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Design of Cooling and Monitoring Electric Motorbike Batteries Based On Internet Of Things (IoT)

Anaga Ozthandrick De Dhito[1] and Zakiyah Amalia[1*]

[1] *Automotive Electronics Engineering, State Polytechnic Of Malang, Malang, Indonesia*

Corresponding Author: Zakiyah Amalia, zakiyah.amalia@polinema.ac.id

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Abstract

The temperature increase in the battery occurred when the battery was used and charged. This temperature increase would give a negative impact on the battery such as reducing the battery life, and could even cause battery damage. The objective of this research was to design a battery cooling device based on the Internet of Things using the blynk application to monitor the battery condition. Using this device, the battery temperature would be maintained and its condition would be monitored when the battery is charged. The test was carried out on a LiFePO4 battery pack with a capacity of 10% and charged to 100%. Various fan rotation speeds were collected using PWM with a Duty Cycle of 25%, 50%, and 100% and variations in charging current, battery temperature, and charging time, and the results were explained to find the effect of using a cooling device. The results showed that the battery cooling and monitoring device worked well. The higher the fan rotation speed, the lower the battery temperature, which is 32.04 ° C. The higher the charging current, the shorter the charging time. When charging the battery with 6A charging current, took 2956.34 seconds. The average temperature difference from the 4A and 6A charging current variations was 1.07 ° C. Data logging on the bylnk application on the smartphone showed the trend of current (A), temperature (°C), voltage (V), battery capacity (%) and fan rotation speed (%).

Keywords : Battery cooling device, IoT, battery, PWM, Battery monitoring

1 Introduction

Electric vehicles are vehicles that are quite popular with Indonesians because there are no emissions produced when these vehicles are used or can be said to be environmentally friendly vehicles. Electric vehicles use batteries as the main energy storage component and are also the main component that supplies the entire existing system, so that it can be used according to the function of each component [1]. There are 2 types of batteries that are most promising for use in electric vehicles. These types of batteries are lithium ion batteries and lithium iron phosphate batteries (LiFePO4). Lithium-Ion batteries have the advantage of having a high power density and high efficiency values. In addition, Lithium-Ion batteries have a low self-discharge rate, a relatively long service life, and do not have a memory effect [1]. Meanwhile, lithium iron phosphate batteries (LiFePO4) also have several advantages, such as low maintenance costs, non-reactive, environmentally friendly, and high capacity [2]. Apart from the advantages they have, the two types of batteries above definitely also have disadvantages. One of them is the temperature of the battery, which increases with use. This temperature increase is caused by the flow of electrical current through the conductor and causes the conductor to produce heat. Over time, this increase in temperature can cause overheating and reduce the battery lifetime [3]. As in the research conducted [4], the research results obtained from the experiments show that the optimal working temperature for LiFePO4 batteries is in the range of 10ºC to 40ºC.

Based on the description above, to support the development in the automotive world, especially electric vehicles, several studies related to cooling batteries in electric vehicles need further innovation. As in the research conducted by [5], where the researcher built a LiFePO4 battery cooling box using a fan cooler and charging the battery using a solar panel. The research results obtained were that by using a cooling box when the battery was being charged, the battery temperature was maintained and 19% more power was produced compared to when the test temperature was set higher. Regarding the research conducted by [6], the battery cooling is based on the principles of conduction and convection with PCM and cooling plates. The results obtained from this research are a simulation of an effective battery cooling package using PCM and a cooling plate when the battery is fast charging. Therefore, in this research, the researchers designed a cooling device in the form of a box and equipped with a fan whose fan rotation speed can be controlled through programming. With this battery cooling tool, it is hoped that it can maintain the battery temperature and its effect on the battery charging time up to 100% can be seen. By adding a feature in the form of battery monitoring to the Blynk app on smartphones [7], it is hoped that it will make it easier for users to monitor battery conditions in real time during the charging process.

2 Method

The research used an experimental method by designing a cooler box design and a schematic diagram of an electronic circuit to monitor battery conditions, then making a cooler box and assembling electronic components to monitor battery conditions during testing.

2.1 Electronic circuit

An electronic circuit is a series of electrical and electronic components that are interconnected, in order to perform a specific function. In this research, an electronic circuit is used to run readings from sensors used to monitor battery conditions and control cooling systems. Figure 1 shows the schematic of the electronic circuit used in this investigation.

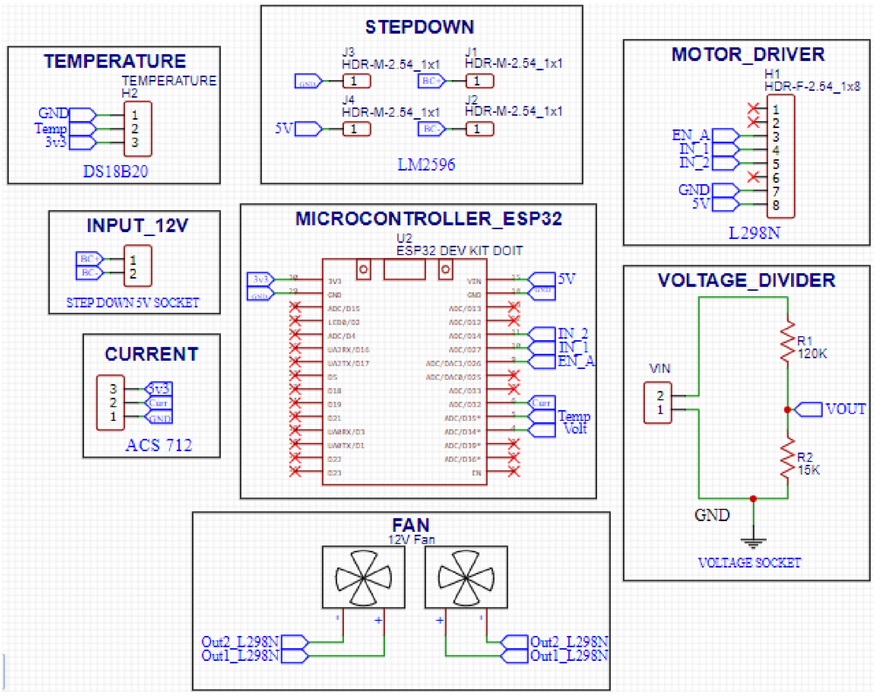


Figure 1: The electronic circuit

The electronic circuit was created using the EasyEDA website. The voltage source for the ESP32 microcontroller input comes from a 12V battery that has been reduced by the LM2596 step-down to 5V. The output of the stepdown is connected to Vin (positive) and GND (negative). The pin of the DS18B20 temperature sensor signal is connected to pin 35 of the ESP32 microcontroller. The ACS712 current sensor signal pin is connected to pin 32 of the ESP32 microcontroller to read the incoming current during the battery charging process. The battery voltage that is charged passes through a voltage divider circuit, which is connected to pin 34 of the ESP32 microcontroller to determine the battery voltage. The pin for controlling the speed of the cooling fan (EN-A) is connected to pin 26, while the IN_1 cooling fan rotation direction control pin is connected to pin 27, IN_2 is connected to pin 14 of the ESP32 microcontroller. The cooling fan input is connected to the L298N motor driver output. All inputs that enter the microcontroller produce reading outputs in the Blynk application. Figure 2 shows the layout of the PCB of the electronic circuit in this investigation. The blue lines indicate the location of the paths connecting the electronic components and are located at the bottom of the PCB (bottom layer), while the red lines indicate the location of the paths connecting the electronic components and are located at the top of the PCB (top layer).

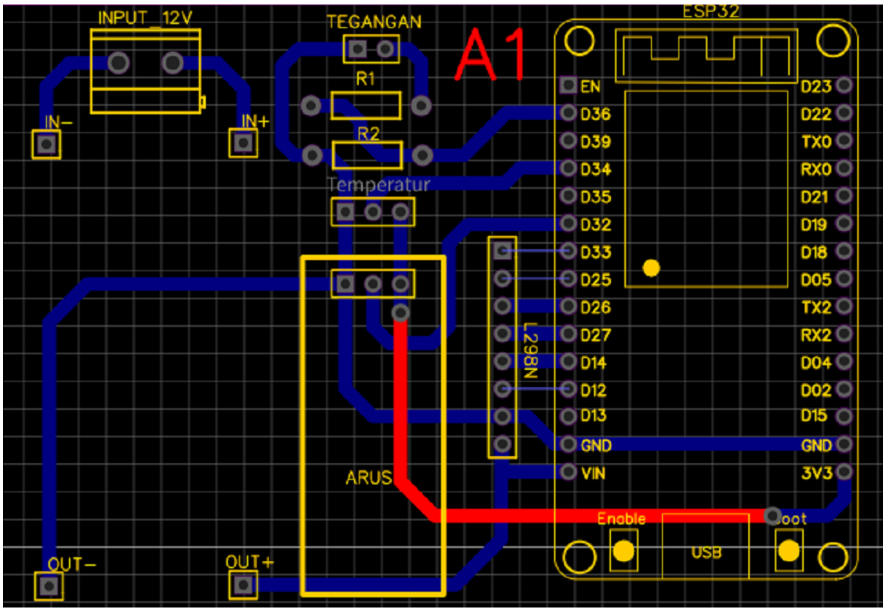


Figure 2: The PCB layout

2.2 LiFEPO4 Pack Battery Cooling Device

The cooling device is an acrylic box with two 1.08 watt cooling fans. The rotation speed of the cooling fan using pwm by changing the duty cycle variation through programming stored on the ESP32 microcontroller. Figure 4 shows the lifepo4 battery pack located inside the cooler box.

2.3 LiFEPO4 Pack Battery Monitoring Tool

Monitoring tool based on an ESP32 microcontroller with a DS18B20 temperature sensor circuit as a reader of temperature changes in the LiFEPO4 battery [8] an ACS712 current sensor as a sensor reader [9], a voltage divider circuit as a voltage sensor [10]. The sensor reading results are then processed by the ESP32 microcontroller [11] to be sent to the blynk application on the smartphone [7]. The results of the monitoring tool can be seen in Figures 4 and 5.

2.4 Experimental setup

Before collecting data, it is necessary to prepare tools and materials according to Figure 6. In this test, changes in temperature, current, and voltage that occur in the LiFePO4 battery pack during the charging process will be read using a sensor connected to the battery circuit and then processed by a microcontroller ESP 32. The tests were carried out with battery charging variations of 4A and 6A. The rotation speed of the cooling fan is controlled by programming it to start slowly (25%), medium (50%), and fast (100%). The direction of the wind produced by the rotation of the cooling fan is towards the opposite side of the fan. In

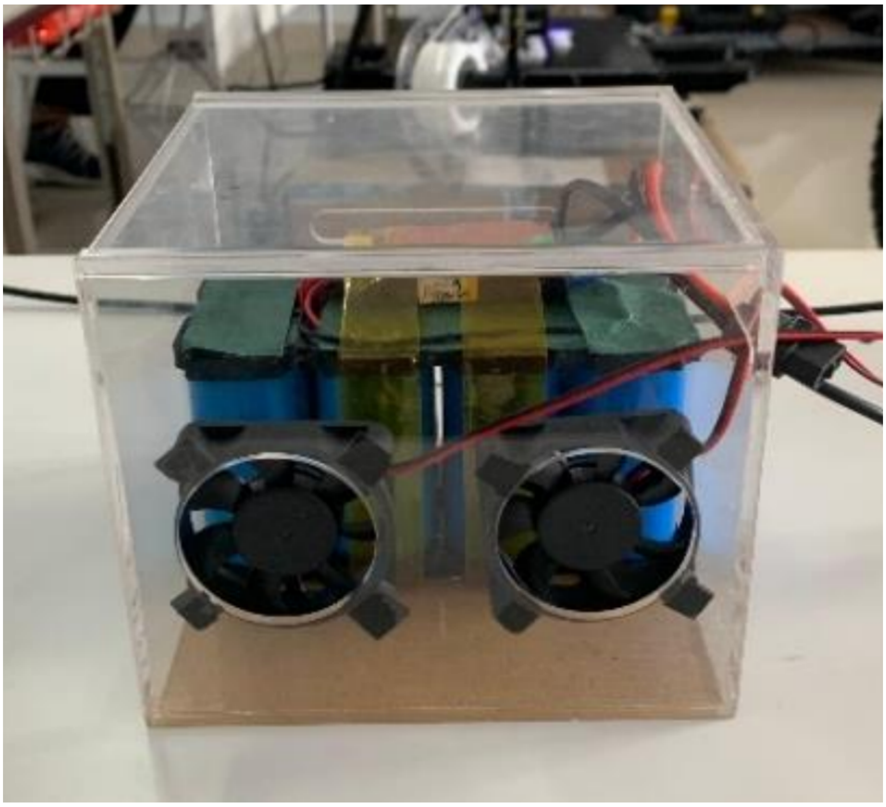


Figure 3: The LiFEPO4 Battery Pack Cooling Tool

each test observed, readings of current (A), temperature (°C), voltage (V), battery capacity (%) and cooling fan rotation speed (%) are taken using sensors and programming that have been integrated into the battery monitoring system and are connected to the Blynk application on the smartphone.

2.5 Data collection process

Data collection was carried out three times for each independent variable, namely three times at cooling fan rotation speeds of 25%, 50% and 100%, and variations in charging current of 4A and 6A. The data collection process begins when the battery capacity is 10%, then records the charging time and temperature of the LiFEPO4 battery pack when charging at 25%, 50%, 75% and 100% battery capacity.

3 Result and Discussion

The research results were obtained by running a lap timer to obtain the charging time for each increase in battery capacity and observing temperature changes via the blynk application on the smartphone. Data collection was carried out 3 times for each variation in fan rotation speed and charge current variation. The research results can be seen in the following explanation.

3.1 Effect of Varying Cooling Fan Rotation Speed on LiFEPO4 Battery Charging Time

Table 1 and Table 2 show the average of the test data for the variation of the fan rotation speed on the charging time of the battery. Based on the data in Table 1 and Table 2, the average charging time graph is obtained in Figure 7, which shows that the rotation speed of the cooling fan affects the battery charging time to capacity 100% or fully charged.

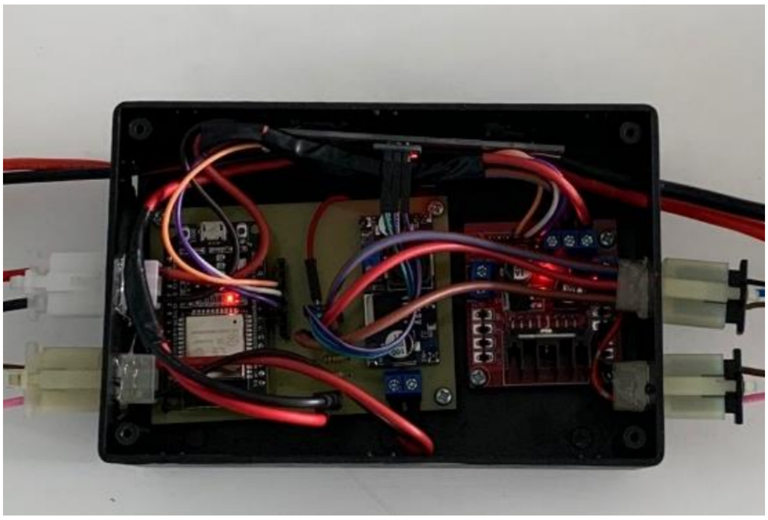


Figure 4: The LiFEPO4 Battery Pack Cooling Tool

Table 1: Average Charging Time at 4A (Seconds)

Batt. Capacity (%) / *Cooling Fan*	25	50	75	100
25	672,33	1130,67	1142,67	1071,33
50	657,00	1124,67	1139,67	1086,33
100	665,33	1112,67	1121,00	1088,67

Table 2: Average Charging Time at 6A (Seconds)

Batt. Capacity (%) / *Cooling Fan*	25	50	75	100
25	476,67	841,67	855,33	782,67
50	473,00	828,33	838,67	768,67
100	469,67	784,33	791,67	768,33

Table 3 shows the average charge time of the battery at 100% capacity. When the charging current was 4A, the higher the fan speed, the slower the charging time. The difference in charge time when the fan speed was 100% and 25% was 17.4 s. However, when the charging current was 6A, the higher the fan speed, the faster the charging time. The difference in charge time when the fan speed was 100% and 25% was 14.4 s. This phenomenon is because the charging current when using the 6A charger in this research is less stable. There is an increase and decrease in current from the 6A charger. Meanwhile, the charging current when using the 4A charger is more stable. The charging current is constant from the start of charging to full battery capacity. A stable charging current ensures that each cell in the battery circuit receives an even voltage until it reaches its maximum charge capacity [12].

Table 3: The Charging Time (s)

Fan Rotation Speed (%)	4 (A)	6 (A)
25	1071,3	782,7
50	1086,3	768,7
100	1088,7	768,3

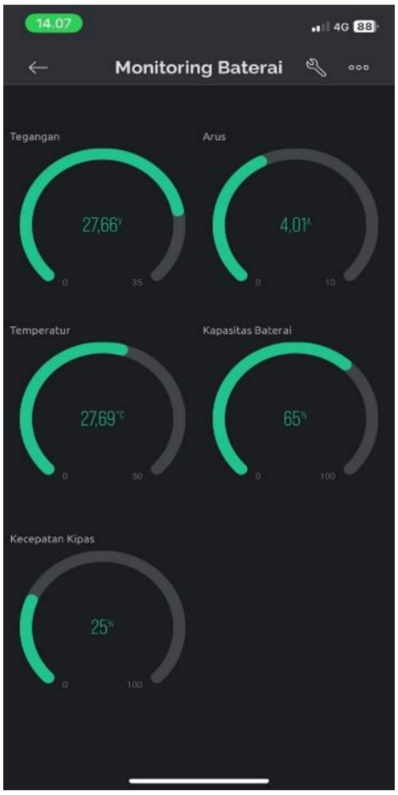


Figure 5: The Blynk Application on Smartphone

3.2 Effect of Varying Cooling Fan Rotation Speed on LiFEPO4 Battery Temperature

Based on the average temperature graph in Figure 8, it shows that the rotation speed of the cooling fan has a significant effect on the temperature changes with each increase in battery capacity during charging. Charging with a charging current variation of 4A has a lower average temperature. When the fan rotation speed was 25%, the temperature at capacity 100% has a higher value than when the fan rotation speed was 100%. This is because, when the fan rotation speed is faster, the cooling circulation is also greater, so the temperature changes that occurred were smaller. In Figure 8b, charging with a 6A charging current has a higher average temperature. According to Joule's law theory, the heat power produced is proportional to the product of the square of the electric current and the electrical resistance [13]. It is formulated as follows:

$$P = I^2 R \tag{1}$$

Where:

- P = Power generated as heat (Watt)
- I = Current flowing through the conductor (Ampere)
- R = Conductor resistance (Ω)

Based on the formula above, if there is an increase in the battery charging current and the internal resistance value of the battery is constant, then the power generated in heat during the charging process will increase. This is because when the current entering during the charging process increases, the heat generated will increase quadratically [14].

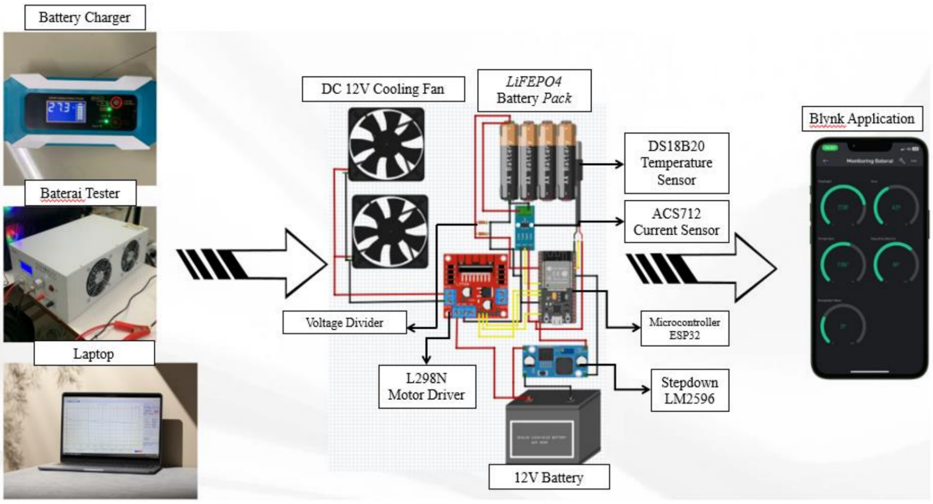


Figure 6: The experiment setup

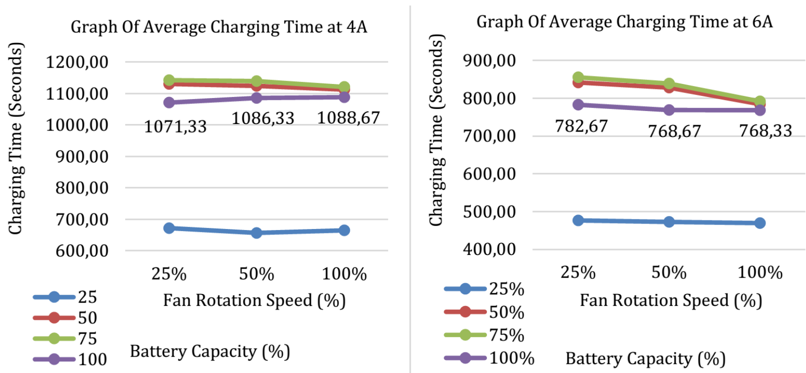


Figure 7: The Average Charging Time

3.3 Effect of Charging Current Variations on LiFEPO4 Battery Charging Time

As in the average charging time graph in Figure 9, it shows that the variation in the charging current has a significant effect on the charging time of the battery. At each variation in fan rotation speed, the charging time with a 6A charging current has a smaller average number than when the charging current is 4A. The battery charging time to be fully charged or the capacity of 100% is the longest at a 4A charging current at a fan rotation speed variation of 25%, which is 4017 seconds, while the longest charging time is at a 6A charging current, which is 2956.34 seconds. So, the difference in the average longest charging time between 4A and 6A charging currents is 1,060.67 seconds.

Based on Figure 9, it shows that the higher the charging current, the shorter the battery charging time. This is in accordance with the battery capacity formula, which is expressed in ampere hours [15], as follows:

$$Ah = I \times t \tag{2}$$

Where:

- Ah = Battery capacity (Ampere hour)
- I = Current strength (Ampere)
- t = Time (hour)

The battery capacity indicates the amount of current flowing in one hour. Battery capacity can be determined by multiplying the current strength by the time required for the battery to be fully charged or by

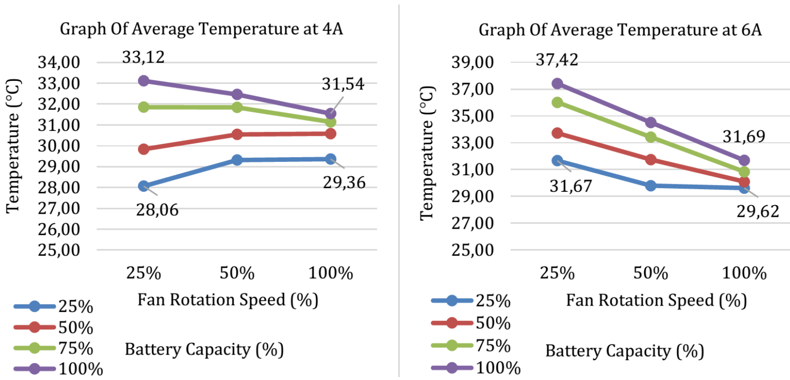


Figure 8: The Average Temperature Profile

the time required for the battery to supply power to the cut-off limit. Thus, the greater the current during charging or discharging, the shorter the time required for the battery to be fully charged or empty.

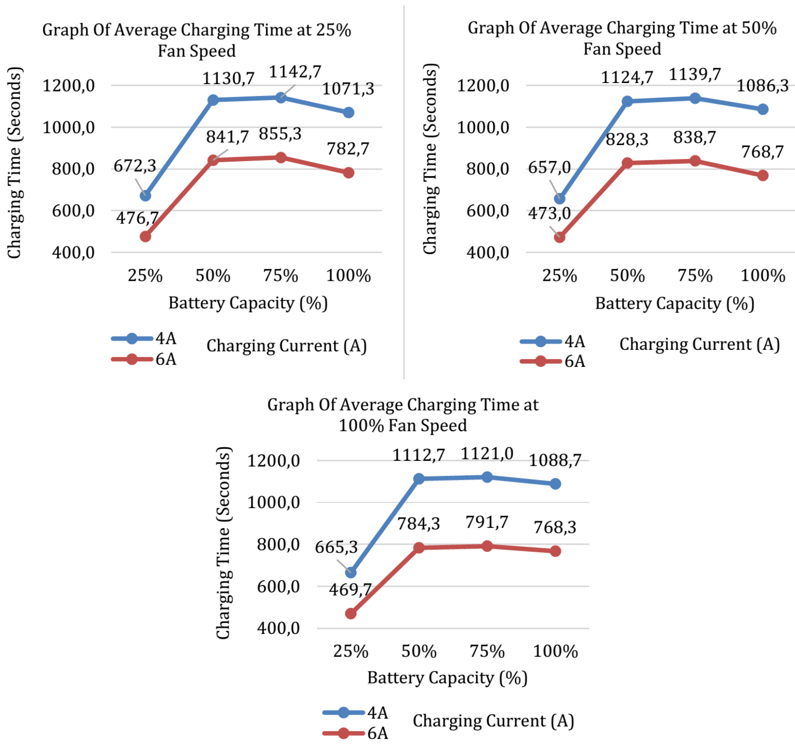
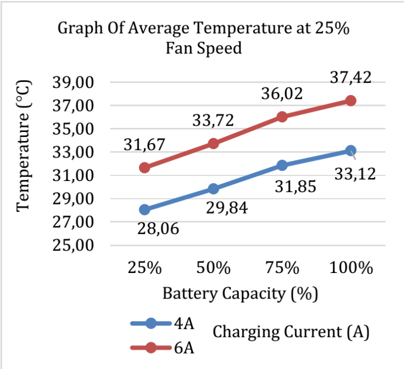


Figure 9: The Average Temperature Profile

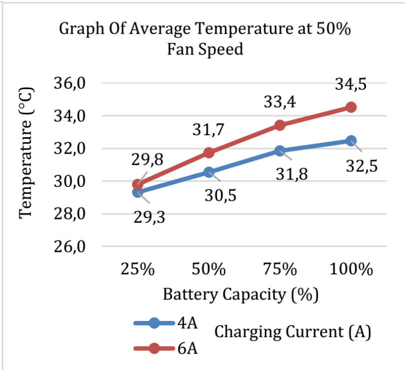
3.4 Effect of Charging Current Variations on LiFEPO4 Battery Temperature

As in the average temperature graph in Figure 10, it shows that the variation of the charging current has a significant effect on the increase in battery temperature. At each variation of fan rotation speed, the battery temperature with a charging current of 6A has a higher average than when the charging current was 4A.

Based on Figure 10, which shows the average temperature graph with variation in fan rotation speed, it states that at fan rotation speeds of 25% and 50%, the higher the charging current, the battery temperature also increases. However, when the fan rotation speed is 100%, the variation in charging current does not significantly affect the increase in temperature. Table 4 shows the average temperature with a battery capacity of 100 %. When the fan rotation speed was 25%, the temperature difference between the 4A and 6A charging currents was 4.3 ° C. When the fan rotation speed was 100%, the temperature difference between the 4A and 6A charging currents was 0.15 ° C. When the fan rotation speed was 100%, the cooling circulation is faster, so the increase in temperature becomes more stable. In accordance with Joule's law theory, this temperature increase is caused because when the charging current is greater, the power converted into heat is also greater [13], [14].



10a. Graph of Average Temperature at 25% Fan Speed



10b. Graph of Average Temperature at 50% Fan Speed

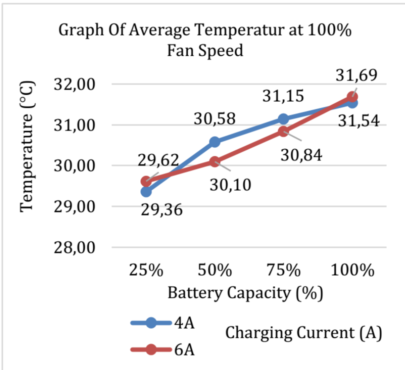


Figure 10: The Average Temperature in Charging Current Variations

Table 4: The Average Temperature When Battery Capacity was 100% (^oC)

Fan Rotation Speed (%)	4 (A)	6 (A)
25	33,12	37,42
50	32,5	34,5
100	31.54	31,69

4 Conclusion

LiFEPO4 battery pack cooler made of acrylic box and equipped with two 1.08 Watt cooling fans, is able to maintain battery temperature in a more stable condition when the fan rotation speed is 100%. Monitoring battery condition during charging based on the Internet of Things (IoT) is able to run well using the blynk application on a smartphone. There is an effect of the fan rotation speed on the battery charging time. The difference in the charging time when the fan rotation speed was 100% with 25% at a charging current of 4A was

17.4 seconds slower, while at a charging current of 6A it was 14.4 seconds faster. This phenomenon is because the charging current when using a 6A charger in this investigation was less stable compared to a 4A charger. Thus, the charging time with a 4A charger tends to be slower than with a 6A charger. For further research, it is recommended to choose a battery charger that meets the specifications in order to obtain better battery charging. Variations in fan rotation speed also affect changes in battery temperature during charging. The faster the fan rotation speed, the faster the cooling circulation, so the battery temperature during charging is lower. There is an effect of variations of the charging current on the charging time and changes in the battery temperature. The longest battery charging time to 100% capacity at a charging current of 4A occurred at a fan rotation speed variation of 25%, which is 4017 seconds, while at a charging current of 6A it was 2956.34 seconds. So, the difference in the average longest charging time between the 4A and 6A charging currents was 1,060.67 seconds. So, the greater the charging current, the shorter the charging time. In each variation in fan rotation speed, the battery temperature with a charging current of 6A had a higher average than the charging current of 4A. So, the higher the charging current, the higher the increase in battery temperature.

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