

TECHNOLOGY AVAILABILITY FOR STRATEGIC OPTIONEERING

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PURPOSE AND SCOPE

Many of the technologies required for strategic optioneering are new and developing rapidly. Voltage Sourced Converter (VSC) HVDC technology was introduced in 1997 and since then has been characterised by continuously increasing power transfer capabilities. Significant developments have taken place in the area of dc cables including the introduction of extruded and mass impregnated polypropylene paper laminate (MI PPL) insulation technologies. New devices are emerging, such as the HVDC circuit-breaker. The present document aims to anticipate how the capability of the key technology areas might develop in coming years and provide an indication of technology availability by year in order to inform planning decisions.

PART 1 –PROCEDURAL

1 INTRODUCTION

Figures are presented for each of the key technology areas, in which technology capability is tabulated against year. The availability of technology with a given capability in a given year is indicated by means of a colour-coded cell. The key is shown in Figure 1. Red indicates that the technology is not expected to be available in that year. It is important to distinguish between the time at which a technology becomes commercially available and the time by which it might be in service; amber indicates that the technology is expected to have been developed and to be commercially available but not yet in service. It has been assumed that project timescales for HVDC schemes are such that a period of typically four years would elapse between technology becoming available and being in service. It is clear that for technology to be in service, a contract will have to have been placed at the appropriate time. Consequently, a hatched green cell is used to indicate that it would be possible in principle for the technology to be in service in a given year provided a contract has been placed. A solid green cell indicates that the technology is in service or scheduled to be in service on the basis of contracts which are known to have been placed.

R	Technology not available
A	Technology available but not in service
C	Technology potentially in service subject to contract
G	Technology in service or scheduled to be in service

Figure 1: Key to figures

In this way, the time at which a technology is fully developed and ready to be offered to the market is identifiable by a change in cell colour from red to amber; the time at which a technology may first enter service is identifiable by a change in cell colour from amber to green or hatched green (depending on whether a specific contract has been placed).

Where the availability of a technology is indicated by an amber cell, its introduction will require an appropriate risk-managed approach that takes account of the lack of service experience. Where the availability is indicated by a green cell, a greater level of experience will be available but appropriate risk management will still be required particularly in the earlier years.

In deriving the forecast availabilities, published information has been used wherever possible. The sources of information are referenced in the text. Where no published information is available, forecasts have been based on a best estimate. The forecasts have not been confirmed or endorsed by the manufacturers. For technologies that are not yet available, the rate of development will depend on the level of demand and is therefore subject to changes in market conditions.

The forecasts presented in Issue 3 of this TGN were updated in August 2015. The reader should be aware that further developments may have occurred since then.

2 TECHNOLOGY AVAILABILITY

2.1 HVDC technology

In the following sections, the component technologies that comprise an HVDC system are considered initially in isolation. Subsequently, the forecast capabilities of HVDC systems are determined by taking into account the forecast capabilities of the component technologies.

2.1.1 HVDC converters

The expected development in the capability of voltage sourced converter (VSC) HVDC technology is illustrated in Figure 2.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
1563 A	G	G	G	G	G	G	G	G	G	G	G	G
1875 A	A	A	A	A	C	C	C	C	C	C	C	C
2000 A	R	A	A	A	A	C	C	C	C	C	C	C
Key												
	R	Technology not available										
	A	Technology available but not in service										
	C	Technology potentially in service subject to contract										
	G	Technology in service or scheduled to be in service										

Figure 2: Voltage sourced converters

Where used with a dc cable circuit, the achievable power transfer capability for the converters will be dependent on the level of dc voltage permitted by the cable. The present generation of modular-multi-level converters are scalable by voltage and could reach the dc voltage level of any foreseeable cable with little development effort. The highest dc voltage for a VSC HVDC system in service is 500 kV pole-to-ground for the Skagerrak 4 project [1], which uses mass impregnated cables and became operational in 2015. It is assumed that

converters will continue to reach the level of dc voltage permitted by the cables as the technology develops.

The level of dc current achievable is determined by the IGBT modules used in the converter valves. The interconnection between France and Spain [2], commissioning in 2015, comprises two HVDC links with a power transfer capacity of 1000 MW each and operating at ± 320 kV, representing a dc current of around 1563 A.

The Caithness Moray HVDC Link, due to be commissioned in 2018, will have a power rating of 1200 MW at ± 320 kV, representing a d.c. current of more than 1875 A [3]. IGBT modules permitting dc currents of 2000 A are expected to be available for contracts placed in 2016 [4]. Achievement of higher dc currents may be possible in future years with further development of semiconductor devices and materials but would be dependent on the availability of cables able to carry such levels of current.

Line commutated converter (LCC) technology has developed to a stage where it could match the voltage and current ratings of any cable or overhead line with which it might be used on the GB transmission system. For example, the Southern Hami – Zhengzhou HVDC link in China operates at ± 800 kV dc and with a power transfer capability of 8000 MW [5]. No figure is given in the present document to illustrate the future development of LCC HVDC converter technology since it is unlikely to represent the limit on the capability of the system in which it is used within the GB transmission system.

2.1.2 HVDC cables

The expected availability of HVDC cables with extruded insulation is illustrated in Figure 3.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
320 kV	G	G	G	G	G	G	G	G	G	G	G	G
400 kV	A	A	A	G	G	G	G	G	G	G	G	G
525 kV	A	A	A	A	G	G	G	G	G	G	G	G
600 kV	R	R	R	R	A	A	A	A	G	G	G	G
650 kV	R	R	R	R	R	R	R	R	R	A	A	A
700 kV	R	R	R	R	R	R	R	R	R	R	R	A
Key												
	R	Technology not available										
	A	Technology available but not in service										
	G	Technology potentially in service subject to contract										
	G	Technology in service or scheduled to be in service										

Figure 3: Extruded dc cables at 70 to 90 °C

Extruded cables with a dc voltage of 320 kV are in service [6]. The highest dc voltage for extruded cables currently on order is 400 kV for the Nemo Link interconnector, scheduled to enter service in 2019 [7]. A 525 kV extruded dc cable system has been qualified [8].

With regard to cable development, the CIGRE Ref. 533 published in April 2013 included the results of a questionnaire that had been sent to cable manufacturers [9]. One respondent indicated that extruded cables for a dc voltage of 600 kV would be available within the next five years and 750 kV within ten to fifteen years. Other manufacturers were also pursuing developments but tended to be less specific and more cautious with regard to their plans.

Figure 3 takes into consideration the range of forecasts for development of extruded cables together with a judgement of the likely timescales for development and testing.

The expected availability of HVDC cables with mass impregnated (MI) and mass impregnated paper polypropylene laminated (MI PPL) insulation is illustrated in Figure 4.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
500 kV	G	G	G	G	G	G	G	G	G	G	G	G
600 kV	A	G	G	G	G	G	G	G	G	G	G	G
650 kV	R	A	A	A	A	A	A	A	A	A	A	A
700 kV	R	R	R	R	R	R	R	R	R	A	A	A
Key												
	R	Technology not available										
	A	Technology available but not in service										
	A	Technology potentially in service subject to contract										
	G	Technology in service or scheduled to be in service										

Figure 4: Mass impregnated dc cables at 55 °C and mass impregnated polypropylene paper laminate cables at 80 °C: Voltage

MI cables are longer established than extruded cables and can achieve higher voltages at present. MI cables at 500 kV are in service on the SAPEI HVDC link between Sardinia and Italy [10]. The highest dc voltage for cables currently on order is 600 kV for the Western HVDC Link, scheduled to enter service in 2016 [11]. The questionnaire reported in the April 2013 CIGRE Ref. 533 also addressed the forecast development of MI cables [9]. In his response, one respondent indicated that MI cables for a dc voltage of 750 kV would be available within ten to fifteen years. Another expected to achieve a voltage level of 800 kV 'in the next few years'.

Figure 4 takes into consideration the range of forecasts for development of MI and MI PPL cables together with a judgement of likely timescales for development and testing.

MI cables may be used with LCC converters, which will be able to match the current carrying capability of the cable. The expected availability of MI cables according to current carrying capability is illustrated in Figure 5.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
1876 A	A	G	G	G	G	G	G	G	G	G	G	G
2000 A	R	A	A	A	A	A	A	A	A	A	A	A
Key												
	R	Technology not available										
	A	Technology available but not in service										
	A	Technology potentially in service subject to contract										
	G	Technology in service or scheduled to be in service										

Figure 5: Mass impregnated cables at 55 °C and mass impregnated polypropylene paper laminate cables at 80 °C: Current

The cables of the Western HVDC Link, scheduled to enter service in 2016, will achieve a current carrying capability in excess of 1800 A [11]. It has been assumed that, with some development, an increase in current carrying capability to 2000 A in the early years would be challenging but possible. This is consistent with the results of the CIGRE Ref. 533 survey [9]. This does not represent a fundamental limit since the conductor cross section could be increased at the cost of more difficult cable installation.

2.1.3 Offshore platforms for HVDC converters

The forecast availability of offshore platforms for HVDC converters is illustrated in Figure 6.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
320 kV	G	G	G	G	G	G	G	G	G	G	G	G
500 kV	A	A	A	A	A	A	A	A	A	A	A	A
600 kV	R	R	A	A	A	A	A	A	A	A	A	A
Key												
	R	Technology not available										
	A	Technology available but not in service										
	A	Technology potentially in service subject to contract										
	G	Technology in service or scheduled to be in service										

Figure 6: Offshore platforms for HVDC converters

The achievable transmission capacity of offshore converters is dependent on the size and weight of the platforms which can be constructed and installed. The dc voltage, in particular, is subject to the limitations of platform physical dimensions due to the clearances in air required for insulation of the valves and dc equipment.

The highest dc voltage for offshore converters in service at present is ± 320 kV, for which a number of examples exist [12 - 14] and more are under construction [15 – 18]. Based on installation vessel lifting capability and fabrication yard size, a ± 400 kV offshore converter is thought to be deliverable. A new or upgraded installation vessel would allow an increase in dc voltage to around ± 500 kV. The lifting vessel AllseasPioneering Spirit, due to commence offshore operations in 2015, will increase the largest available lifting capacity significantly (topsides lift capacity 48,000 t) [19]. However, an increase in fabrication yard size would be required to exploit the full capacity of the vessel. Higher dc voltages could also be achieved, in principle, by adopting a modular converter design for installation in two or more lifts. Further design work would need to be carried out to establish the feasibility of such a solution.

2.2 HVDC systems

The forecast capability of systems comprising HVDC converters and dc cables is determined from the forecast capability of the component technologies illustrated in the previous figures. The achievable MVA rating in a given year is determined from the dc current and dc voltage permitted by the component technologies.

The availability of a given MVA rating in a given year is determined by whichever of the component technologies has the lowest availability. Many combinations of component dc current and dc voltage are possible; results are shown in the figures where an increase in dc current, dc voltage or both allows a higher MVA rating for the system to be achieved. If a given MVA rating is available in a given year, it follows that any lower value of MVA rating will also be available. The combination of dc current and dc voltage permitting the increase in MVA rating is indicated in the figures.

The maximum real power transmissible by the system may be less than the MVA rating, depending on requirements for converters to provide reactive power. For line commutated converters, reactive compensation plant is always provided as part of the scheme.

2.2.1 HVDC systems with converters located onshore

The availability of HVDC systems where VSC converters located onshore are used with extruded cables is illustrated in Figure 7.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035	
1000 MVA	G	G	G	G	G	G	G	G	G	G	G	G	320 kV 1563 A
1200 MVA	A	A	A	G	G	G	G	G	G	G	G	G	320 kV 1875 A
1970 MVA	A	A	A	A	A	A	A	A	A	A	A	A	525 kV 1875 A
2100 MVA	R	A	A	A	A	A	A	A	A	A	A	A	525 kV 2000 A
2400 MVA	R	R	R	R	A	A	A	A	A	A	A	A	600 kV 2000 A
2600 MVA	R	R	R	R	R	R	R	R	R	A	A	A	650 kV 2000 A
2800 MVA	R	R	R	R	R	R	R	R	R	R	R	A	700 kV 2000 A
Key													
	R	Technology not available											
	A	Technology available but not in service											
		Technology potentially in service subject to contract											
	G	Technology in service or scheduled to be in service											

Figure 7: HVDC systems comprising voltage sourced converters and extruded cables

The Interconnector between France and Spain, commissioning in 2015, will achieve a power transfer capability of 1000 MW [2]. The Caithness Moray project, due to commission in 2018, will achieve a power transfer capability of 1000 MW [3]. The forecast increases in dc current and voltage levels of the converters and cables allow a continuing increase in the