Extreme Value Analysis of Wave Energy Converters

K. Doherty1, M. Folley2, R. Doherty3, T. Whittaker2

1Aquamarine Power Ltd.           2 Wave Energy Research Group      3 Formerly of Aquamarine Power Ltd.
Edinburgh, Midlothian, UK                      Queens University, Belfast, UK                       Edinburgh, Midlothian, UK

ABSTRACT

This paper presents a statistical Extreme Value Analysis (EVA) methodology to evaluate the design survivability condition of a Wave Energy Converter (WEC). The technique is applied to the Oyster® WEC design which is being developed by Aquamarine Power Ltd. (APL) but can be easily modified to investigate other technologies that have different operational philosophies. The approach presented considers the extreme statistics of both the incident wave climate at the device location and the complex dynamic response of the WEC in such conditions. This give a more robust evaluation of the WECs survivability condition than a more traditional single design wave approach.

KEY WORDS: survivability; wave energy converter; Oyster; extreme value analysis; peak-over-threshold.

INTRODUCTION

An Extreme Value Analysis (EVA) technique is presented in this paper to evaluate the loading survivability condition of a Wave Energy Converter WEC. Determining the maximum expected load experienced by a WEC during its operational lifetime is of paramount importance to the design process, in particular to the design of the foundation and/or mooring system. Thorough and consistent EVA can reduce/remove the implementation of large safety factors to a WEC design load condition which can have significant cost benefits. Extreme loads experienced by a WEC are not only dependent on the nature of the wave climate within which it is operating but also on the phase relationship between each incident wave and the WECs dynamic response. These unique features make it necessary to develop a custom EVA technique with specific application to WECs. A possible hazard of developing an EVA methodology is that it relies heavily on novel analysis techniques. Despite its mathematical elegance, industry confidence in such a technique is often low because of the novel approaches employed. Consequently large safety factors are often applied to the design load undermining the goal of using EVA. The ethos adopted in this paper is to apply well accepted techniques to minimise uncertainty and hence the subsequent use of excessive safety factors connected with the modelling approach itself. The methodology to determine a WECs design survivability condition can be split into two sections. The first determines the extreme sea states, ranked in terms of their return period, that the WEC is expected to encounter during its lifetime. These sea states are then used in an extensive series of wave tank tests to measure the loads experienced by WEC under such extreme conditions. An EVA technique is then applied to this set of load test data to evaluate the WECs expected survivability load condition.

As a test case the EVA methodology developed is applied to the Oyster® WEC design which is being developed by Aquamarine Power Ltd. Oyster® is a buoyant, seabed mounted, oscillating flap which pierces the water surface and is located in the near-shore region of 10m–15m water depth. In 2009 Aquamarine Power Ltd. successfully deployed a first generation 315kW full scale Oyster® prototype at the European Marine Energy Centre (EMEC) site in Orkney, which has operated it for over 6000 hours. The second generation Oyster® project, a 2.4MW array of three devices is scheduled for deployment at EMEC in the summer of 2011. The survivability strategy of Oyster® has some advantages over other WECs. It is located in the near-shore environment where the incident extreme waves are subject to depth-limited wave breaking and have a significantly reduced directional spread due to wave refraction. In addition to this Oyster® has an inherent safety mechanism in that it decouples from larger waves by rotating to greater angles. Despite these advantages the survivability load conditions must still be evaluated to inform the design of Oysters foundation solution which anchors it to the seabed.

Before the methodology is applied to the Oyster® WEC and results displayed an introduction to the mathematics of the EVA techniques employed is first presented.

EXTREME VALUE METHODS

In recent years the significance of extreme value analysis has become ever more important to a wide variety of disciplines. This has lead to a large development of eloquent and novel statistical techniques, which unfortunately have been accompanied by a gross misuse in their application. Other simpler approaches such as inferring extreme values from an empirically-approximated parent distribution also leads to large uncertainties due to the fact that the extreme values are very often