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Even Keel Wind Comments - RFI Deep-Water HVDC Substations for Offshore Wind

Additional submitted attachment is included below.

HVDC converter stations for floating offshore wind

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Even Keel Wind

General Questions

1. What information or analysis is needed to inform timely and cost-effective development and deployment of deep-water substations and associated offshore electrical infrastructure in existing and future California WEAs? How can publicly funded research and development (R&D) address technological, economic, and environmental uncertainties and better inform strategic technology advancement, feasibility, standards development, and component selection and procurement?

Based on our discussions with equipment suppliers, HVAC and auxiliary systems required in the topsides have relatively reasonable lead-times, and could be installed in the early 2030's. Typically, the hull of the HVAC floating substation should not be a limiting factor in the delivery of those platforms according to the above-mentioned timeline. In addition, WTGs, ports, or other aspects of the project may be longer lead time than the equipment for an HVAC system. However, if instead HVDC systems are considered, the technology development and deployment timeline is a concern and could benefit from public funding to advance the conceptual design of HVDC floating converter stations and dynamic cable.

When talking to submarine cable providers, they are unable to provide exact cable details and pricing for dynamic cable connecting to floating substations. This is because the product does not exist yet. They have designed similar cable for around 500ft water depth. But, the deep water depth for California WEAs requires a new design.

For floating HVDC converter stations, a conceptual design is not yet available, also. Creating a conceptual design of the floating converter station is very important to advance the design of interacting equipment. For example, the three dimensional movements of the floating converter station are required as input to the cable design. It also is required to advance the design of the equipment within the converter station. In the case of HVDC converter stations, the equipment that needs the most attention and technology development to ensure they can be used in floating applications is the "valves", which are the structures which contain the switching devices that convert AC power to DC.

Upon completion of a HVDC converter station conceptual design and corresponding dynamic cable design, developers would have a better understanding of the price of HVDC systems, the qualification timeline, including any necessary technology developments or required prototype testing, and overall feasibility of HVDC systems to support California's timeline.

These designs are not completed, making the barriers to entry for a developer to select HVDC systems very high. High level costs for these designs are in the range of:

- Perform a conceptual Floating HVDC converter topside and hull design (around $1M or more)
- Using the converter design, perform a HVDC submarine cable design (around $1M or more)

Because these studies are expensive and might not even lead to HVDC systems being viable for projects, developers are more inclined to pursue HVAC systems (if their project characteristics allow for it).

In addition, there are not too many options for HVDC OEM equipment in the market, and the manufacturers have an extremely busy customer contract delivery pipeline for the next 6 to 8 years. This poses complications and challenges as it is very difficult to attract attention and engagement from OEMs for floating wind, when they have all their attention on contracted bottom-fixed substations. Highly skilled resources are limited, and technologists are not usually amenable to prioritizing future developments for known technology that has not been implemented before. The dynamic motion inherent in floating offshore wind projects adds another complication in the early development of this technology, which requires specialized engineering resources who are already constrained at the HVDC OEMs.

This is an excellent opportunity for the CEC to support the advancement of the HVDC concept by commissioning these conceptual designs. There is great potential for HVDC systems. Ultimately, they may cost less than HVAC systems for certain projects, and they require fewer parallel circuits which would alleviate some space constraints and subsea environmental impact concerns.

Also, these studies can be crafted so they benefit all developers with California WEAs. Having one central body commission these studies is better than several developers commissioning them separately. This is work that could reduce the development costs for several WEAs, so the cost is theoretically recoverable by slightly reducing the overall cost of generation.

2. What key metrics or factors are required to inform systems integration of offshore wind components, deep-water substations, associated electrical infrastructure, communication networks, data collection, environmental monitoring, and ancillary services such as secondary generation, hydrogen production, and storage?

From a grid analysis and system integration perspective, it may be helpful to know that HVAC systems will come in ~300MW circuits and HVDC systems will come in ~1200MW circuits. Also, it is key to have visibility on the potential points of interconnection and potential landfalls.

From an infrastructure perspective, it is crucial to have a plan for port availability to construct floaters for offshore wind turbines.

There are several innovative ideas about secondary generation, including hydrogen and storage of energy production, however none of those have been proven to be cost effective yet.

3. What specific technical, economic, or other factors are crucial for understanding the viability and success of offshore electrical infrastructure technologies for FOSW development in California? What key performance characteristics and metrics are anticipated to be challenging for California's existing and future WEAs?

For HVDC topsides, it is crucial to understand the distance to shore, the losses and the allowable limitations and tolerances of the HVDC electrical equipment to keep motion as low as possible, which will likely impact the cost of hulls (substructure) and mooring systems as well.

In case of subsea substations, it is crucial to understand the technical limitations, the rate of failure and the OPEX to make that a viable option. Generally speaking, any repairs in deep waters represents a high cost.

4. What environmental, ecosystem, health, and social impacts, including, both direct and indirect impacts, should be evaluated in deep-water substation and offshore electrical component design, procurement, and deployment for California's existing and future WEAs? How should knowledge about these impacts be used to better inform more sound design, procurement, and deployment of deep-water substation and offshore electrical components?

It is important to consider:

- Impacts associated with cable burial (ecosystem, water quality, noise, etc.) and habitat/species recovery post installation.
- Species and habitat impacts associated with various forms of foundations (positive and negative).
- Species and habitat impacts associated with mooring lines and anchors (positive and negative).
- Species impacts associated with inter-array power cables.
- Anticipated frequency of factors leading to secondary entanglement impacts (magnitude of marine debris issues).
- Impacts of cooling systems on floating substation or converter stations For HVAC topsides, it's more common to have 'closed loop' water cooling systems where no cooling water is drained into the ocean. For HVDC topsides, the amount of heat generated is much higher, and the only practical cooling method is to use seawater cooling. This includes returning warmer water to the ocean, within the allowed thresholds of the current rules and codes. More information and estimates on the water temperature is available in the Sunrise and Beacon Wind COP applications, which are publicly available. This can potentially be viewed as a negative environmental impact of HVDC systems.

5. Are there other pressing needs or challenges relating to FOSW electrical infrastructure or transmission R&D that EPIC should consider?

Allowable motion and limitations are crucial in the design of electrical equipment and cables. To the extent that the private industry keeps evolving at a slow pace, support from public agencies could be very important to help seeing progress in several research fields, like dynamic cables and mooring systems.

HVDC Technology and Cost

6. What technical barriers will have the largest impact on development of deep-water HVDC substations in California? How could publicly funded R&D be most effectively applied to help increase timely and cost-effective deployment of new offshore deep-water HVDC substations in existing or future California WEAs?

As discussed in the response to question #1, the biggest technical barriers for deploying floating HVDC converter stations is the readiness of the HVDC valves and HVDC dynamic submarine cable. Other electrical equipment located on the floating converter station, such as transformers, reactors, and GIS, will be more readily available as suppliers study and prepare HVAC floating substations on an earlier timeline.

The process for advancing the HVDC valve design is roughly as follows:

- Create a floating offshore converter design

- Simulate the acceleration and fatigue loads on the HVDC valve design based on the motion for that platform
- Re-design, or add additional supports, to the valve
- Create a physical prototype which is subjected to mechanical and electrical testing

As discussed in the response to question #1, it would be helpful for the first bullet point above to be publicly funded to kickstart this process.

The HVDC dynamic cabling requires a similar amount of R&D work. Cable suppliers are prioritizing the HVAC cabling development because they expect that to be required earlier due to the same concerns about development of floating HVDC converter stations.

These initial efforts, which include the development of a floating converter design and simulating the loads on the equipment, is expected to be funded by developers. This is a perfect place to put public money if it is designed in a way to be usable for all developers. However, because the valve design is specific to the equipment manufacturer, the study should be led by the equipment manufacturer. Unfortunately, they may not be willing to put in the resources for such a study, as OEMs are typically busy with other contracted substations.

The biggest hindrance from advancing the HVDC valve design may be prioritization of resources dedicated by the HVDC equipment manufacturers. The demand for HVDC converter stations is extremely high from onshore transmission projects and fixed foundation offshore wind project. There are only three suppliers which US projects can use at this point - GE, Hitachi, and Siemens. If we were to order a fixed foundation HVDC converter station, for which the design and technology is ready, the earliest we could put it in operation would be 2031-2033 depending on the supplier. There is concern that their backlog is so large that they won't pursue floating wind projects, as developing this product is requires a significant amount of engineering resources.

7. What key cost factors are critical to the timely deployment of deep-water HVDC substations and associated offshore electrical infrastructure that could be addressed through technology advancement or analysis?

A key factor is the weight of the floater. For HVDC systems to be cost competitive, the weight and size of the topside and floater must be kept relatively low. However, increasing the size of the floater and topside can improve the stability of the electrical equipment. Analysis can help define the allowable motions of sensitive equipment, like the HVDC valves, which can help optimize the overall size of the floater. Advancing the equipment so that each item is more resilient or set in a way that the floater motions can be increased can further reduce the weight and cost of the floater and topside.

8. What novel technologies or design concepts proposed for HVDC substations have been successfully demonstrated in a physical or simulated dynamic offshore environment and can provide economic benefits and costs savings for California ratepayers? Are there any specific substation platforms, mooring systems, HVDC electrical components, or other substation technologies that provide clear benefits and advantages for use in the

existing or future California WEAs? How could R&D funding be most effectively applied to improve and optimize these technologies further to reduce cost and improve their technical suitability for California's WEAs?

We're not familiar with any physical or simulated HVDC floater designs. While at least one HVDC equipment manufacturer has a preliminary design, we consider this information proprietary and request that CEC requests feedback from the HVDC OEMs.

9. What key technologies or capabilities are needed in-state, regionally, and nationally to facilitate supply chain, manufacturing, installation, and operations and maintenance needs for deep-water HVDC substations and associated electrical infrastructure? What are the environmental, ecosystem, health, and social impacts associated with these technologies or that should be evaluated for these technologies?

HVDC converters and HVDC submarine cables are highly sought after equipment. Additional cable manufacturing can help reduce the bottleneck. There are several cable manufacturing plants recently built/being built in the US, often associated with state funding. Some examples include LS Cable in Virginia, Prysmian in Massachusetts, and Hellenic in Maryland.

Another major bottleneck in the future is the cable installation vessels. These vessels must be specially equipped for deep water installations to allow for a significant amount of weight to hang from the vessel before it touches the deep seabed.

While the HVDC converters must advance their valve design for floating applications, valve manufacturing is often not their bottleneck. HVDC equipment manufacturers often quote transformer manufacturing and engineering resources as the bottleneck. All three equipment manufacturers are working to increase their engineering resources in the US. In reality, there isn't much benefit to manufacturing the transformers in the US – they should be loaded onto the FOSS at the FOSS manufacturing yard, which will likely be in APAC for California projects.

10. What technologies or processes can monitor the condition and performance of deep-water HVDC substations and offshore electrical infrastructure? What are the current resolution capabilities of these technologies? Are these technologies or processes adequate for application in existing or future California WEAs? What are additional operations and maintenance needs for deep-water HVDC substations?

Considering Mooring System, Floating Foundations, and the Inter-Array Cable as well as Topside Substation electrical system, a periodical inspection and maintenance program will be developed, and tasks and time interval specified. For this purpose, the reliability-based maintenance planning will be carried out by applying three main methodologies for developing the scheduled programs:

- The logic and principles given for Reliability Centered Maintenance (RCM).
- The principles and calculation procedures for Risk-Based Inspection (RBI).
- Application of Condition Monitoring Systems (CMS).
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A more rudimentary, but important, maintenance activity will be to check the torque marks of all physical connections of electrical equipment to the topside structural steel. Torque marks indicate whether connecting bolts have turned due to the fatigue loads on the equipment during floater motions. As an accelerometer will monitor the movements of the topside, torque marks monitor the impact of those movements on the connections of equipment.

11. Are there any other questions or information the CEC should consider for research on deep-water HVDC substations for offshore wind that is not otherwise covered by the questions above?

Most of the questions above were related to platforms and floating electrical substations. However, there are options in the market for subsea substations to be installed in deep waters which have a limited electrical capacity, and therefore projects would require more units of those subsea substations. In general, offshore wind developers are averse to taking risks and the fact that these subsea substations can go out of service for an extended time without the possibility to get access to them could increase the OPEX for floating offshore wind projects significantly. We believe that the CEC could research more on this technology as offshore wind developers would always be more focused on solutions easily accessible that do not require a long time and high cost to be repaired, like subsea substations. This CEC could have a great opportunity to explore more on this technology, to find options that could eventually represent a feasible and more effective approach to design and build floating offshore wind projects.