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Offshore wind power – obtaining patent protection in a dense landscape

The second in a two-part series about IP and offshore wind power by the Carpmaels & Ransford team

The world's first offshore wind farm was installed in 1991 at Vindeby in Denmark. At the time, the electricity industry generally considered offshore wind power to be a folly; each wind turbine has a fraction of the output of a larger central power station, and offshore construction is notoriously difficult, with high winds, difficult access and salty, corroding conditions to contend with. In spite of this, Vindeby turned out to be the start of a now huge industry that experienced 30% year-on-year growth from 2010 to 2018.

The growth in this sector and indeed the growth of the turbines themselves have been enabled by rapid innovation, with the technology associated with wind turbines being broad and far-reaching. Patents in this sector cover structural, mechanical and electrical engineering, robotics, metallurgy, advanced and composite materials, coatings and corrosion protection. Technological advances have allowed offshore wind energy to become more competitive, including new designs and materials for the blades and foundations for supporting increased turbine size, and improvements in coatings and corrosion protection reducing the need for maintenance and repair.

Blades

When it comes to offshore wind power, bigger really is better. The energy captured from the wind is determined by the swept area of the blades, an area which is proportional to the square of the blade length. Doubling the blade length quadruples the energy capture.There is therefore an incentive to have fewer, larger turbines that cost less overall to install and maintain than a higher number of smaller installations. However, with increasing blade length, the thickness and width of the blade also tend to increase, with concomitant increase in the blade mass. Innovations in design and materials have been able to significantly reduce blade mass whilst allowing for longer blades which maintain a high stiffness.

Composite materials made from polymer resins reinforced with fibrous materials have been used to provide a balance between high stiffness and low weight such that blade size can be maximised. The mechanical properties (e.g. stiffness) of fibre-reinforced composites are, at least in part, determined by the identity and volume content of the fibres. Whilst traditional composites comprised borosilicate glass fibres, recent developments in fibre technology have seen carbon, basalt, aramid and even natural fibres incorporated into the composites used in turbine blades.

Mixtures of different fibres and/or secondary reinforcements such as carbon nanotubes, graphene, or nanoclays, have also been combined to make hybrid composites, which achieve a balance of desirable properties, including stiffness, damage tolerance, compressive strength, and polymer resin adhesion. Hybrid materials enable increasingly longer blades to be achieved, the longest wind turbine blade currently in service being GE Renewable Energy's 107m long blade, made from a composite comprising glass and carbon fibers, and wood, fused together in a polymeric resin.

As blades get longer, the amount of material they contain increases and the tolerance for manufacturing defects or errors decreases. Improvements in manufacturing methods help maintain quality and consistency as turbine blades increase in size. A turbine blade typically comprises two faces (aeroshells) joined together with either one or more integral webs linking the upper and lower parts of the blade shell, or a box beam. Aeroshells can be made using "*prepreg*" technology, adapted from the aviation industry, wherein pre-impregnated composite fibres containing an amount of matrix material bonding them together are formed into the required shape. Alternatively, aeroshells can be made using resin infusion technology, in which fibres are unidirectionally orientated in a mould with polymer foams or balsa wood forming the sandwich structure before injecting a resin into the mould cavity, for example under vacuum, and curing. The challenges faced in comparison with the manufacture of composite structures for aerospace are in making blades with much larger thicknesses and larger amounts of materials.

The important question for innovators is, as ever, how best to protect these new materials and manufacturing methods? The prior art landscape in this area is congested, since the materials and methods used in making offshore wind turbines are frequently used in other industries such as aerospace or conventional power generation.

In order to distinguish over the prior art and obtain patent protection, specific structural and compositional characteristics must be clearly defined and claimed. For example, definition of the properties of the composite, the reinforcing fibres, and/or the resin material may be required, including tensile strength and modulus, fibre length, additive particle size, and molecular weight of the resin. When drafting applications including such parameters, it is important to be aware of the requirements for ensuring the invention is clearly and sufficiently disclosed. The European Patent Office, for example, is strict on the examination of the clarity and sufficiency of claims including parameters and sets clear guidelines for patentability. Applicants need to be aware at the outset how to define the characteristics of these materials and methods in a way which is acceptable to the patent offices of the countries in which protection is desired in order to avoid pitfalls in the patent application process.

Foundations

Most offshore wind turbines are built on monopile foundations; large cylindrical steel tubes, which are pile-driven into the sea-bed before the tower is mounted on top. This technology has dominated turbine installation for many years due to its simplicity, but is not without its drawbacks. Increased turbine size means increased monopile diameter, which in turn increases the cross-section of the tube exposed to the sea and thus the hydro-dynamic loading. Just like a skyscraper, the taller the monopiles are, the wider they need to be, again increasing loading. Additionally, pile-driving a 100 metre long tube into the sea bed involves significant forces that reduce the fatigue life of the structure.

Innovation in monopiles, such as in load modelling and using suction buckets to assist in installation, seeks to address these difficulties. Nevertheless, eventually a water depth at which they are no longer economical is reached.

Currently, this is around 35 to 40 metres, and at this point jacket foundations take over. Jacket foundations are lattice frameworks of smaller tubes, and are similar to foundations that have been used by the offshore oil and gas industry for decades. Multiple legs mean that the overall sea-bed footprint is greater than achieved using a monopile, allowing increased stability and use in softer sea-bed conditions. However, their complex shapes give rise to additional issues in manufacture, installation and corrosion compared to a simple monopile, with an associated increase in cost. Whereas a single large jacket can support an oil rig in deep water, the provision of hundreds of deep-water jackets for each turbine in a wind farm would be prohibitively expensive.

Coatings

Longer blades are more aerodynamically efficient and extract energy more efficiently from the area that they sweep, partly due to higher blade tip speeds. However, these high speeds mean that the leading edge of each blade is repeatedly exposed to impacts with rain, sand and hail which can cause pitting of the blades. Pitting and increased surface roughness is detrimental to aerodynamic performance, causing a loss of blade efficiency of up to 20% and an estimated 22% of turbine faults. Off-shore wind turbine towers face additional challenges associated with long-term exposure to high humidity, high salinity, UV radiation and intense wave action, such that enhanced corrosion of vulnerable areas in the turbine mast can occur. This not only increases maintenance costs but also leads to leakage of low-carbon steel and zinc into the oceans which can be environmentally damaging. Innovation in protective coatings continues to identify ever more effective materials to preserve the efficacy of turbines over their lifetime.

Coatings are used to protect towers, blades, hub castings and other components. While turbine blades have traditionally been finished with hard, hydrophobic surfaces to prevent accretion of ice and abrasion by airborne particles, recently developed blade coatings are softer and less brittle. Innovative new coatings include functional materials to extend the lifetime of the blade and reduce the risk of leading-edge erosion. So-called self-healing materials have been developed, such as elastomeric polymer composites with a catalyst and healing agents microencapsulated in the polymer matrix.

Self-cleaning lubricating organogels[1] have also gained interest. SLUGs take inspiration from their slimy namesake, using a gel and liquid-repellent substance. When the temperature falls below freezing, liquid is expelled from the gel to make the surface slippery and prevent ice adhering to the surface. These kinds of coatings are important for offshore turbines in extreme Northern locations such as Alaska and Canada where ice has been found to accumulate on wind turbine blades, resulting in the blades becomes unbalanced and inoperable.

Specialised coatings have also been designed to protect components in the ‘splash-zone’, the area of the tower positioned just above the waterline. This zone suffers both from atmospheric and immersion-type corrosion, as well as general abrasion and damage by impact of maintenance boats. For example, Hempel designed a series of splash-zone coatings incorporating its patented fibre technology and which contain higher percentages of reactive diluents rather than conventional solvents, increasing the cross-linking properties of the coating and improving corrosion resistance[2].

1. *Self-lubricating organogels (SLUGs) with exceptional syneresis-induced anti-sticking properties against viscous emulsions and ices*, C. Urata et al., *Journal of Materials Chemistry* 2015, 3(24)

2. *New Offshore Coatings Focus on ‘Splash Zone’*, Paint Square 2017, https://www.paintsquare.com/news/?fuseaction=view&id=16665

While the opportunities for seeking patent protection for new coatings is vast, many patent applications fail at the EPO due to a lack of technical detail. As already mentioned in respect of turbine blades, clear definitions of the coatings are necessary to distinguish over the use of similar coatings in aerospace technology, oil rigs and sea vessels. Failure to include methods for measuring unusual parameters, such as “erosion resistance” or “surface roughening”, and using indefinite relative terms such as “transparent” or “repellent”, will often lead to clarity objections from a European examiner. In combination with the EPO’s strict approach to added subject-matter, applicants can quickly end up in rough water, unable to clarify the relevant terms by amending the claims in order to progress the application. When drafting patent applications, it is therefore important to adopt a rigorous, forward-thinking approach, with definitions and testing methods included in the specification, even for terms that might be considered clear in every-day language.

While protective coatings are applied to towers to protect against salt-water corrosion, studies have shown that half of all premature failures in corrosion protection materials are in fact related to the application process. Ensuring a fast-drying, solvent-free coating with low thickness and the ability to be applied in fewer coats is critical to the success of a turbine coating, especially where coatings have to be applied *in situ* during routine maintenance. The importance of the application process was acknowledged in 2018 when the Arkona wind farm project, a collaboration between E.ON and Ramboll, won the German renewable Innovation Product of the Year for its TSA (thermally sprayed aluminium) method. In this automated method, molten aluminium is sprayed robotically onto the turbine monopile, after which the surface is sealed with synthetic resin resulting in a significant reduction in corrosion and subsequent deposition of corrosion products into the sea. It is therefore clear that innovation in this field is not limited to the coating materials themselves, but also extends to methods of preparation and application.

Patents directed to coating technology in this field are therefore able to create further distance from the aerospace industry by the inclusion of process claims, which deal with a specific problem faced by remote salt-water structures.

Electrochemistry

It is a complex and costly process to repair coatings on offshore turbines, particularly coatings below sea level and in the splash zone. Protective coatings such as those described above are therefore often combined with a corrosion protection system to further reduce the amount of maintenance required during the lifetime of the turbine.

Galvanic anode cathodic protection systems (GACP) and impressed current cathodic protection (ICCP) are two options for corrosion protection. GACP relies on sacrificial anodes, typically made of aluminium-based alloys, which are consumed in preference to the steel structure of the turbine. ICCP uses an external power source and rectifier to supply a negative current to the turbine structure and a corresponding positive current to non-consumed anodes mounted adjacent to the turbine.

Obtaining patent protection for these systems can face difficulties similar to those for coatings. Corrosion protection systems are well-known in the oil and gas industry, nuclear power plants, offshore pipelines and coastal defences, and it can be difficult to distinguish systems used for wind turbine protection from those used in other technology fields. Applicants seeking to patent new cathodic protection systems may therefore expect prior art to be cited from any field related to marine structures with corrosion-resistant piles. It is therefore key to ensure the application is directed to the innovative aspects of the technology, and those specifically related to wind turbines. For example, although corrosion protection systems are relatively well-known, the innovation in offshore wind turbine corrosion protection often arises from the need to retrofit the corrosion protection system inside the submerged monopile structure. These systems have to carefully balance several issues including weight and manageability of anodes for offshore installation, options for mounting the anodes, and hydrogen evolution in a sealed environment.

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Summary

The technology associated with wind turbines is broad and far-reaching and there is significant overlap in the materials used for offshore wind farms with other sectors, including oil rigs, sea vessels and aerospace. Nevertheless, it is clear that innovative approaches are required to address the specific challenges faced by offshore wind power generation. Careful consideration of modifications to, or new ways of using, existing technology specifically for the offshore wind sector is required in order to identify and define patentable subject-matter in what might already be a patent-dense field. With a wealth of inter-disciplinary knowledge and experience, we can ensure that your innovations are looked after by the best team of people in order to provide robust and commercially meaningful patent protection.
The first article in this series on offshore wind power is available to read here.

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