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132 kV MECHANICALLY SWITCHED CAPACITOR BANKS AND DAMPING NETWORKS

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PURPOSE AND SCOPE

This Specification describes the National Grid technical requirements for a relocatable 132 kV connected Mechanically Switched Capacitor (MSC) and a 132 kV connected Mechanically Switched Capacitor incorporating a damping network (MSCDN). It also describes the requirements for an additional damping network (DN) to enable the adaptation of an existing 132 kV MSC into an MSCDN. This Specification does not include the associated circuit breaker, disconnectors, and certain earthing switches, which will be specified in the Enquiry Document on a site-specific basis.

Reference is made to TS 1 in respect of the general applicability of the requirements of this and other (NG)TS specifications to non National Grid connected Users of the Transmission System.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 Introduction

National Grid has installed many 132 kV connected 60 Mvar Mechanically Switched Capacitors (MSCs). Some of these MSCs have subsequently been reduced in rated output to a nominal 53 Mvar by the removal of capacitor units in order to reduce the magnitude of the voltage step upon being switched in or out. Additionally, at selected sites, it will be necessary to add a damping network (DN) to existing 60 Mvar or 53 Mvar MSCs as appropriate.

All new (static) capacitive reactive compensation connected at 132 kV will be arranged as either 45 Mvar MSCs or 45 Mvar MSCDNs. It may also be required to add damping networks to 45 Mvar MSCs at a future date. When damping networks are to be added to an existing MSC, the existing inrush reactor will normally be retained. However the resulting MSCDN design will allow for the removal of the inrush reactor should it fail.

To permit standardisation and minimise spares holdings, the electrical parameters for the major components of these MSCs, MSCDNs and damping networks are defined in this Specification. However, other aspects, for example the protection, continue to be defined on a functional basis.

1.2 Overall

This Specification describes the technical requirements for the major components used in various types of 132 kV connected MSCs, 132 kV connected MSCDNs, or additional damping networks to enable the adaptation of an existing MSC into an MSCDN, namely:-

- a) Adaptation of an existing 60 Mvar or 53 Mvar, 132 kV connected MSC into an MSCDN by the addition of a damping network, refer to Appendix H - Figure H1.
- b) Adaptation of an existing 45 Mvar, 132 kV connected MSC into an MSCDN by the addition of a damping network, refer to Appendix H - Figure H2.
- c) 132 kV connected 45 Mvar MSCDN, refer to Appendix H - Figure H3.
- d) 132 kV connected 45 Mvar MSC (with current limiting inrush reactor) refer to Appendix H - Figure H4.

The MSC, MSCDN or damping network(s) components (excluding any HV switchgear part of the connection to the existing substation) and associated control and protection equipment shall be able to be relocated and ready for operation at another similar voltage substation within three months of final de-energisation at the original site. Of particular importance are the requirements for minimal foundations and the ability to relocate the MSC, MSCDN at minimal cost to National Grid (both in terms of labour/construction costs and asset write-off costs).

1.3 Particulars of Point of Connection to National Grid System

The 132 kV system conditions and the required rated voltages for the equipment are stated in NGTS 1. The rated three-phase short-circuit current for the system shall be taken as 40 kA. Any other site specific connection requirements (e.g. banked connection etc) shall be specified in the Enquiry Document.

1.4 Life, Reliability and Availability

The MSC, MSCDN or additional damping network (as applicable) and associated civil works shall have a minimum design life expectancy of 40 years and an overall availability (including planned maintenance) in excess of 98%. The MSC, MSCDN shall be designed for continuous operation, however it is anticipated that the normal utilisation of the MSC, MSCDN is that it will be energised for 12 hours on average each day, 5 days a week, being switched on in the morning and switched off in the evening. Any components which the Tenderer considers to be unable to meet the life expectancy of 40 years shall be listed in the Tender Document as well as the reason for the non-compliance.

The need for routine maintenance shall be minimised and shall not be required more than once every two years. All plant 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.

The Tenderer shall provide indicative method statements for the maintenance and replacement procedures for major plant items. Fully documented maintenance and replacement procedures shall be provided as part of the Contract.

The layout of the MSC, MSCDN or additional damping network (as applicable) shall be such as to allow suitable access for maintenance or repair of all primary plant using a Mobile Work

Elevated Platform (MWEF), e.g. assisting in the replacement of a failed capacitor unit or performing an internal inspection of a resistor. Access shall be possible without the need to remove any structural member or support including insulators, main connections, busbars or any other normally fixed equipment. Tenderers shall confirm their compliance with this requirement by supplying detailed layout drawings in their Tender Submission.

1.5 Insulation Co-ordination

The rated lightning impulse level (1.2/50 μ s wave) for 132 kV equipment is 650kV. In order to reduce the level of any lightning induced impulses imposed on the 'damping network' associated with MSCDN applications, a surge arrester shall be connected between the low voltage of the main capacitor 'C1' and earth to restrict the voltage at this point to a value less than 100 kV for all lightning and switching surges. All damping network components shall be protected, including any cable connections to remote damping network compounds (where applicable). Minimum lightning impulse levels, both across components and to earth are indicated in Appendix H – Figures H1 to H4.

For those installations requiring a cable connection to a remote compound, a second similar surge arrester shall also be connected at the damping network compound end of the cable, refer also to Appendix H – Figures H1 to H3. This enables the specification of all 'damping network' equipment to be of 24 kV voltage class (with an associated BIL level of 125 kV).

Tenderers shall note that the design and rating of surge arresters, for which the requirements are given in Clause 1.6.5) are based on the assumption that the surge arresters are connected as close as is practically possible to the associated 'protected' plant e.g. the resistor 'high voltage' terminal and damping network cable sealing end (main capacitor 'C1' end), as applicable. Tenderers shall confirm their compliance with this requirement by supplying detailed layout drawings in their Tender Submission.

1.6 MSC, MSCDN and Damping Network Equipment Component Values and Ratings

The requirements for component values, tolerances, minimum ratings and other key parameters relating to the MSC, MSCDN or additional damping network (as applicable) are given in Appendix A. The Tenderer must complete the missing items of the relevant associated Level 3 NGTS Schedules as part of any Tender submission. Tenderers should note that failure to complete all parts of all Schedules may cause National Grid to disqualify the Tender.

1.6.1 Capacitors

All capacitors and associated equipment shall comply with the requirements of TS 3.11.1.

The specification of the component values, tolerances, minimum ratings and other key parameters of the capacitor bank(s) are defined in Appendix A.

The following requirements shall also be noted:-

- a) Maintenance shorting switches are not required for all 'new' capacitor banks. In addition, where an existing MSC is upgraded to become an MSCDN, any existing shorting switches shall be removed.
- b) The racking of the auxiliary capacitor bank 'C2' (where applicable) shall permit the mounting thereon of the auxiliary resistor bank(s).
- c) The base insulation for the main capacitor bank 'C1' shall, irrespective of its initial duty (e.g. as an MSC with associated inrush current limiting reactor), permit without modification the possible future upgrading to an MSCDN by the addition of a damping network (in which instance the main capacitor bank 'C1' would no longer be in the 'neutral end' of the circuit). In this respect Tenderers should note that the structure of the bottom rack of the main capacitor bank may not be at the same potential as its LV

terminal and due allowance must therefore be made in the selection of an adequate insulation level for such insulators.

- d) For those applications where an existing MSC is upgraded to an MSCDN by the addition of a damping network, the auxiliary capacitor bank 'C2' may be equipped with either external or internal fuses. The fusing arrangement is not required to be of the same type as for the 'existing' main capacitor (C1). The new 'C2' units are also not required to be of the same manufacture as the 'C1' units.
- e) The design of existing 132 kV connected 60 Mvar MSCs is such that a reduction in their output to 53 Mvar is feasible by the removal of capacitor units. The fusing of auxiliary capacitor banks forming part of any damping network shall not limit this action (the minimum fundamental frequency current in the auxiliary capacitor under this condition is approximately 200A). The contractor shall demonstrate full compliance with this requirement.

1.6.2 Reactors

The specification of the component values, tolerances, minimum ratings and other key parameters of the reactors are defined in Appendix A. Tenderers shall also note that National Grid may further provide on a 'site specific', basis a reactor harmonic current spectra in the Enquiry Document to enable the accurate assessment of reactor sound power levels only; such spectra shall not be employed to derive component ratings or to form the basis of reactor type and routine testing requirements.

Oil filled reactors shall comply with TS 2.3.

Dry-Type reactors shall comply with NGTS 3.3.2.

1.6.3 Resistors

The specification of the component values, tolerances, minimum ratings and other key parameters of the resistors are defined in Appendix A.

Air insulated resistors shall comply with TS 3.11.2.

1.6.4 Surge Arresters

The performance of the surge arresters with respect to certain ratings and other key parameters are defined in Appendix A.

Surge arresters shall comply with NGTS 3.2.3. They shall be designed on the basis that no point-on-wave switching facilities exist, irrespective of the fact that such facilities may be installed.

A surge arrester monitoring device shall be provided; in respect of mechanical counter type devices they must be capable of being safely read with the surge arrester energised and in service, and without requiring entry into any interlocked restricted area in which the surge arrester may be located.

1.6.5 Discharge Voltage Transformers

Discharge Voltage Transformers shall be supplied in order to discharge the capacitor bank following de-energisation and shall be connected between the line terminal and earth. The Discharge Voltage Transformer shall be able to discharge the MSC/MSCDN capacitor banks to 50V within 20 seconds. The number of discharges shall be 2 in rapid succession without causing damage to the equipment. The rest period between two successive discharges shall be a maximum of 2 hours.

For new MSCs, the specified discharge voltage shall be $(2.5 \times \sqrt{2} \times U_n)$ where U_n is the capacitor bank rated voltage, as defined in Appendix A.

For new MSCDNs, the specified discharge voltage shall be $(2.5 \times \sqrt{2} \times U_n)$ where U_n is the main capacitor bank (C1) rated voltage, as defined in Appendix A. Alternatively, a lower discharge voltage may be accepted by National Grid provided calculations are given to define the worst case re-strike voltage for the MSCDN and evidence is provided to show that the discharge voltage transformer offered is capable of this discharge duty. Calculations supporting a lower discharge duty shall be provided in the Tender Document.

All discharge voltage transformers shall comply with the requirements of TS 3.2.5.

1.6.6 Earth Switches

A fixed primary earth switch shall be supplied and connected between the HV terminal of the MSC/MSCDN main capacitor bank (C1) and the MSC/MSCDN circuit breaker to provide a means of discharge in addition to those provided by the discharge voltage transformer (refer to clause 1.6.5) above) and the individual capacitor unit discharge resistors. If the MSC/MSCDN or damping network equipment is located in a ground level compound(s) the earth switch shall be mechanically interlocked with the MSC/MSCDN or damping network compound gate(s) such that access into the compound(s) cannot be gained until the earth switch is closed.

The earth switch shall comply with the requirements of NGTS 3.2.2 and shall have a three-phase short-circuit current rating of 40kA.

1.6.7 Capacitive Voltage Transformer

Where applicable (see clause 1.9 below) a single (yellow) phase Capacitive Voltage Transformer shall be supplied and connected to the HV busbar side of the MSC / MSCDN circuit breaker to provide a measurement of busbar voltage to the Automatic Reactive Switching (ARS) system and where applicable a reference voltage signal for any point on wave control facility for the MSC / MSCDN circuit breaker.

The capacitive voltage transformer shall comply with the requirements of TS 3.2.5.

1.7 Site Details

The Tenderer shall provide the following information in relation to layout(s) and the civil requirements for the design tendered: -

1.7.1 Site Area

The Enquiry Document defines the initial site area and the areas on to which the equipment maybe re-located. The equipment shall be designed to occupy the minimum area and facilitate subsequent relocation whilst permitting adequate space for maintenance access and egress. The Tenderer shall provide general layout drawings of all equipment configurations to verify compliance of the design with the specified land area requirements.

1.7.2 Civil Details

The Enquiry Document will specify whether the civil details will be provided by National Grid or by the Tenderer. The civil design of the MSC / MSCDN compound shall comply with both DH 10, in particular clause 2.16, and TS 3.1.2, in particular clause 1.21. The Tenderer is required to detail the civil requirements necessary to relocate the MSC or MSCDN to all site areas and layouts detailed in the Enquiry Document. The cost of MSC or MSCDN civil requirements will be taken into account at the tender assessment stage. Details of the method of assessment will be provided in the Enquiry Document.

1.7.3 Other Site Layout Details

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 MSC, MSCDN or damping network compound without danger while the equipment is both isolated from the National Grid system and earthed. Therefore cables (in particular CT secondary wiring), cable management systems etc shall not be surface laid without prior agreement by National Grid; similarly cables, busbars or supporting structures shall not be placed less than 2 metres above the ground without prior agreement by National Grid (this requirement also applies to inter-pole cabling / pipework of the MSC or MSCDN circuit breaker where supplied by the Tenderer). Access to the plant during in-service operation is not required.

1.7.4 Site and Plant Safety Hazards

Tenderers are reminded that current legislation requires them to declare all safety hazards relating to the equipment offered. This shall include those hazards associated with the physical arrangement of the equipment (e.g. trip/fall hazards) which may pose a danger during maintenance access, and those associated with the in-service operation of the equipment (e.g. stray magnetic fields, high temperatures, oil leakages, etc).

1.8 Requirements for Relocation

It shall be possible to transport the MSC or MSCDN 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 MSC or MSCDN (excluding any HV switchgear part of the connection to the existing substation) and associated control and protection equipment from one site to another within 3 months (13 weeks). This relocation time comprises the time period between final de-energisation at the original site, and the completion of commissioning at the new site. It assumes immediate availability of circuit outages, pre-prepared foundations and HV switchgear (where necessary) at the new site.

All control and protection equipment associated with a new MSC or MSCDN bay shall be contained in a relocatable building. This building shall also contain the necessary ac and dc auxiliary supplies in accordance with NGTS 2.12. A separate outdoor non-relocatable marshalling kiosk shall be provided in which any ring cabling or common cables (e.g. busbar protection CT wiring) shall be terminated before continuing into the portable building. This is to enable such ring cabling to be reconnected in the event of a relocation thus minimising disruption to the operation of the substation.

The Tenderer shall demonstrate by the submission of drawings and other supporting documentation that their design of the MSC or MSCDN can be relocated to all of the site layouts detailed in the Enquiry Document. Indicative instructions for a complete relocation shall be provided at the tender stage to justify the relocation time-scales and costs quoted in the Tender Submission. Included in the submission shall be a detailed breakdown of redesign costs, asset write-off costs, manpower, vehicle, time and overall relocation costs. It shall be assumed that each relocation shall involve transporting the MSC or MSCDN 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.

The costs of relocating the MSC or MSCDN will be taken into account by National Grid at the tender assessment stage. Details of the method of assessment will be provided in the Enquiry Document. Unless otherwise specified in the Enquiry Document, it shall be assumed that the MSC or MSCDN will be relocated 3 times during its Design Life.

Fully documented relocation instructions shall be provided as part of the contract to enable relocation to be performed by a third party.

1.9 Control Requirements

The control requirements are specified in NGTS 2.7 and associated specifications. The Enquiry Document will define if Automatic Reactive Switching (ARS) control equipment is also to be included.

1.10 Control Interfaces and Alarm Requirements

The control system shall be designed in accordance with the requirements of NGTS 3.7.3, NGTS 3.7.4, and NGTS 3.7.19.

1.11 Protection

The protection of the MSC, MSCDN or damping network shall accord with TS 3.24.11. Any specific requirements for the power circuit components will be found in the NGTS relevant to the components concerned.

Current transformers for direct connection at 132 kV shall comply with the requirements of NGTS 3.2.4 and shall be suitably rated to match the full rating of the MSC, MSCDN or damping network. The rating, voltage class, transformation ratio, output, and accuracy classes for any CT located within the MSC, MSCDN or damping network shall be selected by the Tenderer to satisfy the requirements of the specific application.

The Tenderer shall provide full details of all the CT variants being offered. Test and isolation facilities for CT secondary circuits shall be in accordance with NGTS 2.6.

Voltage transformers for direct connection at 132 kV shall comply with the requirements of TS 3.2.5. The requirements for Discharge Voltage Transformers are specified in clause 1.6.5) above. The rating, voltage class, transformation ratio, output, and accuracy classes for any VT located within the MSC, MSCDN or damping network shall be selected by the Tenderer to satisfy the requirements of the specific application.

The Tenderer shall provide full details of all the VT variants being offered. Test and isolation facilities for VT secondary circuits shall be in accordance with TS 2.6.

The Tenderer shall detail the specific protective systems offered.

1.12 Electromagnetic Compatibility

The radiated radio interference fields, measured at a distance of 250 metres from any point on the boundary of the MSCDN, shall not exceed the levels shown in Appendix E.

1.13 Magnetic Fields

In normal operation of the MSCDN, it shall not be necessary for staff to enter any part of the MSCDN area where the magnetic field exceeds the National Radiological Protection Board (NRPB) reference level applicable at the time of the contract, under all rated conditions. The NRPB reference levels must not be exceeded outside the MSCDN site areas listed in the Enquiry Document.

The Tenderer shall provide magnetic field contour plots covering any points external to the MSCDN perimeter fence or footprint area (for all of the site layouts listed in the Enquiry Document) at which the magnetic field exceeds 0.1 mT.

1.14 Earthing

The earthing of the MSC or MSCDN shall be designed in accordance with TS 3.1.2, in particular clause 1.21. The following requirements shall also be noted:

- (i) Tenderers shall ensure that the earthing of individual MSC or MSCDN components (e.g. support insulator pedestals) shall not form closed metallic loops around air cored reactors.
- (ii) Connection of the MSC or MSCDN star point to earth. The MSC or MSCDN neutral end star point shall be created above ground by cabling between the individual phases. The cabling shall be at least 1000V rated and be black in colour. The neutral cables shall be installed in underground troughs/ducts/trenches which shall be segregated from any troughs/ducts/trenches containing secondary cabling. No connections shall be made underground; all connections shall be double bolted above ground. The star point thus created above ground shall be connected to earth via earth tape or green/yellow insulated flexible conductor.

1.15 Environmental Noise Control

The steady state noise from all the MSCDN equipment together, when installed and operating under rated conditions (refer to clause 1.6), shall not exceed the sound power levels listed in the Table below unless otherwise indicated in the Enquiry Document. The levels include a 5 dBA correction for tonal content in accordance with BS 4142:1997.

Frequency (Hz)	63	125	250	500	1k	2k	4k	8k	A-weighted
DB Ref 10 ⁻¹² W	91	90	79	77	78	79	76	64	84.5

Unless otherwise agreed by National Grid, the Tenderer shall supply all the acoustic noise performance data detailed below:

- a) The sound power level of each major plant item in each octave band and the overall A-weighted level, with full details of the measurement technique and conditions. These conditions shall be chosen to afford a reliable assessment of radiated sound power.
- b) The total sound power level of the installation in each octave band and the overall A-weighted level.
- c) Directivity data for any plant item whose directivity index varies by more than 2 dB around the plant in the horizontal plane.

For transformers and iron-cored reactor noise requirements see TS 2.3.

The noise performance data required for air-cored reactors shall be determined in accordance with BS EN ISO 3746 or BS EN 9614. Tenderers are also reminded that where air-cored reactors are utilised, calculations shall take full account of the maximum continuous rated fundamental and harmonic currents as declared in NGTS 3.3.2. However as discussed in clause 1.6.2 above, National Grid may also provide on a 'site specific' basis a further reactor harmonic current spectra in the Enquiry Document to enable the accurate assessment of reactor sound power levels.

1.16 Point-on-Wave Control of MSCDN Circuit Breaker

The Enquiry Document will specify the requirements (where applicable) for circuit breaker Point-on-Wave (POW) switching facilities and for testing thereof.

For MSCDN applications where POW switching facilities are required, the design of the MSCDN itself (i.e. excluding the circuit breaker) shall however assume that the POW facilities are inoperative.

In the event of failure of the POW switching facilities associated with an MSCDN, the circuit breaker and the MSCDN shall continue to be operative and to meet all of the requirements of this Specification and the Enquiry Document. However in the event of failure of the POW switching facilities with an MSC, the MSC shall not remain operative.

2 TEST REQUIREMENTS

2.1 Equipment Tests

Test programmes and place of testing shall be agreed between National Grid and the contractor prior to the commencement of testing. A copy of the main supplier(s) records of all tests shall be made available as soon as each test has finished. A formal report shall then be supplied to National Grid.

Type and routine tests of the component parts of the MSC, MSCDN or damping network are defined in the relevant (NG)TS. Where tests on equipment are not specified by National Grid, then Type and Routine tests shall be proposed by the Tenderer, and agreed by National Grid before the commencement of testing.

2.2 Site Commissioning Tests

Where appropriate, site commissioning tests for the component parts are specified in the relevant (NG)TS. In addition, site tests shall demonstrate that the MSC, MSCDN or damping network meets this specification and the contractor shall propose suitable tests for the agreement of National Grid.

The impedance of the complete MSC, MSCDN or MSC adapted to an MSCDN, erected as for service shall be measured over a frequency range of d.c. to 1550 Hz. The results shall be submitted to National Grid prior to energisation.

All primary equipment installed, relocated or connected shall be tested for RFI, and for hot spots using a thermal imaging camera, after being energised for at least 1 hour. The contractor shall return after 1 month of in-service operation to repeat these tests and take any necessary corrective action.

3 TYPE REGISTRATION

National Grid considers an MSC, MSCDN or damping network as a 'System', and will therefore apply its Type Registration procedure that is specific to such installations.

This process assists suppliers in demonstrating to National Grid that the 'strength and capability' of plant and electrical equipment is not exceeded so as to cause 'danger' and is suitably designed for the environment in which it operates.

Note that in this instance, Type Registration will be granted for the System as a whole, and not to the individual items of plant and equipment which form the System.

Summarised, the process requires the Main Supplier to:

- a) submit completed TS 1 and TS 2.26 schedules and complete and sign a 'tender stage' and a 'final' Self-Certification Statement (see Appendix F of this document) to underwrite that the plant and equipment supplied complies with this specification.
- b) provide an index of the plant and equipment being offered whose strength and capability will be demonstrated.