The UK's Lifetime Extension Environment of Onshore Wind Turbines

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Abstract

With the beginning of 2024, the UK is facing a significantly increasing wind turbine capacity that is reaching its end of design lifetime. This paper presents additional UK-specific results of a European survey on the current state-of-the-art of onshore wind turbine lifetime extension. Apart from an in depth historical deployment analysis, specific UK related approaches as well as their challenges and uncertainties are raised originating from the survey executed in late 2016. Overall, results reveal that the UK's lifetime extension market is in its infancy and an asset's lifetime extendibility is determined by individual factors such as the land lease and grid connection agreement or its legal consent that can vary significantly. Further, the development of a governmental regulation may reduce uncertainty to unlock the full potential of the UK's ageing fleet.

Keywords: lifetime extension, wind turbine, UK, decision making

1. introduction

The lifetime extension analysis of wind turbines depends on country-specific circumstances such as i) the available subsidy scheme, ii) site and turbine conditions, iii) repowering characteristics, as well as iv) legal requirements [1–3]. Therefore, the analysis's framework is a key driver governing the degree of due diligence and resource commitment of the assessment. Where Ziegler et al. [1] aim to provide a comprehensive overview on the state-of-the-art of lifetime extension in Europe, this paper presents additional information gathered during the interviews aimed at presenting a more detailed picture of the UK. This is facilitated by a thorough market analysis and the consultation of experts in the UK. The latter through 6 guideline-based interviews originating from [1]. The remaining text is structured as follows. Section 2 presents an analysis of the UK's historical wind energy development, whereas in Section 3 the UK's survey methodology is discussed followed by the presentation of complimentary survey results in Section 4. Section 5 presents this paper's limitations and eventually in Section 6 findings are concluded.

2. The UK's Historical Wind Energy Deployment

The UK's wind energy market has increased significantly with the beginning of the 21^{st} century, reaching a total installed capacity of 13.6 GW as illustrated in Figure 1. This capacity in MW is distributed among 63% of onshore and 37% of offshore wind turbine generators (WTGs). However, offshore installations are expected to become the dominant share

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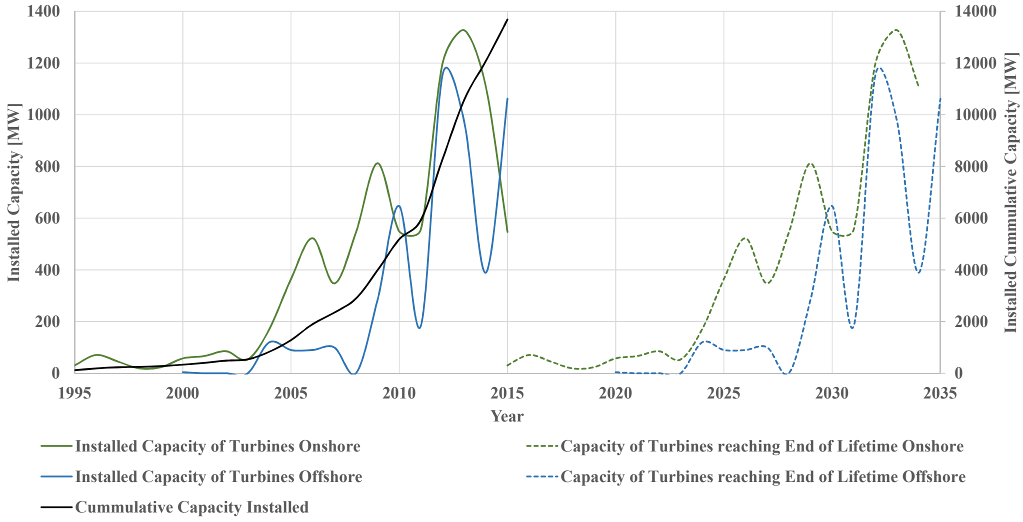

Figure 1: Annual capacity in the UK that will reach the end of lifetime (20 years) in the future [5].

in the future due to the overall reduction of onshore subsidies [4]. Historically, until 2007 the growth in capacity was mainly driven by upscaling paired with increasing installation numbers as illustrated in Figure 2. From 2007 onwards the average installed turbine size has maintained a relatively stable power rating reaching a plateau of 2.28 MW for onshore and 3.58 MW for offshore turbines, respectively. Onshore, legal requirements are likely to be the result of this scaling plateau, whereas offshore the two main turbine suppliers (Siemens and Vestas) have been very successful with their turbines rated at around 3 and 3.6 MW [5]. Nevertheless, it is expected that new offshore turbine models will soon increase the mean installation rating with the installation of 5 MW offshore turbines in 2015, 7-8 MW models in 2016 [6], and presumably $>$ 10 MW models in the near future. Consequently, in between 2007 and 2015 the growth was mainly driven by installation figures rather than upscaling.

Contrary to recent installations, it is important to analyse the share of turbines that will reach its end of designed lifetime as illustrated on the right-hand side of Figure 1. At present there is a small but yet substantial onshore capacity with an average rating below 1 MW (Figure 3) reaching its end of design lifetime. These turbines are predominantly located in Wales, Northern Ireland, and England with an average fleet age of 10.5, 8, and 6.6 years respectively [7]. For assets that reach their end of design lifetime, the owner or operator must decide whether to decommission, repower, or life extend either a wind farm or individual turbine. The capacity of end-of-life turbines is relatively small until 2024 (20-70 MW/year), which subsequently is growing exponentially reaching 400 MW in 2025. Assuming a capacity factor, CF of 0.28 as well as an electricity spot price of £40/MWh, this results in an annual revenue stream of £39,2 million/year.

In addition, the first offshore turbines (Blyth wind farm) will reach their 20^{th} year of operation in UK waters in 2020 (2nd: North Hoyle and Scroby Sands wind farm in 2024) [5].

At this stage the size distribution of turbines in their 20^{th} year will also has changed significantly as depicted in Figure 3; i.e., in 2025, 1.4% of the turbines will be below 0.5 MW, 37.7% in between 0.5 and 1 MW, 26.2% in between 1 and 2 MW, 30% in between 2 and 3 MW and finally 4.6% in between 3-4 MW. After 2025 the share of 2-3 MW turbines reaching their end of operational lifetime will increase continually, whereas the share of turbines below 0.5 MW will drop substantially.

At present, 15 onshore wind farms are beyond 20 years of operation in the UK [8]. While the renewable obligation (RO) is in its final termination stage, for the successor subsidy scheme contract for difference (CfD) continuous onshore subsidies are unclear [9]. With the

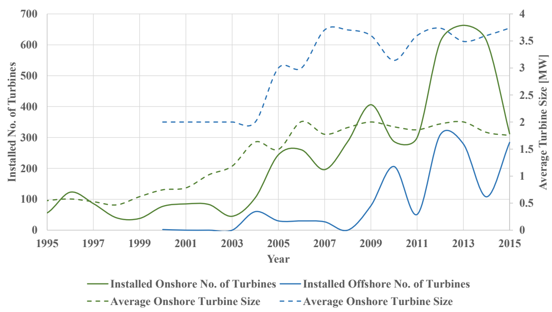

Figure 2: Annually installed turbines from 1995, paired with the average annually installed turbine size [5].

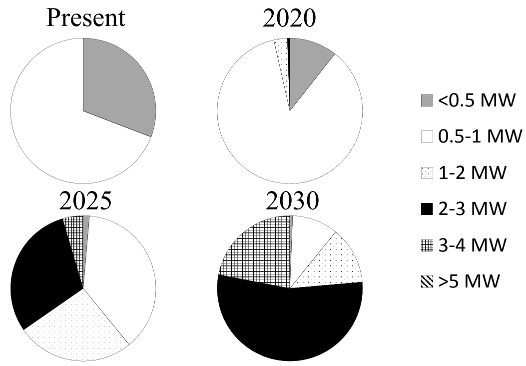

Figure 3: Distribution of turbine capacity reaching its 20th year of operation [5]. Boundary turbines are categorised in the higher class.

removal of onshore subsidies for new as well as repowering investments, the likelihood of lifetime extension is becoming more and more thought-provoking as identified by Everoze [7].

Especially, due to extended subsidies beyond 20 years of operation; i.e, the installed capacity that entered the RO prior to June 2008 is eligible for subsidies beyond 20 years of operation until the closure of the old RO scheme in 2027 [11, 12]. For this capacity, economic profitability will subsequently be defined by the spot-market electricity price from the beginning of 2027. With regards to the capacity that entered the RO scheme after June 2008, there is a fixed compensation period of 20 years, thus capacity reaching its 20th design life will directly be exposed to the market electricity price, although in 2027 there will be a move to a fixed price certificate [10]. With the termination of the grace period in 2019, the RO will be closed in 2039.

Further, the northern parts of the UK have one of the highest wind resource in Europe resulting in lower cost of energy [2, 4, 7, 13] and thus in comparison to other countries, there exist increased profit potential beyond the design life.

3. Survey Methodology

The overall survey design and execution is published by Ziegler et al. [1]. With regards to the detailed UK survey execution, in total 12 individuals were pre-determined to be suitable to participate based on their degree of industrial exposure on lifetime extension in the UK. 6 out of the 12 identified experts agreed to participate in a guideline-based interview that was conducted in person as well as over the phone.

4. Complimentary Survey Results

As presented by [1], survey participants of all targeted countries agreed to life extend in order to maximise the return of investment (ROI). In addition, participants in the UK highlighted the existing and hard-won local stakeholder relationships and an asset's available infrastructure. Participants further stressed that for many wind farms there are local constraints (tip height, access, noise), thus options such as repowering are not perceived as advantageous especially under the light of the terminated RO.

In practise, participants agreed on a two-split lifetime assessment approach based on i) data evaluation as well as ii) inspections. For the former, in-house designed assessment approaches were encountered in the UK as there is no governmental lifetime extension regulation in place, contrary to for example Germany and Denmark [1].

With regards to the applied toolbox to identify the health status of an asset, participants mentioned the following activities. A review of: i) maintenance reports (maintenance history, operation, reliability and failure data), ii) structural survey reports (if available), iii) operational reports (turbine availability as well as lifetime output), and iv) the wind history (permanent met. mast and hub anemometer). In addition, the asset manager was consulted besides reliability based analysis with supervisory control and data acquisition (SCADA) systems. Also, data from condition monitoring systems (CMS) is taken into consideration if available (predominantly drive train accelerometers). Mentioned data processing techniques are benchmarking of individual turbines (turbulence intensity, mean wind speed[1], yawing and pitching activity) and trend evaluation. Operators are further looking into measurement campaigns to evaluate loading of the tower, blades, and drive train although at present this has not been executed.

All participants highlighted the requirement for inspections, with most participants being aware of the component inspection list of DNV GL's guideline [14]. Recertification was not seen essential to the analysis. Details concerning intended/executed inspections are annual drive train inspections, non-destructive inspection (NDI) of all welded and bolted connections (e.g. measurement of bolt torque), checking for corrosion as well as the overall health evaluation of the blades (6/12-month inspection intervals). Annual maintenance strategies are continued as business as usual. With regards to the electrical equipment, respondents mentioned to check oil samplings of transformers.

The considered extension age is a combination of the historic wind conditions as well as the technical asset status. In terms of the optimal evaluation timing, in theory year 12-15 was mentioned as options narrow down quickly; however, in practise this is rather dealt with in year 18-20. With regards to obtaining turbine data from OEMs, results showed a pessimistic expectation/experiences, thus for potential future in-depth load analyses, generic data is likely applied.

Concerning difficulties and concerns, interviewees pointed at the requirement for more dedicated services and the general lack of experience. For example, it requires skilful and experienced technicians with a critical eye to thoroughly inspect turbines and identify critical components. Ideally critical components are repaired, replaced or monitored by CMSs. With regards to the availability of spare parts to retrofit turbine components, participants responded incoherently with some seeing the sourcing as a challenge while others do not expect any difficulties. Uncertainty in the UK's policies and regulation further feed into the tendency to limit the considered lifetime extension period in order to ensure economic feasibility. Also, there is a lack of clarity, if a few turbines within a wind farm require decommissioning (likely the ones with the more severe historical loading) as selected turbine removal may require amendment of the asset's land lease and grid connection agreement as well as planning consent and thus may consume significant resources. In fact, the younger the wind farm the tougher are its contracts in place; i.e., there are examples of indefinite and limited contract lengths concerning an asset's land lease, grid connection as well as planning consent. This further prohibits a standardised lifetime extension approach. With regards to the wind history, participants stressed that data from permanent met. masts or nacelle anemometers may become unreliable and require adjustment. Further changes to an asset's environment can influence the local wind regime as occurred in a case where a forest was planted within the vicinity of a wind farm. Lastly, participants stressed that procurement of original design standards can be challenging to obtain. If original design standards were not accessible, IEC design standards were applied as an alternative. It was also mentioned that lifetime extension does not generate balance sheet growth and thus is not necessarily

[1] a higher uncertainty was expressed for the turbulence intensity than the mean wind speed due to terrain impacts

appreciated by investors.

Overall, interviewees are confident about their in-house lifetime extension practices, albeit the previously mentioned difficulties and concerns. It is important to maintain a holistic view on lifetime extension in order to determine economic as well as technical feasibility. From a strategic point of view, there may be different extension approaches emerging in the future such as i) short-term < 5 years (lowest operational expenditure oriented or continuation in the form of business as usual) and ii) long-term > 5 years (investment based – retrofits).

5. Paper Limitations

This paper relies on experiences from in total 8 onshore wind farms that have been subjected to a lifetime extension assessment by industry. Consequently, this paper allows an inside at a few case studies within the UK that results give an impression about current lifetime extension practises as well as its difficulties and concerns. The results are further limited to the UK market and may change in the future, thus results are not likely to be applicable in other countries. Lastly, the UK is leading the offshore installation capacity in Europe; however, offshore assets experience a different loading profile than onshore, thus results are not generically applicable.

6. Conclusions

This paper presents complimentary market data and survey results that depict challenges and concerns in the UK's lifetime extension environment. Findings may guide operators, third party service providers as well as governmental institutions to tailor projects to streamline and support the lifetime extension assessment framework within the UK. Due to the current changes within the country's subsidy scheme, lifetime extension is expected to become an ever-increasing field of interest for researchers, owners and investors, third party service providers as well as certification bodies. At the same time gathered survey results reveal that lifetime extension is not a straight forward process, thus requirements and evaluation processes are uniquely dependent on an asset's environment.

Based on the interview findings, the UK government is actively encouraged to draft a lifetime extension guideline as this was observed as a key operational risk in long-term decision making. From a technical point of view this may include to develop the potential for more qualified inspection personal. One possible strategy may be to provide governmental certification for independent institutions to train and certify wind turbine technicians for end of lifetime inspections. This will ensure a thorough and more robust inspection process with a critical eye for detail. This could reduce the need for costly aero-elastic simulations as aimed for in the Danish legislation [15].

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