Faculty of Science and Engineering

2020 Australian Government Research Training Program Scholarships

Strategic Project Profile

PROJECT TITLE: Development of negative stiffness damper for offshore wind turbine vibration control

FIELD OF RESEARCH CODE: 0905

PROJECT SYNOPSIS:

Wind energy as one of the renewable energies is serving as an indispensable role in generating new electric power. The worldwide installation of wind farms has considerably increased recently. In Australia, the first offshore wind farm, the Star of the South, is also under development. This wind farm is located off the south coast of Gippsland, Victoria. 250 turbines will be constructed and the estimated total cost reaches $8 billion. After completion, it could power up to 1.2 million homes and provide nearly 20% of Victoria's current power.

Offshore wind turbines are constructed with large rotor and slender tower in order to effectively extract wind resources. These flexible structures are vulnerable to the external vibration sources such as wind, sea wave and even earthquake. The excessive vibrations of wind turbines can reduce the efficiency of wind energy conversion, lead to the structural fatigue damage and even result in the catastrophic total failure of wind turbines in harsh environmental conditions. It is therefore imperative to control the adverse vibrations of offshore wind turbines.

Research status:

Various methods by respectively utilizing the passive, active, hybrid and semi-active mechanisms have been proposed and used to mitigate the vibrations of wind turbines, and to ensure their safeties and serviceability. Among these methods, the passive control devices such as tuned mass dampers (TMDs), tuned liquid column dampers (TLCDs) and tuned liquid dampers (TLDs) were most widely used since these methods have simple configurations and do not need external power source. However, to achieve obvious and robust control effectiveness, large oscillating mass is needed, which impedes their applications in practices since the space in the nacelle, where it is installed, is relatively small.

A parallel direction to the TMD approaches is introducing negative stiffness elements for vibration control. The central concept of this approach is to reduce the stiffness of the damper by introducing negative stiffness into the system. The natural frequency of the system is thus significantly reduced, and the transmissibility of the system for all frequencies above the natural frequency can be reduced, which in turn enhances the control effectiveness. However, the negative stiffness in the damper may significantly reduce the static load capacity of the system, and therefore make the system unstable.

Research aim:

In this project, a novel negative-stiffness based TMD will be developed and used to control the vibration of offshore wind turbine subjected to wind loads. This novel system will combine the benefits of both the TMD and negative stiffness dampers while overcome their limitations. On the one hand, the damper will be designed to have the overall static stiffness of the conventional TMD, so that it will be stable under both the static and dynamic loads. On the other hand, due to the incorporation of negative stiffness, extraordinary damping will be added to the structure, and the vibration of the wind turbine can be therefore reduced evidently.

Methodology:

The damper will be developed in the Structural Dynamics Lab in Curtin University. In particular, disc springs will be used to achieve the negative stiffness due to its small size and high robustness. The developed damper will be tested by using the universal testing machine in the lab, and the mechanical behaviours of the damper will be examined. The damper will be further applied to a scaled wind turbine model, and shake table tests (which are available in the lab) will be performed to examine the performances of the wind turbine with and without the damper by equating the wind loads along the tower to the input at the base. Moreover, extensive parametric studies will also be carried out based on numerical analyses. In particular, the numerical models of the damper and the wind turbine will be calibrated by the experimental study, and the influences of the key parameters of the damper including the stiffness and damping will be systematically investigated.

Benefits:

This cutting-edge project builds directly on the research strength of Dr Kaiming Bi. His ARC DECRA (2015-2018) and DP (2019-2021) projects are on the vibration control of offshore structures (offshore pipeline and floating platform respectively). This project will be co-supervised by the ARC Laureate Fellow Prof. Hong Hao. All the selection criteria are met. The successful completion of the project will extend the service life of offshore wind turbines, which will significantly benefit the economy of Australia. It will also develop connections with offshore industry with the possibility of applying for competitive research grants such as ARC Linkage and CRC projects in the future.

FEASIBILITY AND RESOURCING – DESCRIPTION OF THE SUPPORT THIS PROJECT WILL RECEIVE:

The project will be supervised by Dr Kaiming Bi and ARC Laureate Fellow Prof. Hong Hao. Both have tremendous research and supervising experiences in the related fields. Dr Bi's ARC DECRA and DP projects both work on the related area, and he has successfully supervised four PhD students to finish.

All the equipment required in the project (universal testing machine and shaking table) are available in the Structural Dynamics Lab in Curtin University. The licences of the software for the numerical analysis are also available. This project will be funded by Dr Kaiming Bi's ARC DP Grant.

WHAT MINIMAL ATTRIBUTES AND SKILLS EXPECTED BY THE CANDIDATE BE COMPETITIVE:

The candidate should have research experience on Structural Dynamics. In particular, the one with the experiences in the following fields will be preferred:

1. Structural vibration control
2. Random vibration
3. Wind engineering

The candidate is also expected to be familiar with commonly used finite element software such as ANSYS or ABAQUS.

THE SIGNIFICANCE OF THE PROJECT/ PROGRAM FOR THE ENROLLING SCHOOL OR INSTITUTION:

The successful completion of the project will extend the service life of offshore wind turbines, which will significantly benefit the economy of Australia. The project will also demonstrate the ability of Curtin University to carry out cutting-edge research, which will contribute to Curtin's leading position in science and research. Moreover, the developed negative-stiffness based damper has great commercialization potentials, it will attract industry partners to jointly apply for the competitive grants such as ARC Linkage and CRC projects, which will also significantly benefit the school and university.

Students are advised to contact the Project Lead listed below prior to submission of their scholarship application to discuss their suitability to be involved in this strategic project.

PROJECT LEAD CONTACT

NAME: **Kaiming Bi, Senior Lecturer, Faculty of Science and Engineering**

EMAIL: **kaiming.bi@curtin.edu.au**

CONTACT NUMBER: **+61 8 9266 5139**

CO-SUPERVISOR

NAME: **Professor Hong Hao**

EMAIL: **hong.hao@curtin.edu.au**