Aeroelastic Analysis of Multi-Rotor System Wind Turbines

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論 文 内 容 の 要 旨
Thesis Summary

The approach to increase the harvested power out of wind in the past few decades, was by increasing the size of the rotor of a wind turbine. Multi-rotor system (MRS) wind turbines can be a competitive alternative to large-scale wind turbines.

MRS are superior to large-scale wind turbines from the aspect of less weight/power ratio, ease of transportation and maintenance. However, one of the main challenges of MRS wind turbines is the complex supporting structure. The tower of MRS is subject to complex dynamic loads and coupled vibrational modes which are difficult to model, and hence manufacture.

The aim of this thesis is to address the structural behaviour of the MRS turbine tower. In order to do this, an in-house aeroelastic tool has been developed to study the dynamic responses of a MRS configuration wind turbine consisting of multiplicands of the NREL 5MW rotor. The developed tool has been verified by comparing the results of a single-rotor configuration to a FAST analysis for the same simulation conditions.

Steady flow and turbulent load cases were investigated for the twin-rotor configuration. Results of the simulations have shown that elasticity of the tower should be considered for studying tower dynamic responses. The tower loads, and deformations are not straightforward with the number of rotors added. For an equivalent tower, an additional rotor will increase the tower-top deflection, and the tower-base bending moment both in the fore-aft direction to be more than doubled. The tower torsional stiffness becomes a crucial factor in the case of twin-rotor tower to avoid severe torsional deflection. Tower natural frequencies are dominant over the flow conditions regarding the loads and deflections.

Furthermore, Three-Rotor and Four-Rotor configurations were modeled. Dynamic responses for each configurations' tower have been studied. The results showed that severer loads appear on the tower, although a stiffer tower was used to support those configurations. It also showed that the effect of a single-rotor in a MRS configuration on the torsional stresses are reduced compared to the twin-rotor configuration.

This thesis is structured into 6 main chapters. Chapter 1 Gives an introduction about the wind energy, its history, current status of its usage, introduces MRS and why they are superior over single-rotor wind turbines, objective of the thesis and finally the methodology followed to achieve it. Chapter 2 Describes the mathematical model used for building the in-house tool. Governing equations of the blade element momentum (BEM) theory, as well as the virtual work method used for the structure analysis as explained. Finally, the aeroelastic coupling between the two theory needed to create an aeroelastic simulation. Chapter 3 Includes verification of the developed in-house tool. The approach for validation is by comparing the results of the present tool to a similar FAST simulation. The verification

process goes step by step from the aerodynamics of the rotor, through the modal analysis, and finally to the aeroelastic analysis. The blades' loads, and deformations are compared, then the same is done for the tower. Chapter 4 Includes simulation for the twin-rotor configuration. The T-shaped tower of the twin-rotor configuration is modelled. Load cases for steady and turbulent wind conditions were studied, and the main tower and side booms' loads, and deformations are introduced. Chapter 5 Shows the simulation for Multi-Rotor configurations. Results for Three-Rotor and Four-Rotors configurations. Steady and turbulent flow conditions were simulated and compared to the single-rotor and twin-rotor configurations. Finally, Chapter 6 Concludes the thesis, to point the main findings of this work. Finally, it proposes the future work planned to improve the in-house tool and make it more reliable for more simulation conditions and parameters.