

This document is for internal and contract specific use only.

Disclaimer

NGG and NGET or their agents, servants or contractors do not accept any liability for any losses arising under or in connection with this information. This limit on liability applies to all and any claims in contract, tort (including negligence), misrepresentation (excluding fraudulent misrepresentation), breach of statutory duty or otherwise. This limit on liability does not exclude or restrict liability where prohibited by the law nor does it supersede the express terms of any related agreements."

Copyright © National Grid plc 2011, all rights reserved

All copyright and other intellectual property rights arising in any information contained within this document are, unless otherwise stated, owned by National Grid plc or other companies in the National Grid group of companies. No part of this publication may be reproduced in any material form (including photocopying and restoring in any medium or electronic means and whether or not transiently or incidentally) without the written permission of National Grid plc

This information should not be forwarded to third parties.

HIGH VOLTAGE DIRECT CURRENT (HVDC) CONVERTERS

TABLE OF CONTENTS

PURPOSE AND SCOPE.....	1
PART 1 – PROCEDURAL	1
1 GENERAL REQUIREMENTS	1
2 PERFORMANCE REQUIREMENTS.....	13
3 TEST REQUIREMENTS	18
4 TYPE REGISTRATION PROCEDURE	19
PART 2 - DEFINITIONS AND DOCUMENT HISTORY	19
5 REFERENCES	19
6 DEFINITIONS	22
7 AMENDMENTS RECORD	23
8 IMPLEMENTATION.....	23
PART 3 - GUIDANCE NOTES.....	23

PURPOSE AND SCOPE

This document specifies the functional requirements for HVDC converters connected to the National Grid Electricity Transmission System in the UK and located onshore. It includes the HVDC converter station and its component equipment items. Functional requirements for the protection and control of HVDC transmission are specified in TS 3.24.90.

Site specific requirements for HVDC converters will be specified in the Enquiry Document.
Requirements for HVDC converters located offshore will be specified in a future document.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 General

HVDC converter stations and their equipment shall comply with the requirements specified in the Enquiry Document, all relevant National Grid Technical Specifications and the British, European or International standards listed in Section 5. With regard to the hierarchy of requirements given in these documents, the order of precedence shall be the Enquiry Document, National Grid Technical Specifications, British Standards, European Standards and International Standards.

In some applications, the Grid Code, the System Operator – Transmission Owner Code (STC) and the Security and Quality of Supply Standard (SQSS) impose requirements that are relevant to HVDC converters. Where such requirements apply, they will be indicated in the Enquiry Document.

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

The Supplier shall be responsible for the design of the HVDC converter station and its components such that no damage shall be caused to it and the equipment within it as a consequence of equipment and cable failures, faults in the a.c. networks and malfunction of controls.

HVDC converters shall have an anticipated asset life of not less than 40 years. Where equipment requires mid-life refurbishment in order for the HVDC converter to achieve its anticipated asset life, the scope of the activity shall be clearly indicated by the Supplier in his tender submission.

The design of the HVDC converter station 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, light fittings and any other items requiring maintenance or replacement that might be located at height within the valve halls.

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 NGET and provide associated risk assessments and method statements.

The layout of the HVDC converter station shall be such as to allow access for maintenance, repair or replacement of all primary plant from a suitable working platform. 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. It shall be possible to replace failed components such as filter reactors while minimising outage requirements.

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 shall be provided with permanently installed lifting facilities.

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

Provision shall be made to permit pre-outage work to minimise outage requirements should equipment require mid-life refurbishment, such as space for installation and testing of protection and control cubicles.

1.2 Environmental service conditions

Plant, equipment and apparatus shall be suitable for operation under the environmental service conditions specified in TS 1.

Converter valves shall be housed indoors in a clean controlled environment.

Other a.c. and d.c. equipment shall be located indoors or outdoors as specified in the Enquiry Document.

The site IEC 60815 pollution class will be specified in the Enquiry Document.

Electronic equipment shall comply with the requirements of TS 3.24.15 applicable to its location.

1.3 Power system characteristics

AC plant and equipment shall fulfil the electrical requirements specified in TS 1. AC system parameters to be used in determining a.c. harmonic filter requirements are specified in Clause 2.3 of this specification.

Site-specific a.c. system parameters for each converter station including short-circuit level, a.c. system harmonic impedances, levels of existing harmonic distortion, the level of negative phase sequence voltage, requirements for reactive power exchange with the system and data for sub-synchronous resonance studies etc. will be specified in the Enquiry Document.

1.4 Protection and Control

Protection and control system requirements are specified in TS 3.24.90.

1.5 Insulation Co-ordination

Voltage withstand requirements, insulator creepage distances and clearances in air for HVDC converter equipment as well as the location, protective levels and energy handling requirements of the required surge arresters shall be determined by means of an insulation co-ordination study in accordance with the procedures given in IEC 60071-5 and the guidance given in ELECRA No 96 and CIGRE Technical Brochure No 34. The range of switching duties for circuit-breakers and disconnectors shall also be determined.

The protective margins given in Table 1 shall be used to obtain the required withstand voltages from the corresponding surge arrester protective levels.

Note: The margins given in Table 1 are defined as:

$$\text{Margin} = [(\text{impulse withstand voltage}/\text{impulse protective level}) - 1] \times 100\%$$

Table 1: Minimum insulation margins for equipment

Equipment	Switching impulse	Lightning impulse
Valves	15%	15%
DC valve hall	15%	15%
Smoothing reactors	15%	20%
DC switchyard	15%	20%
AC switchyard	20%	25%
AC filters	15%	25%
Converter transformers – line side	20%	25%
Converter transformers – valve side	15%	20%

The Tenderer shall provide a report on the insulation coordination study defining the following as a minimum:

- ♦ Surge arrester locations
- ♦ Surge arrester protective levels
- ♦ Surge arrester energy handling requirements
- ♦ Insulation withstand voltages for equipment

- ♦ Transient current stresses for equipment
- ♦ Insulation clearances for equipment
- ♦ Creepage distances for insulation

Minimum clearances of live parts

For live parts on the a.c. side of the converter, the requirements for minimum clearances specified in TS 2.1 shall apply.

The requirements for minimum clearances of live parts on the d.c. side of the converter shall be similar, except that the minimum electrical clearance shall be stated by the Supplier and shall be fully consistent with the results of the insulation coordination study. The electrical clearances shall not be less than the minimum air clearance given in Table A.1 of BS EN 60071-2 for lightning impulse withstand voltage or in Table A.2 for switching impulse withstand voltage except where it has been proven by test that the standard impulse withstand voltages are met under all applicable environmental conditions.

Electrical safety clearances

For live parts on the a.c. side of the converter, the requirements for electrical safety clearances specified in TS 2.1 shall apply.

The requirements for electrical safety clearances on the d.c. side of the converter shall be similar, except that the Safety Distance shall be stated by the Supplier and shall be fully consistent with the results of the insulation coordination study. The Safety Distance shall be greater than the electrical clearance by a margin of at least 0.3 m.

1.6 Component Equipment Items

1.6.1 General

All component equipment items shall comply with the general conditions specified in the relevant Technical Specifications and British, European or International Standards stated below for the selected voltage and current ratings. Full account of any allowances for harmonics as detailed in clause 2.3 below shall be taken by the Supplier in selecting the voltage and current ratings of relevant component equipment.

1.6.2 External Insulation

Ceramic insulation for a.c. application shall comply with the pollution performance requirements for ceramic insulation specified in TS 2.1

Composite (non-ceramic) insulation for a.c. application shall comply with the pollution performance requirements for composite (non-ceramic) insulation specified in TS 2.1.

DC Insulation located outdoors shall have a minimum specific creepage distance of 60 mm/kV of the maximum steady state effective voltage for ceramic insulation and 51 mm/kV of the maximum steady state effective voltage for composite (non-ceramic) insulation.

DC insulation located indoors shall have a minimum specific creepage distance of 14 mm/kV of maximum steady state effective voltage across the insulation for valve hall equipment and 30 mm/kV of maximum steady state effective voltage across the insulation for d.c. hall equipment.

Where insulation is subjected to a combined a.c. and d.c. stress, the minimum specific creepage distance applicable to d.c. insulation shall apply. In such a case, the r.m.s. value of the highest operating voltage across the insulator shall be used to determine the creepage

distance. Both d.c. voltage and possible a.c. voltages including harmonics shall be considered.

1.6.3 Converter valves

General

Thyristor valves shall comply with the applicable sections and principles of BS EN 60146 and BS IEC 60747-6. IGBT valves shall comply with the applicable sections and principles of BS IEC 60747-9.

The design of the valve structure shall take into account the requirements for assembly, maintenance and replacement of the valves. It shall be possible to exchange power semiconductors and other valve components with the minimum disassembly of any power or water cooling circuit and with the minimum dismantling of any overall converter module. Special tools required for the replacement of these parts shall be provided under the contract. Means of applying earthing devices for the control of trapped charge, induced voltages or inadvertent re-energisation of the valves shall be provided. It shall be possible to carry out maintenance on valves and replace all valve components in a safe manner. Adequate provision shall be made for any necessary access equipment. The design of the valve structure shall make sufficient allowance for it to withstand all mechanical stresses to which it may be subjected, including any associated with maintenance and replacement.

The valve design shall take into account electrical stresses arising from the range of possible faults and disturbances to which it may be subjected including valve short circuits, commutation failures and switching and lightning overvoltages.

Valves shall be designed to minimise the risk of a fire developing and to limit the consequences. Components shall be rated for normal and abnormal operating conditions that may occur during the operating life and adequate allowance made for ageing and degradation. Materials shall be selected to minimise fire risk and ensure that any fire is contained.

Redundancy and bypass facilities shall be provided such that the in-service failure of any single HVDC valve component will not prevent the continued operation of the HVDC converter. Should a failure occur, the control system shall automatically notify the existence of the failure and log the date and time of its occurrence. A clear indication of the failed component location shall be provided on the operator workstation and SER. Where the number of failed valve components exceeds the provision for redundancy, protective action shall be initiated in accordance with TS 3.24.90. The Supplier shall provide details as to how the requirement for redundancy will be implemented and how the voltage stresses applicable to the non-bypassed components are affected. A sufficient level of redundancy shall be provided to allow valves to operate for a period of two years between scheduled maintenance. For thyristor valves, at least 3% redundant thyristors or 2 redundant thyristors (whichever is the greater) shall be provided. For IGBT valves, at least 5% redundant IGBTs or 2 redundant IGBTs (whichever is greater) shall be provided.

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

The Supplier shall provide details of the provisions for valve protection.

Impregnants, where used, shall not contain PCB or other toxic or hazardous materials.

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

Jacket materials for fibre optic cables shall be of a material that does not support combustion or the fibre optic cables shall be enclosed in protective channels of appropriate fire stopping materials.

Valve Cooling

The valve cooling system shall be capable of providing effective cooling for any specified mode of operation of the HVDC converter. The cooling plant shall be arranged to minimise the auxiliary power requirements of the HVDC converter throughout its range of operation and during periods when the converter is shut down.

The Supplier is reminded that vessels and associated pipework where the product of the pressure in bars multiplied by the internal capacity in litres of the receiver is equal to or greater than 250 bar litres are required to comply with the Pressure System Safety Regulations 2000. Where the Pressure System Safety Regulations apply, the Supplier shall provide the corresponding Written Scheme of Examination (WSE).

The Supplier shall provide details of flow rates, pressures, temperatures and other parameters appropriate to the type of cooling system for converter operation at no-load and rated load conditions at the maximum ambient temperature defined in TS 1. Indicative cooling plant ratings shall also be provided.

Redundancy shall be provided to ensure that the failure or shut down of any vital component of the cooling system or its control system such as pumps, fans, three-way valves, heat exchangers and filters will not result in a reduction of transmission capacity of the converter under any foreseeable combination of load and ambient conditions. It shall be possible to switch between redundant parts in the event of a failure without interrupting converter operation.

It shall be possible to gain access to and perform maintenance on or replace any redundant part of the cooling system safely while the remaining parts of the cooling system remain in operation with no loss of capacity.

Valve cooling shall remain fully effective during changeover between primary and back-up auxiliary supplies as specified in Clause 1.8 and vice-versa.

The control system shall monitor quantities critical to cooling system operation such as temperatures, pressures, flow rates, coolant conductivity and coolant levels, shall generate alarms where the above exceed limits and indicate failures of pumps or fans, loss of coolant, loss of electrical supply, etc. Instrumentation for monitoring the above quantities shall remain within calibration for a minimum period of two years and shall be arranged to be fail safe. Transient indications and alarms associated with these devices shall be stored/logged before resetting.

To maximise the 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 Supplier shall state the criteria used to achieve the pump rotation optimisation. Changeover between cooling pumps shall be achieved in such a manner that the cooling plant may continue in operation without reduction in performance whilst the changeover is occurring.

The Supplier shall indicate any item of equipment that is only required to operate infrequently or at certain times of the year and shall detail the provision made to ensure that any such component will operate satisfactorily when required following a long period of inactivity, such as some form of periodic running as deemed necessary.

Lockable electrical isolation facilities shall be provided to allow for maintenance of fans and pumps. The isolation facilities shall be easily accessible from ground level or fixed access platform. It shall be possible to isolate electrically any pump or fan for maintenance or

replacement with the other pumps and fan groups operating under manual or automatic control.

Separate electrical protection devices shall be provided for each fan and pump motor, arranged so that tripping of one motor will not affect the operation of the remaining motors.

Where a liquid cooling medium is provided, the Supplier shall provide evidence to demonstrate that the coolant is fully compatible with the pipework and all other materials into which it will come in 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 sub-systems (e.g. a pure water system to a water glycol mixture system) is possible. The growth of algae and bacteria within the cooling system shall be prevented.

Valves shall be provided to allow isolation of the converter, each cooler bank and each pump from the rest of the cooling system. All valves (except bleed valves) shall be lockable and shall be easily accessible from ground level. Where it is not possible to arrange for a valve to be easily accessible from ground level, permanent access shall be provided.

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

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

Water treatment plant shall be provided where necessary to ensure a low conductivity.

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.

Evaporative coolers shall not be used.

A heating, ventilation and air conditioning system shall be provided to maintain the correct environmental conditions within the valve hall.

Valve System Insulation Co-ordination

Series Switching Device Connection Issues

Valve Availability

Failure rate guarantee, valves and capacitors.

1.6.4 AC Capacitors

AC capacitors shall comply with the requirements of TS 3.11.1.

The rated capacitor bank voltage (U_n) shall be not less than the requirements of clause 9.2.3(a) of DD IEC PAS 62001:2004, equation 9-6. However when low voltage capacitor banks are installed in a.c. harmonic filters the rated voltage derived from the above equation shall where necessary be increased to ensure that the capacitor banks can withstand the transient stresses. The rating methodology shall be agreed with National Grid.

1.6.5 DC converter link capacitors