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AEP increase by rotor-based improvement measures - an overview

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BACKGROUND

In times of zero subsidy bids and lowest cost of energy competition in the wind industry the margins of wind farm business cases are becoming rather tight. It is not enough anymore to simply keep the availability of the wind turbines on a reliable and high level to meet the business case expectations. Well, this paves the way for wind turbine optimization measures in order to regain the last 5-10% losses that a wind turbine might suffer as well as to tap additional performance potentials hidden in the turbine design. In addition, there is usually an indirect added value, as such improvement measures are usually not only increasing the annual energy production ("AEP"), but also reduce loads and stress considerably in the wind turbine components. Such indirect profitability lowers the cost and increases the value of wind farm assets by less wear & tear, therefore lesser maintenance & repair efforts and higher availability. On top longer component lifetime yield potentially additional years of operation, which all adds up to a better business case for your wind assets.

OBJECTIVE

- Emphasize importance of meeting AEP expectations, hence performance expectations of the wind assets
- Provide an overview on methods and tools to improve the performance of wind assets
- Assessment of the improvement potential
- Emphasize the importance of automatization in a fleet wide role out

METHODS

If dealing with wind turbine performance improvements, there are a couple of questions, that owners & operators usually would like to get answered before they are entering into such an investment:

- What are now the root causes for underperformance in wind turbines?
- Where can we find additional percentage points beyond the warranted power curve?
- Which methods and tools are available on the market?
- What is the improvement potential for my wind farm / turbine types?
- How can the performance improvement reliably be validated?
- What risks have to be considered in applying these measures?
- What is the return of investment, the business case for the application of such methods / tools?

Hence, this paper has investigated available sources in order to provide a rough overview on means, tools and optimization potential.

RESULTS

The following table shall give an overview on methods to improve the performance of wind turbines mainly in terms of the annual energy production (AEP), but also in terms of more availability (AV) in case of curtailment, noise reduction (N) and extension of component lifetime (LT). But it might also be the case, that the tool described simply serves to increase the safety of the wind turbine or to comply mandatory safety requirements (S).

Rotor based improvements are understood as being applied in the rotor plane mainly. Most of them have their physical effect logically in the domain of aero-dynamical improvements.

Adding up all the methods one easily collects 10-15% improvement potential accompanied by considerable investment cost. Hence, the question about the business case for the application of such methods needs to be answered and we also need to have a look into how such improvements can be optimally validated and what uncertainties need to be considered. We need to have a look into the tools, methods available today on the market for performing power curve / performance comparisons in order to become visibility on the business case of such appliances. It is one of the biggest challenges for the industry to validate any performance improvements as real AEP gains conclusively, since the major uncertainty in the performance calculation is coming from the wind measurements itself. Comparing just on the power level is certainly possible as well but requires at least two wind turbines with almost the same wind conditions and at least one year of measurements. Otherwise the uncertainties of such methods would easily exceed the actual improvements resulting in an inconclusive validation. As volatile, changing and dependent from so many factors as the wind is, it is therefore quite difficult to come up with methods that are able to validate smaller improvement steps in the range of 1%.

Issue on the wind turbine	Affects	How to improve	Applied measure / technologies	Improvement potential (always up to x%)	Improvement class
stall effects on the blades (Gaudern, 2019)	LoP, LT, N	Reduce tendency to separate from the air foil	Vortex generators	- 4%	AD
Stall effects in the blade root region reduce the lift (Gaudern, 2019)	LoP, N	Reduce tendency to separate from the air foil in the root region	Gurney flaps	- 2%	AD
Vortex after the trailing edge increases noise emissions (Gaudern, 2019)	N	Reduce vortex effect behind the trailing edge	Serrations	- 3 dB	AD
Low capacity factor – blade far beyond design loads	LoP	Increase length of blades with extensions	Blade root or tip extensions	Dep. on the ext.	AD
Drag from the cylindrical root shape (Sjo, Wittkampf, Eecen, & Donnelly, 2016)	LoP	Create lift instead of drag by adding a strip in the root section	Blade root spoiler	- 1%	AD
Vortex at the tip of the blade yields losses (Sjo, Wittkampf, Eecen, & Donnelly, 2016)	LoP, N, LT, AV	Vortex is weakened at the tip and position of the vortex changed	Winglets	- 2.8%	AD
Old blade designs are neither optimal in terms of aerodynamics nor in terms of loads (eTa4x, 2019)	LoP, LT, AV, N	Improve overall aerodynamic performance of the blades	Re-blading with an optimised design	- 20%	AD
Drag in the blade surface boundary layer (Riblet Surfaces - Wind Power, 2019)	LoP, LT, N	Reduce turbulences in the boundary layers	Blade surface optimisation	- 6%	AD
Layers of ice or dust deteriorate air foil shape (Schlögl, 2018)	LoP, LT, N, AV, S, MP	Detect icing or dust on the blades and remove them in time	Ice / dust detection and removal	- 5% (10%)	AD
Erosion and defects on the blades (Gaudern, 2019)	LoP, LT, N, AV	Repair erosions and other defects on the blades	Blade repair	- 4%	AD
Wind turbine doesn't head correctly into the wind (Hohlen, 2016)	LoP, LT	Re-align rotor axis with the wind direction	Static yaw misalignment correction	- 3%	AD
Wind turbine nacelle moves in a wide range around the actual wind direction (Hohlen, 2016)	LoP, LT	Reduce the range the nacelle moves around the wind direction	Dynamic yaw misalignment correction	- 1%	CO
Set and operate optimal pitch angles as supposed by the turbine design (Elosegui, Egana, Ulazia, & Ibarra-Berastegi, 2019), (Engineering, 2019)	LoP, LT	Detect static & dynamic pitch angle misalignments and correct them	Camera or laser-based detection campaign	- 3.5%	CO
In the wake of other turbines wind turbines suffer from reduced energy content and higher turbulences (Volker, 2014) (Blegg, Purcell, Ruisi, & Traiger, 2018)	LoP, LT	Wake avoidance	Dynamic park controller application	- 5%	CO
Low availability due to wind site conditions outside the design parameters	LoP, LT	Optimise sector management	Analyse wind site conditions	Dep. on curtailment	CO
Mass unbalances in the blades	LT, N, AV, LoP	Re-balancing and Blade CMS supervision	Mass balancing of blades	n/a	ME

Table 1: Overview improvement measures
Improvement class: AD...aerodynamical, CO...control, ME...mechanical
Affects: LoP... loss of energy production, LT... loads and increased component life time, AV... availability, N... noise emission, S... safety, MP... necessary manpower

FLEET WIDE IMPLEMENTATION

After successful demonstration projects with the selected and validated method to improve the performance, the next objective is, to implement the measurements, applications, algorithms and rules in integrated SCADA & asset management systems which allow to analyze the data coming in from such 3rd party IoT systems automatically based on the learnings from the demo project. Hence, that the work effort, for a fleet wide application doesn't need to be done manually anymore and becomes scalable. Subsequently a case should be opened automatically, where any anomalies can be explored. Or this will be transferred into work orders directly addressing the issue to ISP's. Such an integrated systems (e.g., Drive+ Pro from Power Factors) will then further help to achieve performance improvements scalable, fleetwide and keeping the cost low.

CONCLUSIONS

The retrofit market for the wind industry offers a lot of tools and methods to improve different weaknesses of the original wind turbine design or to tap additional performance potentials. However, it is tremendously important to understand, where the underperformance of the wind turbines is coming from or where such additional potentials can be tapped to apply the right tools and methods. Therefore, a detailed analysis of each specific wind farm with its usually unique environmental conditions based on the existing information is highly recommended. Based on this, the right approach to validate the benefits of the applied methods is equally important to justify the investments.

Subsequently it is tremendously important to implement the analysis algorithms and automate any remedy workflows in a fleet wide application in integrated asset management systems to justify the business case.

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