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Analysing the Lifetime of a Wind Turbine – Operation past Design Life

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Abstract

The lifetime of a wind turbine is a minimum of 20 years according to IEC 61400 [1]. However, differences between the design loads and the actual loads on-site can lead to the possibility of operating the WEC longer than the design life. Using an aero elastic simulation the individual overall lifetime can be calculated per main component.

Objectives

Each WEC has an individual lifetime which is affected by the on-site wind conditions. Using an analytical approach, the lifetime of each WEC main component can be calculated (Table 1). Consequently, the weak points of a WEC can be determined and the risk of damage caused by fatigue can be reduced (Figure 1). Knowing the overall lifetime serves as a basis for reliable organisational and financial decisions.

Figure 1. Fatigue can cause severe damage

Methods

The individual WEC type is modelled using the aero elastic software ADCoS [2]. Afterwards, the model is exposed to the site-specific loads to calculate fatigue load spectra. The site-specific loads result from the wind conditions and include the average wind speed and the natural and effective turbulences.

First of all the fatigue load spectra of the design process are calculated. Next the fatigue load spectra of the site, taking into account ambient turbulences and surrounding wind turbines, are calculated. For both configurations the fatigue load spectra are determined in cross sections for the blade hub, centre of the hub, tower head and foundation respectively and compared with each other.

From the fatigue load spectra the damage equivalent loads are derived and the resulting overall lifetime of the cross sections are calculated. The values for the overall lifetime are given per main component (Table 1).

The components of wind turbines are made of various materials. Therefore the analysis is carried out irrespective of the material. The specific resistance against fatigue of each material is characterized by the slope of the S-N curve.

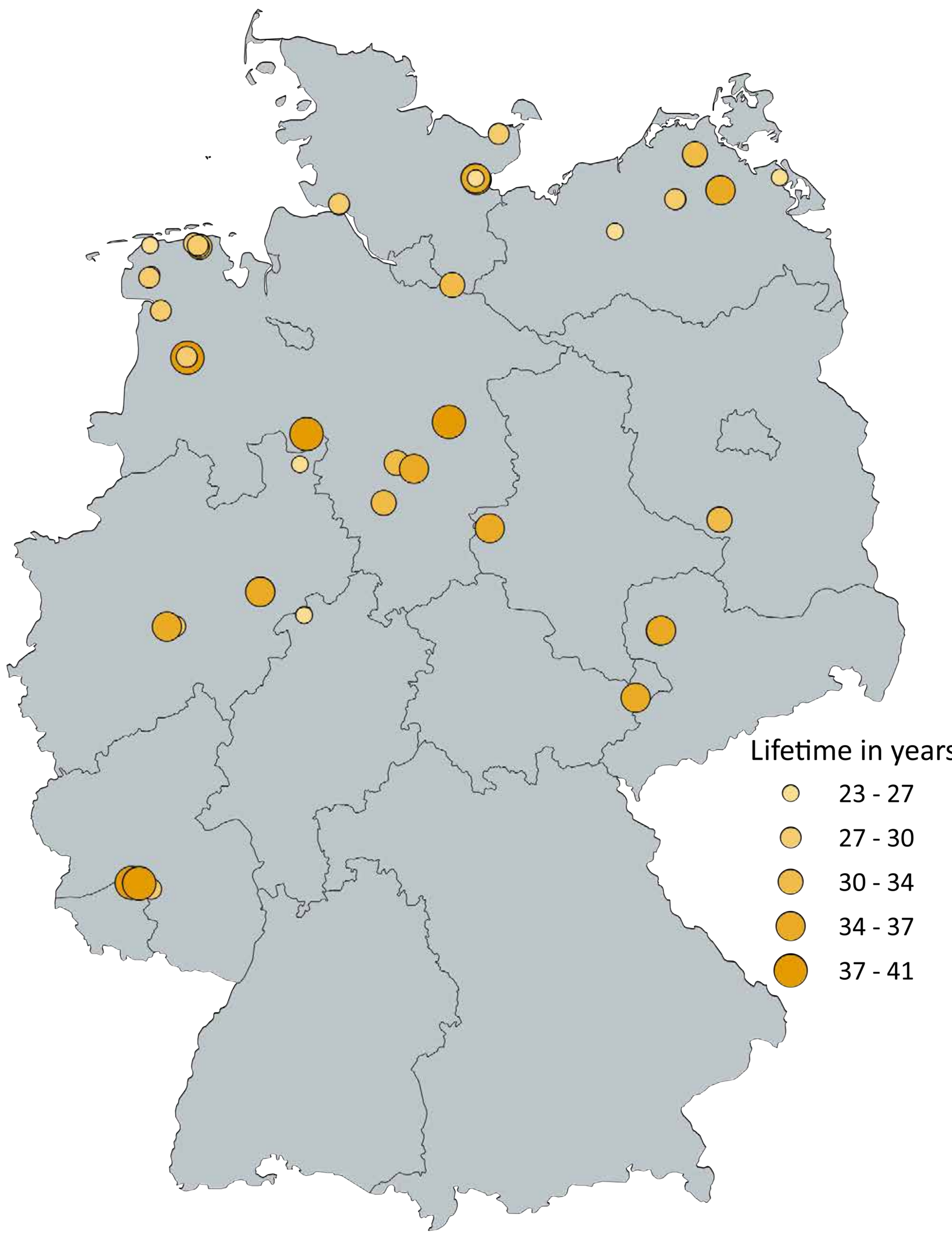

Figure 2. Regional distribution of lifetime in Germany

Applications

Different settings for the calculations are imaginable. The simulations can be carried out during the planning process of a wind farm if an advanced planning reliability is needed.

Moreover, the analysis helps to estimate financial and structural risks when the conditions on-site change e.g. in the case of new WECs built in the direct vicinity of existing WECs. The new wind turbines influence the turbulence on-site and cause a wake effect. This might lead to lower energy yields of the existing wind turbines and even influence the structural safety in a negative way. The analysis offers a direct comparison between the two settings.

In addition, the results of the simulation can be used to give advice on how to operate a WEC more safely and adjust it to the individual on-site conditions.

Also, the individual maintenance plan can be adjusted according to the lifetime of the main components and repairs of critical components can be planned in a long-term schedule. In the regular inspections it is possible to check the weak points, e.g. the rotor blade connection (Table 1), more closely and notice anomalies at an early stage. To extend the lifetime of the wind turbine it is possible to

- » adjust the operation mode and/or
- » renew the affected component.

Results

So far, more than 30 projects show that the simulated WECs can be operated past their design lives (Figure 3). The results lie between 23 and 41 years of overall lifetime for a design life of 20 years each.

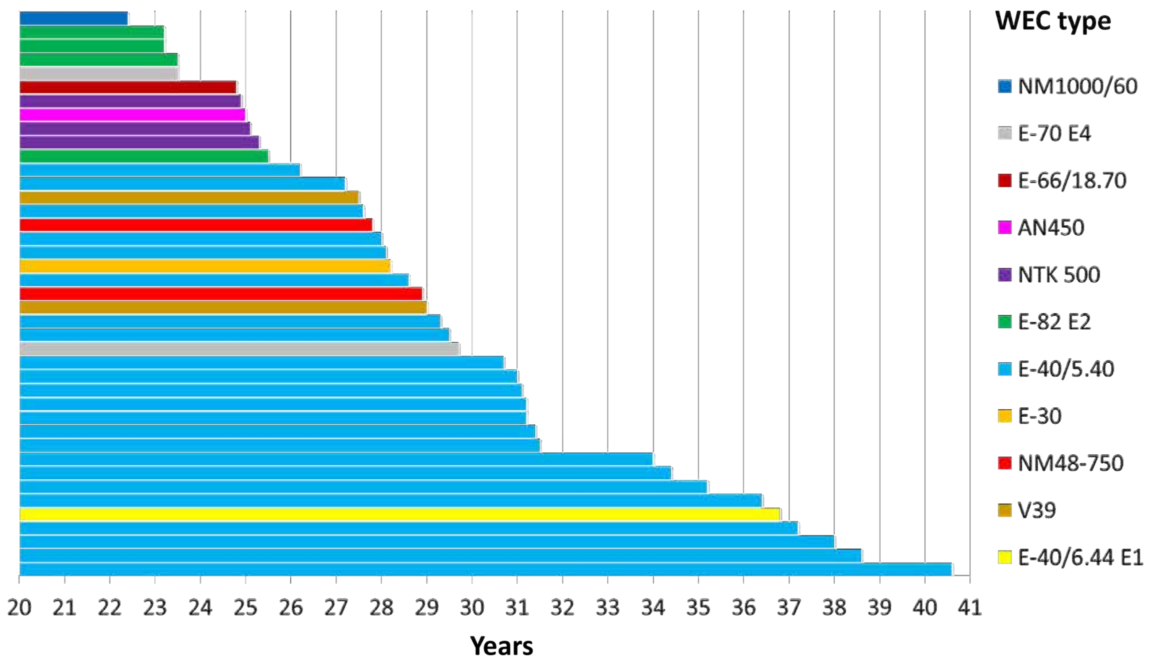

Figure 3. Analysed lifetime of the weakest component

In most cases a retrofit or renewal of the weakest component can easily be carried out after a few years of operation. That way it even prolongs the overall lifetime for several years.

Conclusions

In summary, each WEC has its individual lifetime which can be analysed based on the on-site wind conditions. Thus, the analysis enables operators, project developers and investors to plan individually and with a high reliability. Various scenarios for the analysis are imaginable and lead to a base for financial and organisational decisions.

Table 1. Examples of the minimum lifetime in years per component for different wind turbines

	Manufacturer	Vestas	NEG Micon	NEG Micon	Enercon	Enercon	Enercon	Enercon
	Turbine	V39	NM48-750	NM1000/60	E-40/5.40	E-66/18.70	E-70 E4	E-82 E2
	Quantity	3	> 100	2	3	2	1	4
	Site	Germany	Spain	Germany	Germany	Lithuania	Netherlands	Germany
Component	Rotor blade	> 50	47,7	22,4	> 50	28,1	48,4	31,7
	Bolted blade connection	30,3	27,8	22,9	30,7	24,0	28,3	23,2
	Hub	> 50	> 50	> 50	> 50	> 50	> 50	> 50
	Axle pin / Main shaft	29,0	> 50	23,0	> 50	> 50	> 50	> 50
	Mainframe	29,0	> 50	23,0	42,6	30,7	> 50	> 50
	Tower	29,8	> 50	23,3	46,4	30,8	> 50	43,0
	Connection foundation - tower	28,4	38,4	22,7	46,5	30,8	49,2	39,2

References

1. IEC 61400-1:2005+AMD1:2010. *Wind turbines – Part 1: Design requirements - Wind turbine classes.* International Electrotechnical Commission, Geneva, Switzerland.
2. Kleinhansl, S., Mayer, M. (2003, October 21). *Short Summary of Aeroelastic-Code ADCoS.*