Offshore wind power is set to contribute a higher share of the global energy mix in the future

Preparing for a marked wind change in global energy future

COATINGS Whilst the wind industry has been on a growth path for several decades now, huge strides have been made in the past year to make offshore wind energy more viable as a leading source of power. This is rather than a supplementary one for many economies blessed with access to deep waters and strong winds. While we may still rely heavily on traditional sources of power for most of the world's energy needs, thanks to significant advances in offshore wind technologies and increased investment in developing supporting infrastructure, wind power is on the rise. Protection of assets, such as the use of sustainable coatings, can reduce maintenance requirements and improve projects viability, writes Anders Voldsgaard Clausen, global key account director of Wind Power at Hempel AS, a supplier of protective coatings for the maritime and offshore industries.

The development of more powerful and larger turbines, paired with technological innovation and enhanced expertise in working further offshore, has reduced the cost of installing turbines and made investment in offshore wind farms more attractive for energy majors and governments alike. This increased appetite has added scale and capacity, while the cost involved in producing electricity from offshore wind farms has reduced. As a result, producing energy from offshore wind is now financially competitive with gas and modern nuclear power plants, and the viability of a sustainable, cleaner energy future is looking more realistic with each passing year.

Viability of offshore wind energy

These technological, logistical and ideological advances have led to a marked increase in the adoption of offshore wind facilities worldwide, with 25% additional offshore wind capacity added across Europe in 2017 alone. Many new offshore wind projects are starting small but modelling on the successes of the likes of Denmark, which at the start of this year produced 43% of its electricity from wind. However, with China pushing for a more sustainable energy future, and willing to invest worldwide, the economies of scale are growing, and the outlook for the wind energy market looks very positive.

That said, wind turbines are only a financially competitive option compared with traditional energy sources if the assets have a long service life, and low through-life maintenance requirements. Any work required to fix, update or strengthen wind turbines once installed offshore is extremely costly and can easily offset the gains made in using wind energy. Ensuring assets are protected against the harsh environment offshore – both above and below the waterline – by using the correct coatings in the first place is essential to enhancing the longevity of turbines in operation.

Offshore wind farms undoubtedly face some of the most severe operational and environmental conditions on the planet, constantly exposed to a corrosive marine atmosphere. Although the offshore wind industry is known to be generally conservative, its search for cost savings has encouraged Hempel, a coatings manufacturer, to research and develop new and innovative coatings that can be applied more quickly, and which offer good protection.

Layering for harsh environments

Having worked with the wind energy industry since its early development, Hempel understands that asset owners want to invest in a coating that reduces both risk and the total cost of ownership (lower cost per kW/h); and which ensures prolonged service life with little or no maintenance. Experience shows that to achieve maximum protection, wind farm tower foundations have been coated with a heavy-duty epoxy paint system and the tower structure above the water is coated with a zinc-epoxy three-coat system.

To find the most effective protective coating for offshore wind installations, research started in 2007 to examine ways to improve the effectiveness of conventional zinc-rich epoxy coatings, and an important discovery was made. While a typical conventional organic zinc-rich epoxy coating contains about 80% zinc, only one third of that actually contributes to corrosion protection. The research showed that only the zinc located in the 20 to 30µm closest to the steel was consumed by the galvanic reaction in a zinc-rich coating with a dry film thickness (DFT) of 60 to 80µm. Hence at least 60% of the zinc added to the primer was not used in a galvanic reaction.

This led to the development of the activated zinc-rich epoxy primer coating technology that incorporated tiny hollow glass spheres (~40µm in size) and a special proprietary additive – an "activator". Because of the synergy of these components, the coating provides three types of corrosion protection: a galvanic effect, a barrier effect, and an inhibitor effect.

These three-coat systems providing protection in the tough environment of offshore wind farms encompass a zinc-rich epoxy primer at 60 to 80µm DFT, a two-component polyamide adduct cured, high solids, high-build epoxy intermediate of 140 to 180µm DFT, followed by a two-component acrylic polyurethane topcoat, cured with aliphatic isocyanate of 60 to 80µm DFT.

These systems use high levels of zinc dust as a pigment in an organic binder (epoxy) or inorganic binder (silicates) to create a galvanic effect that protects the underlying steel substrate from corrosion. The zinc particles are more active than steel and act as 'anodes' in the coating that corrode instead of the steel when exposed to water, oxygen, and/or chlorides. It is these zinc-rich based coatings systems that are ideal for protecting wind towers, and organic zinc-rich primers are often preferred over inorganic zinc-rich primers, as they are less sensitive to surface preparation, over-application, and humidity, making application easier.

Leveraging scientific advancements

With the formulation of activated zinc-rich epoxy primer coating technology now utilised in Avantguard®, offshore wind assets are more effectively protected from the elements. For galvanic protection, the activator in the coating increases the zinc's ability to carry the corrosion current throughout the coating even if the zinc particles are not in direct contact with each other, which greatly improves the cathodic protection of the steel. The corrosion product of the zinc provides the coating's barrier properties and self-healing characteristics.

Typically, the corrosion product of a zinc-rich primer is zinc oxide (ZnO). In the activated zinc-rich primer the corrosion product created a more insoluble salt – zinc chloride hydroxide hydrate. This insoluble salt forms a uniform protective layer on the surface of the primer, which acts as a barrier that blocks water, oxygen, and chlorides from reaching the steel surface. Additionally, by-products from the rapidly corroding activated zinc fill any cracks caused by mechanical damage in the coating, essentially enabling the coating to heal itself.

The addition of the hollow glass spheres enhances the coating's physical properties. The spheres improve the film's crack resistance by blocking the propagation of microcracks, and they also contribute to the coating's low permeability. Additionally, the glass spheres are important contributors to the coating's inhibitor effect. An accumulation of insoluble complexes of zinc, oxygen, and chlorides on the surface of the glass spheres become part of the coating instead of reaching the steel substrate. The zinc corrosion product created during galvanic corrosion also acts as an environmental scavenger by capturing chloride ions as they diffuse into the coating from the environment, creating an inhibitor effect.

Enhanced in-service life of assets

A recent inspection was carried out on the *Thunoe Knob* offshore wind farm in Aarhus, Denmark, which was coated by Hempel in 1995. Four of the ten turbines were chosen at random and evaluated through visual examination, photographic documentation and dry film measurement. Despite being more than 20 years old, surveyors found that both the interior and exterior coating systems were in good condition and could be expected to remain so for at least another ten years, demonstrating a practical coating lifetime of more than 30 years.

In the same year, the *Horns Rev 1* wind farm, located in the North Sea off the Danish city of Esbjerg, was also inspected. In this hostile area, the environment has been classified, under the ISO 12044-part 2 standard, as C5 M – a very highly corrosive marine environment with high salinity. Once again, four wind turbines were chosen at random and evaluated. The exterior and interior coated surfaces were again found to be in prime condition and, from the overall results, it was estimated that the coating system would have a service life of at least 27 years.

Protected for the future

The long service life of each of these assets offsets the production and installation cost against the power produced and profitability of assets over the longer-term, thereby making offshore wind more economically viable as an energy source. As can be seen, the right choice of coating for a wind tower is a high-performing coating that can protect the structure for its entire service life, with minimal or zero maintenance. New and innovative paint technologies can meet this requirement, and it is essential that operators take the time to invest in reliable and robust protection for their assets.