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# THE DYNAMIC EFFECTS OF MARINE GROWTH ON A POINT ABSORBING WAVE ENERGY CONVERTOR

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## Abstract

Wave energy convertors have the potential to generate a sizeable proportion of Ireland's energy needs. Such platforms will be susceptible to bio fouling over their design life with marine growth capable of altering the hydrodynamic loading. Marine growth causes member effective diameter, mass, drag coefficients, force and hydrodynamic added mass to increase. In this paper, marine growth of various thickness and surface roughness is numerically modelled on two torus shaped point absorbers moving against a monopile in operational conditions using combined potential flow boundary element method and Morison equation viscous drag. Marine growth thickness and surface roughness have a notable effect on the platform hydrodynamic forces. However, the power matrix remains generally similar. The smaller WEC shows the greatest change with a 20 % increase in draft and 5 % increase in power.

## 1 Introduction

Marine growth (MG) on offshore structures and vessels has been of interest to offshore industries. MG is described as the accumulation of biological deposits on the device, also commonly termed biofouling. Biofouling is divided into microfouling, the formation of a biofilm with bacterial adhesion and macrofouling, attachment of larger organisms. Examples of macrofouling organisms include the "hard" encrusting animals such as barnacles, molluscs, tube worms, bryozoans and the "soft" non-calcareous biofoulants include hydroids and seaweed.

MG is capable of altering the hydrostatic and hydrodynamic characteristics of offshore platforms. These characteristic are modified by the increased mass of the platform, and increased member effective diameter and surface roughness, which leads to increased drag coefficients, force and hydrodynamic added mass. MG can also increase fatigue loading and accelerate corrosion of the platform. The surface roughness

influences the viscous drag force that the member experiences. This drag force increases as surface roughness increases, due to increasing boundary layer turbulence and shear forces, which decreases the momentum of the fluid.

Increased fuel costs due to increased drag from MG on vessels is a well-known problem.

In the area of marine renewable energy convertors there has been much debate over what the effect of MG will be on device performance and in reality the answer to this question will be device and site specific. Reference [1] measured MG deposits on a demonstration point absorbing (PA) wave energy convertor (WEC) and modelled the effects of MG additional mass in the frequency domain. Noting a 5% increase in draft and 5% decrease in power. Reference [2] used time domain modified Morrison's equation and BEM to model the effects of various MG roughness and thickness's on a tension moored floating wind turbine and found a 62% decrease in minimum tension for the worst case scenario, increasing the risk of tendon failure due to loss of tension. Reference [3] noted significant effects of MG on an experimental model of a bottom-hinged flap type WEC.

## 2 Model

This paper analyses the effect of marine growth on power production of a pitch restrained heaving PA WEC. The site resource, WEC model and numerical model methodology are detailed in this section.

### 2.1 Resource Characterisation

For this study the wave resource at the M5 meto-ocean data buoy, located off the South-East coast of Ireland (51.6900°N 06.7040°W) is used. Eleven years of data are used from October 2004 to September 2015. No data handling of missing values, when the buoy was inoperational is undertaken as the papers aims is not to characterise the resource at this location or optimise the design of the WEC. Figure 1 shows the resource average annual power. The average power at this site is 13.4 kW/m. Those sea-states which have a summed average yearly power of greater than  $2 \times 10^5$  (kW/m) and wave height less than the cut-out condition

of 4 m are used to generate the device power matrix. This limit results in 31 sea states, that characterise the exploitable wave power at this site, and are used in order to save computational time. These sea-states are marked in Figure 1 by crosses.

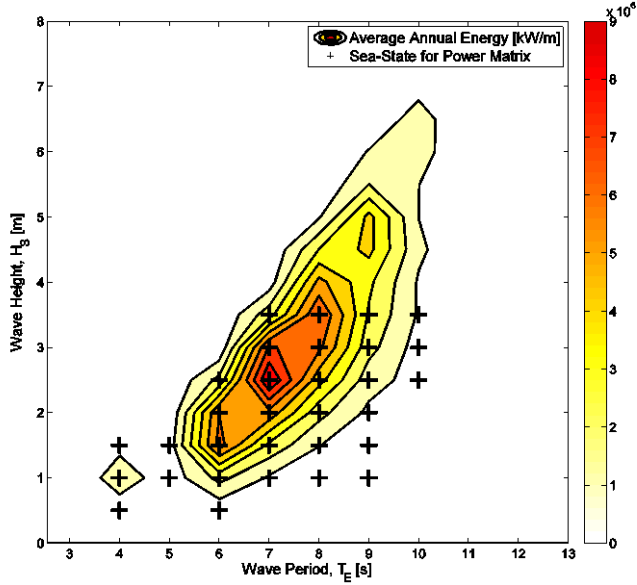


Figure 1: M5 wave resource and sea-states for analysis.

## 2.2 Wave Energy Converter

Two pitch restrained heaving wave energy converters are chosen for this paper, a large and small device. Both devices are torus shaped and have inner diameters of 6.5 m. The large WEC has an outer diameter of 20m, height of 12 m and draft of 6 m. The small WEC has an outer diameter of 10m, inner diameter of 6.5 m, height of 6 m and draft of 3 m. The reactance device is a fixed monopile of 6m diameter, and could be assumed an offshore wind turbine support structure. The optimal power take off (PTO) damping is chosen by matching the radiation damping as shown in Equation (1). A linear damping model is applied. The large and small WECs have a rated power of 270 kW and 50 kW respectively. It should be noted that the WEC's have not been optimised for this site, although the natural heave period for each is in the peak wave power occurrence region of 6 -7 s

$$B_{PTO} = \sqrt{B_{33}(\omega)^2 + \frac{1}{\omega^2}(-m + A_{33}(\omega))\omega^2 + K_{H33}}^2 \quad (1)$$

## 2.3 Marine Growth

Marine growth is modelled as an additional thickness added to the surface area of the WEC from +2 m to its deepest draft. The density of MG was taken as 1325 Kg/m<sup>3</sup>. Thickness is 100mm. This results in a 6% increase in the large WEC mass and a 3.7% increase in draft. The small WEC mass increases by 28% and draft by 19.8%. In order to distinguish the effects of both the increase in WEC size, and thus the hydrodynamic

loading and the increase in surface roughness, causing an increase in drag force, these two effects are analysed separately. The simulation cases are illustrated in Table 1, and are equal for each WEC. Surface roughness length is taken as 0.002m for the smooth case and 0.05m for the marine growth case. The same cases are used for each WEC size. Roughness and drag values are taken from [4].

Case No.	Marine Growth	
	<i>t</i> (m)	<i>k</i> (m)
1	0	0.002
2	0.1	0.002
3	0	0.05
4	0.1	0.05

Table 1: Simulation cases

## 2.4 Numerical Modelling

Hydrodynamic parameters are computed from Ansys Aqwa for 50 wave frequency's from 0.008Hz - 0.4Hz. Time domain modelling is carried out using Orcaflex. Hydrodynamic interactions between the torus and the monopile were not accounted for, and as the later was fixed, was not modelled hydrodynamically. The torus motion was restrained to only move in a vertical direction. Quadratic viscous drag elements were added using modified drag only Morrison's equation elements. A Bretschneider wave spectrum was used. The time series length was 4096s and chosen so that at least 200 waves were generated for each sea-state.

## 2.5 Power Calculation

Once the velocity of the WEC is determined, the instantaneous power can be calculated from Equation (2) and the mean power from Equation (3) [5]. The mean power can be multiplied by the average annual occurrence to determine the average annual power production (AAPP)

$$P_{inst}(t) = B_{PTO}\dot{X}(t)^2 \quad (2)$$

$$\bar{P}_T(H_S, T_E) = \frac{1}{T} \int_0^T P_{inst}(t) dt \quad (3)$$

## 3 Results

### 3.1 Power Matrix

The power matrixes for both WECs case 1 are shown in Figure 1 & 2. The percentage change for each of the subsequent cases is then shown in Figures 4 - 10. The large WEC can be seen achieve the rated power of 270 kW at a H<sub>S</sub> of 3.5 m and T<sub>E</sub> of 10 s. The small WEC achieves its 50 kW rated power at the same sea-state. Cases 2 – 4 are compared against the base Case 1. Case 2 and 4 show the same trend in change of power from Case 1. For the large WEC, the power at the 5 s sea-states decreases, elsewhere the power increases,

with a maximum increase of 2.5 % at the lower period. Case 3 shows an insignificant decrease in the power matrix. For the small WEC the same trend can be observed with both Case 2 and 4 being similar. Here the increase in power is greater the greater the wave period. For Case 3, the power decreases in higher wave heights, due to the drag force being proportional to the relative velocity squared.

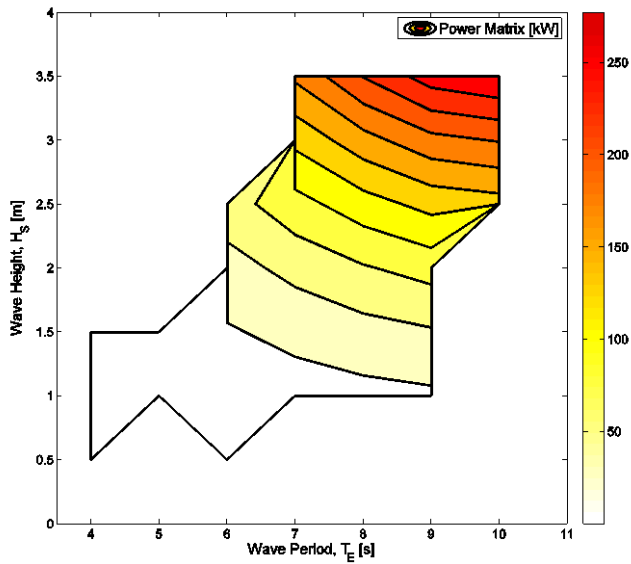


Figure 2: Large WEC power matrix, case 1

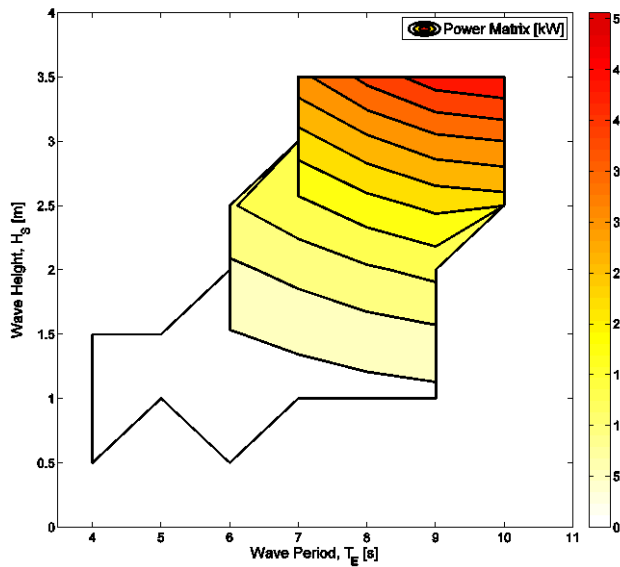


Figure 3: Small WEC power matrix, case 1

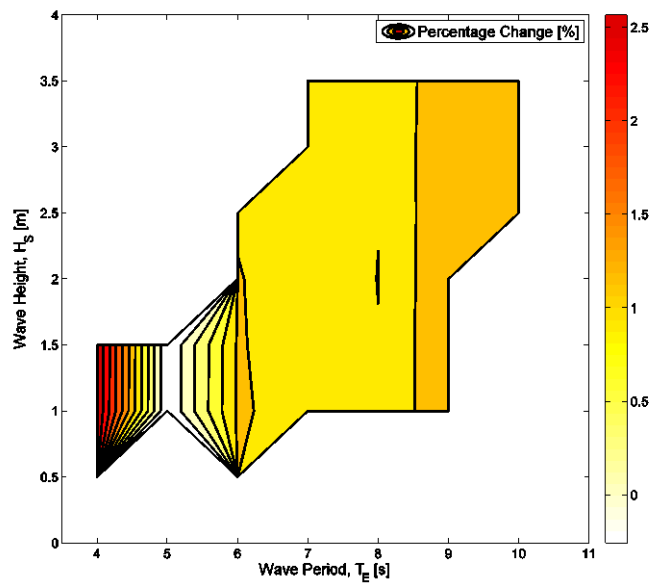


Figure 4: Large WEC power matrix percentage change, case 2 - 1

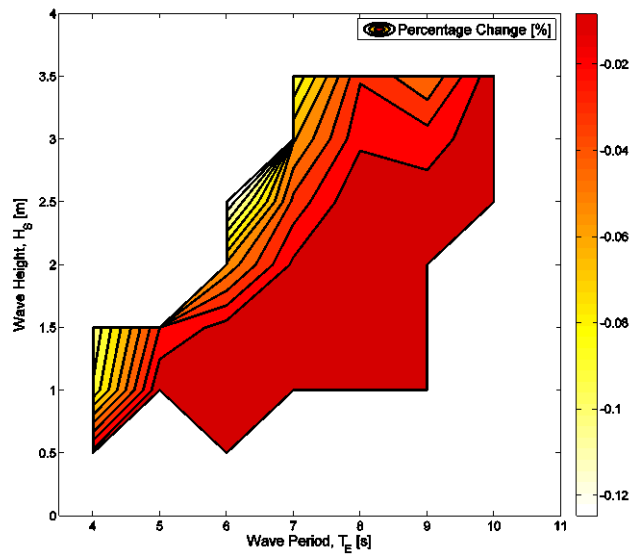


Figure 5: Large WEC power matrix percentage change, case 3 - 1

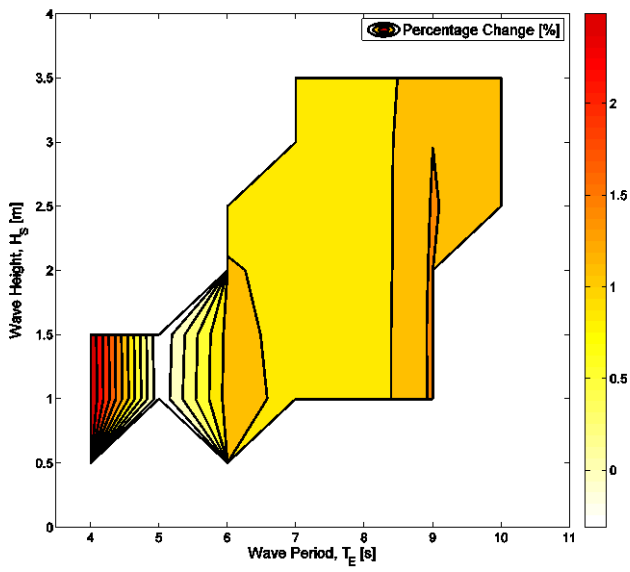


Figure 6: Large WEC power matrix percentage change, case 4 - 1

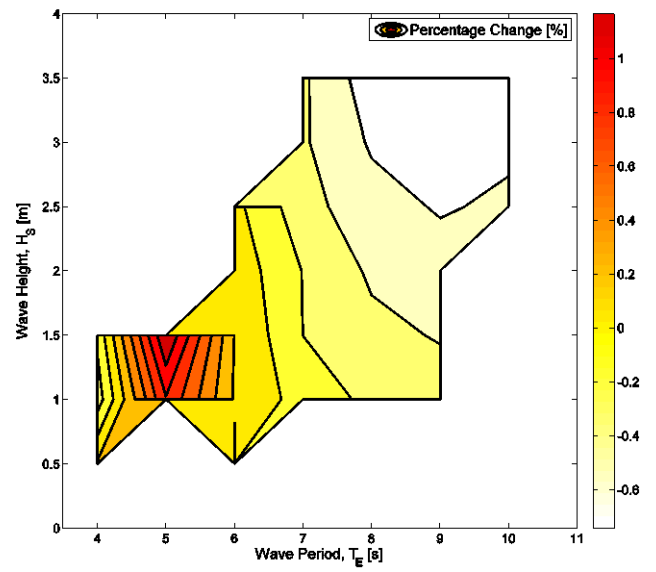


Figure 8: Small WEC power matrix percentage change, case 3 - 1

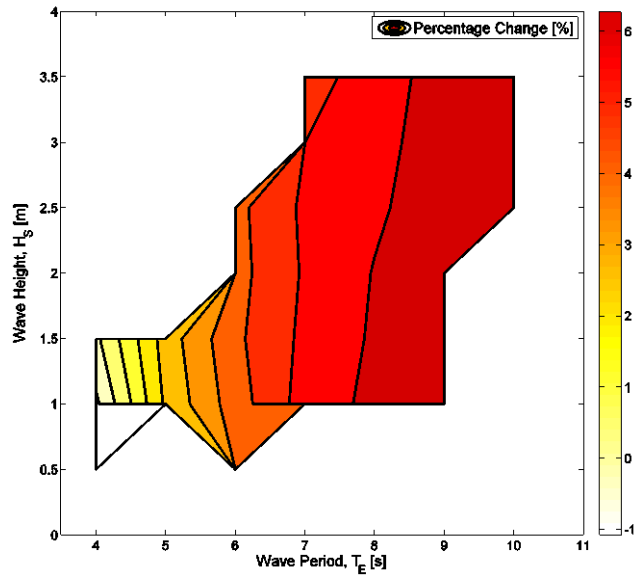


Figure 7: Small WEC power matrix percentage change, case 2 - 1

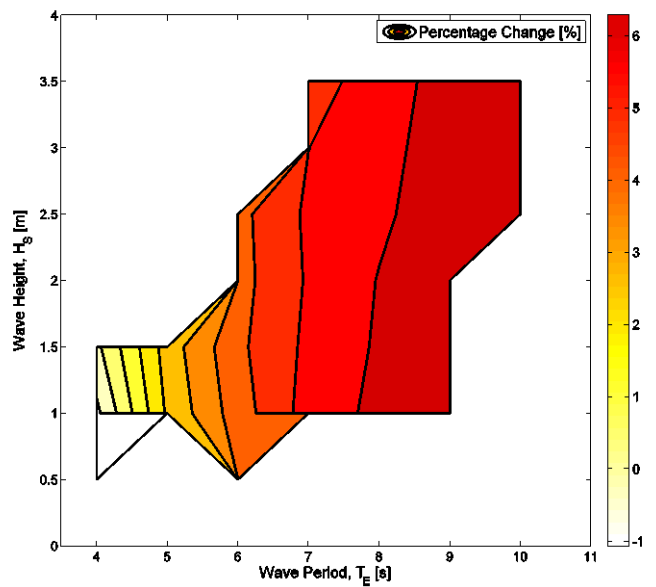


Figure 9: Small WEC power matrix percentage change, case 4 - 1

	Sum of Power Matrix [MW]			
WEC Size	Case 1	Case 2	Case 3	Case 4
Large: 20m	0.48	0.51	0.48	0.51
Small: 10m	2.66	2.69	2.66	2.69

Table 2: Sum of power matrix.

### 3.2 Average Annual Power Production

The average annual power production was then calculated for each device and all cases. Figure 10 and 11 show the AAPP for the large and small WEC consecutively for case 1. The greatest power generation occurs at a sea-state with  $H_S$  of 2.5 m and  $T_E$  of 7 s

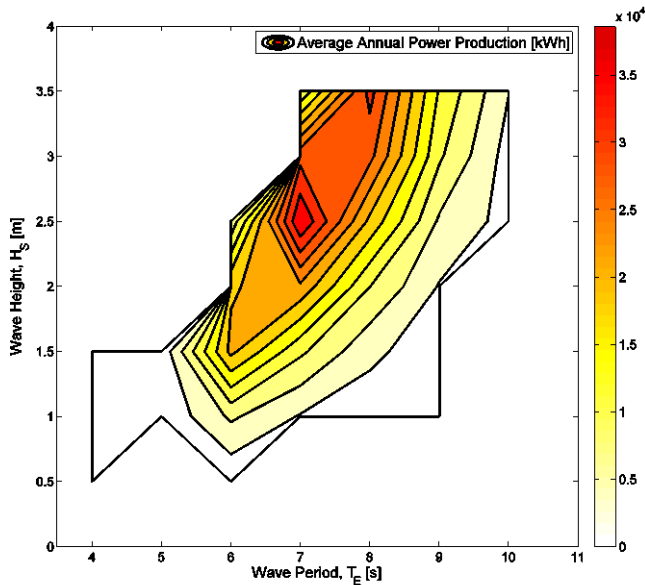


Figure 10: Large WEC Average Annual Power Production, Case 1

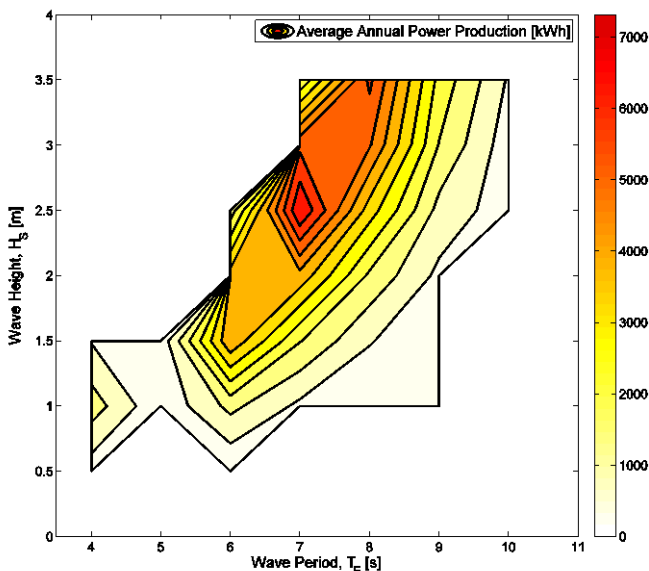


Figure 11: Small WEC Average Annual Power Production, Case 1

WEC Size	Sum of AAPP [GWh]			
	Case 1	Case 2	Case 3	Case 4
Small: 10m	0.063	0.066	0.062	0.066
Large: 20m	0.331	0.334	0.331	0.334

Table 3: Total Average Annual Power Production.

## 4 Conclusions

The effect of marine growth on two pitch restrained heaving WEC's has been demonstrated in this paper. The change in WEC mass, effective size and draft are shown to have a greater effect than the change in surface roughness. The smaller WEC shows the greatest change in total average annual power production, with a 5.4% increase, the larger platform shows a 1% increase. These increases may be because the WEC's were not optimised for the site, and decreases of similar amplitudes may be observed if that was the case. Future work will take this and a greater study on the effective of surface roughness on drag coefficients.

## Acknowledgements

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