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HARVESTING WAVE ENERGY WITH LINEAR GENERATOR

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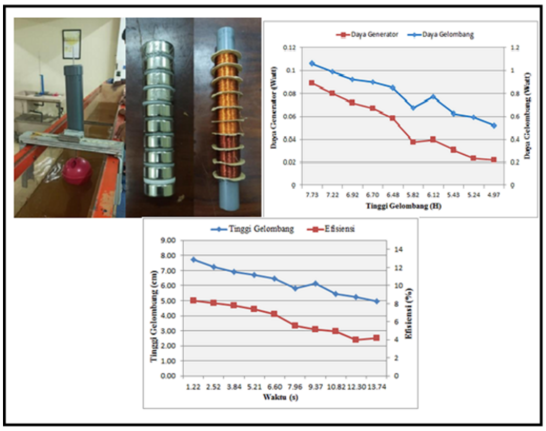
Graphical abstract



Abstract

Ocean wave energy has great potential to be converted into electrical energy. In recent years researchers have focused on harvesting ocean wave energy into electrical energy with several technology models, one of the technologies used is to use linear generators. Generator placement becomes a separate problem when harvesting wave energy. This paper examines the placement of linear generators in a vertical position to optimize wave energy conversion under conditions of non-constant seawater wave height. The experimental research method uses a linear generator design mounted vertically with a float ball positioned flush with the water surface, waves are generated in a simulation pond to harvest wave energy. The results showed that the vertical installation position of the linear generator increased the wave energy conversion by 8.36% with a wave period of 1,22 seconds. The increase in efficiency is due to an increase in the step length of the magnetic shaft and the area of the linear generator stator coil that is subjected to electrical induction.

Keywords: Application, linear generator, Harvesting, water wave energy

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1. Introduction

The use of fossil fuels can cause environmental problems, such as air pollution, depletion of the ozone layer, and rising sea levels. environmental problems are a global concern for countries around the world. therefore, efforts are needed to find and use energy sources that are clean and environmentally friendly and do not cause impacts that can threaten life and the environment. the solution to overcome these problems is to reduce the use of fossil energy sources by switching to renewable energy sources. the ability of renewable energy sources is available in large quantities in nature and will not run out. The utilization of offshore renewable energy consisting of energy extraction from offshore wind, waves, tides, and ocean currents provides a new alternative that has great potential to play an important role in achieving the reduction of fossil fuel use [1-2]. Ocean wave energy is one of the outstanding renewable energies that has a much greater energy density than wind and solar power, as well as a relatively consistent energy magnitude throughout the year. The annual ocean wave energy potential is about 32,000 TWh considering all coastal areas with a wave power density of more than 5 kW/m [3]. Therefore, many researchers developed ocean wave energy conversion devices to harvest ocean wave energy.

Despite this, the high potential of ocean energy in helping to promote the future blue economy is still very underdeveloped [4]. Wave energy contributes very little to the global renewable energy mix. This is due to the lack and immaturity of technological designs for harvesting wave energy. Efforts to accelerate and optimize the utilization of wave energy are to improve wave energy harvesting devices [5-7]. Ocean wave energy conversion devices for harvesting renewable energy from the ocean can be classified into several models, such as; oscillating water columns [8], overtopping devices [9], and oscillating bodies [10,11]. The oscillating body model ocean wave energy conversion device is the most researched device among all ocean wave conversion technologies due to its their design and operational versatility and greater energy conversion per oscillating body.

Several buoy model studies have been conducted to harvest wave energy, such as; li et al designed an oscillating resonant buoy to find the effect of changing the buoy geometry on the performance and hydrodynamics of the buoy [12] Ahmed et al modified the buoy geometry with various buoy point absorbers [13,14] the use of a spherical buoy model with a power take-off model can be more optimal. The ocean energy capture efficiency of ocean wave conversion systems is critical for applications, where resonance between the incident wave and the point absorber system as a way to increase the output power. The configuration model of relative motion between floating and submerged objects is used to extract energy [15]. Pastor and Liu compared various diameters and drafts to increase the power absorption capacity by using several buoys and shapes [16]. The absorption capacity of the multiple body system is much higher than that of the single body system. In addition, Silvia et al. added that a submerged load can increase the wave energy capture of the device by up to 40% [17]. Model of ocean wave energy absorbing type power take-off system can be converted into electrical energy. Linear electric generator type together with a power take-off system can be applied to generate electricity from ocean wave energy [18-20].

Application of linear generators in power take-off systems consisting of a translational part, the translator, mounted with permanent magnets and a static part with windings, the stator, enclosed in a pipe that protects the generator components from seawater. When a moving buoy is set in motion by waves, it drags the translator relative to the stator by a stroke length limited by the end stop. due to the motion of the translator, Voltage is induced in the stator windings [21].

The buoy is placed on the water surface and connected to the linear generator by push rod (figure 3). Results from several studies on power take-off systems show better absorption of wave energy. Various approaches have been proposed to control the wave energy device. However, power take-off systems can be tuned on different time scales, seasonal, daily, hourly, and wave-to-wave scales. Therefore, a power take-off system with a linear generator requires a natural resonant frequency to match the energy period of ocean waves. In addition, few studies have revealed the effect of wave height on power take-off systems using linear generators with vertical motion mode. In this study, we aim to analyse the effect of wave height on energy extraction potential using linear generators. The research scale uses controlled artificial waves to obtain different wave height variations at laboratory scale.

2. Material and Method

2.1 Material

The research equipment used to assess the extraction of ocean wave energy into electrical energy using a power take-off system with a linear generator consists of; a simulated water pool, wave generating unit, linear generator, rectifier, and buoy. The size specifications of the simulated water pool are long, wide, and high (5000 x 400 x 500) mm. The simulated water pool is made of acrylic material as a water container. The rectifier used to convert the three-phase alternating current (AC) from the liner generator into direct current (DC) is 20 amperes. The buoy is an important part of the linear generator system that can make the rotor move vertically due to the force received when the wave hits the buoy in the simulation pool. The float used is made of ABS plastic material with a diameter of 6 inches. Linear generators consist of magnets that can move vertically to produce induction to the coil on the stator which then creates a potential difference that triggers the generation of electrical energy. This rotor component has two parts, namely the translator (shaft) and magnets with type Neodymium grade N-50 total 10 pieces. stator as a container for coils consisting of several coils of 0.5 mm wire with 4000 turns with a coil diameter of 1.5 inches which can receive induction from magnets when the rotor moves vertically. The wave generating unit uses a plate with dimensions of 250 x 250 x 2 mm which is driven using a linear actuator motor with a DC voltage of 24 volts, stroke length of 300 mm, force of 1000 Newtons. presented as figure 2.

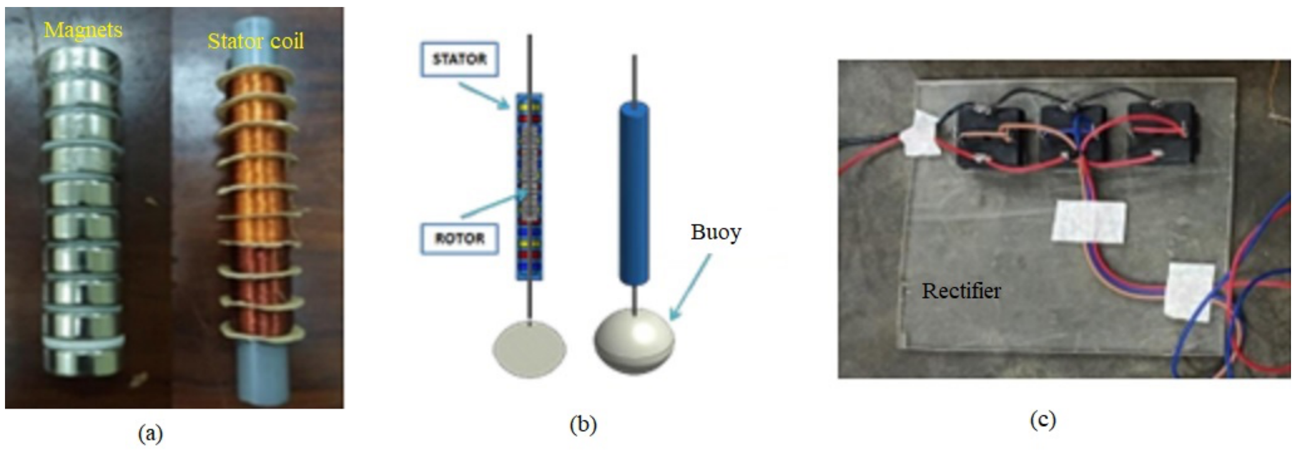
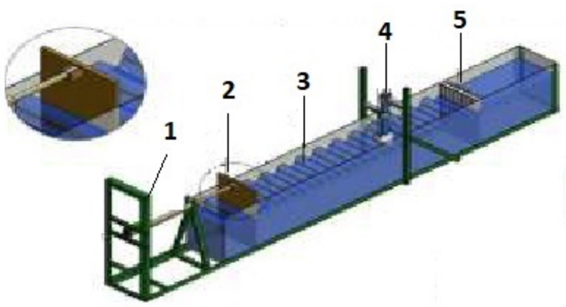


Figure 1. Power take-off system components

The components of the power take-off system for electricity generation from ocean wave energy are magnets, stator coils, buoys, electric current rectifiers, wave generators, and water pools. the working mechanism of the system is that the wave generator will generate waves of water in the water pool, the waves generated will push the buoy mounted on the magnet shaft, due to the push of the buoy the magnet moves linearly along the stator coil groove which causes electrical induction in the stator coil. as presented in Figure 1.



Description;
1. Frame
2. Wave generating unit
3. Water container
4. Linear generator
5. Wave damper

Figure 2. Power take-off system equipment with linear generator

2.2 Method

The performance measurement of the power take-off system with a linear generator was carried out using artificial waves in a water pool. The artificial wave is generated from the mechanical thrust of the plate by the linear actuator motor installed at the edge of the simulated water pool. The forward thrust of the wave-generating unit will generate waves on the water surface. The wave will press the buoy to move upward when it comes into contact with the wave crest and will return downward when it comes into contact with the wave valley. The up-and-down movement of the buoy will drive the linear generator shaft. The three-phase alternating current (AC) of the linear generator is converted into direct current (DC) using a rectifier. Measurement of the output power generated by the linear generator using a voltmeter and ammeter with a constant load of 100K ohms. Presented in Figure 3.

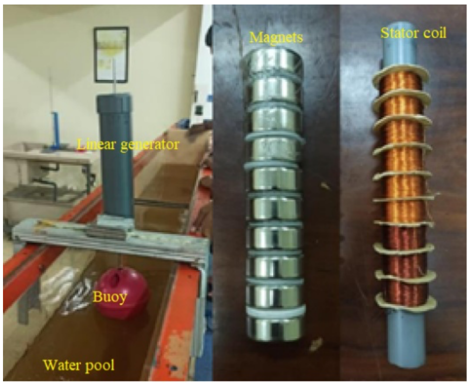


Figure 3. Power take-off system Instrument with linear generator

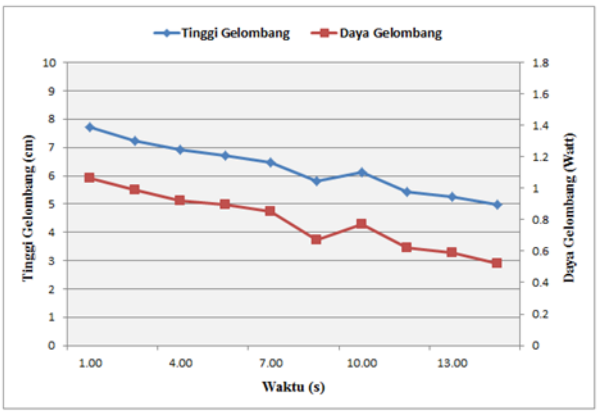
3. Result and Discussion

Harvesting wave energy using a Power take-off system with a linear generator. where the wave characteristics test data is primary data consisting of several measurement variables on the tool and visual observation results. Data in the form of peaks, valleys and wave heights are obtained from visual observations and using Tide Staff measuring instruments, while to obtain wave period data using the frame method on Replay media in the form of videos displayed against time.

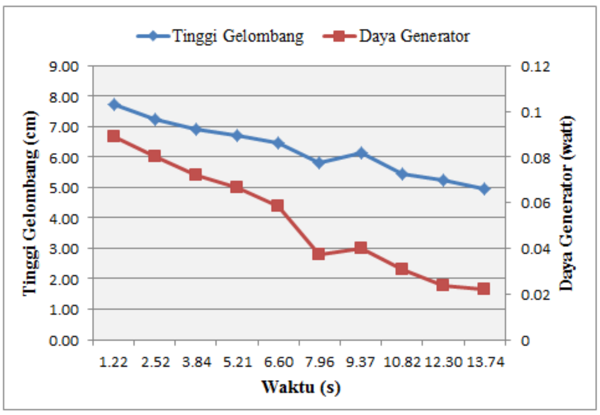
Table 1. Performance of linear generators

Wave height (Cm)	Voltage (Volt)	Electric current (mA)
7,72	3,89	22,84
7,20	3,65	21,80
6,92	3,35	21,46
6,70	3,27	20,32
6,48	2,94	19,86
6,12	2,21	17,98
5,82	2,06	18,21
5,43	1,87	16,52
5,24	1,59	14,76
4,97	1,73	12,63

Wave height is proportional to wave power. The increase in wave height has an impact on increasing wave power, thus providing a greater push on the buoy. The push of the buoy to the generator rotor shaft causes an increase in voltage and the electric current generated is getting bigger too. The factor that can affect the wave height is Reflection Wave. When a wave meets a plane, it will cause a reflection in the opposite direction of propagation, which can affect the next wave. The calculation results show that at a wave height of 7.73 cm, it produces a wave power of 1.064 W with a wave period of 1.22 s, then the minimum wave power that can be produced is 0.520 W at a wave height of 4.97 cm and a wave period of 1.44 s. Presented in Figure 4. Presented in Figure 4 (a).



(a)



(b)

Figure 4. High wave effects (a) Wave Power, (b) Output Power of Linear Generator

Wave height can affect the output power generated by the linear generator. The results of the analysis show that the higher the wave height, the greater the generator output power generated by the linear generator. This shows that the wave height is directly proportional to the voltage and current. The voltage that occurs at the output of the linear generator system is created due to the potential difference that occurs in the coil due to the vertical translational movement of the rotor which contains several magnets. The potential difference occurs when the rotor moves up due to the impact of the waves. When the rotor starts to move down, it experiences a rotor shaft movement speed that can reduce the power generated by the linear generator. The output power generated by the linear generator is 0.089 W at a wave height of 7.73 cm, and a wave period of 1.22 s, and output power of 0.022 W at a wave height of 4.97 cm, and a wave period of 1.44 s. Presented in Figure 4 (b).

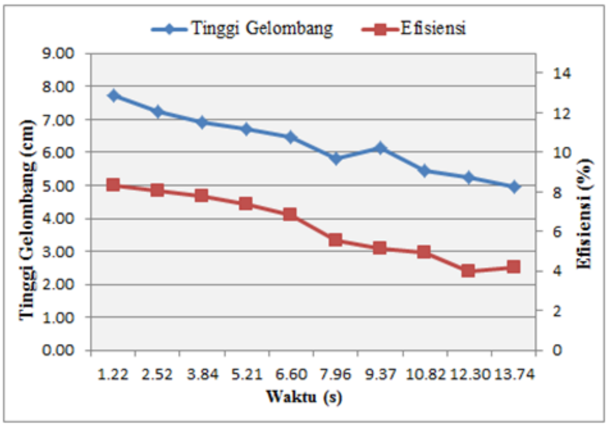


Figure 5. Efficiency of power take-off system with linear generator

The efficiency produced by the wave energy conversion system using power take-off system with a linear generator shows results that are directly proportional to the wave height. where, high waves can affect the size of the vertical translational motion steps of the linear generator in producing electrical energy. When the wave height begins to decrease due to the wave reflection phenomenon, it can affect the output power of the linear generator, this results in a decrease in the efficiency of the take-off power of the system with a linear generator. the decrease in efficiency is quite significant at a wave height of 7.73 cm, the maximum efficiency value is 8.3%. After experiencing the impact of the wave reflection phenomenon that occurs in the pool simulation, the efficiency value drops by 3.9% at a wave height of 5.24 cm.

4. Conclusion

Wave energy harvesting system using power take-off system with linear generator shows very good performance when the wave height is high. The design of this system helps to convert the mechanical energy of waves into electrical energy easily. The electrical energy generated by the power take-off system with linear generator can be utilized to meet the need for electrical energy, especially in coastal areas and can produce electrical output power that is directly proportional to the wave height. The performance of the power take-off system with linear generator increases when the height increases by producing a maximum efficiency of 8.3%. The increase in the efficiency of the linear generator is due to the increased step length of the magnetic shaft which causes the process of increasing the area of the linear generator stator coil experiencing electrical induction. The results of this study can serve as a basis for the practical application of a linear generator with a vertical mounting position to harvest wave energy on the beach for a beach lighting system.

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