Evolution in Electrical and Electronic Engineering Vol. 4 No. 2 (2023) 874-884
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Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Development of a Solar Powered Portable Cooler or Warmer

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DOI: https://doi.org/10.30880/eeee.2023.04.02.105
Received 10 August 2023; Accepted 10 September 2023; Available online 30 October 2023

Abstract: This project focuses on the typical issues Malaysians encounter when participating in outdoor activities or purchasing food and drinks from street sellers. These problems include beverages staying cold for an extended time and food going bad. Refrigerators and microwaves, which are commonplace alternatives, are bulky and difficult to transport. This is remedied by the introduction of a portable box using thermoelectric Peltier technology that weighs about 5 kg. With the help of this device, food and beverages will stay at the right temperature for a longer time, maintaining freshness. Based on the obtained result, the time taken for the temperature inside the box to reach the desired point will be around 30 minutes. The temperature inside will remain within the 2°C difference. It also uses solar power as an alternate energy source, which aims to prolong the product operation time and lower electricity costs. As solar energy has been applied, the product operation hours have been extended from 11 hours to 16 hours. For outdoor activities and use by street vendors, the "Solar powered portable cooler and warmer" is a practical and effective option.

Keywords: Solar Powered, Cooler, Warmer.

1. Introduction

Nowadays, people like to go out and participate in outdoor activities. When people go out with family or friends, food and beverage supply is a must while they are having some fun together. In addition, the number of street vendor or hawker in Malaysia keep increasing annually. The most familiar product by this street vendor will be food and beverage. However, the most common problems faced by people are that the food will easily get stale and the beverage will remain at a low temperature for a very short period.

The most common solution for this problem is to store the food and beverage in a refrigerator. Refrigerators refer to a large container which is kept at a low temperature inside, usually powered up by electricity, so that the food and drink in them will stay fresh for a long time. To keep the food warm, usually the microwave will be used. Microwave oven, better known as microwave, uses electromagnetic

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radiation to heat up or cook food. On the other hand, an oven is a general term for a thermally insulated chamber that is used for heating, cooking, or baking food. A microwave oven heats food efficiently with safe radiation. But both appliances have the same issue which they are very heavy and inconvenient to bring along.

Therefore, this project is introduced, not only for outdoor activities but also suitable for street vendor use. This is a small box that will weigh around 5kg and can be carried anywhere. With the heating and cooling characteristics of thermoelectric Peltier, this invention can help those who want to keep their food and beverage at a certain temperature and remain fresh for a longer period. [1] and [2] This invention also aims to reduce the electricity bills by its additional power source which is solar power in this 'Solar powered portable cooler or warmer'.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

A. Materials

The overview of this project is shown in Figure 1. The main components of the list used in this project is given in Table 1.

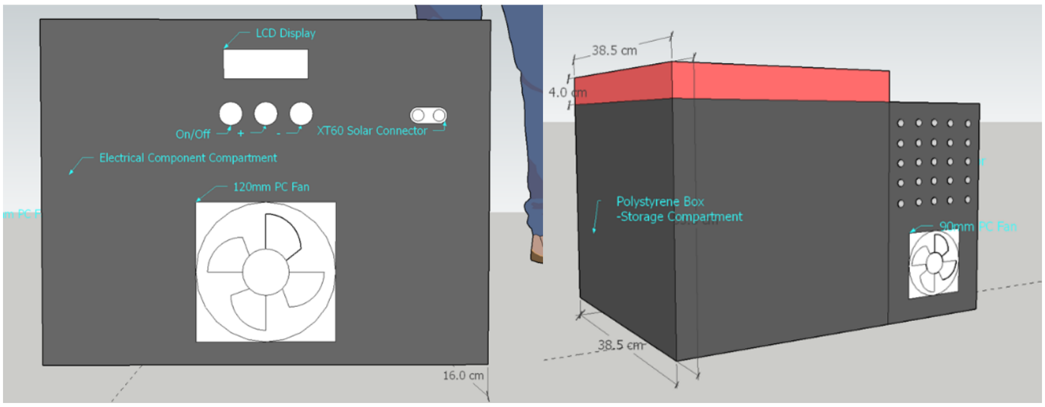

Figure 1: An Overview of The Project

Table 1: List of the Main Components

Main Components	Parameter
Polystyrene Box	(340x460x400) mm
12V Pc Fan 0.3A	(120x120)mm
12V Pc Fan 0.3A	(40x40) mm
12V PC Fan	0.3A (80x80) mm
12V Mini Water Pump	0.3A
PC Cooling Water Tank	200ml
Aluminium Water Cooling Heatsinks	(4040x20) mm
Aluminium Heatsink	(40x40x25) mm
Aluminium Pc Cooling Radiator	(120x120) mm
Transparent Pc Cooling Water Hose (per meter)	-
Thermoelectric Peltier Tec-12706	-
Lithium Deep Cycle Battery 30ah	-
Arduino Uno R3	-
LCD Screen	(16x2)cm
DS18B20 Temperature Sensor	-

2 Channel Spdt Relay Module	12V 30A
4 Channel Spdt Relay Module	12V 10A
Battery Capacity Indicator Module	-
Boost Converter	12-35V 150W
Solar Charge Controller 30A	-
Battery Charge Controller 30A	-
Pvc Enclosure Box	(6X8X4) INCH

B. Methods

This project aims to develop a thermoelectric Peltier-based cooling and heating device integrated with a solar power source to keep food and beverages at a constant temperature and prevent them from becoming stale. The project involves the following steps in Phase 1:

(a) Determine the project title and establish the problem statement, objective, and scope.

(b) Conduct a study on related articles and journals that explore the characteristics of thermoelectric Peltier devices and the design considerations for incorporating a solar system into the project.

(c) Select the components for the system based on the characterization of the thermoelectric Peltier device and the design requirements for the solar system. Consider the total project cost to meet the needs of users, such as hawkers.

(d) Design a 3D model of the system using SketchUp software to accurately measure dimensions and facilitate the hardware design process. This model also helps streamline the material acquisition process and reduce costs.

(e) Design the circuitry and coding for the temperature controller and charge controller. Utilize Arduino UNO as the main component, along with the DS18B20 temperature sensor and several relays for temperature control. An LCD screen will be used for temperature display and adjustment.

(f) The Arduino IDE and Proteus 8 Professional software will be used to build the circuit. The Proteus 8 Professional will monitor closely to the system's circuit and ensure that the circuit is connected properly. The code for this project will be written using the Arduino IDE software and uploaded to the Arduino Uno board.

Phase 2, this phase focuses on developing the hardware, specifically the temperature and charge controllers. The temperature controller regulates the system's temperature by controlling the forward or reverse bias of the thermoelectric Peltier device. The charge controller manages the voltage and current supplied to the battery pack to prevent damage.

Designing a suitable solar system for the "Multi-Purpose Box" is crucial and requires detailed calculations based on previous research. The heat absorption by the Peltier module is calculated using the equation Q = P x I x t (3.1), where P represents the Peltier Coefficient, I is the current, and t is the time.

Power calculations involve determining the power consumption by the load, calculated using the equation Power = IL x VL (3.2), where IL is the load current and VL is the load voltage. The battery specifications include its voltage (VB = 12V) and capacity (CB = 30Ah).

The watt-hour calculation of the battery is determined by multiplying the battery voltage and capacity, as shown in equation (3.3). The theoretical complete time of operation from a fully charged battery is calculated using equation (3.4), while the practically obtained result takes into account an 80% depth of discharge, as shown in equation (3.5).

The total operating time is determined based on the above calculations, taking into consideration the time required to achieve the desired temperature and the system's running intervals.

To meet the power requirements, solar panels with a total power of 72W are needed, based on the Watt-hour of the battery divided by the sun hour, as shown in equation (3.6). In this project, a 200W solar panel is oversized two times to accommodate variations in sun hour at different locations.

C. Hardware setup

In Figure 2, the front view of the prototype consists of the control panel that will be used to control the temperature and monitor the battery power left. On the back side also all the electronic components will be installed. There is a 12x12 cm PC fan that will be installed for water-cooling purposes. Also, the XT-60 DC connector connects with the solar panel and DC adapter while charging. Figure 3 shows the side view of the prototype. There are a lot of ventilation holes designed to maximize the ventilation in the component area. The reason to maximize the ventilation is to remove the unwanted heat produced by the thermoelectric Peltier and the charge controller more efficiently. Another 8*8 cm PC fan has also been installed to increase the ventilation. Figure 4 shows the top view of the product. The internal layer of the box is wrapped with aluminum foil to increase the rate of heat exchange. Figure 5 is the internal view of the electrical compartment. All the electrical components will be assembled here nicely.

Figure 2: Front view of 'Solar Power Portable Cooler and Warmer'.

Figure 3: Right side view of 'Solar Power Portable Cooler and Warmer'.

Figure 4: Top view of 'Solar Power Portable Cooler and Warmer'.

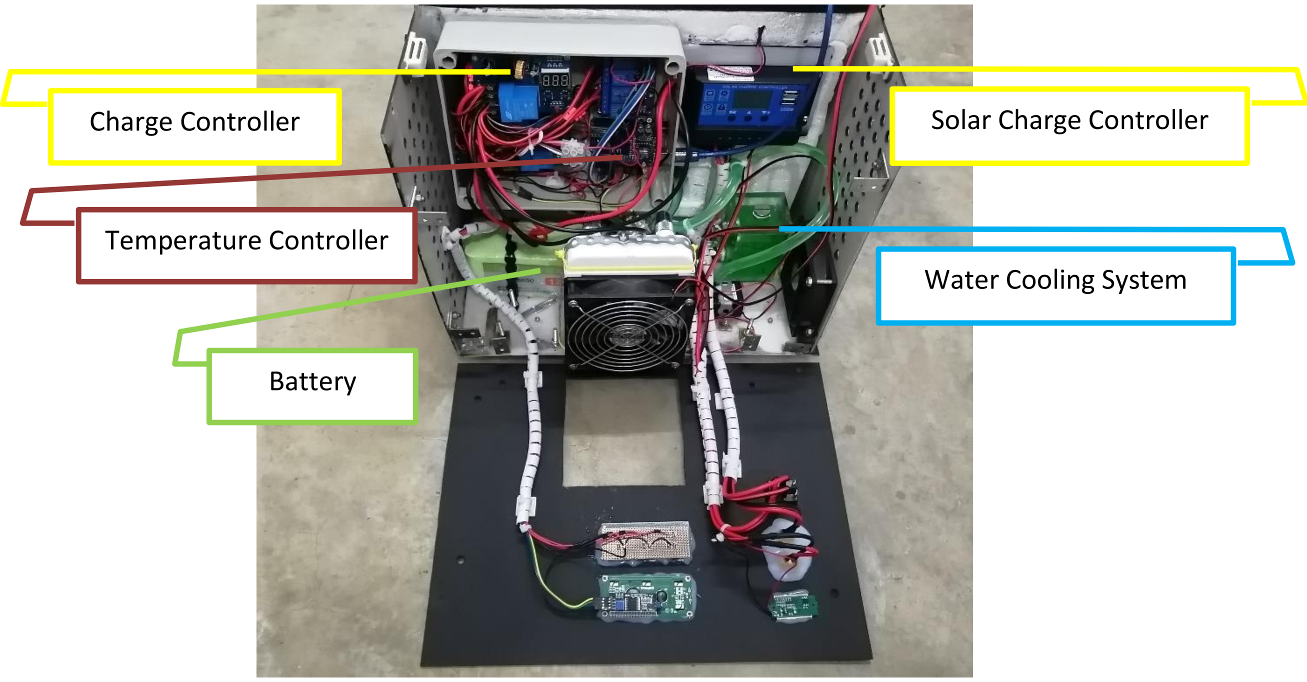

Figure 5: Internal view of 'Solar Power Portable Cooler and Warmer'.

3. Results and Discussion

A. Temperature controller

The temperature controller is crucial for maintaining the desired temperature inside the box. To test its effectiveness, an empty box will be used, ensuring no external factors influence the temperature. The box's temperature will match the ambient temperature. The system will be turned on and set to either the lowest (8°C) or highest (70°C) temperature for testing. The temperature controller will be monitored until it reaches the set point, and the temperature readings will be recorded. Afterward, the system will run for an additional hour, and a final temperature reading will be taken. If the temperature remains stable, it indicates that the temperature controller is functioning properly. Figure 6 displays the temperature readings on the LCD screen during the test, with the upper layer representing the box's temperature and the lower layer indicating the desired temperature.

Figure 6: Temperature display on the LCD screen.

Figure 7 shows the Temperature (°C) vs. Time(min) Graph which is the result of the cooling effect by thermoelectric Peltier inside the box. The ambient temperature during this test is 31.8°C. From minutes 1 to 5, the temperature reading is taken every one-minute interval. The reason for this is the temperature will drastically change during this period. After 5 minutes the temperature reading will be taken every 3 and 5 minutes since the temperature will drop very slowly after that. The graph shows that the time taken for temperature drop from ambient temperature to 8°C is around 30 minutes. The temperature drop during this period is 23.8°C. From the plotted graph it can also be said that the temperature dropping characteristic is almost linear. The ability of thermoelectric Peltier to cool down the temperature to 8°C is proven.

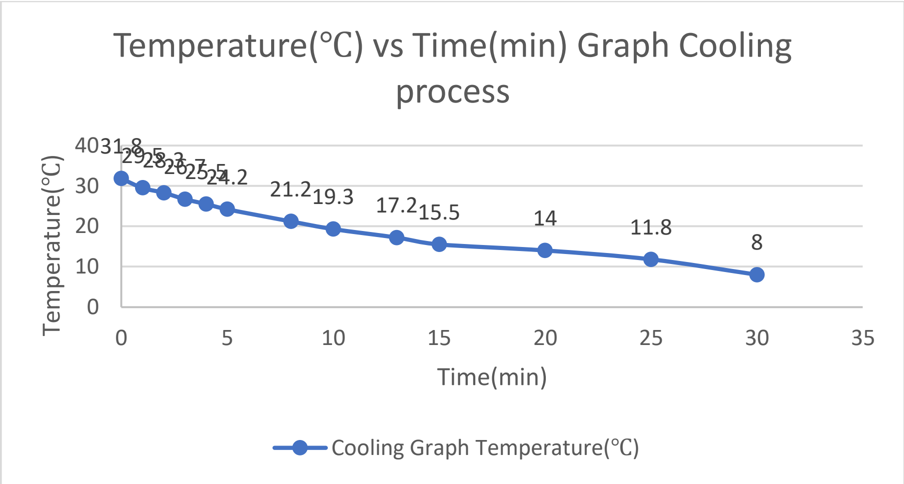

Figure 7: Temperature (°C) vs Time(min) Graph (Cooling Effect)

Figure 8 shows the Temperature (°C) vs. Time(min) Graph which is the result of the heating effect by thermoelectric Peltier inside the box. The ambient temperature during this test is 31.8°C. From minutes 1 to 5, the temperature reading is taken every one-minute interval. The reason for this is the temperature will drastically change during this period. After 5 minutes the temperature reading will be taken every 3 and 5 minutes since the temperature will rise very slowly after that. The graph clearly shows that the time taken for temperature rise from ambient temperature to 70°C is around 43 minutes. The temperature rise during this period is 38.2°C. From the plotted graph it can also be said that the temperature dropping characteristic is almost linear. The ability of thermoelectric Peltier to raise the temperature to 70°C is proven.

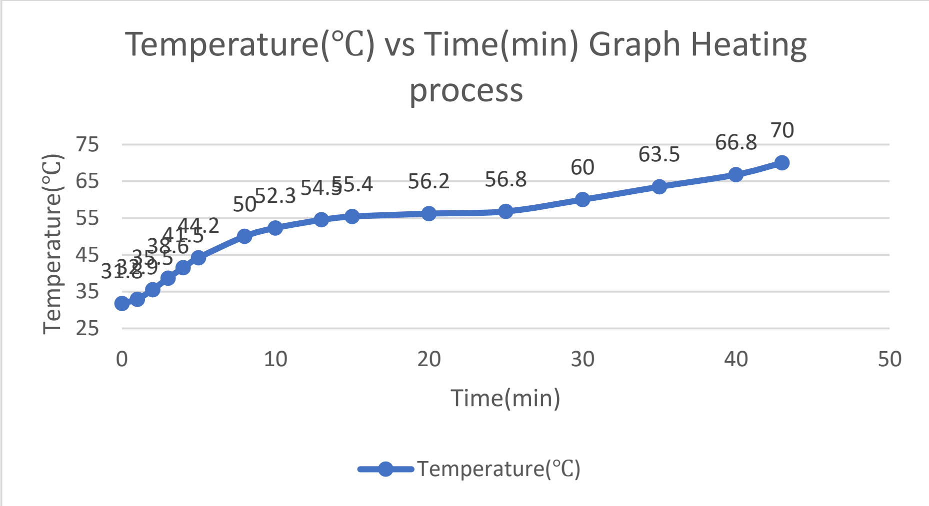

Figure 8: Temperature (°C) vs Time(min) Graph (Heating Effect)

B. 12V 20A Charging System

The main power supply for this product comes from the 12V 20A AC/DC adaptor. The product can be fully charged within 2 hours. The charging current design for the system is 10A. Since the battery used for this product is a lithium battery, the full charging voltage will be 12.6V and the lowest design voltage is 10.5V which there are 20% remaining in this battery itself. The depth of discharge for this battery is designed to drop up to 80%. To perform this test, the battery capacity must be drained first until 20% left which is 10.5V. Then, plug in the adaptor and switch on the main switch of the product. Record the voltage reading from the charge controller until it reaches 12.6V. Figure 9 shows the setup to perform the charging process by using the adaptor. The adaptor will plug into any 13A socket outlet available and convert to 12Vdc. Then the DC source will supply the product for charging purposes. Figure 10 shows the voltage (V) vs. Time (min) graph for the charging process by using an AC/DC adaptor. The graph proves that the charging system designed can fully charge the product within 2 hours. The voltage reading is recorded every 10-minute interval. The graph shows that it is almost linearly presented. Can be concluded that the voltage increases when the charging time increases. The battery voltage is almost directly proportional to the charging time.

Figure 9: The setup to perform the charging process by using an adaptor.

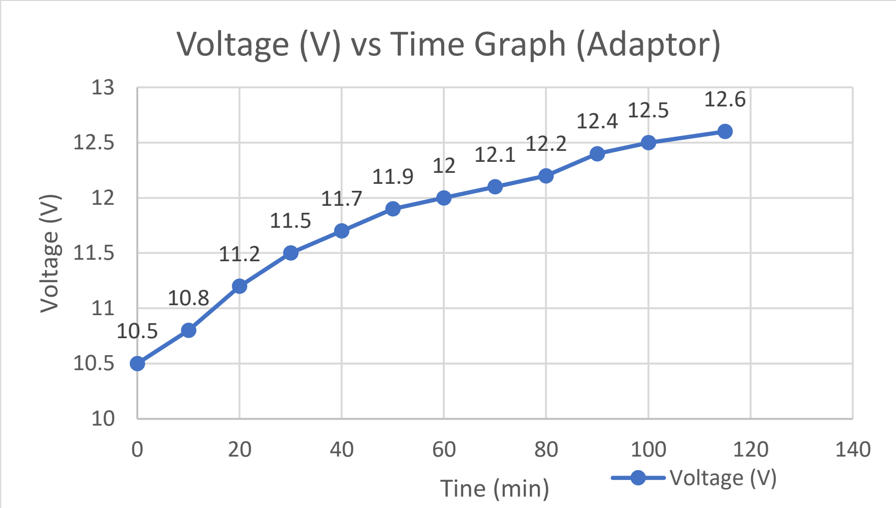

Figure 10: voltage (V) vs. Time (min) graph for the charging process by using an AC/DC adaptor.

C. Solar Charging System

Solar Systems act as the external power source for the product. It is also applicable to fully charge the product if there is more solar panel available to provide power. To perform the hardware test for solar systems, an 80W monocrystalline solar panel is used as the power source. As the solar energy source will be mostly dependent on the weather, the test is carried out on a sunny day and is expected to last 5 hours which is from 10 am to 3 pm. The testing for the solar charging system running for 2 days (18 and 19 May 2023) for 5 hours is not enough to fully charge the 80% drained battery. Figure 11 shows the physical setup to test the solar charging system. Figure 12 will present the Voltage (V) vs. Time (min) [10 am to 3 pm] Graph (18 and 19 May 2023) for the solar charging process. In this process, the total recorded time taken is 10 hours. The battery reaches its full charge voltage 8¬¬th¬ hours after the charging process. Figure 13 presents the rise of the battery voltage concerning the taken time from 10 am to 3 pm on 18 and 19 May 2023. From the graph can notice that the battery voltage will rise the most from 12 pm to 1 pm. So, this is proven that the strongest sun rays occur during this period. The voltage remains constant when reaches 12.6V due to the cutoff function of the solar charge controller.

Figure 11: Physical setup to test the solar charging system.

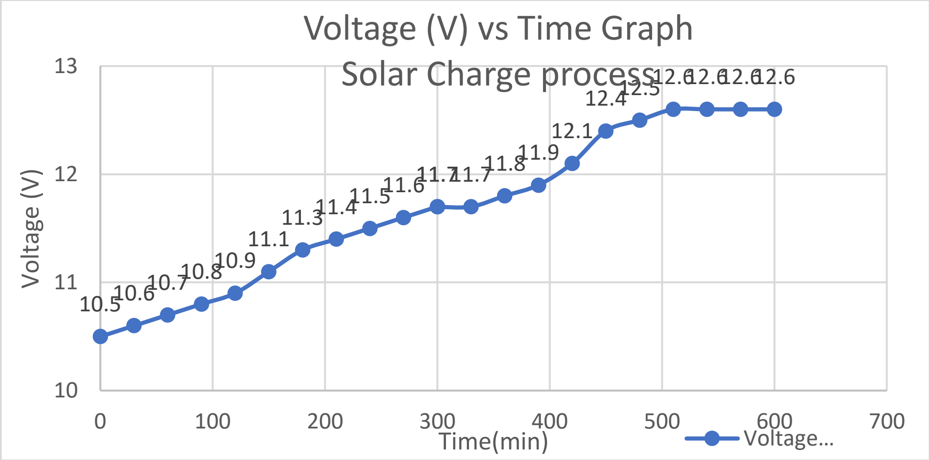

Figure 12: Voltage (V) vs. Time (min) Graph (18 and 19 May 2023) for the solar charging process.

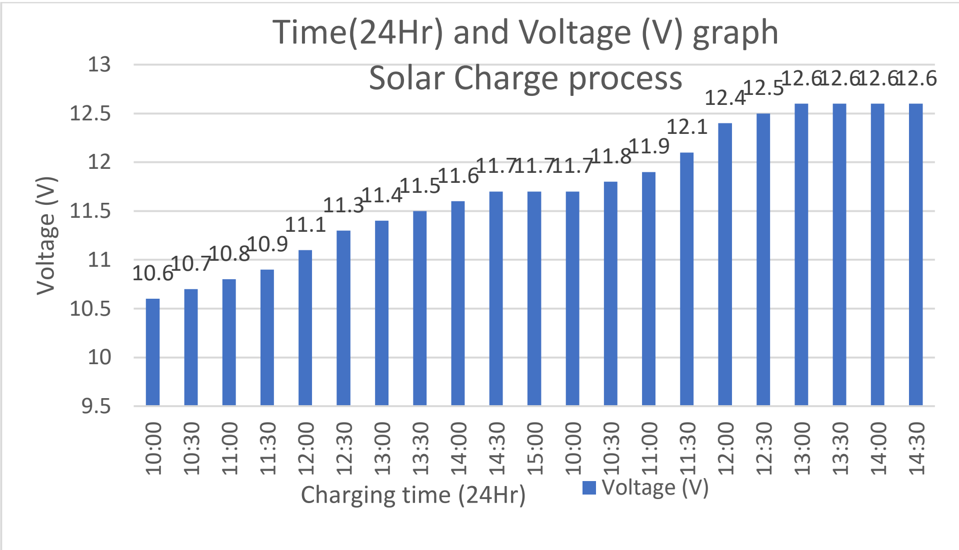

Figure 13: Time(24Hr) [10 am to 3 pm] and Voltage (V) Graph (18 and 19 May 2023) for solar charge process.

D. Battery Capacity

The battery is the most important part of 'Solar Powered Portable Cooler and Warmer'. Without a battery, the whole system will have no power source and will be unable to operate. A huge capacity and lightweight battery are the aim of this product. To carry out the testing process of the battery capacity, the operation hours of the product will be the focus. The longer the product can operate, the bigger the capacity of the battery. Figure 14 shows the physical setup to test the durability of this product on 13 May 2023. The temperature is set constantly to 15°C and the battery is in full condition. During the testing period, the battery is not allowed to have any external power source connected to it.

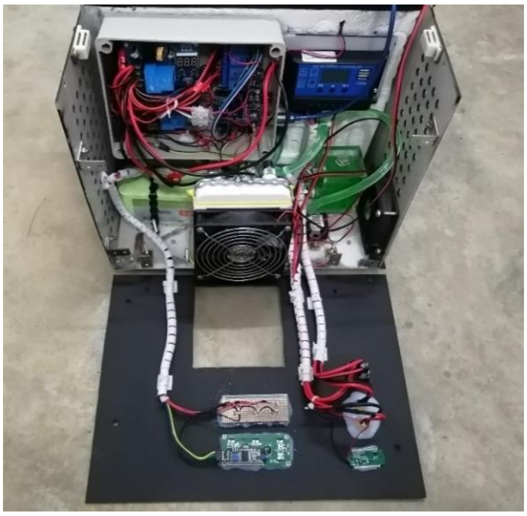

Figure 14: Physical setup to test the durability of this product on 13 May 2023.

Figure 15 presents the voltage (V) vs. time (min) graph during the discharge process on 13 May 2023. The voltage reading for this graph will be recorded every 30-minute interval. The graph clearly shows that the time taken for the battery voltage to drop from 12.6V to 10.5V will take around 10 hours. Since there is no other load or material that will absorb and release heat in the box, the only losses are through the lid and the polystyrene itself.

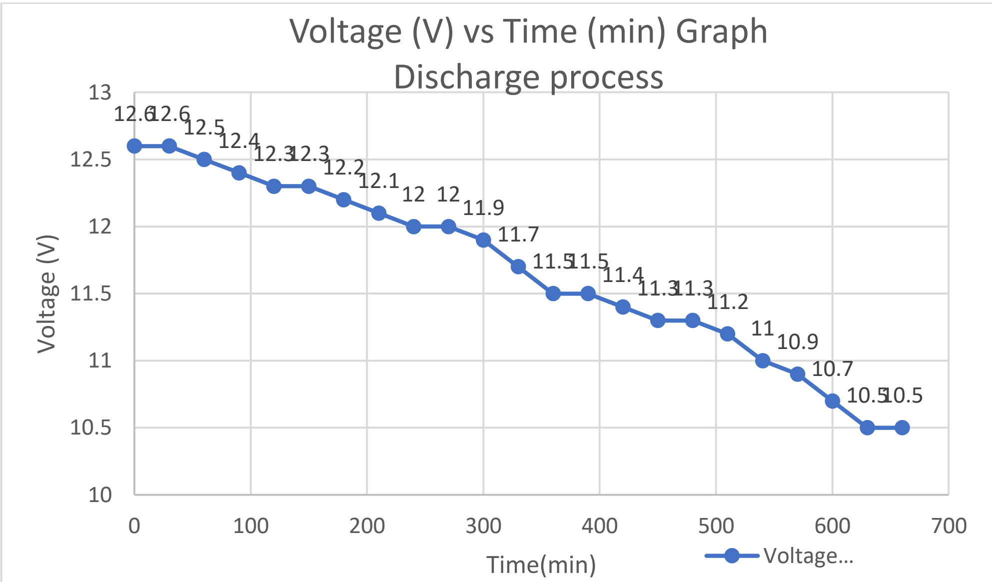

Figure 15: Voltage (V) vs. time (min) graph during the discharge process on 13 May 2023.

Figure 16 presents the voltage (V) vs. time (24Hr) graph of the discharge process on 13 May 2023. The purpose of plotting this graph is to analyze the power consumption depending on the weather or the ambient temperature. In the morning session, the battery voltage will drop slower than afternoon session. This is due to the ambient temperature that is lower in the morning and higher in the afternoon. The graph proves this finding as the battery voltage drops faster from 12 p.m. to 1 p.m. The consumption after that is less due to the rainy weather.

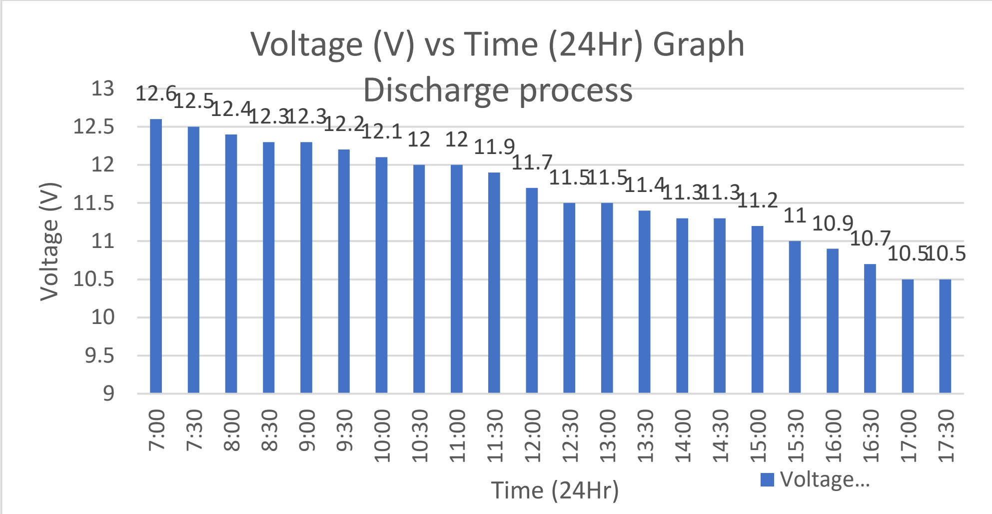

Figure 16: voltage (V) vs. time (24Hr) graph during the discharge process on 13 May 2023.

4. Conclusion

This project aims to design a 'Solar Powered Portable Cooler or Warmer' that is portable enough to carry along to store any materials that are sensitive to the temperature. The other interesting aspect is it can be powered up by solar energy which is the clean energy that will bring less effect to the environment. The user can easily monitor the battery level from the battery indicator and also control the temperature that they need. Other than that, the system is designed to achieve a maximum lowest temperature of 8^{o}C and the highest temperature of 70^{o}C. The material used to insulate the temperature is a hard polystyrene box to maximize the efficiency of the cooling or heating effect.

Furthermore, the concept of solar energy has been successfully implemented in this product to prolong the operating period. With the solar panel (200W) connected to the product, the product can keep running and charging at the same time. Finally, this product has also been tested to maintain the temperature inside it for at least 11 hours. This test has been conducted to ensure that the temperature inside the box will remain constant for a long time without any external source interruption. With that being said, users can securely store anything sensitive to temperature change in the product for a long period.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

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