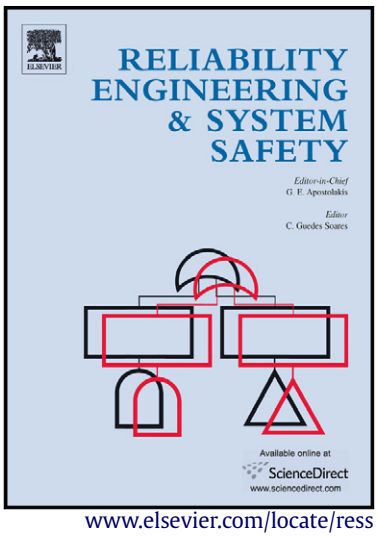

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Mahmood Shafiee, Maxim Finkelstein, Christophe Bérenguer

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An opportunistic condition-based maintenance policy for offshore wind turbine blades subjected to degradation and environmental shocks

Mahmood Shafiee [a]*, Maxim Finkelstein [b,c], Christophe Bérenguer [d,e]

[a] *Cranfield University, College Road, Cranfield, Bedfordshire MK43 0AL, United Kingdom*
[b] *Department of Mathematical Statistics, University of the Free State, 339 Bloemfontein 9300, South Africa*
[c] *ITMO University, 49 Kronverkskiy pr., St. Petersburg 197101, Russia*
[d] *Université Grenoble Alpes, GIPSA-lab, F-38000 Grenoble, France*
[e] *CNRS, GIPSA-lab, F-38000 Grenoble, France*
*Corresponding author. Tel.: +44 1234 750111.
E-mail addresses: m.shafiee@cranfield.ac.uk (M. Shafiee), FinkelM@ufs.ac.za (M. Finkelstein), christophe.berenguer@grenoble-inp.fr (C. Bérenguer).

ABSTRACT

Offshore wind turbine blades are subject to multiple types of internal and external damages. Internal damages (such as fatigue, wear and cracks) are generally caused by system degradation, whereas the external damages (such as icing, wind and wave shocks) result from harsh marine environments. In this paper, we investigate an optimal opportunistic condition-based maintenance (OCBM) policy for a multi-bladed offshore wind turbine system subjected to stress corrosion cracking (SCC) and environmental shocks. When the length of a crack in a blade reaches critical size D, the blade breaks and it has to be replaced by a new one. An environmental shock is minor with probability $1-p$ and catastrophic with probability p $(0 \le p \le 1)$. A minor shock causes an instant drop in power output without resulting in any system failure, whereas a catastrophic shock stops the wind turbine and requires system replacement. When the length of a crack in one of the blades exceeds a threshold d $(< D)$, it undergoes a major repair and a preventive maintenance (PM) action is performed on the other blade(s); otherwise, a planned PM task is conducted for the whole system when its operational age attains a value of T (>0). The problem is to simultaneously determine the optimal control parameters d^* and T^* such that the average long-run maintenance cost per blade per unit time is minimized. The explicit expression of the objective function is derived and under certain conditions, the existence and uniqueness of the optimal solution are shown for the infinite-horizon case. The proposed maintenance model is tested on a three-bladed wind turbine and its performance over the system life cycle is evaluated using a Monte-Carlo simulation technique.

Highlights

- Opportunistic condition-based maintenance for systems subject to degradation and shocks.
- To determine an optimal maintenance policy for multi-bladed offshore wind turbines.
- Necessary/sufficient conditions for the existence and uniqueness of optimal solution.
- To evaluate the performance of maintenance policy compared to existing practices.
- To investigate the effect of harshness of marine environment on maintenance policy.