Statistical Availability Analysis of Wave Energy Converters

Khalid Abdulla, Jessica Skelton, Kenneth Doherty, Patrick O’Kane, Ronan Doherty, Garth Bryans
Aquamarine Power Ltd.,
Edinburgh, Midlothian, United Kingdom

ABSTRACT
Availability of a Wave Energy Converter (WEC) is of paramount importance if it is to become a commercially successful technology. This paper presents a statistical Monte Carlo methodology to assess the availability of WECs which is driven both by the reliability of components and the time to repair a failure which is dependent on external factors such as weather windows and other restrictions on marine operations. This methodology is applied here to the Oyster® WEC design which is being developed by Aquamarine Power Ltd. but can be modified to investigate other technologies which have different operation and maintenance philosophies.

KEY WORDS: Availability; wave energy converter; reliability; maintenance; Oyster.

INTRODUCTION
The push towards the requirement for new and renewable energy sources in recent years has lead to a rapid increase in the number of commercial wave energy device developers. Aquamarine Power Ltd. (Aquamarine) was founded in 2005 to develop Oyster®, a device designed to interact with the dominant surge forces found in the nearshore wave environment.

Oyster is a unique design of Wave Energy Converter (WEC) due to its nearshore location, the use of a bottom-hinged flap that completely penetrates the water column, and an onshore hydraulic power take-off (PTO). The oscillating motion of the flap is used to pressurise water and pump it to shore via a hydraulic piston and pipeline system. The pressurised water is then converted into electrical power through the use of a Pelton wheel system to turn an electrical generator. The water is then recycled through the system via a low pressure return pipeline. The Oyster 1 315kW proof-of-concept prototype was successfully installed at EMEC on Orkney in 2009. To date it has operated for over 6000 hours. This paper focuses on Oyster 2, the next generation device and a pre-commercial demonstrator with 3 flaps pumping to a single onshore hydroelectric power plant, rated at 2.4MW.

The availability of any generator is key when calculating the economics (in particular, cost of power) of the device as the development progresses from demonstration to a commercial product. An availability model should be developed as early in the design process as possible, ideally comprising both reliability and maintenance capability aspects, in order that the device design encompasses not just efficiency but also the requirements for the maintenance strategy and component access. A design with high conversion efficiency has compromised commercial potential if it cannot be maintained cost-effectively. A study of the availability of offshore wind farms used Monte-Carlo simulation approaches and attempted to take weather windows into account (Van Bussel, 1999). The drop-off in availability of a wind farm with distance to shore was modelled, using trend curves developed from many Monte Carlo runs rather than modelling the availability using M-C methods directly, and a storm database that was used to determine the ‘inaccessibility factor’ for maintenance crews due to poor weather for a given wind speed. This found that a nominal onshore availability of 97% dropped to 76% for a farm located 15km offshore for a wind speed of 8 m/s. This study was extended (Van Bussel & Zuajier, 2001) to investigate possible design improvements and their associated costs for offshore wind farms to increase availability. It was found that significant availability improvements could be made for relatively modest increased effort and costs, but that the analysis must be performed at an early point in the design process, to allow the investigation of different concepts before technology maturation.

The relative immaturity of WEC technology means that few developers have had the opportunity to investigate in depth the principal drivers underlying availability using quantitative tools. Few, if any, of the components involved have been tested under such onerous conditions, and therefore component lifetimes and failure likelihoods are poorly understood.

In terms of availability and the modelling thereof, the key feature of the Oyster WEC is that the majority of the complex equipment and all of the electrical and electronic plant is located onshore where it can easily be accessed for inspection and maintenance. The availability model discussed here is concerned with only the offshore components of Oyster, the accessibility and maintenance of which are constrained by the weather and other factors affecting marine operations.

This paper presents a numerical modelling approach developed with the purpose of determining device availability for the Oyster 2 WEC, and examines the key drivers underlying availability for WECs in general. A definition of availability is provided and an overview of the modelling approach and layout of the model is given. The main body of the paper presents and discusses the results of the modelling work, including the forecast availability and sensitivity studies into the impact of changing the model assumptions; the maximum sea-state in which maintenance vessels can operate, the rate at which components wear out, the ability to carry out maintenance outside of daylight hours, and the inclusion of tidal restrictions on maintenance.

The limitations of the modelling and further work required are highlighted and summary conclusions are presented.