

Design and Development of a Footstep Energy Harvesting Floor using a DC Generator

Mussafa Billah

Department of Electrical Engineering
Universitas PGRI Adi Buana Surabaya
Surabaya, Indonesia
Mussafa.billah@gmail.com

Sagita Rochman

Department of Electrical Engineering
Universitas PGRI Adi Buana Surabaya
Surabaya, Indonesia
sagita@unipab.ac.id

Abstract—Indonesia's demand for electrical energy continues to increase, creating a need for small-scale alternative energy sources. One potential source is mechanical energy from human footsteps, which is normally dissipated as waste energy. This study presents the design and development of a floor-based electricity generator that converts footstep energy into electrical energy using a DC generator. The research employed an experimental method consisting of product design, component selection, fabrication, testing, and data analysis. A mechanical transmission consisting of a floor mechanism, gear, shaft, and spring transfers mechanical energy from a footstep to the DC generator. The generated electrical energy is stored in a lithium-ion battery through a solar charge controller and is subsequently used to power an LED lamp. Experimental results showed an average output voltage of 3.33 V and an average current of 11.31 mA. The measured average energy was 0.045 J, with an average footstep duration of 1.14 s. The highest measured voltage and current were 4.8 V and 12.5 mA, respectively, while the highest recorded energy was 0.072 J. The results indicate that the proposed system can be used as a small-scale renewable energy harvesting device, particularly in locations with high pedestrian traffic.

Keywords—DC generator, footstep energy, floor, renewable energy

I. INTRODUCTION

Indonesia has substantial energy resources, including coal, petroleum, natural gas, and biomass, which have been used to meet the country's energy demand. However, petroleum and coal are non-renewable resources. Continued dependence on limited resources, together with population growth and increasing electricity consumption, encourages the development of alternative and renewable energy sources. Solar, wind, and hydroelectric generation are among the commonly applied renewable energy technologies. This study also considers mechanical energy that is normally dissipated during human movement as a potential small-scale electricity source.

Previous studies have investigated the use of piezoelectric elements to harvest energy from human footsteps. Rohman [3] developed a piezoelectric floor for converting footstep pressure into electrical energy, while M. Isra [2] investigated a piezoelectric-based speed bump. These approaches demonstrate the feasibility of converting mechanical pressure into electricity, but the reported electrical output was relatively small and the speed-bump design also presented dimensional and material limitations.

Ade [1] similarly investigated a piezoelectric prototype for human footsteps. Based on these studies, this work proposes a floor mechanism that uses a DC generator and mechanical gear transmission to convert footstep energy into electrical energy.

The objective of this study is to design and develop a floor-based electricity generator driven by human footsteps and to evaluate the voltage, current, power, and energy obtained from the system. The proposed device is intended as a small-scale renewable energy harvesting system that can be applied in areas with high pedestrian activity.

II. METHODS

A. Product Design

The research used an experimental method involving data collection, component selection, mechanical and electrical design, fabrication, testing, and data analysis. The floor mechanism was designed so that a downward footstep produces mechanical displacement and force that are transferred through a gear mechanism to a DC generator.

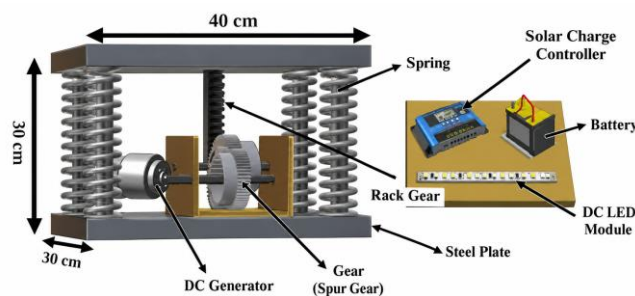


Fig. 1. Product design of the footstep energy harvesting floor.

B. Operating Principle

The operating sequence begins when a person steps on the floor. The applied mechanical energy causes the floor mechanism to move and compress the spring while simultaneously acting on the gear rod. The gear rod rotates the transmission gear, which in turn rotates the DC generator. The generator converts the mechanical energy into electrical energy. The generated electrical energy is stored in a battery and is subsequently supplied to an LED lamp.

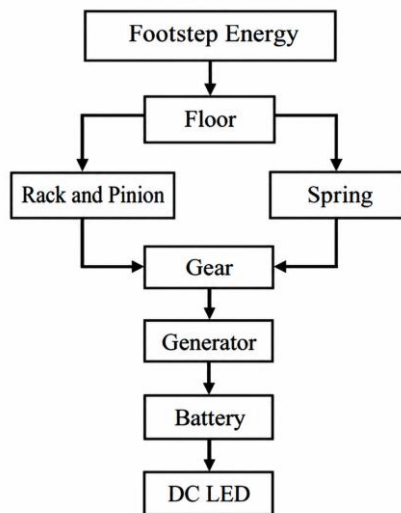


Fig. 2. Block diagram of the system.

C. Electrical Configuration

The electrical system consists of a DC generator, a solar charge controller, a lithium-ion battery, and an LED lamp. The generator output is connected to the charge controller for battery charging, while the stored electrical energy is supplied to the LED load.

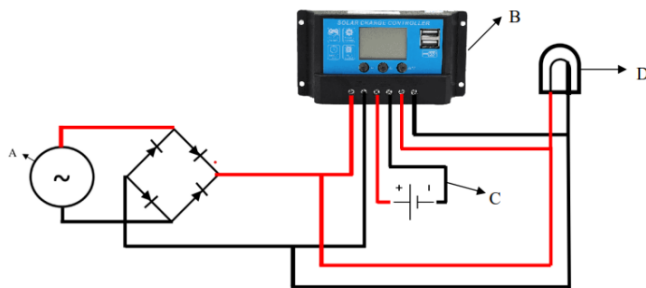


Fig. 3. Electrical wiring diagram.

D. Experimental Procedure

The research procedure consisted of data collection, component selection, design and fabrication, device testing, data analysis, and preparation of the research report. Product testing included comparison with a piezoelectric footstep system, measurement of generated voltage and current, and measurement of generated energy.

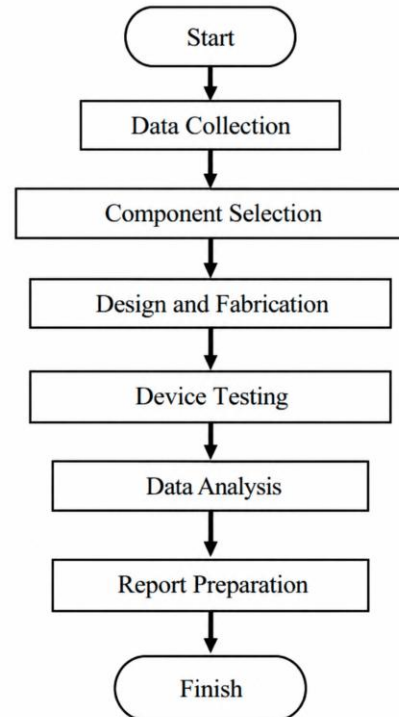


Fig. 4. Research flowchart.

E. Variables and Data Analysis

The independent variable was footstep weight. The dependent variables were generator voltage, generator current, and generator rotational speed. The fixed variable was the stepping point, which was maintained at the center of the floor to obtain maximum mechanical input. Voltage and current were measured for different respondents, and the resulting data were used to determine average electrical output.

Electrical power was calculated from voltage and current using (1):

$$P = V \times I \quad (1)$$

where P is electrical power in watts (W), V is voltage in volts (V), and I is current in amperes (A). Electrical energy was calculated using (2):

$$W = P \times t \quad (2)$$

where W is electrical energy in joules (J), P is electrical power in watts, and t is the duration of the footstep input in seconds (s).

III. RESULTS AND DISCUSSION

A. Product Evaluation

The developed floor can be used as a small-scale alternative electricity generator by utilizing the mechanical pressure produced by human footsteps. The proposed application includes stairs and public facilities with high pedestrian movement. The prototype dimensions were 40 cm long, 30 cm wide, and 30 cm high. A 2 mm thick iron plate was used as the main structural material. The prototype was

considered relatively heavy and less convenient to move. The study also identified the need for a generator with low rotational-speed requirements and high torque so that the available mechanical input can be converted more effectively into generator rotation.

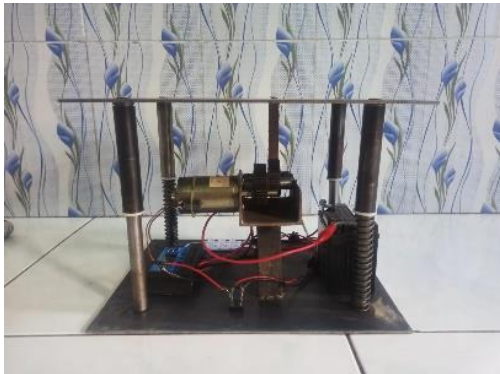


Fig. 5. Prototype of the footstep energy harvesting floor.



Fig. 6. Prototype view.

B. Comparison with a Piezoelectric Floor

The comparison test used footstep weights similar to those reported in the piezoelectric study. The piezoelectric system produced voltages between 1.37 and 1.74 V and currents between 65.76 and 96.91 μA for the reported weights. The DC-generator floor produced voltages between 2.2 and 3.8 V and currents between 8.7 and 15 mA for the corresponding comparison measurements. The experimental data therefore show higher measured electrical output from the DC-generator configuration for the tested conditions.

System	Weight (kg)	Voltage (V)	Current
Piezoelectric	36	1.37	65.76 μA
Piezoelectric	48	1.59	74.46 μA
Piezoelectric	56	1.62	83.53 μA
Piezoelectric	62	1.64	85.84 μA
Piezoelectric	73	1.67	90.61 μA
Piezoelectric	82	1.74	96.91 μA
DC generator	38	2.2	8.7 mA
DC generator	45	3.6	15.0 mA
DC generator	54	3.2	10.5 mA
DC generator	62	2.6	11.6 mA
DC generator	75	3.8	12.3 mA
DC generator	80	3.0	10.5 mA

TABLE I. COMPARISON OF THE PIEZOELECTRIC AND DC-GENERATOR FLOOR OUTPUTS.

C. Voltage and Current Output

Eight respondent measurements were conducted to determine the electrical output of the DC generator. The measured voltage ranged from 2.2 V to 4.8 V, while the current ranged from 6.5 mA to 15 mA. The average measured voltage was 3.33 V and the average current was 11.31 mA. The highest voltage, 4.8 V, and a current of 12.5 mA were obtained from respondent 8.

Respondent	Voltage (V)	Current (mA)
1	2.2	6.5
2	3.6	15.0
3	3.2	12.0
4	2.6	10.0
5	3.4	14.0
6	3.0	10.5
7	3.8	10.0
8	4.8	12.5
Average	3.33	11.31

TABLE II. MEASURED VOLTAGE AND CURRENT OF THE DC-GENERATOR FLOOR.



Fig. 7. Generated voltage.

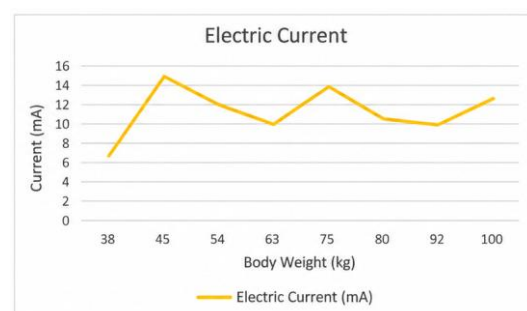


Fig. 8. Generated current.

D. Power and Energy Output

Using the average voltage of 3.33 V and average current of 11.31 mA, the calculated electrical power is 0.039 W according to (1). The source article also reports an average power value of 0.39 W in its discussion table; this value is not consistent with the stated voltage-current multiplication. Therefore, the directly calculated value of 0.039 W is retained here as the result of the stated equation, while the source-reported table value is identified as a data inconsistency.

The measured energy data ranged from 0.015 J to 0.072 J. The average energy was reported as approximately 0.045 J, with an average footstep duration of 1.14 s. The highest recorded energy was 0.072 J, with a reported power of 0.054 W and a duration of 1.34 s for respondent 2.

Respondent	Energy (J)	Power (W)	Time (s)
1	0.015	0.014	1.11
2	0.072	0.054	1.34
3	0.030	0.038	0.78
4	0.028	0.026	1.08
5	0.065	0.053	1.23
6	0.033	0.0315	1.07
7	0.057	0.038	1.52
8	0.058	0.060	0.97
Average	0.045	0.39*	1.14

TABLE III. MEASURED ENERGY, POWER, AND FOOTSTEP DURATION.

a. *The source article reports 0.39 W as the average table value, while its voltage-current calculation gives 0.039 W.

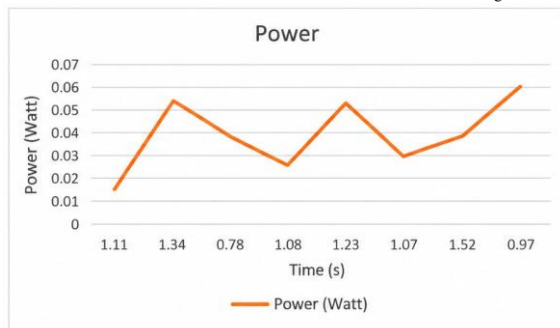


Fig. 9. Generated power.

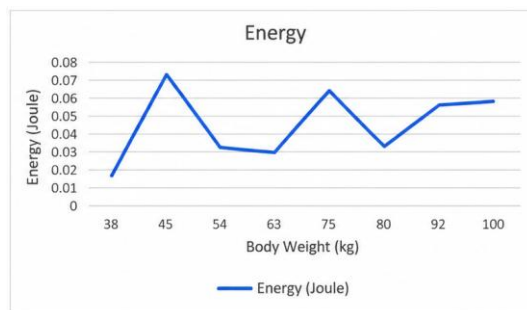


Fig. 10. Generated energy.

The output characteristics indicate that the device converts repeated footstep input into measurable electrical energy. Because the output of one step is small, practical energy harvesting depends on the number of footsteps and the placement of the device in locations with high pedestrian traffic. The study also indicates that the mechanical dimensions and generator characteristics should be improved in future designs to obtain higher conversion performance.

IV. CONCLUSION

A footstep energy harvesting floor using a DC generator was designed and experimentally evaluated as a small-scale renewable energy harvesting device. The system converts

mechanical energy from human footsteps through a gear mechanism into electrical energy, stores the generated energy in a battery, and uses it to supply an LED load. The experimental results produced an average voltage of 3.33 V and an average current of 11.31 mA. The highest measured voltage and current were 4.8 V and 12.5 mA, respectively. The measured average energy was approximately 0.045 J, while the highest recorded energy was 0.072 J.

Future development should focus on improving the generator specification, particularly the low-speed/high-torque characteristics, and redesigning the prototype dimensions to reduce its weight and improve portability and mechanical efficiency.

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