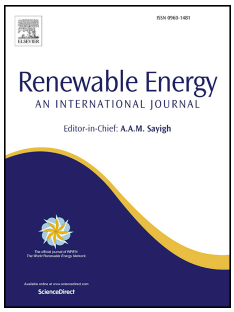
Accepted Manuscript



Maintenance scheduling based on remaining useful life predictions for wind farms managed using power purchase agreements

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PII: S0960-1481(17)30244-6

DOI: 10.1016/j.renene.2017.03.053

Reference: RENE 8646

To appear in: *Renewable Energy*

Received Date: 24 September 2016

Revised Date: 9 March 2017

Accepted Date: 17 March 2017

Please cite this article as: Lei X, Sandborn PA, Maintenance scheduling based on remaining useful life predictions for wind farms managed using power purchase agreements, *Renewable Energy* (2017), doi: 10.1016/j.renene.2017.03.053.

Maintenance Scheduling Based on Remaining Useful Life Predictions for Wind Farms Managed Using Power Purchase Agreements

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ABSTRACT

Prognostics and Health Management (PHM) technologies have been introduced into wind turbines to forecast the Remaining Useful Life (RUL). PHM with RUL predictions enables predictive maintenance for wind turbines prior to failure, thus avoiding corrective maintenance that may be expensive and cause long downtimes. For a wind farm managed using a power purchase agreement (PPA), a simulation-based European real options analysis model is used to schedule predictive maintenance by maximizing the predictive maintenance option value. For multiple wind turbines indicating RULs concurrently, the predictive maintenance value for each turbine depends on the operational state of all the other turbines, the amount of energy delivered, and the energy delivery target, prices and penalization mechanism for under-delivery defined in the PPA. A case study is presented in which the optimum predictive maintenance opportunity is determined for a wind farm managed using a PPA. To the authors' knowledge, this is the first wind farm maintenance model including a PPA, and the case study demonstrates that the optimum predictive maintenance opportunity for a PPA-managed farm is different from the same farm managed using an "as-delivered" contract, and also differs from the optimum predictive maintenance opportunities for the individual turbines with RULs managed in isolation.

Keywords: remaining useful life (RUL), prognostics and health management (PHM), wind farm, real options analysis (ROA), predictive maintenance, power purchase agreement (PPA)

1. INTRODUCTION

1.1. Background

Maintenance practices for wind turbines generally include corrective maintenance and proactive maintenance: the former is implemented after failures occur, while the latter is carried out at predetermined intervals or time points to prevent failures. Proactive maintenance can be divided into preventive maintenance (also known as scheduled maintenance) and predictive maintenance that results from the inclusion of some type of system health management technology (either condition monitoring or prognostics and health management (PHM)) in the turbine. The major difference between preventive maintenance and predictive maintenance is that the former is performed after a fixed time or usage interval, while the latter is only implemented when there is a need for maintenance.

A failure refers to the event or inoperable state in which the system or part of the system does not perform as previously specified, while a fault is the immediate cause of the failure. After a failure has happened, fault diagnosis can be employed to detect, locate, identify and isolate the fault by applying diagnostic algorithms, e.g., checking the consistency of the feature information of a real-time process that the system is experiencing against a healthy system [1,2]. After fault diagnosis, a corrective maintenance activity can be scheduled.

Condition monitoring is the process of monitoring one or more parameters of condition, in order to detect a significant change that may be an indicative of a developing fault [3], in a system prior to failure. Condition monitoring for wind turbines applies vibration analysis, acoustic emission, oil analysis, strain measurement, thermography and other techniques to monitor the current health of the major subsystems such as blades, gearbox, generator, main bearings and the tower, and also identifies the developing faults in real time [4–6]. PHM assesses the current state of health or reliability of a system that has not failed under its actual application conditions, and makes continuously updated predictions of when failure will occur