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Research paper

Development of Energy Harvesting from Raindrop

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Abstract

This paper presents an experimental study of harvesting from the mechanical energy produce from raindrop. The energy is harvested using round piezoelectric transducer disc that is installed horizontally with the raindrop. This project aims to produce a simple prototype of raindrop power generator by using multiple numbers of piezoelectric transducers. The raindrop power generator major components are consisting of water pump, water tank, piezoelectric plane, and raindrop maker. Each piezoelectric transducer has the diameter size of 25mm. This projects analyses the energy produced with increasing number of piezoelectric transducer with the total diameter ranging from 25mm, 50mm, 75mm, 100mm and 125mm respectively. The piezoelectric trandsducer with the diameter of 125mm will produce and harvest the highest output voltage, current, and energy compared to the other diameters of the piezoelectric transducer. The highest output voltage and current harvested for the piezoelectric transducer of 125mm is 3.3V and 0.47mA respectively. The energy produced from the piezoelectric transducer was determined through calcultion. In this case the output energy produced was 54.45μJ.

Keywords: *Energy Harvesting, Raindrop, Piezoelectric transducer, output energy*

1. Introduction

The need for electricity generation to be clean and safe has never been more obvious. Nor have those attributes ever been as popularly supported. Environmental and health consequences of electricity generation are important issues, alongside the affordability of the power which is produced. It is important because the electricity demand will always increase. However, the generation of power plants effect the environment due to the hazardous waste produced. Like a wind generator or solar cells, piezoelectricity is also a type of technology can be used to harvest energy [1]. This is because energy harvesting provides clean and safe energy. c from rain has force that can produce mechanical energy. There are many ways to recover some of this energy in the form of electricity. The easiest and the space saving way to produce electricity is from piezoelectric property of certain crystals [1]. When looking at the amount of kinetic energy produced in the average roof of a house, harvesting electricity from rain makes sense.

Roof piezoelectricity is electrical energy harvested from mechanical pressure such as raindrop falling on the roof. When pressure is applied on an object, a negative charge is created on the expanded side and a positive charge is created on the compressed side. As this pressure is relieved, electric current flows across the substance. Piezoelectric roofs are designed to capture the wasted energy and resources, and store or redistribute them where they are needed [2]. Energy is generated when it rains on the roofs that feature piezoelectric attributes. The amount of energy generated depends upon the intensity of the rain and maximum deflection. This kinetic energy is converted into electricity. Piezoelectric roofing is ideal for places that rain often. It can be installed at any building that has a roof, roof of a car and any surface that can be exposed to the rain.

Hence, the objectives in this harvesting project are to simulate the circuit of rectifier and booster that is incorperated with the raindrop piezoelectric generator.

Second is to design a model of the raindrop piezoelectric generator with proper design and fabrication. Lastly is to develop a model of the raindrop piezoelectric generator and working prototype of energy harvesting module.

In this project it is proposed that the piezoelectric is implemented at the rooftop of a house. In this case energy can be harvested when it rains. Rain is one of sources of energy that provides kinetic force to the rooftop. Basically, Piezoelectric is installed inside the roof of the house and electricity will be generated from the force and vibration produced from the rain. The vibration produced from the piezoelectric will form an alternating current output. Therefore a full bridge rectifier must be included to produce a stable direct current. To provide a more stable voltage output the output of the rectifier will be fed to a dc boost converter. The boost converter will step up the voltage to 12V and then the output dc voltage will charge the battery to store the electricity produced. In this project the objective is to provide an alternating current supply. To achieve the alternating current output, the battery is then inverted from 12V DC to 240 AC to alternating current using an inverter. The output of the inverter 240 alternating current to supply the load.

Energy Harvesting is playing an increasingly important role in supplying energy to applications, it is also the process of capturing minute amounts of energy from one or more naturally-occurring energy sources, accumulating them and storing them for later use. The most widely used method of energy harvesting nowadays is the application of Solar or recognized as photovoltaic cell. In recent studies shows that piezoelectric can also be a major contributor in energy harvesting. In this case the, piezoelectric can be implemented at any situation that produces vibration and mechanical force. For example, at bridges and roads that produces vibration from vehicles

2. Research Methods

2.1. Designing of the raindrop energy harvesting system

This project provides the analysis, design and implementation of the raindrop power generator. The raindrop power generator piezoelectric generator operates through few parts of circuit which is rectifier, boost chopper, battery charger, and an inverter.

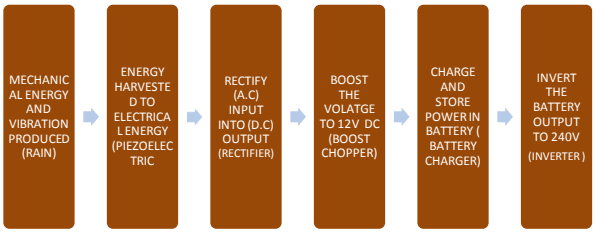

Figure 1: Block Diagram of raindrop power generator module

Figure 1 shows that the blocks diagram of raindrop power generator module. The mechanical vibration or pressure applied on the piezoelectric disk caused a small disk displacement that creates piezoelectric stress on it substance that leads to conversion of mechanical energy into electrical energy through piezoelectric effect. The output of voltage and current generated by the piezoelectric transducer are in alternating current form. From there a rectifier circuit is needed to convert the generated AC power to DC power.

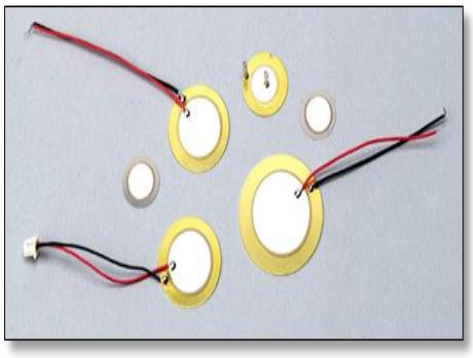

Figure 2: Piezoelectric Disk

Figure 2 shows the piezoelectric disk is used as a transducer for energy harvesting module as shown in Figure 1. It is used to convert mechanical energy to electrical energy. Thus, the wasted energy from the environment can be utilized with more efficient. The mechanical force produced by water raindrop will be the source that will trigger the piezoelectric to produce energy.
In order to store the generated energy, DC to DC booster converter is very much needed to increase the rectifier output. Varying the DC supply can improve the performance of the DC chopper. The boost chopper is able to control and vary a constant dc. The step up voltage is then stored in a temporary storage which is either a battery or a capacitor.

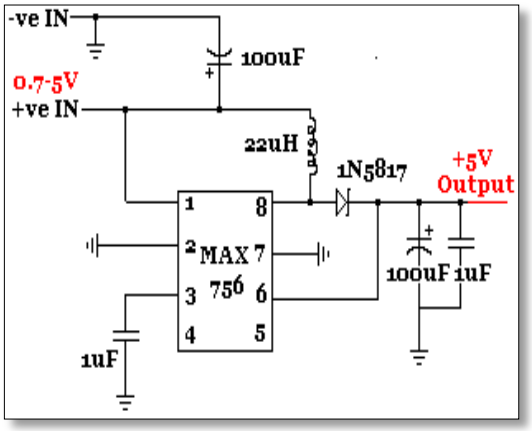

Figure 3: DC Boost Converter

In addition, Figure 3 show circuit for voltage booster required in order to step-up the output voltage. Varying the DC supply can improve the performance of the DC chopper. It will also help to improve controllability of the equipment. The boost chopper is able to control and vary a constant dc. The boost converter is capable to boost up the voltage with the minimum voltage of 1.5V and produce an output with minimum of 5V. This boost converter is very reliable due to the efficiency is up to 87%. The maximum output current can be generated by the booster is 200mA. Generally 200mA is sufficient for wide range of applications including LED lighting. The function of the inverter is to convert DC power from the battery storage to AC power. The inverter is needed for supplying alternating current to an AC load. The AC power supplied is essential so that it can be connected to any commercial type of load such as fluorescent lamp.

2.2. General flow chart to obtain power of raindrop energy harvesting

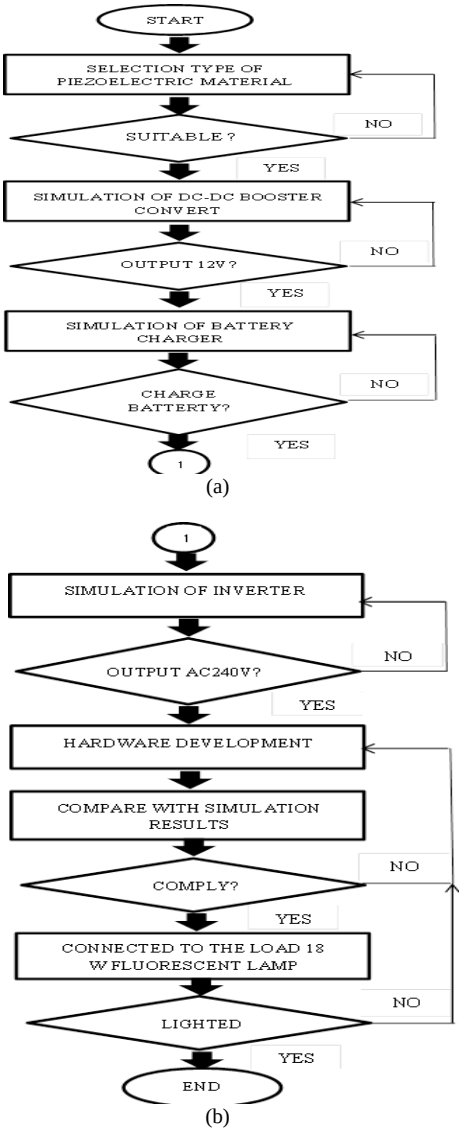

Figure 4: Project flow chart

Figure 4 shows that the flowcharts of the hardware and simulation development implemented in this project. The first step is to choose the most significant piezoelectric material that for the project. In this case, the project requires a robust and cost effective type of piezoelectric such as Lead Ziroconate Titanate (PZT) ceramic material. Second, simulate the boost circuit for the raindrop piezoelectric generator project. The main function of the boost circuit is to give stable dc output. The simulation must comply with getting a 12 V dc output from the DC boost chopper. The next step is to simulate the battery charger to store the energy generated from the piezoelectric generator for the continuous power supplied to the load. Afterward, proceed to the next step which is the simulation for the inverter circuit. The function of the circuit is to convert from DC to AC output so that it can be supplied to an AC load. Each circuit in this project has a different role in the functionality of this project. Thus every circuit is crucial in perfecting this project.

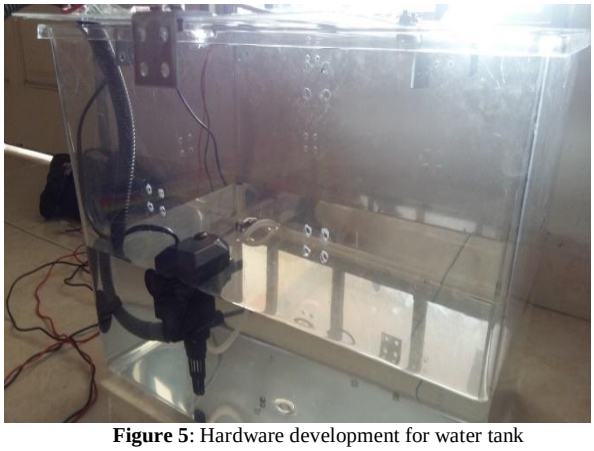

Figure 5: Hardware development for water tank

Figure 6: Hardware development for Hardware piezoelectric transducer roof

Figure 5 and 6 show the hardware development for the water tank and the hardware transducer roof. The hardware consists of the water tank, the prototype piezoelectric roof and all the circuit that is needed for the project. Lastly, the project will be connected to a load that requires AC 240 V. The raindrop power harvesting project will provide 240 V AC voltage for commercial use such as outdoor lamp at rating 18 watt.

3. Results and Discussions

In this project, the main output parameter value that needs to be measured and analyzed is voltage and current output that has been harvest by the raindrop power generator prototype by using piezoelectric transducer as shown in Figure 7. The output value of voltage and output current is measured by using a digital multimeter at capacitor in storage device. The basic measuring to get a voltage value is by connecting it parallel to the capacitor and current value is by series to the capacitor. The procedure to measure the output voltage and output current will be repeated by varying different diameter sizes of piezoelectric transducer. Varying different diameter sizes of piezoelectric transducer can be done by controlling the water droplets from the raindrop maker.

Figure 7: Experimental result testing

The schematic circuit for measuring output voltage and output current is shows in Figure 8. All value or data will be recorded.

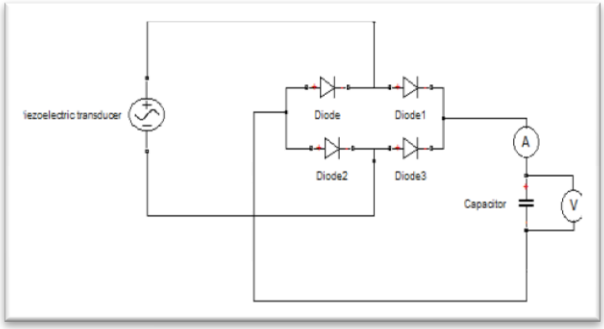

Figure 8: Schematic circuit of measurement

The procedure to measure the output voltage and output current will be repeated by varying different diameter sizes of piezoelectric transducer. All data of output voltage and current that has been harvest by the prototype will be tabulated. Table 1 shows the measured output value of voltage, and current that has been harvest by piezoelectric transducer.

Table 1: The harvesting output values of piezoelectric generator

Size diameter (mm)	Voltage (V)	Current (mA)
25	0.85	0.04
50	1.08	0.10
75	1.45	0.22
100	2.20	0.40
125	3.30	0.47

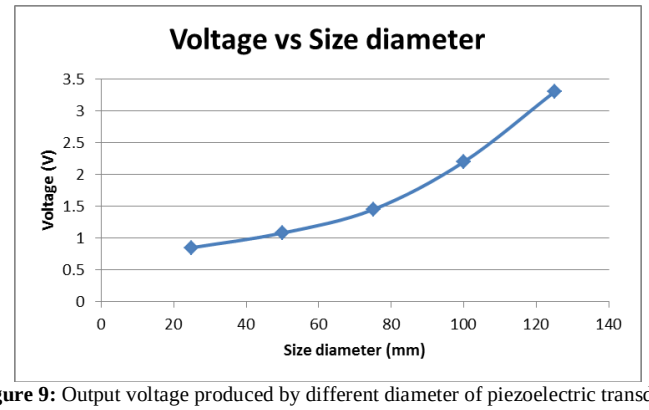

Figure 9: Output voltage produced by different diameter of piezoelectric transducer

Figure 9 shows that the graph of output voltage versus diameter of piezoelectric transducer. From Figure 9, the bigger the diameter of piezoelectric transducer, the higher output voltage will be generated. The hypothesis that can be made based on the graph is the value of output voltage will increase when the size of diameter of piezoelectric transducer increased. Therefore, the diameter size of piezoelectric transducer could influence to the output value of the raindrop power generator.

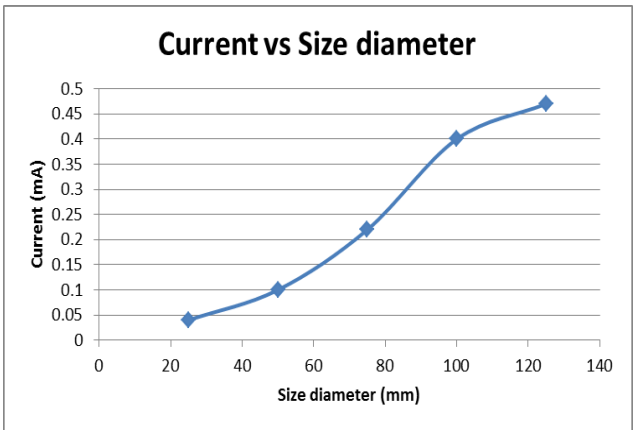

Figure 10: Output current produced by different diameter of piezoelectric transducer

Figure 10 shows the graph of output current produced from the prototype of the piezoelectric generator versus the diameter size of piezoelectric transducer used. The increased in diameter sized of the piezoelectric energy to harvest energy will increase the outout current of the piezoelectric transducer. Therefore, the diameter sizes of piezoelectric transducer could influenced the output current. The energy produced by the prototype is stored in the capacitor and the calculation on the energy is obtained by using equation:

$$E = \frac{1}{2}V^2C \quad (1)$$

where:

E = energy (J)
V = voltage the capacitor (V)
C = value of capacitor (F)

To calculate the energy on prototype of raindrop power generator produced for each tap or press on the piezoelectric transducer, this equation is applied:

$$E = \frac{1}{2}(V1^2 - V0^2)C \quad (2)$$

where:
V1 = voltage after the tap or press the piezoelectric transducer
V0 = voltage before the tap or press the piezoelectric transducer

Table 2: The values of energy producing by prototype of piezoelectric generator

Size diameter (mm)	Energy (µJ)	Power (µW)
25	3.61	34
50	5.83	108
75	10.51	319
100	24.20	880
125	54.45	1551

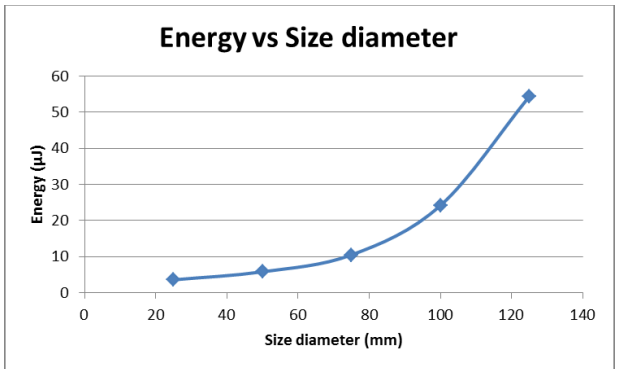

Figure 11: Energy produced by prototype generator of different diameters

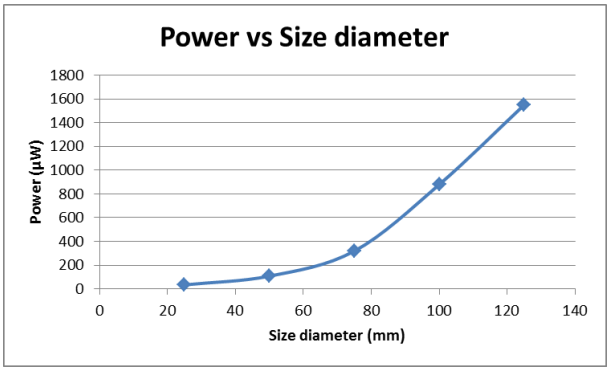

Figure 12: Power produced by prototype generator of different diameters

Figure 11 shows a graph of energy produced by the raindrop power generator prototype versus diameter sizes for piezoelectric transducer. The value of energy is increased when the diameter size of piezoelectric increased. Figure 12 shows a graph of power produced by the raindrop power generator prototype versus diameter sizes for piezoelectric transducer. The value of power is increased when the diameter size of piezoelectric increased.

Based on equation (2), the energy produced is depends on the output voltage harvested from the piezoelectric tranducer. Theoritically, the higher the value of output voltage, the higher the value of energy. Since the energy produced depends on output voltage, the sizes of piezoelectric transducer that mechanical vibration and vibration applied could influence the value of energy produced by the raindrop power generator prototype.

4. Conclusion

Energy harvesting from raindrop is still new. Therefore, this project plans to manifest the proposed plan of rain power generator that can be renewable, clean and unpolluted. The prototype of the piezoelectric power generator is produced by using round piezoelectric transducer. Piezoelectric element is very suitable to be used to harvest the energy from the rain because it can be operated in a simple operation with high output voltage. Piezoelectric element also produces a clean energy without producing harmful effects to the environment because it only needs are vibration energy to operate. From the expected result section in this project, the output voltage, output current, and output energy that has been harvesting was influenced by the diameter sizes of piezoelectric transducer. From the expected result of the piezoelectric power generator, theoretically the bigger the diameter size of piezoelectric transducer, the higher output voltage, output current and output energy it will harvested. Therefore, the size of piezoelectric must be selected with the suitable mechanical pressure that raindrop can be produced to harvest the energy for the piezoelectric transducer.

In this project, there are still lots more room for future improvement to produce a better project. In order to improve this study in the future it is recommended to implement a voltage doubler to increase twice the output voltage by twice the value that will be harvested by piezoelectric transducer. Other than that, it also recommended to use a battery charger circuit to indicate that the battery is fully charged. The raindrop power generator is also recommended to implement the harvesting module at rooftop incorporated with a solar system and harvest energy by utilizing the vibrations produced by the rain during rainy days and can also harvest energy by utilizing the sunlight produced by the rain during sunny days.

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