7 Where the equipment is fenced off, the height of structures or plinths used to support the platform-to-ground post insulation shall be a minimum of 1000 mm above finished ground level to ensure sufficient clearance for environmental conditions such as snow accumulation at the base of the installation.
- 1.6.8 Where the equipment is fenced off, it shall only be possible to gain access to the compound while the equipment is both isolated from the transmission system and earthed. Under these circumstances it shall be possible to walk within the SC compound without danger. A Safety Interlocking scheme shall be provided to facilitate this in accordance with TS 3.1.1.

Informative : Access to the plant within the compound, during in-service operation shall not be required.

- 1.6.9 Where required, fences shall be supplied in accordance with clause 4.3 of this specification and shall not restrict visual inspections of the equipment contained within the compound when viewed from outside the compound perimeter.
- 1.6.10 Over-sailing Hazards shall be avoided (or designed out) during the design stage which may prevent or restrict access to equipment for maintenance or component replacement activities. The series compensation design and layout shall comply with the requirements of TS 2.1 clause 5.102.

Informative : Further guidance regarding safety clearance distances and the avoidance of over-sailing can be found in TGN(T) 186, 'Guidance for working in proximity to live conductors – reducing the risks'.

- 1.6.11 Sufficient space within the compound shall be provided to enable the safe movement and operation of a MEWP to allow high level access to the boundaries of the capacitor platform, its associated guard rail system and any components installed around the boundaries of the capacitor platform for the purpose of inspection, maintenance or repair.
- 1.6.12 The Solution Provider shall provide general layout drawings of all equipment configurations to verify compliance of the design with the specified land area requirements as detailed in the Enquiry Document.
- 1.6.13 The location of foundations and support structures shall not impede access to the capacitor platform boundaries by use of a MEWP.
- 1.6.14 Cables and pipework shall not be surface laid either at ground level or on the platform without prior agreement by National Grid.
- 1.6.15 Cables, pipework or supporting structures shall not be placed less than 2 metres above the finished ground level or platform level without prior agreement by National Grid.
- 1.6.16 The use of ladders to gain access to the series capacitor platform shall be avoided.
- 1.6.17 Where the use of a mobile stairway or other suitable means of access is required to gain access on to the capacitor platform, it shall only be possible to position (or raise / lower) the access system to / from the high level platform once the platform has been electrically isolated from the live transmission system and primary earths have been applied on all isolated sides. The reverse logic shall apply during the removal of the stairway, i.e. it shall only be possible to remove the primary earths in preparation to return the equipment back in to service, once the mobile stairway has been removed / lowered from the platform access position back to its stowed position. This shall be achieved by a suitable interlocking scheme.
- 1.6.18 The design of the stairway and capacitor platform shall ensure an individual can make a safe transition from the stairway on to the capacitor platform. Once on the platform, it shall be possible to securely close any access gate to prevent an individual from falling through the access gate opening.
- Informative : This may take the form of a landing platform at the top of the stairway to achieve a safe transition from the stairway on to the platform.*
- 1.6.19 Any individual who is required to stand on the capacitor platform shall be protected from the risk of a fall hazard by the design of an appropriate perimeter guard rail and toe board system. The toe boards shall also protect any individual who may be at ground level, from the risk of a falling object.
- 1.6.20 The guard rail and toe board system shall be designed in accordance with the requirements of BS 3595-1, BS 6180 and The Working at Height Regulations.

- 1.6.21 The space requirements of, and around the components installed on the capacitor platform shall take into consideration all foreseeable inspection, maintenance and repair activities. This shall include the allowance of sufficient room to work with tools including any special tools) and facilitate safe movement around the components. TS 2.1 clause 7.101 further defines these requirements and provides anthropometric data, which is derived from those set out in BS EN 547-3.

Informative : These should be considered as the minimum requirements and where specific activities require additional space; this shall be taken in to consideration during the design and layout of the capacitor platform.

- 1.6.22 The Solution Provider shall supply a safe method to enable all consumable / replaceable components installed on the platform to be accessed and replaced without introducing manual handling or working at height risks. Sufficient space on the capacitor platform shall be allowed in the design stage to accommodate such requirements.

- 1.6.23 Particular attention shall be given to the method employed to safely discharge the capacitor units prior to the start of any work on the platform.

Informative : The use of a temporary ladder on the platform is not considered an acceptable method to access high level components as this introduces a working at height risk.

- 1.6.24 The Solution Provider shall supply a safe method to enable all tools required to carry out work and any replaceable components installed on the platform to be lifted from ground level and transferred to and from the platform without introducing manual handling or working at height risks. In addition, particular attention should be given to the method employed to safely withdraw and replace capacitor units mounted in racks on the platform.

- 1.6.25 If a hoist or small lifting device is employed on the platform, the Solution Provider shall detail the statutory inspection requirements for the lifting equipment.

1.7 Life and Availability

- 1.7.1 The SC and its control system is required to have an availability of 98% (excluding planned maintenance outages) while the overall availability shall exceed 95% (including planned maintenance outages). The Solution Provider shall supply an availability study demonstrating compliance with this requirement.

- 1.7.2 Reference is also made to clause 2.23.18 of this specification in respect of the specific availability requirements for thyristor valve equipment.

- 1.7.3 The SC primary equipment and associated civil works shall have a minimum design life of 40 years.

- 1.7.4 The P&C systems associated with the SC shall have a minimum design life of 15 years as detailed in TS 2.24.

- 1.7.5 The power electronic devices shall have a minimum design life of 25 years.

- 1.7.6 Consideration shall be given and details supplied during the Tender stage on how to facilitate the replacement of the P&C and power electronic systems / devices with the minimum of down time for the series compensation installation. The relevant detailed design calculations and documentation shall be supplied by the Solution Provider to facilitate this requirement.

1.8 Duplication

- 1.8.1 To achieve the required performance, the SC installation shall follow a philosophy to ensure that no single failure may cause a fault to remain connected to the primary system. To

implement this, independent and duplicated systems shall be considered by the Solution Provider for the following items.

- (i) Digital controllers and relays
- (ii) Power supplies to the platform (or derived on the platform)
- (iii) Platform to ground signal columns (including the optical fibres)
- (iv) Current transformers and current sensors
- (v) Circuits to trigger any forced triggered gap, or equivalent, where used
- (vi) Closing coils for the bypass switch

1.9 Redundancy

1.9.1 For the following items, redundancy shall be provided to prevent any single failure to cause the series capacitor to be switched out of service or to lead to a permanent bypass of the series capacitor.

- (i) Metal Oxide Varistors (MOV) in service 'hot' spares specified
- (ii) Capacitor cans in service
- (iii) Thyristor valves in service (in the case of a TCSC design)
- (iv) Cooling system components such as fans and pumps as detailed further in clause 2.23.13 (in the case of a TCSC design)

1.10 Maintenance Requirements

1.10.1 Routine maintenance shall be minimised and shall not be required more than once every two years.

1.10.2 During the Tender stage the Solution Provider shall indicate how the design would differ if a 6 yearly maintenance routine was to be adopted.

Informative : Moving to a 6 yearly interval would allow all SC plant and equipment maintenance requirements to be aligned thus reducing the overall down time and resource requirements of the installation.

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

1.10.4 The Solution Provider shall supply fully documented method statements for the maintenance and replacement procedures for major plant items, equipment and systems that may be located both on and off the capacitor platform.

1.10.5 The layout of the SC shall be such as to allow suitable access for maintenance or repair of all primary plant. Where practicable this shall be through the use of a MEWP for actions such as assisting in the replacement of a failed capacitor unit or the removal of a failed MOV device. The Solution Provider shall supply detailed MEWP access drawings identifying MEWP access routes.

1.10.6 Access to the primary plant shall be possible without the need to remove any structural member or support including insulators, main connections, busbars or any other normally

fixed equipment. The Solution Provider shall confirm their compliance with this requirement by supplying detailed layout drawings in the Tender submission.

1.10.7 Any special tools or equipment that may be required to carry out routine maintenance or repairs shall be identified by the Solution Provider and shall be provided for each series capacitor installation / location with the agreement of National Grid.

1.10.8 The maintenance requirements for the P&C equipment are detailed in TS 3.24.88.

1.11 Spares

1.11.1 The Solution Provider shall maximise the use of individual component designs across as many variations of the overall solution being offered to allow for a common spares holding.

1.11.2 The Solution Provider shall recommend to National Grid during the Tender stage, the quantity and type of components that should be held as spares for both maintenance activities and as strategic replacements.

1.11.3 Sufficient spare MOV devices (see clause 1.9 of this specification) shall be provided to achieve a 40 year lifetime. Calculations shall be provided to supplement the recommended numbers.

1.11.4 Sufficient spare thyristor valve modules or valve components shall be provided at the time of commissioning to allow for the rapid replacement of failed valve modules up to a 25 year life where valve refurbishment may take place.

1.11.5 Strategic spares shall be provided in accordance with PS(T) 024.

1.12 Training

1.12.1 The Solution Provider shall make provision for a training programme to include operator/dispatch and maintenance training for engineering, operating and maintenance personnel.

2 PRIMARY PLANT

2.1 General

2.1.1 This section defines the FSC main components and the technical requirements.

2.1.2 The additional requirements for a TCSC are detailed in clause 2.23 of this specification.

2.1.3 All plant, equipment and apparatus shall comply with the general conditions specified in TS 1.

2.1.4 Individual items shall also comply with the relevant level 2 and level 3 TS's, British, European and International standards or specifications, including the requirements detailed below.

2.1.5 All equipment and auxiliary systems directly associated with plant items (ie mechanism boxes, marshalling kiosks, termination boxes and associated wiring), in addition to complying with clause 2.1.3 and 2.1.4 of this specification, shall comply with the relevant requirements of TS 2.19.

2.1.6 The Nameplates for each item of plant, equipment and apparatus shall meet the minimum requirement as detailed in IEEE Std 824-2004 clause 8.

- 2.1.7 Full account of any allowances required for the effects of harmonics as detailed in this specification shall be taken in to consideration by selecting the appropriate ratings of all components.

The Solution Provider shall provide details of their SC sub-component rating methodology to demonstrate compliance.

2.2 Capacitor Banks and Capacitor Units

- 2.2.1 All capacitors and associated equipment shall comply with the relevant requirements of TS 3.11.1 and BS EN 60143-1:2004.

- 2.2.2 Only one type of capacitor unit shall be used for the series compensation installation. A second type of unit may only be used if required in the design of a Spark Gap (SG).

- 2.2.3 For maintenance purposes, a suitable method shall be provided in accordance with National Grid NSI 11 to enable the short-circuiting, discharging and connecting to earth of the capacitors and bus-work.

- 2.2.4 The impregnant shall be non-flammable, biodegradable and be Poly Chlorinated Biphenyl (PCB) free. The Solution Provider shall supply the relevant Control of Substances Hazardous to Health (COSHH) Data sheet for the impregnant.

- 2.2.5 Capacitor Rated Voltage

The root mean of squares (r.m.s.) capacitor voltage rating (U_N) shall be determined according to the calculation given in BS EN 60143-1:2004, i.e.

$$U_N = X_N \times I_N$$

Where X_N is the rated reactance and I_N is the rated current and shall take in to account any harmonics present.

- 2.2.6 Capacitor tolerance

Capacitor tolerances shall be in accordance with BS EN 60143-1:2004 clause 5.3.2, in summary;

- (i) Individual capacitor units shall not vary by more than +/-7.5 % of the nominal value at the reference temperature.
- (ii) Banks with a rated output less than 30 Mvar shall not vary by more than +/-5 % of the nominal value at the reference temperature.
- (iii) Banks with a rated output greater than 30 Mvar shall not vary by more than +/-3 % of the nominal value at the reference temperature.
- (iv) Capacitance shall not vary by more than 3 % between any two phases or segments within the same module with a bank rated output of less than 30 Mvar at the reference temperature.
- (v) Capacitance shall not vary by more than 1 % between any two phases or segments within the same module with a bank rated output greater than 30 Mvar at the reference temperature.

2.2.7 Capacitor Units

Capacitor units may be fuseless, internally fused, or externally fused. Further guidance on the different designs can be found in BS EN 60143-1:2004 Annex C. The Solution Provider to demonstrate the benefits of the option offered.

The capacitor unit bushing Basic Impulse Level (BIL) shall be coordinated to be consistent with the designed protective level of the installation.

2.2.8 Internally fused capacitor units

Internally fused capacitor units shall comply with the requirements of BS EN 60143-3:1998.

The values of u_1 and u_2 within BS EN 60143-3:1998 clause 2.2 shall apply unless the Solution Provider can demonstrate with good reason why these values should be changed.

The Solution Provider shall include the fuse's time-current coordination curve in their proposal.

2.2.9 Externally fused capacitor units

Due to previous operational experience with externally fused capacitor installations for shunt compensation, preference is given to internally fused or fuseless designs of capacitor units.

However, where externally fused capacitor units are offered, the Solution Provider shall demonstrate the reliability of the fuse element and its design exceeds that of the capacitor unit it is fitted to, under all environmental and electrical conditions defined within this specification.

Externally fused capacitor units shall comply with the requirements of BS EN 60143-1:2004 Annex A.

2.2.10 Fuseless capacitor units

Fuseless capacitor units shall comply with the requirements of BS EN 60143-1:2004 Annex C.

Fuseless capacitor units shall have a protection scheme that detects the shorting of an entire series group of capacitor elements within a capacitor unit. This is to ensure the possible occurrence of a ruptured capacitor unit is successfully detected.

2.3 Capacitor Overvoltage protector

2.3.1 The capacitor overvoltage protector shall be provided in accordance with BS EN 60143-1:2004 clause 5.1 and BS EN 60143-2:1994 clause 2.1.

2.3.2 The overvoltage protection shall be stable and shall not operate for the conditions defined in BS EN 60143-1:2004 clause 7.

Informative : The capacitor overvoltage protector may consist of a combination of Spark gaps and / or MOV.

2.4 Protective Spark Gap (or equivalent)

2.4.1 Where used, the protective spark gap (or equivalent) shall be provided in accordance with BS EN 60143-2:1994 clauses 2.1.1 and 3.3.

2.4.2 The Solution Provider shall state the classification of the spark gap (type K or type L) and the triggering principles (self or forced triggered).

- 2.4.3 The Solution Provider's spark gap (or equivalent) design shall meet all specified performance requirements under all environmental conditions defined in or referenced by this specification are considered when designing spark gaps, particularly when calculating the minimum non-triggered spark-over voltage.
- 2.4.4 The minimum non-triggered spark-over voltage of the spark gap shall be greater than the MOV residual voltage at the MOV high-current bypass threshold during such environmental conditions.
- 2.4.5 The Solution Provider shall detail the maximum time delay from the point at which the MOV high-current and/or high-energy bypass threshold is exceeded until spark gap conduction is achieved.
- 2.4.6 The Solution Provider shall detail the minimum number of conductions the spark gap can withstand at the maximum calculated fault current level before the main electrode contact surfaces require maintenance.
- 2.4.7 After each operation, the spark gap must be able to recover its full dielectric strength within 15 seconds, consistent with Delayed Auto Reclose (DAR) policy.
- 2.4.8 A facility shall be provided to automatically record the number of spark gap operations. The facility shall be manually re-settable.

2.5 Metal Oxide Varistors

- 2.5.1 The MOV bank shall be provided in accordance with BS EN 60143-2:1994 clauses 2.1.2 and 3.4.
- 2.5.2 The individual varistor columns that make the complete MOV bank shall comply with the relevant requirements of TS 3.2.3.
- 2.5.3 The individual varistor columns shall be designed to ensure that failure of one column in the MOV bank does not physically damage any adjacent columns in the bank or other components on the platform.
- 2.5.4 The design, location and orientation of the individual varistor gas diverter nozzles (where fitted) shall be such that their operation does not impact on or cause damage to any adjacent varistor columns in the bank or other components on the platform.
- 2.5.5 The required energy rating of the MOV bank shall be calculated by the Solution Provider, taking into consideration fault levels, fault duty cycles, internal faults, external faults and the DAR and Delayed Auto Re-Insertion (DARI) requirements for the circuit to have the SC installed and the circuits connected to substations within the affected transmission network.
- 2.5.6 The design of the MOV bank shall take in to consideration uneven current sharing between varistor columns.
- 2.5.7 The Solution Provider, based on their overvoltage protector design, shall recommend the number of spare varistor columns required per phase of the installation. These 'spare' varistors shall be supplied at the same time as the main varistors and shall be connected in service on the capacitor platform as part of the overall varistor bank installation.
- 2.5.8 The Solution Provider shall state the Continuous Over Voltage (COV) rating of the chosen MOV design.
- 2.5.9 A facility shall be provided to automatically record the number of MOV conductions. The facility shall be manually re-settable.

2.6 Bypass Switch

- 2.6.1 The bypass switch (bypass circuit breaker) shall be provided in accordance with BS EN 60143-2:1994 clauses 2.2 and 3.5 and BS EN 62271-109.
- 2.6.2 The bypass switch shall comply with the relevant requirements of TS 3.2.1.
- 2.6.3 The data and information required by and detailed in TS 3.2.1 shall be provided.
- 2.6.4 The bypass switch shall be to Class M1 as defined in BS EN 62271-109 and capable of a minimum of 2000 bypass operations under internal fault conditions without requiring maintenance, adjustment or replacement of components.
- 2.6.5 The operation cycle shall be the reverse of a 'normal' circuit breaker, ie (O)-C-OC-OC.
- 2.6.6 The closing circuit shall have two independent closing systems. The closing releases shall be arranged to supply from independent battery systems and shall have segregated circuits such that failure of one device in a circuit does not prevent closing of the bypass switch.
- 2.6.7 The Solution Provider shall detail the following characteristics of the bypass switch;
- (i) The rated short time withstand current ($kA_{RMS,1 \text{ second}}$).
 - (ii) The rated peak withstand current (kA_{PEAK}).
 - (iii) The rated by-pass making current (I_{BP}).
 - (iv) The rated by-pass insertion current (I_{INS}).
 - (v) The rated continuous conduction current (A_{RMS}).
 - (vi) The rated reinsertion voltage (U_{INS}).
 - (vii) The rated insulation level across the switch.
 - (viii) The rated insulation level between phase to earth.
 - (ix) The maximum closing time (ms) of bypass switch.
 - (x) The maximum opening time (ms) of bypass switch.
 - (xi) The maximum difference in non-synchronous time between phases during three-phase closing (ms).
 - (xii) The maximum difference in non-synchronous time between phases during three-phase opening (ms).
 - (xiii) The maximum total open-close cycle time of the bypass switch (ms).
 - (xiv) The operation sequence (without recharging); (O)C - ____s – OC.
- 2.6.8 When in the open position, the interrupter of the bypass switch is exposed to voltages resulting from currents through the capacitors and to the protective level voltage during power system faults. The bypass switch shall be designed to withstand these voltages both internally across the interrupter(s) and externally across any insulation.
- 2.6.9 The voltage recovery capability of the bypass switch in open positions shall be such that the bypass switch will not re-strike at a voltage equal to the maximum protection level voltage,

after breaking the maximum insertion current (A_{RMS}) with a time (ms) to peak as specified by the Solution Provider.

- 2.6.10 The bypass switch associated with the series capacitor installation shall be mounted outside the interlocked boundary fence (where provided) of the installation to enable operational access to the disconnectors and their mechanisms.

2.7 Series and Bypass Disconnectors

- 2.7.1 The series and bypass disconnectors shall be provided in accordance with BS EN 60143-2:1994 clauses 2.3 and 3.6.
- 2.7.2 The series and bypass disconnectors shall also comply with the requirements of TS 3.2.2.
- 2.7.3 The data and information required by and detailed in TS 3.2.2 shall be provided.
- 2.7.4 The series and bypass disconnectors shall have an on-load transfer capability of a minimum of 60% of the continuous current rating of the series capacitor installation. The voltage measured across the bypass disconnector shall not exceed 300 V as defined in TS 3.2.2 unless the disconnector has specifically been tested to a current and voltage duty in excess of this requirement.
- 2.7.5 Special consideration shall be given to the capacitive current switching duty of the series and bypass disconnectors. If required (as determined by the Solution Provider), disconnectors with on-load current switching and capacitive current switching capability shall be supplied in accordance with PD IEC/TR 62271-305 to the relevant capacitive switching duties imposed on them by the series capacitor installation.
- 2.7.6 Operational interlocking in accordance with TS 3.1.1 shall be designed to ensure the bypass switch is always closed for either automatic or manual operations (either locally or remotely) before the bypass and/or series disconnectors can be operated, to limit capacitive current switching of the disconnectors.
- 2.7.7 All disconnectors associated with the series capacitor installation shall be mounted outside the interlocked boundary fence (where provided) of the installation to enable operational access to the disconnectors and their mechanisms.

2.8 Earth Switches

- 2.8.1 Earth Switches shall comply with the requirements in TS 3.2.2.
- 2.8.2 The data and information required by and detailed in TS 3.2.2 shall be provided.
- 2.8.3 If the Line side earth switch of the series capacitor installation is the Overhead Line Entry Earth Switch for the circuit that the series capacitor is connected to, then the earth switch shall meet the requirements of clause 1.5 in PS(T) 006 with respect to induced and circulating current switching capabilities.
- 2.8.4 All earth switches associated with the series capacitor installation shall be mounted outside the interlocked boundary fence (where provided) of the installation to enable operational access to the earth switch without the need to enter the compound.

2.9 Current Limiting Damping Equipment

- 2.9.1 The current limiting damping equipment shall be provided in accordance with BS EN 60143-2:1994 clauses 2.4 and 3.7.

Informative : The damping circuit usually consists of a current limiting damping reactor which may, depending on the SC design and system need, have a current limiting damping