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A Comparative Analysis of Thermoelectric Generator Type SP1848-27145 SA Using Three Circuit Variations

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ABSTRACT
Thermoelectric generators (TEGs) are devices that convert heat energy into electrical energy based on the Seebeck effect. This study analyzes the performance of the SP1848-27145 SA thermoelectric generator using three different circuit configurations to determine the most efficient setup for power generation. The research evaluates the voltage, current, power output, and efficiency of each configuration under controlled temperature conditions. The experimental results indicate that different circuit arrangements significantly affect the power output of the thermoelectric generator. The series configuration produced the highest voltage output, while the parallel configuration generated a higher current. The hybrid configuration (a combination of series and parallel) provided a balance between voltage and current, resulting in optimal power efficiency. These findings contribute to the optimization of TEG applications in renewable energy systems, especially in low-power generation scenarios. Further studies could explore heat dissipation techniques and advanced materials to enhance thermoelectric efficiency.

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INTRODUCTION

The development of renewable and environmentally friendly alternative energy needs to be carried out in order to meet energy needs and survival, therefore a tool is needed that can capture temperature differences into electrical energy for thermoelectric generators. The need for electrical energy cannot be separated from the needs of living things in carrying out daily activities. This has an impact on the increasing rapid growth in the field of technology, the need for energy will also increase, but not all energy sources currently used can be renewed so that over time this fossil fuel source will run out. For example, non-renewable energy is conventional energy. Conventional energy is energy that is available in limited quantities. One example of the most widely used conventional energy is fossil energy. (Muhammad Ady Pradana, 2020).

Now the availability of energy in Indonesia is decreasing. This is caused by the decreasing energy sources, due to the imbalance between the needs and the amount of energy available. In the development of technology today, many alternative energy and new renewable energy are planned to reduce the impact of global warming. However, the availability of new renewable energy sources in Indonesia has not been utilized optimally. maximum. This research was conducted based on the utilization of new renewable energy sources, especially geothermal energy to produce electrical energy, namely using a thermoelectric generator (TEG) as an alternative energy source. Thermoelectric generators can convert temperature differences into electrical quantities directly, but TEG still has several shortcomings, namely having a low efficiency value of 10%. Things that reduce efficiency are the heat convected in the TEG is not perfectly absorbed and the cooling system is not perfect so that the TEG cannot work optimally. This is the basis for this research, namely designing a heat insulation system to maximize the work of the TEG module. In addition, the utilization of electrical power results is carried out to charge the battery as an alternative energy producer. (Shanti Candra Puspita et al., 2017)

Thermoelectric generators have long been used to generate electrical energy where when a temperature difference occurs between two different semiconductor materials, this thermoelectric module will flow current so that it produces voltage. In general, the utilization and working principle of the thermoelectric generator module is almost the same as in solar panels considering that the capacity of the electrical power that can be produced is not too large as a battery charger, but the advantage of the thermoelectric generator can be used at any time considering the availability of unlimited heating sources, therefore this study was conducted to find out more about the potential of the SP1848 27145 SA type thermoelectric generator when assembled in series, parallel and series parallel which later from the three testing processes will It is known how much voltage, current and electrical power can be generated in each circuit test.

Literature Review

Previous Research

In this final project research, a literature study will be conducted as a search for references that are relevant to the case or problem to be solved. The sources used include books, articles and related journals. Research related to Thermoelectric Generators has been conducted by several universities and research institutions in Indonesia itself or abroad.

According to (Sumarjo, 2017) with the research title "Utilization of heat sources in stoves using 10 thermoelectric generators arranged in series for lighting applications". Thermoelectric generators are one of the alternative energies that use a temperature difference system to produce electrical energy. In this thermoelectric generator system, a stove is used as a medium for utilizing the heat needed. The thermoelectric system that we studied used 10 TEG-SP1848-27145 SA thermoelectrics arranged in series with variations in combustion media in the form of firewood, LPG gas and spiritus. The use of different combustion media affects the voltage output provided by the thermoelectric. The temperature difference between the cold side and the hot side of the thermoelectric generator (ΔT) when stable is 35 ° C using wood fuel, 39 ° C using LPG gas fuel and 20 ° C using spiritus fuel. The optimal voltage provided using LPG gas fuel with (ΔT) 39°C with an output of 1.62 Volts (Sumarjo, J., et al., 2017).

According to (Adriyani Rusli, 2019). with the research title "Conversion of Heat Energy into Electrical Energy Using a Thermoelectric Generator" In this final project, a

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Conversion of Heat Energy into Electrical Energy Using a Thermoelectric Generator was carried out. The goal to be achieved is to find out how a thermoelectric generator converts heat energy into electrical energy. The methods used include literature studies, taking tools and materials, designing, and data collection. From the design results, it can be concluded that the heat of the fire absorbed by the Heansink is then distributed to the Thermoelectric Generator at 01:00 to 01:10 with an average voltage of 1.46 V to 6.15 V, a current of 0.04 A to 0.15 A, and a power of 0.0584 W to 0.9225 W. From the results of the experimental observations carried out, the difference in input and output currents experienced a significant difference from the input voltage, which was 2.32 V, while the output was 12.15 V, 13.55 V, 14.76 V, 15.43 V, 16.23 V, 17.55 V, 18.87 V, 19.43 V, 20.32 V, 21.54 V, 22.84 V, 23.66 V, 24.54 V, 25.32 V to 26.67 V. After we get a voltage of 26.67 V, we can adjust the voltage that will turn on each load (Rusli, A., et al., 2019).

According to (Pradana, 2020) with the research title“Prototype Generator Thermoelec tric Generator Using Aluminum, Brass, and Zinc Heat Conductors” alternative energy that can be utilized to meet electricity needs is solar energy. The use of this energy can be done by utilizing light radiation and its heat temperature. The purpose of this study is to create a prototype of a thermoelectric generator using aluminum, brass and zinc heat conductors. The heat source used in this study is sunlight, so that it will be able to provide a recommendation for an electricity generating device using the seeback method. The results of the highest electrical voltage output obtained when using a brass heat conductor plate with a thickness of 1mm by assembling TEG in series using ice water obtained 9.2 Volts on the 10th day, then using a zinc plate with a TEG series circuit obtained 3.56 Volts on the 1st day, and the last using an aluminum plate with a TEG series circuit obtained 2.95 Volts on the 5th day with an average temperature produced by TEG of 53.53 ° C during the 10-day test period (Pradana, et al., 2020).

According to (Sasmita, 2019). with the research title "Alternative Electric Power Generation Using Thermoelectric Generator Principles" Thermoelectric power generation (Thermoelectric Generator, TEG) has been used to generate electrical energy, the working principle of TEG, the temperature difference between two materials, will flow current, and produce a potential difference. This principle is known as the "Seebeck effect" which is the opposite phenomenon of the Peltier effect (Thermoelectric Cooling, TEC). This study was conducted to determine the capacity of electrical energy generated for 10 TEG modules in series. Testing was carried out by utilizing heat energy from asphalt, water flow and connected to 10 TEG modules. The test results showed that the maximum voltage was 18Voltdc 0.49Ampere (Sandy, et al., 2019). From the research above, it is found that there are differences from related research that only use series and parallel circuits without even using a test circuit, while the research proposed by the author utilizes three types of circuits, namely series, parallel, and series parallel. From this test, it can also be seen how much output voltage can be achieved by the SP1848 27145 SA type thermoelectric generator in testing using a series parallel circuit against temperature differences.

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Thermoelectric Generator

Thermoelectric Generator is a technology for generating electricity using heat energy. This tool uses a component called "Peltier". In general, Peltier is a ceramic that can produce heat and cold energy if given voltage. The way this generator works is if there is a temperature difference of more than 30 ° C between the two sides of the Peltier, the Peltier will produce electricity (Adriyani Rusli, 2019).

Thermoelectric components work by converting heat energy into electricity directly (thermoelectric generator), or with the opposite function, namely from electricity to produce cold (thermoelectric cooler). To obtain electricity, thermoelectric components are simply placed in such a way in a circuit that connects the heat and cold sources. The prototype that designed to produce a certain amount of electricity according to the type and amount of material used The work of thermoelectric coolers is not much different. If the thermoelectric component is electrified, the heat around it will be absorbed. Thus, to cool the air, there is no need to use a cooling compressor like conventional cooling machines. For the purposes of power generation, the materials generally used are semiconductor materials. Semiconductors are materials that can conduct electric current but not perfectly. The semiconductors used are n-type and p-type. The semiconductor materials used are extrinsic semiconductor materials. The problem for thermoelectrics is to obtain materials that can work at high temperatures (Muhammad Ady Pradana, 2020).

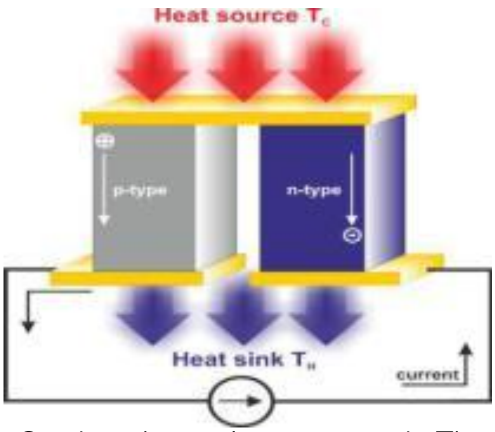

Figure 1. Semiconductor Arrangement in Thermoelectrics

The temperature difference in the two components Bismuth and Telluride causes the movement of electrons from the negative pole to the positive pole, the greater the difference temperature, the faster the electron movement, so the current produced will be greater (Sandy Anggriawan Sasmita, et al., 2019).

$$\Delta T = TH-TC............... \quad (1)$$

Basically, a thermoelectric generator consists of three basic components according to (Vasquez, et al. 2002), namely:

a. Supporting structure, which is the place where the thermoelectric components are placed, as researchers have placed them in the exhaust gas flow and some have only utilized the heat of the exhaust gas channel walls to avoid any... *back pressure*exhaust gas flow.

b. Thermoelectric components that depend on the temperature range, thermoelectric materials that can be used can be materials *silicon germanium*, lead telluride, and bismuth telluride.
c. Heat dissipation system, which regulates heat transmission through thermoelectric modules.

Currently, thermoelectric modules have been widely used for various applications as thermoelectric coolers or better known as TEC by utilizing the thermoelectric generator effect and as thermoelectric generators or commonly known as TEG which function as power generators with apply effect Seebeck. Temperature difference in thermoelectricity generator obtained with the formula:

How Thermoelectric Generators Work

Thermoelectric technology works by converting heat energy into electrical energy directly (thermoelectric generator), or vice versa, from electricity to produce cold (thermoelectric cooler). To generate electricity, thermoelectric materials are simply placed in such a way in a circuit that connects the hot and cold sources. From that circuit, a certain amount of electricity will be produced according to the type of material used. The work of thermoelectric coolers is not much different. If the thermoelectric material is supplied with electricity, the heat around it will be absorbed. Thus, to cool the air, no cooling compressor is needed as in conventional cooling machines (Muhammad Ady Pradana, 2020).

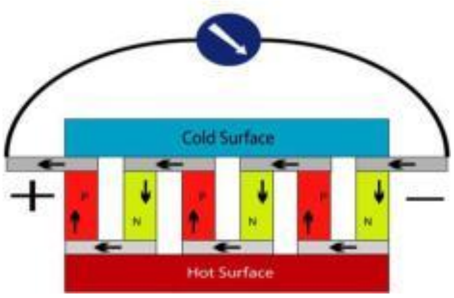

Figure 2. How a Thermoelectric Generator Works

The TEG structure can be seen in Figure 1. It shows the TEG structure consisting of an arrangement of N-type elements (electron deficiency material) and P-type (electron excess material). Heat enters on one side of the TEG and the heat is released through the other side. The heat transfer process produces a voltage that passes through the TEG structure connection and the magnitude of the voltage produced is proportional to the temperature difference (Sandy Anggriawan Sasmita, 2019).

AC Alternating Current

AC current or alternating current is a current that changes its polarity at certain intervals alternating current can be a periodic signal or a non-periodic signal periodic signal is a signal that is repetitive for a certain interval of time that is the same period which is usually expressed in a sinusoidal function The period of alternating voltage and current is the time required by the current and voltage to form one positive part and one negative part of its cycle. In other words, the period is the time to produce one full wave The period is the time required for one full wave to propagate Alternating Current or commonly abbreviated as AC is a type of alternating electric current. The idea of AC current was developed by Nikola Tesla in collaboration with the Westinghouse company and was used commercially in the mid-20th century. horizontal (short for alternating current) or commonly referred to as alternating current, is an electric current whose value changes with respect to time units. The most common source of AC current comes from electromagnetic induction, namely from an AC generator that is exclusively operated by the State Electricity Company (PLN) or from a portable generator (AC generator). The most common use of AC current is in households, where AC current is used as an energy source to power devices. electronics such as television, air conditioner (AC), home lights and so on. (Gideon, S., & Saragih, KP 2019).

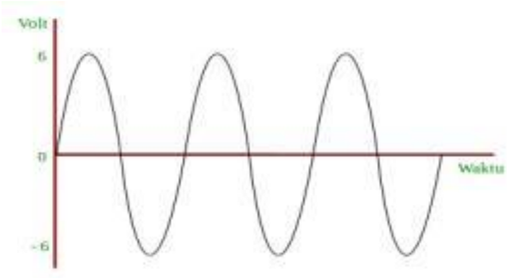

Figure 3. Full Period Sinusoidal Waveform (AC)

DC Direct Current

Solar or DC electric current has a fixed amplitude value and a predetermined direction of current flow. Direct Current or commonly abbreviated as DC is a type of direct current. The idea of DC current was developed by Thomas Alva Edison through his company, General Electric, and was used commercially in the late 19th century. The most commonly used DC current sources come from chemical processes, electromagnetic induction results, and even from renewable natural energy sources. DC current sources that come from chemical processes include batteries (Volta elements) and accumulators (commonly called accumulators). (Gideon, S., & Saragih, KP 2019). DC current sources that come from electromagnetic induction include dynamos (generators/DC motors). DC current sources that come from energy sources renewable nature is solar cells/panels, which utilize sunlight in their use. The most common use of DC current is car batteries, which are the source of electrical energy for electronic devices in cars such as car lights, tapes, cigarette lighters and so on. In theory, DC current is the flow of electrons from a point with higher electrical potential energy to another point with lower potential energy. The characteristics of DC current include:

a. The value of the electric current is always constant or constant with respect to changes in time;

b. The polarity always remains the same on each terminal and The waveforms of both I (current) vs t (time) and V (voltage) vs t (time) are horizontal, where the values of V and I always remain constant with respect to changes in time. (Gideon, S., & Saragih, K. P, 2019)

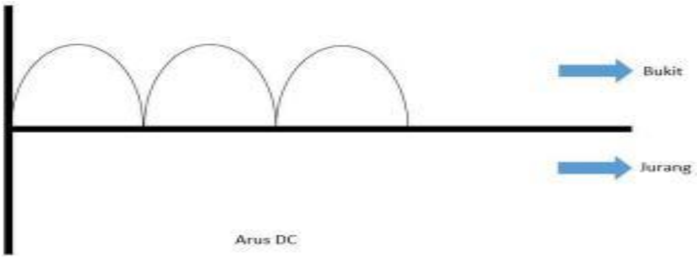

Figure 4. Direct Current (DC) Waveform

METHODS

The research method is a scientific way to obtain data with the purpose and use, the research method used is the design method. Design is a stage of activity to define or describe the results of an analysis of a system into technical language in order to get a clear and detailed picture of a component that is applied (Sugiyono, 2017). The research method used in this study is the experimental method, with this method the author continues to develop various research that has been carried out, both in terms of achieving results and those that have not been successful, so that from the development carried out, results can be obtained in accordance with the objectives to be achieved and of course it can still be done for improvement in further experiments. In the process of making research tools, it is divided into three stages, the initial stage is determining the materials, then determining the tools needed to help the tool making process and the final stage is the assembly and testing process. The main components in making a thermoelectric generator characteristic test tool include the following:

a. Thermoelectric generator
   The thermoelectric generator used in this study is the SP1848 27145 SA series as can be seen in Figure 5.

Figure 5. Thermoelectric Generator

b. Aluminum plate
   The aluminum plate used for making the experimental furnace is divided into sizes for the base section which has a thickness of 3mm while for the tank section at the top it has a thickness of 2mm as can be seen in Figure 6.

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Figure 6. Aluminum Plate

c. Water pump machine
   The water pump machine used here is an aquarium pump type machine as can be seen in figure 7.

Figure 7. Water Pump Machine

d. Thermal paste
   Thermal paste functions to coat the base of the cross-section and thermoelectric generator. By coating it with thermal paste, it is hoped that the heat and cold absorbed by the generator can be absorbed evenly.

Figure 8. Thermal Paste

e. Temperature sensor
   The temperature sensor used is the SK-28 Thermometer Hygrometer type, two of which will be placed on the hot side and cool side as can be seen in Figure 9.

Figure 9. Temperature Sensor

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f. Digital volt ampere
Volt ampere is used to measure the output voltage and current produced by the thermoelectric generator as can be seen in figure 10.

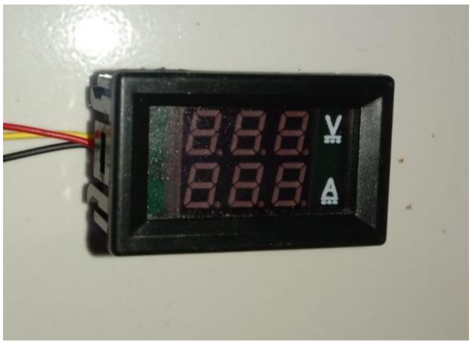

Figure 10. Digital Volt Ampere

g. Water hose
The water hose is used to connect the inlet and outlet lines to the tap in the cooling tank as can be seen in Figure 11.

Figure 11. Water Hose

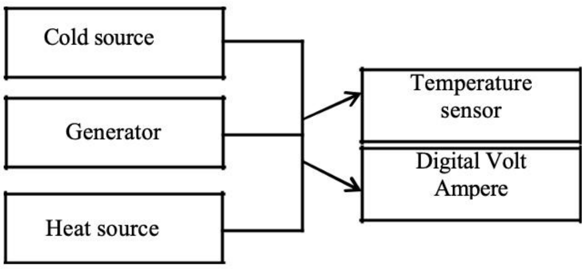

Figure 12. Design Schematic of Thermoelectric Generator Characteristics Tool

A block diagram is a picture of the entire system design that will be designed, each system has its own function. Block diagrams include the following:

a. Thermoelectric generators have two parts, namely hot side and cool side, a heat source used to heat the hot part of the thermoelectric generator using a spertus-fueled stove, and a cooling source to cool the cool side using a water-based cooling source.

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b. To measure the temperature on the cool side and hot side of the thermoelectric generator, the SKU-28 Thermometer Hygrometer is used.
c. To measure the output voltage and current of the thermoelectric generator, a digital ampere-volt meter is used.
d. Thermoelectric generators are arranged in series, parallel, or a mixture of series and parallel.

RESULT

In testing the characteristics of the thermoelectric generator, it is divided into two stages, the initial stage is by conducting a test without load, while in the 2nd stage of testing, it is carried out by adding a DC lamp load of 5-12 Volts. The data from the test results carried out on the tool or system made are as follows:

No-Load Testing

The results of the circuit testing produced the following research data: Series Circuit Thermoelectric Generator Test Results

Table 1. Series Circuit Thermoelectric Generator Test Data

NO	Th	Tc	ΔT	Voltage	Minute
1	32°C	24°C	8°C	5.8	0.13
2	28°C	22°C	16°C	8.87	0.16
3	46°C	22°C	24°C	10.58	0.46
4	57°C	22°C	35°C	12.04	0.52
5	63°C	19°C	44°C	19.19	0.78

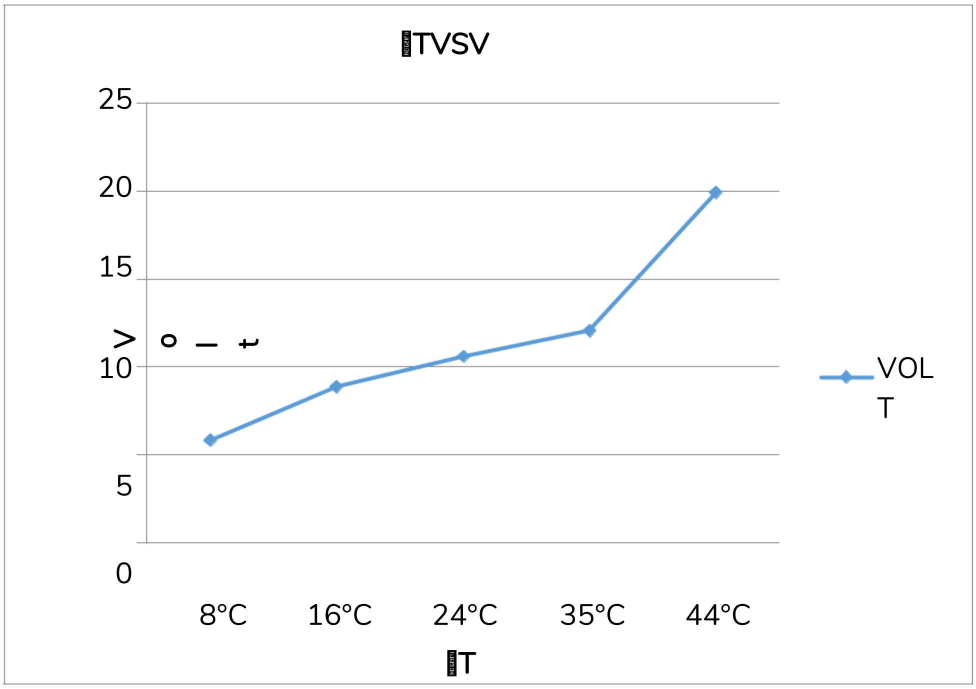

Figure 13. Graph ΔT and Series Circuit Voltage

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Test Results of Parallel Circuit Thermoelectric Generator

Table 2. Test Data of Parallel Circuit Thermoelectric Generator

NO	Th	Tc	ΔT	Voltage	Minute
1	60°C	25°C	35°C	1.53	1.00
2	66°C	25°C	41°C	1.82	1.30
3	68°C	25°C	43°C	2.57	2.00
4	70°C	25°C	45°C	3.11	2.30
5	72°C	25°C	47°C	3.45	2.53

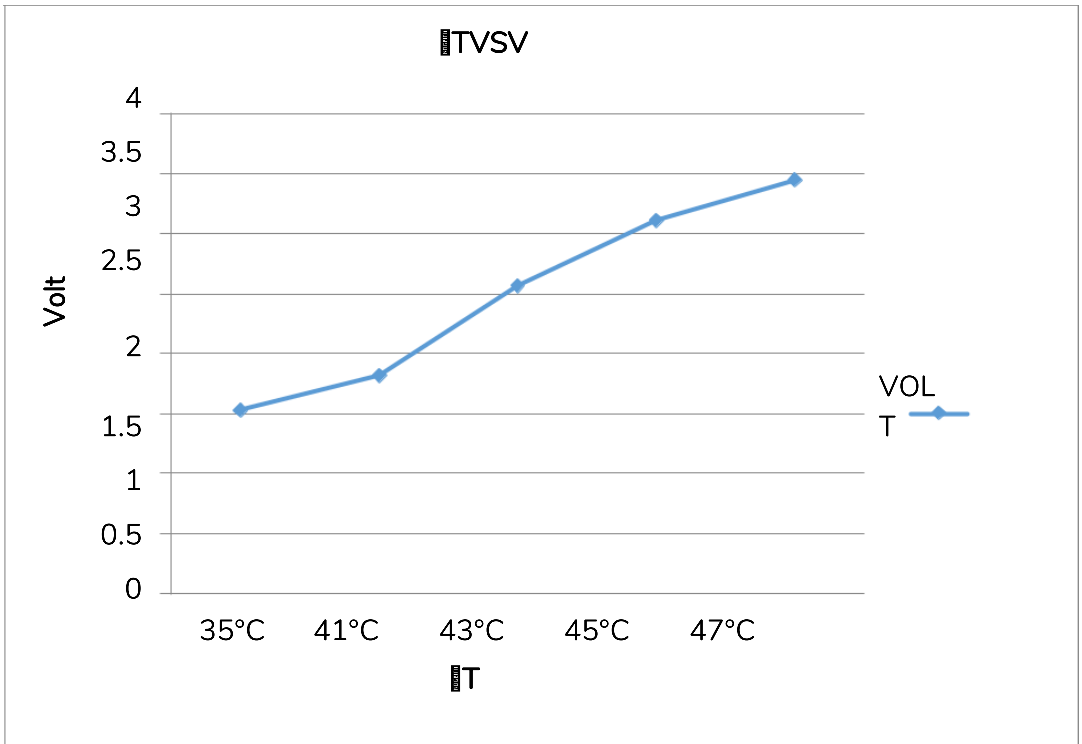

Figure 14. Graph ΔT and Parallel Circuit Voltage

Thermoelectric Generator Test Results Series Parallel Circuit

Table 3. Series Circuit Thermoelectric Generator Test Data Parallel

NO	Th	Tc	ΔT	Voltage	Minute
1	53°C	26°C	27°C	8.75	1.00
2	62°C	26°C	36°C	10.65	1.30
3	66°C	26°C	40°C	11.73	2.00
4	68°C	26°C	42°C	11.96	2.30
5	70°C	26°C	44°C	12.82	3.00

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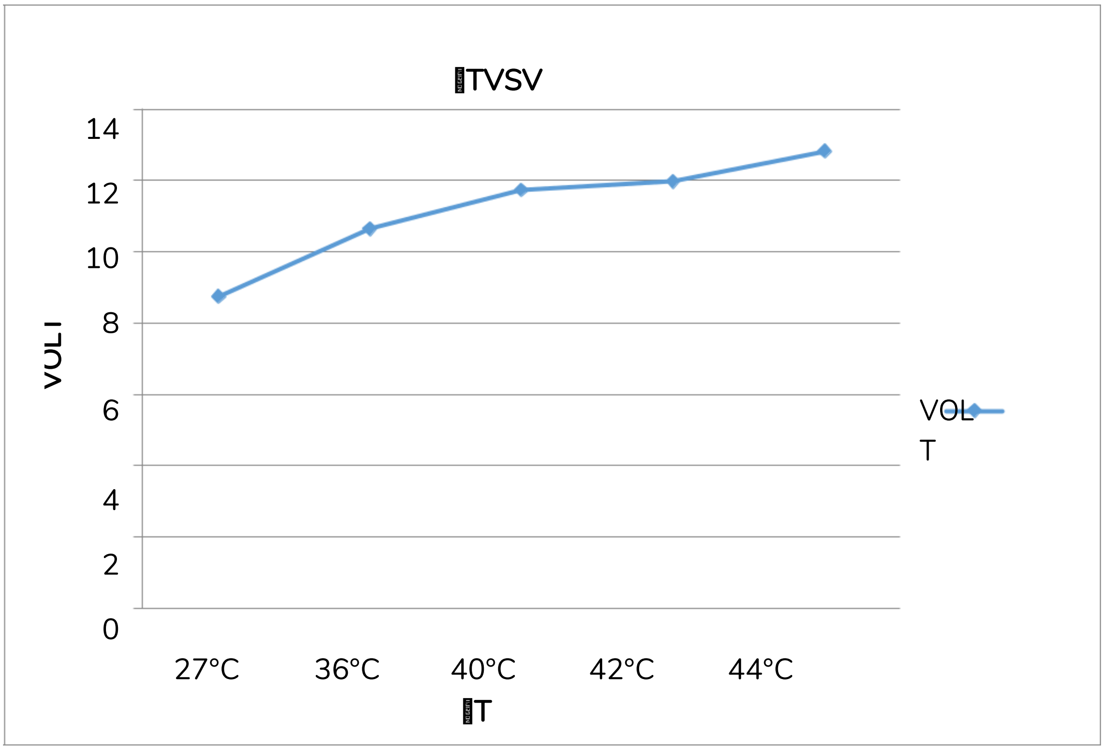

Figure 15. Graph ΔT and Voltage of Series Parallel Circuits

The results of the series thermoelectric generator test data without using a load can be seen in table 1. During the initial test precisely at 0.13 minutes with Th 32°C, Tc 24°C, and ΔT 8°C The output voltage that can be produced by the thermoelectric generator is quite large at 5.8 volts, this value continues to rise and peaks at 0.78 minutes. with Th 63°C, Tc 19°C and ΔT 44°C the output voltage that can be produced has reached 19.19 volts.

Testing using a parallel circuit, the voltage increase is relatively slow, as can be seen in table 4.2, even after testing for 3 minutes, the voltage that can be generated by the circuit is parallel is only 3.4 volts with Th 72°C, Tc 25°C and ΔT 47°C, this can This occurs due to the nature of the parallel circuit type itself, where the positive and negative output of each thermoelectric generator are connected together, in other words, 10 thermoelectric generators are equivalent to 1 generator.

Testing using a series-parallel mixed circuit, the voltage increase is not very fast, but the voltage generated is quite stable, as can be seen in table 4.3. During the 1.00 minute test, the voltage generated is generated recorded 8.75 volts with ΔT 36°C then rose to 10.65 volts at 1.30 minutes, then rose to 11.73 volts at 2.00 minutes, 11.96 at 2.30 minutes and the highest voltage was 12.82 volts at 3 minutes with Th 70°C, Tc 26°C And ΔT 44°C.

Load Testing

The test results data include the following:

Table 4. Series Circuit Thermoelectric Generator Test Data

NO	V	I	Th	Tc	ΔT	Minute	Watt	Light
1	5.8	0.04	32°C	24°C	8°C	0.13	0.2	Life
2	8.87	0.11	28°C	22°C	16°C	0.16	0.9	Life

NO	V	I	Th	Tc	ΔT	Minute	Watt	Light
3	10.58	0.17	46°C	22°C	24°C	0.46	1.7	Life
4	12.04	0.21	57°C	22°C	35°C	0.52	2.5	Life
5	19.91	0.25	63°C	19°C	44°C	0.78	4.9	Dead

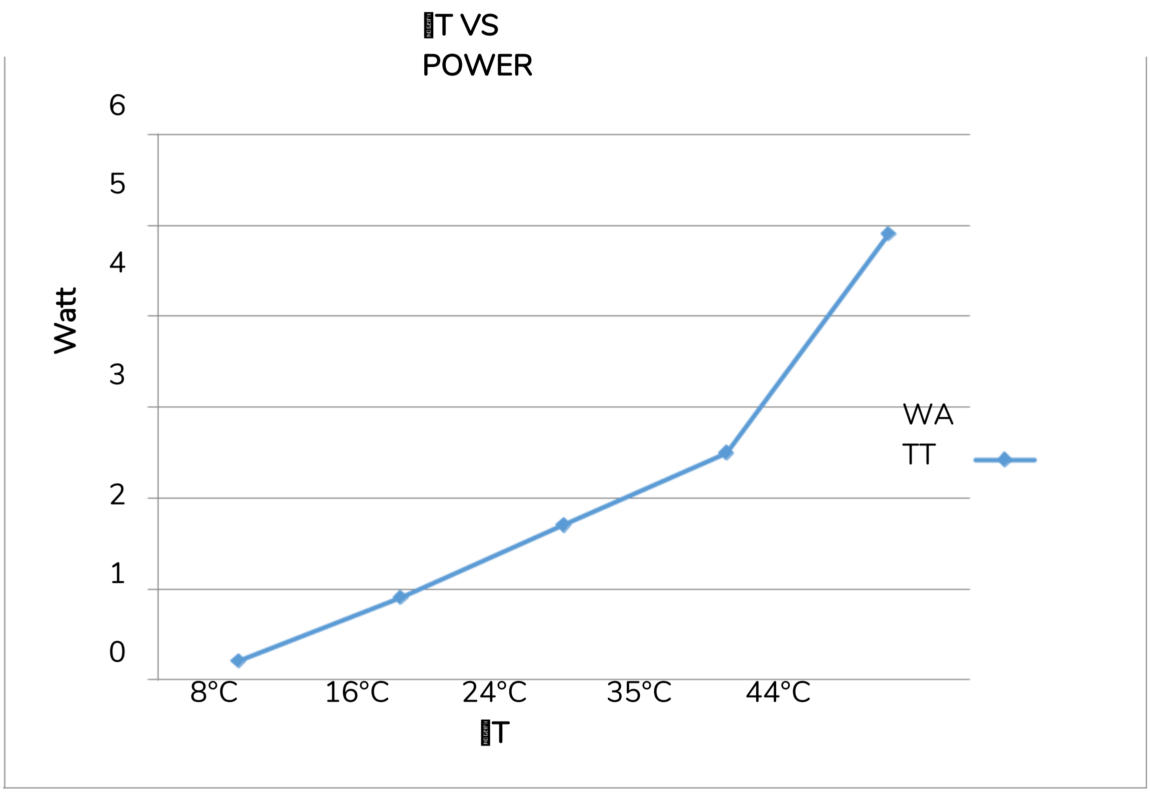

Figure 16. GraphΔT and Power of Loaded Series Circuits

Parallel Circuit Thermoelectric Generator Test Results

Table 4.5 Parallel Circuit Thermoelectric Generator Test Data

NO	V	I	Th	Tc	ΔT	Minute	Watt	Light
1	1.53	0.09	60°C	25°C	35°C	1.00	0.14	Dead
2	1.82	0.17	66°C	25°C	41°C	1.30	0.30	Dead
3	2.57	0.25	68°C	25°C	43°C	2.00	0.64	Dead
4	3.11	0.39	70°C	25°C	45°C	2.30	1.21	Dead
5	3.45	0.42	72°C	25°C	47°C	3.00	1.44	Dead

In the series circuit thermoelectric generator load test, the highest power that can be achieved is 4.9 watts, in the parallel circuit generator test, the highest power that can be achieved is 1.44 watts, and in the parallel series thermoelectric generator test, the highest power is 9.74 watts. From the test of the three types of circuits using a 5-12 volt LED lamp load, the highest power results were obtained in the test using a series circuit. parallel with a result of 9.74 watts atΔT 44°C, and for the highest current obtained in testing using a series parallel circuit also, the final results were recorded at 0.76 Ampere. It can be concluded that in the test with the highest power and current load obtained in testing using a series parallel circuit.

CONCLUSION

This study conducted a comparative analysis of the SP1848-27145 SA thermoelectric generator (TEG) using three different circuit configurations: series, parallel, and hybrid (series-parallel). The objective was to determine the most efficient configuration for power generation by evaluating the voltage, current, power output, and overall efficiency. The experimental results show that: The series configuration produced the highest voltage output, making it suitable for applications requiring higher voltage levels. The parallel configuration generated a higher current output, which is beneficial for applications requiring higher current flow. The hybrid configuration provided a balance between voltage and current, resulting in optimal power efficiencycompared to the other two configurations.
Overall, the findings suggest that the choice of circuit configuration depends on the specific energy requirements of the application. The hybrid configuration is recommended for maximizing both voltage and current output, making it ideal for practical TEG-based energy harvesting systems. Future research should explore advanced heat dissipation techniques, material enhancements, and real-world applications to further improve the efficiency of thermoelectric generators.

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