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Optimization of Thermoelectric Generator (TEG) Configuration for Burning Sugarcane Bagasse as an Alternative Energy Source

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Abstract: Sugarcane bagasse is waste from the sugar industry which has the potential to be an efficient fuel for producing electricity by converting heat energy into electrical energy using a Thermoelectric Generator (TEG). TEG can be optimized to burn sugarcane bagasse as an alternative energy source in Indonesia. This research uses series and parallel configurations to test the optimal TEG configuration to increase energy conversion efficiency. The research results revealed that supercapacitors' parallel configuration produced the highest power in the 66th minute at 0.26 W. In comparison, the series configuration with supercapacitors produced 0.21 W of power in the 63rd minute. For the parallel configuration without supercapacitors, the energy produced reaches 0.20 W in the 69th minute, and the series configuration without supercapacitors produces 0.19 W in the 63rd minute. The parallel configuration shows more optimal performance than the series configuration, making it a promising solution in diversifying energy sources, especially in supporting efforts to utilize agricultural waste sustainably. Optimization of the thermoelectric generator configuration for burning sugarcane bagasse can be used as an alternative energy source.

Keywords: Energy; Thermoelectric Generator; Sugarcane bagasse

Introduction

Sugarcane is one of the most abundant natural resources in Indonesia. Stockpiling bagasse over a certain period causes problems for factories. This material has the potential to be flammable, pollute the surrounding environment, and take up quite a large area of land for storage (Riajaya et al., 2022; Nurbaeti et al., 2018). Bagasse is biomass from solid waste produced from grinding sugar cane stalks (Saccharum officinarum) in the sugar industry. The amount of bagasse produced in the sugar cane processing industry can reach 90% of each cane processed. So far, the use of bagasse as raw material for making particle board, boiler fuel, organic fertilizer, and animal feed is limited and has low economic value (Setiati et al., 2016; Yudo & Jatmiko, 2008). Wasted sugarcane bagasse can be used as an alternative energy source.

Currently, demand for renewable energy continues to increase, while fossil fuel reserves are increasingly depleting, and the impact of environmental pollution due to the use of fossil energy is an issue that is widely discussed (Yi et al., 2023; Holechek et al., 2022; Osman et al., 2023). One of the things being discussed is a solution to reduce the use of fossil energy. As an archipelagic country, Indonesia has abundant Renewable Energy resources and excellent development potential (Raihan, 2023; Gani et al., 2024). These resources include water, sun, wind, geothermal, ocean waves, ocean waves, biomass, and nuclear (Muharnif et al., 2022; Pramudiyanto & Suedy, 2020).

Energy sources can be divided into two types based on their electricity production capacity: macro and micro (Prabhu & Mukhopadhyay, 2023; Uddin et al., 2023). One example of the application of micro capacity is the utilization of heat from burning biomass using a Thermoelectric Generator (TEG). TEG is an alternative

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technology that can efficiently convert heat energy into electrical energy and can be applied on a large and small scale (Win et al., 2024; Khalid et al., 2016; Sasmita et al., 2019; Saha et al., 2023; Manghwar et al., 2024).

Thermoelectric is pairs of semiconductors that transmit electricity from a material's heating process, which can be arranged in series or parallel. The thermoelectric junction and its electrical interconnections are sandwiched between two ceramic substrates (Basu, 2023; Siregar, 2022). Thermoelectricity is a phenomenon that converts temperature differences into electrical energy or vice versa; electrical energy is converted into temperature differences. This phenomenon has been developed into modules that can be used as electricity generators or as devices for cooling and heating (Rafika et al., 2016; Puspita et al., 2017). TEG can be applied to the automotive industry, converting industrial waste heat into electrical power and utilizing industrial waste into electrical energy. One example of industrial waste that can be optimized into electrical energy is sugarcane bagasse (Du & Wu, 2024; Asaduzzaman et al., 2023; Jouhara et al., 2021; Punin et al., 2018).

Based on the explanation of the implementation of TEG, we will create a TEG configuration design to produce alternative energy by utilizing the heat from the biomass stove plate produced by burning sugarcane bagasse as fuel to produce electrical power. The heat of the stove plate will be converted into electrical energy using a TEG. TEG will be designed using 48 modules arranged in series and parallel. By using this solution, the heat produced by the biomass stove plate, which was previously wasted, can be used efficiently to produce electrical energy.

Method

The research methods include TEG configuration design, data collection techniques, and data analysis. The tools and materials used in this research include TEG type SP-1848-27145, Digital Multimeter, Thermometer, Heatsink, Supercapacitor, Stopwatch, Biomass Stove, Iron Cover, Sugarcane Bagasse, and Moisture Meter. The TEG configuration design consists of two types: series and parallel. In the series configuration, several thermoelectric modules are connected sequentially to increase the voltage cumulatively, as shown in Figure 1. Meanwhile, in the parallel configuration, which can be seen in Figure 2, each module produces a voltage based on the temperature difference at both ends, with the current from each module being added together to make a larger output.

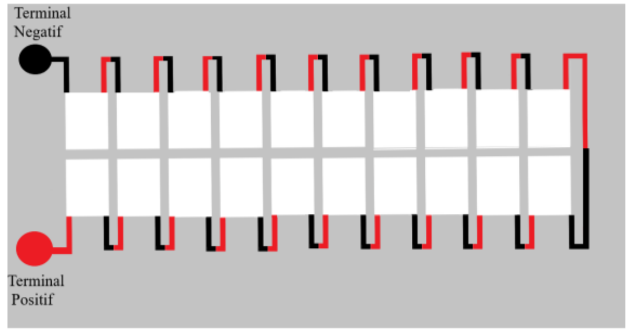

Figure 1. Series configuration on TEG

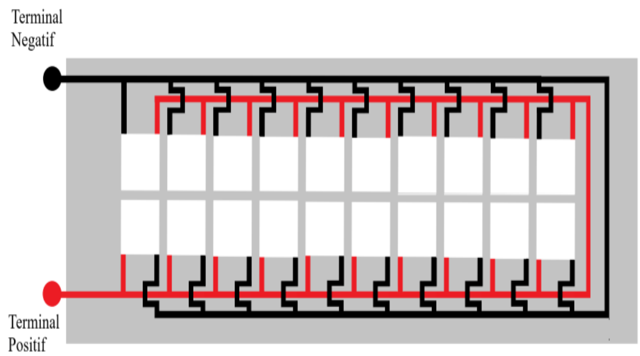

Figure 2. Parallel configuration on TEG

The research began by preparing 8 kg of bagasse fuel with a low water content. Then, the prepared bagasse is put into the kiln. Then, the 48 TEG pieces are assembled in series and parallel by attaching the heatsink to the top of the TEG circuit like the flow chart of research in Figure 3. The TEG is assembled on an iron cover plate that covers the stove. Next, measure the temperature of the plate cover as the hot side using thermometers on eight different sides. The heatsink temperature is measured as the cool temperature on eight different sides. Finally, measurements of the voltage and current produced without or using a supercapacitor were taken.

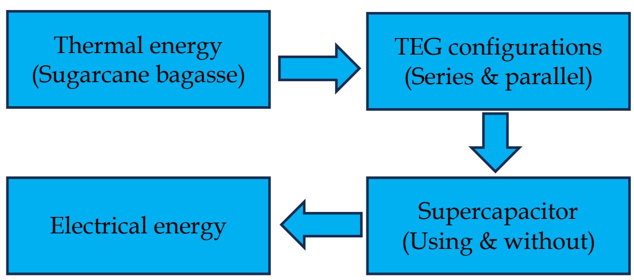

Figure 3. Flow chart of research

Result And Discussion

Power is the amount of energy absorbed or produced in an electrical system. Energy sources, such as voltage and current, can produce electrical energy.

Power can be considered energy consumption in an electrical system or circuit (Galih & Eko, 2022).

Power of TEG Design Using Supercapacitors

Research data regarding the burning of bagasse biomass in TEG designs in both series and parallel configurations obtained the electric current and voltage. These two parameters are used to calculate electrical power using the formula $V \times I$. For information, V is voltage (V), and I is current (A) (Mamur & Ahıska, 2014; Cekdin et al., 2020).

Based on the research results, the power in series and parallel configurations obtained when using supercapacitors shows in Figure 4.

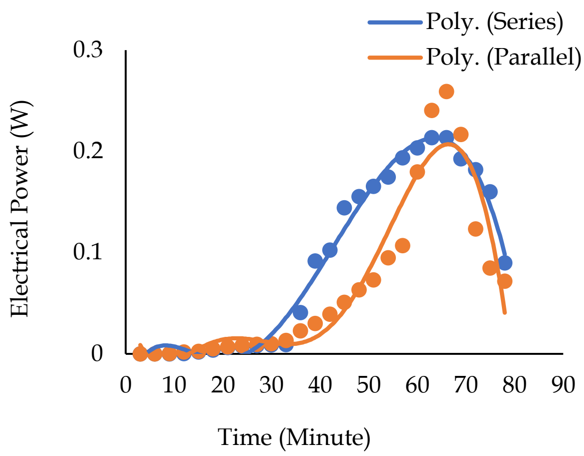

Figure 4. Comparison graph of electrical power between series and parallel configurations

Based on Figure 4, it can be seen that in the power comparison between series and parallel configurations. The parallel configuration shows the highest power value of 0.26 W. Meanwhile, the series circuit produces 0.21 W of power. Electrical power depends on the voltage and current produced by the TEG. The application of supercapacitors in TEG has excellent potential to be developed to store electrical energy. This is due to the supercapacitor's ability to store energy with high density, power, and faster charging speeds. Therefore, using supercapacitors can increase electrical power significantly (Riyanto, 2014).

Table 1. Power results using supercapacitors

Configuration	Time (Minutes)	Current (A)	Voltage (V)	Power (W)
Series	63rd	0.21	1.02	0.21
Parallel	66th	1.04	0.25	0.26

Table 1 shows that the power yield in the parallel configuration is higher than in the series configuration. The research results revealed that supercapacitors' parallel configuration produced the highest power in the 66th minute at 0.26 W. In comparison, the series configuration with supercapacitors produced 0.21 W of power in the 63rd minute. The use of supercapacitors has a significant impact because they have a large electrode surface and a thin dielectric material, so they can achieve much higher capacitance than without the use of supercapacitors. Therefore, supercapacitors are a very effective solution as an energy storage device (Riyanto, 2014). Optimization of the thermoelectric generator configuration for burning sugarcane bagasse can be used as an alternative energy source.

Power of TEG Design Without Using Supercapacitors

Based on research, the power output results in series and parallel configurations obtained without using supercapacitors shows in Figure 5.

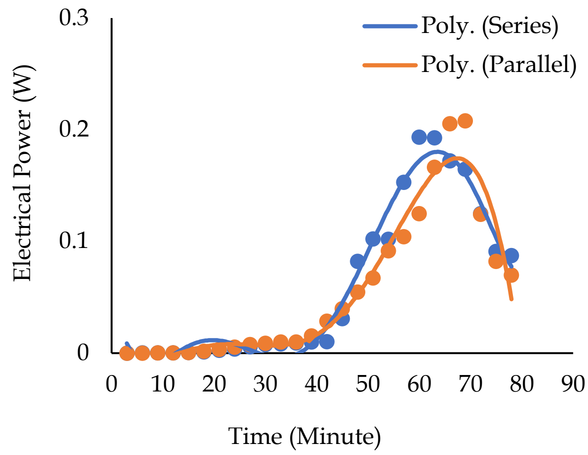

Figure 5. Comparison graph of electrical power between series and parallel configurations

Figure 5 shows that the parallel configuration produces more power than the series configuration. In the parallel configuration, the maximum power reaches 0.20 W, while in the series configuration, it reaches 0.19 W. The parallel configuration shows more optimal performance than the series configuration, making it a promising solution in diversifying energy sources, especially in supporting efforts to utilize agricultural waste sustainably. Table 2 compares the maximum power in series and parallel configurations.

Table 2. Power results without using supercapacitors

Configuration	Time (Minutes)	Current (A)	Voltage (V)	Power (W)
Series	63rd	0.19	1.02	0.19
Parallel	69th	1.02	0.20	0.20

Based on Table 2, the parallel configuration without supercapacitors, the energy produced reaches 0.20 W in the 69th minute, and the series configuration without supercapacitors produces 0.19 W in the 63rd minute. When not using a supercapacitor, the output value is obtained directly from the TEG terminal. As a result, the output is lower than that of supercapacitors. Temperature differences significantly impact the output produced by TEG (Hamida et al., 2021). Optimization of the thermoelectric generator configuration for burning sugarcane bagasse can be used as an alternative energy source.

Conclusion

The effect of time on the value of electrical power using a supercapacitor is that the longer the combustion lasts, the greater the voltage and current produced so the electrical power also increases. Conversely, when combustion is stopped, the current and voltage decrease, which results in a reduction of the power value. The parallel configuration using supercapacitors produces the highest power of 0.26 W, while the series configuration is 0.21 W. The parallel configuration without supercapacitors produces 0.20 W of power, and the series configuration produces 0.19 W. The electrical power in series and parallel configurations using supercapacitors is higher than those without supercapacitors. So, optimization of the thermoelectric generator configuration for burning sugarcane bagasse can be used as an alternative energy source.

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Author Contributions
Rahmiaty Abd. Karim: Conceptualization, methodology, writing—original draft preparation; Asri Arbie: Methodology; Muhammad Yunus: Curation, conceptualization; Mursalin: Writing—review and editing, curation; Dewa Gede Eka Setiawan: Formal analysis; Haerul Ahmadi: Validation, formal analysis.

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Conflicts of Interest
The authors declare no conflict of interest.

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