JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

The Effect of Temperature Differences on the TEG-Based Conversion of Thermal Energy into Electrical Energy

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Received: August 15, 2024
Revised: September 28, 2024
Accepted: October 25, 2024
Published: October 31, 2024

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DOI: 10.29303/jossed.v5i2.9170

Abstract: Thermoelectric Generator (TEG) is an energy conversion device used as an electricity generator to create hot electric currents through temperature differences. This research aims to determine the effect of time on temperature differences from burning rice husks (*Oryza sativa L.*) in series and parallel configurations. This research method was carried out experimentally by burning rice husk biomass in a kiln and utilizing the heat of the fire to convert it into electrical energy. The TEG total of 48 TEG pieces which produce the highest current in the series configuration produces the highest with respective values of current 0.09 A and voltage 1.02 V, and the parallel configuration TEG produces the highest with respective values of current 0.98 A and voltage 0.25 V. The highest temperature difference reaches 30.5°C in the series configuration and 31.8°C in the parallel configuration. The longer the burning time, the more significant the resulting temperature difference. Likewise, the greater the electric current and voltage, the longer the burning time.

Keywords: Electrical; Energy; TEG; Temperature; Thermal.

Introduction

The Indonesian people's energy needs are very dependent on electricity from fossil fuels, a type of non-renewable energy (Pambudi et al., 2023; Kusnandar, 2022; Raihan, 2023). The supply of fossil energy continues to decrease, especially in petroleum, natural gas, and coal (Parinduri et al., 2020). Fossil energy is used by reusing biomass as an alternative energy source by changing heat energy into other forms, including rice husks (Baderan & Hamidun, 2016). Rice husks (*Oryza sativa L.*) are the outer protective layer of rice grains after the milling process to produce rice (Yilmaz, 2023; Udjianto et al., 2021). So far, rice husks, often considered waste that damages the environment, are a source of thermal biomass energy. This is important for overcoming the energy crisis problem because the high cellulose content in rice husks can produce consistent and stable combustion (Awasthi et al., 2024; Pujotomo, 2017; Ramírez et al., 2024). Therefore, alternative energy is needed to utilize rice husk waste, which is used as fuel for rice husk biomass, coupled with thermoelectric technology, which converts heat energy into electrical energy directly through Thermoelectric Generator (TEG) to produce electrical energy that can be utilized in everyday life (Win et al., 2024; Silaban et al. 2020).

TEG is an energy conversion device used as an electricity generator to create hot electric currents through temperature differences (Saha et al., 2023; Wardati et al., 2020; Kandi et al., 2023). The basic principle of thermoelectricity comes from the Seebeck effect, which explains that when two materials are connected and exposed to different temperatures, an electric current will flow in the material (Dadhich et al., 2023; Hafiz et al., 2019). In a thermoelectric power generation system, if a temperature difference is maintained between the two sides of the thermoelectric pair, heat energy will flow through the device (Montero et al., 2023; Ajit et al., 2014; Tang et al., 2023; Tyagi et al., 2023).

Thermoelectric devices require a heatsink to absorb heat from the cold part of the Peltier element and remove it from the hot part of the Peltier element (Ginanjar & Suryadi, 2019). Heatsinks have two main parts: the part that takes heat and the part that releases heat (Baskoro et al., 2021). In other words, electrical energy can flow if there is a temperature difference on both sides of the TEG (Hudaya, 2021). This research was carried out to create a TEG configuration design by utilizing burning

How to Cite:
Lapananda, N. F., Arbie, A., Yunus, M., Latief, M. F., Kurniasari, S., & Meidji, I. U. (2024). The Effect of Temperature Differences on the TEG-Based Conversion of Thermal Energy into Electrical Energy. *Journal of Science and Science Education*, *5*(2), 186–190. https://doi.org/10.29303/jossed.v5i2.9170

rice husks as an alternative energy source that can be converted into thermal energy to produce electric current and voltage through the effect of temperature differences.

Method

The tools and materials used in this research are TEG type SP-1848-27145, Multimeter, Thermometer, Heatsink, Supercapacitor, Stopwatch, Biomass Stove, Iron Cover, Rice Husk (*Oryza sativa L.*), and Moisture Meter. The flow chart of the research starting from thermal energy until electrical energy in Figure 1. This research uses two types of TEG configurations: series in Figure 2 and parallel in Figure 3.

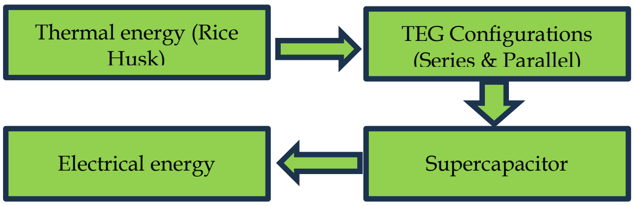

Figure 1. Flow chart of research

The stage of this research was to measure the water content of 9 kg of rice husk fuel. Then, the rice husks are entirely put into the kiln. Assemble 48 TEG pieces in series by attaching the heatsink to the top of the TEG circuit. The TEG is assembled on an iron cover that covers the stove pot. Measure the pot's temperature as the hot side using a thermometer on eight sides. Measure the heatsinks temperature, using the cold temperature on eight different sides, to see the temperature difference produced at each measurement time. After that, take measurements of the voltage and current produced using a digital multimeter running through the supercapacitor.

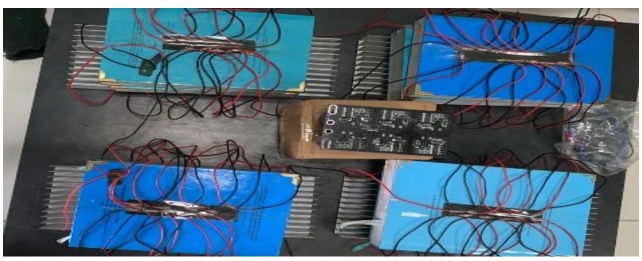

Figure 2. Series configuration on TEG

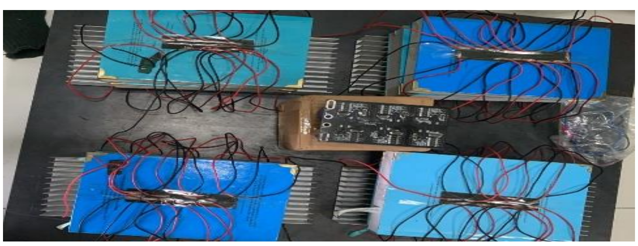

Figure 3. Parallel configuration on TEG

Result and Discussion

Results of Time on Temperature Differences

The thermoelectric generator can work because of the temperature difference produced between the two opposite sides of the TEG. In a thermoelectric power generation system, heat energy will flow through the thermoelectric device if a temperature difference is maintained between the two sides of the thermoelectric pair.

In this research, the hot side of the TEG utilizes heat from burning rice husk biomass on a biomass stove, while the cold side uses a heatsink. The temperature difference between the hot side and cold side of the thermoelectric produces electrical energy. The relationship between temperature difference and time in series and parallel configuration circuits shows in Figure 4.

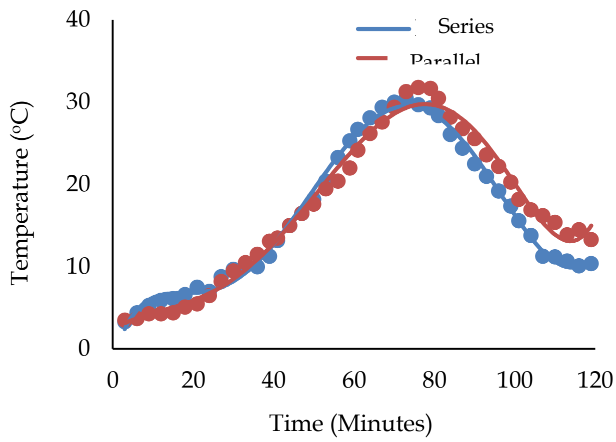

Figure 4. The relationship between time and temperature differences in series and parallel configurations.

Figure 4 shows that time significantly influences the increase in temperature differences. The contribution of burning rice husk biomass to the results of temperature differences is that the longer the burning time, the greater the temperature produced, so the temperature difference will increase. The most significant temperature difference in the series configuration reached 30.5°C at the 75th minute from the results of 81.1°C as the hot side and 50.6°C as the cold side. Meanwhile, the parallel configuration produces a temperature difference on the hot side of 83.5 °C and the cold side of 51.7 °C, so the temperature difference reaches 31.8 °C at the 78th minute. This is due to the Seebeck effect, which explains that electrical energy will flow if there is a temperature difference between the two sides, namely the hot and cold sides (Purwanto, 2020). It shows that the temperature difference in the parallel configuration is higher than the series configuration, so the parallel configuration produces more incredible electrical energy due to the different combustion factors.

Results of TEG Design Using Supercapacitors

When using a supercapacitor, the data obtained includes the electric current and voltage stored in the supercapacitor. The heat source on the biomass stove cover is a total of 48 thermoelectric chips, measured every 3 minutes when burning rice husks for 120 minutes using a series and a parallel configuration. Graphs of series and parallel configurations of current and voltage with time variations shows in Figure 5 and Figure 6.

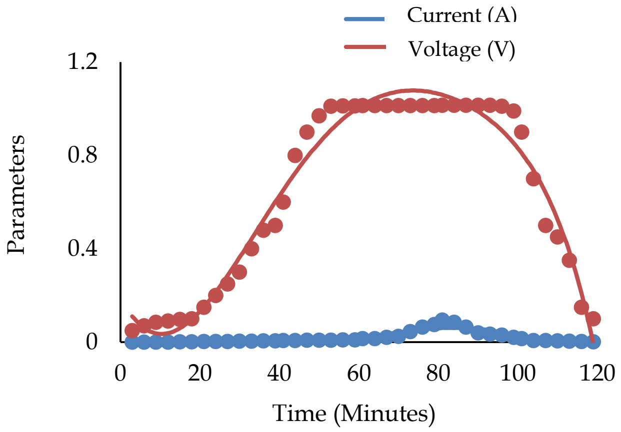

Figure 5. The relationship between time to current and voltage parameters in series configuration

Figure 5 shows a graph of the length of time for burning rice husks, which significantly influences the temperature increase. The highest current value in the series configuration occurred at the 84th minute and the voltage at the 90th minute with respective values of current 0.09 A and voltage 1.02 V. These results show that in a series circuit on the TEG, the voltage difference increases and the current tends to remain constant. This is because the total voltage is the sum of the voltages in each TEG circuit, which causes the voltage to increase and the current to remain the same (Morelli, 2023).

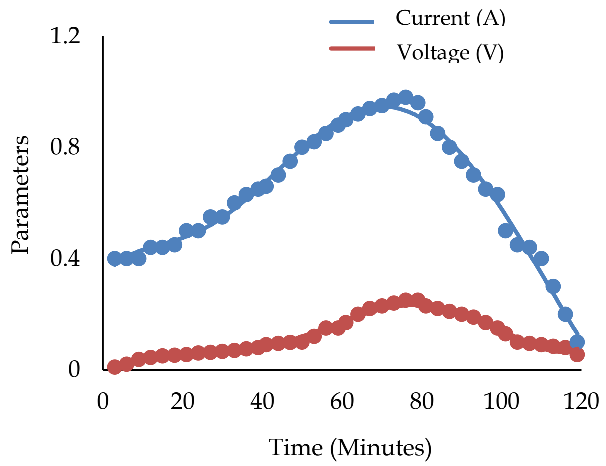

Figure 6. The relationship between time to current and voltage parameters in parallel configuration

In Figure 6, the highest current and voltage values in the parallel configuration coincide at the 78th minute, reaching 0.98 A and 0.25 V. These results show that in parallel circuits on the TEG, the current difference increases, and the voltage tends to remain constant. This is because the total current from each branch causes a total current more significant than the voltage produced (Morelli, 2023).

Increasing temperature also causes the resulting voltage and current to increase. On the other hand, when combustion is stopped, the temperature will decrease, resulting in the voltage and current declining. This can be seen in the series configuration measurements at the 87th and 99th minutes. The current strength and voltage decreased. Meanwhile, in the parallel configuration, it decreased at 81 minutes. The longer the heating time, the greater the temperature difference obtained (Khalid et al., 2016). This will directly impact the value of the electrical energy produced by TEG.

Conclusion

TEG converts thermal energy into electrical energy using the results of burning rice husks using a biomass stove, with two configurations: series and parallel. A series circuit produces a large voltage and a small current. Meanwhile, parallel circuits produce large currents and small voltages. The series configuration produces the highest with respective values of current 0.09 A and voltage 1.02 V, and the parallel configuration TEG produces the highest with respective values of current 0.98 A and voltage 0.25 V. The highest temperature difference reaches 30.5°C in the series configuration and 31.8°C in the parallel configuration. The longer the burning time, the more significant the resulting temperature difference. Likewise, the greater the electric current and voltage, the longer the burning time.

Acknowledgments
Thank you to the entire team at the Physics Laboratory, Faculty of MIPA UNG, for their assistance so that this research was carried out well.

Author Contributions
Nuraliva F.P. Lapananda: Conceptualization, methodology, writing—original draft preparation; Asri Arbie: Methodology; Muhammad Yunus: Curation, conceptualization; Muh. Fachrul Latief: Writing—review and editing, curation; Septiana Kurniasari: Formal analysis; Icha Untari Meidji: Validation, formal analysis.

Funding
This research received no external funding

Conflicts of Interest
The authors declare no conflict of interest.

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