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Implementing Peltier Device on Refrigeration System Based on Solar Energy

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ABSTRACT: The performance of a solar refrigeration system incorporating peltier module is presented in this study. Thermoelectric cooling is provided by thermoelectric modules, which are the most important components in this refrigerator. Peltier module, heatsink, charge controller, solar panel, battery, microcontroller kit, wooden box, and other components make up this project's system. One of the greatest challenges in today's society is power consumption. However, semiconductors are an excellent solution for reducing power usage. If we are successful in effectively utilizing the semiconductor, we will be able to cut power consumption. One of the better solutions for this is the Peltier module. In this project, a peltier module is employed, where one side is cooled while the other becomes hot and rejects heat to the environment with the use of fans, resulting in cooling without the usage of greenhouse gases. As a result, the global warming generated by conventional refrigeration systems would be reduced.

Ozone layer depletion has become a major problem for both industrialised and developing countries as a result of rising CO₂ emissions. For its operation, our article makes use of solar energy. Solar refrigeration with a thermoelectric module will be one of the most cost-effective, environmentally friendly systems available. This paper does not require any type of refrigerant or mechanical equipment, such as a compressor or prime mover, to function. The major goal of this initiative is to give refrigeration to locations where there is no access to electricity.

KEYWORDS: Refrigeration system, Solar energy, Peltier module, Ozone layer depletion.

I. INTRODUCTION

In recent years, renewable and alternative non-conventional green energy technologies utilised for heat pumping applications have shown actual virtues and reawakened interest, particularly in small-scale portable heating applications. One of these cutting-edge technologies is solar-powered thermoelectric heat pumping. Solar energy is the most cost-effective, non-competitive, and universal source of energy because sunlight is available everywhere. Photovoltaic technology can turn this energy into usable electrical energy. Thermoelectric heating (or cooling) technology has recently reawakened attention due to its unique characteristics when compared to other heating (or cooling) technologies, such as vapour-compression and electric heating (or cooling) systems. Thermoelectric (TE) modules use the Peltier effect between the junctions of two semiconductors to create solid-state heat pumps (or refrigerators in the case of cooling). The TE modules require a DC power supply in order for current to flow through the TE module, causing heat to be transported from one side to the other, resulting in a hot and cool side. The heating and cooling system service's main goal is to be suitable for usage by those who reside in distant sections of the country where load shading is a major issue. The system can also be employed in isolated areas of the world or in harsh environments where electric power is not available. Refrigeration has been one of the most significant aspects of our daily lives since the last century. The globe is currently leaning toward renewable energy resources as a source of energy. This is done for two reasons: first, because of the lower quality of life caused by air pollution; and second, because of the strain that an ever-increasing global population places on our natural energy resources. These two facts lead to the conclusion that the available natural energy resources will not continue indefinitely. The main concept is to use a photovoltaic-driven refrigeration system with a battery bank, which is fueled by a direct current source or a solar panel. Thermoelectric Refrigeration uses thermoelectric effects to provide cooling rather than the more common traditional techniques of using the "vapour compression cycle" or the "gas compression cycle."

II. LITERATURE REVIEW

On by reviewing the literature's on solar operated thermoelectric refrigeration of the various researchers, the literature's here described as:

The performance of domestic refrigerator was evaluated through R152a and R32 as refrigerants (Bolaji 2010). The experimental work result gives that R152a offers lowest energy consumption, COP value about 4.7% higher than

R134a. The performance of refrigeration system with R152a closely follows the refrigeration system operating with R134a.

R134a has been used as the alternate refrigerant to CFC's and HCFCs in refrigeration systems. Tasi (2005) indicated that various ecological problems like global warming, environmental partition, photochemical potential, etc would be occurred due to the usage of R134a in refrigeration systems. According to the international protocols, ecological degradation and human healthiness, refrigerant R134a is to be changed from the domestic and industrial refrigeration systems.

Erol Arcaklioglu et al (2006) formed an algorithm to find the volumetric cooling capacity and COP of the refrigerant mixtures considered for replacement of the CFC's. Among various mixtures, the mixture of R290 and R600a was recommended to be a suitable substitute for R12.

Fatouh & El Kafafy (2006) carried out simulation analysis on domestic refrigeration system with Hydrocarbon mixture (HCM) to identify the alternate for R134a. The various performance characteristics like pressure ratio, discharge temperature, mass flow rate, cooling capacity, condenser capacity, volumetric cooling capacity and COP were considered in their analysis. The refrigeration system performance has been analyzed with different mass fraction values of propane in their proposed mixture to replace R134a.

Senthilkumar & Rajagopal (2007) carried out the computational and experimental analysis on the refrigeration system with refrigerant mixture of R123 and R290. Various mixture ratios of these refrigerants were analyzed and the mixture 7/3 (R123 70%+R290 30%) provides better performance and matching with R12.

Their result concludes that the mixture 7/3 gave higher performance compared to R12 at various operating conditions and it could be substituted as an alternate to R12. Baskaran & Koshy Mathews (2012) discussed the performance analysis of VCR system with eco-friendly refrigerants.

Mohanraj et al (2009) found that the HCM of R290 and R600a could be considered as an alternative to R134a in domestic refrigerators. The experimental performance was analyzed with different refrigerant mass values like 40, 50, 60 and 70 g. Among these, 60 g of refrigerant charge having lower power consumption and discharge temperature is about 11.1% and 8.5-13.4K compared to R134a respectively.

III. METHODOLOGY

A. Experimental setup

1. Solar panel

Light or other electromagnetic radiation is converted directly into electricity. Solar photovoltaic cells, or PV cells, are produced from silicon crystalline wafers, which are comparable to computer processor wafers. Silicon wafers are created using a variety of manufacturing methods and can be polycrystalline or monocrystalline. There is a variation of solar rays on a solar panel whenever the sun rays fall on it. In the solar refrigeration system, we employ a charge controller to prevent the sun rays from fluctuating on the solar panel. Charge controllers also protect batteries from overcharging and electrical overload. In our solar refrigeration system, we use an MPPT (Maximum Power Point Tracking) based solar charger.

2. Battery

The battery's primary function is to provide a source of current for the system's operation. Specification,

- a) Current 6 A
- b) Voltage 12v

The voltage and current of the battery with built-in inverter employed in this investigation are 12 V and 12 A. With a 14 V converter, the output for four ports is 12V DC. Recent battery-based inverters are capable of converting DC to AC power. When the inverter/charger is connected to an AC power supply, it opens up a whole new world of application possibilities. Generators have long been the most prevalent off-grid backup source, improving system performance and flexibility when employed in high-power, infrequent loads. During a period of overcast weather, it can power loads while also assisting in battery recharge. The generator can lower the cost of a PV-based system by allowing it to be sized for average yearly insolation rather than the short winter daylight hours. A generator can serve as a stand-alone backup to the inverter system if the batteries or inverter fail. The CPU cooler has effectively vented the heat created by the components and actively cools the processor by bringing in cooler air before the heat causes harm to the components. It's the most cost-effective and practical technique to keep the Peltier cool and safe from overheating. The CPU fan is essential for ventilating heat created by the components and actively cooling the Peltier by bringing in more cooling air before the heat destroys it. Peltier cooling fans come in a variety of sizes and are usually paired with an aluminium or copper heatsink fan. The CPU cooling fans are directly connected to the Peltier and work in tandem with an aluminium heatsink fan to keep it cool. The fan is coupled to the fin-like structure and improves the transfer of hot

air by dragging hot air away from the components' electrical heat and pushing in more cooling air between the aluminium fins, keeping the processor cool.

3. Charge controller

A charge controller is an important component of any solar refrigeration system that uses batteries to charge them. Its goal is to keep a battery well-fed and safe for a long time. A controller's core functions are straightforward. There is a variation of solar rays on a solar panel whenever the sunrays fall on it. In the solar refrigeration system, we employ a charge controller to prevent the sunrays from fluctuating on the solar panel. Charge controllers also protect batteries from overcharging and electrical overload.

4. Peltier module.

Peltier is a semiconductor module that uses bismuth telluride as the module material. Peltier is a cooling and heating system that works at the same time. It functions as a dc supply; when dc current runs through the system, two sides emerge: one for cooling and the other for heating. The refrigeration system uses the cooling side, while the heat sink uses the other side to remove heat from the system. When the positive and negative module leads are connected to the corresponding positive and negative terminals of a D.C. power source, the cold side, which is likewise made of aluminium, comes into contact with the cold side of a thermoelectric module and is absorbed by the module's cold side. The thermoelectric effect is the conversion of temperature differences into electric voltage and back. When the temperature on both sides of a thermoelectric device changes, it produces a voltage. Because an electrical current is delivered across the junction of two distinct metals, heat will be removed from one and redistributed to the other. The Peltier effect, commonly known as the thermoelectric effect, is used in thermoelectric coolers.

5. Refrigeration chamber.

Thermocol is used to keep the inside of the refrigeration chamber cool. A thermocol box can be used to cool a cabin or a space. It is the material of choice for all types of thermal insulation. Other materials have an open cell structure and are therefore ineffective when exposed to moisture. Second, thermocol is fungi-resistant, tasteless, and odourless. It's one of the most dependable and cost-effective ways to keep your items safe throughout travel. It's incredibly light. It may be moulded into any shape while being hard enough to withstand impact.

6. Heat sink.

The hot side of a thermoelectric module is in touch with the heat sink, which is commonly constructed of aluminium. Heat is rejected by the module's hot side when the positive and negative module leads are connected to the respective positive and negative terminals of a Direct Current (D.C) power supply. The heat sink speeds up the heat removal process. Heat sinks are often used as intermediate stages in the heat removal process, where heat is transported from a heat source to an external medium. Depending on the size of the refrigerator, common heat sinks include free convection, forced convection, and fluid cooled.

B. Working

The thermoelectric module is made up of thermocouple pairs made up of P-type and N-type semiconductor thermo elements that are coupled electrically in series and thermally in parallel. Due to their solid state, the modules are considered to be highly reliable components that will provide long, trouble-free service in most applications. In cooling applications, an electric current is supplied to the module, causing one side of the module to become cold and the other side to become hot. Thermoelectric module working principle Temperatures on the cool side (T_c) Temperature on the hot side (T_h) The operating temperature difference (T) is the difference in temperature between T_h and T_c . The amount of heat that will be absorbed at the cool surface of the TEC. This is referred to as heat. The symbol for it is Q_c , and the unit is watt.

● COLD SIDE TEMPERATURE :-

If the object to be cooled is in direct contact with the TEC's cold surface, the required temperature is the temperature of the TEC's cold side. The object of this project is air, which must be cooled as it passes through an aluminium heat sink; the goal is to cool the air as it passes through the heat sink; when this type of system is used, the cold side temperature of the TEC must be several times cooler than the desired temperature of the air.

● HOT SIDE TEMPERATURE :-

The two factors are primarily responsible for the hot side temperature (T_h). The first parameter is the temperature of the ambient air in the environment where the heat is being rejected, and the second is the efficacy of the heat sink, which is the distance between the hot side of the TEC and the ambient air.

● TEMPERATURE DIFFERENCE :-

T is a highly crucial factor in the two temperatures T_c and T_h , and the difference between them is seen in the following equation.

$$\Delta T = T_h - T_c$$

The difference between the hot and cold sides of the TEC is the actual T .

According to the study, we will construct a wooden box and insulate it with aluminium foil and thermocol. We'll put the Peltier module on the heat sink and test it. The control unit's microcontroller circuit and programme will be implemented. We'll test the solar panel and charge controller circuit, then put everything together in order.

1. SEEBECK EFFECT.

Thomas Seebeck discovered in 1821 that if the connections of two dissimilar metals were kept at two different temperatures, an electric current would flow constantly in a closed circuit. The Seebeck effect, which is based on voltage generation along a conductor subjected to a temperature gradient, is used in thermoelectric power supply generators. An electromotive force is created when a temperature gradient is applied to a conductor. The voltage difference created is proportional to the temperature differential between the hot and cold connections of the thermoelectric module.

$$\Delta V \propto \Delta T$$

At the junction of different types of wires, the Seebeck effect converts heat directly into electricity. The Seebeck effect is a classic electromotive force (emf) that produces measurable currents or voltages in the same way that any other emf does. The Seebeck effect, which is based on voltage generation along a conductor subjected to a temperature gradient, is used in thermoelectric power supply generators. An electromotive force is created when a temperature gradient is applied to a conductor. The voltage difference created is proportional to the temperature difference between the two junctions of the thermoelectric module.

2. PELTIER EFFECT:

Jean Peltier, a French watchmaker and part-time scientist, discovered that an electrical current causes a temperature differential at the intersection of two dissimilar metals in 1834. "When an electric current travels across two dissimilar conductors, the junction of the conductors will either absorb or expel heat depending on the flow of the electric current," it states. The amount of heat that is absorbed or released at the junction is proportional to the electric current that is applied. Peltier coefficient is the constant of proportionality. All thermoelectric cooling applications are primarily based on the Peltier effect. It's in charge of heat absorption and removal. It asserts that when an electric current travels over two dissimilar conductors, the junction of the conductors will either absorb or radiate heat, depending on the current flow.

3. CONDENSATION :

1. Condensation, which causes corrosion and erodes the TE's intrinsic reliability, is a common problem with TE cooling.
2. When the dew point is achieved, condensation begins. The dew point is the temperature at which water vapour begins to condense when air is cooled at constant pressure.
3. Condensation occurs when the air loses its ability to convey the condensing water vapour. The water vapour carrying capacity of the air diminishes as the temperature drops. Condensation is a problem with TE coolers since they can cool to low, even below ambient temperatures. Silicon rubber is the most commonly used sealant. The most effective sealing agent for protecting the chip from water has been determined through research.
4. The weight gain due to water entering a TE cooling device was measured after four sealants were employed to seal it. The finest sealants should result in the least amount of weight gain.

C. MATERIAL SELECTION AND PROPERTIES

1. THERMOELECTRIC MATERIALS :

Semiconductors are the best material to sandwich between two metal conductors because they allow you to manage the charge carriers in the semiconductor and boost the heat pumping capacity. Because of its relatively high figure of merit,

Bi₂Te₃ is the most often utilised semiconductor for electronics cooling applications. However, the material's performance is still poor, and it should be replaced.

2. Bi₂Te₃ PROPERTIES:

The figure of merit (Z), Seebeck coefficient, electrical resistivity, and thermal conductivity of Bi₂Te₃ are plotted as a function of temperature in the graph below. The figures below will be affected by carrier concentration.

IV. EXPERIMENT AND ANALYSIS

1. Weather Condition

The testing are carried out in open areas that are exposed to direct sunlight. The meteorological conditions must be known because they influence the performance of the solar cells that will be employed. Solar radiation is absorbed by photovoltaic cells and stored in batteries. The Peltier components in the cooling process are driven by battery power. The weather conditions are measured over the course of five days. In one minute, the measuring time range is completed. The weather conditions parameters are shown in Table 1.

Table 1. Weather conditions during experiments

Day	Average ambient temperature (oC)	Average relative humidity (%)	Average solar radiation (W/m ²)
1	29.65	63.06	187.23
2	29.11	79.21	178.22
3	28.97	81.87	165.32
4	29.78	77.11	162.44
5	28.34	82.21	166.35

Temperature, humidity, and solar radiation intensity were the meteorological parameters that were measured. Figure 12 depicts the conditions of radiation measurements and solar radiation on theoretical calculations on the first day. According to the experimental data gathered from the measurement findings, solar radiation normally appears between 06.20 and 18.32 WIB for five days of experiments.

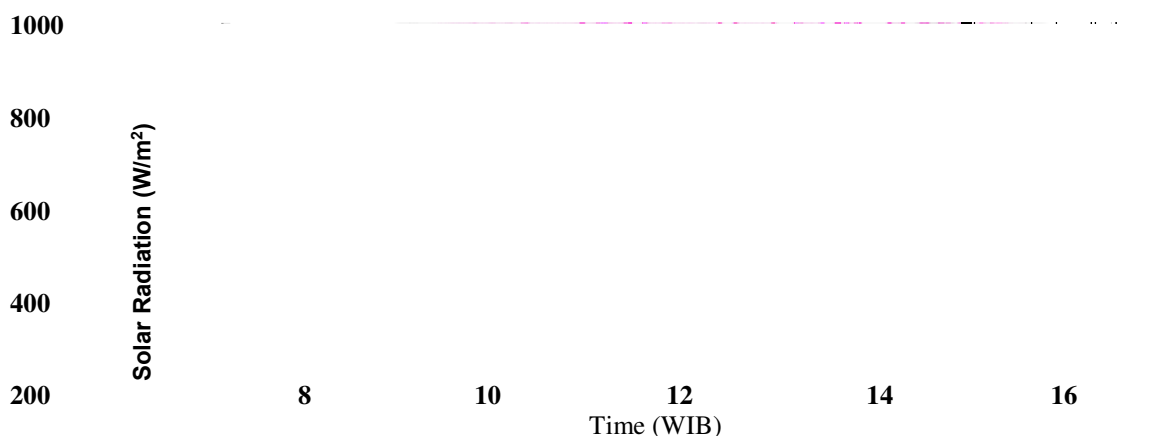


Fig.1. Typical Of The Intensity Of Solar Radiation first day

2. Photovoltaic Performance.

The Peltier refrigeration system uses solar cell panel components to absorb solar radiation to generate electrical energy. To calculate the estimated power of PV modules required it is necessary to know the average power needed by the cooling system every day. The electronic equipment used in the cooler is four small fans with a power of 1.8 watts each and four thermoelectric type TEC1- 12706 with a power of each 72 watts. Average electricity usage for 8 hours

for one day is 2361Wh. Since the electricity usage of PV is 100%, then the required PV output per day is 2361 Wh. As a note that for the calculation of power estimation power is then assumed the conditions of sunny weather with the intensity of solar radiation an average of 8 hours per day. In this study, also used batteries that serve to store electrical energy that has been generated by PV modules and used as an energy source to drive the fan and Peltier components. The battery used has a specification of 12V, 70Ah. The value of voltage and current coming out of solar panels ranges from 18.9 V and 5.3 A which is set by SCC to 12 Volt and 10 A to charge 70 Ah battery.

3. The Solar Thermoelectric Cooler Performance:

The thermoelectric cooling system is tested by placing thermocouple sensors at multiple places throughout the cooler to determine temperature fluctuations. For the ambient temperature, the top cover wall, the left wall, the right wall, the lower wall, and the cooled objects, the thermocouple sensor is situated outside of the cooler. The studies lasted eight hours, commencing at 09.00 WIB and ending at 17.00 WIB. The testing lasted five days and were conducted in a variety of weather situations. The temperature distribution of the cooling wall and cooled objects during experiments is depicted in Figures 13 through 17.

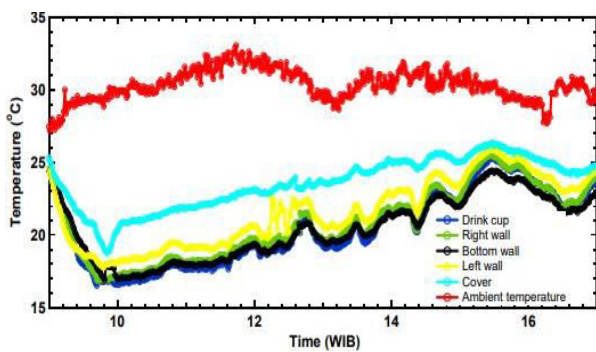


Fig.2. Temperature distribution in the cooler day.

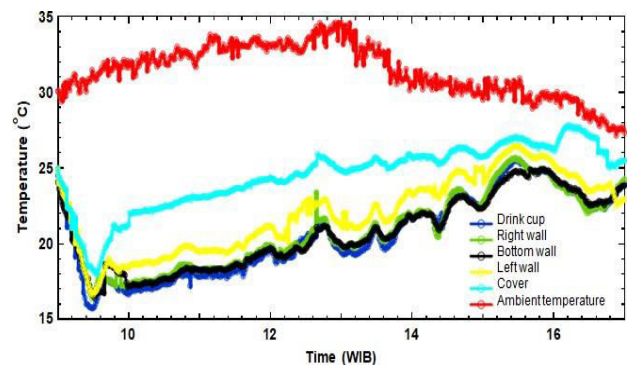


Fig.3. Temperature distribution in the cooler on the first on the second day.

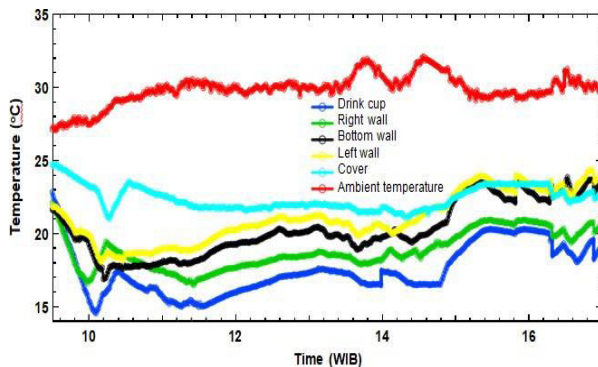


Fig.4. Temperature distribution in the cooler on the third day

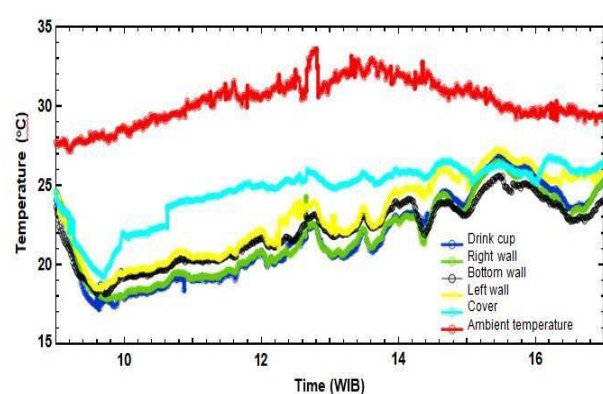


Fig.5. Temperature distribution in the cooler on the fourth day

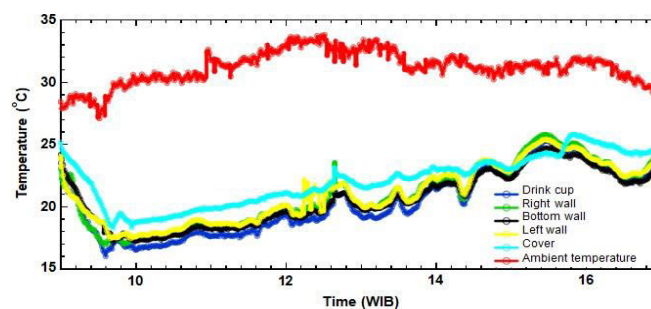


Fig.6. Temperature distribution in the cooler on the fifth day

On the interior and exterior of the Peltier cooler system, measurements are taken. The temperature of the inside of the cooler box was measured on the left wall, right wall, lower wall, top cover wall, and drink cup. The cooler box's outside top wall, which is immediately exposed to sunlight, is considered the outside.

The minimum temperature of the drink cup during the studies was 16.51oC, 15.72oC, 14.57oC, 17.24oC, and 16.03oC, respectively. On the second day, with an average environment temperature of 31.34°C, the drink cup reached its lowest temperature of 14.57°C. The lowest temperature of a drink cup is usually reached between 09.15 - 10:00 WIB.

During the studies, the average temperature of the drink cup was 20.30oC and 20.32oC. During tests, the cooling box's inner wall temperature swings from 16 to 26 degrees Celsius. The average temperature of the outside air from the first to the fifth day is 30.54°C, according to the measurements. The greatest air temperature reached during the studies was 33.79°C on the fourth day, according to the experimental data. In general, the temperature distribution at the measured component's point differs from the rest of the temperature distribution. The distance between heat sink components and the left, right, and bottom walls influences this.

The experimental data shows that the measuring point on the cooler box's outer wall has the highest temperature, which is due to the influence of air temperature and the effect of heat released by the fan from the heat sink attached to the surrounding environment. The results show that the temperature distribution in the cooler is very uniformly distributed on both sides. The temperature difference between the measurement points, which ranges from 0.023 to 0.231°C, demonstrates this. The average temperature differential between inside and outside the cooler is roughly 9-12°C. This situation denotes the cooler's heat dissipation mechanism, which results in a cooling effect on the cooled object, in this case a drinking cup placed in the cooler. The experimental data also reveal that, starting at 12.00 WIB, the temperature of the components recorded in the cooler rises during the course of five days of experiments. The temperature increase in the cooler could be attributable to a variety of things, according to an investigation. The rise in air temperature outside the cooler, for starters, has an impact on the temperature change inside the cooler. Second, running the fan for an extended period of time can cause heat to build up in the cooling system. Third, the thermoelectric element is not performing properly due to lower power on the battery as an energy source to drive the fan and Peltier components on the cooler. Table 2 shows the COP value of a thermoelectric cooling box achieved during experiments.

Table 2. The COP value during experiments

Day	Initial temperature (oC)	Minimum temperature (oC)	Coolingtime (minute)	COP
1	26.77	16.51	53	0.190
2	26.76	15.72	40	0.356
3	26.95	14.57	55	0.213
4	26.86	17.24	49	0.209
5	26.78	16.03	47	0.254

On the second day, with a cooling time of 40 minutes, the greatest COP value attained is 0.356. The average COP values achieved during the studies are 0.245, with cooling times ranging from 40 to 55 minutes to achieve a minimum temperature. Multiple regression analysis tools are used to verify the effect of meteorological conditions on the COP value. The coefficient of determination (R²) for the statistical study is 0.859, indicating that meteorological circumstances have an 85.90 percent influence on the COP value.



V. CONCLUSION

We may deduce from this study that cooling the system without the use of a compressor and refrigerant is conceivable. There are a variety of cooling systems available to remove heat from industrial and medical enclosures, but as technology progresses, thermoelectric cooling is becoming a really feasible solution that can be beneficial in the handling of certain small to medium applications. The benefits of thermoelectric cooling, such as self-contained, solid-state construction that eliminates the need for refrigerants or connections to chilled water supplies, superior flexibility, and lower maintenance costs through higher reliability, will continue to grow as the efficiency and effectiveness of thermoelectric cooling improves. It can be used in an ambulance to store medical equipment or in a remote location to store medicines, among other things. The freeze drying procedure is used to make blood plasma and medicines. To create a real-time model that combines the functions of an air conditioner and a room heater into a single system, i.e. a thermoelectric hot and cold room conditioner. And so, in the future, we must create refrigeration systems that rely on sustainable energy sources such as solar energy and the Peltier effect. A portable heating and cooling system was constructed and tested for cooling and heating purposes using a thermometer module and an electric control unit.

The system is designed in such a way that it can generate self-power and be used in isolated and remote areas of the country where load shading is a major issue. Another important point to remember is that it is a one-time investment in the free, and that the system's efficiency can be improved by improving module contact residency and thermal interface.

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