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Making Wind More Efficient with Offshore Substations

Wind farm substations – those systems that transform and export electricity generated by wind turbines through submarine cables – are an essential component of the offshore wind farm, especially as these installations become larger and heavier. These substations are given the enormously important responsibility of converting and exporting energy to the grid in the most energy efficient matter to ensure the greatest return on investment, but there is still a long way to go before offshore wind substation technology becomes mature. And given that the typical cost breakdown for large scale offshore wind installations includes 7.5% for supply costs such platforms, cabling, and substation equipment there is significant opportunity for greater cost effectiveness and efficiency.[i]

Size Considerations for Offshore Wind Park Substations

The main purpose of a substation is to increase the voltage of the generated electricity before it is transmitted to shore in order to reduce electrical losses. But there are unique circumstances that create obstacles that the industry must overcome in order to demonstrate the most efficient, safe, cost-effective technology for such substations.

Perhaps one of the greatest challenges when designing an offshore wind farm substation is the sheer size of the components required. As with the installation of actual wind turbines, the infrastructure both onshore and offshore for transporting and installing components that weigh hundreds (sometimes thousands) of tonnes and require a lot of physical real estate is both costly and logistically challenging. The first substations for offshore wind farms usually consisted of simple topside frames with modules installed on top of them or within them. These were intended to be operated unmanned and to require few visits from personnel. In many cases, these substations weighed as little as 400 tonnes.

Today, substations are more fully developed, consisting of topside solutions installed on top of monopole and jacket structures. Other options now include self floating and self installing solutions which install without the need for expensive marine crane spreads. As a result, current substations weigh upwards of 4,000 to 22,000 tonnes.[ii]

One example are the two substations that were installed at London Array offshore wind farm in the UK in a collaborative project between Dong Energy (a Danish energy company), EON (from Germany), and Masdar (the Abu Dhabi government-owned renewable energy company). At the time of installation, this project was dubbed the world's largest wind farm at sea, with the capability of providing energy to 750,000 homes. This substation will transform the energy from the wind turbines from 33,000 V to 150,000 V, after which the electricity will be exported through cables measuring 50 km in length to the onshore substation at Cleve Hill near Faversham. There the voltage will be further increased to 400,000 V so that it can be fed into the national grid.[iii]

But these substations weigh more than 1,260 metric tonnes – the equivalent weight of 200 African elephants.[iv] The installation of these substations required the use of a 3,300 tonne lift-capacity floating crane in order to manoeuvre the 25 m by 23 m by 22 m tall system onto a foundation that's 15 km from shore – a costly venture.

Overcoming Size Challenges with Self-Installing Offshore Substations

Siemens Lillgrund offshore wind park substation platform

One option for overcoming some of the traditional challenges of substation installation is to use a self installing platform, which is a solution being used by ABB and Alstom Grid. Their HVDC self-floating and self-installing offshore substation for offshore wind farms technology is being used to connect the MEG 1 offshore wind farm in Germany to the German high voltage direct current system. It will feed in 400 MW of total power, which is enough to supply 450,000 households with energy and mitigate 1.35 tonnes of carbon dioxide emissions annually.[v]

Siemens is also deploying systems for offshore substations in wind farm projects. Their WIPOS (wind power offshore substation) has several configurations, including self lifting, topside and jacket, as well as floating, all of which involve prefabricated sections with flexible configurations for both AC and DC applications.[vi]

Like the ABB self-installing system, the Siemens self lifting solution offers the option of self installation which vastly reduces the costs and the risks that come with the requirement for heavy life vessels. In this configuration, the foundation is the substructure base frame which is connected to the piles that are driven into the seabed. The topside includes a rectangular pontoon with customizable internal walls and decks. Attached to the topside are the self jacking legs which are immersed and then connected to the substructure base frame.

Overcoming HVDC Design Challenges for Offshore Substation Designs

For very remote offshore wind projects where the distance to shore is 50 km or more, it is often most beneficial to use direct current to provide the most efficient transmission of power. For these applications, high voltage direct current (HVDC) technology is often employed. Yet HVDC technology is often much larger and heavier than high voltage alternating current (HVAC) technology.

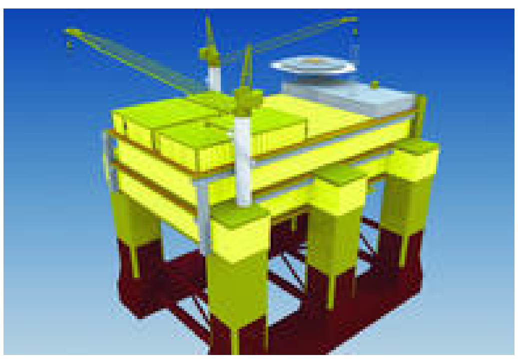

ABB GBS Platform for TenneT DolWin 2

HVDC therefore has an even bigger size challenge than HVAC technology. But some designers are overcoming the size factor for wind park offshore substations by creating smaller systems. In general, standard converter technology is insufficient because of the size required for such installations – they are frequently too large to fit on an offshore platform. As such, smaller converter technology is configured to fit on smaller platforms. The ABB HVDC Light is one example.

The ABB GBS platform, which stands for Gravity Based System, will be installed at the TenneT DolWin 2 project, and will demonstrate their HVDC Light (high voltage direct current Light technology) system, which reduces the electrical losses for optimizing wind energy transmission.[vii] This system includes enhanced voltage/VAR support, black start capability, and minimal short circuit contribution.

While size is certainly one of the biggest challenges for offshore HVDC substations, another challenge with HVDC technology is that it requires an onshore converter station. This can be problematic in populated areas where space is at a premium and costly. Additionally, where

HVDC circuit breakers are lacking and multi-terminal designs are a challenge, though some are solving this problem with AC CBs as switches. As such, HVDC and export cable technologies are relatively costly for projects over 500 MW.[viii] To overcome this problem, suppliers are working on submarine cables and converter equipment but much more testing is still required.

Maintenance Challenges for Substation Design

Configuration of a substation, access points, and storage areas for maintenance equipment are all important questions when considering the design of a wind farm substation. They all impact how easily and how often an offshore substation can be serviced and maintained by personnel. But there are many factors complicating the regular maintenance of an offshore substation.

Not least of which is that fact that these offshore substations are relatively new – the industry is breaking new ground by installing high voltage equipment at sea. This makes it difficult to know just how often they should be serviced. Additionally, because of the extreme weather conditions and vibrations an offshore substation must endure, the life expectancy of an offshore substation is not yet known, but will more likely be shorter compared to land-based substations.

Yet maintaining anything offshore is very costly, and finding operators to do the work is difficult given that skilled personnel are in short supply. As a result, most offshore substations are not maintained by every 3 months.[ix] This results in increased risks related to equipment breakdown and early retirement if maintenance cannot be made simpler and more efficient.

Industry is responding to these maintenance challenges on several fronts. For one, they are working to make more frequent maintenance visits in order to detect failures and problems early. With detailed records, personnel should be able to identify weak points, which will inform better designs for the future.

One of the most prevalent weak points already identified are the transformers that use oil as electrical insulation and are made of thin steel, which have been shown to be susceptible to corrosion. To overcome this challenge, designers are working with gas-insulated transformers that are healthier and safer for personnel to deal with. Additionally, some substation designs are moving transformers indoors which should help to minimize exposure to the elements.

These and many other maintenance challenges will need to be dealt with as substation designs become more mature, especially if a standardized offshore substation design is to be developed. What is certain is that, though many old technologies have problems in the extreme offshore environment, they are tested and proven, making them safe for now.

More Research and Standardization Required for Better Offshore Substation Development

The industry is currently grappling with the best designs for these offshore substations and innovating new solutions to achieve greater cost-effectiveness and energy transmission efficiency, though this segment of the market is not yet mature. Much has yet to be accomplished before a solid system for developing offshore wind substations has been developed.

Perhaps one of the biggest opportunities in the world of offshore substation development is standardization. If the industry can develop consistent standards or modules that can be deployed efficiently and in a time-sensitive manner, a great deal of time and money can be saved. It's no surprise that standardization has yet to be reached of course - to date, just over 20 substations have been built around the world.

Images via Siemens and ABB.

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