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Electrical Energy Harvesting Using Piezoelectric Tiles with Force Amplification Mechanism

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Abstract: The traditional method of generating electricity by burning fossil fuels (coal and oil) such as using a motor to generate the farm would result in increased emissions, therefore, the piezoelectric generator can help decrease the emissions. The sudden power cut off by industrial will affect the well-being of the livestock in the farm. Therefore, the design of a prototype piezoelectric tiles-based chicken/model is introduced. This project is about piezoelectric tiles for poultry purposes. The prototype design piezoelectric tiles help harvest electrical energy from the chicken or model steps. The tile surface must be solid at the electrode and fluid around the surrounding surface. A piezoelectric harvesting system consists of the circuit to convert the AC signal from the piezoelectric material to the DC signal which is used for supplying to charge a 12V DC portable battery. The project uses Proteus software to simulate part of the circuit that is functional and able to supply a small load application. It is a comparison of series and parallel connection with force amplification mechanism. It uses piezoelectric tile and indirectly helps reduce consumer bills. Piezoelectric electrical generation depends on the frequency entry compression on the piezoelectric tiles and it will generate electricity of 1kg weight or more.

Keywords: Piezoelectric, Tiles, Harvesting, Force Amplification Mechanism

1. Introduction

Global economic growth in the 21st century has pushed energy demand to new highs, outpacing total energy supply. The traditional method of generating electricity by burning fossil fuels (coal and oil) would result in increased emissions. As a result, renewable energy is a viable option that is becoming increasingly necessary and widespread. Wind, solar, hydro, and geothermal are all well-known renewable energy sources. There was also research on combining a few of them for efficient power generation, e.g., by combining solar, rain, wind, and lightning [1].

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Piezoelectric generator work based on the piezoelectric effect which is the ability of certain materials to create electrical potential in response to the mechanical changes of the material. That means the compression, expansion, or shape-changing in piezoelectric material will produce voltages. The piezoelectric material realizes energy conversion through a piezoelectric energy harvester as the carrier, and the energy harvester is buried, and is required to have good force electric conversion efficiency, structural strength, structural durability, and compatibility to adapt to complex conditions [2]–[4].

This research will focus on piezoelectricity and on the methods to harvest piezoelectric energy from chicken steps. Chicken travel averages 91.44 - 320.01 meters of their barn [5]. To generate useful electrical energy, motion is required in this case chicken steps. Every motion in nature can be a potential source of kinetic energy. Therefore, mechanical energy is the most prevalent form of energy [6]. Using mechanical energy scavenging, sufficient power can be provided to ensure long-term autonomy in terms of electrical energy [7].

2. Materials and Methods

2.1 Flow of the Project

Figure 1 shows the overall project flow.

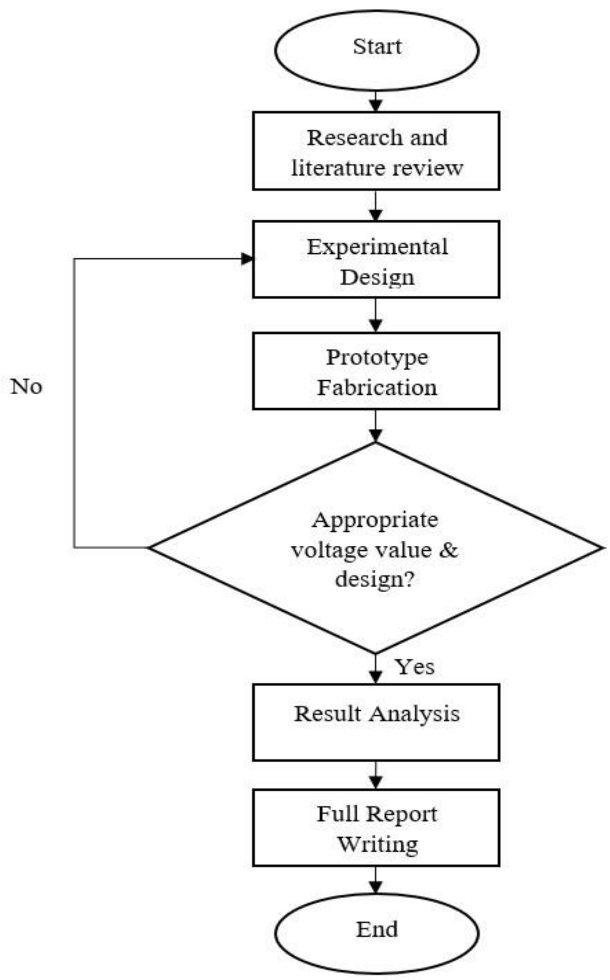

Figure 1: Flowchart of project

2.2 Proposed Design

The piezoelectric harvesting system consists of one circuit. A circuit to convert the AC signal from the piezoelectric material to the DC signal which is used for supplying a portable battery. The design for the energy harvesting circuit so that the power produced can be stored in the batteries. The block diagram of the process is shown in **Figure 1**.

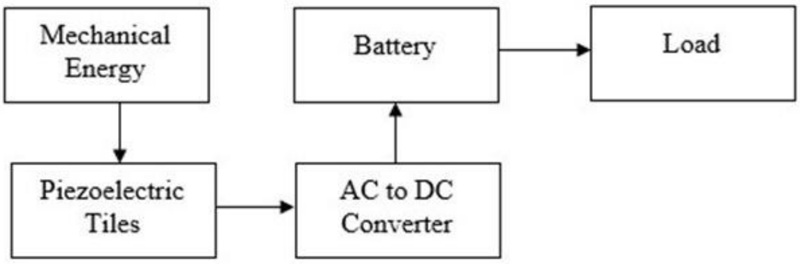

Figure 1: System Outline.

2.2.1 Diffusion of tiles surface

The tiles surface use material of square cardboard in this project. Each of the square cardboard is interconnected with a string. The interconnection of tiles accounts for surface topology, allowing pressure to flow naturally over surfaces of any genus. Furthermore, we can efficiently localize reaction diffusion by utilising the tile structure.

2.2.2 Piezoelectric Generator

In this study, the Piezoelectric (PZT) generator was constructed. The piezo material is shown in **Figure 2** a thin disc mounted on a spherical disc. As indicated in **Figure 2**, 19 pieces of piezo have been connected in parallel. The size and number of piezo have only been tested arbitrarily. To avoid a short circuit when water drips on it, all soldering on the plate and wires were covered by a layer of plastic.

Previous research has shown that connecting piezoelectric in series increases the amplitude of the AC voltage. The series, however, will not produce any voltage if one of the discs is not pressed. According to [8], the greater the force applied, the greater the voltage generated, but the voltage increment becomes less steep as the force applied is increased. Because the average generated voltage of 5V is enough to charge the 3.7V battery, this study decided to connect all transducer discs in parallel.

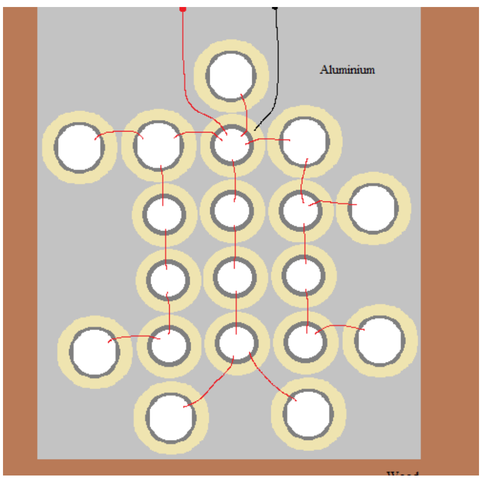

Figure 2: 19 units of piezo connected in parallel.

2.2.3 AC to DC Converter

AC-DC converters are electrical circuits that transform alternating current (AC) Piezoelectric generators into direct current (DC) output. AC to DC converters use rectifiers to turn AC input into DC output and reservoir capacitors(C1) to smooth the pulsating and load resistance (R1). Because D3 and D5 cannot be conducted concurrently, as can D2 and D4, the load current was only in the positive cycle. When D3 and D4 were conducted, the positive voltage source flowed through the load, and when D5 and D1 were conducted, the negative voltage source flowed through the load. The software that being used for the simulation is Proteus as shown in Figure 4. The targeted output is 12V.

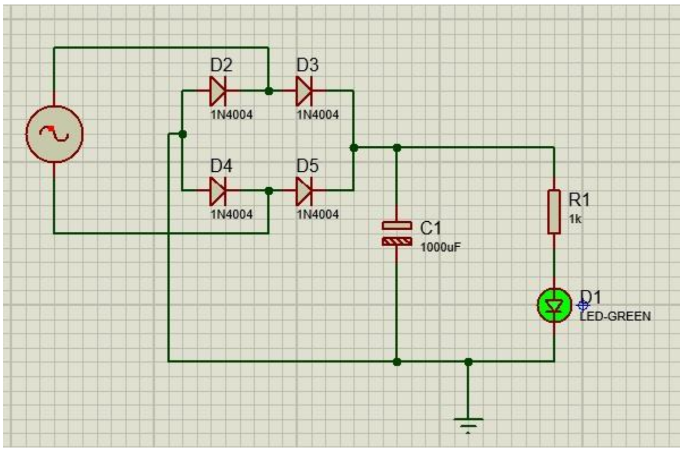

Figure 3: AC to DC circuit design.

2.2.4 Battery

As indicated in the last section, the output of the piezoelectric generator needs to be stored. The battery stores DC output from sources and supplies DC charges with power. There is a rated 3.7 V battery is utilized. The battery Amps hour (Ah) values influence how many charges can be stored in the battery. 3.7 V battery Ah values could range from minor amounts such as 200 mAh to 1000 mAh. The battery type utilized is shown in **Figure 4**.

Figure 4: Lead-Acid Battery.

2.2.5 Overall circuit

The area of the prototype module is $385cm^2$. It will embed to the floor with 35*11cm plain wood supported below the $385cm^2$ area. The module is connected to an AC DC converter to convert the piezo AC source to a DC source. Next, the DC source will go to the lead acid battery of 3.7V 250mAh. The load will be a 3.7V lamp bulb.

2.2.6 DC lamp

By the design goals, the best performance and cost of the DC lamp must be considered in this project. This choice should be carefully considered before selecting a lighting luminaire. This DC lamp requires 1.5V to turn on based on the output voltage of the Lipo battery. Luminaires are designed to fit specific types of bulbs. Lamps are made to operate at a specific voltage and wattage (power consumption). In general, the higher the wattage rating of a lamp, the more efficient it is. Figure 5 depicts the size of the DC lamp used in this mini-project. The current load that can be catered by the system is a 3.7V DC bulb since this is a mini-project.

Figure 5: DC lamp

3. Results and Discussion

The result is observation of the voltage output of the piezoelectric based on the model step of chicken. Since 1000uf is used the charge and discharge of the capacitor require a long time since the connection is in parallel. The reason the circuit is in parallel is that if it is in series, it is the required weight that can apply to all piezoelectrics at the same since the chicken step is hard to predict. In these cases, a bottle of 1 liter is used to imitate the chicken weight which is 1kg. A module of 19 parallel piezoelectric can generate a maximum of 1.76V shown in Figure and reach 3.7V, it is required a total of 3 modules or more that are connected in series and that is where the 1000uf capacitor plays a huge role in the duration of discharge. Although this test is not being conducted in the coop, the hypothesis that can be made is that the array will produce voltage amplitude if the force due to chicken movement is applied. To summarize, charging the battery occurs when the rectified piezoelectric voltage is greater than the open circuit voltage of the battery cell.

Table 1 and Table 2**Error! Reference source not found.** tabulate the output of the piezoelectric in AC and the voltage value of the piezoelectric. For piezoelectric AC voltage, the 4cm diameter voltage varies from 0.1 to, 1.2 and for the 5cm diameter, the voltage varies from 0.1 to 0.8 voltage. Each piece of the piezoelectric is labeled and gently applied with a weight that ranges from 100gram to 1kilogram. The reason for the difference in the diameter is because of the size of the metallic membrane but the size of the electrode is fixed. Table 3 tabulates the parallel connection of piezoelectric to detect the flaw of the component. Each piece component affects the performance of the system. Meanwhile, Figure 7 shows the output module of piezoelectric.

Table 1: Each piece of 4cm diameter piezoelectric AC output based on weight.

Unit \ Weight	100g	200g	300g	400g	500g	600g	700g	800g	900g	1000g
A	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
B	0.1	0.1	0.1	0.1	0.1	0.1	0.1-0.2	0.1	0.1-0.2	0.1-0.2
C	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
D	0.1	0.1	0.1	0.1-0.4	0.1-0.5	0.1-0.4	0.1-0.5	0.1-0.7	0.1-0.7	0.1-0.7
E	0.1-0.2	0.1	0.1-0.2	0.1-0.4	0.1-0.5	0.1-0.6	0.1-0.6	0.1-0.7	0.1-0.7	0.1-0.8
F	0.4-0.8	0.1-0.8	0.1-0.8	0.1-0.9	0.2-1	0.1-1	0.1-1	0.1-1.1	0.1-1.2	0.1-1.2
G	0.1-0.7	0.1-0.6	0.1-0.6	0.1-0.6	0.1-0.6	0.1-0.8	0.1-0.8	0.1-0.8	0.1-0.8	0.1-0.8
H	0.1-0.4	0.1-0.4	0.1-0.5	0.1-0.8	0.1-1	0.1-1.1	0.2-1	0.1-1.2	0.1-1	0.1-1.2
I	0.1	0.1	0.1	0.1	0.1-0.4	0.1-0.4	0.1-0.6	0.1-0.7	0.1-0.7	0.1-0.7
J	0.1-0.4	0.1-0.4	0.1-0.4	0.1-0.7	0.1-0.8	0.1-0.9	0.1-0.9	0.1-0.9	0.1-0.9	0.1-0.9

Table 2: Each piece of 5cm diameter piezoelectric AC output based on weight.

Unit \ Weight	100g	200g	300g	400g	500g	600g	700g	800g	900g	1000g
1	0.1	0.1	0.1	0.1	0.1	0.1-0.5	0.1-0.5	0.1-0.6	0.1-0.6	0.1-0.8
2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1-0.2	0.1-0.2	0.1-0.2
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.1	0.1-0.2	0.1-0.4	0.1-0.4	0.1-0.5	0.1-0.6	0.1-0.6	0.1-0.6	0.1-0.6	0.1-0.8
7	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
8	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 3: Parallel connection 4cm diameter piezoelectric DC output.

Unit \ Weight	1kg	1.1kg	1.2kg	1.3kg	1.4kg
BD	0.03-1.2V	1.4V	1.5V	1.6V	1.62V
BDEF	1.02V	1.2V	1.4V	1.54V	1.61V
BDEFGH	0.9V	1.3V	1.4V	1.55V	1.67V
BDEFGHIJ	0.85V	1.44V	1.51V	1.55V	1.56V
BDEFGHIJAC	0.89V	1.2V	1.29V	1.5V	1.55V

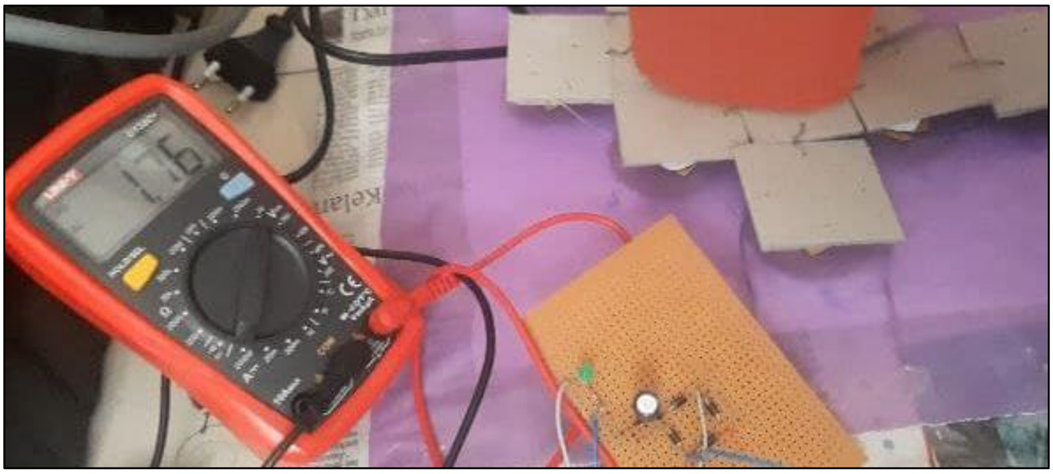

Figure 7: Output module of piezoelectric.

4. Conclusion

In conclusion, it is shown that the piezoelectric electrical generation depends on the frequent compression of the piezoelectric tiles. This is the key reason that decides the output of the piezoelectric tiles. The number one objective of this thesis is achieved to design tiles that can harvest f the chicken. The number two objective of analysing the electrical output of the tile is moderate because the cost of a module is more than RM200 and it requires more modules for the system to generate more voltage. It is also based on where the step pressure is applied. The surface of the piezoelectric must be packed with chicken steps that constantly travel around.

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