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## Prototype of Electrical Generator Device from Piezoelectric with Serial Configuration - Based on Mechanical Pressure

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# Prototype of Electrical Generator Device from Piezoelectric with Serial Configuration - Based on Mechanical Pressure

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**Abstract.** This study discussed about of prototype of electrical generator device from piezoelectric with serial configuration - based on mechanical pressure. A prototype of a piezoelectric-based power plant that is able to convert mechanical energy (footing) or object load on piezoelectric into electrical energy was the aim of this research. The piezoelectric generation system can be applied to serve limited loads and can be a support system for a distributed generation system. The method of research was device design and experimental testing. The experimental testing was carried out by varying pressures on piezoelectric to produce the desired output voltage. In testing, the pressure was generated by two different objects, a human footing and a object load with varying weight. The average voltage produced on human footing was 9.736 V for 60 kg body weight. The average voltage produced on object loads was 1.33 V for 5 kg object weight. This research has succeeded in making a prototype of a power plant using piezoelectric.

## 1. Introduction

Electrical energy can be converted from various sources of energy, both non-renewable or renewable. The energy source can be heat energy, motion energy, sun energy and other forms of energy. Electricity can be used to supply both high and low energy consumption equipment. A number of electronic equipment consume low energy which is generally supported by batteries.

This study discusses the prototype of alternative power plants. Electrical power is generated through the conversion of kinetic energy generated from human movements in the form of mechanical pressure through a piezoelectric harvesting system [1]. This prototype can be used to produce electricity for the low-power electronic instruments consumption.

Specifically, the purpose of this research is to make a prototype of a piezoelectric-based power plant that is able to convert mechanical energy (footing) or object load on piezoelectric into electrical energy. In this study, the magnitude of voltage generated by the prototype is also measured. The piezoelectric generation system can be applied to serve limited loads and can be a support system for a distributed generation community [2-4].

The research with aim to design energy hybrid harvesting system was carried out in 2011 by Wei C K and Ramasamy G [5]. The system is combination of mechanical and piezoelectric harvesting system. The another research by Pisharody H G in 2011 [6]. Piezoelectric transducers were planted on a mat. The paper studied about a number factor that influence the system design for piezoelectric energy harvesting was conducted by Ali W G and Nagib G in 2012 [7].



## 2. Piezoelectric System

Piezoelectric material is a material that when exposed to voltage or mechanical strain will generate an electric field. On the other hand, if the material is exposed to an electric field, the material will experience mechanical strain or stress. There are two types of piezoelectric materials based on the manufacturing process, namely natural and artificial. Quartz, Berlinite, Tourmaline and Rossel Salt are examples of natural materials. Meanwhile, Barium Titanate (BaTiO<sub>3</sub>), Lead Zirconium Titanate (PZT), Lead Titanate (PbTiO<sub>3</sub>) are artificial materials. Piezoelectric can be formed by several different types of material which can be classified into three parts [1].

- Crystal material, for example: Quartz (SiO<sub>2</sub>), Gallium Orthophosphate (GaPO<sub>4</sub>)
- Ceramic material, for example: Barium Titanate (BaTiO<sub>3</sub>), Lead Zirconate Titanate (PZT)
- Polymeric material, for example: Polyvinylidene Difluoride (PVDF)

The displacement of the electric charge density in piezoelectric material can be expressed through Equation (1).

$$D = \varepsilon E \quad (1)$$

where:

- D = transfer of electric charge density
- $\varepsilon$  = permittivity
- E = electric field strength

while the equation for finding a strain based on Hooke's Law is stated by Equation (2).

$$S = sT \quad (2)$$

where:

- S = strain
- s = compliance
- T = pressure

These two equations, when combined will produce Equations (3) and (4).

$$\{S\} = [s^E] \{T\} + [d^E] \{E\} \quad (3)$$

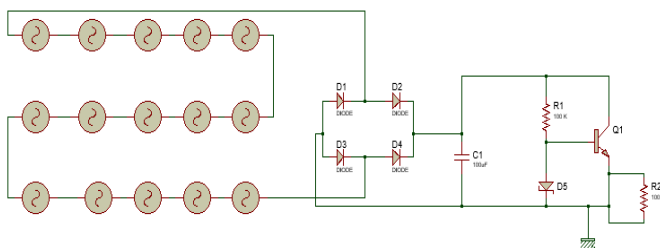
$$\{D\} = [d] \{T\} + [\varepsilon^t] \{E\} \quad (4)$$

where

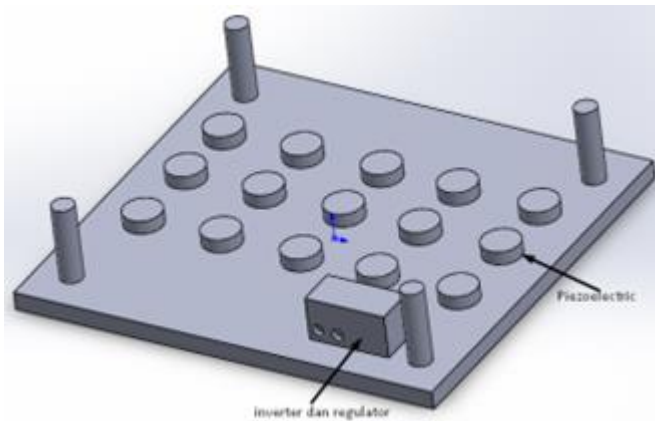
- [d] = matrix for direct piezoelectric effects
- [d<sup>t</sup>] = matrix for the opposite piezoelectric effect
- power E = zero electric field, or constant
- power T = zero field pressure, or constant
- power t = transposition of a matrix

## 3. The prototype

The initial step taken was to design a design that will be applied in a prototype. Figure 1 shows the electrical circuit design of the prototype. While, Figure 2 shows the physical design of the prototype.



**Figure 1.** Electrical circuits design of prototype



**Figure 2.** Prototype physical design

The second step was the process of assembling and making prototypes. The assembly and manufacturing process conducted through two stages. The first stage was the process of making a prototype frame that serves as a place for laying piezoelectric and other electronic components. The design of the framework on the prototype as shown, to protect connecting cables and diodes. It also serves as a place for piezoelectricity that will function to change mechanical pressure into electrical energy.



**Figure 3.** Prototype display

The second stage was the process of piezoelectric assembly and the electronic components in the prototype. Electronic components contained in the prototype include piezoelectric, diode, resistor, capacitor. In addition, there was a converter circuit that will convert the AC output voltage into DC and a cable (connector) that will connect all the electronic components. The physical appearance of the prototype is shown in Figure 3.

#### 4. Results and Discussion

The type of piezoelectric material was used is PZT type ceramics. The series circuit testing was carried out using 15 piezoelectric pieces with 3 experiment sets. The process of measuring the voltage generated by the prototype was carried out using a digital multimeter. Human body weight at intervals of 20 kg to 60 kg with functions to produce mechanical stress that is correlated with the output voltage. In addition, object loads were also used at intervals of 1 kg to 5 kg.

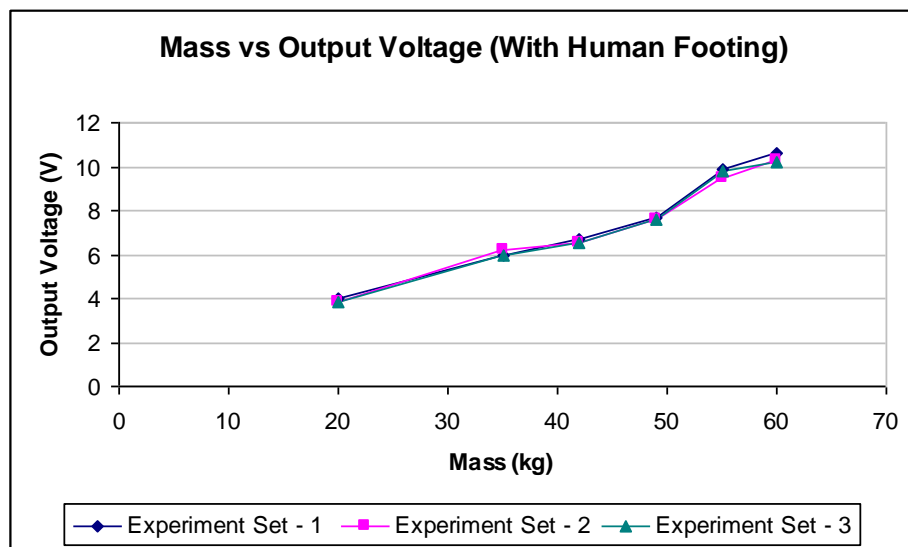
#### 4.1. Testing with Human Footing

The output voltage generated by the prototype in a series circuit with human footing is shown in Table 1.

**Table 1.** Testing result with human footing

No	Mass (kg)	Voltage (V)			Average
		Exp. 1	Exp. 2	Exp. 3	
1	20	4.0	3.8	3.8	3.9
2	35	6.0	6.2	6.0	6.1
3	42	6.7	6.5	6.5	6.6
4	49	7.7	7.6	7.6	7.6
5	55	9.9	9.5	9.8	9.7
6	60	10.6	10.3	10.2	10.4

The results in Table 1 show that testing with a weight of 20 kg produces an average voltage of 3.9 volts. The last test with a body weight of 60 kg produced an average voltage of 10.4 volts. The data generated by 3 experiments set on prototype series circuits for human footing shows a difference that is not too large. Although there are some data that experienced a decrease in output voltage, it does not show such a large difference. The difference in the three sets of experiments above can be seen through Figure 4.



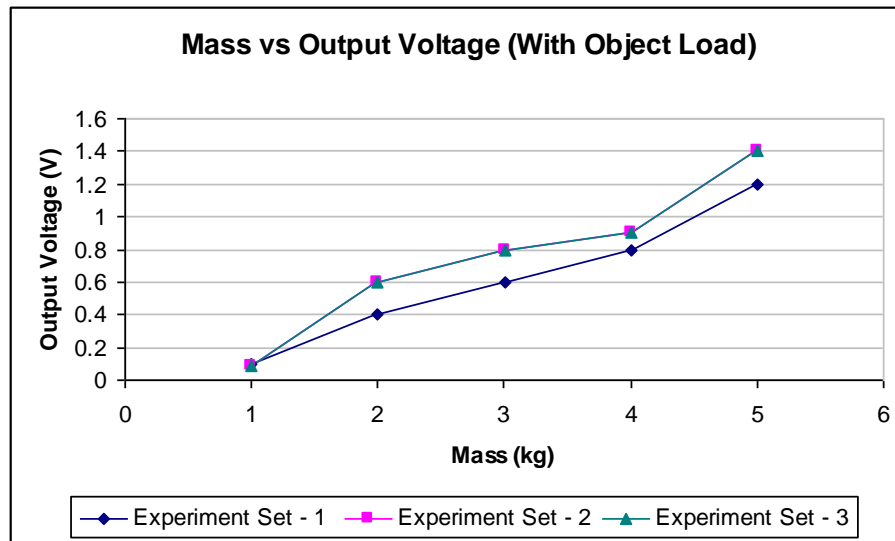
**Figure 4.** Comparison of output voltage for 3 sets of experiments (with human footing)

#### 4.2. Testing with Object Loads

The output voltage generated by the prototype in a series circuit with an object load is shown in Table 2.

**Table 2.** Testing result with object load

No	Mass (kg)	Voltage (V)			Average
		Exp. 1	Exp. 2	Exp. 3	
1	1	0.1	0.09	0.09	0.093
2	2	0.4	0.6	0.6	0.53
3	3	0.6	0.8	0.8	0.73
4	4	0.8	0.9	0.9	0.87
5	5	1.2	1.4	1.4	1.33



**Figure 5.** Comparison of output voltage for 3 sets of experiments (with object loads)

The results in Table 2 show that a mass of 1 kg produced an average voltage of 0.093 volts. The last test by using a mass of 5 kg produced an average voltage of 1.33 volts. The resulting output voltage increases when given an increase in load (mass) even though the output produced is not as large as that produced by a series of circuits on a human footing. The difference in the three sets of experiments above can be seen through Figure 5.

## 5. Conclusion

This research has succeeded in making a prototype of a power plant using piezoelectric. This prototype is able to convert mechanical energy derived from human footing and object load pressure into electrical energy. The largest average voltage generated in a series circuit for a footing load of people weighing 60 kg was 10.4 volts. As for the load object with a weight of 5 kg produced an average voltage of 1.33 volts

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