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Point Absorber Method as Wave Energy Convertor Device for Power Generation: Effect of Buoy Arrangements

M. A. Yussof[1], N. I. Ismail[1], M. J. Aiman[1], M.F. Abdullah[1], B. A. Gurunathan[1], M. R. A. Rahman[1], M. R. Saad[1]*

[1]Department of Mechanical Engineering, Faculty of Engineering,
National Defence University of Malaysia, Kem Perdana Sg. Besi, 57000, Kuala Lumpur

*Corresponding author

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Abstract: A point absorber is a floating structure with components that move relative to each other due to wave action. They utilize the up and down movement of the wave height at a single point for energy conversion. The relative up and down which is bobbing motion caused by passing waves used to drive electromechanical energy converters to generate power output. This experiment investigates behaviour of the point absorber device used the pneumatic sensor to take the frequency of the displacement of buoy while testing in the wave maker generator. Then, study the efficiency power output of point absorber WEC device and studies the behaviour of the point absorber in a regular wave. Fabricate the linear generator which as power absorption to estimate the effectiveness power output on different configuration by using the multimeter device. The point absorber at the front position of the configuration has good behaviour because of the high frequency produced. By estimated the behaviour of the device on configuration achieved. Configuration shape design of the point absorber used in this testing is square, diamond and parallelogram shape for an estimate the best power output. The configuration of the parallelogram has the best power output compared to another configuration. The best arrangement of the device for efficiency by measure the output voltage as power output is 68.14 mV and increase 8% in every minute.

Keywords: Wave Energy Converter, oscillating bodies, point absorber, arrays, floating structures

1. Introduction

Renewable energy is frequently referred to as a clean energy. The most common definition of renewable energy is energy from a sustainable power source, normally from an energy asset that is replaced rapidly by a natural process [1]. Ocean wave energy or commonly known as wave energy is an ocean-based renewable energy source that uses the power of waves to generate electricity [2]. The specific difference between wave energy and tidal energy is that tidal energy uses the movement and flow of the tides while wave energy utilises the surface water's vertical movement that produces the tidal waves. Wave energy is a renewable energy and is considered a sustainable power source due to the replenishable nature of oceanic waves. Wave energy is also known as a sustainable power source because both wave and tidal energy are produced by winds blowing across the surface of the ocean [3]. This is unlike petroleum or other fossil fuels which can run out in the near future when new oil discoveries cease to happen. Fossil fuels also create power with harmful by- products such as gas, waste, and pollution. Fossil fuels derivatives, while theoretically sustainable on a very long timescale, are abused at rates that may exhaust these assets sooner rather than later. Energy harnessed from waves can be channelled directly into electricity-producing machinery and used to operate nearby power plants and generator [4] [5].

A point absorber is a floating structure with moving components that move relative to each other caused by wave action. They use ascending and descending altitude waves at one point to generate energy. The relative up and down bobbing movement due to waves are used to drive electromechanical or hydraulic power converters to generate power output [6]. There are many configuration parameters that can be considered in designing a WEC system. The main

**Corresponding author: rashdan@upnm.edu.my*

features are the form of the point absorber buoy, the overall layout of the system, and the arrangement of the point absorber WEC. The point absorber in the heave movement represents a single common type of WEC. Many analytical studies[7] as well as numerical and experimental research have been done to optimise their shape and performances [8] . Hence, this study focusses on the effect of buoy arrangements on the power generation.

2. Methodology

This study used mainly an experimental method to define the efficiency of power output in a WEC array.

2.1 Computer Aided Design (CAD) Modelling of Point Absorber WEC

SolidWorks software is a CAD software used to generate a CAD drawing of point absorber WEC. Its purpose is to design the structural image of point absorber WEC which can be used to guide the fabrication of this model design. Three-point absorber WEC designs were produced. Each design had their own array of point absorber buoys and different distances between each point absorber. In this experiment, each design had their own range of width and length. The first design had a length 0.5 m and a width of 0.5 m. For the second design, the width of the design was 0.4 m and the length was 0.4 m. The third design, the width was 0.6 m and the length 0.2 m. The triangular-shaped array had a width of 2 m and a length of 1.5 m. The dimensions refer to the limitations of the experiment. The isometric view for this arrangement of point absorber WEC is a square array design in Figure 1, diamond array design in Figure 2, parallelogram array design in Figure 3 and triangular array design in Figure 4.

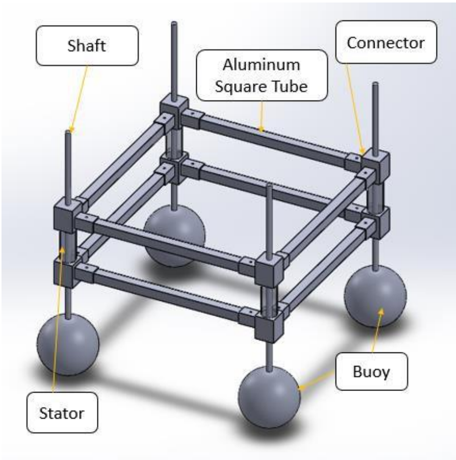

Fig. 1 - Square shape design of point absorber array

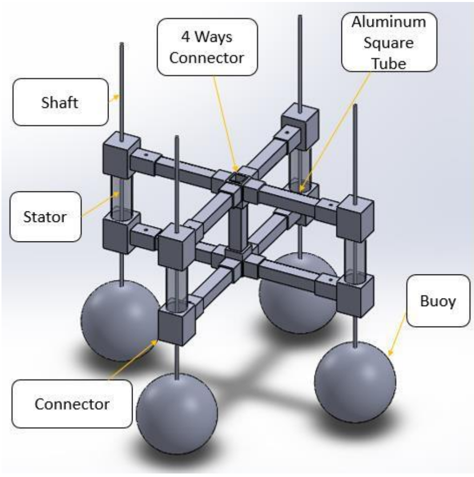

Fig. 2 - Diamond shape design of point absorber array

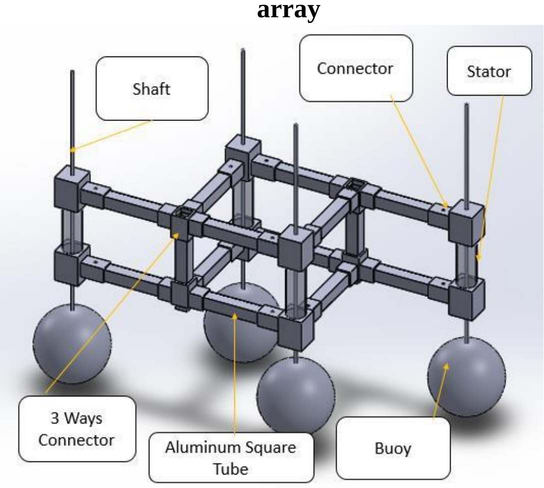

Fig. 3 - Parallelogram shape design of point absorber array

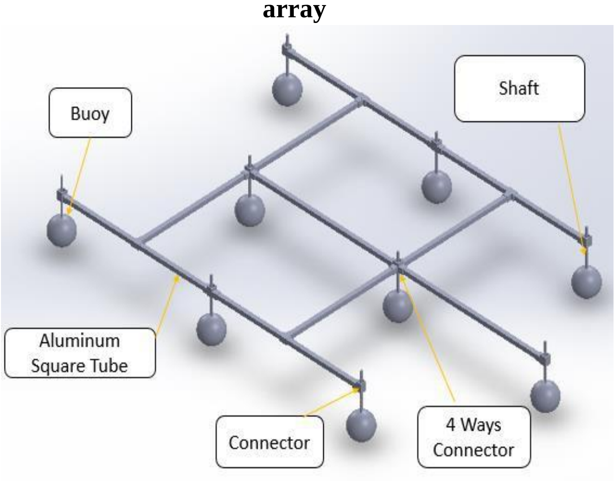

Fig. 4 - Triangular shape design of point absorber array

2.2 Computer Aided Design (CAD) Modelling of Point Absorber WEC

3D Printers or Additive Manufacturing (AM) relates to the different processes used to create three-dimensional objects and can be in any form or geometry. In 3D printing, successive layers of materials can be formed under the control of a computer to create objects and form 3D models, but there is a size limit for this model. A 3D Printer 4S model was used to fabricate the connector of the linear generator.

2.3 Computer Aided Design (CAD) Modelling of Point Absorber WEC

The experiment was conducted using the Wave Maker at the Pusat Maritim, National Defence University of Malaysia. The test portion walls are transparent which allows models to be seen from any perspective. The point absorbers were arranged by testing various arrangements to get a stable and best power output. The point absorbers were tied with a tiny rope before being tested. Then, the normal Windows credentials were used to ensure the computer lab was connected directly to the control panel by dedicated Ethernet connection. The user interface, wave period in seconds and wave height in metres were set up. Next, the graphs were shown live on the screen of the computer, showing the position Demand (m) ramping up.

Meanwhile, the actuator should also be moving to the start position. The headline for the wave maker at working depth is 1.33m, where the depth of water affects the size of wave that can be created. Its internal length is 10 m from the paddle towards the endcap face, working width is 2.5 m, working length is 3 m to 4 m where 3.5 m is suitable for evanescent waves to settle while 4 m is for the absorber with a maximum wave height at 0.2 m and wave period of 0.5 seconds to 2.5 seconds. The overall length, width and height is 12.13 m, 3.2 m and 1.76 m respectively. The wave maker uses 240v AC 13A power. directly to the control panel by dedicated Ethernet connection. The user interface, wave period in seconds and wave height in metres were set up.

3. Results and Discussion

The behaviour of each buoy in period (T) can be determined. The frequency can be measured by taking the peak to peak oscillation from the graph. The periods T1, T2, and T3 at three different peaks are measured and Tmean calculated. The mean frequency of each point absorber is the output of the behaviour of the device in the configuration. Table 1 shows the calculation results of each point absorber that has been tagged.

3.1 Tabulation of Data on Behavior of Point Absorber

Experimental analysis on behavior of point absorber is based on the results and data tabulated from the wave maker simulator experiments. All the procedures and methodology were described in previous section. The analysis is important in order to illustrate the performance of each point absorber in the different design models.

The triangular configuration array contains three lines of obstacles aligned parallel to the direction of wave propagation which is at 90 degrees to the point absorber. The behaviour of the point absorber can be determined by measuring the frequency of the point absorber by using formula (1). The frequency is produced by the up and down movement of the point absorber buoy when hit by a wave. The formula for frequency is

$$\boldsymbol{f = \frac{1}{T}} \tag{1}$$

Where f is the wave frequency and t is the period of one oscillation of the point absorber. The position of the point absorber WEC array and the number of buoys in the array model are shown in Figure 5. Each of the point absorber was tested by using the pneumatic actuator sensor at 1 minute intervals. Figure 6 shows the example graphical result obtained from point absorber 1. The same test were done to the rest of point absorber to obtain graphical result. Fig. 6 and Table 1 show the performance of each point absorber WEC in terms of the displacement of the point absorber buoy by the incident wave. The best performing point absorber in this configuration is point absorber 1 because of its position at the front which means it received a direct wave. The point absorber at the back line which is the last to receive a wave has a low frequency. This is due to the shadow effect that occurs in this configuration. Point absorber 4 has a larger frequency than point absorber 3 because there is a wave interference at its location in the form of a constructive wave that increases the wave energy. Constructive interaction occurs when two waves come close to each other and their effects add up [9].

The highest part of the combined waves will be the sum of the height frequency from the original crests and is known as constructive interference. However, when two waves are not perfectly aligned, one wave will be dragged down by the trough of the other wave and is known as destructive interference [10]. The lowest frequency in this configuration is at point absorber 8 because of the radiation of wave occurring at it position caused by the obstacle from point absorbers 2 and 5. The radiation occurs in the interaction of any oscillation of the point absorber buoy with the rest of the array where it adds mass, damping and also excitation forces on all other point absorber buoys [11]. The radiated wave almost loses a little energy wave.

3.2 Tabulation of Data on Behavior

This experiment studied the behaviour of point absorbers. This behaviour was then applied in the fabrication and configuration of point absorbers to get more power output. The experiment used a wave maker simulator to conduct an experiment with fixed variable period, 1 s and wave height 0.08 m. The depth of water was set at 1.3 m in the wave maker. The depth of water is important in order to see the effect of wave size. The width and length of the wave maker is 3.2 m and 12.13 m respectively, which is the limit for the size of point absorbers that can put to test in the wave maker. The configuration array of each design contained a few obstacles parallel to the direction of the wave propagation and 90 degrees from the point absorber. The figures below show the position of the arrays of point absorber WEC. Figure 7 shows the tagging of point absorbers in a square array, Figure 8 shows the tagging of point absorbers in a diamond array, and Figure 9 shows the tagging of point absorbers in a parallelogram array.

In the experiment on the model point absorber arrays, data is collected on the voltage reading using a Fluke 115 digital multimeter. Each of the point absorber is tested using the multimeter at 3 minutes as the wave maker generator takes a longer period to create a stable wave. After that, in order to capture the performance of each buoy, the millivolt reading in the multimeter is taken as the result after the time interval is reached. Figure 10 shows the total output voltage of each configuration taken after 3 minutes. The millivolt reading in the multimeter is taken as the result after the time interval is reached.

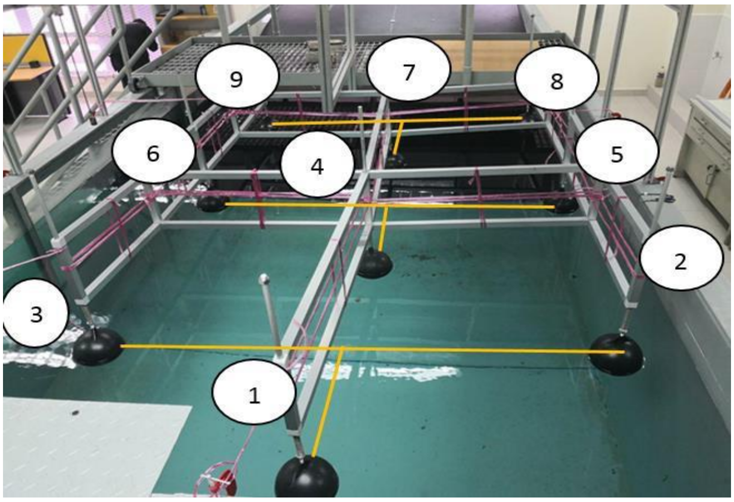

Fig. 5- Position each buoy of point absorber on triangular configuration

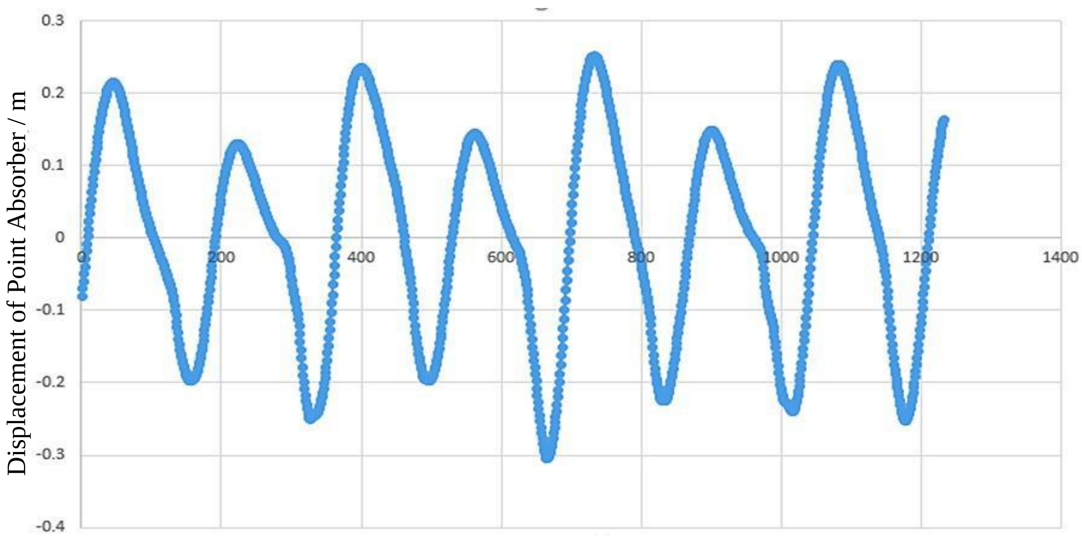

Fig. 5 - Graphical result obtained from point absorber 1

Table 1 - Calculation of the frequency on each point absorber WEC

Point Absorber Location	Oscillation(s) Period			Mean Period, T_{mean} (s)	Frequency, f_{mean} (Hz)
	T_1	T_2	T_3		
1	190	190	180	186.7	0.0054
2	230	190	200	206.7	0.0048
3	220	260	240	240.0	0.0042
4	220	220	240	226.7	0.0044
5	300	310	240	283.3	0.0035
6	220	300	270	263.0	0.0038
7	260	280	280	273.3	0.0037
8	390	320	440	383.3	0.0026
9	220	300	270	263.0	0.0038

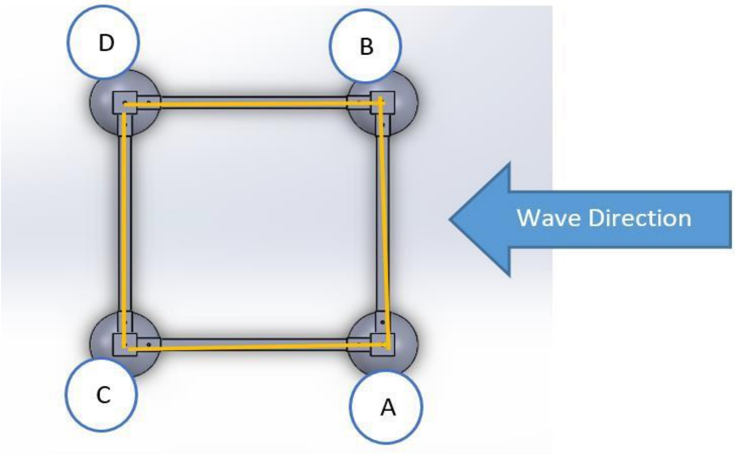

Fig. 7 - Tagging position of point absorber in square array design

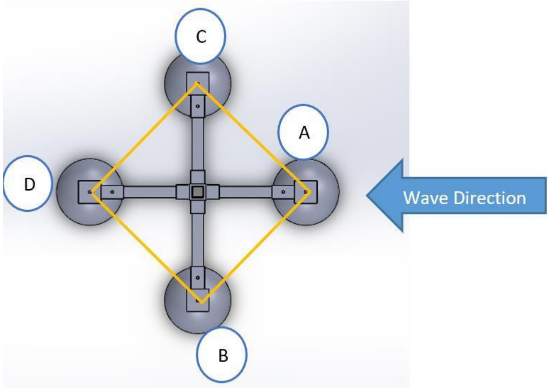

Fig. 8 - Tagging position of point absorber in diamond array design

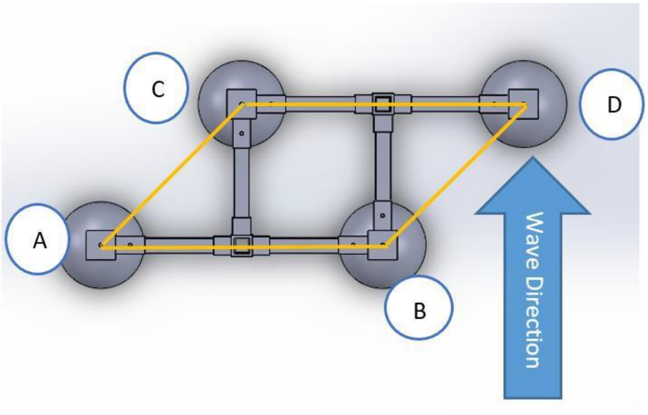

Fig. 9 - Tagging position of point absorber in parallelogram array design

The bar chart in Figure 10 shows the total output voltage of each configuration taken after 3 minutes. This is because the output voltage after 3 minutes in every configuration is the best output compared to the other time intervals. The best output voltage in this experiment was produced by the parallelogram-shaped design configuration with a 68.14 mV output voltage. The lowest output voltage in this experiment was produced by the square-shaped configuration with a total output of 56.54 mV. The diamond-shaped array came second with 61.74 mV. However, every configuration has their own advantages. The parallelogram-shaped array has great output but low stability in generating electrical energy. This is caused by the point absorber arrangement which has wave interactions, so the output voltage will not be generated consistently. However, the parallelogram array is still the best because the output voltage increased by 8 % during the test duration. In terms of output voltage stability, the square-shaped array is the best with an output in the range of 57.97 mV, although the output is still low. The diamond-shaped design is also good at generating energy because the output voltage of the point absorber is gradually increasing with time. However, the output voltage of this configuration is still lower than that of parallelogram-shaped array [12]

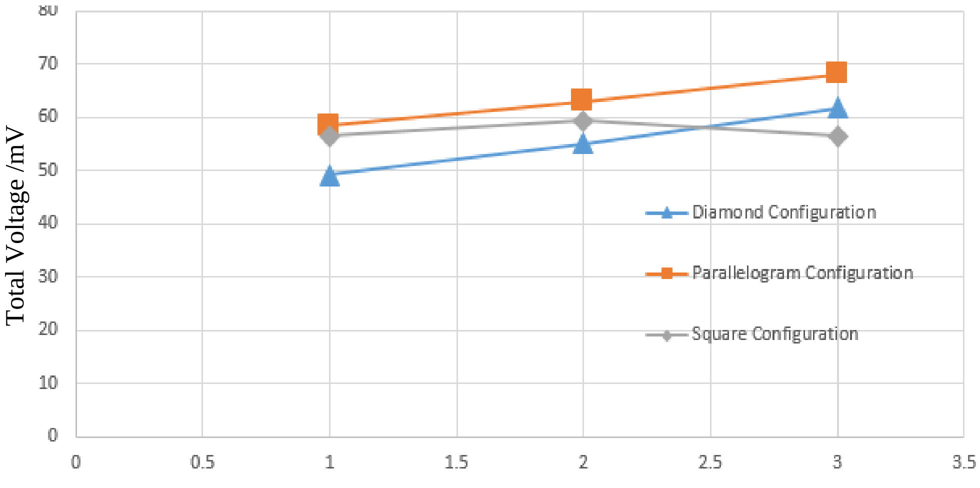

Fig. 10 - Performance total output voltage of each configuration after 3 minutes

4. Conclusion

The reaction of the device was influenced by the position of the device in a configuration. The near trapping that allow the radiation occurs in interaction of any oscillation of buoy of point absorber with the rest of the array changes it added mass and damping and also excitation forces on all other point absorber buoys. The radiated wave almost lost its energy in the configuration. In some device positions in this configuration the wave interference or constructive interaction occurs when two waves come close to each other and their effects are combined. However, when two waves that are not perfectly aligned come close, one will be dragged down by the trough of the other wave. The combined wave will then have a shorter crest than the original wave and is known as destructive interference. Constructive interference becomes notably effective when the platform is placed in the centre of the triangular array in the wave directions. The influence of separating distances in the design of arrays demonstrates that destructive effects are dominant at short distances. Destructive interference can be decreased by increasing the distance between each point absorber. But it is not necessary to make the separating distances too long [13]. The configuration that generated the highest power output in the most efficient way was found to be the parallelogram array design. The best arrangement to achieve point absorber efficiency by minimising the destructive effect and radiated waves, and with constructive interference was also determined. Constructive interference becomes notably effective when the platform is placed in the centre of the triangular array in the wave directions. The distance between point absorber increase to promote the lower radiation of wave will occur.

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