ANALYSIS OF THERMOELECTRIC POTENTIAL SP1848-27145 SA AS A POWER PLANT WITH UTILIZING THE HEAT ENERGY OF COMBUSTION

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This research is experimental and aims to determine the characteristics of the SP1848-27145SA generator thermoelectric module in the form of power generated and its performance as a power plant by utilizing heat energy from a combustion furnace. The method used in testing the thermoelectric characteristics of the generator is a direct experimental method by measuring the output voltage, current, hot side, and cold side of the thermoelectric and the power generated by the module attached to the combustion furnace. Thermoelectric testing of the SP1848-27145 SA generator as a power plant by utilizing heat energy from a combustion furnace with a maximum voltage generated electronic device load of 2.25 Volts at ΔT 46°C and a maximum generated power of 0.09 watt. The thermoelectric performance of the SP1848-27145 SA generator is obtained in three different configurations: single, series, and parallel. The highest thermoelectric power produced is in the series configuration, where the power obtained is 0.25 watts, while the results from the parallel arrangement have the same power value. very small, namely 0.02 watts, and the highest efficiency value only reaches 3.40%.

Keywords: Thermoelectric, Thermal Energy, Combustion Furnace

1. Introduction

Today's electrical energy plays an important role and is one of the primary human needs. In carrying out daily activities, electricity is also a cog in the economy. In the current era, with the increasing human population, the need for electricity is also increasing. Conventional energy is energy that is available in limited quantities [1]. One example of the most widely used conventional energy is fossil energy. The massive use of conventional energy sources has an impact on the limited availability of natural resources, especially in Indonesia.

The use of energy derived from fossil fuels also affects the ozone layer [2]. In the 21st century, humans are starting to realize the importance of clean energy in reducing carbon emissions. Efforts are made to utilize renewable energy. Consideration of energy use also includes how to use energy without destroying nature or the sustainability of the ecosystem on this earth. The use of clean energy is a big concern. One of the uses of new renewable energy is energy harvesting. Renewable energy is energy that comes from "sustainable natural processes". The history of renewable energy became known in the 1970s. As an effort to make an innovation so that energy does not run out quickly and to help offset the development of nuclear and fossil fueled energy [3]. The most common understanding of renewable energy is that it is an energy source that can be quickly renewed naturally, and the process is sustainable. In harvesting energy, there are many alternative energies that can be utilized, starting from vibrations, sound, electromagnetic signals, and heat that come from various sources [4].

The focus of this research is the utilization of heat energy. Thermal energy is energy that can easily be found in our daily lives, ranging from heat provided by nature, namely from the sun's heat, to heat that comes from chemical reactions, as well as heat generated by frictional machinery and furnaces. If this heat energy can be converted into electrical energy, it will certainly be able to help meet the increasing energy needs.

Thermoelectric technology is an alternative source for answering these energy needs. In addition to being more environmentally friendly, this technology is highly efficient, durable, and capable of producing energy on a large or small scale by using a thermodiocene generator that converts heat from heat energy sources into electricity. This is included to obtain renewable and environmentally friendly energy sources. The thermoelectric power generator is a power plant based on the seebeck effect, which was first discovered by a German scientist named Thomas Johann see beck in 1821. In his experiments, he connected copper and iron in a circuit. Between the two metals, a compass needle was placed, and when the metal side was heated, the compass needle turned out to move. This happens because the electric current that occurs in the metal creates a magnetic field; this magnetic field is what moves the compass needle. This phenomenon is then known as the seebeck effect [5].
Thermoelectric generators work by converting heat energy directly into electricity (thermoelectric generators) or vice versa, using electricity to produce cold (thermoelectric coolers) [6]. To generate electricity, the thermoelectric material is simply placed in such a way that it connects the hot and cold sources. In the circuit, a certain amount of electricity will be generated according to the type of material used. The work of thermoelectric coolers is not much different. If the thermoelectric material is electrified, the heat around it will be absorbed. Thus, to cool the air, a refrigeration compressor is not needed, as is the case in conventional refrigeration machines.

In this research, a Series and Parallel circuit of seven thermoelectric modules was made by utilizing the principle of the Seebeck effect as a generator. The source of heat energy used is burning charcoal as a heat source. This is to get a good temperature to ensure that the thermoelectric generator is suitable for use as a generator. Coupled with an aluminum plate as a heat conductor and heat sink, water cooling acts as additional cooling for the heat sink in the cooling process.

2. Materials and Methods

a. Types of research

This study is an experimental study. The method used in testing the thermoelectric characteristics of the generator is the direct experimental method by measuring the output voltage, current, hot, and cold sides of the thermoelectric, and the power generated by the module, which is attached to the combustion furnace. The measurements carried out produce data in the form of voltage and current obtained from the temperature difference. The data in the form of numbers will be processed and analyzed to obtain the values of power, efficiency, and the thermoelectric seebeck coefficient. Then the data is converted into graphic form and line equations to make it easier to understand, compare, and analyze.

b. Data Analysis Technique

The data analysis technique used in this research is descriptive quantitative analysis, where the results of the data are calculated using the calculation formula and then presented in graphical form to determine the characteristics of the relationship between voltage (V), current (I), power (VA), and temperature differences (ΔT).

\[ \alpha = \frac{V}{\Delta T} \]  
Information:
\( \alpha \) = Seebeck coefficient  
\( V \) = voltage  
\( \Delta T \) = Temperature difference between the two joints

\[ P = V \times I \]  
Information:
\( P \) = Power (Watts)  
\( V \) = Voltage (Volts)  
\( I \) = Current (Amperes)

\[ T_m = \frac{T_c + T_h}{2} \]  
Information:
\( T_m \) = Average TEG module temperature (°C)  
\( T_c \) = TEG module hot side temperature (°C)  
\( T_h \) = TEG module cold side temperature (°C)

\[ Z = \frac{\sigma S^2}{k} \]  
Information:
\( Z \) = Figure of merit  
\( \sigma \) = Electrical conductivity of the material (0.053 Ω-1 m-1).  
\( S \) = Seebeck Coefficient (V/°C)  
\( k \) = Thermal conductivity of material (W/m °C) (0.8 W/m°C)

\[ \eta = \left( 1 - \frac{T_c}{T_h} \right)^{\frac{1 + 2T_m - 1}{1 + 2T_m - T_h} \times 100\%} \]  
Information:
\( \eta \) = Generator thermoelectric efficiency  
\( T_m \) = Average temperature (°C)  
\( T_c \) = Cold side temperature TEG (°C)  
\( T_h \) = Hot side temperature TEG (°C)
3. Results

Based on the research results, the thermoelectric module produces characteristics in the form of curve diagrams, and the results of quantitative analysis with control variables show generated power, efficiency, and performance. Then, with the data obtained from the TEG SP 1848-27145 SA module, the data is processed using a quantitative method. Characteristics of the SP1848-27145SA generator thermoelectric module with a single configuration: 7 modules in series and 7 modules in parallel. Then the results of data processing and calculations. Thermoelectric characteristics can be seen by graphing the relationship between voltage (V), current (I), and temperature difference (ΔT), then a graph of the resulting power comparison from the three configurations, as well as a graph of the voltage difference generated.

![Experiment Design Results](image)

**Table 1. Single TEG Module Configuration Measurement Instruments**

<table>
<thead>
<tr>
<th>Time (Minute)</th>
<th>Temperature (°C)</th>
<th>ΔT (°C)</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (VA)</th>
<th>Resistance in (Ω)</th>
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</thead>
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<td>Th (°C)</td>
<td>Tc (°C)</td>
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<td><strong>2</strong></td>
<td><strong>0,05</strong></td>
<td><strong>0,02</strong></td>
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**Table 2. Measurement Instrument Configuration of 7 Modules in Series**

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<th>Time (Minute)</th>
<th>Temperature (°C)</th>
<th>ΔT (°C)</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (VA)</th>
<th>Resistance in (Ω)</th>
</tr>
</thead>
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<tr>
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<td>Th (°C)</td>
<td>Tc (°C)</td>
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<td></td>
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<td>30</td>
<td>10</td>
<td>0,7</td>
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<td>0,03</td>
</tr>
<tr>
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<td>0,05</td>
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<tr>
<td><strong>Average</strong></td>
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<td></td>
<td><strong>2,2</strong></td>
<td><strong>0,05</strong></td>
<td><strong>0,07</strong></td>
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**Table 3. Measurement Instrument Configuration of 7 Modules in Parallel**

<table>
<thead>
<tr>
<th>Time (Minute)</th>
<th>Temperature (°C)</th>
<th>ΔT (°C)</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (VA)</th>
<th>Resistance in (Ω)</th>
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</thead>
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<td>0,09</td>
<td>0,04</td>
</tr>
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<td>0,05</td>
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<tr>
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<td>64</td>
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<td>16</td>
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<td>0,12</td>
<td>0,05</td>
</tr>
<tr>
<td>30</td>
<td>65</td>
<td>50</td>
<td>15</td>
<td>0,3</td>
<td>0,09</td>
<td>0,02</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>0,4</strong></td>
<td><strong>0,09</strong></td>
<td><strong>0,02</strong></td>
</tr>
</tbody>
</table>
4. Discussion

The voltage on a single thermoelectric configuration can produce a minimum voltage of 0.5 volts with an $\Delta T$ of 12 °C, and the maximum voltage that can be generated is 3.3 volts with an $\Delta T$ of 91 °C. The graph experiences a sharp rise at 1.9 V to 2.5 V, where the $\Delta T$ is 35 to 37 °C. The internal resistance value of the thermoelectric module is 4.2 $\Omega$.

![Figure 1. Graph of Voltage (V) and $\Delta T$ Single Configuration](image)

The graphical relationship between the temperature difference ($\Delta T$) and the current in the thermoelectric can be seen in Figure 2. From the results of measuring current with a load of 1 $\Omega$, two thermoelectric configurations in series can produce a minimum current of 0.03 amperes when $\Delta T$ is 12 °C, and the maximum current that can be generated is 0.06 amperes at $\Delta T$ of 91 °C.

![Figure 2. Graph of Current Relationship with ($\Delta T$) Single Configuration](image)

In Figure 3, the current in a single thermoelectric configuration can produce a minimum current of 0.03 Amperes with a Voltage (V) of 0.5 V, and the maximum current that can be generated is 0.06 Amperes with a Voltage of 3.3 V. The graph experiences a non-linear increase from 1.1 V to 2.5 V, where the resulting currents are 0.04 and 0.05 Amperes.
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In Figure 4, the current in a single thermoelectric configuration can produce a minimum power of 0.01 VA with an efficiency of 2.50%, and the maximum power that can be generated is 0.05 VA with an efficiency of 7.20%. The graph experienced a non-linear increase at 0.07 VA towards 0.15 VA, where the resulting efficiencies were 4.70% and 7.20%.

In Figure 5, the voltage on the Thermoelectric configuration of the Series 7 module can produce a minimum voltage of 0.7 volts with $\Delta T$ of 10 °C, and the maximum voltage that can be generated is 3.6 volts with $\Delta T$ of 29 °C. The graph experiences a non-linear increase at 1.8 V to 3.2 V, where the $\Delta T$ is 17 to 24 °C. Then the data obtained from the measurement results shows that the voltage generated by the thermoelectric module only reaches 3.6 Volts due to the resistance in the module, which reaches 3 kilos $\Omega$. This affects the voltage generated by the thermoelectric module.

In Figure 6, measuring current with a load of 1 $\Omega$ on the thermoelectric configuration of Series 7 can produce a minimum current of 0.04 amperes when $\Delta T$ is 14 °C, and the maximum current that can be generated is 0.07 amperes when $\Delta T$ is 29°C.
The current generated by the thermoelectric module is very small, because it is influenced by the internal resistance, which is 3 Kilo Ω, this greatly affects the output of the thermoelectric module: the higher the internal resistance value, the lower or smaller the current generated by a thermoelectric module in producing electric current.

\[ y = 0.006x + 0.0307 \]
\[ R^2 = 0.922 \]

Figure 6. Graph of Current Relationship with \( \Delta T \) Series Configuration

In Figure 7, the current in the Series 7 thermoelectric configuration can produce a minimum current of 0.04 Amperes with a Voltage (V) of 0.7 V, and the maximum current that can be generated is 0.07 Amperes with a Voltage of 3.6 V. The graph shows a non-linear increase from 1.4 V to 3.2 V, where the resulting currents are 0.04 and 0.06 Amperes.

\[ y = 0.006x + 0.0307 \]
\[ R^2 = 0.922 \]

Figure 7. Graph of Current and Voltage Relationship (V) Series Configuration

In Figure 8, the current in the Thermoelectric configuration of the 7 Series can produce a minimum power of 0.03 VA with an efficiency of 2.50%, and the maximum power that can be generated is 0.25 VA with an efficiency of 3.90%. The graph experienced an increase that was not constant from 0.05 Watt to 0.25 VA, where the resulting efficiency was 3.00% and 3.90%, respectively.

\[ y = 0.0026x + 0.0225 \]
\[ R^2 = 0.7685 \]

Figure 8. Efficiency Graphic Relationship (%) With Power (VA) Series Configuration
In Figure 9, the voltage in the thermoelectric configuration of 7 parallel modules can produce a minimum voltage of 0.4 volts with ΔT of 19 °C, and the maximum voltage that can be generated is 0.5 volts with ΔT of 16 °C. The graph decreases by 0.3 V at a temperature difference of 15°C.

Figure 9. Graph of the Relationship of Voltage (V) with ΔT in Parallel Configuration

In Figure 10, the current in the thermoelectric parallel configuration of 7 pieces can produce a minimum current of 0.4 Amperes with a Voltage (V) of 0.07 V, and the maximum current that can be generated is 0.12 Amperes with a Voltage of 0.4 V. There is a decrease, and the current voltage is 0.09.

Figure 10. Current Graph Relationship with ΔT Parallel Configuration

In Figure 11, the current in the 7 parallel thermoelectric configurations can produce a minimum power of 0.02 VA with an efficiency (%) of 3.40%, and the maximum power that can be generated is 0.05 VA with an efficiency of 2.50%. The graph has decreased from the resulting efficiency measurement results of 3.40% to 2.30%.

Figure 11. Graphical Relationship between Efficiency (%) and Power (VA) in Parallel Configuration

Based on Figure 12, the power generated by the Series configuration is higher than the single and Parallel configurations. The thermoelectric configuration arranged in series has a greater power output of 0.18 watts than the single configuration of 0.04 watts, and the thermoelectric configuration arranged in parallel has a power output of 0.05 watts. The parallel arrangement
produces the lowest power compared to other configurations. This proves that to obtain the desired maximum power when using the SP1848-2715 SA Thermoelectric, a series connection can be used in the configuration arrangement.

![Figure 12. Graph of Power Comparison (VA) for Series, Single and Parallel Configurations](image-url)

Based on Figure 13, the voltage generated by the Series configuration is higher than the single and Parallel configurations. In the thermoelectric configuration arranged in series, the voltage that is raised is greater, namely 3.6 V, compared to the single configuration of 3.3 V, and the thermoelectric configuration arranged in parallel is 0.5 V. Parallel arrangements produce the lowest Voltage compared to other configurations. This proves that to generate the desired maximum voltage when using the SP1848-2715 SA Thermoelectric, a series connection can be used in the configuration arrangement.

![Figure 13. Graph of Comparison of Voltage (V) and Time (Minutes)](image-url)

In Figure 14, we can see that in all single and series configurations, the greater the value of ΔT is the greater the efficiency value. In a single thermoelectric configuration, the efficiency generated is greater than in series and parallel configurations. The series arrangement produces the highest power at ΔT 78 °C, which is equal to 7.10%. The parallel configuration produces the lowest efficiency of the other configurations at ΔT 91 °C, which is 2.10%. This proves that to obtain the desired maximum efficiency when using a TEG SP1848-27145 SA Thermoelectric, a series connection can be used in the configuration arrangement.
Figure 14. Graph of Comparison of Efficiency (%) and $\Delta T$ in Single, Series, Parallel Configurations

In Figure 15, the power generated is too small, namely 0.09 watts, where the efficiency value reaches 4.80%. So that thermoelectricity used in producing electrical energy cannot be stored in a power bank. Because the current and voltage drop when a load is applied. The current generated by the thermoelectric module does not reach 1 ampere, where the voltage and current are directly proportional to get power. The maximum power generated by the thermoelectric is 0.09 watts, so in testing the thermoelectric module when loaded, there is a decrease in performance because the current and voltage generated are too small.

Figure 15. Graph of the relationship between Efficiency (%) and Power (Watts) with Electronics

5. Conclusions

The thermoelectric performance of the SP1848-27145 SA generator as a power plant by utilizing heat energy from the combustion furnace is obtained from 3 different configurations: single, series, and parallel. The highest thermoelectric power produced is obtained in a series configuration, where the power obtained is 0.25 watts, while the results of the parallel arrangement have a very small power value of 0.02 watts and the highest efficiency value only reaches 3.40%. In this study, the heat source from the combustion furnace was the residual heat that was wasted from the fuel, namely charcoal, so that the temperature obtained was unstable and constant. Then for the configuration of the series arrangement, it is most suitable for use for generating electrical energy because of the power produced, but from all the results of measuring the efficiency values of the three thermoelectric configurations, the resulting power value does not reach 1 Watt even though it has used water cooling, so that the thermoelectric performance in producing energy is very low.

References

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