DEVELOPMENT BATTERY PACK FOR ELECTRIC ATV USING 40AH POUCH BATTERY CELLS

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Article history
Received
7th December 2022
Received in revised form
7th December 2023
Accepted
8h December 2023
Published
28th December 2023

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Abstract

The existing electric ATV in the Automotive Laboratory, P21 of Universiti Teknologi Malaysia, had been abandoned without any purpose due to the lack of a battery. Therefore, developing a battery pack for the electric ATV using the 40 Ah lithium-ion pouch cells can make the electric ATV functional again. To do this, the battery needs to be designed to fit inside the cargo load of the ATV, which is the space of the previous battery. Next, the battery pack's capacity needed to be designed based on the requirement of the electric ATV existing in the automotive laboratory. The complete battery system must include a cooling system, battery management system (BMS), charging system, and battery packaging. Finally, the objectives of this project are achieved whereby a good performance battery with 74 V 80 Ah of capacity equipped with a cooling system, battery management system, charging system, and battery packaging is successfully developed.

Keywords

Battery capacity, cooling system, battery management system, charging system, battery packaging.

Introduction

Batteries are made up of one or more cells, each of which produces an electron flow in a circuit through chemical reactions. An anode (the '-' side), a cathode (the '+' side), and some forms of electrolyte are the three basic components of all batteries (a substance that chemically reacts with the anode and cathode) [1]. When we connect the anode and cathode of the battery to a circuit, a chemical reaction occurs between the anode and the electrolyte. This reaction sends electrons across the circuit and back to the cathode, undergoing another chemical reaction. Batteries that must be thrown away after use are known as primary batteries, while rechargeable batteries are called secondary batteries.

A battery pack is a collection of identical batteries or individual battery cells in any quantity. They can be arranged in series, parallel, or a combination to produce the required voltage, capacity, or power density [2].

A complete battery system used in an electric ATV requires a cooling system, battery management system, charging system, and battery packaging. Electric vehicle design is a complicated idea, especially regarding the battery, which is the heart and soul of any electric vehicle. The battery must be developed to meet the vehicle's motor(s) requirements and charging mechanism. This includes physical constraints such as maximizing capacity through effective packaging within the vehicle's body. Therefore, designers must consider the battery's placement within a vehicle as it is the main contributor to weight in an EV, which can affect the overall power efficiency and vehicle handling characteristics [3].

Methodology

A well-prepared research methodology is crucial in achieving the project's objectives and preparation for the fabrication process in UGP 2. Firstly, design synthesis is made to select the final battery design for fabrication. Then, fabricate the selected battery design according to the planned workflow. Lastly, the developed battery is tested with several tests to study its performance.

2.1 Design Synthesis

For the first design concept, plywood with the size of 738 x 285 x 25 mm was used as the base of the battery, which can be fitted perfectly inside the cargo load of the ATV. Next, the lithium-ion pouch cells were arranged vertically in this case, where the cell tabs are located at the top and bottom, as shown in Figure 1. This vertical arrangement was designed to allow maximum airflow between the cells, which have gap sizes of 3 mm.

In addition, this design concept requires two (2) blocks of plywood to support all the cells to prevent the connectors, the cell tabs, and the wiring from being compressed. An acrylic board is selected for the battery's casing, where the cooling fans will be installed on the board at the back of the battery. Finally, the cell tabs will be connected using bolts and nuts with the copper bus bar, which acts as the interconnector.

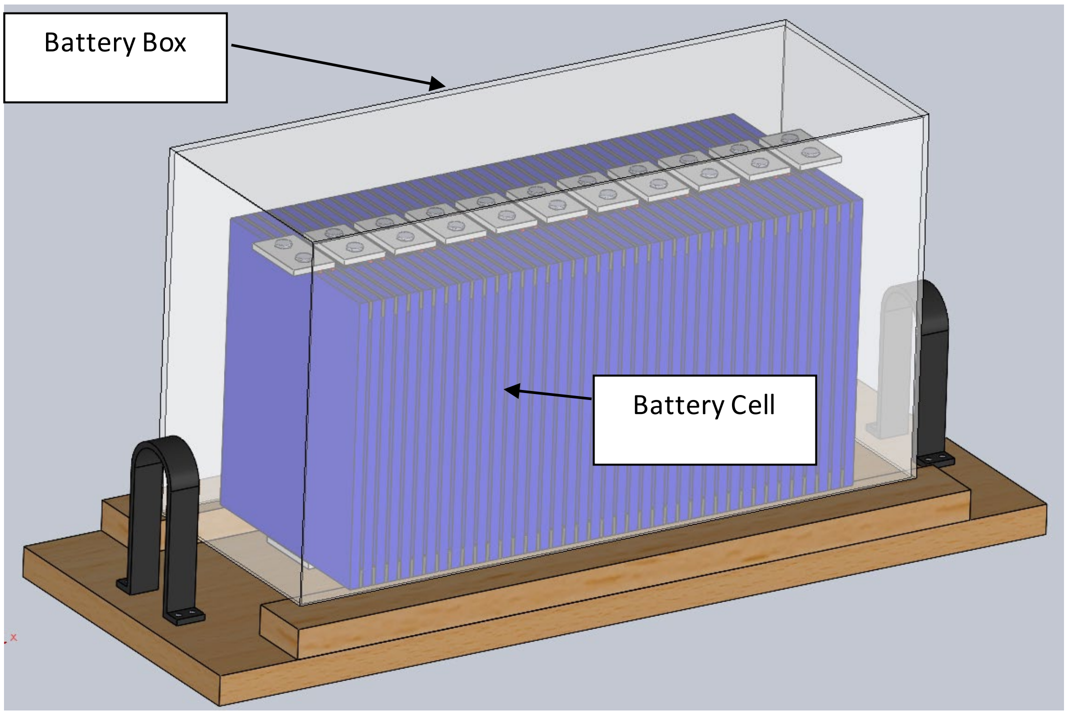

Figure 1: First battery design concept

The second design concept is modifying the first to ease fabrication, improve safety, and increase rigidity. Firstly, the arrangement of the pouch cells was changed from vertical to horizontal, with the cell tabs at the front and back, as shown in Figure 2. This is mainly due to the difficulty in placing the battery management system (BMS), as the BMS couldn't be placed on top of the cells since the cell tabs are at the top. Next, the cooling fans will be placed at the front of the battery instead of at the back due to the spacing constraints at the cargo load of the ATV.

Besides, a mounting board cut into strips was used as the separator between each cell to provide a larger gap size of 5 mm. Moreover, plywood replaced the acrylic board for this second design concept since it is easier to fabricate, such as cutting, drilling, and finishing. Finally, the cell tabs were connected using the fold and clip method, where the cell tabs were folded with each other before being clipped using the aluminum flat bar for rigidity purposes.

Table 1, which shows the Product Design Specification (PDS) concept scoring matrix, is constructed for a better comparison of both designs and to choose a better design concept. With the total score from Table 1, the second design concept is selected as the final design for the battery fabrication due to its better overall performance.

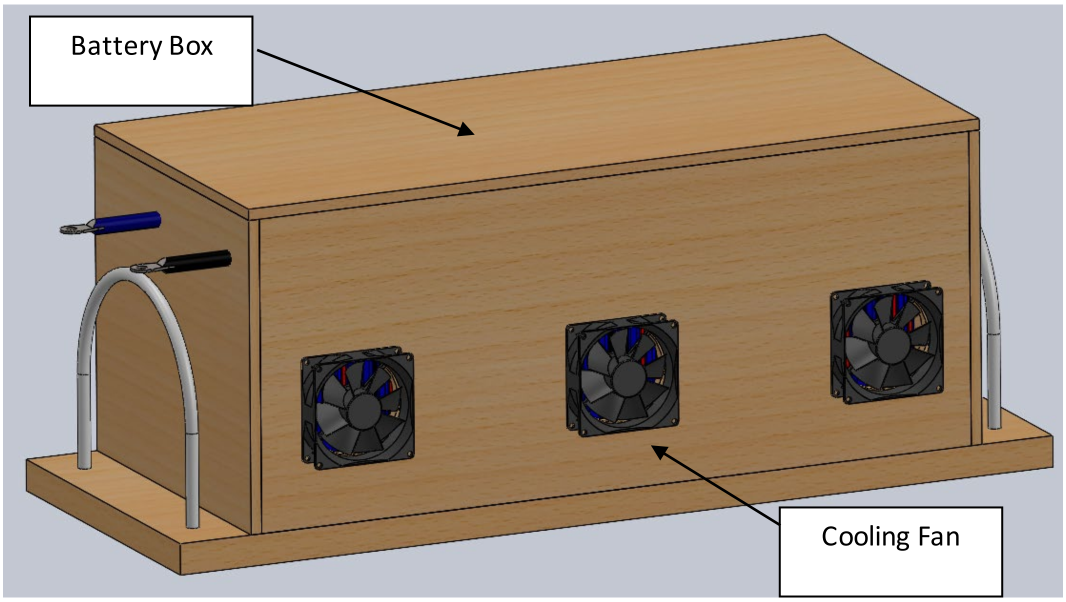

Figure 2: Second battery design concept

Table 1: Product Design Specification (PDS) concept scoring matrix

Design Concept		**First (1st)**		**Second (2nd)**	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
The rigidity of the battery structure	20 %	3	0.60	4	0.8
Temperature tolerance	20 %	5	1.00	5	1.0
Efficiency of battery cooling	20 %	3	0.60	4	0.8
Ease of fabrication	15 %	3	0.45	4	0.6
Usage of raw material	15 %	3	0.45	4	0.6
Ease of modification	10 %	4	0.40	3	0.3
Total Score:	**100 %**	**3.50**		**4.10**	

2.2 Flow Simulation

Flow simulation allows forecasting and examining how complicated geometry might affect a flow in a real-world setting [4]. In this project, SolidWorks flow simulation is used to determine the flow trajectories of air and the velocity range of air flowing through the battery as given in Figure 3. The air velocity produced by the fans is set to be 1.23 m/s.

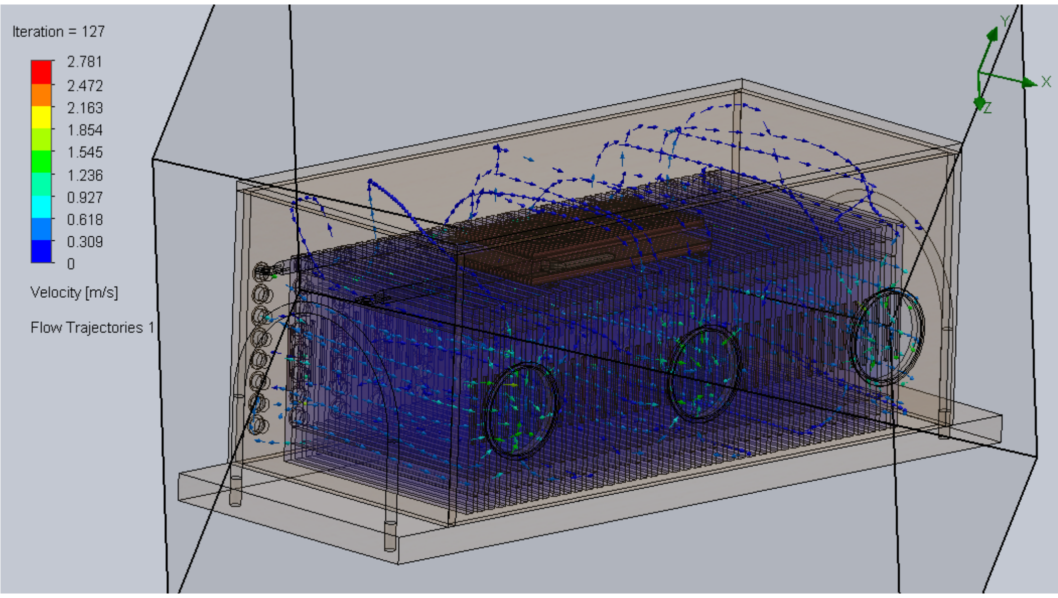

Figure 3: Airflow trajectories for the battery design

2.3 Fabrication Process

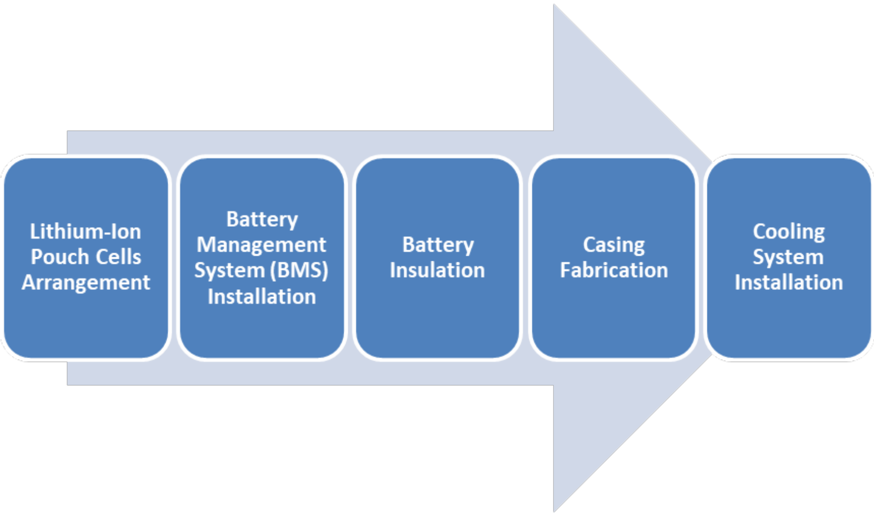

Figure 4: Fabrication process workflow

The fabrication of the battery starts with the arrangement of the lithium-ion pouch cells, then the installation of the battery management system (BMS), battery insulation, battery casing fabrication, and finally, the installation of the cooling system, as shown in Figure 4.

2.4 Charging and Discharging Test

After the battery is installed and activated with the BMS, it needs to be tested with the charging and discharging process to ensure that the BMS can be charged and discharged normally. After that, the battery is charged to the maximum capacity using the ITECH Auto Range DC Power Supply machine. Then, the battery will be discharged from 95 % SOC to 20 % SOC using the ITECH DC Electronic Load machine to collect several data required for this project.

The data that are being recorded are the SOC reduction per time, discharged capacity per SOC, and voltage drop per SOC. Besides, the temperature changes with the cooling fans activated are also recorded for both the charging and discharging processes. This is repeated with the deactivation of cooling fans to compare the temperature change between the data with and without the cooling system.

RESULTS AND DISCUSSION

3.1 Result of State of Charge (SOC) Versus Time

Figure 5 shows that the battery SOC dropped steadily from 95 % to 20 %, with a decrease of about 4 % SOC in five minutes. Temperature and C-rate are the two main elements that have a short-term impact on the battery SOC [5]. Therefore, the steady drop in battery SOC proved that the operating temperature and the C-rate for the discharging process are in an optimum range. Besides, the steady drop in battery SOC is true since the battery was not discharged below 20 % SOC. This is because over-discharging lithium-ion batteries will cause the battery to experience capacity degradation, which will cause a significant drop in battery SOC [6].

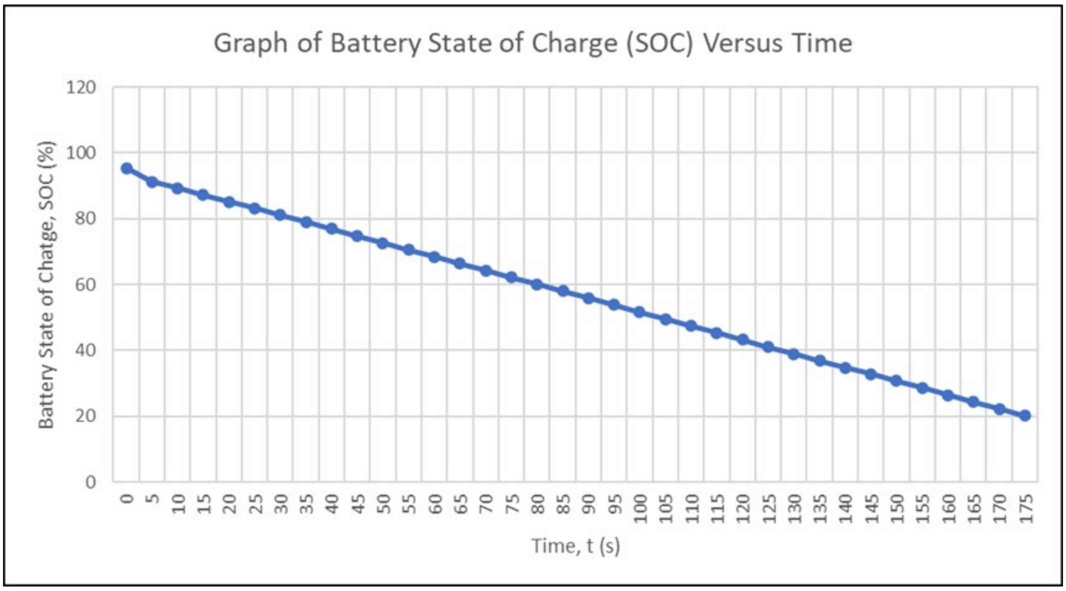

Figure 5: Graph of battery state of charge versus time

3.2Result of Change in Battery Capacity Versus SOC

It is noted that the discharging machine, the ITECH DC Electronic Load machine limits the discharging rate to 20 Amps. This means the battery is discharging at 0.25 C of the discharge rate. The battery took about 3 hours to discharge from 95 % SOC to 20 % SOC and discharged for a total capacity of 57.348 Ah. For an 80 Ah capacity battery, fully discharging at 0.25 C discharge rate will take about 4 hours. Therefore, discharging 75 % of battery SOC will result in having a discharge capacity of (0.75 * 80 Ah) = 60 Ah with the time taken of (0.75 * 4 hours) = 3 hours. The discharge capacity for the battery of 57.348 Ah, which took about 3 hours, is very close to the calculated value. So, it can be proved that the battery has an 80 Ah capacity that can charge and discharge normally. Figure 6 shows the battery discharge capacity versus battery state of charge as elaborated above.

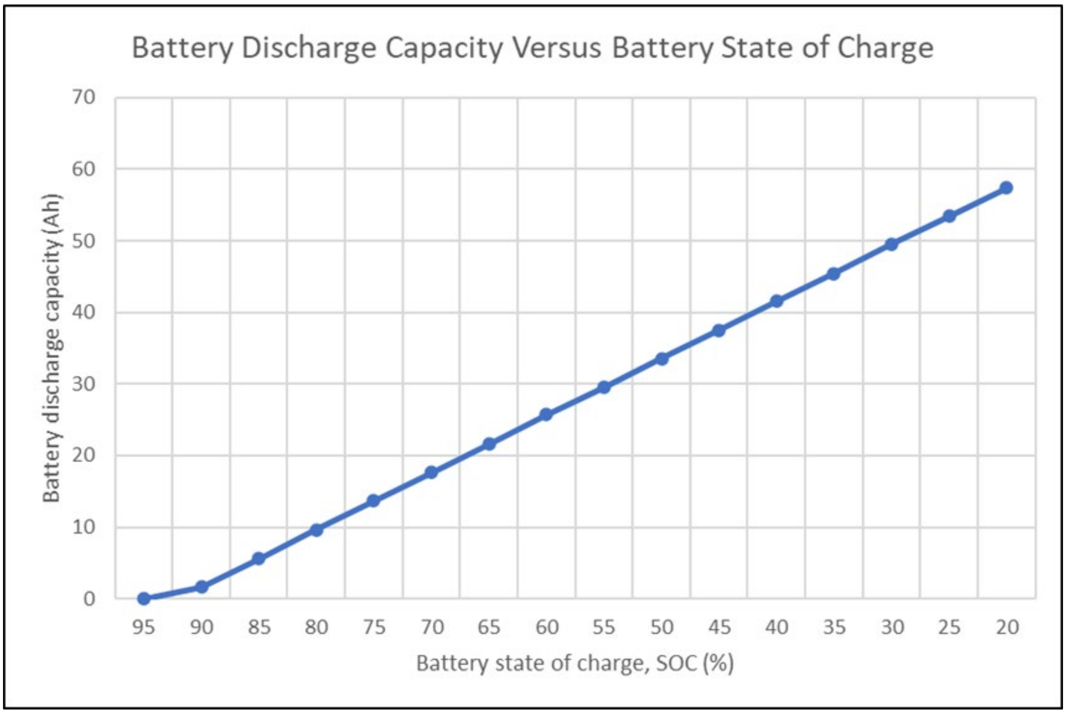

Figure 6: Graph of battery discharge capacity versus battery state of charge

3.3Result of Charging and Discharging Temperature Versus Battery SOC

From the observation of Figure 7 and Figure 8, the battery temperatures without activating the fans are higher for the charging process than the discharging process. When charging, the heat source releases more heat than when discharging [7]. This shows that the data collected are valid, as all the charging temperatures are higher than the discharging temperatures.

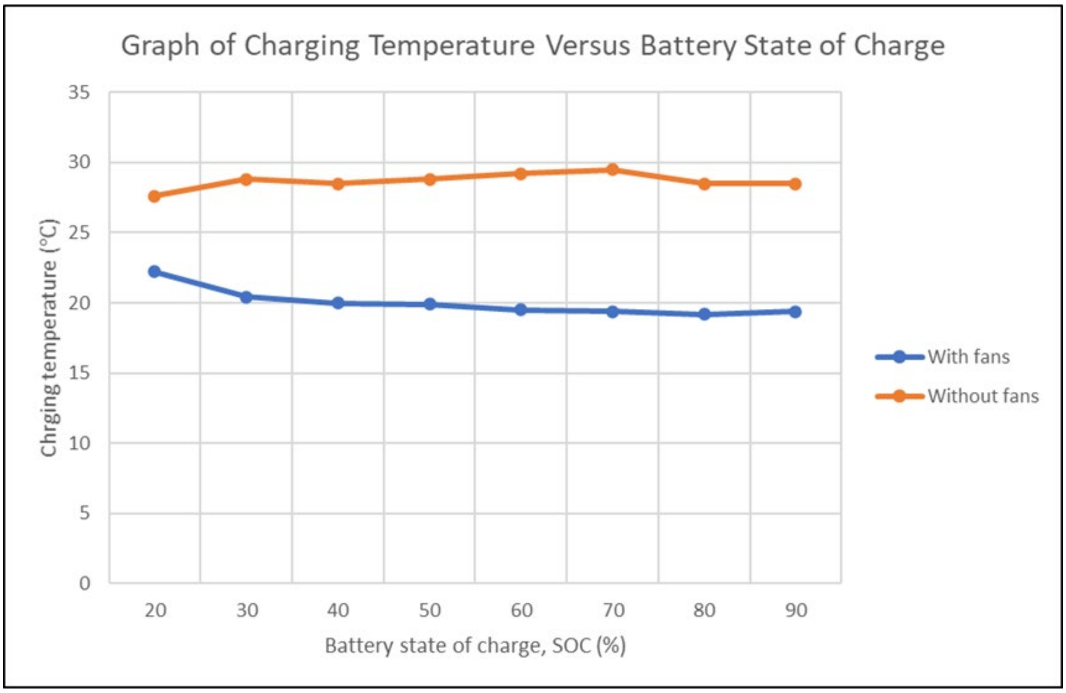

Figure 7: Graph of charging temperature versus battery state of charge

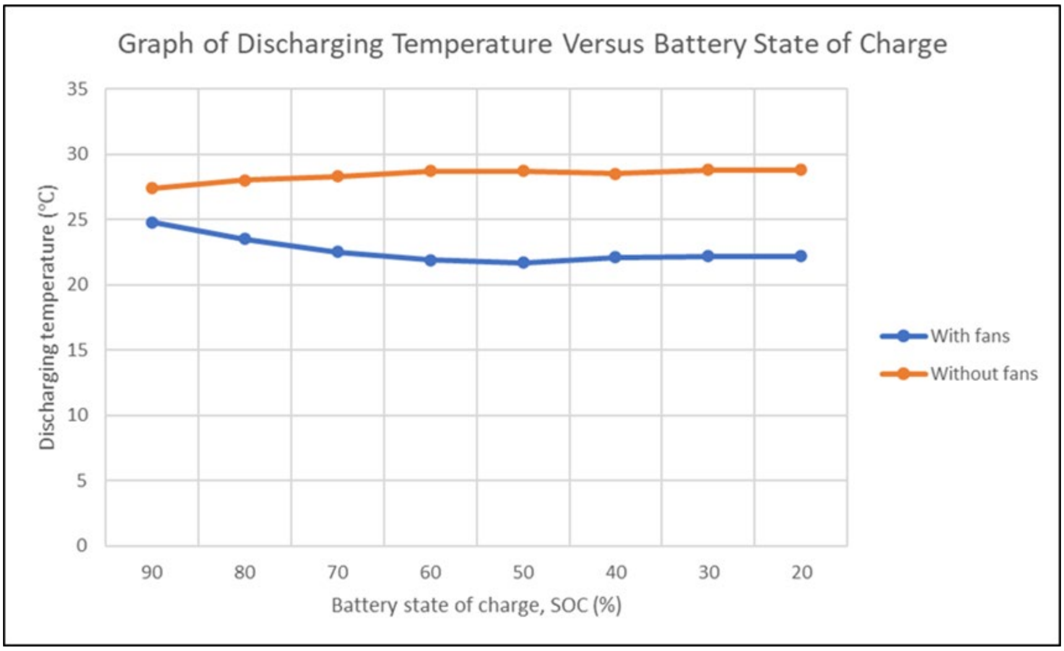

Figure 8: Graph of discharging temperature versus battery state of charge

Figure 7 shows the highest cooling efficiency for the charging process, which is 34.24 %, while Figure 8 shows the highest cooling efficiency for the discharging process, which is 24.39 %. The average charging temperature without fans is 28.68 °C, while the average discharging temperature without fans is 28.40 °C. This concludes that the higher the temperature, the higher the cooling efficiency of the air-cooling system using the DC fans.

Conclusion

In conclusion, the objectives of this project are achieved whereby a battery pack for the electric ATV with a capacity of 74 V and 80 Ah is successfully developed. The dimension of the battery is 738 x 285 x 335 mm, which fits beautifully inside the ATV's cargo load area, and the battery's performance has been tested. First, the final developed battery is equipped with a cooling system, battery management system (BMS), charging system, and battery packaging, which is a complete battery according to the objective. Next, the base area of the battery is 738 x 285 mm, which is the area of the spacing provided by the cargo load of the electric ATV. With this, the battery can be easily installed onto the electric ATV and ready to go. In addition, the battery is tested with the discharging test to determine its discharging capacity, which theoretically is 80 Ah. After the discharging test at 20 Amps of discharging current, the battery shows a 60 Ah discharge capacity after discharging from 95 to 20 % battery SOC for a time of about three hours. This proves that the battery has a discharge capacity of 80 Ah, as the calculation shows that further discharging to 0 % battery SOC will reach 80 Ah of discharge capacity. The cooling efficiency test proved that the air-cooling system is sufficient for the designed battery as the highest cooling efficiency reached 34.24 %, which cools down the battery to about 10 °C. Some of the recommendations for this project are to use a waterproof casing material, install a battery support structure to prevent the battery from vibrating and install a grid plate on the battery casing to protect the battery from dirt and dust.

Acknowledgement

This research was funded by a grant from Research University Grant (UTM-TDR: Q.J130000. 3551. 06G06).

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