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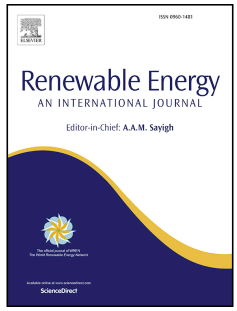

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Wave forecast and its application to the optimal control of offshore floating wind turbine for load mitigation

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Abstract

Control algorithms play an important role in energy capture and load mitigation for offshore floating wind turbines (OFWTs). One of the advanced and effective control techniques is the feedforward or model predictive control approach, which requires the forecast of incoming environment conditions. For OFWTs, wave loading is one of the dominant sources to excite structural responses. This study is thus motivated to develop forecasting algorithms for wave elevations and wave excitation forces with the purpose of applying feedforward controllers on OFWTs. Two forecasting algorithms, the approximate Prony Method based on ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques) and SVM (Support Vector Machine) regression, are developed and validated using wave records from tank tests. Utilizing the forecasted wave elevations and wave excitation forces, a feedforward LQR controller is designed to mitigate structural loads of an OFWT system.

Key words: offshore floating wind turbine, wave forecast, optimal control, load reduction

1. Introduction

The ocean environment provides enormous sources of renewable energy, among which one of the most promising is the offshore wind energy. A recent trend of the wind industry is to go further offshore to overcome limited land availability and avoid visual and acoustic pollution. Besides, the ocean wind tends to blow more strongly and consistently, allowing the utilization of larger wind turbines that enjoy better economics per rated megawatt (MW). Meanwhile, using floating support structures in offshore wind farms adds more complexity to the system and leads to more technical and economic challenges. One important aspect of current research aiming to overcome such challenges is to develop advanced control systems to optimize energy capture or achieve load mitigation.

Several advanced control approaches were proposed over the last decades to achieve load reduction or power optimization of onshore and offshore wind turbines. One promising approach is to use feedforward or model predictive control (MPC) to improve disturbance rejection. Extensive studies have been done on model predictive controls on onshore and offshore wind turbines with regard to wind induced loading (Körber & King 2010, Laks et al. 2010, Raach 2014). These studies have shown that, with a model predictive controller, the fatigue loads at critical structural sections can be significantly reduced when wind speed predictions are provided to the controller.