TECHNOLOGY FACTSHEET

POWER TRANSFORMER OFFSHORE HV

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Sector	Infrastructure
ETS / Non-ETS	Non-ETS
Type of Technology	Network
Description	This factsheet describes the use of HVDC power converters for alternate current/direct current (AC/DC) conversion. HVDC converters are mainly divided between current source converters (CSC) and voltage source converters (VSC) technologies. CSC have been commercially in use since the 50s, making it a well-established technology, based on the use of high power thyristors. The technology is widely used for back-to-back links between asynchronous grids. Due to its conversion technique, these converters absorb reactive power from the adjacent AC grid, generating harmonic currents having a negative impact on the quality of the electrical power. Therefore, reactive compensation and harmonic filters are required. As a result, the converter depends on the AC system's voltage to ensure the correct operation. DC current flows unidirectionally, to reverse it in a CSC connection, the DC control system reverses the polarity of the DC voltage. DC cables are still limited to lower voltages and power levels [4]. DC cables power capabilities are limited due to electrothermal heating and problems arising out of possible electrothermal instability of the insulation that could result in rapid failure under certain conditions of operation [8]. VSC technology is based on the use of Insulated Gate Bipolar Transistors (IGBT). VSC devices are self-commutating, making the operation of converter independent of the AC system's voltage and a more controllable. An advantage over CSC is that it does not require reactive power compensation and less AC harmonic filtering, resulting in less ancillary equipment. The VSC HVDC systems in service so far have been limited to lower voltages and power ratings than CSC systems due to its low overload capability, limited by the capability of the IGBT devices. Nevertheless, new projects such as NordLink and NorthSeaLink with a 1400MW rated power are under construction [7].
TRL level 2020	TRL 8
	CSC technology has followed many years of improvement. Thyristor devices can operate at voltages up to 8.5kV and switch DC currents of up to 6250A. An important characteristic of this thyristor-based technology is its short time overload capability and its high efficiency, with a total operating power loss in a converter station of typically 0.7 – 0.8%. It is considered a technology with a TRL 9. Compared to the CSC technology, VSC is a less mature technology and still in development, using IGBT devices rated up to 6.5kV and 2000A. The overload capability of this technology is still low (limited by the IGBT devices), despite the rise on the power and voltage ratings. The operating losses of VSC technology have decreased dramatically in recent years to reach about 1% per converter station (half-bridge solution). The 'half-bridge' solution is at a TRL 7. Future development in VSC is the 'full-bridge' configuration that allows a more flexible operation. This solution is at a TRL 4 [3].

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MW		-								
			Min			-			*Max*		
			Current			2030			2050		
Potential			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Market share		%	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*

Capacity utlization factor	1.00
Full-load running hours per year	
Unit of Activity	
Technical lifetime (years)	
Progress ratio	
Hourly profile	
Explanation	An ENTSO-e study estimates a need for 35 GW of new cross border reinforcement for 2025. For 2030 the study finds that 50 GW extra would be cost-efficient, representing a 17 bn € investment in the European transmission grid. By 2040, 43 additional GW of cross border capacity on top of the needs for 2030 is required. This increase would represent about 28 bn € of investment. DC technologies will play a significant role in the efforts to meet this reinforcements goals [5]. By 2018, 10% of the cross border lines were DC, while there are around 30 GW of cross border DC projects in the pipeline for 2030 [9]. Added to the demand for cross border interconnection capacity, Europe has 22.1 GW of offshore wind capacity, and according to European Commission's roadmap on offshore renewable energy, over 250 GW of installed offshore is anticipated by 2050. This means that the need for onshore and offshore converter stations will be needed to support the installation of HVDC interconnectors between countries and to integrate offshore wind power plants [6].

COSTS

Year of Euro	2015								
	Euro per Functional Unit	Current			2030			2050	
Investment costs	mln. € / MW	0.09			0.09			0.09	
		0.08	–	0.10	0.08	–	0.10	0.08	–	0.10
Other costs per year	mln. € / MW	-			-			-	
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	0.00			0.00			0.00	
		0.00	–	0.00	0.00	–	0.00	0.00	–	0.00
Variable costs per year	mln. € /	-			-			-	
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Costs explanation	Correlations were identified between both rating (MVA) and the number of transformers in a station. There were two categories: 1-4 converter transformer per station and 6-8 converter transformers. There was an even mix of VSC and CSC in the 1-4 converter transformers category. VSC tended to have a higher cost per MVA than CSC within the 1-4 converters category, although this breakdown cannot be shown due to the size of the samples. The sample size was determined by European TSOs who submitted their most recent newly constructed assets, going back no more than 10 years [2].								

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-0.99			-0.99			-0.99		
			-0.99	–	-0.99	-0.99	–	-0.99	-0.99	–	-0.99
	Electricity	PJ	1.00			1.00			1.00		
			1.00	–	1.00	1.00	–	1.00	1.00	–	1.00
	Propane	PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Energy in- and Outputs explanation	CSC have a total operating power loss in a converter station of typically 0.7 – 0.8%. Whereas the operating losses of VSC technology are about 1% per converter station [4].										

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Material flows explanation											

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS)											
	Substance	Unit	Current			2030			2050		
Emissions			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Emissions explanation											

OTHER										
Parameter	Unit	Current			2030			2050		
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Explanation										

REFERENCES AND SOURCES	
1	NorthSeaGrid (2015). Offshore Electricity Grid Implementation in the North Sea
2	ACER (2015). Report on unit investment cost indicators and corresponding reference values for electricity and gas infrastructure.
3	ENTSOE (2019).Technologies for Transmission System. Technical Final version after public consultation and ACER opinion.
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7	Hartel et al. (2017) Review of investment model cost parameters for VSC HVDC transmission infrastructure.
8	C. C. Reddy,(2009). Theoretical Maximum Limits on Power-Handling Capacity of HVDC Cables
9	ENTSOE (2019). Statistical Factsheet 2018.