Through life management of wind assets:
a holistic decision-making process

By 2040, it's expected that around 4GW of the UK's onshore wind capacity will be repowered projects. The next few years sees slow growth in this sector: around 100 MW per year from 2020 but increasing to around 500 MW per year by 2035. So as a significant number of wind turbines begin to reach the end of their original planned life service, our attention is focused on the topic of life management strategies to support owners make smart business decisions about the next phase of their wind farms.

Iain Dinwoodie

Head of Advanced Performance Engineering

iaind@naturalpower.com

Neil Marshall

Senior Due Diligence Project Manager

neilm@naturalpower.com

The decision on life extension is complex and inevitably includes technical, economic and legal considerations as well as acknowledging uncertain future electricity market prices and revenue streams, which determine if life extension is economically feasible.

The main options to consider are decommissioning, repowering or continued operation. Although wind turbines are generally designed for a service life of 20 years, many can continue to operate past their original design life. As the size and capacity of turbines increase, and technology continues to improve, the economic case for life extension is likely to become clearer. In fact, the lifetime of a wind turbine can often be extended by minor and low-cost repairs.

During 2018, the International Electrotechnical Commission (IEC) - IEC TS 61400-28 accepted a new global wind farm technical specification for development: 'through life management and life extension of wind farms'. This introduced the concept of independent verification of the strategies for equipment maintenance throughout the entire lifecycle of a wind farm.

A key objective of the technical specification is to establish independent guidance on best practices for wind farm operations. Throughout a typical lifecycle of a wind farm, qualitative and quantitative information will be collated and assessed to improve decisions on equipment performance, farm operation and maintenance.

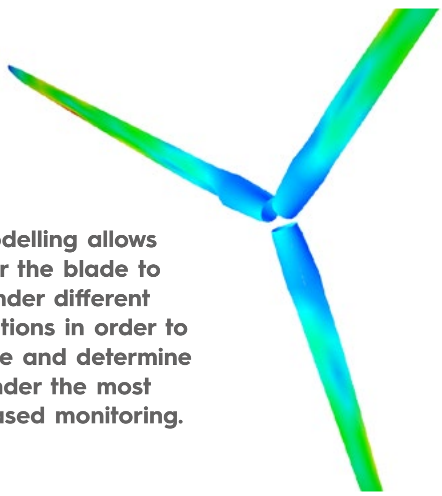
The aim is to provide impartial and independent assistance to all wind farm stakeholders as they weigh up decisions about retrofitting, repowering or life extension. These insights can be gained from a thorough assessment of the condition of all operating systems in a wind farm as the plant ages.

It's clear that increasing standardisation and increased experience at operating wind farms beyond their design life has already had a dramatic impact on reducing uncertainty for all wind farm stakeholders and helping to reduce the cost of electricity generated from wind. The new IEC technical specification will build on that.

To accurately assess the potential for life extension, a methodical approach will support the decision-making process, and includes a number of critical stages.

DESIGN SERVICE LIFE

Manufacturer assumptions are factored into turbine design to define the service life for the wind turbine. All operational, safety and construction relevant components and load-bearing parts of the turbine are designed, built and dimensioned to withstand foreseeable loads and stresses caused by wind, weather and operation for the length of this period. This design service life is usually 20 or 25 years, provided the specified maintenance is completed, regular inspections and testing are performed, and faults are immediately rectified.



Aero-elastic modelling allows the loading over the blade to be evaluated under different operating conditions in order to assess useful life and determine the locations under the most stress for increased monitoring.

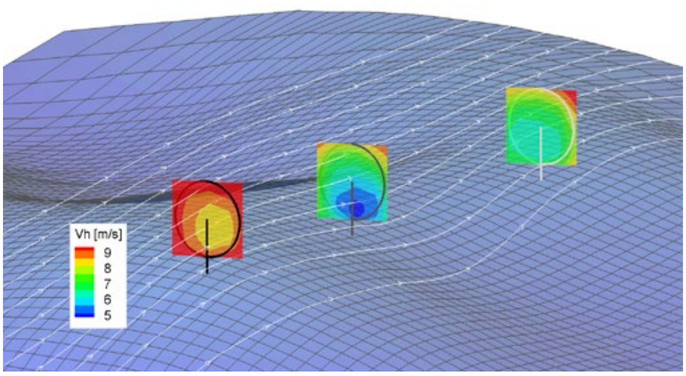
PRINCIPLES OF A LIFETIME EXTENSION ASSESSMENT

Owners are increasingly considering life extension decisions earlier in the life cycle of wind farms, as making the correct decisions early on ensure the lowest cost over the life of a project and allow any end of life strategy to be adopted. Indeed, many owners are considering through life management right from the start of the project.

After the analytical evaluation and on-site inspections, which provides preliminary results to indicate whether continued operation is feasible, a report is prepared specifying the requirements and actions for lifetime extension. For instance, repairs or precautionary replacements of the bolted connections of the rotor blade are often necessary, as these are usually the first elements to reach their design load limits. In some cases, it may be necessary to inspect key components in order to establish their condition. As part of this, an accurate financial estimate of the potential costs involved in a lifetime extension can be generated, which is important in assisting wind farm operators with decision-making.

ANALYTICAL EVALUATION

At this stage, operating loads are compared with design loads. The results of a physical inspection are also considered in these calculations. Fatigue loads in the turbine components are simulated using software-based models that take into account site-specific wind conditions and operational data. All load-bearing components contributing to the structural stability of the turbine are examined: the tower and foundation; load-bearing parts of the drive train; the hub; the shaft; the rotor blades; braking systems and the safety functions. This analysis identifies the remaining time until design loads are potentially reached as well as outlining measures required for continued safe operation that become necessary at defined points in time, like exchange of parts, individual inspection strategies or structural monitoring.



Computational Fluid Dynamics (CFD) illustration shows varying site conditions across 3 turbines on the same site.

STRUCTURAL ASSESSMENT

One critical factor in the safety evaluation process is establishing the structural stability of a wind turbine. The tests required to verify structural stability are mainly focused on the load-bearing components, from the rotor blades to the foundation, as well as the safety devices, braking systems and turbine control systems. The actual loads to which a turbine has been exposed during its operational lifetime need to be calculated based on operating data, data from the nacelle anemometry and compared with loads resulting from design conditions. This information is obtained from computer simulations that reflect design conditions after type testing, as well as environmental operating conditions. On top of this, an on-site inspection of the turbine is performed.

In particular during the structural review, the focus falls to understanding the fatigue life of the wind turbine and how the design conditions have performed against the actual conditions. If it is found to have experienced less damage cycles than the design envelope, then there is potential to extend the operational life of the wind turbine. Where it is found to have been potentially exceeded or close to its designed capacity, an inspection and maintenance regime could be developed to help manage the remaining life of the foundation.

ENVIRONMENTAL CONDITIONS

The potential for continued operation is calculated based on turbine technical documentation, as well as the environmental operating data. Wind farm operators are responsible for arranging the assessment and for presenting the relevant documents, including information relating to construction and commissioning; the operating permit of the turbine; repair, inspection and maintenance reports; operating and yield data; wiring and hydraulic diagrams; foundation design and construction quality documents. Additionally, a technical report documenting the conditions of the rotor blades, carried out within the last year of operation, is required.

There are a range of issues to consider in relation to life extension opportunities, most of which will be site specific and may vary greatly between sites. On the planning side, the process could range from no action required to a simple variation of a condition or at the other end of the spectrum, the need for a full EIA planning application. It largely depends on the existing consent and the conditions attached to it. It will also depend on whether the repowering or life extension proposal would result in an expansion of a site beyond the originally consented project. Key to progression on any site would be engagement with the relevant planning authority.

PHYSICAL INSPECTION OF A TURBINE

The objective of the physical assessment is to document any damage or unusual wear and tear to the turbine's components and equipment. The physical condition of a turbine is assessed through an on-site inspection during the practical part of the lifetime extension evaluation. Prior to the on-site testing and inspection of the turbine, the information and data already available are analysed. Technical documentation and reports, as well as weather and performance data, are examined so that the turbine can be checked for specific weaknesses and defects.

Load-bearing and safety-relevant components are examined in detail. Maintenance records are checked, and the turbine condition is compared with the technical documentation. In particular, inspectors search for signs of corrosion, visible cracks and suspicious noises in the gearbox or other gear and bearing assemblies. Also, a detailed investigation is carried out for weaknesses or flaws associated with a particular type of wind turbine, such as known shortcomings in the quality management during specific production periods or certain components or design flaws that lead to premature defects. Close attention is also paid to any changes in the surrounding environment of a wind farm.

Cracked bearing.

Blade damage, before and after repair.

DECOMMISSIONING VS REPOWERING

A lifetime extension assessment determines whether continued operation is possible and assists owners when planning for the future of their assets. Our experience shows that many turbines can still be operated beyond their design lives with some older platforms targeting a 30-year operating life. Previous lifetime extension inspection campaigns have provided widely differing results. The condition of a turbine coming to the end of its 20-year certification has been found to be largely dependent on several factors such as environmental, topographical and wind regime. However, the most important factor has been the site maintenance regime throughout the lifespan. A good maintenance and inspection programme from commissioning of the site ultimately ensures that routine servicing, continual monitoring, good tribological considerations and advance predictive maintenance and repair strategies are in place. This maximises the likelihood of the turbine's capability to extend beyond initial certified life is maximised. A good lifetime extension inspection will be able to report on the maintenance strategy deployed and its effect on the status of the turbine.

The results of a lifetime extension assessment can also be used to plan maintenance shutdowns and to forecast the costs that are likely to be incurred during the remaining lifetime of a turbine. This assessment is also recommended when applying for extension of insurance policies and is generally required by service providers after the end of the design life of the turbine.

If it's deemed uneconomical to extend the life of a wind farm and the site is not suitable for repowering due to planning, infrastructure or other financial constraints, it may be viable to extend the operation of individual turbines within a wind farm using key components from decommissioned turbines.

With so many contributing factors and site-specific issues to consider, a holistic approach is essential to making the optimal decision for each site.

To find out more and discuss how we can help you with the next steps in your assets life, contact:

Iain Dinwoodie, head of advanced performance engineering
iaind@naturalpower.com

Neil Marshal, senior due diligence project manager
neilm@naturalpower.com

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