Optimizing Wind Power Generation: Developing a Digital Twin for Real-Time Monitoring & Analysis

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Introduction

- Build a digital twin of the electrical system of an offshore wind turbine.
- Help address challenges with the intermittency of wind resources.
- Create a digital counterpart to capture the system dynamics, and improve efficiency, reliability, and predictive capabilities.

Methods

- Engineered a comprehensive mathematical model of the wind turbine in Simulink/MATLAB, capturing essential electrical and control system dynamics.
- Transitioned the Simulink-based mathematical model to a real-time digital simulation platform, enabling the emulation of a power grid.
- Analyzed the dynamical model and control systems for adequate data acquisition.
- Designed a data driven model to mirror the behavior of the simulation

Results

A data-driven approach to building a digital twin based on dynamic mode decomposition (DMD) has shown encouraging results. DMD is model-free and, unlike typical machine learning methods, is amenable to physical interpretation, uses moderate dataset sizes, and is highly efficient computationally.

Discussion

The project will culminate with a power-hardware-in-the-loop (PHIL) simulation setup, including real but downscaled power-electronic modules, controllers, and a 6-kW permanent magnet synchronous generator driven by a controlled-speed induction motor that emulates the wind turbine.

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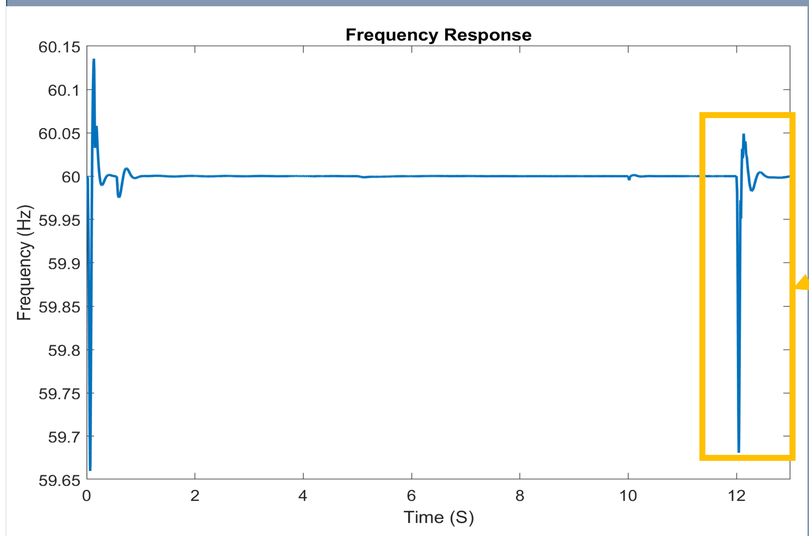
ACKNOWLEDGEMENTS: Dr. Marcos Netto and Dr. Philip Pong for their research expertise, guidance, support, encouragement, and suggestions. NJIT and NJ- Wind Institute for supporting my engagement with renewable energy research and application.

The developed DMD method-based digital twin:

1. **captures well the dynamics of an offshore wind generator and control systems.**
2. **It's computationally efficient because it relies on linear algebra tools.**
3. **shows promise as a building block for a digital twin of an entire offshore wind power plant.**



The frequency response of the mathematical model under electrical fault

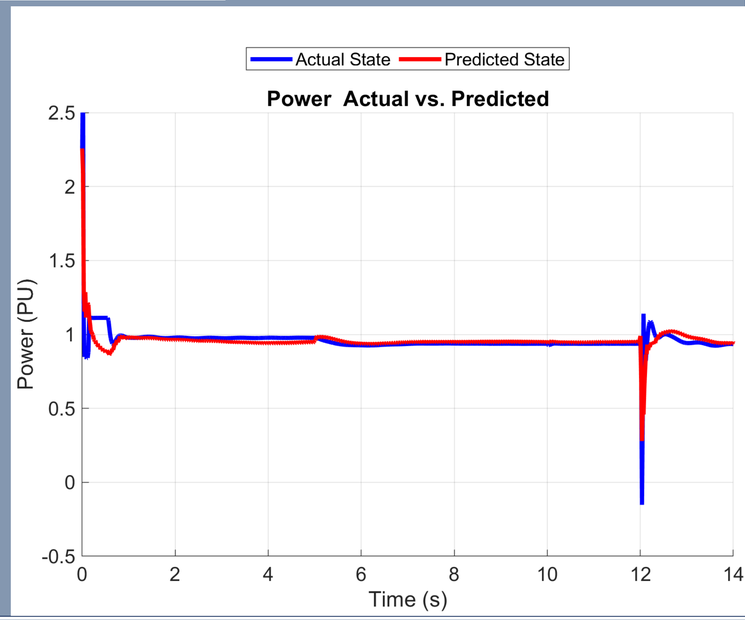
Active power response of

mathematical model

vs.

data-driven DMD method

- **Mean Square Error: 0.16 %**



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