Northeast States Collaborative on Interregional Transmission

# HVDC Equipment Standardization and Supply Chain Considerations for Offshore Wind Transmission

Northeast States Collaborative on Interregional Transmission
White Paper

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*Note: This White Paper is a work product of the Collaborative but does not represent the views of any state or state official.*

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## 1. Introduction

State governments along the Eastern Seaboard are embarking on a significant endeavor: to harness the power of offshore wind. With a collective ambition to procure over 30 gigawatts (GW) of new offshore wind generation resources by 2030 and 80 GW by 2050, these states face an urgent technical challenge—connecting these vast new resources to the existing grid both swiftly and cost-effectively. Meeting these state energy goals requires making technologically complex investment decisions.

States have signaled an openness to commit to standardizing transmission technology to facilitate more cost-effective projects and provide optionality for an interconnected offshore grid in the future. The National Renewable Energy Laboratory's *Atlantic Offshore Wind Transmission Study*[1] highlights a networked high-voltage direct current (HVDC) transmission grid as the most cost-effective long-term solution. Others advocate for an alternating-current (AC) "mesh ready" system to address near-term opportunities. The New England States, Maryland, New Jersey and New York have required or have expressed interest in either type in their effort to coordinate the planning of transmission facilities, mirroring a broader global trend toward comprehensive transmission strategies, particularly as seen in Europe's long-term plans and large-scale commitments to purchase the necessary equipment.

Growing global interest in offshore wind and dedicated transmission facilities, however, means that demand for specialized transmission equipment, in particular HVDC equipment, is outpacing the current supply. To address this, U.S. states may find it beneficial to standardize HVDC equipment configurations to ensure long-term compatibility in parallel with exploring AC mesh solutions to address near term opportunities, like those required in New York,[2] New Jersey,[3] and other places.

Standardizing HVDC transmission equipment as soon as possible has several potential benefits:

- **Minimizing supply chain challenges**: Adopting standardized equipment specifications may ease supply chain constraints by allowing original equipment manufacturers (OEMs) to focus on a single equipment standard that can be used in multiple states, with or without network capability.
- **Maximizing forward compatibility between systems**: Adoption of "network ready" equipment standards may smooth future efforts to network offshore wind collector substations across state and regional boundaries. This is particularly important for networking HVDC lines, which is possible only if the same HVDC technology and voltage levels are used by all facilities in the network.

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[1] *See* https://www.nrel.gov/wind/atlantic-offshore-wind-transmission-study.html.

[2] *See* https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00P8z000003THkyEAG (requiring HVDC transmission technology with AC-mesh-ready offshore substations).

[3] *See* https://bpuoffshorewind.nj.gov/fourth-solicitation/solicitation-documents/Final-Solicitation-Guidance-Document-with-attachments.pdf.

- **Accelerating investment in domestic supply chains**: Clarifying state interest in HVDC transmission may help encourage investment of private capital in HVDC manufacturing by providing certainty about future demand.
- **Encouraging adoption of global HVDC standards**: Europe is largely coalescing around 525 kilovolt (kV) multi-terminal, multi-vendor HVDC platforms that allow for connection of 2,000 to 2,400 megawatt (MW) offshore wind farms, which tend to be more cost-effective than smaller projects.

## 2. The Northeast States Collaborative

The Northeast States Collaborative on Interregional Transmission (States Collaborative) is a group of ten states – Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont – working together to expand the transmission grid in partnership with the U.S. Department of Energy (DOE) and the DOE's Grid Deployment Office. In July 2024, these states formalized their collaboration through a Memorandum of Understanding[4] to explore regional and interregional transmission facilities, including both on- and offshore options.

The States Collaborative serves as a central organization for coordinating with the DOE, independent system operators (ISOs), regional transmission organizations (RTOs), and other stakeholders. Its goal is to identify key transmission priorities and develop practical solutions to building the onshore and offshore transmission grid. The Eastern Seaboard is home to three ISOs, each with its own transmission planning processes, making state cooperation essential for cost-effectively meeting state clean energy goals.

The States Collaborative also provides a potential framework to develop technical standards as outlined in this whitepaper. While participation in the States Collaborative is voluntary, establishing best practices and recommended configurations will provide states and private developers with clearer contracting guidelines.

## 3. European HVDC Initiatives

Europe has taken a multi-national approach, with broad industry participation, to building offshore wind transmission facilities necessary for connecting its goal of 300 GW of installed capacity by 2050.

### 3.1 North Seas Energy Cooperation (NSEC)

The NSEC was formed in 2010 and involves nine countries -- Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden, and the European Commission. The NSEC, "supports and facilitates the development of the offshore grid development and the large renewable energy potential in the region."[5] NSEC's 2020–2023 work program includes an emphasis on cross-border offshore wind and grid projects (hybrid projects) with the potential to reduce costs and space of offshore developments.[6] NSEC operates via a memorandum of understanding between the countries, which makes "NSEC a **bottom-up cooperation initiative**," as described by Michel Wallemacq, of the Embassy of Belgium in the United States.

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[4] *See* https://energyinstitute.jhu.edu/wp-content/uploads/2024/07/MOU-Northeast-States-Collaborative-on-Interregional-Transmission.pdf.
[5] *See* https://energy.ec.europa.eu/topics/infrastructure/high-level-groups/north-seas-energy-cooperation_en.
[6] *See* https://energy.ec.europa.eu/document/download/beefb646-fae4-451f-ab29-a56399dc7185_en?filename=Actie%20agenda%20DEF.pdf.

As described by Mr. Wallemacq, the NSEC works across four "support groups," focused on project development. Support Group #1 works on interconnection of new generation, cost allocation and technical standards. Support Group #2 deals with maritime spatial planning including developing concepts for coordinated planning and development of coordinated offshore wind grids and scenario development. Group #3 focuses on project finance and design of incentives. Group #4 focuses on development of future technologies, such as using offshore wind to make green hydrogen, other innovative technologies, development of best practices for onshore transmission planning and related topics.

### 3.2 InterOPERA

InterOPERA's "Enabling interoperability of multi-vendor HVDC grids" initiative[7] is designed to "make future HVDC systems mutually compatible and interoperable by design, to improve the grid forming capabilities of offshore and onshore converters and pave the way for the first HVDC multi-terminal, multi-vendor, multi-purpose real-life projects in Europe." As InterOPERA explains:[8]

> Future HVDC systems will be modular. Thanks to common functional specifications and standard interfaces, modules based on different technologies and modules supplied by different manufacturers will be able to integrate seamlessly and operate together.

InterOPERA developed standard functional design requirements for HVDC offshore grid platform technology and expects to conduct testing of multi-vendor HVDC System control and protection compatibility by 2028.

- Phase 1 of the InterOPERA initiative focuses on the development of the frameworks and on the definition of the functional specifications for multi-terminal, multi-vendor operations.

- Phase 2 is focused on building a real-time physical demonstrator project where "frameworks from phase 1 are applied and consolidated," as well as defining "the procurement strategy and prepares the future real-life projects."

In addition to technical standards, InterOPERA also seeks to bring about agreement on "procurement, commercial, legal and regulatory frameworks that will facilitate the tendering, building and operation of full-scale HVDC multi-terminal, multi-vendor, multi-purpose real-life applications anticipated by 2030."

## 4. AC Mesh Initiatives

Many wind farms in the United States currently rely on AC connections to shore. Several states are already requiring HVDC lines for interconnecting new wind farms to shore, because HVDC transmission can deliver more power over the same right of way. These states are also developing technical standards for "mesh ready" offshore substations, which would enable the creation of networked links between the radial HVDC cables that offshore wind plants are using to deliver their power to shore. These standards will initially allow wind developers to connect to shore via a radial HVDC cable while enabling future networking of these offshore facilities.

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[7] *See* https://interopera.eu/.
[8] *See* https://interopera.eu/objectives/.

AC connections are generally less expensive over short distances, as noted by the New Jersey Board of Public Utilities in its offshore wind solicitation evaluation.[9] New York, for example, has also determined that HVDC projects meshed with short AC links would be more flexible (and more compatible with different HVDC technologies) than the utilization of offshore HVDC links (which requires that each of the radial HVDC cables utilize the same HVDC technology). Over longer distances between networked windfarms, however, HVDC links may become preferable (because AC links are limited in the distance they can cover).

Given the widespread use of AC technologies in the utility industry, AC equipment and cables also face fewer supply chain delays compared to other energy infrastructure components. Additionally, using AC equipment to link offshore wind farms does not suffer from the vendor incompatibility that HVDC converter stations do. However, the technology for controlling the flow of power between HVDC offshore wind platforms and onshore injection points, even with an AC mesh grid, is still under development, and the availability of necessary transformers and control equipment will impact the design and cost of offshore collector platforms. While previously the supply chain was of moderate concern, with the growing demand for offshore wind, there is a related growing demand for HVAC cables needed to collect the energy from the individual turbines and transmit it to the collector platforms. As such, the demand for HVAC submarine cables may soon outpace their supply as well.

Interlinking windfarms with HVDC may also offer greater transfer capability between states or regions than AC links, potentially resulting in a higher economic benefit-to-cost ratio and enhanced reliability whenever the radial transmission lines are not fully utilized to deliver wind power to shore. This interlinking could provide significant economic and operational advantages, making higher-capacity HVDC links a potentially attractive option for future offshore wind projects, even given the higher upfront capital costs and technical challenges. Such HVDC links between offshore wind plants, however, require that the same (standardized) HVDC technology is used for every one of the radial HVDC transmission lines.

## 5. HVDC Equipment Challenges

### 5.1 Procurement Lead Times

The supply of HVDC equipment is highly constrained, with multi-year lead times for procuring necessary components. The long lead time is in part due to the engineering time and resources for designing the converter systems and platforms to suit the specific needs of each project as there is no industry standard design. Further, OEMs have expressed concerns with investing in the U.S. market, in part, because of higher manufacturing costs, lack of a trained engineering workforce, and concerns over whether demand for offshore wind components will materialize on the schedules laid out by state and federal policymakers.

As a consortium of HVDC manufacturers recently noted:[10]

> Global demand for HVDC transmission converters, cables, and associated transportation and installation vessels has accelerated dramatically over the last few years. Demand now exceeds supply. Consequently, solicitation requirements from state agencies and installation timelines from Governor's offices must carefully consider whether the solicitation

[9] *See* https://www.brattle.com/wp-content/uploads/2022/10/New-Jersey-State-Agreement-Approach-for-Offshore-Wind-Transmission-Evaluation-Report.pdf.
[10] *See* https://www.dnv.com/news/dnv-joint-industry-project-calls-for-bold-action-from-u.s.-states-to-build-out-hvdc-offshore-transmission-network.

requirements and installation timelines are aligned with (or divergent from) global market conditions.

In Europe, utilities and offshore wind developers have placed large orders for delivery of standardized HVDC equipment into the 2030s through the development of "frame agreements" where utilities commit to purchasing a certain amount of HVDC equipment in the future and provide a deposit to secure their spot in the manufacturing queue.[11] For example, in 2023 alone, TenneT, the large European Transmission System Operator, entered into eleven contracts worth €23 billion to three consortia, enough to connect 22 GW of offshore wind in the Dutch and German North Sea by 2031.[12] In a similar vein, the Scottish & Electricity Networks (SSEN) finalized its commitment in July 2023 to procure 525kV HVDC converters for its Eastern Green Link 2 Project.[13]

Currently, the United States market does not have a comparable credit-worthy counterparty to serve in this long-term contracting role nor has made a similar commitment to standardized HVDC technology, potentially leaving states in the United States at a significant disadvantage in the global market and subject to shorter-term procurement options.

## 5.2 Multi-Terminal Capability in Development

Currently, offshore wind developers design projects with radial interconnections to shore, where power from an offshore wind farm is transmitted via HVAC or HVDC export cables to a single location on the existing grid, an onshore injection point. An offshore mesh grid with interlinks between offshore platforms could provide alternative paths to bringing power to shore and enable power to flow from the onshore grid to the offshore facility for reinjection at another onshore injection point, thus reinforcing the onshore grid. Incorporating interlinks requires that an offshore converter substation has the ability to be connected to multiple other "terminals," allowing power to flow to more than one terminal and in both directions between terminals. Europe continues to advance on this front with its first HVDC multi-terminal project at 320 kV that will interconnect the Viking offshore wind farm with the Shetland Islands and the Scottish mainland.[14] To make such capability available universally would require the use of the same HVDC technology for all export cables and interconnection terminals, which requires standardizing the design of HVDC converter systems and associated substation equipment, as well as ensuring interoperability of equipment from multiple HVDC vendors.

## 5.3 Multi-Vendor Capability in Development

HVDC converter systems, which can cost up to $2 billion per pair of converter substations, are typically specialized designs tailored to the needs of specific projects and resulting from innovations by different OEMs. As a result, today, HVDC systems from different vendors currently are incompatible. To develop an HVDC-based offshore transmission grid, states must either develop "multi-vendor" standards ensuring

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[11] *See, e.g.*, https://www.gevernova.com/news/press-releases/two-ge-led-consortiums-in-agreement-with-tennet-for-award-of-contracts-build-hvdc-systems-netherlands-germany *and* https://www.tennet.eu/news/tennet-accelerates-grid-expansion-and-energy-transition.

[12] *See* https://www.windpowermonthly.com/article/1818899/tennet-awards-%E2%82%AC23-billion-hvdc-offshore-grid-contracts-dutch-german-north-sea.

[13] https://www.ssen-transmission.co.uk/news/news--views/2023/7/national-grid-and-ssen-transmission-select-hitachi-energy-and-bam-as-preferred-suppliers-for-eastern-green-link-2-converter-stations/

[14] *See* https://www.ssen-transmission.co.uk/projects/project-map/shetland/.

interoperability or require all offshore wind and transmission developers to purchase their transmission equipment from a single vendor. The former option would increase technology compatibility risk, while the latter option would increase counterparty risks and reduce competition, given that the single, selected transmission equipment supplier would have significant pricing power over future grid expansions, without competition among equipment manufacturers. The European InterOPERA initiative is reducing technology compatibility risk by specifying multi-vendor capability standards, by developing equipment specifications, and testing reliability, with an expected completion of the effort around 2028. They have already established standards for certain parts of the HVDC ecosystem, such as offshore platform construction. Lessons learned from InterOPERA efforts can yield actionable findings that the U.S. and collaborating states can leverage in standardizing offshore HVDC transmission designs.

## 5.4 Selection of a Standard Voltage

The European market is converging on a 525 kV, bipole configuration, with multi-terminal and multi-vendor capability. This configuration offers several advantages, such as enabling the development of larger wind farms (2,000–2,400 MW) reducing the number of shore crossings necessary to bring offshore wind onshore, which reduces the environmental footprint of the projects.

Adopting the 525 kV platform design, though, is far from straightforward. First, grid operators in the United States typically do not allow for connection of single large projects. For example, the grid operator in New England currently does not allow the interconnection of projects greater than 1,200 MW, with slightly larger projects allowed in New York and PJM. These limits are known as the "Most Severe Single Contingency (MSSC)" or "Single Largest Contingency" limit, representing the largest acceptable loss of generation source. Second, the proposed standard for 525 kV HVDC used in Europe results in offshore substations that are extremely heavy, requiring specialized vessels for transport and installation—vessels that are currently scarce and not compatible with the Jones Act.[15]

## 5.5 Reliability Standards and HVDC technology

Another important consideration is how reliability standards and modeling practices affect offshore wind supply chain development, and in particular, the selection of a 525 kV HVDC standard platform design. How HVDC lines should be modeled for the purposes of meeting reliability standards can have a significant impact on how regional grid operators plan for next-generation offshore wind farms and are likely to drive, for example, ISO/RTO approaches to addressing the MSSC (Loss of Source) limit necessary to pave the way for larger 525 kV platforms.

The North American Electric Reliability Corporation (NERC), for example, considers each pole of a bipole HVDC system separate for purposes of reliability planning—an approach similar to those used by European grid operators. NERC's Transmission Planning Standard TPL-001-5 defines the loss of a "single pole of a DC line" as a "single contingency," event and defines the "loss of a bipolar DC line" as a "multiple contingency," equivalent to the loss of "[a]ny two adjacent (vertically or horizontally) circuits on common structure."[16] However, regional reliability entities can implement additional requirements that are more stringent than the NERC standards.

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[15] A consequence of the Jones Act is that wind farm projects may incur additional costs and longer construction schedules as vessels may operate out of foreign ports or require use of feeder barges.
[16] *See* https://www.nerc.com/pa/Stand/Reliability%20Standards/TPL-001-4.pdf.

The Northeast Power Coordinating Council, Inc. (NPCC) takes the more conservative approach of treating the removal of the entire HVDC line as a single contingency event, regardless of whether the design is a monopole or bipole. For the bipole configuration, it may be more appropriate to test for the loss of 50% of the capability as a single contingency event, better reflecting its actual design, capability, and operation. Such a change would require modifying the NPCC and ISO-NE criteria to match the current NERC TPL standard.

The type of technology used for a bipole HVDC converter system and its ability to reliably operate with a single pole will also be relevant when considering probability of outages, but neither the NERC standard nor the NPCC criteria address differences in converter technology. Technology types may be a candidate for a future update to the reliability standard.

## 6. Perspectives from Government, Industry and Environmental Organizations

### 6.1 Letter from DNV and Joint Industry Project

On April 1, 2024, DNV, on behalf of itself, OEMs, and offshore wind developers,[17] issued an open letter[18] calling for establishment of offshore wind transmission standards in the short, medium, and long-term. As the letter describes the effort:

> The global offshore wind industry has evolved rapidly over the last few years. Global demand for offshore HVDC transmission equipment and resources now exceeds global supply. Consequently, designs that may have been possible three years ago (e.g., AC mesh solutions and 400 kV HVDC transmission) are no longer viable for the offshore market within the proposed timescales.
>
> Considering the above (and other factors), the signatories of this letter seek to foster greater dialogue between the states and the offshore wind industry. The goals of this dialogue are to ensure:
>
> 1. Near-term deployment victories to ensure viability of the U.S. offshore wind industry.
>
> 2. Development of cost-effective and highly capable offshore transmission networks.

For short-term projects, i.e., those before 2030, the letter urged states to "procure 320 kV HVDC symmetric monopoles without AC or DC interlinks to enable successful project delivery. Successful and timely project development is the best way for the public to witness the value proposition of offshore wind." Doing so means that the radial lines used to deliver offshore wind would not be "mesh ready," so could not be easily networked in the future.

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[17] The letter was signed by representatives from Atlantic Shores Offshore Wind; DNV Energy, USA; EDF Renewables; Equinor; GE Grid Solutions; Hitachi Energy USA; Invenergy; National Grid Ventures; OW North America; PPL Translink; RWE Offshore Wind Holdings; Shell; Siemens Energy; TotalEnergies Research & Technology, USA; and WindGrid.

[18] *See* https://www.dnv.com/news/dnv-joint-industry-project-calls-for-bold-action-from-u.s.-states-to-build-out-hvdc-offshore-transmission-network.

In the mid-term, the letter predicts that, for projects on the Eastern Seaboard, intra-regional "525 kV HVDC bipoles with DC interlinks … will become the predominant offshore transmission technology as a direct result of the large number of such projects that are being procured by TenneT and others."

## 6.2 Letter from American Council on Renewable Energy (ACORE)

On April 11, 2024, ACORE sent a letter to the States Collaborative on HVDC equipment standards[19] and recommended "that state policy makers move forward with planning and solicitations for planned offshore transmission systems utilizing the de facto global hardware standards that have emerged through collaborative work between European utilities and the electric equipment supply chain."

The ACORE letter notes that there have already been "significant 525kV HVDC equipment orders, now totaling over $36 billion, to multiple vendors – both for converter platforms and transmission cables." ACORE encourages:

> …policy makers to avoid needless go-slow approaches that may operate under the false impression that years of work are still needed before multi-vendor cable and platform voltages can be specified in no-regrets, scalable transmission solicitations. The long lead time nature of transmission equipment, the schedule for both on and offshore permitting, and the consumer cost benefits of interconnection certainty in offshore wind pricing provide further counsel for near term action relying on developed supply chain equipment standards so that states can realize their energy policy goals.

## 6.3 DOE/BOEM Atlantic Offshore Wind Transmission Action Plan

In March of 2024, DOE's Grid Deployment Office published the Atlantic Offshore Wind Transmission Action Plan.[20] The report is the culmination of a multi-year joint effort between DOE and the Bureau of Ocean Energy Management, with input from a broad spectrum of industry representatives, to develop an Action Plan to address the offshore wind transmission challenges. The Action Plan provides recommendations for four time frames: immediate (before 2025), near-term (2025-2030), mid-term (2030-2040) and sustained actions. Recommendations include:

- **Before 2025:** Establish collaborative bodies that span the Atlantic Coast region; clarify some of the building blocks of transmission planning, including updating reliability standards and identifying where offshore transmission may interconnect with the onshore grid; and address costs through voluntary cost assignments.
- **From 2025 to 2030:** Simultaneously convene and coordinate with states to plan for an offshore transmission network; with industry to standardize requirements for HVDC technology; and with federal agencies, tribal nations, state agencies, and stakeholders to identify and prioritize transmission paths on the outer continental shelf.

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[19] *See* https://acore.org/resources/letter-to-the-northeast-states-collaborative-on-hvdc-transmission-standards/. The letter was signed by representatives of ACORE; American Clean Power Association; Acadia Center; Alliance for Clean Energy New York; Environmental League of Massachusetts; League of Conservation Voters; Maine Renewable Energy Association; Mid-Atlantic Renewable Energy Coalition; New York Offshore Wind Alliance; Northeast Clean Energy Council; Oceantic; RENEW Northeast; and Sierra Club.

[20] *See* https://www.energy.gov/gdo/atlantic-offshore-wind-transmission-action-plan.

- **From 2030 to 2040:** Establish a national HVDC testing and certification center to ensure compatibility when interconnecting multiple HVDC substations to form an offshore grid network and codify updates to transmission planning through regulated interregional joint planning, transfer capacity minimums, and market monitoring.

## 6.4 NYSERDA Mesh-ready Offshore Wind Transmission Study

In April 2024, New York State Energy Research and Development Authority (NYSERDA) issued a report that evaluated the costs and benefits of implementing mesh-ready offshore wind transmission solutions versus individual radial generation ties.[21] The study considered varying levels of OSW and different configurations of pathways for bringing the offshore wind to shore. The benefits that were considered included adjusted production cost savings, increased offshore wind availability, and avoided onshore transmission costs. The costs were based on the NYSERDA Mesh-Ready Technical Requirements.[22] The findings of the study showed that while the benefit of a meshed offshore configuration is limited in the near term, the benefits of networking radial HVDC lines exceed the costs by a factor of 1.5 or greater by 2040. The study also found that constructing "mesh-ready" offshore substations (which would allow for the construction of interlinks in the future) only increases the cost of an offshore wind plant by 1-2%—which is the reason why the New York PSC approved NYSERDA's request to require that offshore wind plants be constructed with mesh-ready offshore substations. Due to the absence of standardized HVDC designs and vendor compatibility, NYSERDA specified its mesh-ready standard based on two 400 MW AC interlinks (for each offshore substation) to minimize compatibility risks while ensuring that interlinks for up to 800 MW of transfers between offshore substations can be added in the future if desirable.

Among the findings and recommendations is the importance of standardization to provide the optionality for accessing these benefits.

> **Network-ready equipment standardization and HVDC technical issues**
> Regarding HVDC technical issues, specific requirements would need to be met to ensure multivendor interoperability. Developing HVDC technical standards and establishing common meshed-ready design standards for use across state OSW solicitations are crucial to realize interregional benefits. These technical considerations are being addressed through interstate collaborative efforts and standardization DOE-supported work.

[21] *See* https://www.nyserda.ny.gov/About/Publications/Energy-Analysis-Reports-and-Studies.
[22] New York State Energy Research and Development Authority. 2022. "Offshore Wind Solicitation ORECRFP22-1 – Appendix G - Meshed Ready Technical Requirements."

## 7. Multi-State Engagement on Potential Solutions

As noted by DOE, ACORE, and DNV letters, states have the potential to be leaders in standards adoption. This whitepaper is designed to set the stage for providing that type of leadership. We propose that states may wish to adopt preferred standards on the following topics, with the aid of accelerating cost reductions in offshore wind.

### 7.1 Standardize AC and HVDC Design Options

State governments can play a crucial role in identifying preferred AC and HVDC designs. By creating a "menu" of potential configurations, state regulators can streamline their offshore wind solicitations and engagements with ISOs and RTOs. This approach can address concerns about bespoke designs and foster specialized supply chains that align with the states' goals. Key characteristics to consider include minimum power level, voltage levels, AC or DC options, bi-directional capability, multi-terminal capability, and multi-vendor interoperability. The States Collaborative could also evaluate the pros and cons of adopting European standards under development by the InterOPERA process.

### 7.2 Platform Specifications

States might consider modifying OSW project requirements in their procurements to either emphasize "network ready" specification or forgo such capability for projects selected in the near term. Avoiding mesh-ready requirements could help reduce the size and weight of offshore platforms, addressing vessel and supply chain constraints. These modifications would enable more flexible and immediate deployment of these first generation offshore wind projects (but without the ability to network them now or in the future), while maintaining the potential for networking OSW projects that will be procured in the future.

### 7.3 HVDC Supply Chain & Vessel Coordination

Adopting a 525 kV standard presents significant challenges related to installation supply chain and vessel availability. One approach to mitigate these concerns is to develop domestic shipping capabilities, as seen in Virgina.[23] More broadly, collaboration with federal, state and industry partners can identify solutions and spur expansion of US manufacturing and shipping capacity to support the offshore wind industry's needs. This coordinated effort would address both current constraints and future demands.

Special effort should be given to working across states or with the federal government to evaluate the feasibility of executing frame agreements for future delivery of HVDC equipment into the 2030s to ensure the availability of sufficient HVDC equipment manufacturing capability to meet offshore wind targets. Such arrangements could be facilitated by the U.S. Department of Defense, the U.S. Department of Energy, or by a coalition of states. Similar approaches may also facilitate installation vessel procurement.

### 7.4 HVDC Contingency Analysis

Because the NPCC regional criteria for contingency events involving an HVDC circuit are more stringent than the NERC TPL standards, it will have implications for the feasibility of interconnecting large offshore

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[23] https://news.dominionenergy.com/2024-04-15-Dominion-Energy-Reaches-Major-Milestone-in-Construction-of-Charybdis,-the-First-Jones-Act-Compliant-Offshore-Wind-Turbine-Installation-Vessel

wind projects. Engaging with the regional reliability entities can be a first step in understanding the basis for the more stringent criteria. Recognizing that the current criteria have implications for planning, alternative approaches may provide satisfactory reliability, while avoiding the need for costly upgrades, thus enabling the adoption of a 2 GW, 525 kV bipole HVDC standard. Engaging with the regional reliability entities and ISOs/RTOS can be a first step in understanding the basis for the more stringent criteria.

## 7.5 Identify Potential Partners

Identifying and collaborating with potential partners is essential for advancing standardization efforts. Academic institutions, various offices with the DOE, National Laboratories, and international counterparts such as InterOPERA and NSEC can provide valuable insights and resources. Engaging with these partners can leverage existing knowledge, drive research and development, and identify key areas where increased R&D efforts could accelerate progress.

## 7.6. Identification of Points of Interconnection and Navigable Channels that Could be Reserved for 525 kV HVDC Bipole Circuits

Current configurations of offshore wind projects along the Eastern Seaboard reflect the priorities of early adopters acting with short decision-making time horizons. The nature of the generator interconnection processes within the ISOs/RTOs and the state OSW solicitation processes are both factors influencing the design of offshore wind projects. Consequently, early projects sought out the points of interconnection (POIs) to the onshore grid that minimized the need for new transmission and the cost of the offshore construction. The result is that the majority of offshore wind projects use radial, and often HVAC, connections to connect to lease areas closer to the shore, with power capacities ranging from hundreds of Megawatts to 1,400 MW.

Such early designs constitute the low-hanging fruit of offshore wind development, and future projects will find fewer low cost, near-shore POIs with high injection capability. Further, the current ISO/RTO interconnection processes are not designed to optimize POIs for the comprehensive development of a portfolio of preferred resources across multiple jurisdictions

The space requirements for the export cables present additional challenges. Each project requires developers to install one or more circuits to interconnect the project to the onshore grid. Each circuit has minimum space requirements, depending on the cable design. HVAC circuits generally require more space than HVDC circuits for an equivalent power transfer capability. Other factors contribute to limited availability of development of offshore areas, such as the need to avoid shipping channels or underwater archaeological sites.

Consideration of the overall long-term goals of the states, it may be prudent to study potential on-shore POIs and the physical constraints to access those POIs to assess feasibility of achieving them. Such an assessment would require engaging with the relevant transmission planning organizations and industry experts to analyze the routing constraints for connecting offshore wind plants to the onshore grid.