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Design And Construction Of A Kinetic Power Generator Using A Paving Generator On The Sideway As A Supply For Street Lamps In The Medan Aviation Polytechnic Campus

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Abstract

This study aims to design and develop a kinetic power generation device that utilizes the mechanical energy from pedestrian foot pressure on sidewalks. The working principle of the system is to convert mechanical energy into electrical energy using eight 12V DC car central lock actuators arranged in a series-parallel configuration. The electrical energy generated from foot pressure is directed into an electronic circuit consisting of diodes as reverse current protection, a DC-DC step-down converter to reduce voltage, and a charge controller to regulate the charging process of a 6800 mAh lithium-ion battery. The stored energy is then boosted using a DC-DC step-up converter to match the load requirements, which is a 10W LED lamp operating at 5V DC. To support monitoring, the circuit is equipped with a control panel containing a digital voltmeter and ammeter with an LCD display that shows voltage and current conditions in real time. All components are regularly assembled inside a panel box mounted on a mini light pole, ensuring practicality and safety in operation. The test results show that the device is capable of producing an average maximum voltage of 14.83 V with a current of up to 25 mA when all central lock actuators are pressed simultaneously. The stored energy in the battery can be used to power the LED lamp for several hours, depending on the intensity and frequency of pedestrian footsteps. With its simple design, easily obtainable components, and relatively low production cost, this system has the potential to serve as an alternative solution in supporting energy efficiency and the application of renewable energy-based lighting systems in campus environments as well as other public areas.

Keywords : Kinetic Power Generator, Paving Generator, Car Central Lock, LED Lamp, Renewable Energy

INTRODUCTION

Electrical energy is one of the most fundamental forms of energy in modern human life. This energy originates from electric charges that create static electric fields or from the movement of electrons in conductors (electrical conductors) or positive or negative ions in liquids or gases. The availability of electrical energy plays a vital role in supporting various activities in the industrial, transportation, government, education, communications, and household sectors. Nearly all equipment and infrastructure supporting daily life, such as lighting, computers, production machines, electronic devices, transportation systems, and various other equipment, depend on a stable and adequate supply of electrical energy. Electrical energy is needed to power lights, heat, cool, and operate mechanical equipment that can ultimately produce other forms of energy (Cahyadi et al., 2020). Therefore, the existence of electrical energy is not only a basic need, but also a major driver of the global economy. In the digital era and the industrial revolution, the need for electrical energy continues to increase significantly, in line with population growth, increased community activities, and the rapid development of information technology and electronic devices (Narayana, 2017).

To meet these needs, various power generation technologies have been developed. Generally, power plants are divided into two main categories: fossil fuel-based power plants and renewable energy-based power plants. Indonesia's growing population has led to a corresponding increase in energy demand, particularly electricity, which is the backbone of various economic and social activities. To ensure sustainable economic growth, a sufficient and reliable energy supply is required. Currently, Indonesia's energy mix is still dominated by fossil fuel sources, such as coal-fired steam power plants (PLTU), natural gas-fired gas power plants (PLTG), and diesel-fueled power plants (PLTD) (Budiman, Asy'ari, & Hakim, 2022).

However, fossil fuels have limitations because they are non-renewable, so their availability in nature is limited and cannot be renewed in a short time. In addition, the process of burning fossil fuels produces carbon dioxide emissions and other pollutants that have a negative impact on the environment, such as global warming and air pollution. Therefore, it is necessary to develop renewable energy sources for power generation to support national energy security and maintain environmental sustainability (Prastuti, 2017). One potential renewable energy source is geothermal energy, which is abundantly available and environmentally friendly. The development of geothermal energy and other renewable energy sources is a strategic step in meeting Indonesia's future energy needs in a sustainable manner.

As an alternative, renewable energy is a solution that continues to be developed to achieve energy sustainability and environmental preservation. Renewable energy comes from natural resources that can be renewed naturally and will not run out, such as solar energy, water, wind, biomass, and geothermal energy. Some power generation technologies that utilize renewable resources include Solar Power Plants (PLTS), Hydroelectric Power Plants (PLTA), and Wind Power Plants (PLTB) (Loupatty, 2023). Although environmentally friendly, these technologies have their own challenges, such as high installation costs, dependence on weather conditions, and the need for large areas of land. The potential for renewable energy that can be utilized in Indonesia is enormous, but has not been optimally developed (Ilham, Afgani, Mesin, Teknik, & Surabaya, 2022). The geographical gap between energy supply and demand locations, relatively low technological efficiency, high technological investment, and social factors of the community as energy users are challenges for the government to develop renewable energy-based technologies (Maulia, Ismeddiyanto, & Suryanita, 2019). Therefore, there is a need for new innovations in the field of alternative energy that are local, affordable, and applicable.

One interesting innovation to be developed is utilizing the kinetic energy of human footsteps as a source of electricity generation. Kinetic energy is the energy possessed by moving objects. In this context, the pressure or push from human footsteps when walking on a certain surface can be utilized as mechanical energy which is then converted into electrical energy. This technology is known as the Kinetic Paving Generator, a surface system (paving) that can generate electricity when stepped on. This technology has great potential for application in places with high pedestrian traffic, such as sidewalks, stations, shopping centers, terminals, and campus environments. In addition to not requiring fuel, this system is also weather-independent, easy to implement in limited spaces, and environmentally friendly (Meilani & Wuryandani, 2021).

As a higher education institution, Medan Aviation Polytechnic has a campus environment that is quite busy with the activities of students, lecturers, staff, and vehicles passing by every day. This makes the campus environment a very potential location for the application of kinetic energy generation technology. By utilizing the energy from footsteps on the campus sidewalk area, mechanical energy that has been wasted can be converted into useful electrical energy, one of which is to support street lighting around the campus. This innovation not only provides an alternative solution in energy supply, but also supports the principles of energy efficiency and environmental sustainability of the campus. Furthermore, the application of this technology can be a means of education as well as a direct implementation of the concept of a green campus and appropriate technology (Arsa, 2017).

Based on this background, this research was conducted with the aim of designing and building a kinetic power generator using a Kinetic Paving Generator that can be used as an alternative power source for street lighting on the Medan Aviation Polytechnic campus. This research is expected to provide an applicable solution to support energy efficiency while raising awareness of the importance of developing environmentally friendly energy sources.

Design

Design and construction is a systematic process that includes structured drawing, planning and design activities, including making sketches, models or diagrams, which aims to integrate various separate elements into a complete, integrated system that has operational functions in accordance with the objectives that have been set (Nurhayati, Josi, & Hutagalung, 2018).

Electrical Energy

Energy can be defined as the ability of a system or object to perform work. Meanwhile, electrical energy is a form of energy produced by the presence of an electric charge, whether static or dynamic, which causes the charge to move. Theoretically, a difference in electrical potential (potential difference) can produce energy capable of moving electrons from a point with a lower potential to a point with a higher potential (Sunarlik, 2017).

Basic Concept of Kinetic Power Generation

Kinetic energy is the energy possessed by moving objects. In the context of kinetic power generation, the energy from human movement (for example, footfall) can be converted into electrical energy through specific mechanisms. *The Kinetic Paving Generator* is one technology that enables this conversion by harnessing the pressure from footfall to power *a generator* (Endriatno, Safarun, & Kaimuddin, 2024).

***a Kinetic Paving Generator* Works**

The Kinetic Paving Generator operates on a mechanical-electrical principle, where pressure from the foot presses against *the Paving Generator* or a spring mechanism, which then drives an electric *generator* . The resulting electrical energy can be stored in a battery and then recharged or used directly for specific power needs, such as lighting.

Paving

Paving is a building material used as an alternative surface covering for the ground or pavement. This product comes in a variety of shapes to suit user preferences and can be applied according to individual needs. Its uses range from parking areas, terminals, sidewalks, yards, road paving in residential areas, and other applications.

Generator

A generator is a device that functions to convert mechanical energy into electrical energy. This mechanical energy source can come from various forms, such as heat, water, steam, and other sources. The electrical energy produced by the generator can be in the form of alternating current (AC) or direct current (DC), depending on the construction and type of *generator* used in the power generation system. The working principle *of the generator* is closely related to *Faraday's law* , which states that if a conductor is in a changing magnetic field, then an Electromotive Force (EMF) will arise in the conductor. Based on the type of electric current produced, generators are divided into two main types, namely:

***Generator* (*Alternating Current*)**

An AC generator is a device that converts mechanical energy into alternating current (AC) electrical energy, where the direction of the current changes periodically. These *generators* are often called synchronous generators or *alternators* , and are commonly used in large-

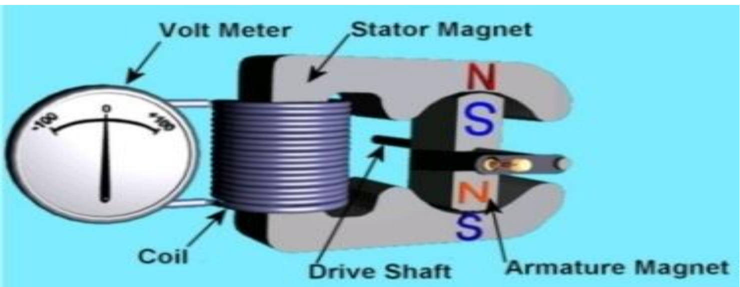

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Figure 1. Ac generator structure

Generator* (*Direct Current)

generator is a device that converts mechanical energy into direct current (DC) electrical energy by using *a commutator* to regulate the direction of the current so that it remains in the same direction as the load circuit (Hakimah, 2019).

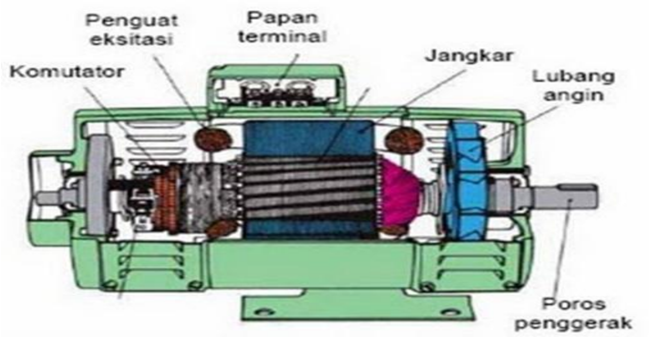

Figure 2. DC Generator Construction

Main Components in the System

Components are parts or elements that make up a system that have specific functions and are interconnected to form a complete circuit. Each component is designed to perform a specific role according to the system's working principles, so the overall performance of the tool is highly dependent on the quality, specifications, and functional suitability of each component used. *Kinetic Paving Generator* is a material that can produce electrical energy when given mechanical pressure and strain and vice versa.

A diode is an electronic component that only allows electric current to flow in one direction so that the diode is also commonly called a "rectifier". Diodes are made of *silicon* and *germanium type semiconductor materials* . Diodes are made from a combination of two types of semiconductors, namely type P (*Positive*) and type N (*Negative*), the diode leg connected to the P-type semiconductor is called the " *Anode* " while the one connected to the N-type semiconductor is called the " *Cathode* ". In its original form, the diode has a circular ring mark on one side, this is used to indicate that the side with the ring is the Cathode leg. Electric current will very easily flow from *the anode* to *the cathode* , this is called " *Forward-Bias* ", but if the opposite is true, namely from *the cathode* to *the anode* , the electric current will be held back or blocked, this is called " *Reverse-Bias* " (Adetayo & Feyisola, 2021).
A step-down regulator module is an electronic component or circuit used to reduce electrical voltage from a higher level to a lower one. This voltage reduction process is important in various electronic applications because many electronic devices, such as microcontrollers, sensors, and communication modules, operate at low voltages.

Battery

A battery is a chemical device for storing electrical energy from Kinetic energy. Without a battery, energy can only be used when there is Foot Pressure on *the Generator paving* . Definition of Battery (Aki) A battery or accu, or can also be an electric cell in which a *reversible electrochemical process takes place* (can be reversed) with high efficiency. What is meant by a *reversible electrochemical process* , is that in the battery the process of converting chemical energy into electrical energy (discharging process), and vice versa from electrical energy to chemical energy, recharging by regeneration of the electrodes used. (Arsa, 2017) The main function of the battery is to store electrical energy produced by *the paving generator* in the form of chemical energy. This stored energy is then used to supply electrical power to loads, such as street lights in the campus environment, as well as other electrical components connected to the system.

RESEARCH METHODS

Research Design

This research uses a research and development method that is structured based on R&D stages that are modified into several stages to suit the needs of the final project, namely as follows:

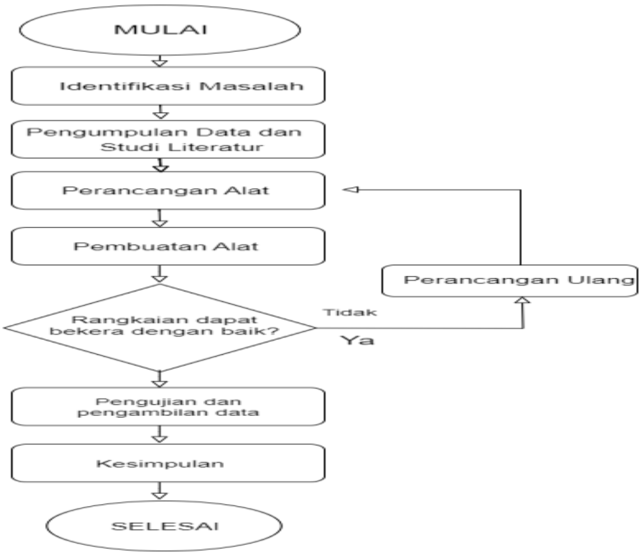

Figure 3. Research Method *Flowchart*

Researchers have observed the potential for kinetic energy generated by pedestrian footsteps on sidewalks as a form of renewable energy that is abundant, sustainable, and environmentally friendly. However, in Indonesia, the utilization of this potential is still very limited and has not yet developed into a practical power generation technology. In contrast, in several developed countries such as Japan, the United Kingdom, and South Korea, *kinetic paving technology* has been effectively implemented to convert foot pressure into electrical energy used in street lighting systems, interactive information boards, and even electronic device charging facilities in public spaces (Setiyo, Saputra, Sudjoko, & Faizah, 2023).
This difference indicates a gap in the utilization of technology that has the potential to provide significant benefits in supporting alternative energy. Therefore, this research is directed at developing *a kinetic paving generator* that is adapted to local conditions, considering the affordability of production costs, as well as relevance to the infrastructure needs of the campus environment. It is hoped that this innovation can be an alternative

solution for providing electrical energy for street lighting and public facilities in Indonesia. Data collection was carried out through literature studies from journals, scientific articles, and research reports related to the utilization of kinetic energy, *generator systems* , energy storage systems, and supporting components such as *central locks* , *lithium-ion batteries* , and LED lights. At this stage, researchers made an initial design of the power generation system, including the selection of main components, the preparation of system block diagrams, and electronic circuit schematics.

The design process for this tool is carried out sequentially so that each step supports each other and can minimize the potential for errors in the assembly process. The process begins with the creation of a mechanical frame using an iron plate shaped to the size of the paving, then a spring is installed at the bottom of the plate to convert foot pressure into linear motion. Next, *the generator is assembled* by installing eight *central locks* on the frame mount, then assembling the output in a series-parallel configuration according to the design to obtain the optimal combination of voltage and current. After that, a protection and rectifier system is installed by placing a *reverse diode* on *the generator output* to prevent reverse current, then *the output* is connected to a 5 V *step-down module* as a voltage regulator before entering *the charger controller* (Priambodo, 2021). The next stage is the energy storage system, namely by connecting the *step-down module* to *the charger controller* and connecting it to a 18650 *lithium-ion battery* connected in parallel to increase the storage capacity. The stored energy is then regulated again through the step-up module to increase the voltage according to the load requirements. In the final stage, *the step-up module output* is connected to a 10 W DC LED lamp as the main load, while an LCD voltmeter-ammeter is installed to monitor voltage and current conditions in *real time* so that the entire system can operate as designed. The tool is tested using several methods, including:

a. Testing the voltage and current *output of the paving generator*
b. *output* signals using *an oscilloscope*
c. Battery charging duration testing
d. Testing the duration of the lamp on a full battery

At this stage, conclusions will be drawn regarding whether the design of the kinetic power plant using *a kinetic paving generator* that has been made is in accordance with the planned research method, and functions optimally as a power source for street lighting in the campus environment. This research design is *quantitative experimental* , where variables such as voltage, current, lamp burning time, and electric wave frequency are observed and measured directly for analysis. Tool design refers to the process of planning, developing, and making tools or instruments for a specific purpose. This involves a series of systematic steps that include identifying needs, conceptual design, tool creation, testing, and implementation (Utami, Faizah, Politeknik, & Surabaya, 2020). Tool design is often part of product development or research, where the tool created can be used to measure or facilitate certain activities. At this stage, the design of a kinetic power plant system is carried out which is designed to generate electrical energy from the pressure of stepping on the paving. Tool design includes component selection, mechanical and electrical arrangements, and integration between parts so that the system can work optimally in converting mechanical energy into electrical energy.

RESULTS AND DISCUSSION

Research result

As explained in the previous chapter, the final project entitled: Design and Construction of a Kinetic Power Generation Device Using *a Paving Generator* on the Sidewalk as *a Supply* for Street Lighting in the Medan Aviation Polytechnic Campus. This final project aims to design a kinetic power generation system that utilizes the pressure of pedestrians' footsteps on the paving. The mechanical energy generated by the footsteps is converted into electrical energy using a DC Generator (Dermawan & Purnomo, 2021). The resulting electrical energy is then stored in a lithium-ion battery and used to light LED lights as street lighting in the campus environment. In its design, this tool consists of several integrated system blocks, namely:

a. *generator* block : Generates electrical energy from the kinetic energy of human footsteps on the sidewalk.
b. Conversion and protection blocks (*regulators* and diodes): Regulate and protect the flow of electricity to keep it stable and safe.
c. Power storage block (battery): Stores generated electrical energy for use when needed. This battery energy storage system functions to efficiently store and distribute electrical energy.
d. Voltage increase block *(step-up converter)* : Increases the electrical voltage from *the battery* to suit the load or LED lamp requirements.
e. Load block and *output monitoring* : Connecting the stored electrical energy to the load (lighting) while monitoring the system *output performance* .

Steps for Making the Tool

The assembly process of the *paving generator tool* involves various components and design stages that must be carefully integrated so that the system can work stably in converting tread energy into electrical energy and carrying out its function as a lighting source.

Discussion of Research Results

This chapter will discuss the test results and analysis of a kinetic energy generator based on *a car's central lock* . The discussion is based on the results of voltage, current, and power generated per step, followed by an estimate of the number of steps required to charge the battery and how long the lights can stay on using the stored energy.

System Component Testing

This test is performed after all components are assembled into a complete system and voltage is applied from the stepping on *the paving generator.* The goal is to ensure that each component functions properly when working together under actual operational conditions.

Generator Central Lock

The paving generator was tested using *an oscilloscope* to observe the waveform and voltage generated. The test results showed that *the paving generator* successfully generated voltage when stepped on, as displayed by *the oscilloscope* as a waveform and its voltage value. This demonstrates that the paving generator is functioning effectively in converting mechanical energy from the stepping force into electrical energy (Widiasaputra et al., 2022).

Testing the diode using *an avometer* showed that the diode was functioning properly. This test successfully proved that the incoming voltage did not return to *the generator* , as indicated by the avometer by the absence of reverse voltage to *the generator* .

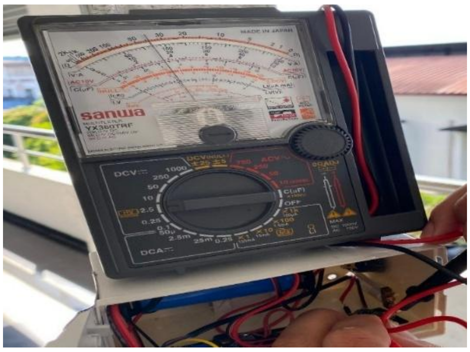

Figure 4. Diode Testing

step-down module test was conducted using *an avometer* to ensure the module's ability to reduce the *generator 's output voltage* . The test results showed that the generator's output voltage, which was initially high, was successfully reduced to around 5 volts according to system requirements. This proves that the step *-down module* functions well in converting voltage, making it safe to use to channel power to the next circuit without damaging components that require low voltage. *The charger controller test* was conducted by flowing voltage from the stepped *generator paving . When the voltage enters, the indicator light on the charger controller module* lights up, indicating that the battery charging process is in progress. This indicates that *the charger controller module* functions well in receiving power from *the paving generator* and channeling it to the battery, so that the charging process runs as expected.

Battery testing was performed by measuring the voltage using *an Avometer* to ensure its condition and performance. The test results showed that the battery had a voltage that met the stated specifications, thus concluding that the battery was in good condition and ready to be used as energy storage in the system (Khoiruroziq & Nilakresna, 2021).

The step-up module was tested by measuring its output voltage using *an avometer* . The test results showed that *the step-up module* successfully increased the voltage from a 3.7 volt battery source to around 5.5 volts, in accordance with the needs of a 5 volt lamp load. This proves that *the step-up module* functions well in increasing the voltage so that it can be used to turn on the lights in the system. LCD testing was carried out to ensure its ability to display the output voltage and current data from the *step-up module* . The test results showed that the LCD successfully displayed the voltage and current values clearly and in accordance with the measurement results using an avometer, so it can be concluded that the LCD functions well as a monitoring tool in the system.

LED lamp testing was conducted to ensure the system's overall performance. Test results showed that the entire circuit, from the paving generator to the *step-up module* , successfully powered a 5-volt, 10-watt LED lamp with a bright, stable glow. This demonstrates the system's effective energy generation and distribution to the final load.

Output Voltage Calculation

The paving generator designed in this study produces a direct current (DC)-based electrical voltage. However, under no-load testing conditions, the resulting signal characteristics exhibit a rapidly fluctuating *sinusoidal wave pattern* due to the momentary kinetic impulse of the footrest. This results in a very rapidly fluctuating voltage (transient), requiring a *multimeter to measure the voltage. (avometer)* cannot accurately capture voltage values. Therefore, the measuring instrument used is an oscilloscope, which can capture instantaneous voltage signals in the form of visual graphs and digital numbers with high time resolution.
The test was conducted three times to obtain the average *output voltage* of *the paving generator* . The results of each measurement are shown as follows: When a full step is taken directly and quickly, the waveform recorded on the *oscilloscope screen* shows a sudden voltage spike. The maximum voltage recorded was 10.1 volts and the minimum voltage was -2.96 volts, resulting in a peak *-to-peak voltage* of 13.1 volts. This waveform is sharp and does not repeat, indicating that the large step force produces significant instantaneous energy.

Table 1. Test 1 One Full Step

No	Parameter	Mark
1	Maximum Voltage	10.1 V
2	Minimum Voltage	-2.96V
3	*Peak-to-Peak* Voltage	19.1.0 V
7	Waveform	Momentary spike

Table 2. Step on it slowly several times

No	Parameter	Mark
1	Maximum Voltage	14.0 V
2	Minimum Voltage	-3.28V
3	*Peak-to-Peak* Voltage	17.0 V
4	Waveform	Wavy fluctuations

Output Current Measurement

The output current of the paving generator was measured using an analog Avometer. During the measurement, the Avometer selector was set to the DCA ×25 mA position, and the pointer indicated 225 on the 0–250 scale. Based on the scale and multiplier, a current value of 22.5 mA DC ampere was obtained (Pratika, Piarsa, & Wiranatha, 2021). This result indicates that the paving generator is capable of producing a current large enough for the battery charging process. In this kinetic power generation system, the battery charging process depends on the amount of energy that can be generated from each step on the paving generator . Therefore, calculations are needed to determine how many steps are needed to charge a lithium-ion battery with a certain capacity (Kadir, 2020).

Estimated Light Turn-On Time Using Battery Power

The energy from the battery will be used to light a 10 W LED lamp that works at a voltage of 5 V. However, because the battery has a voltage of 3.7 V, a *step-up converter module is used* to increase the voltage to 5 V.

$$\text{Lama Pemakaian Bateray (Jam)} = \frac{\text{Energi Bateray}}{\text{Daya Lampu}}$$

$$\text{Lama Pemakaian Bateray} = \frac{50{,}32\ \text{Wh}}{10\ \text{Watt}} = 5\ \text{Jam}\ 1{,}9\ \text{menit}$$

CONCLUSION

Based on the results of the tests and analysis that have been carried out, the following conclusions were obtained:

a. A kinetic energy generator was successfully designed and built using eight central lock generators connected in series and parallel. Pressure from human footsteps on the paving stones rotates the motor, generating electricity.
b. The voltage and current characteristics produced by the system vary depending on the magnitude of the stepping pressure. With slow stepping, the lowest voltage produced reaches approximately 10 V, while with strong and repeated stepping, the highest voltage can reach approximately 20 V. These values indicate that stepping pressure directly influences the magnitude of the voltage and current produced by the paving generator.
c. The voltage, current, and electrical power of the device were successfully measured. From the test results using an oscilloscope and multimeter, the average output voltage reached 14.83V. After going through a rectifier and step-down circuit, the voltage can be stabilized and adjusted for the charging process of a 3.7 V lithium-ion battery. The current generated from the treadle pressure is 22.5 mA with a single treadle power producing 0.37 W.

Suggestion

Some suggestions for further development of this research are:

a. In further development, the kinetic power generation system is recommended to use more paving generator units installed in areas with high pedestrian activity, equipped with a more responsive and efficient mechanical design in transferring energy to the generator.
b. It is recommended to use an AC generator that is suitable for the PJU load, as well as the addition of an IoT-based monitoring system to monitor voltage, current, and battery/lamp status in real-time.

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