NIC Project Medium Voltage Direct Current Link Technical Specification

1 SCOPE

This Specification details SP Energy Networks (SPEN) requirements for a bidirectional Medium Voltage Direct Current (MVDC) Link for the 'Angle-DC' project, being carried out in conjunction with Ofgem's Network Innovation Competition (NIC).

2 ISSUE RECORD

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3 ISSUE AUTHORITY – CHANGE BACK

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4 CONTENTS

Table of Contents

5 INTRODUCTION

This specification details the requirements for a Medium Voltage Direct Current (MVDC) Link, originally required for the SPEN 'Angle-DC' project trial, involving the AC to DC conversion on Medium Voltage AC circuit.

The features of a bidirectional MVDC link should include:

- Enhancing the power flow between two network groups;
- Providing more control of the power flow;
- Providing control of reactive power flows, hence influencing wider area voltage profile;
- Reducing operating losses in the wider distribution area;
- Providing additional ancillary services from the link; and
- The conversion of existing AC assets to DC operation.

This specification provides the functional requirements of the MVDC scheme which will be required to achieve the above. General electrical and environmental requirements for a costal MVDC link are provided in this specification.

6 EXISTING CIRCUITS

The route may consist of a mix of land cables and sections of overhead line. Each circuit can have multiple sections, with several designs of cables (e.g. 3-core, 1-core, copper, aluminium etc.). The existing circuits must have a minimum of two phase conductors to make up DC a circuit. The DC resistance of the existing two circuits may not be the same.

7 CONVERSION TO DC OPERATION

The MVDC scheme should operate as a symmetrical monopole, i.e. with one positive MV terminal and one negative MV terminal, or as a bi-pole, with positive and negative MV terminals and a neutral point. In the latter case, a neutral connection between the converter stations is not required, but the neutral at one station shall be grounded. The supplier should indicate if and how they intend to provide a ground reference for a symmetrical monopole scheme.

The conductors of one existing AC circuit can be parallel connected to form one pole conductor and the same for the other circuit. For two 3-phase circuits, the scheme topology would be as shown in Figure 3.

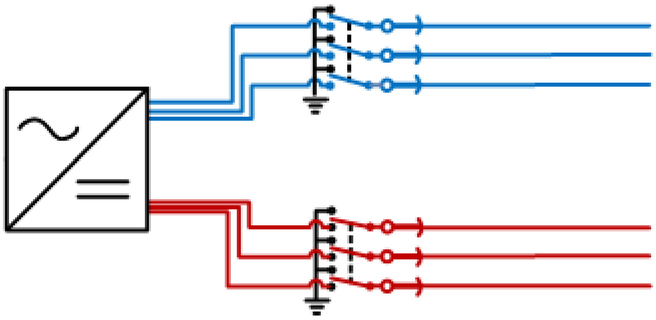

Figure 1. Conversion of three phases to two poles, with 2 position 3-phase DC disconnector earth switch allowing earthed isolation of the DC circuit.

The impact on this arrangement could lead to unbalance in the resistances of the pole conductors. The MVDC equipment supplier should comment on the impact the unbalance in the pole conductor resistances would have on the operation of the scheme.

Where 6-phase conductors are present and a prolonged loss of one conductor on one pole occurs (i.e. due to a cable fault), it is proposed that a complimentary conductor on the other pole is taken out of service by mechanical isolation. This should maintain, as close as possible, the resistance balance between circuits. This can be achieved using 2-position 3 -phase disconnector earth switch with a moulded termination for each phase conductor. The scheme would operate at approximately 67% of normal power, with one termination per pole open, once the disconnector is reclosed.

8 RATINGS

8.1. Power Rating

The notional power rating of the scheme shall be calculated as follows.

$$P_{dc} = 2 \cdot 3 \cdot V_{LG,Peak} N_c \cdot I(T_{MAX}), \qquad (1)$$

where N_c is the number of conductors per pole, $V_{LG,Peak}$ is the peak line to ground voltage and $I(T_{max})$ is the current carrying capacity of the weakest of circuit section, according to ER P17 or ER P27, for a maximum insulation temperature, T_{max}. The maximum insulation temperature will be determined by SP Energy Networks taking into account the age and condition of the cable.

The supplier should assume that the scheme may operate continuously at P_{dc}, with a power factor of lead/lag 0.9, i.e. a scheme rated capacity of $S_{dc} = P_{dc}/0.9$.

The power rating will be confirmed by detailed evaluation early in the project execution phase and the supplier should comment on how higher power levels could be achieved from their designs.

Bi-directional power transfer capability is required, i.e. the rated power is required in both directions.

The target minimum power transfer level of the scheme shall be 0MW. The supplier shall comment on any difficulty in achieving this level and if not possible, the minimum continuous power level which can be achieved.

Over-load rating of the scheme, i.e. operating at higher DC current, is not required. However, the supplier should comment on which items of equipment in their supply would be the limiting factor for short time overload.

8.2. DC voltage rating

The DC voltage is constrained by the insulation capability of the existing cables. The age of the cables is also a factor in the consideration of the DC voltage.

The notional DC voltage for the scheme is ±27kV for 33 kV networks. For other voltage levels the dc voltage shall be,

$$V_{dc} = \sqrt{2} \cdot V_{LL,RMS}/\sqrt{3}, \qquad (2)$$

where $V_{LL,RMS}$ is the RMS line to line voltage. The voltage rating should confirmed by detailed evaluation early in the project execution phase and the supplier is requested to comment on how higher voltage levels could be achieved from their designs.

8.2.1 Voltage Reduction Capability

A voltage reduction capability, to clear a transient fault or allow for changing pollution levels, is desirable. Suppliers shall declare their base voltage reduction capability and any cost options of an enhanced voltage reduction capability over the base value declared. e.g. a base voltage reduction capability could be 80% of nominal, with an enhanced voltage reduction capability of 60%.

8.2.2 DC Creepage

The creepage distance of insulators should be at least 33.3 mm/kV for coastal environments and may be increased to 50mm/kV should the nominal DC voltage cause issues during the commissioning stage.

Where the proximity of the overhead line to the coast introduces the possibility of saline pollution on the insulators, enhanced measures, such as the application of grease, the use of additional sheds or replacement with units of longer creepage distance or by polymeric insulators may be required.

9 DC CIRCUIT PROTECTION

Suppliers should consider the cables and cables and OHL sections capable of withstanding short periods operating at $2 \cdot V_{DC}$ during transient faults. To ensure the safety of the cable, it is proposed that the supplier installs a surge arrester on the DC terminals (+ve and –ve) at either end of the DC link. As a provisional approach, the surge arrestors should have a protective level set at 1.5pu of the nominal DC voltage. This figure will be revised during the post tender design stage.

Protection Current Transformers (CTs) will be required at the MVDC converter connection points for the interconnection cable protection scheme.

In the event of a transient fault, the MVDC converters are expected to recover after a fault and allow DC cable re-energisation provided the circuit has reclosed.

The MVDC link auto-reclose policy shall be in line with the SPEN 33kV Protection and Control Application Policy. Suppliers should reference PROT-01-006 section 13, which states that the operating mode for all auto reclose equipment shall be delayed single-shot auto reclose only, with a minimum dead time setting of between 4 and 10 seconds. Where automatic reclosing systems are connected in series, the minimum grading between each dead time interval shall be 1-second.

Suppliers are responsible for carrying out and providing results from a transient analysis study and recommending pre-insertion resistance values and circuit breaker capacities, so that SP Energy Networks can supply the correct AC side equipment.

The insulation strength of equipment for lightning and switching stresses shall be chosen on basis of calculated over-voltages. The minimum margins used for determination of withstand levels for each piece of equipment should be chosen in accordance to practice on conventional HVDC schemes and to IEC 60071-5.

10 SCHEME OPERATION

SP Energy Networks operators should be able to dispatch power through the link, either as,

- Pre-set power transfer levels, e.g. 100%, 80%, 60%, etc.;
- Vernier control from full load to minimum power.

The power ramp rate shall be adjustable by design, but the operator would implement a fixed rate anticipated to be P_{dc} MW/minute. This ramp rate would apply to steps between pre-set power levels and to Vernier control.

This ramp rate should be confirmed by detailed evaluation early in the project execution phase and the supplier is requested to comment on what limits on ramp rate could be achieved from their designs.

10.1. Polarity Reversal

Due to concerns over XLPE cable insulation, SPEN view DC polarity reversal as a non-beneficial feature of reducing DC cable re-energisation times. Suppliers can include this as a cost option provided its use can be avoided.

11 CONTROL MODES

11.1. Power

The primary control mode for the scheme will be power control, i.e. the scheme is able to operate from minimum power to maximum power, transferring power in either direction through the link. By operator selection, each terminal may function as a rectifier (exporting power) or an inverter (importing power).

11.2. DC voltage

The inverter terminal should control the DC voltage and the rectifier terminal should control the DC current and hence power flow.

11.3. Reactive power

The scheme should be able to control reactive power absorption and generation at each terminal independently and also independent from the direction of power flow. Thus a full "4 – quadrant" capability is required for real and reactive power, as illustrated in Figure 1.

It is anticipated that the voltage or and/or current ratings of the equipment may introduce a limitation on the full 4 – quadrant operation of the converter, as indicated by the inner shape in Figure 1. The supplier is requested to confirm the converter operating capability at the points indicated in Table 1.

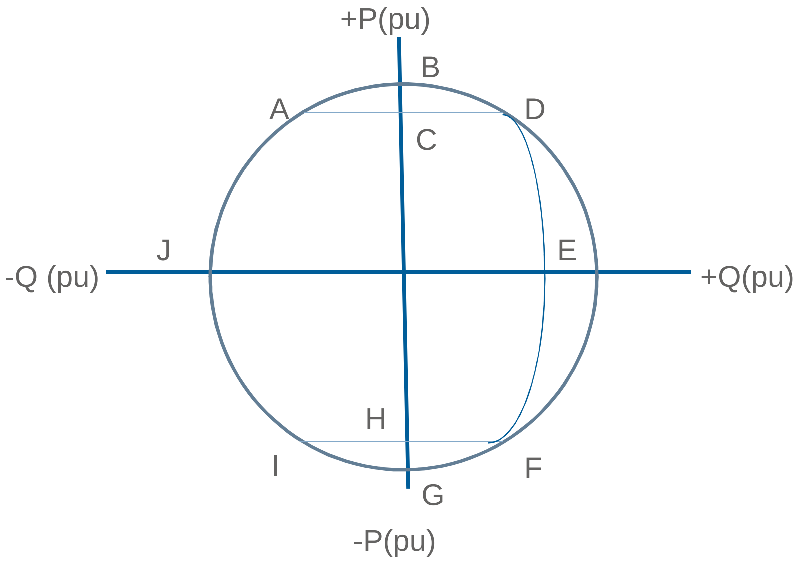

Figure 1. Real/reactive power capability diagram.

In the following table operating points B, E, G and J are requested To Be Confirmed (TBC) by the supplier. All other operating points are a mandatory requirement of this specification.

Table 1. Scheme operating points.

Operating point	Power (pu)	Power factor (pu)	Comment
A	1.0	-0.9	Required
B	TBC	0	Requested
C	1.0	0	Required
D	1.0	0.9	Required
E	0	TBC	Requested
F	-1.0	0.9	Required
G	TBC	0	Requested
H	-1.0	0	Required
I	-1.0	-0.9	Required
J	0	TBC	Requested

11.4. AC bus voltage

The scheme should be able to operate in a voltage control mode, such that the operator may select an AC bus voltage and the converter will automatically adjust converter reactive power absorption or generation to achieve the desired voltage.

Normal operating range of the 33kV distribution system is ±6%.

11.5. STATCOM operation

In the event that the DC circuit is unavailable, e.g. due to a major cable fault, each converter station should be capable of operating as a STATCOM, i.e. providing reactive power output at points E and J in Figure 1. This will require that any equipment required for initial energisation, e.g. pre-insertion resistors, is installed at both terminals.

11.6. Power run-back

Under certain contingencies on the distribution system, e.g. the loss of a key circuit or generator, there may be the need to instigate a power "run-back" from the present operating power transfer level to a pre-defined operating level. Studies in the early project execution phase will determine if this facility is required and to what levels power run-back would be set. Note that "run-back" can imply power reduction and power increase, the latter limited by the rating of the scheme.

11.7. Black start

Not required.

11.8. Power oscillation damping

Not required.

11.9. Control Interface

The scheme should be designed for un-manned operation, with remote control via a SCADA system from SP Energy Networks operation centre. The MVDC converters shall have the following interfaces:

1. A HMI interface with remote access; and
2. A hardwired SCADA interface accepting remote and local control commands.

Suppliers shall describe any input parameters required to configure and operate the solution (fixed and time-variant) and also the full list of parameters to be monitored during live operation of the flexible power link.

The MVDC control system should be capable of interfacing with SCADA Remote Terminal Units (RTUs); including digital I/O at 48 V and analogue inputs at 0-10 mA DC and SCADA systems using industry standard SCADA protocols IEC 61850.

12 RELOCATION CAPABILITY AND BUILDING DETAIL

MVDC link converters will be housed in buildings sympathetic to building aesthetics of similar building types in the local vicinity. The volume and height of the MVDC converters stations should be as small as is reasonably practicable.

A re-locatable MVDC housing solution is not an essential requirement. However, in the unlikely event that the MVDC converters cannot operate the DC circuit as designed, the converter may be required to be relocated to a different site. The incremental cost and any space and height variation of this feature should be listed as optional, with variation details provided. The supplier should also give cost consideration to external cladding/finish, which would be sympathetic to local building aesthetics, if recommending the containerised variation.

Where site civils preparation work will be carried out by a SP Energy Network’s contractor, ground surveys do not need to be taken into account. The site preparation works will include concrete bases, power cabling, embedded earthing tape and auxiliary cables for the MVDC apparatus.

The earthing arrangements for the MVDC converters, the housing, in conjunction with the existing substation earthing system will need to be assessed and designed by the MVDC converter supplier.

13 OPERATING TEMPERATURE

For low lying and costal locations of both converter stations, converters must be capable of normal operation between the following ambient temperatures:

- Maximum - For equipment rating purposes = +40°C
- Maximum - For rated power transfer capability = +35°C
- Minimum - For rated power transfer capability = -20°C
- Minimum - For equipment rating purposes = -20°C

The system must deliver P_{dc} MW at +35°C and remain operational at +40°C, although power could be reduced if necessary. The system must be able to remain in operation at -20°C and achieve rated power.

14 NOISE LEVELS

Allowable noise levels will largely be dictated by the distance from the MVDC converter site boundary to the nearest dwelling or place of business.

A guidance maximum noise level in dB Lar (15 minutes) at a location 3.5 metres from the façade of any nearby residential property will be agreed, between with local authority Environmental Health Officers and SP Energy Networks, following a 2-week site period of background noise monitoring in accordance to Section 11 of British Standard 4142:2014.

The supplier shall provide noise emission data, including the number of noise sources and their locations within the MVDC substation compound, to allow SP energy networks to establish a combined noise limit, of the MVDC equipment, at 1 m from the substation boundary.

15 RELIABILITY AND AVAILABILITY

As a single DC link will replace one existing AC link, the reliability of the scheme and the availability of energy are critical. The following target performance figures are requested:

- Forced outage rate (FOR) <3 trips per annum
- Scheduled energy unavailability (SEU) <1%
- Forced energy unavailability (FEU) <1%
- Energy availability (EA) >98%

The supplier shall indicate what reliability and availability can be achieved from their design. Converter operation will be monitored for a period of 5 years after the start of commercial service. It is a requirement that the above conditions are met in each year of the 5 years.

Outages of the converters, as a result of failures on the cable and overhead line distribution circuits, are excluded from the above limits, unless it is clear that such failures are a direct result of a mal-operation of the converters.

Suppliers are to calculate the Mean Time Between Failure values of system components and include costs for enough spares to last 5-years. The supplier must demonstrate a replacement program that will enable the MVDC link to operate for a minimum of 20-years.

16 OPERATING LOSSES

The following target operating losses are requested for each converter station and if not considered to be achievable the supplier should confirm what level of operating losses can be achieved.

- No-load losses < 0.25% of scheme rated power; and
- Load losses < 2.0% of scheme rated power.

The supplier shall provide a chart or range of loss values across various real and reactive power throughputs of the MVDC converter.

17 HARMONIC DISTORTION

The contribution to the Total Harmonic Distortion (THD) and individual harmonic voltages, created by the MVDC link either side of the DC link, shall not exceed the 95% cumulative probability levels given in Engineering Recommendation G5/4.

The effect of network segregation will be taken into account using monitoring data taken either side of the segregated AC network.

18 AUXILIARY POWER

The supplier shall confirm the maximum level of auxiliary power required to operate each converter station. It is anticipated that the primary source of auxiliary power (at 415V) will be supplied by SP Energy Networks from the local distribution network. The supplier shall indicate what back-up power supplies are needed to allow the MVDC scheme to ride-through momentary disturbances to the auxiliary power supply and the effect of auxiliary power loss on the MVDC converter operation.

19 NETWORK DYNAMIC PERFORMANCE

MVDC Converter equipment should be designed to tolerate a 2% voltage unbalance as defined is ER P29. Within the voltage unbalance limit, levels of harmonic distortion should remain within those set out in Section 17.

As the MVDC link does not connect to the transmission system, it does not need to adhere to the Grid Code but rather the Distribution Code which serves a similar purpose. However, unlike the Grid Code, the Distribution Code does not enforce Fault Ride Through upon its connected assets. The MVDC link should retain fault ride through capability as indicated in ENTSO-E – 'Establishing a Network Code on Requirements for Grid Connection of Generators' (p22, Table 3.1) so that the MVDC Link is capable of supporting system disturbances at the distribution level.

20 PRE-INSATLLATION TESTING

The supplier shall test the equipment prior to delivery and provide an outline of the commission test procedure and requirements.

21 EMC

Where secondary equipment is located within the control and relay building, or within separate relay rooms or within outdoor enclosures, it shall be designed to ensure adequate protection against electromagnetic interference and shall comply with ENA TS 48-05.

At the time of commissioning, the MVDC converter equipment, circuit-breaker and disconnector normal switching operations shall be performed to demonstrate that EMC has in fact been achieved within the substation environment.

In addition, the MVDC equipment itself will need to achieve EMC compliance against third party interference. The emission levels at the substation perimeters will also need to be estimated at the design stage and assessed and measured during the MVDC 'burn-in' period.

General emissions standard	BS EN 61000-6-3: 2007
Radiated Immunity	BS EN61000-4-3 10V/m Criteria A
Radiated Emissions	BS EN55011 Class A
Conducted Immunity	BS EN6100-4-6 10V/m Criteria A
Conducted Emissions	BS EN55011 Class A

22 SAFETY

Potential suppliers must comply with BS EN 61010 and with their statutory obligations under Construction (Design and Management) Regulations 2007. Manufacturers should provide method statements and risk assessments to the Network Operator. The Network Operator will use these documents to facilitate the assessment of safe installation procedures for energised and non-energised installations.