Extended Abstract

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Vibration mitigation of a 3 MW wind turbine through passive structural control

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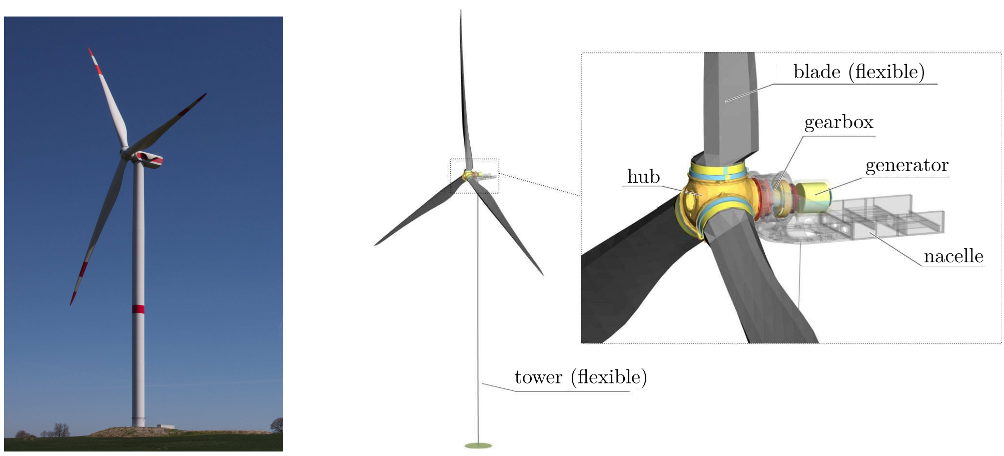
The increasing demand on renewable energy leads to strict requirements on the performance of wind turbines in order to compete on the energy market. These requirements result in the development of wind turbines with increasing rotor diameters and hub heights to achieve a power output at multi Megawatt scale. However, this leads to increasingly large, slender wind turbine structures that are prone to wind-induced vibrations.

The aim of adding structural control concepts to a wind turbine is to improve the overall dynamic behaviour of the turbine during operation by mitigating wind-induced structural vibration and fatigue damage. This results in an extension of turbine lifetime and thus in reduced economical effort. A common approach of structural control is the implementation of passive tuned mass dampers (TMD). The application of TMDs to wind turbine structures has been a focus of research during the past years. Especially the mitigation of the tower fore-aft vibration as well as the mitigation of blade vibration have been investigated and show promising results [1, 2, 3, 4]. The aim of this study is to investigate the performance of TMD to mitigate wind-induced vibrations of the W2E 120/3.0fc wind turbine designed by W2E Wind to Energy. A prototype of the wind turbine was erected in Kankel, Mecklenburg-Western Pomerania, Germany, Figure 1(a).

The overall dynamic behaviour of a wind turbine during operation is strongly nonlinear and depends on the complex interaction between turbine structure, turbine controller and environmental conditions. Using multibody simulation allows for a thorough investigation of the turbine dynamics during operation, resulting in a realistic representation of overall structural loads for different operation conditions. A detailed multibody model of the turbine prototype is built up in the general purpose multibody program SIMPACK [5]. An overall view of the turbine model is given in Figure 1(b). The multibody model is validated by extensive measurements taken on the turbine prototype. The measurements were carried out according to the International Electrotechnical Commission (IEC) standard 6140013 [6]. A detailed description of the multibody model and its validation is given in [7].The use of the validated multibody model of the real turbine prototype enables a comprehensive and realistic evaluation of TMD performance covering the whole operating range of the wind turbine.



(a) (b)

Fig. 1: W2E-120/3.0fc wind turbine: (a) Overall view of the wind turbine prototype erected in Kankel, Mecklenburg-Western Pomerania, Germany (b) Detailed view of the multibody model.

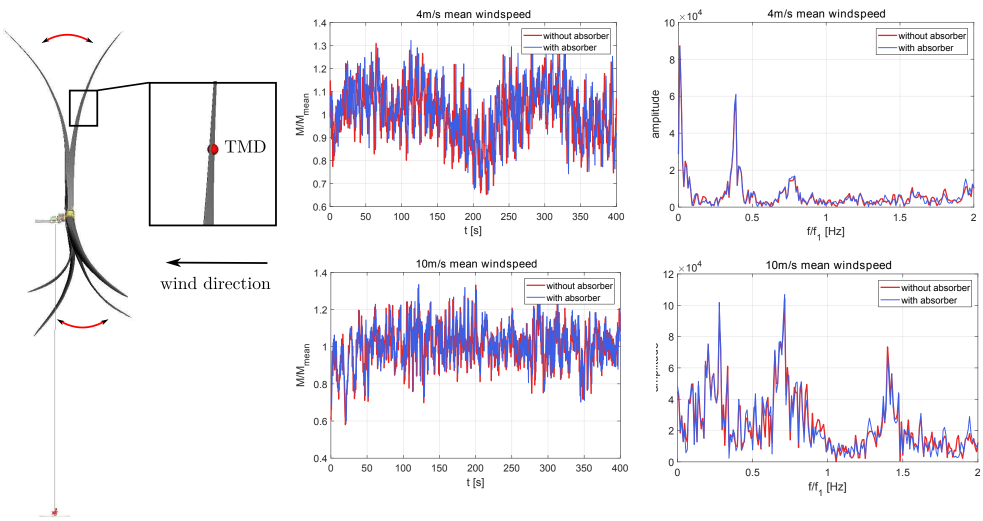


Fig. 2: First blade eigenmode in flapwise direction and exemplary DLC calculation with and without blade TMDs.

In a first investigation a tuned mass damper was mounted to the turbine tower top and tuned to the first turbine fore-aft eigenmode (bending along wind direction) [7]. The performance of the TMD was then judged based on the tilt bending moment (perpendicular to wind direction) at the tower base. However, the influence of the TMD on the operational parameters of the turbine as well as on the operational loads on other structural components was not accounted for. Two different TMD concepts are considered in this study. First a TMD mounted at the tower top, tuned to the turbine fore-aft eigenmode is investigated and its influence on all operational parameters, operational loads and the fatigue damage is analysed. In a second step a TMD is mounted at each turbine blade and tuned to the first blade eigenmode in flapwise direction (bending out of rotor plane). The influence of the blade TMD on the turbine dynamics is judged accordingly. Exemplary calculation results are shown in Figure 2 for the blade TMD comprising time series and the corresponding frequency spectra of the blade root bending moment for the two Design Load Cases (12 % turbulence intensity, 4 m/s and 12 m/s mean wind speed).

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