B4 Newsletter – 30th of June 2023

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1. Recent B4 Activities and Upcoming Events

Upcoming B4 Events

2023 Meeting & B4 Colloquium

Vienna, Austria, September 9-15, 2023

The SC B4 2023 meeting and Colloquium will be held in Vienna, Austria. Dates are September 9 to 15, 2023. Events to take place include working group meetings, SC-B4 meeting, Colloquium, Tutorials and a Technical tour.

More information can be found at:

https://cigre-b4-vienna2023.at/wp-content/uploads/2023/07/Conference_Book_CGIREB4SCMeeting_Vienna_03072023-small.pdf

REGISTRATION IS OPEN!

More information can be found here: B4-Colloquium Vienna 2023 (cigre-b4-vienna2023.at)

The following Working Groups are planning to meet:

Saturday (SEPT 9th):

- B4.89 (Nadine Chapalain) – 9AM-5PM
- B4/C4.93 (Decaho Kong) – 9AM-5PM
- B4.94 (Arash FazelDarbandi) – 9AM-5PM

Sunday (SEPT 10th):

- B4.81 (Kamran Sharifabadi) – 9AM-1PM
- B4.87 (Carl Barker) – 9AM-5PM
- B4.90 (Les Brand) – 9AM-5PM
- B4.94 (Arash FazelDarbandi) – 9AM-5PM
- B4-AG01 (Joanne Hu) – 8AM-10AM
- B4-AG04 (Lyle Crowe) – 9AM-1PM
- B4-WiE (Rebecca Ostash) – 10:30-11:30AM
- Green Book (Stig Nilsson) – 2PM-5PM
- B4.AG04-TF4 (Sergio E. Santo) – 1PM-5PM
- B4.79 (Hong Rao) – 9AM-5PM

Recent Activities from CIGRE National Panels

The Brazilian National committee informs the following two events :

- XXVII National Seminar on Production and Transmission of Electric Energy (XXVII SNPTEE) : XXVII Snptee 2023 : xxviisnptee-com-br.translate.goog

- XIX "CIGRE Ibero-American Regional Meeting" : XIX ERIAC - XIX CIGRE Ibero-American Regional Meeting: www-xixeriac-com-br.translate.goog

The first event (SNPTEE) is Brazil's largest power systems event (occurs biannually), and the latter is a large regional event involving several Portuguese and Spanish speaking National Committees (also biannual).

2. Updates on ongoing WGs

WG B4-84 Feasibility study and application of electric energy storage systems embedded in HVDC systems

Convenor - Hani SAAD, FR

The number of Battery Energy Storage Systems (BESS) and supercapacitor systems connected to power systems is rapidly increasing worldwide. This growth can be attributed to their ability to facilitate the integration of intermittent Renewable Energy Sources (RES) and provide enhanced energy efficiency. Currently, energy storage systems predominantly employ 2-level or 3-level VSC topologies for their energy conversion components. However, this brochure aims to explore the potential of incorporating energy storage in multilevel converter (such as MMC) topologies, as well as integrating energy storage in HVDC and Statcom systems. These advancements would expand the capabilities of these systems and improve their ancillary services.

When considering HVDC systems, there are intriguing options for deciding where to interconnect the Energy Storage (ES) systems. Depending on the design, requirements, specifications, and cost, ES can be placed in various locations within the HVDC substation. Assuming the utilization of MMC technology, ES can be integrated within the submodules of the MMC, either on the AC or DC side of the converter. Figure 1 presents a schematic depicting the three primary locations for ES integration:

- **Option 1 – ES integrated in the AC converter station:** The ES can be interfaced with an additional AC/DC power converter in the AC converter substation of a HVDC link. This option can be considered as an ES-STATCOM augmented with an ES.
- **Option 2 and 3- ES integrated at DC side of the converter station or into a DC network:** The ES can be integrated into the DC link of the HVDC substation (or in a DC grid) and interfaced through a DC/DC converter.
- **Option 4 – ES**. **integrated inside the converter:** The ES can be combined with the main HVDC converter submodules. Depending on the energy requirements, the submodule topology might need to be adapted.

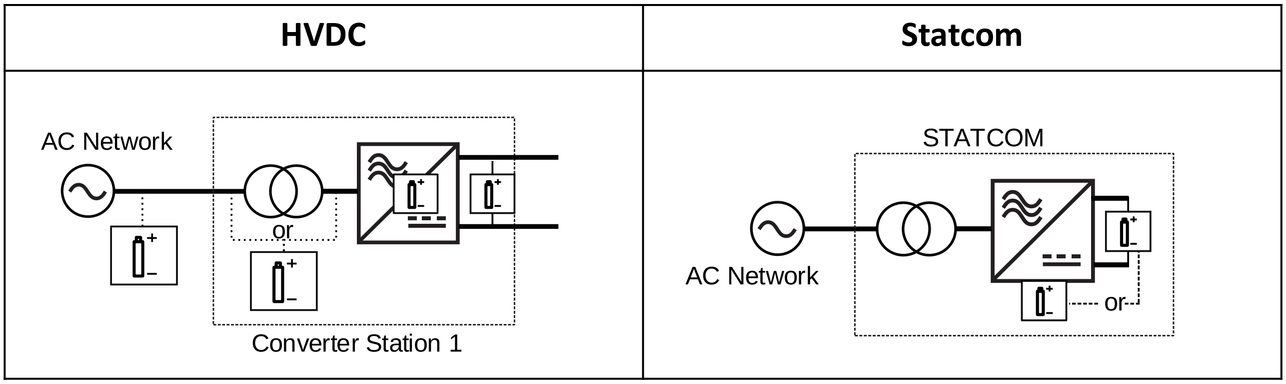

Figure 1 ES potential locations in an HVDC and STATCOM substations.

The WG is in the finalization stage. The table of contents of the upcoming brochure is the following:

1. Introduction and scope
2. Background
3. Application, benefits and motivation
4. Power Electronic converter Interfaced energy storage technologies
5. Modular Converter Topologies with Energy Storage for STATCOM & HVDC Applications
6. Additional Challenges regarding ES-HVDC and ES-Statcom
7. Modeling
8. System studies
9. Conclusion

3. New WGs and TFs

WG B4.94 - Developments in Power Semiconductor Technologies and Applications in HVDC/FACTS

Convenor - Joerg DORN, Germany

Semiconductor power devices for use in HVDC and FACTS has been covered previously in CIGRE Technical Brochure 112 published in 1997. The technology of semiconductors has been further advanced over the last 20 years in terms of materials and ratings which has enabled the increased applications of VSC technologies in high voltage and high power HVDC transmission system which is playing the most important role in green energy transition. Wide bandgap semiconductors such as silicon carbide might also be an option in the future providing new chances and challenges. This WG will provide a technical overview of semiconductor devices and materials, their control, and interactions to other components including an update on the technology of semiconductors as well as their influence on the power electronic system behaviour and properties.

WG B4.95 - HVDC connection of power system with high proportion of photovoltaic (PV) generation

Convenor - Qi GUO, China

Photovoltaics (PV), as a clean and renewable energy source, have become a vital implementation of the global energy transition. Large-scale photovoltaic energy utilizing VSCHVDC transmission technology can effectively address the grid fluctuation and instability, presenting a vast range of application prospects. Despite the technical challenges associated with VSC-HVDC technology, sustaining technological innovation are expected to play a crucial role in the future of HVDC connection of large-scale photovoltaic power generation. This working group will briefly describe the difference between PV and wind power infeed in terms of HVDC connection but with focus on the technical requirements and solutions for HVDC connection of the power system with high proportion PV generation.

WG C4/A3/B2/B4.75 - Guide to procedures for the creation of contamination maps required for outdoor insulation coordination

Convenor - Massimo MARZINOTTO, Italy

Many countries are facing the need to create a contamination map and are proceeding with different approaches, including traditional methods of direct contamination measurements on insulators, but also indirect contamination measurements (dust deposit gauges), leakage current measurements, salt and dust transportation modelling in combination with meteorological data and satellite data. A review of such methods with particular attention to the new approaches based on a mixture of measurements and inference through specific numerical models should be collected by CIGRE with the aim to report the state of the art, discuss pros and cons of each solution and provide guidelines to aid practitioning engineers when conducting this type of analysis.

Contamination maps are essential to optimise the insulator design from the contamination point of view, thus increasing the system reliability and reducing the overall costs deriving from over or under design. The main objective of the JWG is to analyse and compare the experience in the different countries and approaches to give guidelines for the creation of contamination mapping for use in insulation co-ordination and to stress the advantages of the statistical approach for insulator design.

TF B4/B1/B3/C4/D1.95 - Harmonization of voltage designations and definitions across different HVDC component technologies

Convenor - Bruno BISEWSKI, Canada

Differences in voltage designations and definitions between HVDC cable systems and HVDC gas insulated systems (GIS) HVDC substations (IEC TC17) or HVDC Converter stations have come to light. These differences lead to confusion during system integration, thus increase the possibility of interface compatibility issues, and should ideally be avoided. Thus, SC B1, B3, B4, C4 and D1 have agreed to form a joint task force with B4 in lead to address the above issue This JTF will investigate and try to harmonize the different voltage designations and definitions across major HVDC components, to reduce the risk of potentially costly misunderstandings, and to simplify HVDC grid integration and support the uptake of multi-terminal and multi-vendor systems. The scope of the JTF will cover the main HVDC converter station equipment such as converter, transformer as well as HVDC cable and accessories, overhead line (OHL), HVDC GIS, AC/DC switchgear, DC bushings and instrument transformers for both VSC and LCC HVDC systems.

4. News on HVDC Projects and Status

This section is provided by RTE-international and extracted from the HVDC-VSC newsletter

UK offshore wind

Dogger Bank A platform is installed offshore in the North Sea

Heerema Marine Contractors' offshore installation vessel Thialf has installed the first 1.2GW platform for the Dogger Bank A wind farm in the UK North Sea [1].

The platform will convert AC power from 95 offshore wind turbines into DC power, which will be exported 146 km away to an onshore converter station near Beverley, in the East Riding of Yorkshire.

Figure 2: Dogger Bank topside. Credit: SSE [2]

Regarding the other sets, Aibel is expected to deliver the Dogger Bank B offshore substation in Q2 2024 and the Dogger Bank C offshore substation in Q2 2025 [1]. Furthermore, the **operation and maintenance (O&M) base for the whole Dogger Bank wind farm (A, B and C) was officially opened** last month in the port of Tyne, UK. The O&M base houses the control room that will monitor and manage 3.6 GW of wind capacity, representing almost five per cent of the UK's electricity generation capacity.

The Dogger Bank Wind Farm is a joint venture between SSE Renewables (40%), Equinor (40%) and Vårgrønn (20%).

Reference:

1. https://doggerbank.com/construction/worlds-first-unmanned-hvdc-offshore-platform-installed-at-worlds-largest-offshore-wind-farm/
2. https://www.sserenewables.com/news-and-views/2023/04/world-s-first-unmanned-hvdc-offshore-platform-installed-at-world-s-largest-offshore-wind-farm/

German interconnector

SuedOstLink starts building the first converter

The SuedOstLink (SOL) is a joint project between transmission system operators, 50Hertz and TenneT, which will transport up to 2 GW of renewable energy from wind farms in the north-east of Germany to the south through a 540 km underground cable connection. A second HVDC line will run parallel to the SOL, and the two lines will transport around 4 GW of electricity at a voltage level of ±525 kV.

Last month, an official ceremony announced the start of work on the first HVDC converter in Wolmirstedt. The converter is scheduled to be completed in 2025, and the entire system is expected to be commissioned in 2027 [6].

Siemens Energy has been awarded the supply of the bipole converters [7], while the HVDC cables are being supplied by NKT and Prysmian [8].

Figure 3: SuedOstLink route overview. Credit: TenneT

Reference:

3. https://www.50hertz.com/en/News/FullarticleNewsof50Hertz/13316/starting-signal-given-for-european-electricity-highway-converter-for-suedostlink-connection-enters-construction-phase
4. https://press.siemens-energy.com/global/en/pressrelease/siemens-energy-makes-renewable-energy-transportable-german-suedostlink-electricity
5. https://www.4coffshore.com/news/prysmian-and-nkt-secure-suedostlink-contracts-nid17303.html

Italy, Sicily and Sardinia interconnector

Siemens Energy selected to supply converter of the Tyrrhenian Link

The Tyrrhenian Link is a multi-terminal HVDC project consisting of two 1 GW links that will connect the Italian mainland to Sardinia through Sicily, via 970 km of submarine cable.

The Italian TSO Terna has awarded a contract for the supply of four converter stations to the consortium of Siemens Energy and the Italian company FATA [10].

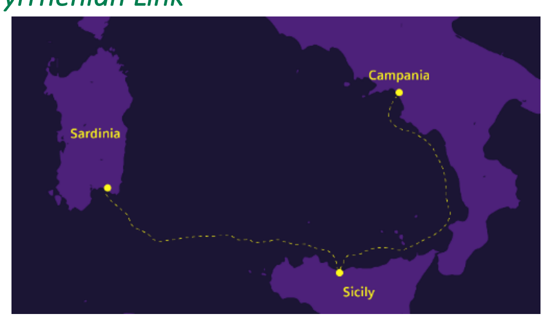

Figure 4: Tyrrhenian Link cable route Credit: Siemens Energy [10]

Siemens Energy will manufacture the main components of the four stations in Europe, such as converters, transformers and switchgear. The consortium partner FATA, in a sub-consortium with the Italian construction companies Impresa Manca Costruzioni Generali S.p.A. and Pizzulo Costruzioni s.r.l., will be responsible for the civil works, the electromechanical installation, the construction of the auxiliary facilities and the pre-commissioning support.

The Tyrrhenian Link contract is the company's first HVDC project in Italy. Construction of the conversion stations is scheduled for completion by the end of 2028.

Reference:

10. https://press.siemens-energy.com/global/en/pressrelease/ramping-renewable-energy-siemens-energy-connects-italys-largest-islands-mainland

New HVDC cable factory

LS Cable & System inaugurates a new HVDC cable factory

LS Cable & System, the South Korean cable manufacturer, has completed Asia's largest submarine HVDC cable factory in Donghae, Gangwon Province, South Korea [6].

The plant, named Submarine Building 4, is a 172 metre high continuous vertical vulcanisation (CVV) tower with a total area of 34,816 square metres. Some 190 billion Won (~$141 million) has been invested into the construction, which began in July 2021 [6].

Figure 5: LS Cable & System HVDC cable factory in Donghae, Corea. Credit: LS Cable & System [6]

Reference:

6. https://www.lscns.com/en/pr/news_view.asp?brd_id=news1&pageNo=1&mode=MOD&idx=116236&lang_cd=en&searchKey=1&searchValue=

Hornsea Three

Hornsea Three offshore substations construction begins

Hornsea Three is a 2,852 MW offshore wind farm developed by Ørsted that will be built 120 kilometres off the north coast of Norfolk, UK. In 2022, Aibel was selected on an EPCI contract for the two offshore platforms (Hornsea 3 Link 1 and 2). The project is being managed from Aibel's office in Oslo, while the construction of the two platform topsides is taking place at Aibel's yard in Thailand.

The First steel Cut Ceremony took place on 20 April, initiating the construction of the two offshore substations. Once built, the topsides will then be transported to Haugesund, Norway, where they will be equipped with Hitachi Energy's HVDC converter valve technology before final completion. The offshore wind farm is expected to be fully commissioned by 2027.

Reference:

7. https://www.offshorewind.biz/2023/04/24/aibel-starts-building-hornsea-three-offshore-substations/

USA onshore transmission

Hitachi Energy selected for SunZia Transmission

SunZia Wind and Transmission is a 3,500 MW wind farm project in central New Mexico, USA, combined with a 3,000 MW HVDC transmission line to the neighbouring western state of Arizona, US.

Hitachi Energy has been selected to supply the HVDC converter stations. Quanta was selected to provide the 550 miles of 525 kV HVDC transmission line. In addition, Blattner Company, a Quanta operating company, was selected for the SunZia wind facility and associated switchyard, which includes the installation of more than 900 turbines, ten substations, several operation and maintenance facilities, and more than 100 miles of wind generation transmission lines.

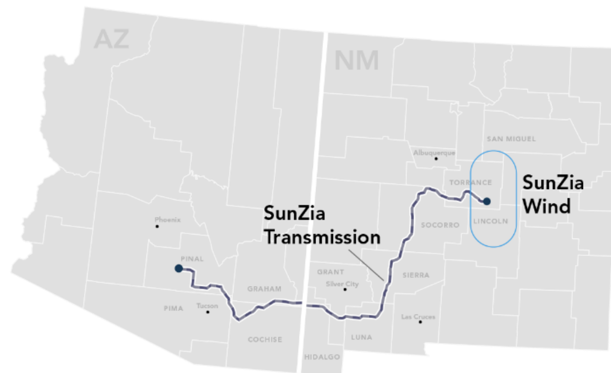

Figure 6: SunZia Transmission cable route. Credit: Pattern Energy Group LP

The SunZia Transmission will enable SunZia Wind to supply customers in Arizona and California during the critical early evening hours when demand is high but available renewable energy supply is low.

Reference:

8. https://patternenergy.com/pattern-energy-selects-epc-contractors-for-americas-largest-clean-energy-infrastructure-project/

TenneT 2 GW standard

NKT, Nexans and LS Cable selected to supply cables for nine TenneT's 2 GW standard

Following last month's announcements of HVDC converter suppliers for the fourteen 2 GW projects [9], TenneT has now awarded cable supplier contracts for nine of these projects [10]. This announcement complements the five projects that were already awarded in March 2023 to NKT and Prysmian [11].

The suppliers' contracts include cable design, engineering, production, delivery, project management, onshore, offshore and near-shore installation of ±525 kV HVDC cables, and all jointing work in the offshore and onshore sections. This represents approximately 7,000 km of cable with a total value of €5.5 billion [10].

In terms of planning, the suppliers expect to begin activities this year. Cable-laying activities are expected to start after 2025 for onshore work, and in 2026 for offshore work. All 2 GW offshore projects are planned to be operational by 2031 [10].

The award-winning supplier and associated projects are [10]:

- **NKT** on three Dutch projects: Nederwiek 3, Doordewind 1, Doordewind 2
- **Nexans** on three German projects: BalWin3, LanWin4, LanWin2,
- The **Jan De Nul/LS Cable/Denys** consortium on three German projects: BalWin4, LanWin1, LanWin5

The consortium has also been awarded the contract for the TenneT part of the onshore 525 kV DC corridor **NordOstLink** – a partner project with 50Hertz expected to be operational by 2032 [10].

Reference:

9. https://www.tennet.eu/news/around-eu30-billion-europes-largest-ever-contracting-pack-age-security-supply-energy
10. https://www.tennet.eu/news/tennet-accelerates-grid-expansion-and-energy-transition
11. https://www.tennet.eu/news/tennet-selects-nkt-and-prysmian-worlds-largest-offshore-cable-systems-connect-increasing-dutch

North Sea Summit

Nine European countries target 300 GW of energy capacity in the North Sea by 2050

Nine European countries - Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, and the UK - met at the North Sea Summit in Ostend, Belgium on the 24th April, 2023. They shared the common ambition of making the North Sea one of Europe's green power plants and committed to increasing the target combined offshore energy capacity to **120 GW by 2030** and **300 GW by 2050** [12].

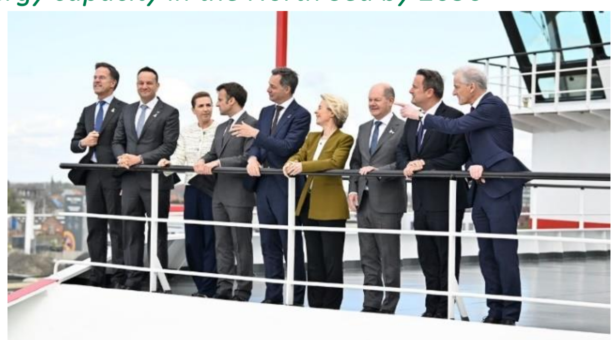

Figure 7: Nine European countries' leaders at the North Sea Summit in Ostend, Belgium. Credit : North Sea Summit

This announcement follows the Esbjerg Declaration at the April 2022 North Sea Summit. Belgium, Denmark, Germany, and the Netherlands came together to announce a combined offshore energy capacity of 65 GW by 2030 and 150 GW by 2050. Moreover, the TSOs of the respective countries have very recently published a technical note to implement these targets [13].

In this new major declaration, the original four countries were joined by France, Norway, the UK, Ireland, and Luxembourg and together they double the capacity originally planned last year [12]. This ambition is formalised in two political declarations: the official Ostend Declaration [14] and a more detailed Energy Minister Declaration [15].

Meanwhile, more than 100 companies representing the entire European offshore wind and renewable hydrogen value chain said in an Industry Declaration [16] that they endorse the ambition of the nine governments, but also underline the urgent need to strengthen Europe's wind energy manufacturing capacity to meet this ambition [16].

To better appreciate these figures, the current installed offshore wind capacity in the North Sea is 30 GW [12]. According to the Industry Declaration [16], the offshore renewable industry supply chain can currently deliver around 7 GW per year and will need to reach 20 GW per year by the second half of this decade.

Reference:

12. https://windeurope.org/newsroom/press-releases/eu-leaders-meet-in-ostend-to-agree-rapid-build-out-of-offshore-wind-in-the-north-seas/
13. https://offshore.amprion.net/Offshore-Vernetzung/EsbjergCooperation_booklet-online.pdf
14. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1154445/ostend-leaders-declaration.pdf
15. https://kefm.dk/Media/638179241345565422/Declaration%20ENERGY_FINAL_21042023.pdf
16. https://windeurope.org/wp-content/uploads/files/policy/position-papers/20230424-Offshore-Renewable-Industry-Declaration.pdf

DC transmission line in Germany

Foundation stone laid for one of Ultranet's converter stations

The **Meerbusch-Osterath HVDC converter** in Germany officially started construction on May 31st, 2023 [17]. This will be Germany's first multi-terminal converter, linking two major HVDC projects in north-west and south-west Germany: A-North and Ultranet.

A-North is a 2,000 MW link that will run 300 km via an underground cable from Emden in Lower Saxony on the North Sea coast to Meerbusch-Osterath in North Rhine-Westphalia, enabling offshore wind power to be transported further south. Work is planned to start in 2024, with commissioning scheduled for 2027 [18].

Ultranet is extending the A-North link further south by transmitting 2,000 MW over 340 km of 380 kV DC overhead line in parallel with a 380 kV AC line to the city of Phillipsburg in Baden-Württemberg. This project, in collaboration with TransnetBW, has just begun construction and should be come into operation in 2026 [18].

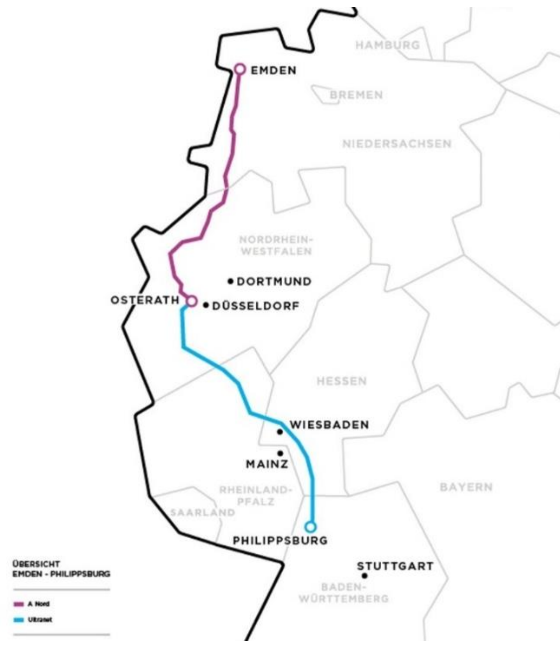

Figure 8: A-Nord and Ultranet route

Reference:

17. https://www.amprion.net/Presse/Presse-Detailseite_53056.html
18. https://a-nord.amprion.net/

NEOM Saudi Arabia

Hitachi Energy selected to supply ENOWA NEOM 3 GW projects

NEOM is one of Saudi Arabia's major projects being developed in the north-west of the country by the Saudi utilities company ENOWA [19].

To supply power to this massive project, in 2022 ENOWA appointed the Saudi Electricity Company (SEC) as EPCM to build one of the world's first 3 GW, 525 kV HVDC transmission systems linking Oxagon to the Yanbu region, more than 650 kilometres further south in Saudi Arabia [19].

Figure 9: Hitachi Energy, ENOWA and Saudi Electricity Company sign agreement. Credit: Hitachi Energy [19]

SEC and ENOWA recently signed an agreement with Hitachi Energy for the design, engineering, supply of HVDC equipment, and commissioning of the converter stations (EPCM), together with its consortium partner, Saudi Services for Electro Mechanical Works (SSEM), one of Saudi Arabia's leading EPC companies specialising in energy, water, and industrial projects, which will be responsible for the design and supply of AC equipment, as well as construction and installation [19].

In addition to this, Hitachi Energy and ENOWA have also signed a preliminary works and capacity reservation agreement for two additional HVDC projects of 3 GW each. Under this agreement, the two companies commit to providing the resources and capacity required to implement these two HVDC systems. As a result, the three HVDC links will have a total capacity of 9 GW [19].

Reference:

19. https://www.hitachienergy.com/uk-ie/en/news/press-releases/2023/05/hitachi-energy-signs-agreements-with-enowa-and-saudi-electricity-company-to-design-and-develop-the-first-phase-of-visionary-neom-region-transmission-system

Transmission line upgrade in the U.S.

Minnesota Power to upgrade Square Butte HVDC power line

Minnesota Power plans to modernise and upgrade the Square Butte HVDC transmission line that allows 550 MW of power to be exchanged between the states of North Dakota and Minnesota in the United States [20].

The 465 –mile (~750 km) overhead line was commissioned in 1977 to carry electricity generated by a power plant built on a lignite coal field in Center, North Dakota, to Hermantown in northeastern Minnesota. The line was acquired by Minnesota Power in 2009 and is being redirected to supply wind energy from the Bison Wind Energy Center in North Dakota [20].

The LCC technology currently used by the transmission line is set to be replaced by VSC, according to [21]. The modernisation project is currently in the development phase. Subject to regulatory approvals, construction could start as early as 2024, with commissioning between 2028 and 2030 [20].

Reference:

20. https://minnesotapower.blob.core.windows.net/content/Content/Documents/Company/PressReleases/2023/PressRelease06012023.pdf
21. https://cdn.misoenergy.org/20230531%20PAC%20Item%2008b%20MP%20RBJ%20Presentation629028.pdf

A new HVDC equipment factory in India

Hitachi Energy opens new HVDC factory in Chennai, India

In February 2023, Hitachi Energy inaugurated a new high-voltage direct current (HVDC) and power quality factory in Chennai, India . The new plant will manufacture and assemble advanced power electronics for VSC, LCC and STATCOM technologies, as well as control and protection systems [22].

According to Hitachi Energy [22], this plant will meet the growing number of high-voltage transmission projects in India as well as export to support global HVDC installations. In fact, India has set a target of generating half of its electricity, or 500 GW, from renewable energy sources by 2030. This implies the construction of nearly 8,000 km of HVDC conductors across the country [23]. "*Over the next few years, India is planning a significant number of HVDC projects to enable India to achieve its goal of net zero consumption,*" said N. Venu, Managing Director and CEO of Hitachi Energy for India and South Asia [22].

Reference:

22. https://www.hitachienergy.com/in/en/news/press-releases/2023/02/hitachi-energy-inaugurates-advanced-power-system-factory-in-chennai-to-meet-the-growing-electricity-demand
23. https://www.thehindu.com/news/national/cost-of-transmitting-clean-energy-in-india-to-exceed-2-trillion/article66235468.ece

5. Insight on new Projects/Technologies

The Grain Belt Express: Interregional HVDC Transmission in the U.S.

By Henry Abrams and Rajat Majumder, Invenergy Transmission, United States

Grain Belt Express
An INVENERGY TRANSMISSION Project

Developing the Grain Belt Express: 5,000 MW ±600kV Multiterminal HVDC

The United States power system consists of three interconnected asynchronous grids. The largest interconnection is the Eastern Interconnection with a peak load of 681 GW, while the Western Interconnection and Texas Interconnection have peak loads of 168 GW and 76 GW, respectively [1]. Within each interconnection are Regional Transmission Organizations (RTOs) or vertically integrated utilities, which are responsible for the transmission system planning and reliability of their designated area.

The U.S. also has existing HVDC infrastructure including transmission projects within a single synchronous interconnection and back-to-back (B2B) converters between asynchronous interconnections. The installed capacities for HVDC projects existing in the U.S. is summarized in Table 1 and a map of the U.S. interconnections, RTOs, and existing transmission infrastructure is shown in Figure 1 [2].

Interconnection	Quantity	Combined Capacity
Eastern, Transmission	9	6,460 MW
Western, Transmission	3	5,900 MW
Eastern-Western, B2B	7	1,320 MW
Eastern-ERCOT, B2B	2	800 MW

Table 1. Existing HVDC in the U.S.

Recently, VSC-HVDC has created tremendous opportunity for further development of transmission projects in the U.S. These projects are primarily developed for one of two reasons: (1) to interconnect renewable generation to load over long distances, or (2) to connect different areas of the existing power system to alleviate congestion, provide emergency power support, and improve market efficiencies. Occasionally, a project may be poised to provide both benefits. The Grain Belt Express shown in Figures 1 and 2 below, is one such project.

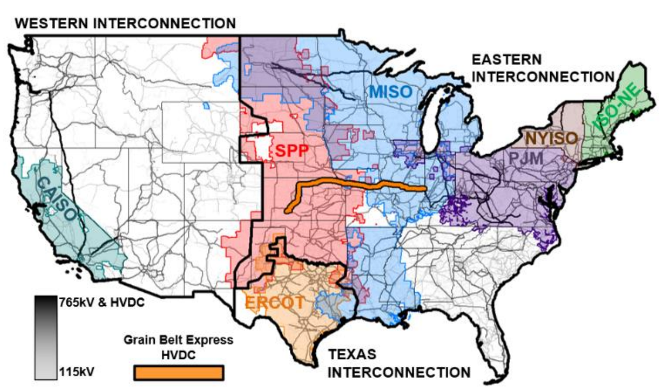

Figure 1. U.S. Power System and the Grain Belt Express

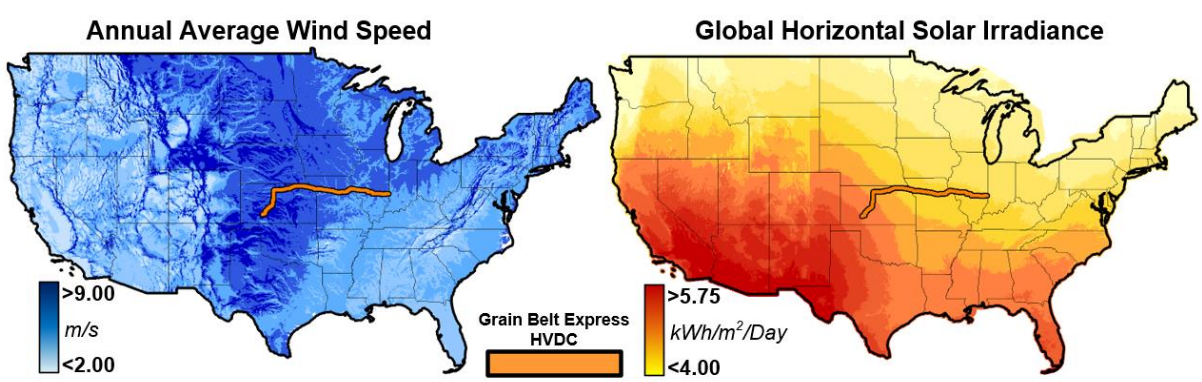

Figure 2. Grain Belt Express and Renewable Energy Resource [3]

The Grain Belt Express is proposed to be a 5,000 MW, ±600kV HVDC bipole with dedicated metallic return (DMR) project with a total transmission line length of approximately 1,200 kilometers. The project is primarily designed to transfer renewable energy from west to east but will also be able to reverse power flow or even aid network restoration in the case of an emergency. These emergency features are particularly meaningful as extreme weather events are increasing in frequency and severity, and the project will be able to provide precisely controlled transfer capacity between three distinct RTOs – SPP, MISO, and PJM, as shown in Figure 1.

The Grain Belt Express topology includes three converter station sites. The OEM of three converters is Siemens Energy. In Kansas, the project will have two parallel VSC-HVDC converter stations operating to export approximately 5,000 MW of renewable generation. In Missouri, there will be one VSC-HVDC converter station delivering approximately 2,500 MW to customers in MISO and AECI. In Illinois, there will be an additional VSC-HVDC converter station delivering approximately 2,500 MW to the PJM system. Connecting these converter stations will be one overhead transmission line carrying the ±600kV pole conductors, the DMR conductors, and optical ground wires. Each of the project's AC-side connections will be at 345kV.

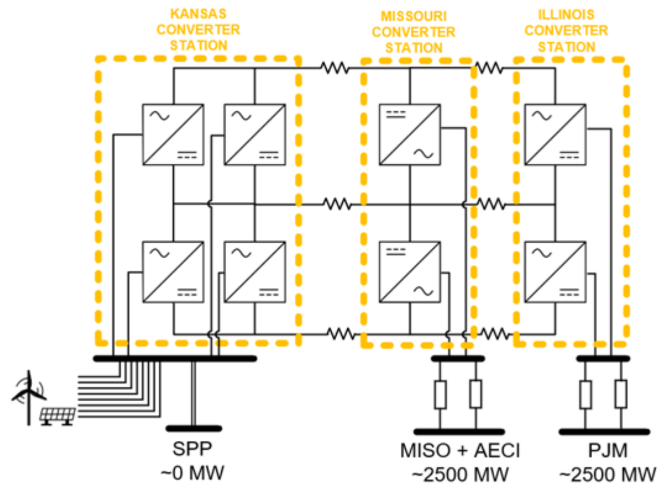

Figure 3. GBX HVDC Topology

The project will help advance several key aspects of HVDC transmission design:

1. Power and voltage ratings of VSC-HVDC for high-capacity applications
2. Multiterminal HVDC grid control and coordination of parallel converters
3. VSC-HVDC fault clearing and restart response for temporary DC-side faults
4. VSC-HVDC for overhead line applications
5. Integration of large inverter-based generation facilities with VSC-HVDC

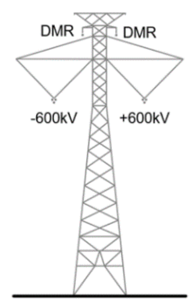

Figure 4. GBX HVDC Structures

Phase 1 of Grain Belt Express is anticipated to begin construction as soon as the end of 2024, pending regulatory reviews. With Grain Belt Express advancing toward construction-readiness, it serves as a meaningful reference for other high capacity, multiterminal, and/or overhead line VSC-HVDC projects in the future.

References:

[1] Load Forecasting Working Group of the Reliability Assessment Subcommittee. "2008-2017 Regional and National Peak Demand and Energy Forecast Bandwidths". North American Electric Reliability Corporation. August 2008.

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Offshore HVDC systems with grid forming controls – Unlocking the full potential of offshore wind energy

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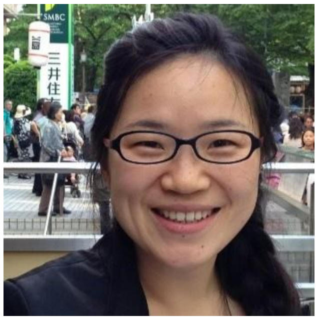

Offshore wind energy – future trends and challenges

Offshore wind energy is playing a key role in transforming the EU's power system and reaching its climate targets. The European Commission has pledged an installed capacity of at least 60 GW ad 300 GW of offshore wind by 2030 and 2050, respectively [1]. To-date, the most dominant offshore wind turbine technologies utilize converters to interface with the AC system, either at the wind turbine level in an AC-connected wind farm or at the wind farm level through a HVDC connection. Consequently, a key challenge emerged when replacing synchronous generator-based generation to renewable energy is system stability due to reduced system inertia and short-circuit level. Therefore, a grid forming behavior will be required by converters in power systems, as already indicated in the amendments of the grid code [2].

Offshore HVDC systems – control concepts and functionalities

Different types of network conditions might impose different requirements on grid forming (GFM) converters for contributing to network stability [3]. Conventional offshore HVDC systems (Fig. 1) utilize the grid following (GFL) controls at the onshore converter, by using a phase-locked-loop (PLL) to synchronize with the onshore AC network. The onshore converter is typically operated in DC voltage control (DVC) mode to maintain a constant DC voltage. The offshore converter acts as the master control of the voltage and frequency (UF mode) for the offshore grid so that the offshore wind turbine generators (WTGs) can maximize their power outputs. The offshore converter in UF mode is also able to black start the offshore AC grid.

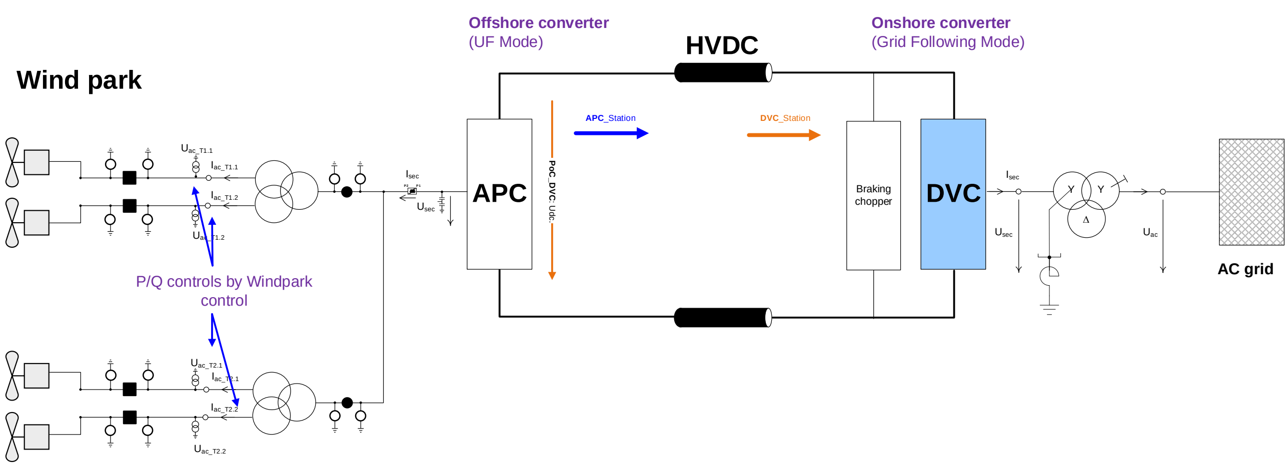

Fig. 1 Overview of conventional offshore HVDC control concept

Conventional control concept

As the onshore converter is operated in GFL mode, the conventional control concept is not able to provide many of the GFM functions. However, frequency support can be achieved, typically via communicating the onshore frequency signal to induce a reaction from the offshore WTGs, unidirectional only.

Grid Forming Onshore - Onshore Converter Only

In this concept, the onshore converter operates in GFM mode, while the offshore converter and the offshore WTGs operate in the same fashion as in the conventional concept. The benefit of this concept is that the offshore system can be operated in a similar fashion as conventional projects with proven stability, meanwhile, inertia contribution is only provided by onshore converter in a limited way without depletion of converter to critical level.

GFM Complete – All components

In this concept, the HVDC converters and the offshore WTGs all use GFM controls, thus this concept can provide a full set of GFM functions, including offshore islanded operation and black start from offshore to onshore are theoretically possible which is under investigation in several public funded research.

Table 1 gives an overview of different offshore HVDC control concepts and their corresponding functions.

Table 1 Comparison of GFM functions of different offshore HVDC control concepts

Functions	Conventional (DVC-UF/PQ)	GFM Onshore (GFM-UF/PQ)	GFM - Complete (GFM-GFM/GFM)	Remarks
Phase angle jump	No	Yes, predominantly depending on HVDC converter capability	Yes, contribution from both HVDC converters and WTGs	Predominantly active power/energy related requirements
Instantaneous Inertia support	No	Yes, limited contribution from HVDC converters	Yes, contribution from both HVDC converters and WTGs	
Frequency support	Yes, via telecommunication; only unidirectional	Yes, via telecommunication; only unidirectional	Yes, communication not mandatory	
Voltage amplitude jump	Yes (not instantaneous)	Yes (instantaneous)	Yes (instantaneous)	Predominantly reactive power related requirements
Fast current injection during Faults	Iq modulation, slope based	Instantaneous	Instantaneous	
Onshore islanding (to load)	No	Only when islanded load is smaller than pre-islanding operating point; and Wind Turbine provide energy	Yes, essentially also depending on OWP ramping speed and chopper energy capability	Active & Reactive power related requirements
Offshore islanding (only WTGs)	No	No	Yes, only depending on GFM-WTG controls	

Fig.2 gives example responses of GFM Onshore (Limited GFM – Red curve) and GFM Complete (Full GFM - blue curve) control concepts to voltage phase angle step and frequency ramp applied in the onshore AC system. To a phase angle step, additional contribution from the GFM-WTGs help in reducing the energy needed from the converters to provide the phase jump power. As shown in Fig.2 (b), with the same GFM control tuning of the HVDC converters, higher inertia can be expected with the full GFM control case. For frequency support, a GFM Onshore control concept will be still relying on telecommunication; while electrical coupling via the DC voltage and frequency can be used in the full GFM control, thus improving the system's reliability.

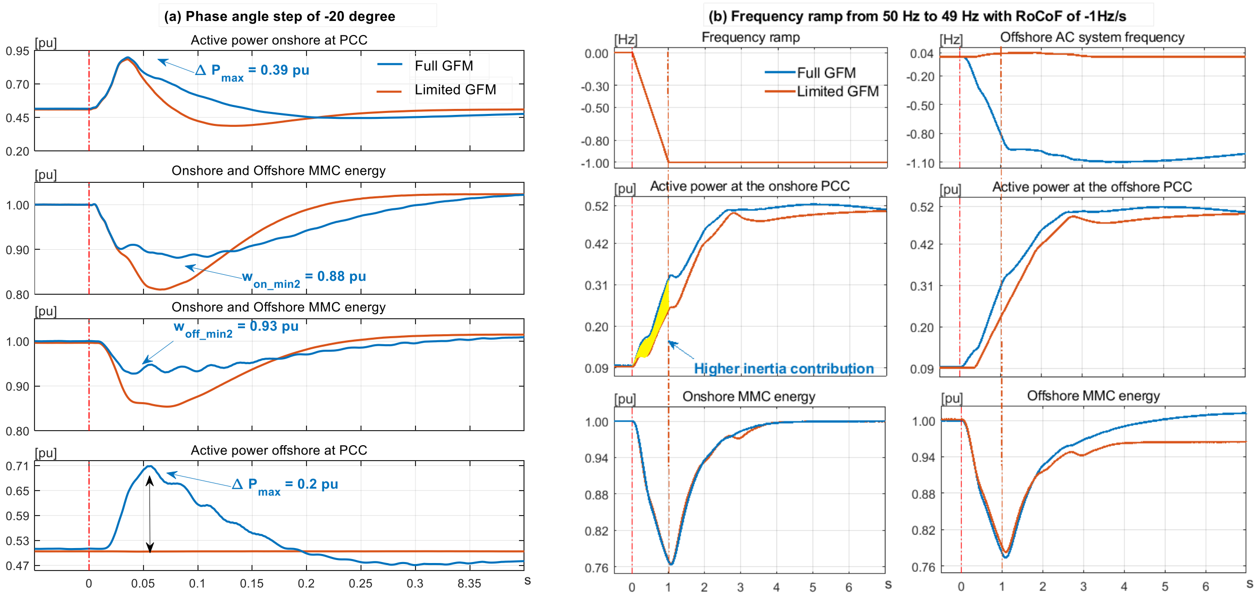

Fig. 2 Example responses of Limited and Full GFM during (a) phase angle step and (b) frequency ramp

In summary, offshore HVDC system with GFM controls are considered to be the key to unlock the full potential of offshore wind energy, particularly on providing instantaneous inertia, voltage angle & amplitude jump support and system restoration services. For power systems with a high share of renewable based generation, these services are of paramount importance to maintain system stability.

References

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[2] ACER, "Draft amendments to the Network Code on requirements for grid connection generators", https://www.acer.europa.eu/sites/default/files/events/documents/2023-05/NC_RfG_ACER_10_and_11_May_final.pdf.

[3] Huq, et. al, "Methods and Requirements for the Upgrade of HVDC and STATCOM with Grid Forming Functions for Multi-Level Converter Topologies", Cigre Session Paris, 28 Aug. – 02 Sept., 2022.

6. Contact and Call for information

We warmly welcome and encourage all of you to share your feedback on this newsletter and/or to propose new contributions for upcoming newsletter related to B4 activities. A list of non-exhaustive topics for your contributions are :

- New developments of Power Electronic Based Device and System
- B4 activities performed by CIGRE national committees
- Latest news on HVDC projects and status.
- Your experience with CIGRE especially with CIGRE B4
- Any suggestions/idea(s) and questions to B4

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