Lessons Learned by Offshore Oil Industry Boost Offshore Wind Energy

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There is a significant energy resource in the form of wind offshore of much of the United States. For example, a recent study done at Stanford by Dvorak, Jacobson and Archer suggests that there is an exploitable wind resource of up to 200 terawatt hours (TWh) off the coast of California. Unfortunately, 90% of it is in waters more than 50 meters deep, so a lot of this energy is not regarded as economically viable with the current monopile tower technology.

In general, the offshore oil industry has found that the cost of a bottom founded platform is a function of depth cubed so the cutoff depth is a function of the value of the energy asset (whether it's oil, gas or wind). This is a cubic function because if the water depth doubles, the platform height (from the bottom to the water line) doubles, so the amount of steel in it doubles. Then if the platform doubles in height, the base dimensions have to increase, roughly linearly, because the overturning arm on the base increases at least linearly. (The weight the lower section supports also increases as well, which adds some more steel cost.)

Fortunately, the offshore oil industry faced this problem in the late 80's, when the price of oil fell dramatically and the industry developed a number of options to economically exploit small oil fields in deep water. Most of these concepts are even more applicable to wind power, because another critical problem of many oil platforms is the high payload weight (which can vary substantially during operation) needed to support equipment to condition and control reservoir fluids. Wind turbines do not represent such high payloads, and they don't vary, so many of the concepts developed for offshore oil can be simplified.

Floating platforms represent the most straight forward solution. The basic concept behind a floating system is that most of the wave load comes from the water plane, where the body pierces the water surface, but the buoyancy can be anywhere, so the motions of a platform due to waves can be reduced by having most of the body well submerged with only small members piercing the surface.

To be a bit more specific, the natural period of a floating body (and hence its response to wave energy) increases as the mass of the body increases (including the "added mass" of the water closely surrounding it, which moves with it), and decreases with larger waterline. In addition, the acceleration of the fluid in the waves produces a force in a submerged body opposite to the rise of the wave — under the crest of a wave there is a downward component of force, and under the trough, an upward force. As a result, a body with a relatively small waterplane and larger submerged bodies has a range of wave periods where the net heave (vertical) forces are minimal or even zero. This gives us the two basic forms for fully buoyant platforms, either a semi-submersible or a spar.

For a full discussion of semi-submersible or spar platforms, as well as three addition "hybrid" platform concepts, click here to read the full article in the Alternative and Renewable Energy Developments Institutes' (AREDI) Summer Newsletter.

Other Considerations for Offshore Platforms

Another consideration for offshore wind is extreme wave height. It would probably be unfortunate for a moving turbine blade to be struck by a wave. In most cases, extreme waves will be associated with severe wind, such that the blades will be stopped, but occasionally, large swells can form from a distant storm. These will be long period waves, so a floating platform with a long period will be able rise and pass safely over these swells, but a bottom fixed system will not.

Finally, the power generated must come ashore. This poses two issues, cable dynamics in the case of a floating platform, and power. A flexible power cable is required, and it will subject to motions from the platform at the top end, as well as effects from ocean current throughout its length, so it has to resist fatigue damage for twenty years or more, as well as marine environmental effects such as corrosion and marine growth. The technology for flexible oil hoses used in some offshore systems is available for power export cable design, but it is likely that some research effort will be required to adapt these components for the high current and voltage requirements of export power cables.

Cables with alternating current (AC) will also produce severe inductive losses if immersed in a conductive medium, so it is likely that high voltage, direct current (DC) will be required for transmission. The equipment to produce this current will have to be in each individual platform, which increases complexity of the platform, but also provides opportunities.

Instead of a single large generator, offshore wind systems have been proposed with multiple smaller generators driven by a bull gear off the rotor. These would generate AC and each one would have its own step-up transformer and rectifier to produce high voltage DC, which would then be combined. This might reduce cost and dynamic stresses in the drive train, and would produce redundancy and easier maintenance (an especially important consideration offshore).

Developers around the world are working on various applications of these concepts for offshore wind energy. Some notable programs include Norske Hydro efforts on spar systems, significant research on the dynamics of various floating systems at MIT under Professor Paul Sclavounos, and a semi submersible platform from Marine Innovation and Technology in Berkeley, California. Blue H Group, in the Netherlands, has a set a tension leg wind turbine test platform in

108 meters of water off the coast of Italy.

It is clear that there is a significant energy resource in offshore relatively deep water wind sites, and thanks to this accidental synergy between offshore oil and renewable energy there are many viable concepts to exploit these resources.

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