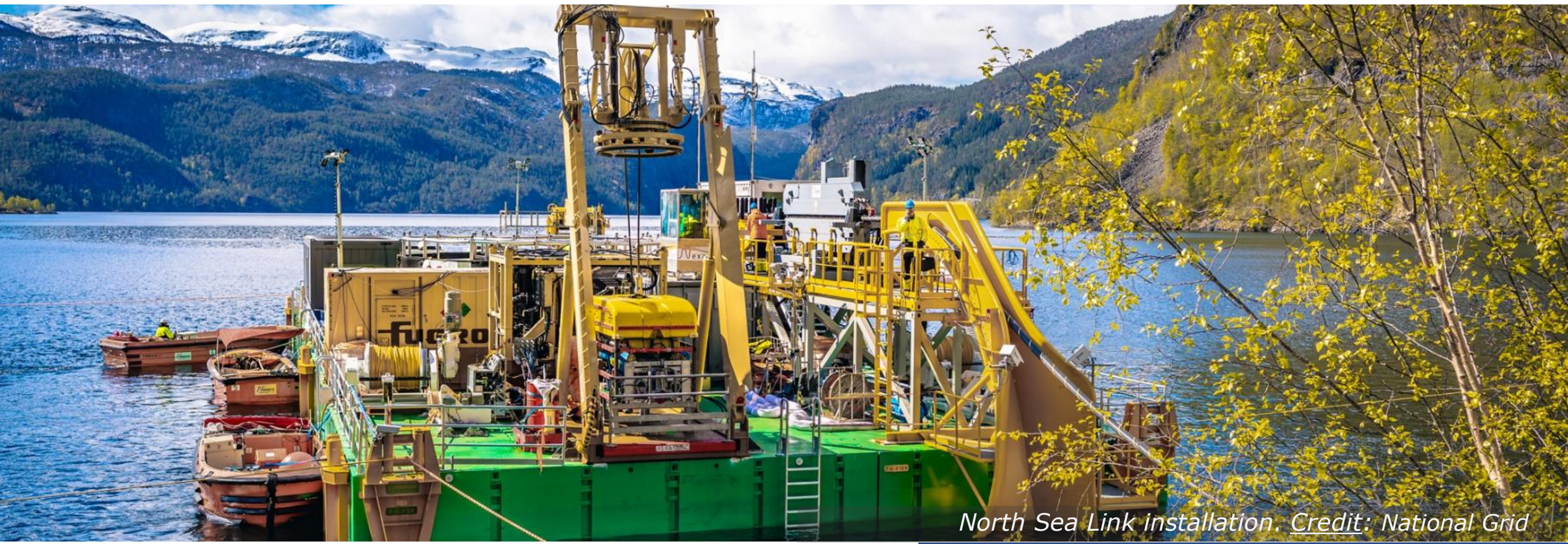
HVDC-VSC Newsletter

November 2022



North Sea Link installation. Credit: National Grid

Contributions

Thank you to Geoff Henderson (SyncWind Power Ltd) for his contribution.

Corrections

As a correction to the last month's newsletter HVDC-VSC project list:

DolWin4 and BorWin4 HVDC converters are manufactured by Siemens Energy and not by Hitachi Energy as was written in error in last month's HVDC-VSC project list. Thank you to Dijana Cof (Hitachi Energy) and Benjamin Hinrichs (Siemens Energy) for bringing this to our attention.

Please also note that the North Sea Link cable has a DC voltage of ±515 kV and not ±525 kV as was written in error.

For any comments and feedback, we kindly invite you to reach out to us via: HVDC@rte-international.com

Power Electronics & Studies department

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Editor: Markus Vor dem Berge; Author: Robin Lemaire; Design: Camille Noguès; Reviewers: Sébastien Dennetière, Alice Bacon; Contributor: Hani Saad

Technology outlook

Synchronous power-train of Type 5 wind turbine

Geoff Henderson, Vahan Gevorgian, "Type 5 wind turbine technology : how sychronised, synchronous generation avoids uncertainties about inverter interoperability under IEEE 2800:2022", 21st Wind & Solar Integration Workshop, 2022

A proven Type 5 (synchronous) wind turbine exists and over 100 units have been running at 0.5 MW scale in a 46 MW wind farm in New Zealand since 2006 and eight turbines in Scotland since 2013. The U.S. National Renewable Energy Laboratory (NREL) is conducting a study on the impacts on grid reliability, stability and resilience of Type 5 wind turbines. The project consists of both simulation and testing tasks and will result in proposing a variable generation solution that will help system operators and utilities address all reliability and most resilience challenges in the evolving grid.

Offshore wind farm connection model

The PSCAD model used is a 1 GW offshore wind power plant HVAC-interconnected to onshore grid using a 50 km of 230 kV transmission with SCR = 3 at the onshore Point Of Interconnection (POI). 250 MVAR of shunt compensation is used in both sending and receiving ends of the submarine cable.

Three cases are simulated. The first two cases use a grid-following (GFL) Type 4 wind turbine while the third case uses a Type 5 wind turbine. The plant is exposed to a single phase to ground 200 ms fault at the POI upstream of the onshore substation transformer.

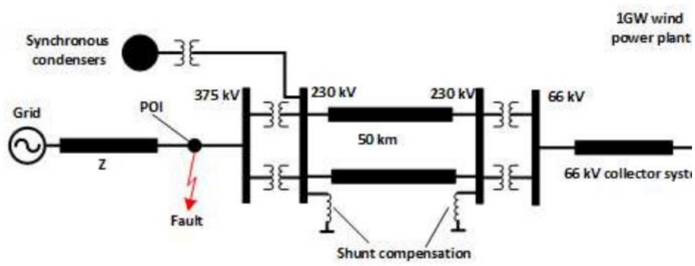

Figure 1: Modelled system

Results

In the first case, the plant rides through the fault but recovery from the transient is accompanied by significant voltage and current transients at the POI despite the wind turbines at the sending end not seeing such significant transients. The reason for such severe transient behaviour at the POI is because of weak POI (SCR=3) in combination with the impedance characteristics of the transmission line and shunt compensation.

In the second case, synchronous condensers (200 MVAR total) are connected to the onshore POI with being exposed to the same fault. The results show that synchronous condensers have significant mitigating impact on voltage and current transients. Synchronous condensers are operating in voltage control mode improving voltage stability at the POI, and at the same time helping to increase the SCR of POI.

The third case with Type 5 offshore wind power plant demonstrates fault ride-through without significant overvoltage and fast recovery compared to the GFL Type 4 case.

RMS voltage at the 230 kV POI bus for all three cases is compared as a function of SCR. The mitigating effect of synchronous condensers on voltage stability of the GFL Type 4 wind plant is obvious by comparing traces for cases 1 and 2. The Type 5 wind power plant demonstrates stable operation for very low SCRs without synchronous condensers.

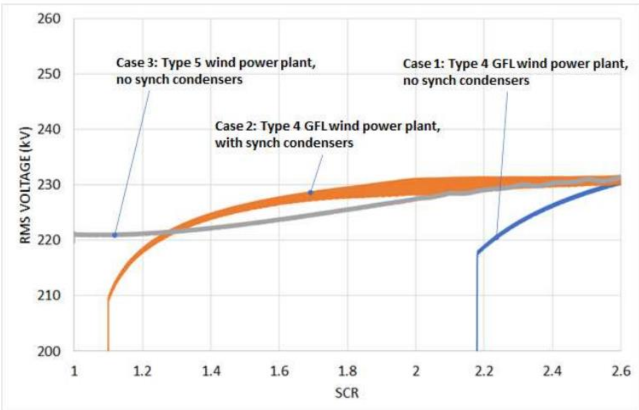

Figure 2: Voltage stability at POI as a function of SCR

The NREL project is now in the modelling stage to characterize the performance of Type 5 turbines under various conditions including fault-ride through.

Summary of type 5 system

- Eliminates the inverter rated at 40-100% of turbine power in Type 3 and 4 turbines
- Instead uses a mechanically Variable Speed (VS) gearbox which includes a differential stage and adds some hydraulics rated at only 5% of turbine power, in order to keep the power-train cost less than that of a Type 3 turbine

- Originally provided only narrow-band VS (torque-limiting) capability, but has recently been enhanced to provide also broad-band VS (the patented LVS system)
- Is readily scalable to multi-megawatt turbines (1-20 MW) by modifying the 3-stage gearbox architecture for a 4-pole DFIG generator, which remains the most common drive-train in the wind industry
- Has demonstrated its ability to act as a synchronous condenser for steady reactive power support (even when the wind is not blowing)
- Has demonstrated its ability for islanded (i.e. black-start) operation
- Has demonstrated its ability for frequency control using a combination of: very fast hydraulic control of reaction torques, with large rotor inertia to limit turbine speed excursions

News

HVDC-WISE project

European HVDC-WISE project at SuperGrid Institute

The HVDC-WISE project officially began on the 10th of October 2022 with a kick-off meeting which brought together all project partners in Lyon (France). The meeting was hosted by the project coordinator, SuperGrid Institute. This new European project – part of the Horizon Europe 21-22 framework – will foster the development of large HVDC-based transmission grid infrastructures, to improve the resilience and reliability of existing electrical systems and facilitate the integration of forthcoming large amounts of renewable energy [1].

More information about the objectives of the project can be found here [2].

Reference:

1. https://www.supergrid-institute.com/2022/10/18/supergrid-institute-coordinator-european-project-hvdc-wise/
2. https://cordis.europa.eu/project/id/101075424/fr

UK offshore wind plan to 2030

National Grid ESO Holistic Network Design

In July 2022, the National Grid ESO published the 2030 Holistic Network Design (HND), a study that sets out the UK network requirements to facilitate the connection of 23 GW of offshore wind projects. Combining existing and developing offshore wind projects, the HND should enable meeting the U.K. government's further goal of connecting 50 GW of offshore wind by 2030 [3].

The study recommends HVDC technology for most offshore wind farm connections (shown in blue lines on the following map) and for offshore grid reinforcement (shown in green lines). Other HVDC links are also considered on a regional scale, in particular in the form of multi-terminal DC offshore.

This report is the result of the HND phase 1. A second phase will be concluded in the first half of 2023.

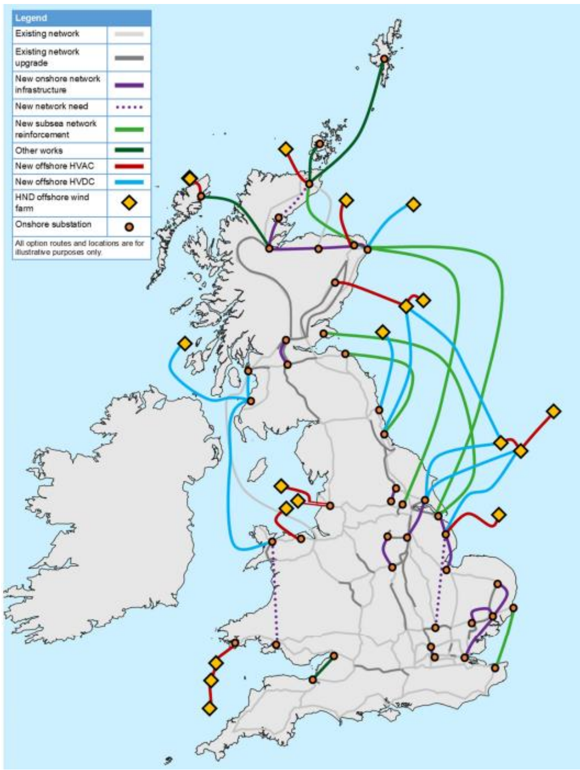

Figure 3: Final HND GB Map. Credit: National Grid ESO

For more details, see the webpage [3] with its interactive map and the Pathway 2030 report.

Reference:

3. https://www.nationalgrideso.com/future-energy/the-pathway-2030-holistic-network-design

EU offshore wind

1.3 GW Dogger Bank D planned

There seems to be further development in the Dogger Bank area. A spokesperson told OffshoreWind.biz: "SSE Renewables and Equinor are currently assessing seabed for the potential of expanding Dogger Bank Wind Farm, which is currently under construction, with an additional phase, Dogger Bank D. The potential project is supported by a grid connection for up to 1320 MW" [4].

Reference:

4. https://www.offshorewind.biz/2022/10/06/breaking-sse-equinor-plan-1-3-gw-dogger-bank-d-offshore-wind-project/#dogger-bank-gigawatts

New Jersey offshore wind

New Jersey State Agreement Approach for offshore wind

As a first news story for New Jersey, the governor announced last month the **increase of the state's offshore wind goal** from 7,500 MW by 2035 to **11,000 MW by 2040**. In addition, the New Jersey Board of Public Utilities (BPU) is also in charge of studying the possibility of further increasing the target [5].

As a second news story, the New Jersey Board of Public Utilities (NJBPU) has just **published the Evaluation Report on its State Agreement Approach (SAA)** for the selection of developers to connect offshore wind farms [6].

To provide some context, the regional TSO, PJM Interconnection LLC, launched solicitations and has already awarded the connection of the 3 offshore wind farms: Ocean Wind 1 (1,100 MW) in a first solicitation, and Atlantic Shores 1 (1,510 MW) and Ocean Wind 2 (1,148 MW) in a second one.

In 2021, a third solicitation was launched. The NJBPU evaluated the proposals received in response to the solicitation of offshore wind transmission solutions under the State Agreement Approach (SAA). The aim of this approach is to reduce costs and risks of delay. The SAA solicitation defined several scopes to which the transmission developers could respond: (1a) the reinforcement of the existing onshore grid, (1b) the construction of new onshore facilities, (2) the construction of the connection from onshore facilities to the offshore wind farms, (3) the construction of transmission links between the offshore substations.

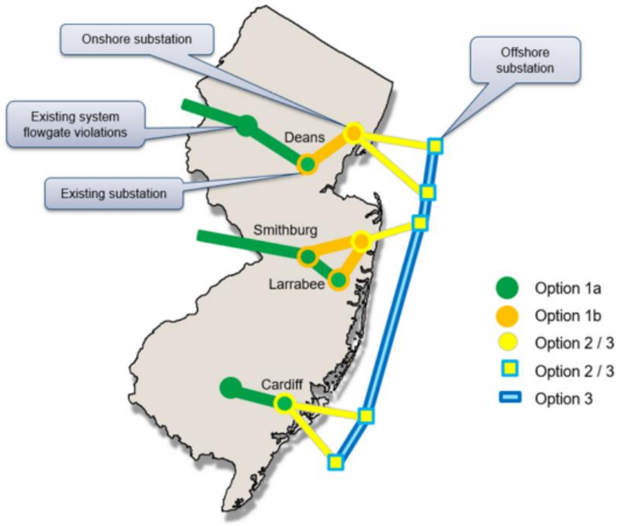

Figure 4: Illustrative offshore wind transmission layouts. Credit: PJM [7]

The NJBPU announced in October the selection for Option 1b of the Larrabee Tri-Collector Solution (LTCS) proposed by Mid-Atlantic Offshore Development (MAOD) and Jersey Central Power & Light Company [6].

The Evaluation Report details the SAA methodology here [7].

Reference:

5. https://nj.gov/governor/news/news/562022/approved/20220921a.shtml
6. https://nj.gov/bpu/newsroom/2022/approved/20221026.html
7. https://lnkd.in/drNqPp5b

ISO-NE state offshore wind

8.4 GW of offshore wind by 2040 target for ISO-NE states

Five New England states issued a Request For Information (RFI) on the development of thousands of megawatts of new transmission needed over the next 20 years to connect offshore wind farms and other clean energy resources [8].

The RFI outlines a "**modular**" framework, stating that the right solution will be "scalable, cost-effective, and flexible to accommodate up to 8.4 GW of current and future New England leaseholds." Solutions are expected to come operational with increments of 1.2 GW by 2040 [8].

The states are actively considering **HVDC solutions** in their offshore wind integration plan with some parameters already shown in the exhibit 1 of the document here [9].

Reference:

8. https://www.utilitydive.com/news/5-new-england-states-propose-modular-transmission-plan-to-incorporate-84/631199/
9. https://newenglandenergyvision.files.wordpress.com/2022/09/transmission-rfi-notice-of-proceeding-and-scoping.pdf

Links in development

EuroAsia Interconnector enters its construction phase

On the 14th of October 2022 in Nicosia, Cyprus, an official ceremony announced the **launch of the construction** of the EuroAsia interconnector [1010]. The interconnector is a 1,000 MW HVDC VSC **multi-terminal** project connecting the grids of Greece, Cyprus and Israel. It includes three converter stations connected by a 1,200 km submarine cable. The first phase will connect Cyprus to Greece, while the second phase will connect Cyprus to Israel. Completion is scheduled for the end of 2026. Once commissioned, it will be the deepest and longest submarine electricity interconnection in the world. Preferred bidders were selected for the first phase: Siemens Energy was announced in 2020 for the converters [11] and Nexans was announced in 2022 for the supply of the cables [12].

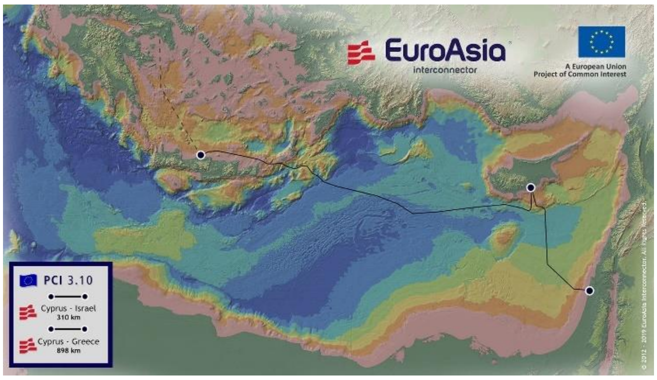

Figure 5: EuroAsia Interconnector route. Credit: EuroAsia Interconnector

Fast facts:

- 3 x 1,000 MW HVDC-VSC converters stations
- Bipole scheme with sea-electrode
- 1,208 km long ±500 kV DC submarine cable:
  - 310 km from Cyprus to Israel;
  - 898 km from Cyprus to Greece.

Reference:

10. https://ec.europa.eu/info/news/commission-participates-launch-euroasia-electricity-interconnector-2022-oct-14_en
11. https://euroasia-interconnector.com/preferredbidder/
12. https://www.nexans.com/en/newsroom/news/details/2022/07/nexans-selected-as-preferred-bidder-for-euroasia-interconnector.html

NeuConnect cable production starts

The NeuConnect Interconnector between the UK and Germany is a 1,400 MW HVDC-VSC project of around 725 km of land and submarine cables. It has been announced that the Prysmian Group has **started production of the cable** ahead of major construction work to begin in 2023 [13]. The project NeuConnect reached Financial Close in July 2022.

Reference:

13. https://neuconnect-interconnector.com/cabling-production-starts-on-neuconnect-in-important-milestone-for-first-ever-uk-german-energy-link/

Links in operation

North Sea Link in normal operation

The North Sea Link (NSL) interconnector between UK and Norway is now in **normal operation** after a year of trial operation since the October 1st, 2021 [14].

The 1,400 MW HVDC VSC link is the world's longest interconnector in VSC technology with a ±525 kV DC cable of 720 km undersea. This project allows Norway to import wind power from the UK and the UK to import hydropower from Norway.

During the year of trial operation 4.6 TWh was exported from Norway to the UK, while imports from the UK to Norway was 1.1 TWh [15].

Figure 6: North Sea Link. Credit: Hitachi Energy

Reference:

14. https://www.statnett.no/en/about-statnett/news-and-press-releases/news-archive-2022/nsl-interconnector-between-uk-and-norway-in-regular-operation/
15. https://www.offshore-energy.biz/north-sea-link-begins-regular-operations/

France-Italy first 600 MW link in service

The Savoie-Piémont HVDC interconnection became **partially operational** on November 7th, 2022, after seven years of work. It has been announced by RTE, the French transmission system operator. [16] This interconnection is composed of 2 VSC-HVDC links in symmetrical monopole topology at a total rating of 1200 MW. The first link of 600 MW has been put in service. The 2nd link is expected to be in full operation in 2023 [17].

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16. https://www.rte-france.com/actualites/mise-service-partielle-interconnexion-electrique-france-italie-savoie-piemont
17. https://www.rte-france.com/en/projects/savoie-piemont-190-km-of-european-solidarity-from-chambery-to-turin#Theproject

Recent papers

Book

Davide del Giudice, Federico Bizzarri, Daniele Linaro, Angelo Maurizio Brambilla, "**Modular Multilevel Converter Modelling and Simulation for HVDC Systems, State of the Art and a Novel Approach**", Springer Cham, 2023, https://doi.org/10.1007/978-3-031-12818-9

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1. Abdalrahman, Y. -J. Häfner, P. Maibach and C. Haederli, "**A Way Forward to Achieve Interoperability in Multi-Vendor HVDC Systems**," 2022 24th European Conference on Power Electronics and Applications (EPE'22 ECCE Europe), 2022, pp. 1-10.
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7. Z. Blatsi, S. Neira, S. Finney and M. M. C. Merlin, "**Comparative Evaluation of Partially-Rated Energy Storage Integration Topologies for High Voltage Modular Multilevel Converters**," 2022 24th European Conference on Power Electronics and Applications (EPE'22 ECCE Europe), 2022, pp. 1-9.
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IEEE Systems Journal

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Overview of HVDC-VSC Systems

Operational systems

Reference: VSC-HVDC Newsletter 06-2022, Prof. Mike Barnes. Supplemented and continuously updated by RTE international. New updates for this month are highlighted in blue.

	Name	Year Commissi-oned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
1	Hällsjön, Sweden	1997	3	±10	10	10 OHL	ABB	https://www.hitachienergy.com/about-us/case-studies/hallsjon-the-first-hvdc-light-transmission
2	Gotland, Sweden	1999	50	±80	77	70 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/the-gotland-hvdc-link
3	Eagle Pass, USA	2000	36	±15.9	138	Back-to-Back	ABB	https://www.hitachienergy.com/about-us/case-studies/eagle-pass
4	Direct Link / TerraNora, Australia	2000	3x60	±80	132/110	65 underground	ABB	https://www.hitachienergy.com/africa/en/about-us/case-studies/terranora-interconnector
5	Tjaereborg, Denmark	2000	7,2	±9	10,5	4,3 underground	ABB	https://www.hitachienergy.com/africa/en/about-us/case-studies/tjaereborg
6	Murraylink, Australia	2002	220	±150	132/220	180 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/murraylink
7	Cross Sound, USA	2002	330	±150	345/138	40 subsea	ABB	https://www.hitachienergy.com/africa/en/about-us/case-studies/cross-sound-cable
8	Troll A 1&2, Norway	2005	2x44	±60	56/132	70 subsea	ABB	https://www.hitachienergy.com/about-us/case-studies/troll-a
9	Estlink, Finland	2006	350	±150	400/330	74 subsea 31 underground	ABB	https://www.hitachienergy.com/africa/en/about-us/case-studies/estlink
10	Caprivi Link, Namibia	2010	300	±350	330/400	950 underground	ABB	https://www.hitachienergy.com/uk-ie/en/about-us/case-studies/caprivi-link
11	Trans Bay Cable, USA	2010	400	±200	230/138	85 subsea	Siemens	http://www.transbaycable.com/
12	Valhall, Norway	2011	78	±150	11/300	292 subsea	ABB	https://www.hitachienergy.com/about-us/case-studies/valhall
13	Nanhui, China	2011	18	±30	35/35	8,4 underground	C-EPRI	https://pdfs.semanticscholar.org/863e/f05fbffeb04965c8c4b77e2ed27f949fea30.pdf?_ga=2.167546302.1042474684.1664438832-2020044022.1663227250
14	BorWin1, Germany	2012	400	±150	170/380	125 subsea 75 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/borwin1
15	Nan'ao Island, China	2013	200, 150, 50	±160	110	Multi-terminal underground	RXHK, XiDian, NR-Electric	https://www.rxhk.co.uk/solutions/smart-vsc-hvdc-transmission/smart-vsc-hvdc-transmission/nanao-multi-terminal-vsc-hvdc/

	Name	Year Commissi-oned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
16	East West Interconnector, Ireland-UK	2013	500	±200	400/400	186 subsea 75 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/east-west-interconnector
17	Zhoushan, China	2014	400 300 3x100	±200	110/220	129 subsea	XuJi Electric/NR Electric	https://www.tdworld.com/digital-innovations/article/20969421/china-upgrades-capacity-to-the-zhoushan-islands
18	Mackinac, USA	2014	200	±71	138/138	Back-to-Back	ABB	https://www.hitachienergy.com/about-us/case-studies/mackinac
19	Skagerrak 4, Norway-Denmark	2014	700	±500	400/400	140 subsea 104 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/skagerrak
20	INELFE, France-Spain	2015	2x1000	±320	400/400	65 underground	Siemens	https://www.inelfe.eu/en/projects/baixas-santa-llogaia
21	Åland, Finland	2015	100	±80	110/100	158 subsea	ABB	https://www.hitachienergy.com/about-us/case-studies/aland
22	HelWin1, Germany	2015	576	±250	155/400	85 subsea 45 underground	Siemens	https://www.tennet.eu/projects/helwin1 https://www.realwire.com/releases/Successful-Commissioning-Of-BorWin2-And-HelWin1-HVDC-Grid-Connections
23	HelWin2, Germany	2015	690	±320	155/400	85 subsea 45 underground	Siemens	https://www.tennet.eu/projects/helwin2
24	Troll A 3&4, Norway	2015	2x50	±60	66/132	70 subsea	ABB	https://www.hitachienergy.com/about-us/case-studies/troll-a
25	SylWin1, Germany	2015	864	±320	155/400	160 subsea 45 underground	Siemens	https://www.tennet.eu/projects/sylwin1
26	BorWin2, Germany	2015	800	±300	155/400	125 subsea 75 underground	Siemens	https://www.tennet.eu/projects/borwin2
27	Dolwin1, Germany	2015	800	±320	155/380	75 subsea 90 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/dolwin1
28	Xiamen, China	2015	1000	±320	220	6 subsea 5 underground	C-EPRI	https://ieeexplore.ieee.org/document/7800677 https://www.power-technology.com/marketdata/xiamen-mainland-xiamen-island-hvdc-line-china/
29	Luxi, China	2016	1000	±350	500	Back-to-Back	China Southern Grid, RXHK (Yunnan) XD Group/IEECAS (Guangxi)	https://hvdcnewschina.blogspot.com/2017/09/luxi-hybrid-btb-converter-station.html https://www.rxhk.co.uk/solutions/smart-vsc-hvdc-transmission/smart-vsc-hvdc-transmission/yunnan-luxi-b2b/
30	NordBalt, Sweden	2017	700	±300	400/330	400 subsea 40+10 underground	ABB	https://www.hitachienergy.com/africa/en/about-us/case-studies/nordbalt
31	DolWin2, Germany	2017	916	±320	155/380	90 subsea 45 underground	ABB	https://www.hitachienergy.com/about-us/case-studies/dolwin2
32	Johan Sverdrup Phase 1, Norway	2018	100	±80	33/300	200 subsea	ABB	https://www.hitachienergy.com/about-us/case-studies/johan-sverdrup

	Name	Year Commissi-oned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
33	Caithness Moray, UK	2018	800 + 1200	±320	230/400	113 subsea 37 OHL	ABB	https://www.hitachienergy.com/about-us/case-studies/caithness-moray-hvdc-link
34	Maritime Link, Canada	2018	500	±200	230/345	180 subsea 187 OHL	ABB	https://www.hitachienergy.com/about-us/case-studies/maritime-link
35	DolWin3, Germany	2018	900	±320	155/400	83 subsea 78 underground	GE	https://www.tennet.eu/projects/dolwin3
36	Hokkaido-Honshu, Japan	2019	300	±250	275	24 underground 98 OHL	Toshiba	https://www.global.toshiba/ww/news/energy/2019/03/news-20190328-02.html
37	Yu'E, China	2019	4x1250	±420	/	Back-to-Back	RXHK, XuJi Electric and C-EPRI	https://www.rxhk.co.uk/corporate/news/yue-hvdc-commissioning-complete/ https://www.rxhk.co.uk/solutions/smart-vsc-hvdc-transmission/smart-vsc-hvdc-transmission/yue-b2b-hvdc/ https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8779807
38	COBRAcable, Denmark-Netherland	2019	700	±320	400/400	307 subsea 22 underground	Siemens	https://en.energinet.dk/Infrastructure-Projects/Projektliste/COBRAcable
39	BorWin3, Gemany	2019	900	±320	155/400	130 subsea 30 underground	Siemens	https://www.tennet.eu/projects/borwin3
40	NEMO, UK-Belgium	2019	1000	±400	400/380	130 subsea 10 underground	Siemens	https://www.nemolink.co.uk/
41	ALEGrO, Germany-Belgium	2020	1000	±320	380/380	90 underground	Siemens Energy	https://www.amprion.net/Grid-expansion/Our-Projects/ALEGrO/
42	Zhangbei Phase 1, China	2020	2x3000	±535	500/500	Multi-terminal 666 OHL	NR Electric, XuJi Electric, C-EPRI, SiFang and Hitachi ABB	https://www.hitachienergy.com/about-us/case-studies/zhangbei
43	Kriegers-Flak Combined Solution, Germany-Denmark	2020	410	±140	150/400	Back-to-Back	Hitachi ABB	https://en.energinet.dk/Infrastructure-Projects/Projektliste/KriegersFlakCGS https://www.hitachienergy.com/africa/en/about-us/case-studies/kriegers-flak-combined-grid-solutions--kf-cgs--hvdc
44	NordLink, Norway-Germany	2020	1400	±525	0/400/380	516 subsea 54 underground 53 OHL	Hitachi ABB	https://www.hitachienergy.com/about-us/case-studies/nordlink
45	KunLiuLong / Wudongde CSG, China	2020	5000 3000	±800	525	1452 for three terminals OHL	RXHK, Xuji, TBEA, NARI, Xidian	https://www.rxhk.co.uk/corporate/news/wudongde-uhvdc-scheme- commercial-operation/
46	IFA2, UK-France	2021	1000	±320	400/400	240 subsea	Hitachi ABB	https://www.hitachienergy.com/about-us/case-studies/ifa2 http://www.ifa2interconnector.com/ https://www.hitachiabb-powergrids.com/references/hvdc/ifa2

	Name	Year Commissi-oned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
47	SW Link, Sweden	2021	2x720	±300	400	190 underground 60 OHL	GE	https://www.gegridsolutions.com/products/applications/HVDC/South-West-Link-HVDC-case-study-EN-2015-10-Grid-PEA-0574.pdf https://www.svk.se/sydvastlanken
48	Rudong offshore wind farm, China	2021	1100	±400	220/500	100 subsea	RXHK, XJ Group	https://www.rxhk.co.uk/corporate/news/rudong-owf-hvdc-link-goes-live/ https://www.nrec.com/en/index.php/about/newsInfo/107.html
49	North Sea Link, Norway-UK	2021	1400	±515	420/400	720 subsea	Hitachi ABB	https://www.hitachienergy.com/about-us/case-studies/nsl-link http://www.northsealink.com/
50	Pugalur - Thrissur, India	2021	2x1000	±320	/	32 underground 170 OHL	Siemens Energy	https://assets.siemens-energy.com/siemens/assets/api/uuid:a6cb3b5d-ac70-41e9-8b9a-21e0968937b8/2021-11-24-hvdc-referenceflyer.pdf?ste_sid=65764bb21229d02112c445e071d12c5e https://www.nsenergybusiness.com/projects/raigarh-pugalur-trichur-high-voltage-direct-current-hvdc-transmission-project/
51	ElecLink, UK-France	2022	1000	±320	400/400	51 subsea	Siemens Energy	http://www.eleclink.co.uk/
52	Guangdong (partial), China	2022	2x1500	±300	/	Back-to-back	RXHK and partners	https://www.rxhk.co.uk/corporate/news/guangdong-b2b-contract-award/ http://global.chinadaily.com.cn/a/202206/14/WS62a7f8a3a310fd2b29e629e8.html

Future projects (details subject to change)

Reference: VSC-HVDC Newsletter 06-2022, Prof. Mike Barnes. Supplemented and continuously updated by RTE international. New updates for this month are highlighted in blue.

	Name	Year commissi-onned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
1	Johan Sverdrup Phase 2, Norway	2022	200	±80	110/300	200 subsea	Siemens Energy	https://ec.europa.eu/energy/sites/ener/files/documents/10._sharifabadi_kamran_-_multivendor_hvdc_links_supplying_oil_and_gas_installations.pdf
2	Baihetan-Jiangsu UHVDC, China	2022	1000	±400	800	2080 OHL	RXHK, NR-Electric, C-EPRI	https://www.rxhk.co.uk/corporate/news/baihetan-jiangsu-uhvdc-transmission-project-contract-award/
3	Savoie-Piedmont, Italy-France	2022	2x600	±320	/	190 underground	GE	https://www.gegridsolutions.com/products/applications/hvdc/france-italy-hvdc-link-casestudy-en-2018-02-grid-pea-1641.pdf
4	Zhangbei Phase 2, China	2022	2x1500	±535	500/500	Multi-terminal 666 OHL	/	https://www.hitachienergy.com/about-us/case-studies/zhangbei
5	Guangdong (remaining), China	2023	2x1500	±300	/	Back-to-back	RXHK and partners	https://www.rxhk.co.uk/corporate/news/guangdong-b2b-contract-award/ http://global.chinadaily.com.cn/a/202206/14/WS62a7f8a3a310fd2b29e629e8.html
6	Attica-Crete, Greece	2023	2x500	±500	150	335 subsea	Siemens Energy	https://www.admie.gr/en/erga/erga-diasyndeseis/diasyndesi-tis-kritis-me-tin-attiki https://www.nsenergybusiness.com/projects/attica-crete-hvdc-interconnector/ https://press.siemens-energy.com/eu/en/pressrelease/siemens-hvdc-power-bridge-will-connect-crete-mainland-greece
7	DolWin6, Germany	2023	900	±320	/	45 subsea 45 underground	Siemens Energy	https://www.tennet.eu/projects/dolwin6
8	Wando DongJeju Jeju Island, Korea	2023	200	±150	154	100 subsea	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/wando-dongjeju-3-hvdc-converter-station-project
9	Viking Link, UK-Denmark	2023	1400	±525	400/400	630 subsea 135 underground	Siemens Energy	http://viking-link.com/
10	Creyke Beck A, UK	2023	1200	±320	66/420	130 to 190 subsea	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/dogger-bank
11	Northconnect, UK-Norway	2024	1400	±500	400	655 subsea	/	http://www.northconnect.no/
12	Shetland, UK	2024	600	±320	132	267 subsea	Hitachi Energy	https://www.hitachiabb-powergrids.com/references/hvdc/shetland https://www.ssen-transmission.co.uk/projects/shetland/
13	SOO Green Rail, USA	2024	2100	±525	345/345	560 underground	Siemens Energy	https://soogreenhvdclink-os.com/about/
14	Project Lightning Das Island,	2024	2x1000	±400	132/400	150 subsea	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/project-lightning

	Name	Year commissi-onned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
	United Arab Emirates							
15	Ultranet, Germany	2024	2000	±380	400	340 OHL	Siemens Energy	https://www.amprion.net/Grid-expansion/Our-Projects/Ultranet/
16	Greenlink, UK-Ireland	2024	500	±320	/	190 subsea	Siemens Energy	https://www.greenlink.ie/ https://press.siemens-energy.com/global/en/pressrelease/siemens-energy-and-sumitomo-electric-supply-hvdc-technology-power-link-between-ireland
17	Creyke Beck B, UK	2024	1200	±320	66/420	130 to 190 subsea	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/dogger-bank
18	Norfolk Boreas, UK	2025	1800	/	66/400	~50 subsea ~60 underground	Siemens Energy	https://group.vattenfall.com/uk/newsroom/news-press-releases/pressreleases/stories/hvdc-for-norfolk-offshore-wind-farms https://www.nsenergybusiness.com/projects/norfolk-vanguard-offshore-wind-farm/
19	Sofia, UK	2025	1320	±320	400	220 subsea 7 underground	GE	https://www.ge.com/news/press-releases/ge-consortium-awarded-contract-to-build-state-of-the-art-hvdc-system-for-rwe-sofia-offshore-wind-farm
20	Norfolk Vanguard, UK	2025	1800	/	66/400	~50 subsea ~60 underground	Siemens Energy	https://www.nsenergybusiness.com/projects/norfolk-vanguard-offshore-wind-farm/
21	Champlain Hudson Power Express, USA	2025	1250	±400	/	330 subsea 220 underground	Hitachi Energy	https://chpexpress.com/ https://www.hitachienergy.com/ch/de/news/press-releases/2022/09/hitachi-energy-to-support-major-renewable-electricity-transmission-between-canada-and-new-york-city
22	Egypt-Saudi Arabia, Egypt-Saudi Arabia	2025	2x1500	±500	0//	22 subsea 1350 OHL	Hitachi Energy	https://www.hitachienergy.com/news/press-releases/2021/10/hitachi-abb-power-grids-consortium-awarded-major-contract-for-the-first-ever-large-scale-hvdc-interconnection-in-the-middle-east-and-north-africa
23	Project Lightning Al Ghallan, United Arab Emirates	2025	2x600	±320	/	140 subsea	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/project-lightning
24	Mumbai, India	2025	1000	±320	200/400	50 underground 20-30 OHL	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/mumbai
25	Sunrise wind, USA	2025	924	±320	/	160 subsea	Siemens Energy	https://www.4coffshore.com/news/newsItem.aspx?nid=24409
26	BorWin 5, Germany	2025	900	±320	/	120 subsea 110 underground	Siemens Energy	https://www.tennet.eu/our-grid/offshore-projects-germany/borwin5/
27	DolWin5, Germany	2025	900	±320	66/380	100 subsea 30 underground	Hitachi Energy	https://www.tennet.eu/projects/dolwin5 https://www.hitachienergy.com/about-us/case-studies/dolwin-5

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28	EuroAsia Interconnector, Israel-Cyprus-Greece	2026	2000	/	/	Multi-terminal 310+898 subsea 13+10 underground	Siemens Energy	http://www.euroasia-interconnector.com/
29	Creyke Beck C, UK	2026	1200	±320	66/420	196 subsea 7 underground	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/dogger-bank
30	SuedOstLink, Germany	2026	2000	±525	/	580 underground	Siemens Energy	https://www.50hertz.com/en/Grid/Griddevelopement/Onshoreprojects/SuedOstLink https://www.tennet.eu/de/projekte/suedostlink
31	Celtic Interconnector , France-Ireland	2026	700	±320 to ±500	220/400	500 subsea 75 underground	/	http://www.eirgridgroup.com/the-grid/projects/celtic-interconnector/the-project/
32	A-Nord Germany, Germany	2027	2000	±525	380	300 OHL	/	https://a-nord.amprion.net/Projekt/
33	PGCIL Pang - Kaithal, India	2027	2x2500	/	/	/	/	https://www.thehindubusinessline.com/news/power-ministry-clears-leh-kaithal-green-energy-transmission-corridor/article64906313.ece
34	Xlinks1, Moroco-UK	2027	2x1800	/	/	3800 subsea	/	https://xlinks.co/
35	Altantic Shore 2 (Monmouth ECC), USA	2027	1510	±320 to ±500	66 to 150 / 230 to 275	138 subsea 19 underground	/	https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Atlantic-Shores-COP-Volume-1-Project-Description.PDF
36	Suedlink – DC3, Germany	2027	2000	±525	400/400	700 underground	Siemens Energy	https://www.transnetbw.de/de/suedlink https://www.tennet.eu/de/projekte/suedlink
37	Marex, UK-Ireland	2027	750	±400	/	245 underground	/	https://tyndp.entsoe.eu/tyndp2018/projects/projects/349
38	Suedlink – DC4, Germany	2027	2000	±525	400/400	550 underground	Hitachi Energy	https://www.transnetbw.de/de/suedlink https://www.tennet.eu/de/projekte/suedlink https://www.hitachienergy.com/about-us/case-studies/suedlink-dc4
39	AAPowerLink, Australia-Singapore	2027	3000	/	/	4200 subsea 800 OHL	/	https://aapowerlink.sg/
40	Gridlink, UK-France	2027	1400	/	400	140 subsea 20 underground	/	https://gridlinkinterconnector.com/
41	Borwin 6, Germany	2027	980	±320	/	190 subsea 45 underground	GEIRI/C-EPRI	https://www.tennet.eu/news/tennet-awards-land-and-sea-station-grid-connection-project-borwin6-international-consortium
42	Biscay Gulf Link, France-Spain	2027	2200	/	/	300 subsea 80+13 underground	/	https://www.inelfe.eu/en/projects/bay-biscay
43	Western-Isles Scotland, UK	2027	450	±320	150	80 subsea 76 underground	/	https://www.ssen-transmission.co.uk/projects/western-isles/ https://www.ssen-transmission.co.uk/media/6760/arnish-booklet-artwork-digi-single-pages.pdf

	Name	Year commissi-onned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
44	Hornsea 3, UK	2027	2 x 1320	±320	66/400	120 subsea	Hitachi Energy	https://www.hitachienergy.com/news/press-releases/2022/07/hitachi-energy-wins-order-to-connect-one-of-the-world-s-largest-offshore-wind-farms-to-the-uk-power-grid?utm_source=linkedin&utm_medium=social&utm_campaign=bu:global-~cc:global-~cn:grid-integration---hvdc
45	Centre Manche, France	2028	2x1250	±320	/	/	/	https://www.eoliennesenmer.fr/sites/eoliennesenmer/files/fichiers/2022/01/Perspectivesdedeveloppement_reseauelectriqueenmer_facadenormande_janvier2022_0.pdf
46	Marinus Link stage 1, Australia	2028	750	/	/	255 subsea 90 underground	/	https://www.marinuslink.com.au/ https://www.offshore-energy.biz/aemo-marinus-link-should-be-built-urgently-to-deliver-clean-energy/
47	BorWin 4, Germany	2028	900	±320	/	130 subsea 130 underground	Siemens Energy	https://press.siemens-energy.com/global/en/pressrelease/wind-power-18-million-people-siemens-energy-wins-largest-grid-connection-order-date https://www.amprion.net/Press/Press-Detail-Page_44160.html
48	DolWin4, Germany	2028	900	320	/	60 subsea 150 underground	Siemens Energy	https://press.siemens-energy.com/global/en/pressrelease/wind-power-18-million-people-siemens-energy-wins-largest-grid-connection-order-date https://www.amprion.net/Press/Press-Detail-Page_44160.html
49	Higashi-Shimizu, Japan	2028	600	/	275	Back-to-back	Hitachi Energy	https://www.hitachienergy.com/about-us/case-studies/higashi-shimizu
50	Neuconnect, UK-Germany	2028	1400	±500	400	725 subsea	Siemens Energy	https://neuconnect-interconnector.com/
51	Nautilus, UK-Belgium	2028	1400	/	/	/	/	https://www.nationalgrid.com/national-grid-ventures/interconnectors-connecting-cleaner-future/nautilus-interconnector
52	Beacon Wind 1, USA	2028	1230	/	/	/	/	https://www.rechargenews.com/wind/equinor-and-bp-to-pioneer-high- voltage-offshore-wind-export-lines-in-us-atlantic/2-1-1012225
53	FAB Link, UK-France	2028	2x700	±320	400/400	170 subsea 15+25 underground	/	http://www.fablink.net/
54	Eastern Green Link 2, UK	2029	2000	±525	/	440 subsea 67 underground	/	https://www.ssen-transmission.co.uk/projects/eastern-green-link-2/
55	Xlinks, Moroco-UK	2029	1800	/	/	3800 subsea	/	https://xlinks.co/
56	BalWin3, Germany	2029	2000	±525	/	/	/	https://www.tennet.eu/2gw-program-0
57	BalWin1, Germany	2029	2000	±525	/	140 subsea 80 underground	/	https://www.offshorewind.biz/2021/06/11/tennet-issues-offshore-wind-contract-notices/
58	BalWin4, Germany	2029	2000	±525	/	/	/	https://www.tennet.eu/2gw-program-0

	Name	Year commissi-onned	Power (MW)	Voltage DC (kV)	Voltage AC (kV)	Transmission Length (km)	Converter Manufacturer	Reference
59	BalWin2, Germany	2030	2000	±525	/	/	/	https://www.tennet.eu/2gw-program-0
60	Marinus Link stage 2, Australia	2030	750	/	/	255 subsea 90 underground	/	https://www.marinuslink.com.au/ https://www.offshore-energy.biz/aemo-marinus-link-should-be-built-urgently-to-deliver-clean-energy/
61	IJMUiden Alpha, Netherlands	2030	2000	±525	/	/	/	https://netztransparenz.tennet.eu/tinyurl-storage/detail/tennet-develops-first-2gw-offshore-grid-connection-with-suppliers/
62	Eurolink, UK-Netherlands	2030	1400	/	/	/	/	https://www.nationalgrid.com/national-grid-ventures/interconnectors-connecting-cleaner-future-old
63	Altantic Shore 1 (Altantic ECC), USA	2030	1510	±320 to ±500	66 to 150 / 230 to 275	40 subsea 19 underground	/	https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Atlantic-Shores-COP-Volume-1-Project-Description.PDF
64	IJMUiden Beta, Netherlands	2030	2000	±525	/	/	/	https://netztransparenz.tennet.eu/tinyurl-storage/detail/tennet-develops-first-2gw-offshore-grid-connection-with-suppliers/
65	East Anglia 3, UK	2030	1400	/	/	/	Siemens Energy	https://www.offshore-mag.com/renewable-energy/article/14204028/aker-solutions-siemens-energy-to-deliver-uk-north-sea-east-anglia-three-offshore-wind-hvdc-stations
66	Atlantic SuperConnection, Iceland-UK	2030	1300	/	/	1500 subsea	/	https://atlanticsuperconnection.com/
67	LanWin1, Germany	2031	2000	±525	380	170 subsea 220 underground	/	https://offshore.amprion.net/Offshore-Projekte/LanWin1-LanWin3/
68	LanWin3, Germany	2033	2000	±525	380	160 subsea 230 underground	/	https://offshore.amprion.net/Offshore-Projekte/LanWin1-LanWin3/
69	LanWin5, Germany	2035	2000	±525	/	approx. 500 underground	/	https://data.netzausbau.de/2035-2021/NEP2035_Bestaetigung.pdf
70	SENER-BC, Mexico	Pre-tender	1500	±500	/	700 underground	/	https://www.whitecase.com/insight-alert/mexicos-first-transmission-ppp-tender
71	HIP Atlantic Project, USA	In planning	4x1000	/	/	/	/	https://www.4coffshore.com/news/102c000-mw-wind-project-planned-for-north-atlantic-nid23555.html
72	Aquind, UK-France	In planning	2x1000	±320	400	242 subsea	/	http://aquind.co.uk/
73	Schleswig-Holstein / Mecklenburg-Vorpommern, Germany	In planning	4000	±525	/	200 underground	/	https://www.50hertz.com/en/News/Details/12105/50hertz-and-tennet-to-jointly-bring-wind-power-from-the-north-sea-into-the-extra-high-voltage-grid-for-the-first-time
74	Grain Belt Express, USA	In planning	4000	/	/	1280 underground	/	https://grainbeltexpress.com/
75	AWC, USA	Being considered	1000	±320	/	Multi-terminal subsea	/	https://www.transmissionhub.com/articles/transprojects/atlantic-wind-connection

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76	Greenconnector, Switzerland-Italy	Being considered	1000	±400	/	150 underground	/	http://www.greenconnector.it/
77	Lake Erie, USA	Being considered	1000	/	/	117 subsea	/	https://www.itclakeerieconnector.com/
78	Tres Amigas, USA	Being considered	3x750	±300	345	Back-to-back	/	http://www.tresamigasllc.com/