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Design a Simple and Low Cost Wave Generator with IoT Monitoring

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ABSTRACT

This project is to design and develop a wave generator with IoT monitoring. This study focuses on the design and development of a generator and the production of electricity through waves. The electrical energy produced is from a vertical wave generator that is rotated by the wave coming down. The resulting energy can be compared with a variety of wave generators and monitored using NodeMCU. This system is very suitable for teaching and learning purposes to apply Faraday's Law concepts. It works through a combination of magnet and coil, a wave assembly, to produce kinetic energy for electrical power. The development of this project is verified by the amount of electrical energy it can produce using the speed of the wave and the design of the generator.

1. Introduction

Sustainable energy from natural resources is one of humanity's biggest challenges. Energy usage is depleting non-renewable sources like fossil fuels. Fossil fuel production causes air pollution, greenhouse gas emissions, global warming, and many deaths each year. Switching from better energy usage to sustainable energy reduces pollution and energy waste. Renewable energy sources like solar, water, and wind create clean energy and are sustainable according to the statement by Nur Fatimah *et al.,* [1]. Main components to generate electricity is generator. Which the generator consists two main components, rotor and stator. Simple magnets have been used to generate electricity for a long time by using their magnetic fields. They are located inside the cores of generators and motors. The essential idea of power production is governed by the magnetic effect. A voltage is induced in a conductor when it is rotated in a magnetic field, according to the statement made by Grover *et al.,* [2]. Thus, dealing with such conductors will be our focus here. Magnet A simple device to generate electrical energy is an engineless energy generator. Besides that, the number of turns inside the generator is almost always very important to determine the amount of electrical energy produced. By referring to Radi *et al.,* The galvanometer's needle deflects when a magnet is moved in the direction of a stationary loop that is attached to it. There is no deflection visible once

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the magnet ceases. Now, the needle deflects in the other direction when we pull the magnet away from the loop [3]. The purposes of this study are:

i. To design the wave generator by using Faraday's law concept.
ii. To develop a wave generator with varying magnets and numbers of turns.
iii. To monitor the harvesting of energy by using NodeMCU.

According to Hadas *et al.,* an appropriate source of electrical energy for wireless sensors that work in a vibratory environment is the generator. The generator's design causes a relative movement of a magnetic circuit against a stationary coil when it is stimulated by mechanical vibration [4]. This prototype project is designed for teaching and learning purposes. Gieras *et al.,* stated that a renewable energy source that uses the waves as its source is called wave energy. Wind blowing across the sea's surface provides energy to the waves [5]. The fundamental principle of wave energy conversion is that a device that can generate waves optimally can also absorb waves efficiently [6], [7]. This statement was stated by Vining *et al.,* and Ohashi *et al.,* The following aspects must be taken into consideration when designing the wave generator:

i. It has a high force density.
ii. It has reasonable efficiency at low speeds.
iii. Magnets are no longer very expensive.
iv. There is no electrical contact with the translator.

All the factors above are stated by Polinder *et al.,* [8]. In general, as stated by Amundarain *et al.,* Ocean waves are described by linear wave theory as straightforward sinusoidal waves. Surface waves can be categorized based on the relationship between their wavelength (L) and the depth of the water (h) [9]. There are many types of wave energy conversion (WEC) techniques that have been discovered around the world. WECs are generally categorized by type, such as oscillating water columns, overtopping devices, hinged contour devices, etc.

The production of electrical energy from a wave generator depends on how much kinetic energy the wave can produce. The high wave can create high kinetic energy and produce more electrical energy. In this project, the production of electrical energy will be shown using the BYLNK application. This application can be used because of the NodeMCU.

1.1 The Process of the System

Figure 1 shows the process of the overall system. The process starts with harvesting the electrical energy from the generator. When the wave gives kinetic energy to the generator, the generator will convert the kinetic energy to electrical energy by using Faraday's law. After that, the voltage divider is used to regulate the voltage and will give the signal to the NodeMCU to process. By using the BYLNK application, the reading of voltage, current and power will be indicated at the application. According to Marinescu *et al.,* the systems depend on voltage regulators and dump loads to maintain the required frequency and voltage [10]. A wave generator that uses linear motion to generate energy has a 3500-turn coil in it, which helps generate the energy from the magnet via flux. The maximum alternate current voltage generated is less than 8 volts; after rectifying the voltage to direct current, it can reach 5 volts dc. The floating magnet will move in the generator, thus making a flux and generating alternate current (AC). With the help of a rectifier, AC will convert into direct current (DC).

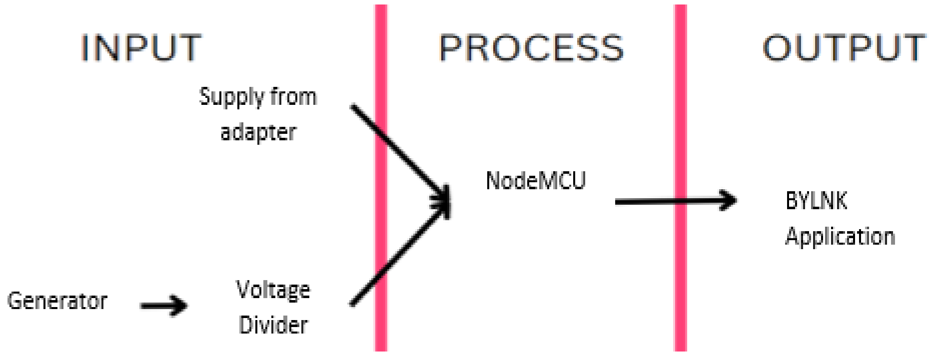


Fig. 1. Process of the system

2. Methodology

2.1 The Schematic Circuit of the Project

Figure 2 show the shows a schematic circuit used in this project. The circuit consists of a voltage divider circuit and a NodeMCU.

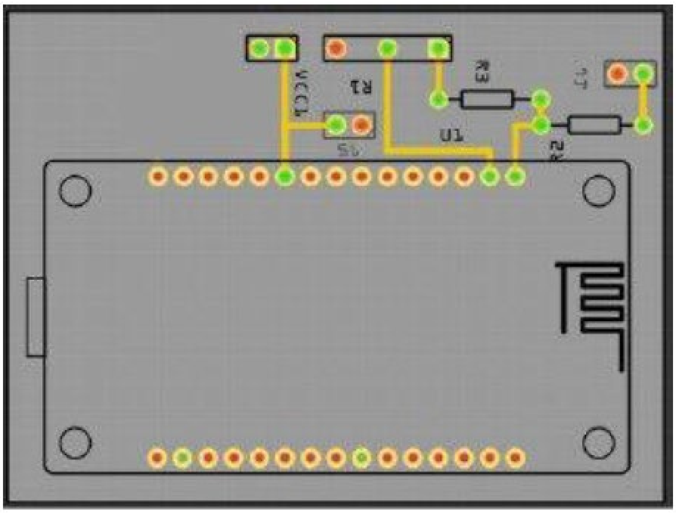


Fig. 2. Schematic circuit

2.2 Description of the Components

Components are an important aspect of a bigger programme or construction in the programming and engineering fields. A component typically performs a single function or a set of related functions. Below are the components that were used in this project.

2.2.1 Wave generator

Figure 3 shows the wave generator. According to Hu *et al.,* the equivalent circuit for a linear generator consists of a series coil of resistors and inductance to produce electrical energy [11]. In design, this generator has 3500 turns of coil and is paired with a rectifier, which makes the generated electricity DC. It can generate from 0.1 volts to 6 volts, depending on how fast the magnet moves across the generator. According to Delli Colli *et al.,* due to their ability to reduce the number of additional energy transformation processes, linear generators are appropriate for direct-drive applications. Moreover, allowing for the reduction of moving parts and streamlining the system, direct coupling of an electrical generator with the reciprocating energy source is also possible. Thus, overall effectiveness is raised [12].

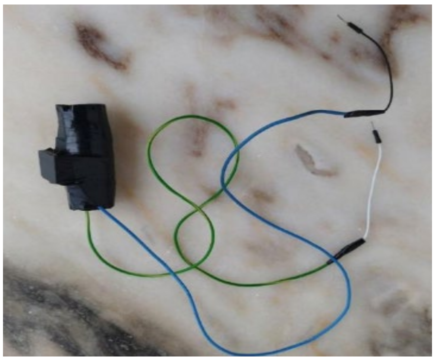


Fig. 3. Wave generator

2.2.2 Magnets

Figure 4(a) shows the magnet that is used in the wave generator. This magnet used to make a flux happen in the generator when moving. The flux will generate AC. The used magnet is a neodymium magnet with a 2cm diameter and a 2cm height to reach the maximum possible magnet effectiveness. Based on Prudell *et al.*, Because of the reduced coil pitch, the fractional generator pole-to-pole pitch has a pitch ratio [13]. Figure 4(b) shows the arrangement of magnet in the wave generator. The magnet setup in this design will be of the Hallbach type. According to the Waloyo *et al.,* by redirecting the magnetic flux at the conductor, it is possible to increase the density of the magnetic flux in the air gap [14].

(a) (b)

Fig. 4. Arrangement of magnet according to Prudell *et al.,* [13]

2.2.3 Voltage divider circuit

Figure 5 shows the voltage divider circuit that was used in this project. This circuit is used to decrease the generated electricity to a smaller scale (under 1 volt) because the NodeMCU analogue pin only supports a 1-volt dc maximum input. Values exceeding the limit might burn the circuit. I used 100 kΩ for V1 and 10 kΩ for V2. According to Win Aung the voltage divider is used to protect the microcontroller from the overvoltage [15].

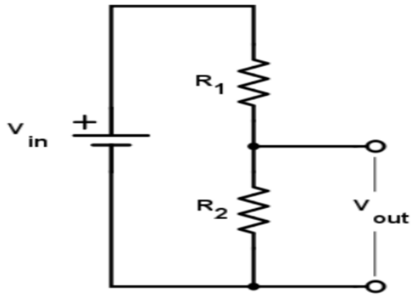


Fig. 5. Voltage Divider Circuit

3. Result

3.1 Product Testing

Figure 6(a) and (b) show the overall product testing for the first attempt wave generator. These prototypes consist of a magnet with a diameter of 2 cm, a coil with a diameter of 2 mm, and a height of 4cm. The end results show a devastating number: the LEDs do not light up even after a flux.


(a) (b)

Fig. 6. Product testing (a) Wave generator coil (b) Broken wave generator

Figure 7 shows the wave generator for the second attempt using a smaller diameter coil compared with the first attempt. The coil that was used for the second attempt is made from copper wire; both have a diameter of 0.2 mm, Figure 7 above shows the coil, which has a diameter of 3cm and a height of 5cm. The end results show a promising number; the LED lights up after a flux happens; the voltmeter shows a reading of 1 Vdc; but the width of the coil is too big, which is not space efficient. Recoil is needed.

Fig. 7. Wave generator for second attempt

Figure 8(a) shows the third attempt. In this design, copper wire with a diameter of 0.2mm was used; the coil has a diameter of 2cm and a height of 5.7cm. Moreover, in this design, aluminium is used as a pole. According to the Chen *et al.,* Given a constant copper loss, the ideal magnet-length ratio—that is, the ratio of the axial length of the radially magnetised magnets to the pole pitch length—must be achieved for maximum thrust-force capability [16]. Besides that, Vese *et al.,* stated, when compared to the rotary-to-linear counterparts, they offer many advantages, the field among them the lack of mechanical gears and gearbox systems, which leads to higher efficiency, better dynamic performance, and increased reliability. They also provide thrust force directly to a payload [17]. The end results show a promising number: the LED lights up after a flux happens, the voltmeter shows a reading of 1Vdc, this can be improvised by using a bigger magnet, and recoil is needed. Figure 8(b) shows the fourth attempt. Copper wire is used for a coil with a diameter of 0.1mm; the coil has a diameter of 2.5cm and a height of 3cm; the magnet has a diameter of 2 cm and a height of 2 cm. The end results show a devastating number: the LEDs do not light up even after a flux, the voltmeter shows a reading of 0.2 Vdc, and the friction in the pole is high, which makes the magnet hard to oscillate. Recoil is needed with more grit for the coil.

(a) (b)

Fig. 8. (a) Wave generator for third attempt: 5.7 cm length (b) Wave generator for Fourth Attempt: 3 cm length

Figure 9 shows the fifth attempt. Still, copper wire is used in this design with a diameter of 0.1mm, the coil has a diameter of 2.5cm and a height of 7cm; and the magnet has a diameter of 2 cm and a height of 2 cm. The end results show a promising number; the LED lit up after a flux happened; and the voltmeter shows a reading of 5 Vdc; The module can be improvised, but it needs more research and cost to improvise it. In conclusion, I assume the module passed. The generator is then embedded in the rectifier. According to the Bostrom *et al.,* To maintain a consistent DC voltage, it will also be required to regulate the power flow in the inverter [18].

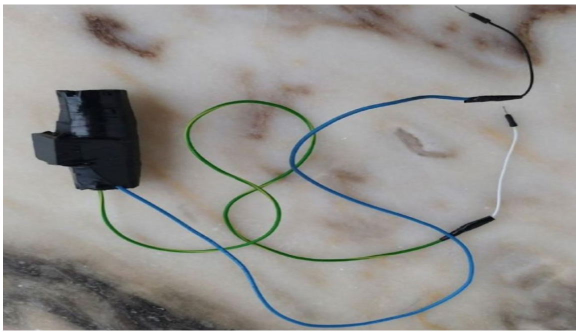
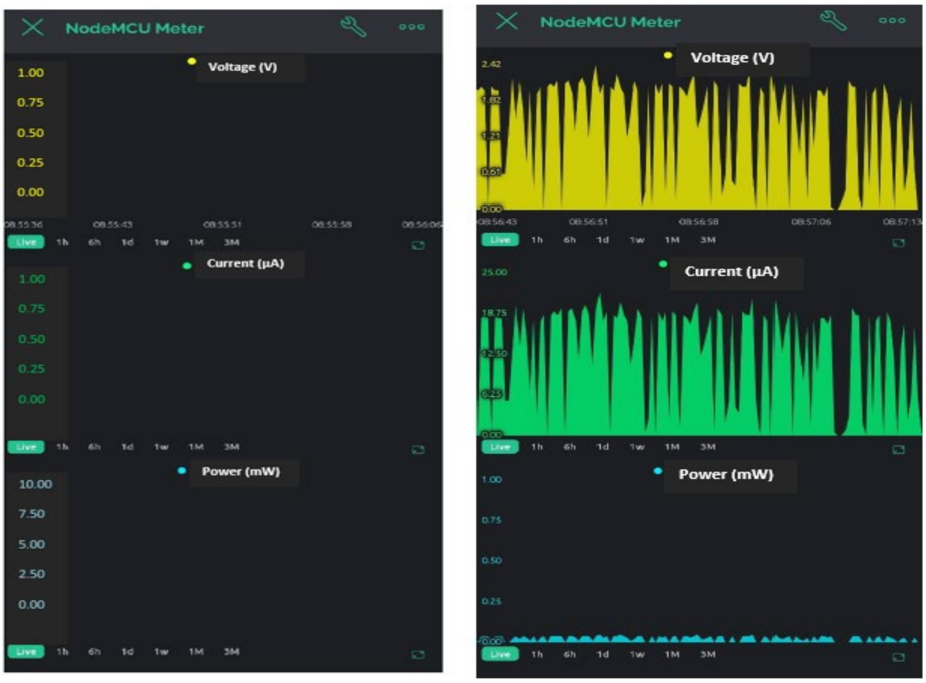


Fig. 9. Wave generator for fifth attempt

3.2 Project Monitoring

Based on Figure 10(a) shows the performance of the output current, voltage, and power when the wave generator is static. On the other hand, Figure 10(b) shows the reading when the generator is working. This monitoring is displayed on a smartphone by using the BYLNK application.



(a) (b)

Fig. 10. The performance of overall system (a) Without wave (b) With wave

3.3 Result of the Production of Electricity

Table 1 shows the performance of producing electricity based on the design of the wave generator. From the observations, the maximum voltage that can be produced for this prototype is 5 volts when using the aluminium as a pole and the height of the generator is higher than others. According to Sun *et al.,* Low moving mass, low cogging force, high generating efficiency, quick response, and great controllability are among the requirements that the linear generator must fulfil. This is because a larger moving mass will increase inertia, lower operating frequency, and enhance responsiveness [19]. The analysis shows that the higher the generator, the more voltage it can produce. This is because it can give a stronger magnetic field for a larger number of turns. Sajwani *et al.,* stated this is caused by the magnetic flux gradient's different polarities, which might result in an unwanted cancellation of simultaneously induced voltages in portions of the coil's turns because of opposing polarity, within the enclosed magnetic field area [20]. This happens because the number of turns is proportional to the production of electrical energy. Besides that, the pole also needs to be considered because, in the Faraday law concept, the magnet can also influence the reading of the producing electrical energy. According to Frost *et al.*, Partial stator over-lap affects the absorption of energy in both a linear and quadratic manner, with frictional losses at least largely to blame for the linear dependence [21].

Table 1
Performance of producing electricity based on variety design of wave generator

No	Coil Diameter	Height of Generator	Generator Diameter	Pole	Output Voltage (Vdc)
1	2mm	4cm	2cm	magnet	0V
2	0.2mm	5cm	3cm	plastic	1V
3	0.22mm	5.7cm	2cm	aluminium	1V
4	0.1mm	7cm	2.5cm	aluminium	5V

4. Conclusions

In this paper, the designing and developing technique for producing electricity by wave generator has been presented, and it is dependent upon the characteristics and material to produce electrical energy. Aside from that, the technique for creating waves is an important part of ensuring the generator's efficiency in producing kinetic energy. Besides that, with this project, the monitoring of current, voltage, and power can be done in real-time by using the BYLNK application.

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