Renewable and Sustainable Energy Reviews 66 (2016) 53–78

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Condition-based maintenance methods for marine renewable energy

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ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form
7 April 2016
Accepted 21 July 2016

Keywords:
Marine renewable energy
Offshore wind turbine
Wave energy converter
Tidal turbine
Condition-based maintenance
Condition monitoring
Fault diagnosis
Fault prognosis

ABSTRACT

With an increasing requirement to lower the costs of delivered renewable energy, the maintenance costs for marine renewable energy (MRE), due to accessibility issues, are an obvious focal point. In particular, condition-based maintenance and prognostics can help to optimise maintenance activities and forewarn of impending maintenance requirements, mindful of the constrained access to MRE systems due to limited weather windows of sufficient duration.

This paper focusses on offshore wind, tidal flow and wave energy as target MRE domains and provides a comprehensive review of condition-based maintenance methodologies currently employed in MRE systems. While, of the three energy domains, offshore wind is the more mature, giving the opportunity to propagate such methods to the less mature areas of tidal and wave, there are also many components and challenges which are common to all three domains, e.g. generator systems and grid interface.

Contents

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http://dx.doi.org/10.1016/j.rser.2016.07.071
1364-0321/

1. Introduction

Concerns about global warming and dependence on fossil fuels have generated considerable interest in renewable power generation technologies over the past three decades. In many industrialised countries, especially in Europe, the growth of renewable energy production capacity has been strongly supported by public authorities [1]. Amongst other technologies, the potential of marine renewable energy (MRE) sources is being increasingly explored.

MRE technologies are particularly challenging in terms of installation, operation, maintenance and survivability. Varying operating speed and load, corrosion, sea life, structural stresses induced by wind, wave and current, all represent threats to the survivability of MRE systems. Furthermore, the location at a long distance from shore and the need for specific vessels make installation, operation and maintenance more costly and challenging. For a given failure rate, a device located offshore will experience more downtime than onshore, since accessibility requires a favourable weather window. On-line condition-based maintenance (CBM) has the potential to increase availability and reduce maintenance costs, and hence improve the competitiveness of MREs with other power production technologies.

CBM can be defined as the “continuous monitoring of system data to provide an accurate assessment of the health, or status, of a component or system and performing maintenance based on its observed health” [2]. It implies that system data are monitored and processed in real-time by a condition monitoring (CM) system. Ideally, a CBM system is able to perform:

- system or component diagnosis, which consists of fault or failure detection, isolation and identification, and/or
- system or component prognosis, which relies on estimates of the remaining useful life (RUL) of the system or component.

CBM goes beyond fault diagnosis and prognosis: firstly, a typology of components and related failures has to be established and prioritised, through methods such as failure modes effects and criticality analysis (FMECA) [3,4]. Furthermore, CBM extends to the development of a whole strategy which takes into account not only diagnosis and prognosis results, but also parameters such as expected weather windows and other schedule constraints [5–7]. Finally, financial aspects also enter into consideration in CBM strategy design [8–10]. In spite of the importance of these additional aspects, the focus of this review is on techniques for fault diagnosis and prognosis in MRE systems, with emphasis on the applicability of the methods presented to automated, on-line systems.

Unlike other MREs, offshore wind is a mature, plentifully deployed, and well-standardised industry [11]. In Europe, in 2014, $18.6 billion were invested in offshore wind projects [1], and the available offshore wind capacity at the end of 2014 exceeded 8 GW, according to the European Wind Energy Association (EWEA). The onshore and offshore wind industry has already carried out significant research to develop reliable CBM strategies for wind turbines (WTs).

In contrast, the total installed capacity of other MRE systems worldwide amounted to only 530 MW in 2012, with 517 MW from tidal barrages alone. In Europe, about 40 MW of tidal and 26 MW of wave energy capacity are expected to be installed by 2018 [12]. Non-wind MRE sources are still at an early development stage [13], and their designs are still much more diverse than offshore wind turbine (OWT) designs. As a consequence, the implementation of maintenance strategies for non-wind MRE systems has received less attention. The blatant resulting imbalance in terms of available literature is reflected in this review.

However, many similarities can be found between most marine energy power generation systems, whether it be in their general structure and essential components [11], or in the various challenges presented by the ocean environment [14–17]. Wave energy converters (WECs) and tidal turbines (TTs), in particular, share a lot with OWTs. WTs, TTs and WECs are all complex engineering structures that capture the fluid energy through external moving parts. Electrical components (generators, power converters and transformers) are also common across these three applications. Therefore, a joint review of CBM methods applicable to OWTs, TTs and WECs can be useful to highlight the possible synergies as well as the specificities of each technology in terms of requirements towards the development of CBM techniques. Another distinctive feature of the present review is that techniques for CBM are successively