Results of the Testing of the Energetech Wave Energy Plant at Port Kembla on October 26, 2005

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Abstract

A full-scale ocean trial of the Energetech wave energy device has taken place at Port Kembla, and real power was generated into the on-board grid. Fresh desalinated water was also produced. The measured power indicates the device performs better than previously predicted from wave tank, wind tunnel, and CFD testing. For example, in two metre waves with periods of seven seconds, the results from the trial indicate the device will produce 321 kW, compared with previous predictions of 268 kW. A lower bound confidence interval estimate suggests the device has a 92.6% probability of producing greater than 218 kW in these conditions. Past analysis had indicated the Energetech technology was capable of producing an annual energy output of at least 500MWh at Port Kembla, where the wave climate averages 7.6 kW per metre of wave front. The results of this floating mode trial predict with even greater probability that the output will likely be in excess of this level. In locations with higher energy densities, the annual output from an Energetech device will be commensurately greater again. The results of this trial are very encouraging, as it indicates the technology is capable of performing better than previously claimed.

Introduction

On October 26, 2005, at approximately 0600 hours, the Energetech wave energy device was towed to a position in the open ocean, several hundred metres off the southern breakwater of Port Kembla Harbour. The device was then held, facing into the waves, in a quasi-static position between two tug boats (via ropes) for the next few hours, at which point it was towed back into the harbour at the completion of the trial.

The purpose of this trial was to demonstrate the ability of the Energetech turbine and control systems to produce real power from the energy in the waves. The power was directed into an on-board grid and dissipated into on-board load banks.

Given the trial was designed such that the device would be operating in a floating mode configuration, the levels of power inside the oscillating water column (OWC) chamber were necessarily going to be low. This was clearly understood to be the case prior to the trial. A floating mode configuration was chosen, as it was more quickly and easily achievable than another fixed mode deployment.

A previous deployment of the device in a fixed mode configuration a few months prior (June 2005) unequivocally demonstrated the ability of the device to focus and transfer wave energy into an amplified water height inside the OWC chamber and an intense airflow past the turbine. These earlier results were fully consistent with prior predictions regarding the wave amplification based on wave tank and computational fluid dynamics (CFD) testing.

However, during this earlier fixed mode configuration trial, the generator was not connected to the grid and, therefore, power production figures could only be inferred rather than directly measured. This more recent trial in floating mode allowed for a quantification of the real power production as a function of the incident wave heights, and also facilitated a measure of the turbine efficiency in terms of output shaft power.

While the actual incident wave heights on the day were moderate, it was recognised the device would heave in response to these waves, resulting in only a fraction of the wave energy being available to the device. By measuring the wave heights which resulted inside the chamber, however, an implicit incident wave height (had the structure been fixed) was calculated from past measurements.

The fact that the implicit incident wave heights were low during this latter trial demonstrated the ability of the technology to produce power during periods of low wave energy. The results of the earlier trial, along with a vast amount of wave tank and wind tunnel testing (as well as CFD analysis), allows for a simple and quite accurate extrapolation of the results of this trial to cases involving larger wave conditions.

The results of the floating mode trial are summarised herewith, and compared to the results and analysis of previous extensive research and testing in wave tanks and wind tunnels at smaller scales by Energetech over a number of years. The aim of this trial can be viewed simply as an attempt to demonstrate that the technology at full–scale is able to meet the expectations of power production implied by previous Energetech and independent research.

It should be noted that, during this floating mode trial, wave periods were approximately seven seconds. All comparisons with previous results should be viewed in this context, as the power available to be extracted is a function of wave period.

During the trial, the on-board monitoring system indicated the regular production of power. On-board sensors recorded a large variety of data, including wave heights, air velocities, pressures, and power output. Several discrete periods of power generation were examined as separate “events” for the purpose of the data analysis. The power generation events were separated by occasions of non-generation “down-time”. During this time, activities related to the re-positioning of tugs and mooring lines etc. took place.

Results

The average aerodynamic efficiency of the turbine during the operational phase of the trial, (based upon the standard measure of turbine efficiency – that is, power produced as a proportion relative to the product of volume flow rate and pressure drop across the turbine), varied between 52% and 81%, with an average value of 69.3%. These results are illustrated in Figure 1.

Air velocities past the turbine during these events generally averaged between 20 and 25 metres per second. This contrasts with the corresponding velocities measured during the fixed mode deployment, where maximums of up to 140 metres per second were encountered.

Previous Energetech research, conducted in collaboration with the University of Sydney’s Department of Aeronautical Engineering in their large wind tunnel facility

(1/3 scale model), had indicated an average aerodynamic efficiency of 68% across all wave heights and periods likely to be encountered at Port Kembla. For the case of seven second period waves with small heights, as was encountered during this trial, previous research had indicated an average aerodynamic efficiency of slightly less than 60%.

Clearly, the actual device performed better in this regard than indicated by previous research. The reason for this is almost certainly due to the ability of the full-scale device to dynamically “track the flow” and optimise both blade angle and rotational speed – an ability not afforded to the smaller scale wind tunnel model. The ability to optimise these parameters is one of the most obvious successes of the technology and of the trial.

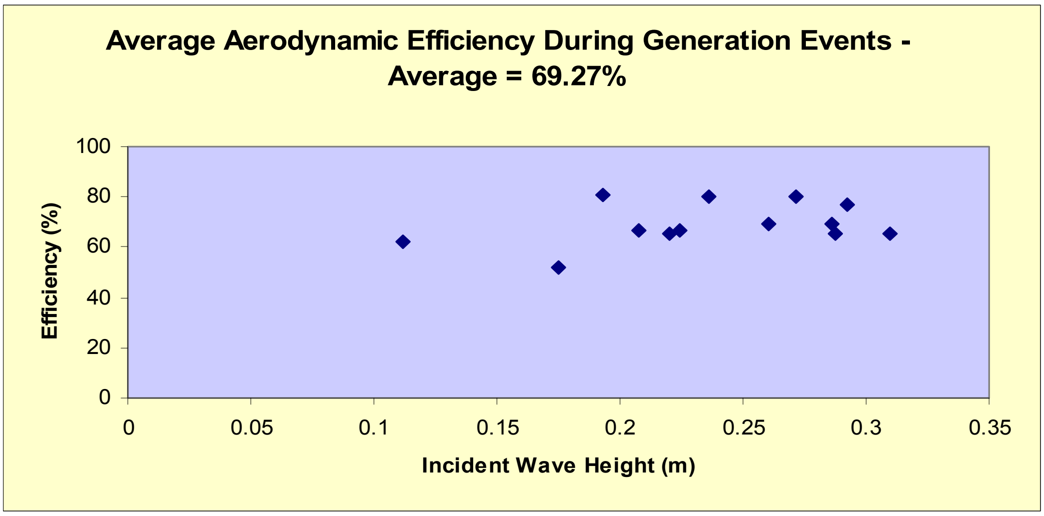

Figure 1

Power during each generation event was also measured along with the chamber wave height. The incident wave height was inferred from the measured wave height inside the OWC chamber, based upon both past research and previously measured hydrodynamic data from the first trial in June 2005.

These power production results are illustrated in Figure 2. They relate to real power delivered to the grid, after all hydrodynamic and aerodynamic losses are taken into account (not including electrical losses). Each event is signified by a diamond shaped icon, and a least squares quadratic curve fit is overlayed on to the diagram. A quadratic (rather than linear) fit was applied, consistent with the fact that, to a high order of accuracy, power levels in waves vary as the square of wave height.

As can be seen from the graph, while the actual power production levels were generally at relatively modest levels (less than 7 kW), so too were the incident wave heights (generally less than 0.3 metres – note, these are actual wave heights, not significant wave heights). The actual power levels generated during the trial events ranged up to 7 kW, corresponding to an incident wave height of 0.27 m.

While the least squares quadratic curve fit results in the "most probable" curve for extrapolation to the realm of higher wave heights, such extrapolation comes at the price of statistical uncertainty. Therefore, a lower bound quadratic curve fit was also applied such that it resided below all the measured generation events (see Figure 2). Confidence limits from sampling theory were then calculated for this curve. Given the sample size of thirteen generation events, there is a probability of 92.6% that any extrapolated generation event will reside at a higher energy level than defined by this lower bound curve.

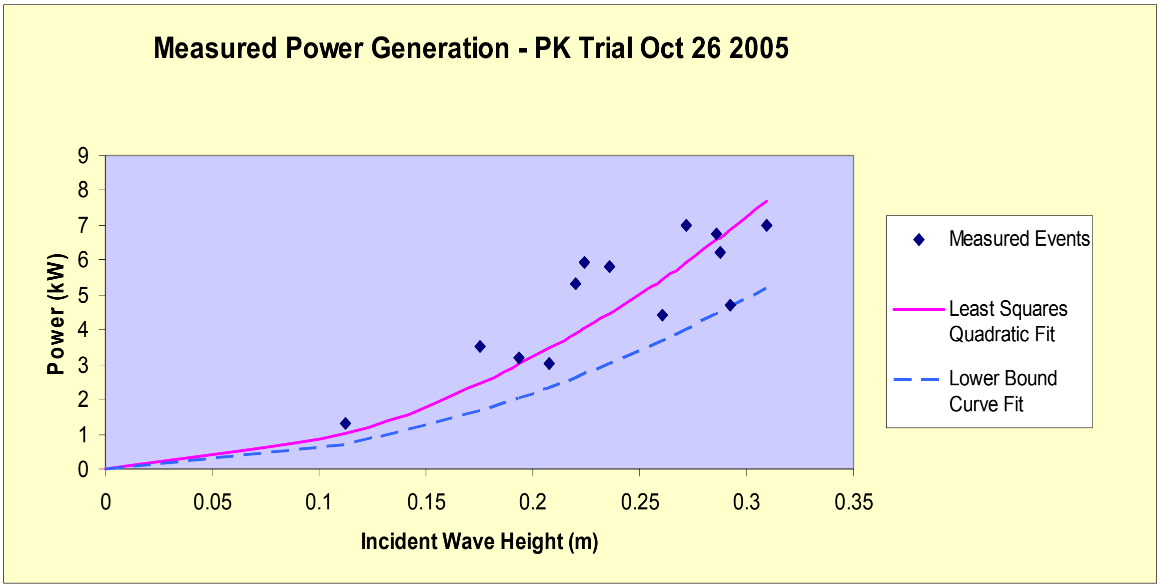

Figure 2

Based on the most probable curve fit and the lower bound curve fit, an extrapolation of these results was produced for larger wave heights, constrained by the requirement that the power curve must plateau at 500kW, in line with the Port Kembla generator rating (this maximum plateau will vary from project to project).

This extrapolation curve is illustrated in Figure 3. Three curves are highlighted – the most probable curve based on the results of the Port Kembla trial, the lower bound based on this same trial, and a curve based on the results of prior wave tank, wind tunnel, and field experiments (i.e. the June 2005 trial deployment) for seven second period waves. The measured events from the floating mode trial are also illustrated at the bottom left of the graph.

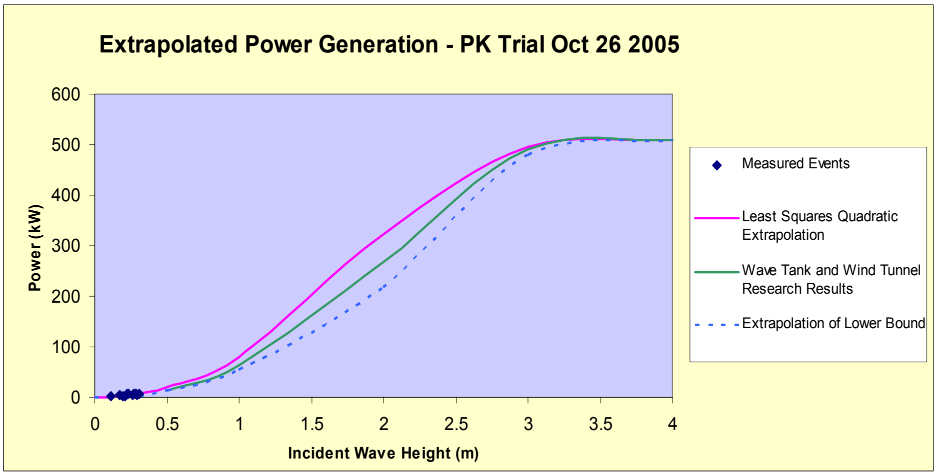

Figure 3

While the relationship between wave height and power generated for the different curves must necessarily converge at very low and very high wave heights, the variance between the results predicted by earlier research and those inferred by the recent trial is relatively modest.

However, the results from the actual operation of the plant are as much as 20% higher than predicted by previous research. For example, for wave heights of two metres (with a period of seven seconds), previous Energetech research predicted the device would produce 268 kW, but the recent trials indicate that 321 kW is the most likely output.

This increase is most probably largely due to the ability of the turbine to be dynamically controlled in real time, both in terms of blade angle and rotational speed. Previous research was unable to properly resolve this fact at smaller scales, and the ensuing estimates erred on the conservative side.

This result is very encouraging. Especially encouraging is the confidence level provided by the lower bound analysis. For example, for two metre waves (with a period of seven seconds), there is a 92.6% probability the device will generate in excess of 218 kW, with a 50% likelihood it will generate above 321 kW.

This probability analysis fully accounts for effects of the relatively small sample size from the trial. The lower bound itself is, at most, only about 20% lower than the predicted results from past research. In fact, based on the results of the floating mode trial, the probability that real outcomes will be higher than previous Energetech predictions is greater than 80%.

Conclusion

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