A generic evaluation of loads in horizontal axis wind turbines - Abstract

Introduction

Wind turbine size has increased year by year especially recently due to the demand for large units offshore. A lot of sophisticated software tools for load prediction of horizontal wind turbines have been developed and in many cases quite substantially validated by field testing. There is nevertheless a lack of a systematic parameterised understanding and quantitative characterisation of trends in wind turbine loads. A preliminary investigation into the impact of blade mass and turbulence intensity on the blade root bending moment is reported in this paper.
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Approach

This project is divided into different sections, which cover dissimilar areas of interests. The first section is to study how the impact of blade mass effects on blade roots. Basically, the blade mass of a wind turbine model would be modified to determine how loads at blade root would amend under the applied blade mass modifications. The simulation of modified blade mass models would be run under different turbulence conditions. It provides information how turbulence influences on different mass blades. Also, the source of hub loading can be divided into deterministic and stochastic. So the load of weight of blade can be obtained from the deterministic part, but the loading from turbulence can be calculated from the stochastic part.

The above mentioned section is a work before any dimension or scaling wise modifications take place as the scaled up wind turbine have completely different dynamics compared with the original unmodified wind turbine. The new dynamics require the new control systems. Thus the research starts from the blade mass modifications which do not have a large influence on the control system and give possibility to use the old control system from the original unmodified model.

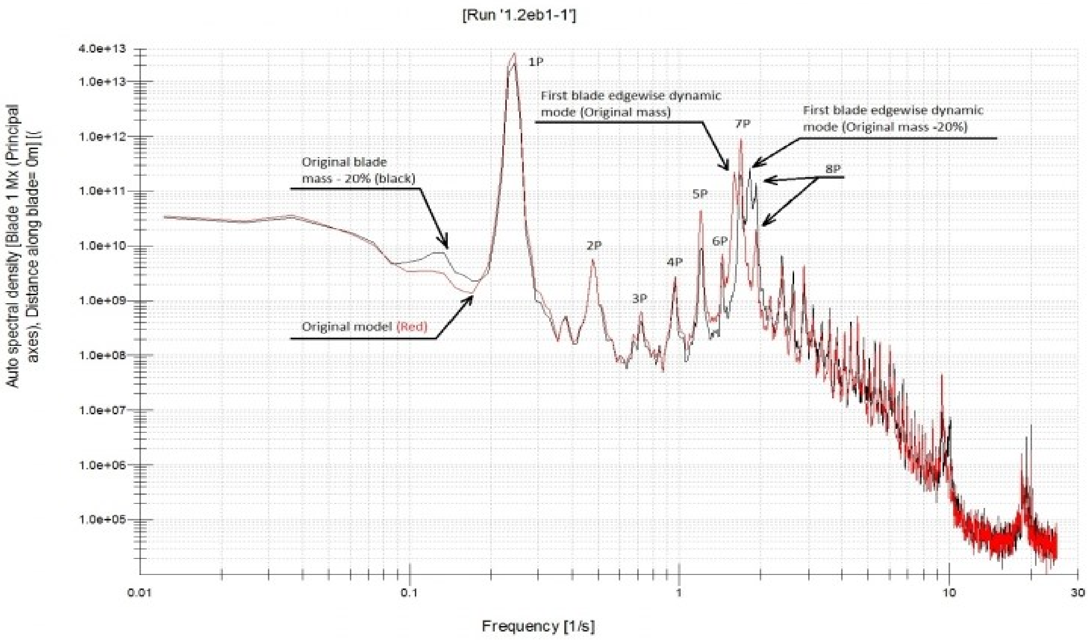
After the completion of the first section the same procedure will repeat but instead of the blade mass modification, the dimensions of blade will be scaled up. The two following sections presented below:

The second section is scaling of loads (extreme and fatigue) with turbine scale considering first turbines scaled with similarity so as to identify the scale impacts of turbulence, wind shear etc.

The third section is impact of self-weight loads with increasing scale and at fixed scale (for example, light, heavy blade and impact on hub fatigue etc.) which may be evaluated in studies separating out fatigue damage due to deterministic and stochastic influences by wind turbulence.

Main body of abstract

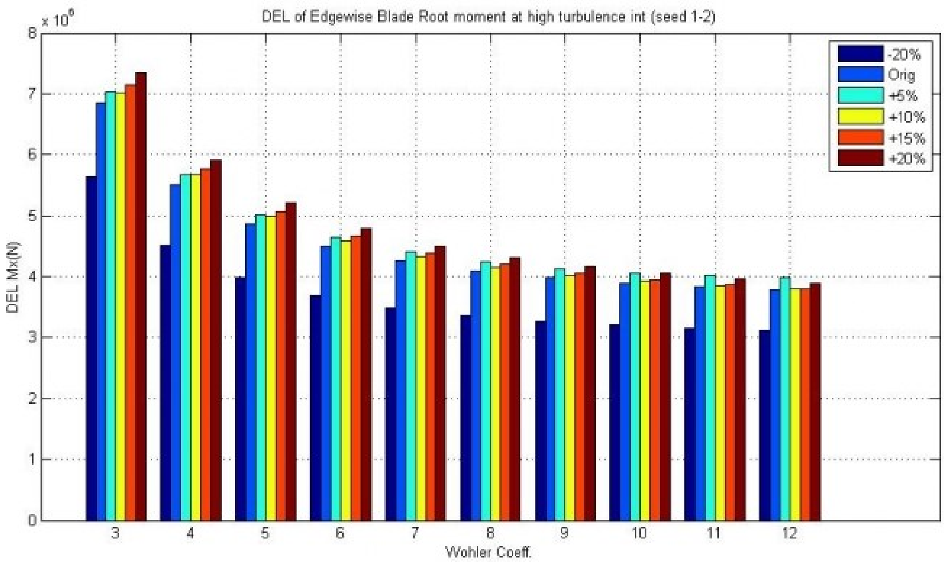
As it was mentioned before the blade mass modifications have to be introduced according to the first section of the project, which do not have any influence on the dynamics of a wind turbine. There were five different blade mass modifications such as: -20%, +5%, +10%, +15% and +20% of original blade mass. The gained data of modified blade mass models was compared with the original blade mass model. The figure



depicts comparisons of edgewise moment in blade root between -20% of blade mass model with the original model at 16 m/s of wind speed.

It is easy to see the most of peaks (1P, 3P, 4P, 5P, 7P and etc.) of original blade mass model are higher that the modified blade mass model (-20%). Thereby the blade root edgewise bending moment of original blade mass has more energy than the modified one which implies the edgewise bending moment of original blade is more severe than reduced blade mass one. Another thing which requires attention is the first blade edgewise dynamic mode of original and modified blade mass models. The blade edgewise dynamic mode moves to the right, the frequency of it becomes higher because of a result of the reduction of the blade mass. Moreover, the structural model of the modified blade mass model is higher than the non-modified one.

The mass of wind blades has influence on the blade roots edgewise moment. It is shown by figure f1 and other figure (such as: auto spectrum density periodic component of moment) which are not included in this abstract. Using other words the edge wise bending moment at a hub gets larger as long as the blade mass of blade increases.



The figure

presents the lifetime Damage Load of edgewise bending moment of blade root wind turbine against the range Wohler coefficients from 3 to 12 for the six different blade mass models. Where, there is 0.16 reference turbulence intensity and 0.015 Hz frequency or 〖10〗^7 cycles per lifespan of wind turbine which is 20 years. The figure f2 demonstrates that reduction of the blade mass by 20 % provided huge reduction of DEL compared with the DEL of the original model for metal (3≤m≥4) m and bit smaller for polymers (5≤m≥12). In other hand, the increasing blade mass by 20 % did not give the huge amplification of DEL. There is 7 % of DEL amplification for 3, 4 and 5 Wohler coefficients, but for the higher Wohler coefficients (11 and 12) the amplification of DEL is 3 % compared with DEL of the non-modified original blade mass model. Moreover, the DEL of + 5 % blade mass model is higher than DEL of +10 % , +15% and +20% blade mass model for high Wohler Coefficients.

The next step is to Increase the turbulence intensity reference by 25%.and see how loads will change. Thereby the I_ref will increase from 0.16 to 0.2.
DEL of 0.2 I_ref depicts a slightly different picture compared with DEL of 0.16 I_ref of the f2 figure, which shows the higher turbulence decreases the DEL values of edgewise blade root bending moment. The table

Description Model / Wohler Coefficients	-20% / Orig. model	Orig. model / Orig. model	+5% / Orig. model	+10% / Orig. model	+15% / Orig. model	+20% / Orig. model
3	1.08	1.06	1.03	1.02	1.03	1.03
4	1.07	1.06	1.03	1.02	1.03	1.03
5	1.07	1.06	1.03	1.02	1.03	1.03
6	1.07	1.07	1.03	1.02	1.03	1.03
7	1.07	1.07	1.04	1.02	1.03	1.03
8	1.08	1.07	1.04	1.02	1.03	1.03
9	1.08	1.08	1.04	1.02	1.03	1.03
10	1.09	1.08	1.04	1.03	1.03	1.03
11	1.09	1.09	1.04	1.03	1.03	1.04
12	1.09	1.09	1.05	1.03	1.03	1.04

demonstrates the table of edgewise bending moment blade root DEL ratio of 0.16 over 0.2 turbulence reference intensity, which proves the above mentioned tense. Also, it states the heavier blades have less DEL value than the light blade for the higher Wohler coefficients. According to that it is possible to conclude that the heavy blades have less influence from the turbulence.

As the mass was modified and stiffness not, the frequency of system was dissimilar compared to with original model. To maintain same frequency the stiffness was changed on same factor as blade mass. The

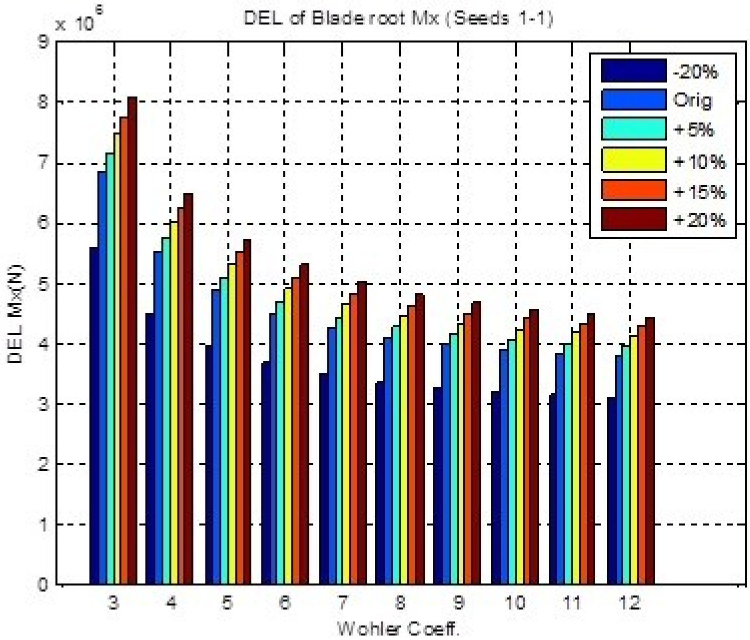


figure shows lifetime DEL of edgewise blade root bending moment for different models at 0.16 turbulence reference intensity. Where blade mass and stiffness of each model was change on same factor to keep frequency unchanged. It is seen from the figure that there is same algorithm of lifetime DEL for each Wohler coefficient.

Conclusion

This work has looked how the blade root loading of a wind turbine depends on changes of blade mass, which are considered non-significant modifications for the original wind turbine model. It gave an opportunity do not tune the control system and use it as it was.

So the modifications have covered the changes with the blade mass (-20%, +5%, +10%, +15%, +20%) of wind turbine due to the above mentioned reason. These models with modifications were tested under two different wind conditions such as: 0.16 and 0.2 reference turbulence intensity. The modification of blade mass amends the frequency. To overcome this issue, the stiffness of blade was modified on same factor to maintain the unchanged frequency for the system. The models with modified blade mass and stiffness were run at 0.16 reference turbulence intensity. The gained data provided the trend of the lifetime damage equivalent loads against to fore mentioned modifications at different wind turbulence conditions. It proves that the technique works and has provided trend of blade root loading changes due to the modifications of blade mass (see figure f4). It can be used to provide systematic parameterised understanding and quantitative characterisation of trends in wind turbine loads.

The comparison of the gained data of dissimilar reference turbulence intensity has showed that the heavier blades have the lower value of lifetime damage equivalent loads because the turbulence has minor effect on heavy blades that light ones (see table f3).

The further validations are required to run the modified blade mass and stiffness model under 0.2 reference turbulence intensity. After the gained data have to be used to see the any alterations of the trend of blade root loading changes due to the modification of blade mass and stiffness a result of different turbulence. Subsequently, it has to be compared with the gained data from 0.16 reference turbulence intensity.

Learning objectives

To reveal systematic trends in wind turbine loads as affected by the most significant influences and key parameters mentioned above.

To relate, at least in a simplified way, loading changes and component design/ cost impacts.

References

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