Intelligent Fault-Tolerant Control of Offshore Wind Turbines via Deep Reinforcement Learning

Final report for the ECR Research Funding Project of EPSRC Supergen ORE Hub

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We greatly appreciate the ECR Research Funding from the Supergen ORE Hub – all the fund has been spent as planned and the project objective has been achieved.

As the key result of this project, an intelligent control strategy was developed for offshore wind turbines, which has fault-tolerance ability to common actuator & sensor faults (e.g., torque actuator offset fault, partial failure and stuck fault of generator speed sensors, etc.). The developed control strategy was based on reinforcement learning (RL) – a state-of-the-art and powerful AI technology for complex control tasks. It combined the merits of data-driven and model-based control methods and formed a novel application-oriented RL structure for the fault-tolerant control of offshore wind turbines. Particularly, this control strategy employs a surrogate model, which is called an incremental model, to capture the potential online system changes (including actuator & sensor faults) based on real-time measurements. Such information is then employed by a critic-actor structure, along with deep neural networks (NNs), to achieve high-performance wind turbine control under faulty conditions and other system uncertainties. Specifically, the critic NN is employed to evaluate control performance via estimating a long-term reward, and the actor NN is employed to update control policy to achieve optimal control (see Figure 1). The proposed strategy performed better than several typical wind turbine control methods (conventional PI control, model predictive control, and another RL-based control method) in high-fidelity simulations (see Figures 2 and 3). It significantly reduced control errors subject to actuator and sensor faults. The result has been organised into a journal paper and it is under review. The proposed RL-based FTC strategy also can lead to spin-off applications in other offshore renewable energy systems.

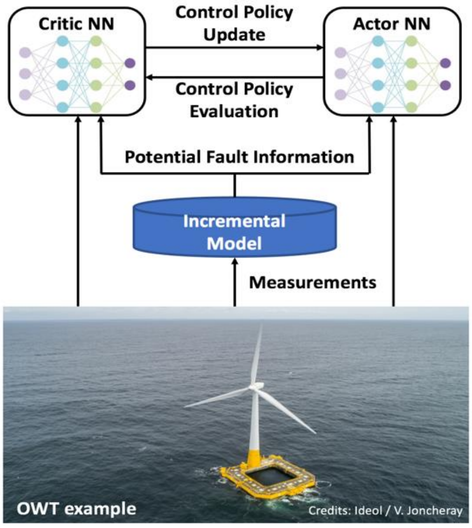

Figure 1: A brief illustration of the proposed control strategy.

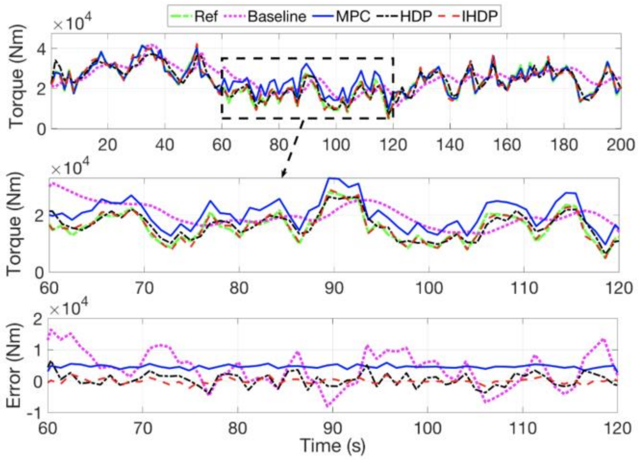

Figure 2: Generator torques under different controllers subject to the offset fault (+5000 N m) – IHDP is the proposed method, which leads to smallest errors.

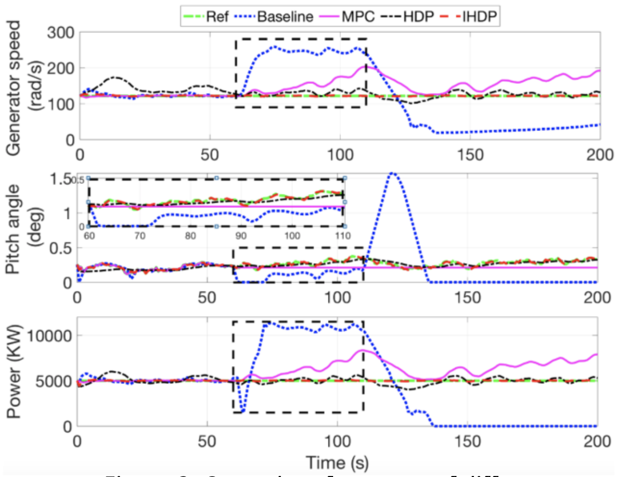

Figure 3: Control performance of different controllers under partial failure sensors and parameter uncertainties – IHDP is the proposed method, which leads to best performance.

A final project workshop with academic and industrial partners was held at Warwick on January 23, 2023, to disseminate the project result. This project has helped both PIs establish creditable track records by integrating their multidisciplinary expertise in reinforcement learning, control engineering and wind energy to address real-world challenges in the offshore wind sector. A PhD student supervised by Dr Lin at Hull will come to Warwick for a six-month secondment to continue this study. This will further enhance the collaboration between Warwick and Hull. Prof Xiaowei Zhao & Prof Li Ran at Warwick and Prof James Gilbert & Prof Ron Patton at Hull will fully support this research cooperation. The result also underpinned a research proposal that Dr Dong and Dr Lin are planning. Moreover, it showcases the great application potential of RL and other AI technologies in the operation of offshore renewable energy systems, contributing to the UK's net zero strategy by providing new data-driven, AI-powered approaches.