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Wave resource variability: Impacts on wave power supply over regional to international scales

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Abstract

The intermittent, irregular and variable nature of the wave energy resource has implications for the supply of wave-generated electricity into the grid; intermittency of renewable power may lead to frequency and voltage fluctuations in the transmission and distribution networks. This study analyses the wave resource over different spatial scales to investigate the potential impacts of the resource variability on the grid supply. It is found that the deployment of multiple wave energy sites results in a reduction in step changes in power, leading to an overall smoothing of the wave-generated electrical power.

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Keywords: Wave resource; Resource variability; Intermittancy; SWAN; Grid integration

1. Introduction

The wave energy resource is intermittent, irregular and variable in nature, with implications for the supply of wave-generated electricity into the grid. Issues relating to resource intermittency and its mitigation through the

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development of spatially separated sites have been widely researched in the wind industry (e.g. [1,2]), but have received little attention to date in the less mature wave industry. As a resource, wave energy is significantly less predictable than tidal energy, although more so than wind and solar [3]. However, the temporal and spatial variability of the wave resource could prove problematic for grid integration if wave energy was to reach the point of large-scale deployment with high levels of grid penetration.

For all intermittent renewable technologies there are two grid-related areas of concern; at the transmission network level intermittency will cause frequency fluctuation, while at the distribution network level, it will cause voltage fluctuations. Supply needs to match demand in order for the system frequency to be maintained at its nominal value, for example 50.00Hz ±1% in the UK. Electricity demand is typically predicted in advance, enabling a matching supply to be arranged. The utilisation of intermittent renewable supplies means these also need to be predicted in order to effectively plan for a matching supply from fossil fuel plants. In addition to this planned matching process between demand and supply, the transmission system operator needs to control the frequency in real-time via operation of gas-fired generation units and back-up generation plants. The availability of these balancing plants is a limiting factor on the grid-integrated intermittent power. This can be seen in Ireland, where the proportion of power from intermittent renewable sources at any time is estimated to be limited to 75% up to 2020, primarily due to the available balancing services [4]. Intermittent power might also cause voltage fluctuation in the local distribution network.

A potential mitigation against these effects, demonstrated in studies for the wind industry (e.g. [1,2]), is the development of multiple, spatially separated sites in order to smooth the supply of power to the grid. From a wave resource perspective, localised geography, weather patterns and tidal conditions can lead to notable differences in levels of resource across regions exposed to a similar wave climate. Therefore, as for the wind industry there is the potential to develop appropriately sited wave farms to contribute to the smoothing, i.e. reduction in short-term variability, and grid integration of wave-generated power. A key parameter when considering electricity supply is the step change, i.e. the change in output power over a specified time period (e.g. 10mins, 30mins, 1hr, 24hr). Smaller step changes indicate a smoother power supply, and they are more beneficial for the grid integration. An example of this is presented in Fig. 1, which shows a temporal sub-section of the wave height records from two buoys separated by 150km in the Southwest UK, and demonstrates a time where an average of the two sites lessens the variability of the wave energy. The peak of the storm occurs 3.5hrs earlier at site 1 than at site 2 and wave heights are greater at site 1 prior to the peak; post-peak, wave heights are greater at site 2. For this case, were wave energy converters to be deployed at both sites then some intermittency in the contribution of wave energy to the national grid could be reduced. For example, the large variations in wave height for both sites between 00:00 and 03:00 (upward for site 1, downward for site 2) would produce large step changes in power output when considered independently. The combined record shows a slower variation because the upward and downward spikes cancel each other out and hence combined power output would show a much smaller step change over an hourly time period.

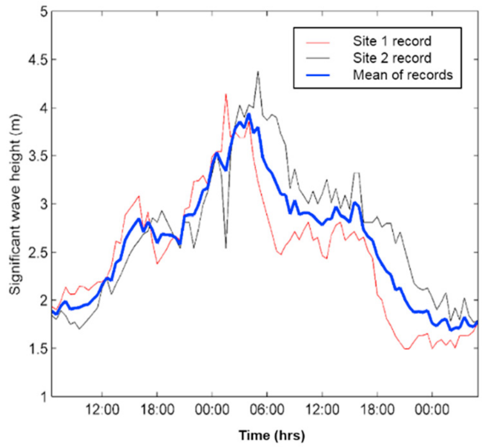

Fig. 1. Example storm event illustrating the potential smoothing achieved through generating wave power at two sites 150km apart.