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WIND ENERGY SCIENCE DISCUSSIONS

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Interactive comment

Interactive comment on "Reducing cost uncertainty in the drivetrain design decision with a focus on the operational phase" *by* Freia Harzendorf et al.

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Dear respected reviewer,

Thanks a lot for the helpful remarks on the manuscript. For a faster understanding of the changes made I allowed myself to copy the comments and type my response and changes made in the manuscript below, R stands for the referee and A for the authors answers.

R: The paper addresses an important issue, and, in my view, should be published as an interesting contribution to an ongoing discussion. However, it cannot be regarded as excellent or a major breakthrough. The conclusions are a bit too trivial.

A: Thanks to your comments, the conclusion section has been rewritten in order to point out the important findings which give valuable insights for the above mentioned discussion. Furthermore, some more application fields and sensitivity analysis have been added to the concept comparison section in order to show the approaches value.

R: They reveal that the proposed method is in principle working, but still suffering from a lack of reliable accessible data. So the original problem is not yet solved.

A: The authors presented a framework for analysing the unplanned maintenance effort due to the drivetrain concept and already filled it with the available historical data. From a statistical point of view the filled data is sufficient enough to allow drawing conclusions. Nevertheless, this framework showed it workability and can now be used for sensitivity analysis and the testing of the influence of future development on this key performance indicator. The referee nevertheless is right that the original problem is not entirely solved. We therefore suggest to develop a physically based approach which would make it possible to estimate probability distributions for the uncertain model input factors.

R: And the advantage of direct drives versus drives with gears when using such a methodology in the way described in the paper comes as no surprise at all. What is not considered is e.g. the role of power density. Gears mean higher power density, and therefore less volume of material. And therefore, less risk of material imperfections and smaller probability of fatigue failures originating from such flaws. This aspect should be addressed.

A: Your comment inspired to add two paragraphs to the manuscript. The first paragraph deals with the question, if the historical data still presents todays' technologies behavior. It comes to the conclusion, that current development should be reflected in an reduced amount of major gearbox replacements and an increased number of major repairs instead. The second paragraph gives insight on how the different drivetrain concepts might perform in future application in terms of drivetrain influenced unplanned operational effort. The application for future turbines is characterized by a rated power of 5 MW and a rotor diameter of 150 m, being the average wind OEMs announced in 2020 for onshore application. The order of advantageousness is not changed due to the change in the application requirements, without taking technological development into account. Though the authors are not able to anticipate future development with certainty they can utilize the presented method to give indications about possible trends. Exemplarily the possible impact of higher torque density in gearboxes, a change to moment bearings and adjusted coil design in electrically excited generators is incorporated. It shows, that the superiority of synchronous generator concepts manifested in historic data is not entirely certain in future application.

R: In detail, I have a remark regarding line 240:"...whereas the two-stage gearbox, the three-stage gearbox with a three-point suspension system, and the DFIG can mainly be attributed to wear out behavior" The term "wear out behavior" is too unspecific and incomplete. There are numerous failure modes and among them are fatigue and also wear; the expression "wear" in itself is comprising various mechanisms. The suitable distributions, e.g. Weibull, and their shapes vary considerably. Therefore, I regard the way gearbox failures are considered summarily and indiscriminate as "wear out" as too simplistic. There should be a comment on this!

A: The referee is totally right. Gearboxes and all other drivetrain components can fail due to a variety of failure modes, which in combination lead to the failure rates available in literature. Due to a lack of failure mechanism specific failure rates in literature, the concept of the bathtub curve is applied here. In the context of bathtub curve wear out is understood in the general way of abrasion and comprises various mechanisms which lead to a failure in the end of a components lifetime. From the used data sources which are studies including aggregated information about failure rates of different drivetrain components for fleets of turbines it is not comprehensible which failure mechanisms lead to the breakdown. Nevertheless, this simplistic distinction is sufficient for giving preliminary statements on the unplanned operational effort in the design stage of a drivetrain concept. Sure, this approach can also be utilized for analysing the effect of a special failure mechanism on the drivetrain induced operational effort. For being able to conduct this analysis a failure mechanism specific distribution function is needed. In the end this analysis can give insights on how expensive the further development of a component should be in order to prevent this specific failure. Nevertheless, this was not the focus of the papers considerations.

I hope all remarks are taken into account to your satisfaction.

With best regards,

Freia Harzendorf

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