TECHNOLOGY FACTSHEET

TNO

ELECTRICITY NETWORK OFFSHORE

Date of factsheet	21-1-2021
Author	Ricardo Hernandez-Serna
Sector	Infrastructure
ETS / Non-ETS	Non-ETS
Type of Technology	Network
Description	Currently, offshore networks are used for offshore interconnectors (e.g. BritNed, COBRAcable) and for connecting offshore wind farms. Future applications are also explored, such as offshore meshed grids that combine interconnection and offshore wind connection. Offshore power transmission is better suited for HVDC (high voltage direct current) technologies than the usual AC (alternate current). Using AC, the transmission voltages are standardized at 220kV, whereas HVDC cables can transport power at higher voltages. Furthermore, the AC cable creates difficulties since reactive compensation cannot be installed in the middle of the route, resulting in lower transmission distances. An HVDC cable has several advantages over AC like connecting areas with different frequencies and transmitting power over long distances at a lower cost. For offshore wind farms relatively close to shore, roughly up until 75-100km, HVAC technology is often the most economical choice. For larger wind farms located further offshore, HVDC becomes economically and technically more feasible than HVAC. Offshore networks are mostly project-specific; this is due to spatial, environmental and technical constraints. For instance, HVAC connections require more and larger cables than HVDC connections, while HVDC substations are considerably larger than HVAC substations. HVAC connections require a strong grid connection. There are two main types of cable technology used in HVDC applications, crosslinked polyethene (XLPE) and mass impregnated (MI) insulation [5]. XLPE cables can be used in voltages up to 330kV while MI cables are available for voltages up to 600kV. [5] XLPE cables are unsuitable for current source converters (CSC) applications where the polarity must be reversed to reverse the power flow direction. This factsheet covers data for XLPE cables.
TRL level 2020	TRL 7 XLPE HVDC cables are used with VSC converters that enable power flow to reverse without polarity reversal. This technology has been implemented up to ±320 kV with a capacity of 1000 MW for a symmetrical monopole. ±525 kV cable systems are now available for commercial purposes [3]. TRL levels range from 7-3 depending on the voltage e.g 600kV cables are currently at TRL 3. It is expected that for 2030 this technology will have a TRL 9 at voltages ranging 320 - 600 kV.

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	km		-								
			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)	40.00
Progress ratio	
Hourly profile	No
Explanation	The Netherlands currently has over 1165 km of offshore HVDC cables used for interconnection between countries such as the United Kingdom, Denmark and Norway with an installed capacity of 2.4 GW. Furthermore, HVDC offshore cables are being used to connect wind farms in the North Dutch Sea.

COSTS

Year of Euro: 2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / km	0.36			0.36			0.36		
		0.36	–	0.76	0.36	–	0.76	0.36	–	0.76
Other costs per year	mln. € / km	1.54			1.54			1.54		
		1.54	–	1.97	1.54	–	1.97	1.54	–	1.97
Fixed operational costs per year (excl. fuel costs)	mln. € / km	0.01			0.01			0.01		
		0.01	–	0.02	0.01	–	0.02	0.01	–	0.02
Variable costs per year	mln. € /	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation: Costs are based on cables with a nominal power level ranging from 700MW to 1400MW, the HVDC sample had a voltage range of 250 to 500 kV. The cost is calculated as the average cost between different power levels. For DC cables, costs broadly increased with the power rating. Costs are on average higher for cables with deeper cable laying depths. Other costs refer to installation costs [1].

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-0.97			-0.97			-0.97		
			-0.97	–	-0.97	-0.97	–	-0.97	-0.97	–	-0.97
	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: For HVDC technologies transmission losses can reach 1-2% over 100 km, whereas HVAC lines losses amount up to 3-4% for every 100 km. Losses are proportional to the cable length [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	(2015) NorthSeaGrid. 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.
4	IEA (2014). ETSAP. Electricity Transmission and Distribution.
5	NationalGrid (2013). High Voltage Direct Current Electricity – technical information.