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Increasing the Effectiveness of Electricity-Generating Floors Through the Mechanical Energy of DC Generators

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ABSTRACT

The increasing electricity consumption of the Indonesian population requires renewable energy as an alternative to electricity generation supplies. Renewable energy can be formed through mechanical energy in its simplest form, namely a footrest. Generally, energy-harvesting floors that utilize human footsteps are designed with piezoelectric sensors. This sensor is responsible for converting mechanical energy into electrical energy. However, the power generated from piezoelectrics is only around 0.041 µW to 240.59 µW. So, in this study, an alternative design for a footstep floor is proposed capable of harvesting electrical energy using a DC generator. The proposed platform consists of a design that utilizes the translational motion of the gears on the gear rack and is assisted by four springs surrounding the sides of the iron plate. Apart from that, the platform has a power management and storage system. Unlike controllers in general, solar charger controllers are used for charging (voltage and current in the accumulator) and flowing current to the load (lights). The subjects used in this floor test ranged from 20-100 kg. Compared to floors that use piezoelectrics, the results are that floors with DC generators experience an increase in power of around 0.62%. Hence, DC generators are more effective in harvesting electrical energy.

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1. INTRODUCTION

Currently, the increase in electricity consumption per capita (MWH/Capita) by the Indonesian population from 2018 to 2020 is 0.02% and 0.01% (according to Electricity Statistics, Director General of Electricity, Ministry of Energy and Mineral Resources). As a result, the supply of electrical energy in Indonesia must also be accompanied by an increase. High dependence on electricity production still comes from Steam Power Plants (PLTU) fueled by coal. Coal contributes a lot to environmental damage through emissions and deforestation. Apart from that, there is a shortage of coal supply for domestic power plants, as evidenced by the ban on coal exports. As a form of solution, Indonesia has the right geographical location for developing renewable energy in electricity production.

Mechanical energy processing is a form of renewable energy. Mechanical energy is the energy an object possesses due to its motion and consists of a combination of potential and kinetic energy [1]. Without realizing it, many daily activities or things around humans produce mechanical energy, such as traditional engrang games, spinning bowls in playgrounds, and rotating motorbike wheels [2], [3]. Apart from that, foot-stepping activity is the simplest activity that humans do most often. Generally, the human heel strike when walking produces 2-20 Watts per step, and the total number of steps made per day is more than 21 trillion steps [4], so it can be calculated how much energy can be harvested every day.

Piezoelectric sensors are a medium for obtaining mechanical energy. Several studies [5], [6], [7], [8], [9] have previously applied piezoelectricity in floors to collect the mechanical energy of walking motion and convert it into electrical energy. This technology is used in several buildings, including student union buildings,

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interior spaces and office buildings. In the health sector, piezoelectric floors monitor elder activity levels in nursing homes [10]. Another application, piezoelectricity, is also used in speed bumpers [11]. Utilizes the pressure generated by the vehicle when passing the speed bumper. Speed bumpers are used to limit vehicle speed.

The electrical energy produced from this piezoelectric design has a fairly weak output power, such as the study of piezoelectric floors that utilize footrests [9] of 0.041 µW to 240.59 µW. So, in this research, it is proposed to increase the electrical power in the energy-collecting floor system using a DC generator. The expected control is greater than the power produced by piezoelectricity.

The DC generator is adapted from a combination of an electromagnetic (EM) generator, which converts translational motion into rotation and a Power Management and Storage (PMS) circuit. The EM generator here is realized with a DC generator and gears to convert the linear motion of the spring from the human footrest into the rotation of the generator rotor. Besides that, the PMS circuit is implemented by a solar charger controller and battery. Then, the collected energy is absorbed by the lamp. The use of solar charger controller components is an innovation in designing DC generators for harvesting floors when compared with existing studies [4], [12], [13].

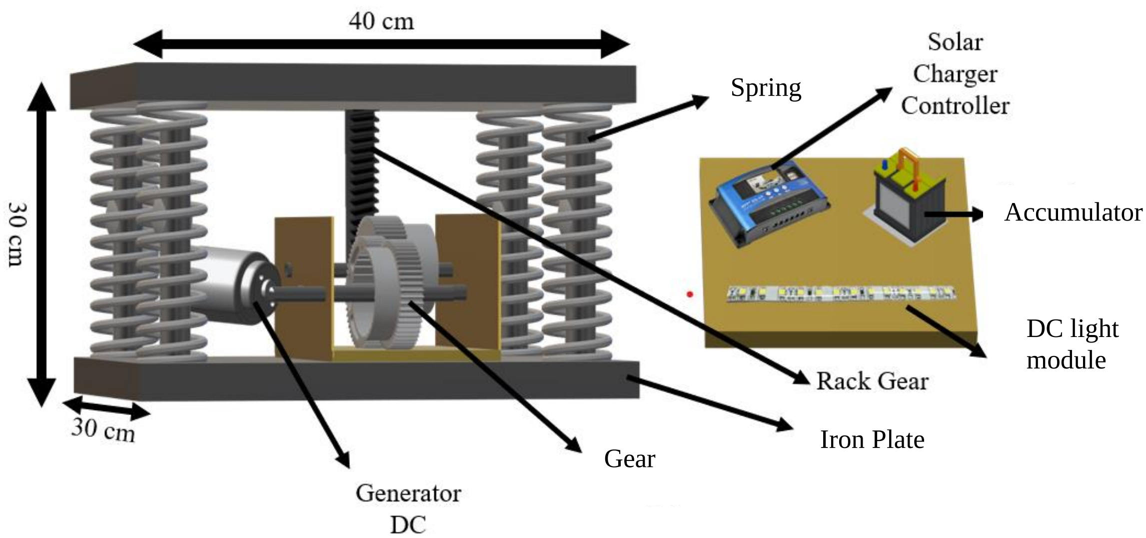
2. METHOD

The electricity-generating floor is arranged on two sides to increase power effectiveness: the platform design, which contains the mechanical design and components. The second side is the power management and storage system, which concentrates more on processing electrical energy.

2.1. Platform Design Plan

The mechanical design of the footrest floor platform is based on the relationship between the gear and the rack gear, the gear rotates, thereby moving the rack gear. The rack gear moves translationally up and down along with the foot on the floor and up and down following the spring. The gear shaft lever is the lever that drives the DC generator. So that mechanical energy is collected through the DC generator drive lever. Next, the energy conversion results from the DC generator entering the power storage and management system.

The footrest floor is made of galvanized iron material with a width of 2 mm, and a weight of 678 gr. The overall platform size is 40x30x30 cm. There are two iron plates, namely the top and bottom. Four springs with static supports inside regulate the connection between these two plates. The overall design of the footrest floor platform is represented in Figure 1(a). The platform was tested on subjects with a body weight of 20-100 kg with the pressure force of a footrest.



(a) (b)

Figure 1. Footrest floor platform with (a) mechanical design (b) electrical energy processing components.

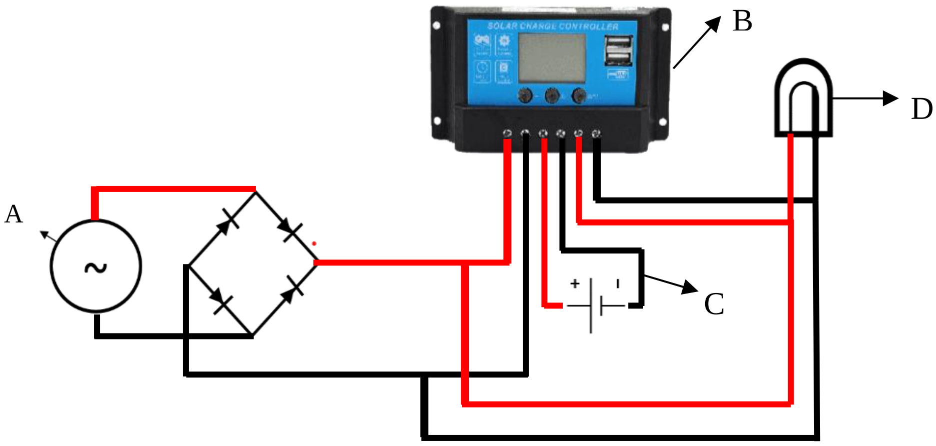


Figure 2. Schematic of an electrical energy processing circuit, where (A) DC Generator, (B) Solar Charger Controller, (C) Accumulator, and (D) Lamp.

2.2. Power Management and Storage System (PMS)

Based on Figures 1(b) and 2, the DC generator shaft rotates and causes electromagnetic induction, thus producing a voltage. and current flows to the solar charger controller. Here, the controller functions as a current distributor and monitors the amount of current supplied so that it does not experience an overload or underload because overloading can reduce the battery's life [14]. The battery gets voltage from the solar charger controller for storing electrical energy. Apart from batteries, the solar charger controller's output is also aimed at lights as an application for using electrical energy. Like lights, many other household appliances can utilize this harvested electrical energy.

The voltage produced by a DC generator varies, so a solar charger controller is needed for the accumulator charging process. There are three phases in charging an accumulator battery, namely the bulk phase (the battery discharges with a voltage of 14.4 – 14.6 V and the current is taken to the maximum), the absorption phase (the voltage is maintained according to the bulk voltage until the timer is reached, the current flowing decreases until the capacity is reached from the battery), as well as the float phase (the battery is maintained at a voltage of 13.4-13.7 V). In the float phase, the load in a lamp can use current from the DC generator.

3. RESULTS AND DISCUSSION

The prototype design results consist of two parts: the implementation of the platform design and the calculation of the power obtained from the energy harvesting floor. Furthermore, similar research will be discussed further regarding the effectiveness of increasing power.

3.1. Platform Design Results

The product design results, as shown in Figure 3 and Figure 4, are a form of direct implementation of platforms on stairs. Furthermore, this implementation can also be used for many public facilities. Several things must be evaluated in the finished platform, namely that the product's dimensions are less efficient as a support for human feet. Apart from that, the 2 mm iron plate material makes the product have a heavy load, so it is less efficient in platform mobility.

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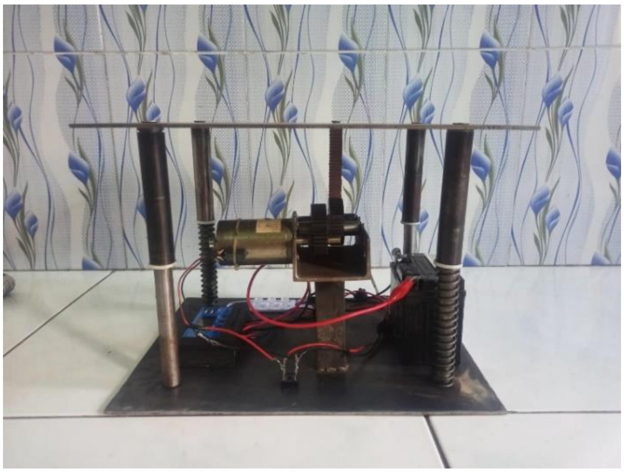

Figure 3. Product Results.

(a)

(b)

Figure 4. Installation of the product as steps (a) side view (b) front view.

3.2. DC Generator Power

To determine the power results produced by the footrest floor using a DC generator, tests were carried out on respondents based on the voltage and current values produced by charging the battery. Based on the eight respondents tested in Table 1, it was found that the average power produced by the footrest floor using a DC generator was 0.039 Watt. This value is greater than footstep floors that utilize piezoelectricity [9].

Table 1. Testing the energy, power and time of the footrest floor using a DC generator

Subject	Energy (J)	Time (s)	Power (W)
1	0,015	01.11	0,014
2	0,072	01.34	0,054
3	0,030	00.78	0,038
4	0,028	01.08	0,026
5	0,065	01.23	0,053
6	0,033	01.07	0,0315
7	0,057	01.52	0,038
8	0,058	00.97	0,06
Average	**0,045**	**01.14**	**0,039**

3.3. Platform Efficiency

Table 2. The difference between electric energy harvesting floors using piezoelectrics [15] and floors using DC generator

Weight (Kg)	PIEZOELECTRIC		DC GENERATOR	
	Voltage (V)	**Current (μA)**	**Voltage (V)**	**Current (μA)**
36	1,37	65,76	2,2	8.7
48	1,59	74,46	3,6	15
56	1,62	83,53	3,2	10.5
62	1,64	85,84	2,6	11.6
73	1,67	90,61	3,8	12.3
82	1,74	96,91	3	10,5

The platform's efficiency was assessed by testing the electric energy harvesting floor using piezoelectrics based on a study conducted by Raja Hendry Ade [15] and using a DC generator proposed by this study. Using subjects with the same weight, Table 2 shows that the DC generator has a voltage that is 2% greater than the Piezoelectric, but the current produced by the DC generator decreases drastically. Refer to Equation (1) for power calculations.

$$P = V \times I \tag{1}$$

Where P is power in Watt units, V is voltage in Volt units, and I is current in microAmpere units. So, the power produced from a DC generator is smaller than that produced by a piezoelectric floor, namely around 18 to 45%. So, in the future, components are needed that can optimize the current obtained for energy harvesting floors using DC generators. The proposed floor platform using a DC generator could be an alternative. Still, several components and designs need to be adjusted to validate the performance of the energy produced. Another advantage is that this platform is environmentally friendly and does not depend on weather changes like wind or solar power generation.

4. CONCLUSION

The electricity-generating footrest floor platform using a DC generator is designed with a gear and rack gear translational movement mechanism and spring components on both iron plates. It was tested on subjects weighing 20 to 100 kg with implementation in front of the steps producing an average power of 0.039 Watts, average energy of 0.045 Joules, and battery charging time of 1 minute 14 seconds. Compared with previous studies using piezoelectric sensors as energy harvesters, these results are considered to have experienced a significant increase in power, namely around 0.62%. So, the DC generator is more effective in harvesting electrical energy. However, comparing the piezoelectric with a DC generator on the same subject weight produces an increase in voltage of 2% but a decrease in current. This needs to be reviewed when considering selecting DC generator specifications.

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