Generating Electrical Power by Using Four Dynamos Installed in a Floating Buoy in Experimental Study

Yasser Mohamed Sadek El-Saie[1], Amira Bahaa AbdElhaseeb[2], Fahmy Salah Fahmy Abdelhaleem[3]

Abstract

Renewable energy sources are wind, sun, sea waves and other sources. The fact this energy is pure, sustainable, and doesn't pollute our environment or harm people's health is its most significant quality. Wave energy has a better possibility of being compared to solar energy or wind energy. Researchers and scientists are attempting to determine the most effective method for harnessing the power of ocean and sea waves to produce electricity. The purpose of this research is to transform wave energy into electricity by an experimental model based on the vertical movement of the waves. Results showed that Wave height has an effect on how much electricity is produced. In proportion to the buoy's weight, more electrical energy is extracted.

Keywords: Wave energy converter; electrical power; environment; Climate change.

1. Introduction

In The light of the enormous increases in the cost of fuel, particularly oil and natural gas. In addition to the burning of fossil fuels like coal and oil, air pollution, environmental degradation, and a significant increase in the buildup of greenhouse gases in the Earth's atmosphere have all contributed to global warming, which has in turn caused changes in climate and the environment, desertification, droughts, and floods, as well as other natural and man-made disasters. This has increased interest in finding clean, ecologically friendly, and cost-effective renewable energy sources. The wind and waves were given special consideration because they are among the sources with the most potential. Wave energy, though, won't be used just yet. Calvário et al., (2020) offered a generalized oil-hydraulic power takeoff concept based on two single-rod cylinders that are attached on either side of an oscillating wave surge converter to extract power from the plate's forward and backward oscillations. The hydrodynamics simulations for a modified Edinburgh Duck wave energy converter were performed by Chao Zhang et al., (2019). Shaohui Yang and colleagues (2019) created a floating array-point-raft wave energy converter and ran a three-month experiment in the Taiwan Strait, China, under actual sea conditions. The studies shown that wave energy may be efficiently converted to electrical energy by leveraging the relative motion between the floating center platform and several oscillating buoys. By comparing experimental results and numerical results, Scott J. Beattya et al. (2019) reported the performance of two self-reacting point absorber wave energy converters. Both designs have the same float, but the first has a responding body that is streamlined while the second has a reacting body that has a damper plate. They discovered that the streamlined reacting body wave energy converter design produces 51.7 kW, while the damper plate reacting body wave energy converter design produces 73.1 kW. By conducting a comprehensive series of practical testing, Claudio A. Rodrigueza et al. (2018) demonstrated various power estimating methods for

[1]Associate professor, High Institute of Engineering, El Shrouk academy, yasser_elsaie@yahoo.com,

[2] Associate Lecture, High Institute of Engineering, a.bahaa@sha.edu.eg, El Shrouk academy,

[3] Associate Professor, Faculty of Engineering, Benha University, Fahmyhri@gmail.com

a floating-point absorber WEC model under regular and irregular long and short-crested waves. The experiment results demonstrated that the kinetic energy harvester approach may be effective as a preliminary tool for the qualitative performance assessment of the WEC when only experimental motions are provided. Masjonoa, et al., (2016) used the JONSWAP (Joint North Sea Wave Project) model and MATLAB computer software to examine the performance of one-way gear wave energy converters that utilized the gravity weight under irregular ocean wave conditions. In order to generate renewable energy, Muchtar et al., (2016) proposed a physical model experiment of a wave energy converter based on the vertical movement of water mass. Based on the vertical movement of the water mass, Masjono Muchtar et al., (2016) developed a physical model experiment of a wave energy converter. The simulation model was presented by Erik Lejerskog et al., (2015) It had a data logging and transmission system, an antenna, a battery, a force transducer, and a mechanism for measuring line forces. The outcome reveals that the buoy size and translator weight have a significant influence on the generator's power absorption. At the Lysekil wave energy research facility, Lejerskog et al., (2015) presented experimental data on power absorption from a wave energy converter. Masjono et al., (2014) investigated the use of a system of one-way gears connected by four buoys and counterweights to convert ocean waves into electrical energy. This study employed numerical simulation using the Matlab software.

2. Experimental Work

2.1 The wave flume

The experiments were conducted at a laboratory rectangular flume of 0.5 m wide, 0.60 m deep and 12 m length. Its side walls are made up of 12 panels, each measuring 1 m in length. glass panels are inserted into a steel frame, to provide users a clear view of the wave movement. As seen in Fig. 1. The experimental test flume is based on a 1:20 scale models. A hydraulic wave generator positioned at one end of the flume generated regular waves with variable height and length. It located at 4m from the inlet of flume. The influence of reflected waves is suppressed by a gravel slope at the other end of the flume.

Fig. 1. General View of the Wave Flume

2.2 The Model

As shown in Fig. 2, the device was positioned 4 meters away from the wave generator and is made up of a wooden frame, a float, and an electric power generator. The wood frame is erected in the flume and measures 0.85 m long, 0.49 m wide, and 0.03 m thick. The plastic buoy has dimensions of 0.36 m wide, 0.345 m long, and 0.23 m high. Two horizontal wood panels that are 0.36 m long and 0.03 m thick and two vertical wood panels that are 0.33 m long and 0.03 m thick encircle it in the center. The weight of the buoy changed from 3 kg, 5 kg and 9 kg. Metal drawer runners on Roman balls and metal hinges connect the vertical wood panels to the frame; their primary purpose is to allow the buoy to move vertically.

Electrical is generated from four DC generators. Each generator is connected to the black rubber roller with a 0.01-meter diameter. The roller passes over the vertical wood panel. Each of the two generators was installed in the middle of each frame column. Additionally, the shaft converters will rotate as a result of the container's up-and-down motion in response to the generator's waves' up-and-down motion, which in turn generates the generator's power. The buoy weight, wave height, and wave period were the only dependent variables used in this converter. Fig. 3 shows sketch of the experimental set up. Table 1 provides a summary of the test circumstances in detail.

Table 1 Test Conditions.

Parameter	Range
Water depth (d_w)	0.24 m
Wave height (h_w)	0.09, 0.08, 0.075, 0.056, 0.039 and 0.031
Wave period (T)	1.28, 1.46, 1.76, 2.09, 2.5 and 2.86
Wave length (L)	2.55, 3.35, 4.86, 6.68 m
The weight of the buoy (W_b)	3, 5 and 9 kg

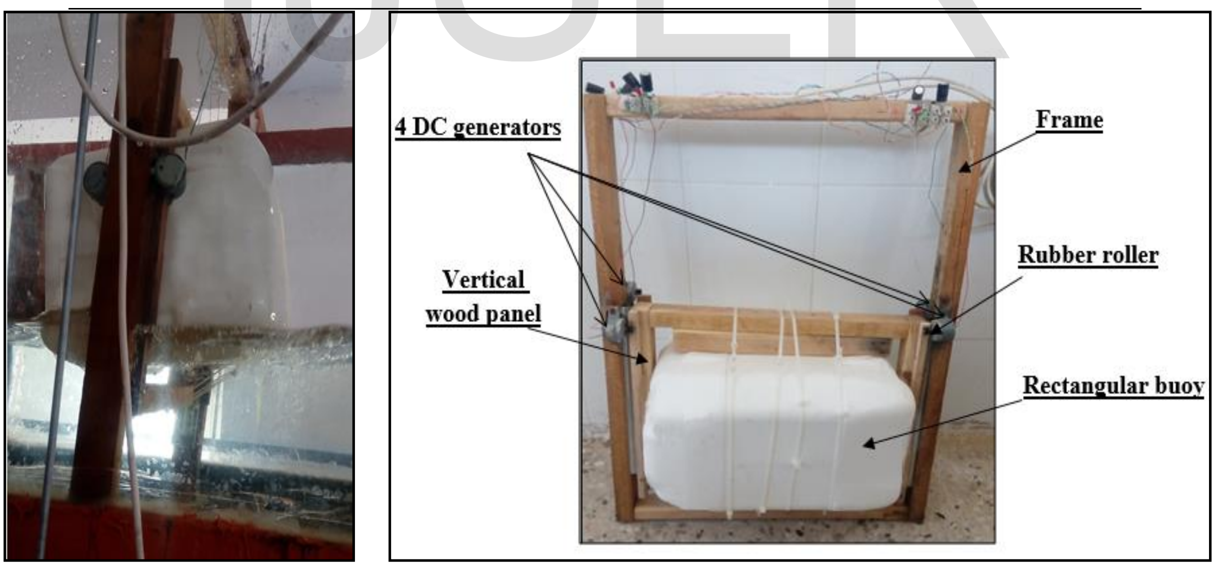

Fig. 2. A photo of wave energy converter model in this study.

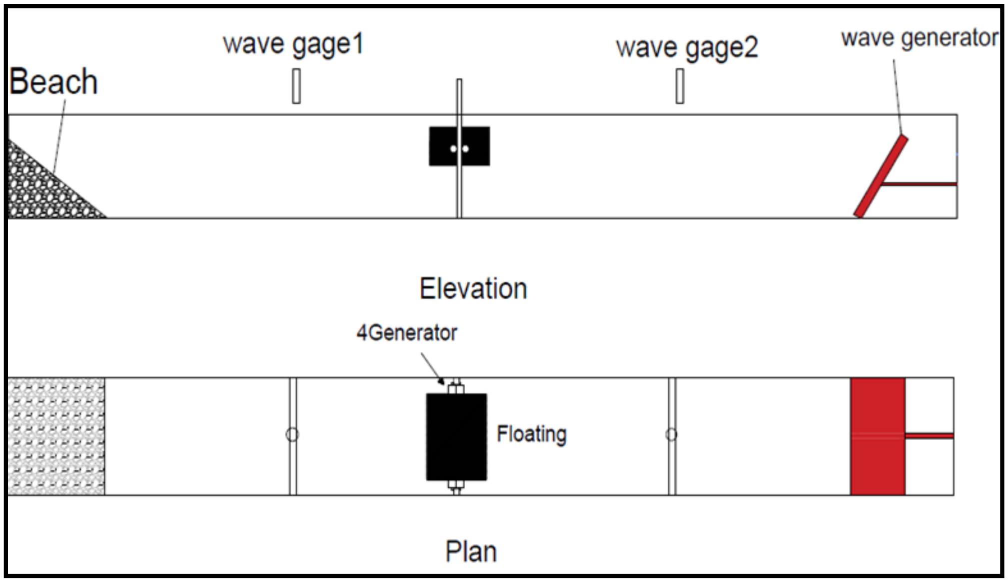

Fig. 3. Sketch of the experimental set up

3. Results and Discussion of Experimental work

3.1 Effect of Relative Waves Height (h_w/d_w)

Experimental research was done on how well a floating buoy powered by four dynamos performed. Three distinct floating buoyancy device weights (W_b=3, 5, and 9 kg) were tested experimentally, along with six different wave heights, in order to determine the relative wave height (h_w/d_w =0.4, 0.367, 0.303, 0.247, 0.2, and 0.167). The connection between electric power and relative wave height (h_w/d_w) at (W_b) = 3 kg, 5 kg, and 9 kg is depicted in Fig. 4. The graphic makes it obvious that the creation of electrical energy increases as the wave's height rises. Because the buoy moves up and down in response to the rise and fall of the waves, there are more shaft converters rotating, which causes the generator to produce power. Additionally, it was discovered that the amount of electrical energy extracted reduces as buoy weight (W_b) increases. To improve power production, it is suggested that the buoy be constructed of lightweight, high-strength materials. Electricity produced when buoy weight (3 kg) is 1.1 times greater than that produced when buoy weight (5 kg), and 1.4 times greater than that produced when buoy weight (h_w/d_w) = 0.4. (9 kg).

3.2 Effect of Wave Length.

According to the graph of electric power vs (d_w/L) in Fig. 5, the highest electric power level was measured to be around 0.126 watts when (d_w/L) was roughly 0.094 and the buoy's weight were 3 kg. The graph also shows that as wave length increases, the electric power rating decreases, indicating that in this system, the relationship between electric power and wave length is inverse.

3.3 Effect of Frequency.

Electric power generation rate is growing with respect to frequency, as seen in the graph in Fig. 6. The highest amount of electric power, 0.126 watt, is taken at a frequency of 0.783 Hz. Power generating rate therefore varies with frequency.

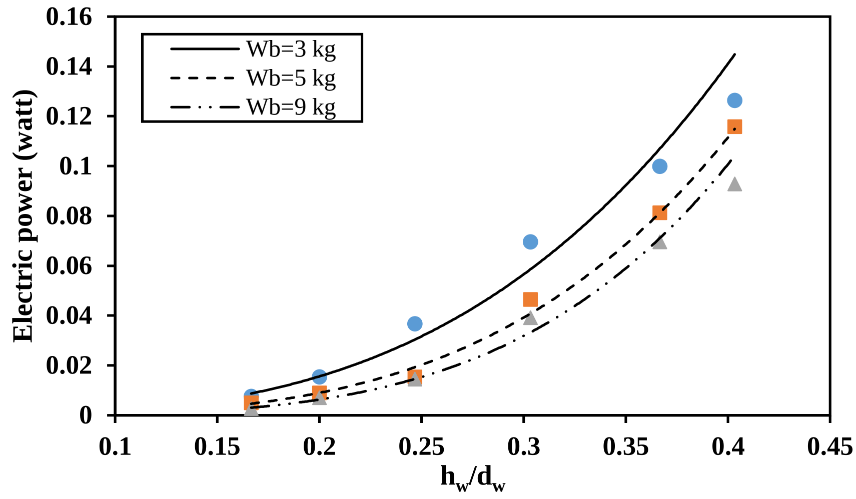

Fig. 4. Electric power vs ($\mathbf{h_w/d_w}$) for various buoyancy weights

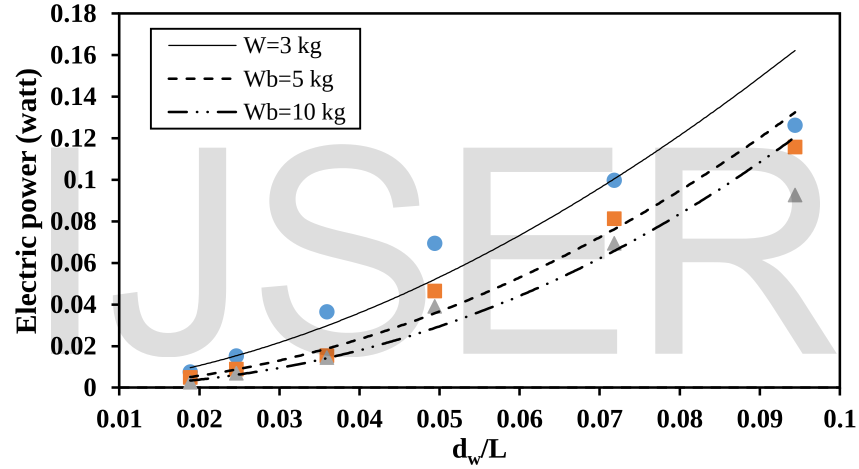

Fig. 5. Electric power vs ($\boldsymbol{d_w}$/L) at deferent buoyance weight

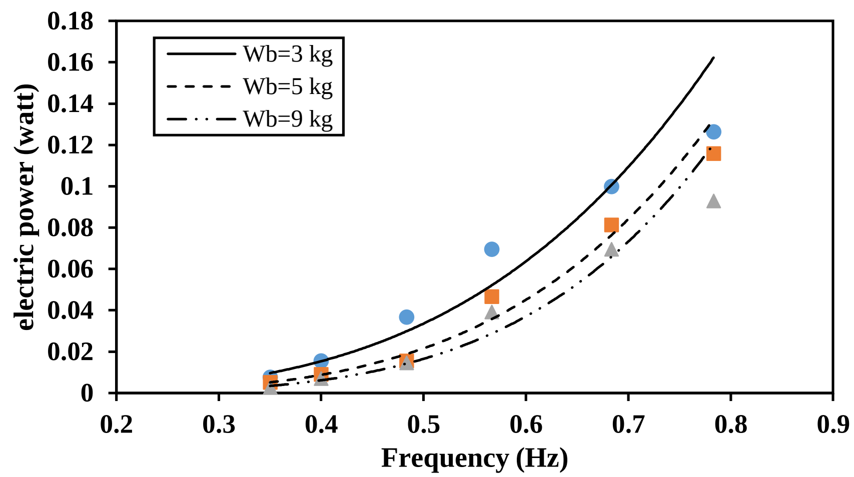

Fig. 6. Electric power against frequency at deferent buoyance weight

Under regular wave, the rectangular buoy moves vertically, starting to drift downward as the wave crest approaches (Fig. 7-a). The float is raised when the wave crest strikes it (Fig. 7-b). When the wave crest recedes and the trough approaches, the float goes downward, and the wave cycle is repeated (Fig. 7-c), the water level starts to fall. The frame of the float rotates a black rubber roller that is attached to a generator and generates electricity during both the upward and downward movement.

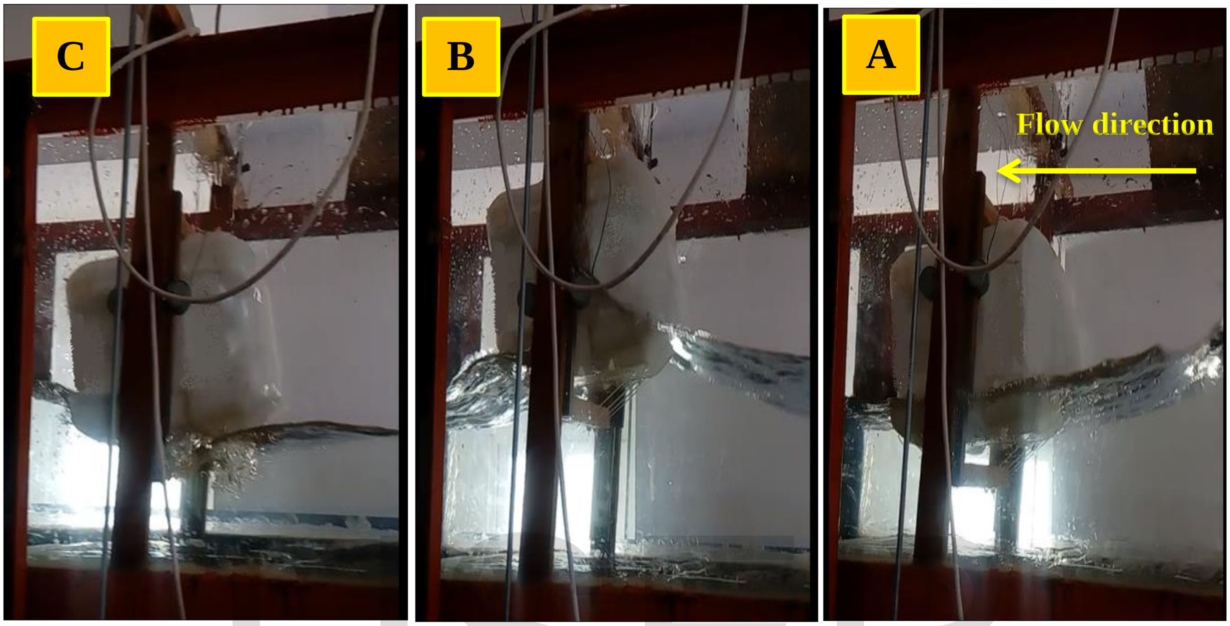

Fig. 7. The buoy with four dynamo motion under regular wave at wave period =1.28sec

4. Conclusion

The performance of physical wave energy converter model on electricity generated. The effects of relative wave height, relative wave length and frequency were investigated. From this investigation, the generation of electric power is impacted by wave height. As the buoy's weight (w_b) increases, so does the amount of electrical energy extracted. The amount of electricity produced by buoy weight (3kg) is 1.1 and 1.4 times greater than that produced by buoy weights (5kg) and (9kg), respectively, when ($\mathbf{h_w}/\mathbf{d_w}$) = 0.4. With the buoy weighing 2.75kg and ($\mathbf{d_w}$/L) at 0.094, a maximum electric power level of roughly 0.126 watts was observed. Additionally, the outcome demonstrates that electric power decreases with increasing wave length. The maximum electric power 0.126 watt, is obtained at a frequency of 0.783 Hz. As a result, the frequency has a direct relationship with the rate of power generation.

Reference

1. BEATTY, S. J.; BOCKING, B.; BUBBAR, K.; BUCKHAM, B. J. AND WILD, P., (2019), “Experimental and numerical comparisons of self-reacting point absorber wave energy converters in irregular waves” Ocean Engineering 173, https://doi.org/10.1016/j.oceaneng.2019.01.034, 173, 716-731
2. CALVÁRIO, M., GASPAR, J., KAMARLOUEI, M., HALLAK, T. & SOARES, C. G. 2020. Oil-hydraulic power take-off concept for an oscillating wave surge converter. Renewable Energy, 159, 1297-1309.

3. LEJERSKOG, E., BOSTRÖM, C., HAI, L., WATERS, R. & LEIJON, M. 2015. Experimental results on power absorption from a wave energy converter at the Lysekil wave energy research site. Renewable energy, 77, 9-14.
4. LEJERSKOG, E.; BOSTR€OM, C.; HAI, L.; WATERS, R. AND LEIJON, M. (2015), "Experimental results on power absorption from a wave energy converter at the Lysekil wave energy research site", http://dx.doi.org/10.1016/j.renene.2014.11.050, 77, 9-14.
5. MASJONOA; MANJANGB. S.; SURIAMIHARJAC. D. A. AND THAHAA. M. A. (2016) "Modelling of One Way Gears Wave Energy Converter for Irregular Ocean Waves to Generate Electricity" Journal Technology (Sciences & Engineering), ISSN: 2180–3722, 37-41
6. MASJONO; MANJANG. S.; ZAINUDDIN. Z. AND THAHA. A. (2014) "Modelling and Numerical Simulation of Multiple One Way Gears Wave Energy Converter to Generate Electricity", ICSGTEIS, 73-77
7. MUCHTAR, M., MANJANG, S., SURIAMIHARJA, D. A. & THAHA, M. A. 2016. Physical Model Performance of Wave Energy Converter Based on Water Mass Gravity Force under Container Shape Variation. Int. J. Sci. Res. IJSR, 5, 1627-1630.
8. MUCHTAR, M; MANJANG, S; SURIAMIHARDJA, A, D. AND THAHA, A, M., 2016. "Model of Ocean Wave Energy Converter Based on Water Mass Gravity Force as a Renewable Energy Source," International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2763, 3, 28-34
9. RODRÍGUEZA, C.A.; ROSA-SANTOSA, P. AND TAVEIRA-PINTOA, F., (2018) "Assessment of the power conversion of wave energy converters based on experimental tests", Energy Conversion and Management, 173, 692–703
10. Yang, S.; He, H.; Chen, H.; Wang, Y.; Li, H. And Zheng, S. 2019, "Experimental study on the performance of a floating array-point-raft wave energy converter under random wave conditions", Renewable Energy, 139, 538-550
11. ZHANG, C.; HUANG, S., YOU, Y. AND SHENG, S., 2019, "Numerical research and open sea tests of A 100 kW modified Edinburgh Duck wave energy convertor", Frontiers in Energy Research, pp. (31).