Internship Report

On

Lithium-Ion Battery

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Internship Duration: June 2025 – Ongoing

Department: R&D

JP MINDA

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Nomenclature

Li-ion Battery	Lithium-ion rechargeable battery used in EVs and electronics
LFP	Lithium Iron Phosphate – A type of lithium-ion battery chemistry
BMS	Battery Management System – Monitors and controls battery performance and safety
SOC	State of Charge – Represents remaining battery capacity as a percentage
SOH	State of Health – Indicates the overall condition or lifespan of a battery
SOP	State of Power – Maximum power a battery can deliver at a given time
DOD	Depth of Discharge – How much battery capacity has been used (e.g., 100%, 75%)
NTC Sensor	Negative Temperature Coefficient sensor – Used to measure temperature
CC	Constant Current – Charging or discharging at a fixed current
CV	Constant Voltage – Voltage is fixed, current gradually drops during charging
CC–CV	Combined method of battery charging
CAN	Controller Area Network – A communication protocol used for data transfer between devices
UART	Universal Asynchronous Receiver Transmitter – Serial communication interface
Cell Assembly	Process of combining individual cells into packs
Bus Bar (2mm, 3mm)	Conductive metal strip connecting battery cells
Pack Voltage	Total voltage of a battery pack

Cell Voltage	Voltage of individual battery cells
Crimping Tool	Tool used to attach terminals to wires securely
Soldering Iron	Tool for joining wires and components with solder
Insulation Tape	Safety material to wrap and insulate wires
Battery Assembly	Full integration of cells, wires, sensors, and connectors
Battery Pack	A complete assembled battery unit
Series/Parallel (e.g. 16s1p)	Configuration describing number of cells connected in series (s) and parallel (p)
Cell Balancing	Process of equalizing the voltage of all battery cells (passive or active)
Machine Cell Balancer	Automated equipment for balancing cell voltages
Buzzer Wire	Safety component for sounding alerts
Ignition Wire	Activates the battery when power is turned on
Power Connector	Main output connector to external devices
Electrifuel Software	BMS software for Electrifuel battery systems
Webber Software	BMS software for Webber BMS
Battery Buddy	BMS software for Vecmocon BMS
SuperPower Software	BMS software for SuperPower systems
CAN Tool	Diagnostic interface for monitoring and configuring CAN-based BMS
Real-time Monitoring	Continuous tracking of voltage, current, temperature, and other parameters
Firmware Update	Updating the BMS software for improved functionality
IoT	Internet of Things – Enables remote monitoring, tracking, and

	diagnostics
Data Logging	Recording real-time battery performance data for analysis
Heat Gun	Used in testing setups to simulate thermal conditions
Parameter Insertion	Inputting voltage, current, temperature, and configuration data into BMS software
Testing Machine	Equipment used to perform controlled charge/discharge cycles
Charge/Discharge Thresholds	Limits set in BMS for protection and performance optimization
Cycle Testing	Repeated charging and discharging to evaluate battery durability
Ambient Temperature	Surrounding temperature during tests – used for thermal delta calculations
Delta Voltage / Temperature	Difference between max and min values during tests (used to evaluate balance/heat)

Abstract

The main ways people travel today are dealing with two big issues: the rising cost of oil and growing carbon emissions. Because of this, electric vehicles (EVs) are becoming more popular since they don't rely on oil and don't release harmful greenhouse gases.This report presents the details of my internship at **JP Minda**, where I worked in the **Research and Development (R&D) Department**, focusing on lithium-ion batteries used in electric vehicles. Throughout the internship, I was involved in a variety of tasks including battery performance testing, Battery Management System (BMS) testing, charger testing, battery assembling, and keeping a complete traceability report for each battery cell. I also helped in entering and setting up important data into the BMS system based on specific battery requirements.

Working on these tasks gave me a strong understanding of how lithium-ion batteries are designed, tested, and prepared for actual vehicle use. I learned how BMS plays a key role in monitoring battery safety and performance, and how important it is to maintain accurate data and follow proper procedures. The hands-on work improved my practical knowledge, while interacting with engineers and technical staff helped me learn more about real-time problem solving and teamwork in an industrial setup.

This internship gave me valuable exposure to the working of electric vehicle battery systems and taught me how theoretical knowledge is applied in real-world industry work. This report includes my responsibilities, the knowledge I gained, the challenges I faced, and how this experience helped me grow both technically and professionally.

1. Introduction

Increasing environmental issues, particularly those having a connection to carbon-based fuel cars' greenhouse gas emissions and pollution, have driven the world towards electric vehicles (EVs). EVs provide a better alternative by lessening polluting emissions and working towards cleaner energy consumption in the transport industry. [4] Popular knowledge demands that increased carbon emissions and declining oil reserves are the globe's biggest issues. Of all energy consumers, the transport sector is the largest contributor to pollution, consuming more than 25% of global energy and emitting huge amounts of greenhouse gases. Road transport contributes over 70% alone in the emissions.[5] Of all the battery technologies employed in EVs, lithium-ion batteries are the most promising and commonly used in the electric vehicles of today[6] Battery technology has made a massive leap over the years from conventional types of rechargeable batteries such as lead–acid, nickel–cadmium, and nickel–metal hydride batteries to the more efficient and widely used lithium-ion (Li-ion) battery since they are more efficient and long-lasting.[1] Lithium and lithium-ion batteries high in energy are primarily responsible for the phenomenal advancement in contemporary technology. They will be used even more in times to come in many fields.[2] Lithium-ion batteries have been the major contributory element in the development of small electronic devices and are now the dominant source of energy for most portable devices. Lithium-ion batteries are already utilized in electric cars and are also under research for use in power grid energy storage. When using these batteries for any other application, energy capacity, power output, charging rate, price, duration of use, safety, and how they affect the environment should be remembered.[3] Lithium-ion batteries are very sensitive to overcharge and deep discharge, which can shorten their lifetime or even develop hazardous conditions. A Battery Management System (BMS) is therefore required. It guarantees that every battery cell functions safely within its recommended parameters.[18]

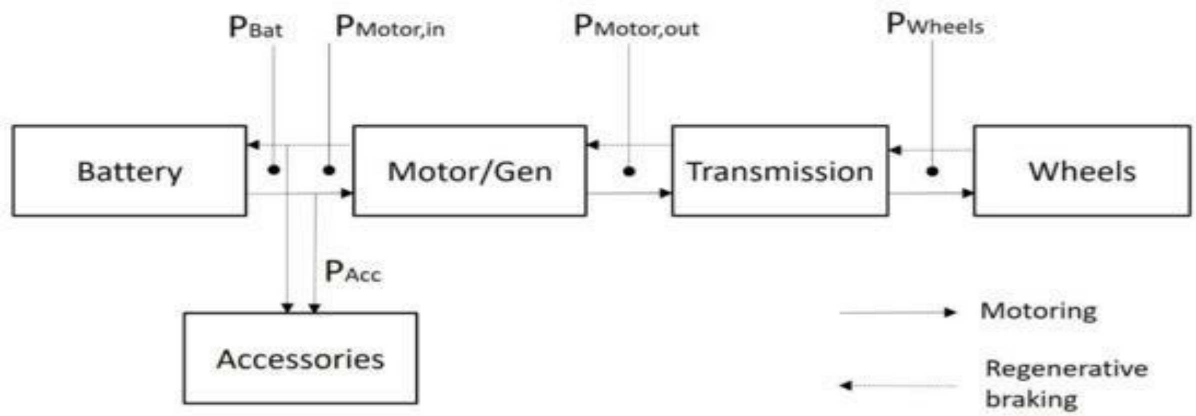


Fig.1 Block diagram of Battery Electric Vehicle[15]

1.1 Lithium Ion Batteries

Lithium-ion batteries are one of the most heavily utilized rechargeable batteries in use today. They are utilized principally in electric cars, cellular phones, laptop computers, and to recharge renewable energy from the sun. They are utilized due to their high content of energy, lower weight, and potential to be utilized in numerous charge and discharge cycles.[9]They are sustainable sources of energy that accomplish this by shifting lithium ions between the cathode (positive electrode) and anode (negative electrode) in a see-saw pattern, enabling them to receive and provide electrical energy.[8]A Li-ion battery is produced by placing individual Li-ion cells parallel to receive more current, series to receive more voltage, or through utilizing a combination of both. A number of such cells are placed on top of each other to create a battery module. A common lithium-ion cell contains a positive electrode (cathode) and a negative electrode (anode), with an intervening medium electrolyte that allows lithium ions to move during charging and discharging. The electrodes are separated by a separator, usually a microporous polymer membrane. This separator permits lithium ions to transport but will not permit electron flow. In addition to the widespread utilization of liquid electrolytes, other forms including polymer, gel, and ceramic electrolytes have been researched to be employed in the Li-ion battery application.[7]

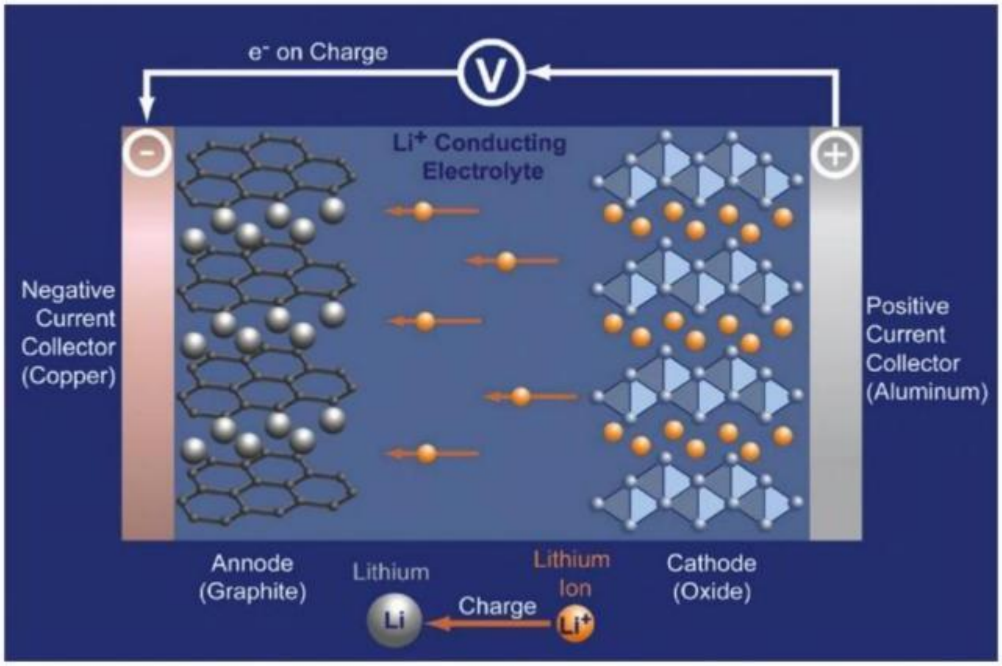


Fig.2 In a lithium-ion cell, during the charging process, lithium ions move and get stored in the anode. During discharging, they flow back to the cathode, releasing energy.[10]

Discharging Reaction [17]

Anode (Negative electrode):
$LiC_6 \rightarrow Li^+ + e^- + C_6$…………………………………………………………(1)

Cathode (Positive electrode):
$LiCoO_2 + Li^+ + e^- \rightarrow Li_2CoO_2$……………………………………………………… (2)

Overall Cell Reaction:
$LiC_6 + CoO_2 \rightarrow C_6 + LiCoO_2$… ……………………………………………………(3)

Charging Reaction [17]

Anode (Negative electrode):
$Li^+ + e^- + C_6 \rightarrow LiC_6$………………………………………………………………(4)

Cathode (Positive electrode):
$LiCoO_2 \rightarrow Li^+ + e^- + CoO_2$… ……………………………………………………(5)

Overall Cell Reaction:
$C_6 + LiCoO_2 \rightarrow LiC_6 + CoO_2$… ………………………………………………… (6)

2. Responsibilities:

Being an R&D intern for JP MINDA Company, my core responsibility lies in researching and developing lithium-ion batteries. I carry out significant activities of testing and assessment of Battery Management Systems (BMS) and proper functioning of battery and charger systems. I am also engaged in the manufacturing of batteries and data management pertaining to battery performance and testing.

3. Technical Engagements

3.1 BMS (Battery Management System):

I am responsible for the configuration, monitoring, and testing of the Battery Management Systems (BMS). This system manages the overall performance and health of lithium-ion batteries, including aspects like charge cycles, voltage levels, and temperature regulation.

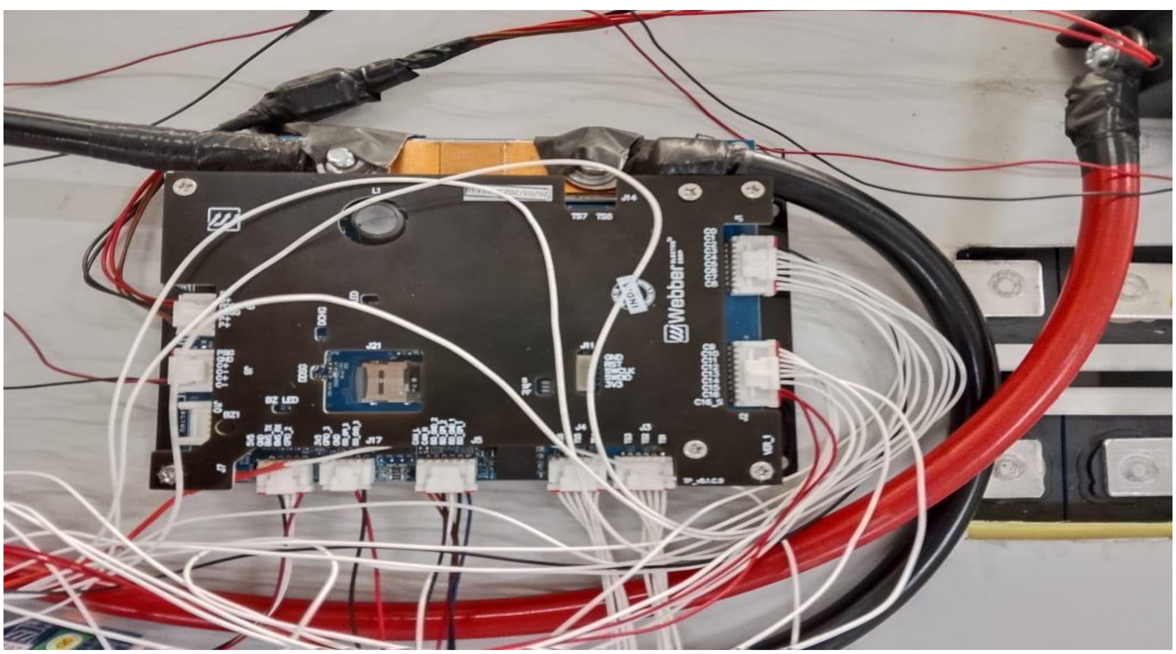


Fig.3 BMS attached to the battery

BMS

Battery Management System (BMS) is a critical component of a multi-cell battery pack that offers efficient and safe performance.[12]It is an electronic system utilized to control rechargeable batteries in electric vehicles, solar powered systems, and cellular devices. Its primary function is to ensure the battery runs safely, longer, and efficiently.[11] The BMS constantly monitors key variables such as the voltage, current, and temperature of every cell battery and the pack itself. With this information, it can quantify how much charge remains (State of Charge or SOC), how well the battery performs (State of Health or SOH), and what level of power it can supply (State of Power or SOP). If something is wrong such as overheat of battery or overcharging the BMS protects from damage or harm.[13] BMS performs a very crucial job of keeping the battery safe from overcharge conditions, over-discharge, high temperatures, and short circuits. It keeps on monitoring and regulating the battery's operating parameters in a way to maintain its efficiency, prolong its life cycle, and operate safely and reliably at all times.[14] It is a part of critical significance in electric vehicles since it makes the battery operate within safe limits. Over-charging or over-discharging the battery may have severe consequences, such as thermal runaway, battery aging, shortened lifespan, and even safety risks to the consumers.[16] The BMS also communicates to the other components of the system, such as a computer in a vehicle or a charger, employing protocols such as CAN or UART. It monitors the use of the battery and assists in finding out any abnormalities early on.

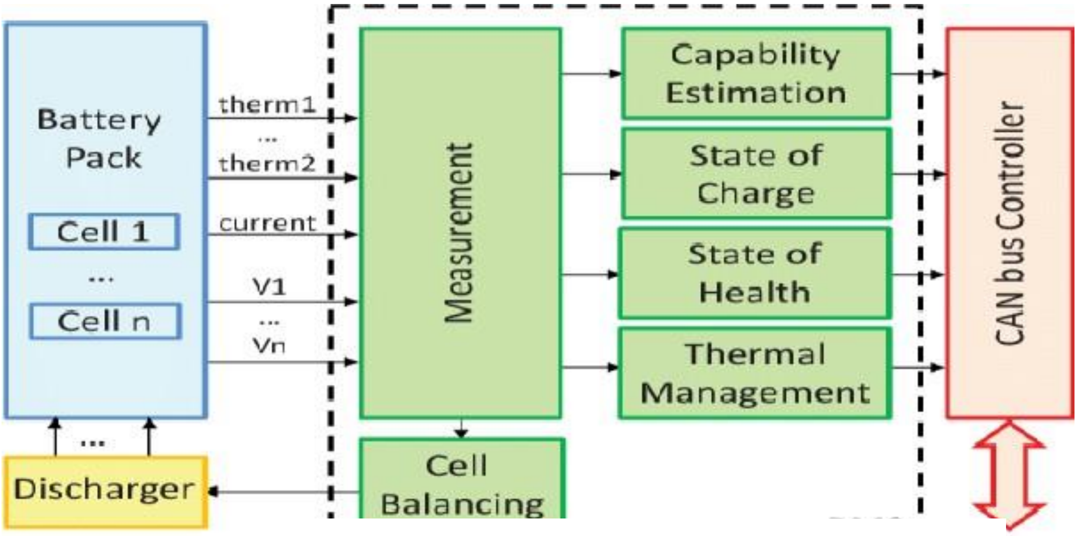


Fig.4 BMS Block Diagram [16]

3.2 Battery Assembly

Aiding in the assembly of battery packs, e.g., placing the cells, modules, and components. Inputting battery parameters such as voltage ranges, temperature ranges, and charge/discharge settings to the BMS or control systems. Maintaining accuracy and design compliance while setting parameters.

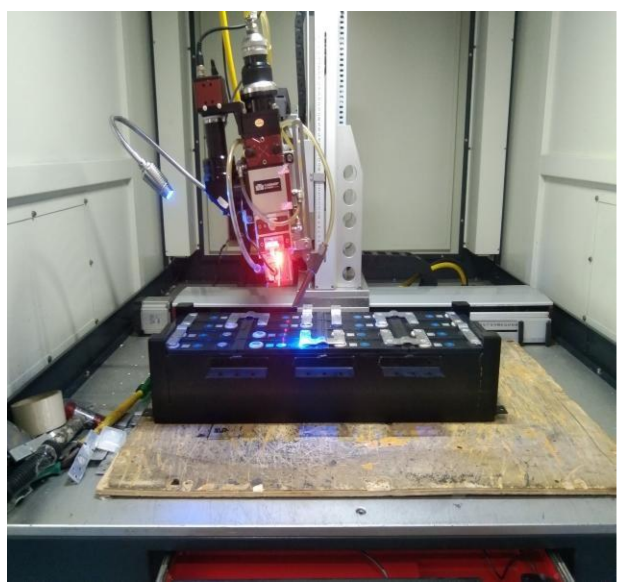


Fig.5 Battery Assembly

Fig.6Laser Welding of Bus Bar

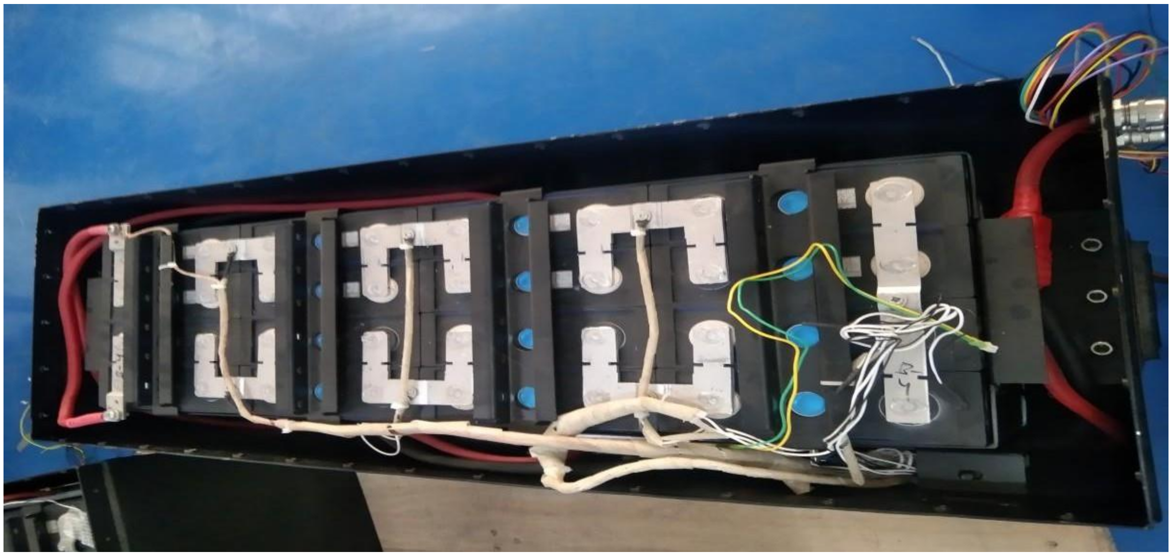


Fig.7 Finalizing Battery

Assembly of batteries is the integration of a few electrical and safety components to form a functional, complete battery pack. It is employed in electric vehicles, standby power systems, and other storage systems. The main steps and materials involved in the process are as follows:

- **Cell Assembly**: The individual cells are combined and paired in parallel and/or series in order to realize the target voltage and capacity of the battery pack.
- **Sensing Wires**: Thin wires attached to every cell to measure the voltages of cells. The information is forwarded to the Battery Management System (BMS) to monitor and balance the cells.
- **Ignition Wire**: This wire is powered by the ignition or power-on circuit of the system. It is utilized to charge or "wake up" the battery during start-up.
- **BMS Attachment**: The BMS is placed on or beside the cell stack and linked to every sensing wire, NTC sensor, and power cable. It controls the performance, safety, and communication of the cells.
- **CAN Wire**: CAN wire is utilized for data exchange with other devices such as a display unit, motor controller, or charger and the battery pack (via the BMS). It carries important battery information like SOC, errors, and temperatures.

- **NTC Wire**: NTC (Negative Temperature Coefficient) sensor wires are provided to be connected to the pack or cells for sensing temperature. Sensors help in temperature monitoring as well as overheating protection.
- **Power Connector**: This is the main outlet of the battery pack. It connects the battery to the load (like a motor or inverter) and must be strong and insulated to handle high current safely.
- **Buzzer Wire**: The buzzer wire is connected to a small audio alarm device that alerts the user in case of faults or errors detected by the BMS, such as over-temperature, over-voltage, or short circuits. It serves as an important warning system for safety.

3.3 Charging and Discharging Testing:

I am involved in testing chargers designed for lithium-ion batteries, focusing on charging speed, efficiency, adherence to safety standards, and verifying the proper transition from Constant Current (CC) to Constant Voltage (CV) mode during testing.

Fig.8 Charging and Discharging Testing By Machine

Charging Test

The **charging test** involves supplying electrical energy to the battery to store charge. This test helps evaluate the battery's ability to accept and store energy efficiently.

- **Constant Current–Constant Voltage (CC–CV)** method is commonly used:
- **Constant Current (CC)** phase: The battery is charged at a fixed current until it reaches its maximum voltage (e.g., 4.2 V for Li-ion cells).
- **Constant Voltage (CV)** phase: The voltage is held constant while the current gradually decreases. Charging stops when the current drops to a cut-off level.

Discharging Test

The **discharging test** involves drawing current from the battery to power a load. This test helps determine how much energy the battery can deliver under specific conditions.

- **Constant Current (CC)** discharging is usually applied: The battery is discharged at a fixed current until it reaches the lower voltage limit (e.g., 2.5–3.0 V for Li-ion cells)

3.4 Software Use and Parameter Insertion:

A vital part of my internship involved working with BMS application software. Using this interface, I inserted and calibrated critical system parameters. These included nominal voltage and capacity, number of cells in series and parallel, overvoltage and undervoltage cut-off limits, charge/discharge current thresholds, temperature protection limits, and cell balancing configurations. I ensured that the parameter values matched the actual battery specifications, which is essential for optimal and safe BMS operation. Additionally, I used the software to monitor real-time battery data, detect faults, and update BMS firmware when necessary.

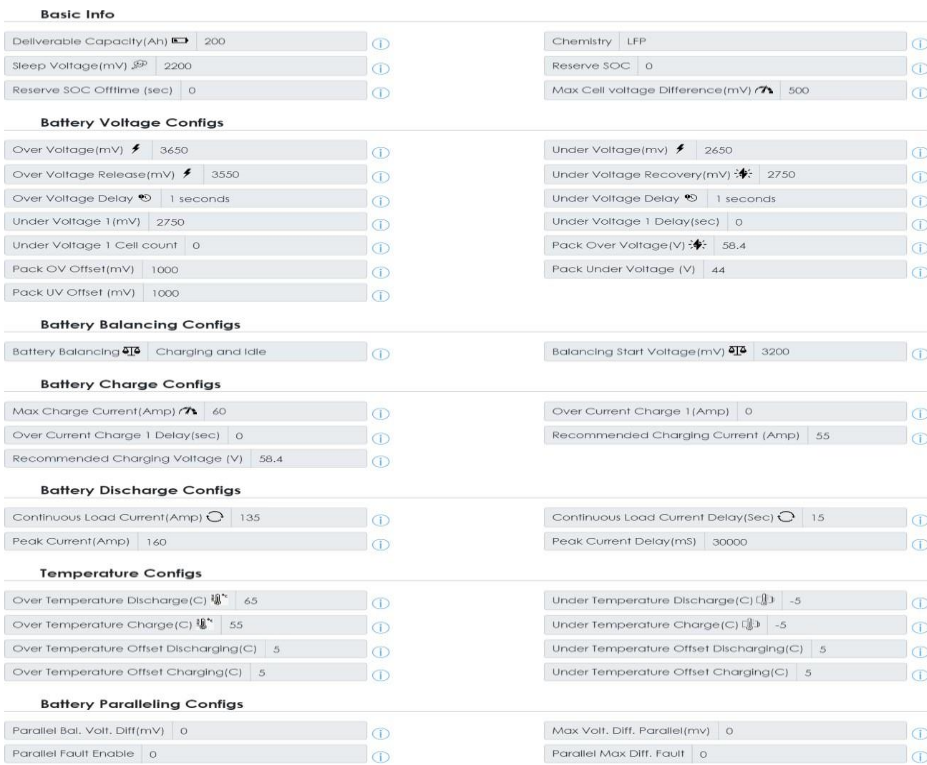


Fig.9 Parameter Insertion in 51.2V 200 Ah Battery

3.5 DataManagement

A key aspect of my role includes managing and analyzing the data collected during battery and charger tests. This data is used to evaluate battery performance, identify trends, and help improve battery systems for future applications.

4. Tools and Technologies Used

4.1 BMS App Software:

I use the BMS App Software to monitor real-time data on the battery's performance. This software helps track parameters such as battery voltage, temperature, charge levels, and overall health, ensuring the effective functioning of the BMS.

Fig. 10 Electrifuel Software for Electrifuel

Fig. 11 Webber Software for Webber Bms

Fig.12 Battery Buddy Software for Vecmocon BMS

Fig.13 SuperPower Software for Superpower BMS

- BMS App Software is a computer or mobile application that connects to a Battery Management System (BMS) and allows users to monitor, configure, and manage battery pack operations. It serves as a bridge between the BMS hardware and the user, offering real-time data visualization, diagnostics, and control functions.

4.1.1 Key Features:

1. Live Monitoring

   The app displays real-time battery data, including:

- Cell voltages
- Battery pack voltage and current
- State of Charge (SOC)
- State of Health (SOH)
- Temperature readings
- Charging/discharging status

2. **Data Logging**

   The software stores continuous data logs of battery parameters during operation. This includes:

   - Charge/discharge cycles
   - Temperature profiles
   - Voltage trends over time
   - Fault event logs

This data can be exported in formats like CSV, Excel, or uploaded to the cloud for analysis.

3. **Error and Alarm Display**

   The software immediately shows any error messages or alarms triggered by the BMS, such as:

- Overvoltage / undervoltage
- Overcurrent
- Overheating
- Communication failure
- Cell imbalance

4 Configuration and Calibration

The app allows the user to:

- Set upper and lower voltage limits
- Adjust charge/discharge current limits
- Enable/disable cell balancing
- Modify temperature protection values
- Upload or modify firmware

5. Data Insertion

A key feature of advanced BMS apps is manual or automated data insertion. This allows:

- Manual input of battery parameters for testing or calibration (e.g., entering nominal capacity, temperature thresholds, balancing current limit).
- Import of configuration files (e.g., .cfg, .json, or .txt) to load predefined BMS settings.
- User-defined profiles to simulate different pack conditions or product requirements.
- Input of test cycle data for validation and automated charge/discharge routines.

  Data insertion ensures consistent BMS behavior across multiple battery packs and speeds up batch testing or production setup.

6 Communication Interface

The software communicates with the BMS using protocols such as:

- CAN Bus
- UART/RS485
- Bluetooth/Wi-Fi (for mobile apps)

4.2 Machine Cell Balancing

Machine Cell Balancing is a process that makes sure all the battery cells in a battery pack have the same voltage or charge level. When battery cells are not equal (some are more charged than others), the battery doesn't work properly and can get damaged over time.

In machine cell balancing, a special machine is used (usually in factories or service centers) to check each cell and either:

- Remove extra charge from the cells that are too full, or
- Move charge from full cells to weaker ones.

Fig.14 Machine Cell Balancing

4.3-Hand Tools for Battery Assembly:

To assist in battery making, I use various hand tools including:

- Wire Cutters – for cutting wires to proper lengths for assembly.
- Nose Pliers – for handling and manipulating small components, especially when working with wires and connectors.
- Soldering Iron – for soldering electrical connections in battery packs.
- Crimping Tool – for attaching connectors to wires securely.
- Insulation Tape – for ensuring safety and proper insulation during assembly.

Fig. 15 Soldering Iron[19]

Fig. 16 Nose Plier[20]

Fig.17 Wire Cutter [21]

Fig. 18 Crimping Tool [22]

5. Internship Research Work

5.1 Bus Bar Testing

During my internship at JP Minda in the Research and Development (R&D) department, I conducted an in-depth study on the thermal behavior of aluminum bus bars with different thicknesses (2mm and 3mm), used in lithium-ion battery packs. The purpose of this research was to evaluate and compare the thermal performance and reliability of these bus bars under actual working conditions. This was part of ongoing efforts to optimize current-carrying components in battery packs for electric vehicle applications.

5.1.1 Objective: The objective of this test is to evaluate the performance and reliability of bus bars with thicknesses of 2mm and 3mm.

5.1.2 Sample Description:

- **Material:** Aluminum
- **Bus bar Thickness:** 2mm and 3mm
- **Battery Arrangement:** 16s 1p (16 cells in series, 1 parallel)

5.1.3 Equipment Used:

1. Battery
2. Testing Machine
3. NTC Wire
4. Heat gun

To perform thermal testing on bus bars, follow these steps:

1. Requirements:

   - 4 NTC wires : These should be placed at different positions on the bus bar to accurately capture temperature variations.

2. Testing Procedure:

   - Charging and Discharging Cycles:

     - Cycle 1: Charge and discharge the battery at 33 amps.

     - Cycle 2: Repeat charging and discharging at 33 amps.

     - Cycle 3: Charge the battery at 50 amps.

     - Cycle 4: Discharge the battery at 50 amps.

3. Testing for Different Bus Bars:

   - Perform the above cycles for both 2 mm and 3 mm bus bars.

4. Data Comparison:

   - After completing the tests, compare the temperatures recorded by the NTC wires with the ambient temperature.

   - Calculate and analyze the temperature delta (difference) between the bus bar temperatures and the ambient temperature.

This process will help you evaluate the thermal performance and heat dissipation of the bus bars under different conditions.

5.1.4 TESTING

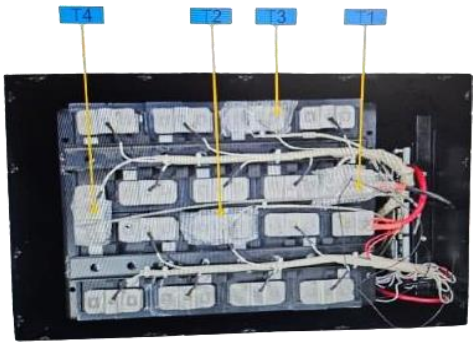
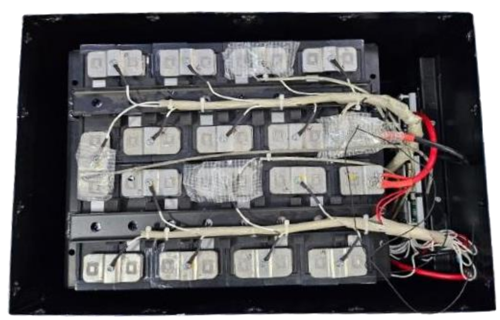
NTC CONNECTION  	**NTC 'S POSITION** ***T1 - Main -ve*** ***T2 - Left side of main -ve*** ***T3 - Right Side of main -ve*** ***T4 - Front side of main -ve***
TESTING 	**BATTERY** 

Fig.19 Testing Requirements

To monitor temperature changes, four NTC (Negative Temperature Coefficient) sensors were installed at key locations on the main negative bus bar: the main terminal, left and right sections, and the front edge. The testing involved a sequence of four charge and discharge cycles**:**

- **Cycle 1:** Charge at 33A
- **Cycle 2:** Discharge at 33A
- **Cycle 3:** Charge at 50A
- **Cycle 4:** Discharge at 50A

These cycles were conducted independently for both 2mm and 3mm bus bar samples, keeping all other parameters constant. After the completion of each test, the temperatures recorded by the NTC sensors were compared with the ambient temperature to compute the temperature delta (ΔT)**,** indicating the extent of heat rise due to electrical loading.

The results demonstrated that the 3mm bus bars consistently exhibited lower temperature rise across all cycles, especially under higher current loads (50A). This confirmed the superior thermal dissipation capability of the 3mm variant. Conversely, the 2mm bus bars showed a sharper increase in surface temperature, indicating greater resistive heating, which could potentially lead to long-term reliability issues in high-load scenarios.

This research highlights the critical role of mechanical dimensions in the thermal performance of bus bars and supports the adoption of thicker conductors in applications where current levels are substantial. The findings also contribute to ongoing design optimization efforts for safe, efficient, and thermally stable battery packs used in electric vehicles and energy storage systems.

5.2 New BMS Testing Report-(SuperPower BMS)

This report presents the performance testing results of the 51.2V 45Ah Lithium Iron Phosphate (LFP) battery pack equipped with a Superpower BMS (Battery Management System). Two battery samples were tested as per the guidelines provided by the customer. The evaluation included charge/discharge cycles, depth of discharge (DOD), efficiency, and machine-recorded data. The results provide insights into battery behavior under different load conditions and discharge levels.

Fig. 20 SuperPower BMS

5.2.1 Battery Specifications

- **Battery Voltage:** 51.2 V
- **Capacity:** 45 Ah
- **Chemistry:** Lithium Iron Phosphate (LFP)
- **Cell Make:** CBAK LFP cylindrical cells (3.2 V, 15 Ah)
- **BMS Used:** Superpower 16S 60A LFP BMS
- **Dimensions:** 235 mm (L) × 165 mm (W) × 350 mm (H)
- **Testing Conducted By:** As per dimensions and conditions provided by the Battery Smart team.

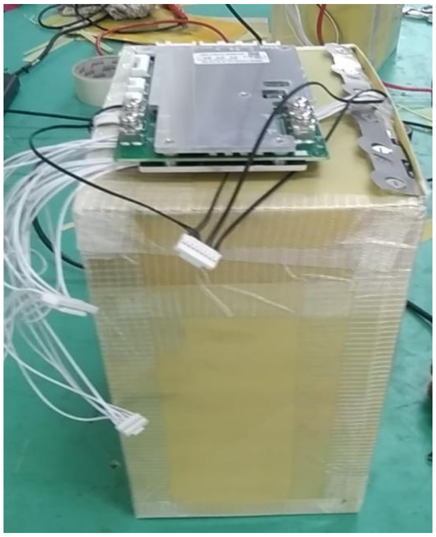


Fig.21 51.2 V 45 Ah Sample for new BMS Testing

Fig.22 Can Tool

5.2.2 Test Procedure

The batteries underwent several controlled tests using Constant Current (CC) and Constant Voltage (CV) protocols. The main test categories included:

- 100% Depth of Discharge (DOD) discharging
- 75% DOD charging (at different currents)
- 75% DOD discharging
- Evaluation of BMS behavior during idle and running states
- Analysis of machine-recorded data.

5.2.3 Test Results

5.2.3.1 100% Depth of Discharge (DOD) Test

100% Depth of Discharge (DOD) refers to the complete usage of a battery's total available capacity, from a fully charged state to a fully discharged state. In practical terms, this means the battery is fully cycled from a fully charged state to its minimum allowable voltage usually set by the BMS to avoid damage. For example, if a battery has a rated capacity of 45 ampere-hours (Ah), then discharging the battery until it delivers all 45Ah of energy corresponds to a 100% DOD.

5.2.3.2 100%DOD test at 22.5 A

In this test, the battery was first charged fully and then discharged completely using a constant current of 22.5 amps. This is called a 100% Depth of Discharge (DOD) test, which means the battery was used until it reached the lowest safe voltage set by the Battery Management System (BMS). The testing machine showed that the battery gave out 44.6 ampere-hours (Ah) of energy, which is very close to the battery's rated capacity of 45 Ah—about 99% of what was expected. This small difference is normal and can happen due to slight energy loss as heat or resistance inside the battery. The battery's voltage dropped steadily during the test without any sudden drops, which means it was working smoothly. The BMS also worked well, keeping everything safe and stable during the test. Overall, this test showed that the battery can safely provide almost all of its energy when needed and is reliable for high-power uses like electric vehicles or energy storage system.

100 % DOD Discharge cycle data logs (22.5 A)									
Date	Mode	Duration	Pack Voltage	Max voltage	Min voltage	Delta	SOC	capacity	Current
10/9/2024 9:56:38 AM	Discharging start	00:00:00	53.87 V	3.374 V	3.363 V	0.011 V	100%	44668 mAh	0.81 A
10/9/2024 11:55:49 AM	cc	1 hr 59 min	47.17 V	2.963 V	2.931 V	0.032 V	0	0	-22.53 A
10/9/2024 11:55:50	Discharging end	Approx. 2 hr	47.4 V	2.976 V	2.947 V	0.029 V	0	0	0

Table 1. 100% DOD Discharge Cycle Data logs at 22.5A

5.2.3.375% DOD

75% Depth of Discharge (DOD) means that the battery has used up 75% of its total energy capacity, and 25% of the energy still remains. For example, if a battery is rated at 45 ampere-hours (Ah), then 75% DOD means 33.75 Ah has been discharged, and 11.25 Ah is left. This method of partial discharge is commonly used because it helps extend the life of the battery. Fully discharging a battery (100% DOD) can cause more wear over time, while operating at 75%

DOD offers a good balance between using the battery's capacity and protecting its health for long-term use.

The 75% DOD charging test was conducted to evaluate the battery's performance during partial recharge cycles, which are commonly used to enhance battery lifespan in practical applications. In this test, the battery was first discharged to approximately 75% of its rated capacity, after which charging was performed.

5.2.3.4 75% DOD Charging Test at 16 A

B3 75 % DOD Charge cycle data logs (16 A)									
Date	Mode	Duration	Pack Voltage	Max voltage	Min voltage	Delta	SOC	capacity	Current
10/16/2024 2:40:52 PM	charging Start	00:00:00	52.34 V	3.275 V	3.268 V	0.007 V	0	0	3.46 A
10/16/2024 4:49:00 PM	CC toCV	2hr 8 min	55.02 V	3.457 V	3.428 V	0.029 V	96 %	33465 mAh	15.71 A
10/16/2024 5:00:32 PM	CV	11 min	55.02 V	3.455 V	3.421 V	0.034 V	100 %	34937mAh	1.49 A

Table 2. 75% DOD Charge Cycles data logs at 16 A

A 75% Depth of Discharge (DOD) charging cycle was carried out using a constant current of 16 A. The charging process began with a pack voltage of 52.34 V and a minimum cell voltage of 3.268 V. During the constant current (CC) to constant voltage (CV) transition phase, which lasted 2 hours and 8 minutes, the battery pack reached a voltage of 55.02 V and achieved a state of charge (SOC) of 96%, delivering a capacity of 33,465 mAh. Following this, the battery entered the CV phase, which continued for 11 minutes, during which the charging current gradually reduced to 1.49 A, and the SOC reached 100%. The final charged capacity was 34,937 mAh, with the maximum and minimum cell voltages recorded at 3.455 V and 3.421 V respectively, resulting in a voltage delta of 0.034 V—indicating effective cell balancing at full charge.

5.2.3.5 75% DOD Charging Test at 20 A

After discharging the battery to 75% of its capacity, charging was performed using a constant current of 20 A. The battery followed the standard CC-CV charging pattern, with a faster charging rate compared to the 16 A test due to the higher current input.

As the voltage approached the cut-off level, the system smoothly shifted to the CV phase, during which the current gradually decreased. Cell balancing was observed during the final stage, managed effectively by the BMS to equalize cell voltages.

The battery handled the 20 A charging without any issues. No overheating, faults, or abnormal behavior was observed, confirming that the battery can safely manage higher charging currents with stable performance

75% DOD Charging cycle data logs (20 A)									
Date	**Mode**	**Duration**	**Pack Voltage**	**Max voltage**	**Min voltage**	**Delta**	**SOC**	**capacity**	**Current**
10/16/2024 9:36:26 PM	**Charging Start**	**00 :00:00**	**51.93 V**	**3.248 V**	**3.244 V**	**0.004 V**	**0**	**0**	**0.74 A**
10/16/2024 11:18:51 PM	**CC to CV**	**1 hr 42 min**	**55.01 V**	**3.464 V**	**3.43 V**	**0.034 V**	**97 %**	**33853 mAh**	**20.3 A**
10/16/2024 11:32:21 PM	**CV End**	**14 min**	**55.01 V**	**3.455 V**	**3.415 V**	**0.04 V**	**99 %**	**34923 mAh**	**1.38 A**

Table 3. 19 75% DOD Charging Cycle Data Logs at 20 A

5.2.3.6 75% DOD Discharging Test at 22.5 A

In this test, the battery was discharged from full charge to 75% of its rated capacity using a constant current of 22.5 A. The purpose was to assess the battery’s behavior during partial discharge, which is common in real-world applications aimed at improving cycle life.

The machine recorded a discharged capacity of **34.86 Ah**, which closely matches the theoretical value of 33.75 Ah (75% of 45 Ah).Throughout the discharging cycle, the battery voltage dropped steadily without any sudden drops or irregularities. The BMS actively monitored the process, ensuring that voltage, temperature, and current remained within safe limits. No faults or warnings were observed during the test.

The results confirm that the battery can maintain stable and reliable output during partial discharges, making it suitable for applications where full discharge is not preferred to preserve battery health.

DOD Discharging cycle data logs (22.5 A)									
Date	**Mode**	**Duration**	**Pack Voltage**	**Max voltage**	**Min voltage**	**Delta**	**SOC**	**capacity**	**Current**
10/17/2024 10:32:00 AM	**Discharging Start**	**00:00:00**	**52.52 V**	**3.287 V**	**3.271 V**	**0.016 V**	**100%**	**34826 mAh**	**-22.52 A**
10/17/2024 12:04:53 PM	**CC**	**1 hr 32 min**	**50.84 V**	**3.182 V**	**3.162 V**	**0.02 V**	**0%**	**0 mAh**	**-22.54 A**
10/17/2024 12:04:57 PM	**Discharging End**	**1 hr 33 min**	**51.55 V**	**3.224 V**	**3.218 V**	**0.006 V**	**0%**	**0 mAh**	**0A**

Table 4. 75% DOD Discharging cycle data logs at 22.5 A

5.2.4 BMS and IoT Integration

The Superpower BMS used in this battery pack is equipped with intelligent monitoring features and seamless IoT integration. During testing, the BMS consistently operated in ideal conditions, ensuring safe and efficient battery management throughout all charge and discharge cycles. Key functions such as overcharge, over-discharge, overcurrent, short circuit, and temperature protection were actively managed without any faults or interruptions.

Cell balancing was observed during the charging phase, confirming the BMS's capability to equalize cell voltages and enhance battery health. The IoT module provided real-time monitoring of battery parameters, including state of charge (SOC), voltage differences between cells, and current flow. It also enabled remote tracking of battery performance and location, supporting traceability and diagnostics.

The combined operation of BMS and IoT not only improved system reliability but also offered a smart interface for predictive maintenance and data-driven decision-making. This integration makes the battery pack suitable for modern energy applications requiring remote control, safety, and performance optimization.

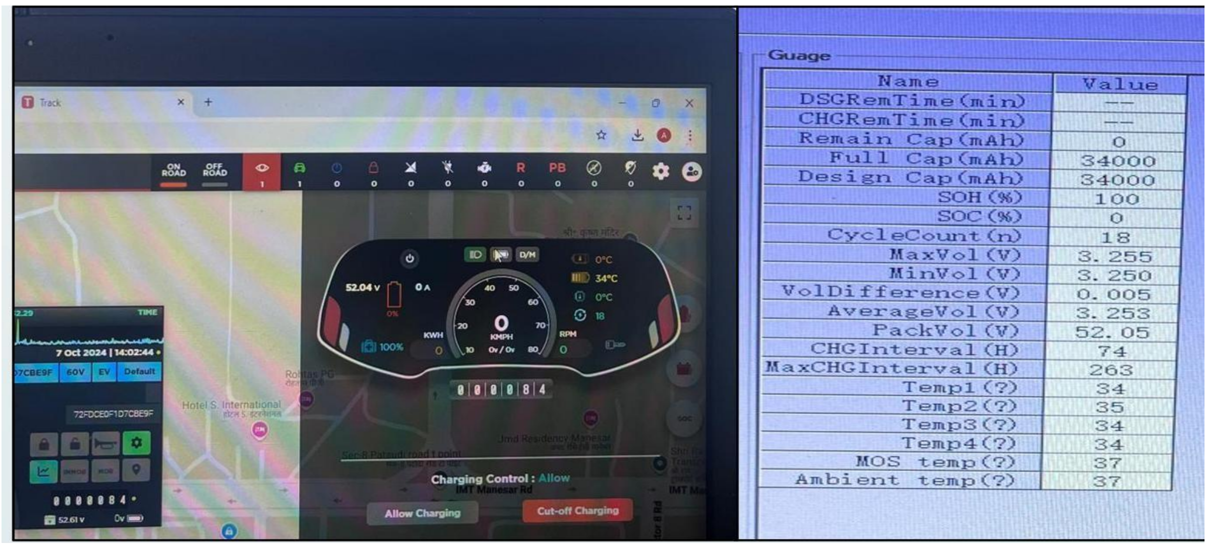


Fig.23 IOT & Checking Battery status in Software

5.2.5 Conclusion

The testing of the 51.2V 45Ah LFP battery pack equipped with the Superpower 16S 60A BMS demonstrates excellent overall performance in terms of efficiency, reliability, and safety. The battery system successfully completed both 100% and 75% DOD cycles under different current rates, with measured capacities closely matching the theoretical values. The BMS maintained ideal operating conditions throughout all phases of charging and discharging, with no abnormal behaviors or cut-offs observed. Active cell balancing was evident, ensuring uniform cell voltage levels, which is critical for extending battery life and performance.

Additionally, the integrated IoT functionality provided accurate real-time data on battery status and location, contributing to enhanced traceability and remote diagnostics. These results confirm that the Superpower BMS is well-suited for advanced battery applications, offering a robust, intelligent, and safe energy management solution for electric vehicles and stationary storage systems.

6. Key Learnings

The internship enriched my understanding of energy storage systems and the critical role of BMS in battery safety and performance. I developed technical proficiency in handling real-world battery modules and analyzing data for performance improvement. Additionally, I enhanced my teamwork and communication skills by collaborating with professionals in the R&D department.

7. Suggestions and Improvements (Time & Cost Focused)

1. **Quick Onboarding Sessions:** A 1–2 hour structured orientation on tools, BMS software, and safety can reduce initial training time and improve early productivity.
2. **Digital Data Logging:** Replacing manual documentation with digital templates or software can save time, reduce human error, and cut paper costs.
3. **Basic Simulations Before Testing:** Using simulation tools can prevent hardware damage, reducing the cost of trial-and-error and saving hours spent on faulty setups.
4. **Separate Testing Setups:** Allocating dedicated charging and discharging stations can cut wait times, increasing daily throughput and reducing overtime labor costs.
5. **Weekly Mentor Check-ins:** Brief scheduled feedback sessions can help detect issues early, minimizing rework time and improving project efficiency.

8. Skills Gained:

Throughout my internship, I have gained practical experience and valuable skills in:

- Understanding the complexities of lithium-ion battery technology and applications.
- Hands-on work with BMS software and battery management systems.
- Battery and charger testing, with a focus on efficiency and safety.
- The process of battery assembly and integration using various hand tools.

- Data collection and analysis for improving battery performance.
- Familiarity with machine charging systems and testing equipment.

9. Conclusion

My internship at JP Minda's R&D department marked a key point in both my academic and professional development. It provided me with deep, hands-on exposure to lithium-ion battery technologies, particularly in the context of electric vehicle applications. Over the course of the internship, I became proficient in a variety of processes, including battery assembly, BMS configuration and testing, cell balancing, charging and discharging cycles, and thermal behavior analysis of critical components like bus bars.

One of the most valuable aspects of this experience was working directly with multiple BMS software platforms such as Electrifuel, Webber, SuperPower, and Battery Buddy. Through this, I learned not only how to input and calibrate essential parameters such as voltage thresholds, current limits, and thermal protections, but also how to interpret real-time diagnostic data and perform firmware updates.

I also contributed to meaningful testing initiatives, including performance analysis under different Depth of Discharge (DOD) scenarios and the evaluation of bus bar thicknesses to optimize thermal efficiency. These tasks improved my understanding of battery behavior under load, the importance of thermal management, and the role of proper hardware-software integration in ensuring battery safety and performance.

Beyond the technical knowledge, this internship strengthened my ability to work in a team-oriented industrial environment. Regular interaction with engineers, mentors, and technical staff helped me develop better communication, documentation, and problem-solving skills. I learned the importance of traceability, standard operating procedures, and data-driven decision-making in product development and testing.

Overall, this internship not only solidified my foundational knowledge of lithium-ion battery systems but also inspired me to pursue a future in the electric mobility and energy storage industry. The practical skills, professional exposure, and real-world learning outcomes I gained here will serve as a strong foundation as I move forward in my engineering career.

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Appendix

Bus Bar -3MM ,Current-0.3 Amp

DISCHARGING-0.3 Amp

DATE-10/08/2024 | BATTERY MODEL-51.2 V 100Ah | BATTERY SR.No-169 | Bus Bar-3mm | Ambient Temperature-30 C | Δ=11

Sr. No	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	10:40	54.45	32.51	98.71	99%	38	37	38	37	3225	3380
2	10:50	52.67	32.54	93.39	94%	38	38	38	37	3290	3295
3	11:00	52.66	32.54	87.44	88%	38	39	38	38	3289	3293
4	11:10	52.61	32.54	81.48	82%	39	39	38	38	3286	3290
5	11:20	52.53	32.55	75.46	76%	39	39	38	38	3282	3286
6	11:30	52.42	32.55	70.25	70%	39	39	39	38	3273	3279
7	11:40	52.24	32.54	64.66	65%	39	40	39	38	3263	3267
8	11:50	52.14	32.55	58.77	59%	39	40	39	38	3257	3261
9	12:00	52.07	32.55	53.12	53%	39	40	39	38	3252	3256
10	12:10	51.98	32.55	47.19	47%	39	40	38	38	3247	3251
11	12:20	51.89	32.55	41.87	42%	39	39	38	38	3241	3246
12	12:30	51.77	32.55	36.18	36%	38	39	38	38	3233	3238
13	12:40	51.54	32.54	29.65	29%	39	39	38	38	3218	3224
14	12:50	51.29	32.54	24.46	24%	39	40	39	38	3202	3208
15	01:00	51.09	32.55	21.3	20%	39	40	39	39	3217	3224
Break											
16	01:35	51.25	32.51	20.5	20%	39	38	39	38	3191	3199
17	01:45	50.53	32.54	15.57	15%	39	39	39	39	3153	3162
18	01:55	50.27	32.55	10.32	10%	40	40	40	39	3135	3146
19	02:05	47.28	32.55	4.89	4%	41	41	41	40	2899	2973
20	02:15	45.53	32.55	3.52	3%	41	41	41	40	2794	2919
21	02:25	51.47	32.58	7.78	7%	41	41	41	40	3212	3239
22	02:35	52.15	32.6	12.76	12%	41	41	40	39	3258	3263

CHARGING TESTING-0.3 Amp

DATE-10/08/2024 | BATTERY MODEL- 51.2 V 100Ah | BATTERY SR.No-169 | Bus Bar-3mm | Ambient Temperature-31 C | Δ=14

Sr. No	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	03:00	45.18	32.55	3.11	3%	42	42	41	41	2768	2899
2	03:06	46.57	32.58	3.38	3%	42	41	41	41	2897	2997
3	03:10	49.71	32.6	5.16	5%	42	41	41	40	3098	3143
4	03:20	52.08	32.6	10.45	10%	41	41	41	40	3253	3259
5	03:30	52.4	32.6	16.03	16%	41	42	41	40	3274	3281
6	03:40	52.9	32.6	21.29	21%	41	42	41	40	3305	3312
7	03:50	53.28	32.61	26.63	27%	41	42	41	40	3329	3335
8	04:00	53.49	32.61	33.14	33%	41	42	41	40	3342	3346
9	04:10	53.54	32.61	38.09	38%	41	42	41	40	3345	3349
10	04:20	53.59	32.6	43.25	43%	41	42	42	41	3348	3353
11	04:30	53.66	32.6	49.05	49%	42	43	42	41	3353	3358
12	04:40	53.74	32.6	54.61	55%	42	43	43	42	3357	3363
13	04:50	53.86	32.6	60.14	60%	43	44	43	42	3365	3371
14	05:00	54.08	32.6	66.77	67%	44	44	44	43	3378	3383
15	05:10	54.12	32.61	71.37	72%	44	44	44	43	3380	3386
16	05:20	54.18	32.61	77.17	78%	44	44	44	43	3384	3390
17	05:30	54.25	32.61	82.75	83%	44	44	44	43	3389	3395
18	05:40	54.35	32.61	88.34	89%	44	44	44	43	3394	3401
19	05:50	54.58	32.61	93.82	94%	44	44	44	43	3407	3418
20	05:55	55.34	32.6	98.74	99%	45	44	44	43	3403	3524
21	06:00	54.59	32.6	98.74	99%	44	43	44	43	3371	3487

Bus Bar -3MM ,Current-0.5 Amp

DISCHARGING TESTING-0.5 Amp											
Date-12/8/2024		Battery Model-51.2V 100Ah			Battery Sr. No.-169		BusBar -3mm		Ambient Temperature- 31		Δ=9
Sr. No-	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	10:35	53.79	50.78	0.15	97%	31	31	30	30	3265	3271
2	10:36	53.26	48.87	97.78	97%	30	31	30	30	3265	3271
3	10:40	52.27	48.91	95.14	95%	31	32	30	31	3265	3269
4	10:50	52.24	48.96	85.51	85%	32	33	32	32	3263	3267
5	11:00	52.13	48.97	78.56	78%	33	35	32	32	3257	3261
6	11:10	52.02	48.99	71.77	71%	33	35	33	33	3249	3254
7	11:20	51.89	48.99	64.54	64%	34	36	34	34	3241	3246
8	11:30	52.18	48.99	55.31	55%	34	37	34	34	3275	3281
9	11:40	51.67	48.99	49.36	49%	35	37	34	34	3226	3232
10	11:50	51.65	48.99	43.09	43%	35	37	34	34	3222	3228
11	12:00	51.36	48.99	34.39	34%	35	38	35	35	3205	3213
12	12:10	51.07	48.99	27.19	27%	35	37	35	35	3187	3195
13	12:20	50.63	49	19.82	19%	36	38	36	36	3156	3166
14	12:30	50.05	49	12.18	12%	38	39	38	37	3121	3132
15	12:40	46.47	49	4.66	4%	39	40	39	38	2847	2928
16	12:50	46.25	0	3.81	3%	39	39	39	39	2851	2959

CHARGING TESTING -0.5Amp											
Date-12/8/2024		Battery Model-51.2V 100Ah		Battery Sr. No.-169		BusBar -3mm		Ambient Temperature- 31			Δ=14
Sr. No-	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	02:20	48.07	48.91	4.02	4%	37	36	37	36	3021	3093
2	02:30	52.46	49.02	13.47	13%	37	38	37	36	3277	3284
3	02:40	53.19	49.03	21.58	21%	38	39	38	37	3323	3331
4	02:50	53.66	49.05	30.95	31%	38	41	39	37	3353	3358
5	03:00	53.88	49.05	39.87	39%	39	41	39	38	3359	3365
6	03:10	53.87	49.08	46.49	46%	40	41	40	39	3365	3370
7	03:20	54.41	49.06	54.53	54%	41	42	41	40	3373	3380
8	03:30	54.21	49.08	62.99	63%	42	43	42	41	3387	3392
9	03:40	54.33	49.08	71.39	71%	43	44	43	42	3393	3400
10	03:50	54.44	49.08	79.14	79%	43	44	43	42	3400	3407
11	04:00	54.71	49.08	90.02	90%	44	44	44	43	3416	3427
12	04:10	55.38	49.08	99.81	99%	45	45	44	43	3403	3504
13	04:14	55.1	49.08	99.82	100%	44	43	44	43	3388	3545

Bus Bar -2MM ,Current-0.5 Amp

Charging-0.5Amp											
Date-7/8/2024	Battery Model- KG 51.2V 100Ah			Battery Sr. No.-01		BusBar -2mm		Ambient Temperature-30			Δ=18
Sr. No-	TIME	Battery Voltage	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	10:20	49.21	50.86	0.17	1%	34	34	34	34	3052	3075
2	10:30	52.41	51.05	5.66	6%	36	34	34	34	3276	3281
3	10:40	52.99	51.16	14.44	14%	37	35	35	34	3311	3318
4	10:50	53.6	51.2	24.63	22%	37	35	35	34	3322	3328
5	11:00	53.88	51.23	31.4	31%	39	36	36	36	3366	3370
6	11:10	53.97	51.25	40.11	40%	41	38	38	37	3371	3377
7	11:20	54.1	51.26	48.79	49%	42	39	39	38	3379	3386
8	11:30	54.25	51.26	56.85	57%	44	41	41	40	3389	3396
9	11:40	54.42	51.29	66.35	66%	45	42	42	41	3399	3405
10	11:50	54.41	51.29	75.02	75%	46	43	43	42	3405	3411
11	12:00	54.6	51.31	83.3	83%	46	43	43	42	3411	3417
12	12:10	54.78	51.31	92.55	93%	47	45	45	44	3422	3430
13	12:20	55.42	51.31	100	100%	48	46	46	44	3962	3485
14	12:22	55.45	51.3	100.16	100%	48	46	46	48	3413	3474

Discharging-0.5 Amp											
Date-7/8/2024	Battery Model- KG 51.2V 100Ah			Battery Sr. No.-01		BusBar -2mm		Ambient Temperature-30			Δ=19
Sr. No-	TIME	Battery Voltage	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	01:54	52.7	50.92	99.86	100%	41	42	43	42	3291	3311
2	02:14	52.7	50.95	84.07	84%	45	43	44	43	3319	3299
3	02:24	52.7	51.22	76.4	76%	45	43	44	43	3272	3312
4	02:34	52.27	51.23	68.43	68%	46	44	44	42	3302	3306
5	02:54	52.34	51.2	67.79	60	45	43	43	44	3341	3346
6	03:04	51.97	51.11	48.63	45%	43	42	43	42	3241	3246
7	03:14	51.84	51.13	38.05	38%	42	41	42	42	3234	3240
8	03:24	51.6	51.17	30.17	31%	43	41	42	41	3221	3227
9	03:34	51.37	51.16	22.82	23%	42	40	42	41	3206	3212
10	03:44	51.65	50.72	15.72	16%	42	41	42	42	3194	3199
11	03:54	50.48	51.16	7.47	7%	43	42	43	43	3150	3157
12	04:04	50.45	50.3	0.2	1%	46	45	45	49	3124	3129
13	04:15	49.4	51.9	0	1%	42	45	46	49	3109	3115

Bus Bar -2MM ,Current-0.3 Amp

CHARGING - 0.3 Amp

DATE-6/08/2024	BATTERY MODEL-KG T-CAT -51.2V 100AH			BATTERY SR.No-0001		Bus Bar-2mm		Ambient Temperature-30			Δ=14
Sr. No	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	10:44	46.7	33.32	0.11	8%	35	34	34	34	2944	2976
2	10:45	50.28	33.75	9.72	10%	35	34	34	34	3116	3129
3	10:55	52.27	33.77	13.06	13%	35	34	34	34	3267	3272
4	11:05	52.53	33.8	18.64	19%	35	34	34	34	3282	3287
5	11:15	53.02	33.8	24.47	24%	36	35	34	34	3313	3319
6	11:25	53.44	33.8	30.13	30%	36	35	35	35	3338	3343
7	11:35	53.66	33.8	36.12	36%	37	35	35	35	3352	3357
8	11:45	53.72	33.8	41.63	42%	37	36	36	36	3356	3361
9	11:55	53.78	33.81	47.4	47%	38	37	37	37	3359	3364
10	12:05	53.84	33.81	52.6	53%	39	38	38	37	3363	3369
11	12:15	58.75	33.81	58.83	59%	40	39	39	38	3368	3375
12	12:25	54.04	33.83	64.72	65%	41	40	40	39	3375	3382
13	12:35	54.21	33.83	70.36	70%	41	40	41	40	3385	3393
14	12:45	54.29	33.83	77.05	77%	42	41	41	40	3391	3397
15	12:55	54.32	33.84	82.49	82%	42	41	41	41	3393	3399
16	01:05	54.37	33.84	88.19	88%	42	42	42	41	3396	3402
17	01:15	54.43	33.84	93.55	94%	43	42	42	41	3400	3406
18	01:25	54.55	33.84	100	100%	43	42	43	42	3407	3414
19	01:35	54.74	33.85	100	100%	43	43	43	42	3419	3428
20	01:45	54.67	33.85	100	100%	44	43	44	43	3386	3450

DISCHARGING-0.3 Amp

DATE-6/08/2024	BATTERY MODEL-KG T-CAT -51.2V 100AH			BATTERY SR.No-0001		Bus Bar-2mm		Ambient Temperature-30			Δ=16
Sr. No	TIME	BATTERY VOLTAGE	BATTERY CURRENT	AH	SOC%	TEM 1	TEM 2	TEM 3	TEM 4	MIN.VOLTAGE	MAX.VOLTAGE
1	13:50	53.63	33.71	100.08	100%	43	43	43	43	3316	3338
2	02:00	52.76	33.78	94.65	94%	44	43	43	43	3296	3300
3	02:10	52.73	33.78	88.2	88%	44	43	44	43	3295	3297
4	02:20	52.7	33.81	82.54	82%	44	43	44	43	3292	3295
5	02:30	52.65	33.81	76.35	76%	44	44	44	43	3289	3293
6	02:40	52.59	33.81	70.2	70%	44	44	44	43	3284	3288
7	02:50	52.45	33.81	64.21	64%	45	44	44	43	3276	3280
8	03:00	52.26	33.81	58.55	58%	45	44	44	44	3264	3268
9	03:10	52.16	33.81	52.48	52%	45	44	44	43	3258	3262
10	03:20	52.06	33.81	44.67	45%	44	44	44	43	3252	3256
11	03:30	51.98	33.81	38.29	38%	44	43	43	43	3246	3251
12	03:40	51.92	33.81	34.64	35%	44	43	43	42	3242	3247
13	03:50	51.78	33.81	28.57	28%	44	43	43	42	3234	3238
14	04:00	51.59	33.8	23.38	23%	44	43	43	42	3222	3226
15	04:10	51.31	33.8	17.59	18%	44	43	44	43	3205	3209
16	04:20	50.96	33.81	11.99	12%	45	44	44	43	3182	3186
17	04:30	50.49	33.8	5.88	6%	45	45	45	41	3152	3157
18	04:40	50.28	33.83	1.94	2%	46	45	45	44	3135	3141
19	04:45	50.85	33.83	0.65	1%	45	45	45	44	3115	3162
Power Cut											
20	05:02	49.08	33.74	0	1%	44	45	45	44	3097	3102
21	05:10	45.88	33.78	0	1%	45	45	45	44	2837	2857
22	05:12	45.32	33.8	0	1%	45	46	46	45	2821	2857

100% Depth of Discharge (DOD) Test

Discharging Start

NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
22	10/9/2024 9:56:39 AM	PACK1	Normal	53.43	3.34	3.341	3.337	0.004	20.9	99	44678	44700	44700	13	355
23	10/9/2024 9:56:40 AM	PACK1	Normal	52.81	3.3	3.304	3.289	0.015	1.12	99	44678	44700	44700	13	355
24	10/9/2024 9:56:41 AM	PACK1	Normal	52.72	3.295	3.299	3.283	0.016	0	99	44672	44700	44700	13	355
25	10/9/2024 9:56:42 AM	PACK1	Normal	52.68	3.292	3.296	3.281	0.015	-22.53	100	44666	44700	44700	13	355
26	10/9/2024 9:56:43 AM	PACK1	Normal	52.62	3.289	3.293	3.277	0.016	-22.53	100	44659	44700	44700	13	355
27	10/9/2024 9:56:44 AM	PACK1	Normal	52.58	3.286	3.29	3.274	0.016	-22.53	100	44653	44700	44700	13	355
28	10/9/2024 9:56:45 AM	PACK1	Normal	52.55	3.284	3.288	3.273	0.015	-22.53	100	44653	44700	44700	13	355
29	10/9/2024 9:56:46 AM	PACK1	Normal	52.51	3.282	3.285	3.27	0.015	-22.53	100	44647	44700	44700	13	355
30	10/9/2024 9:56:47 AM	PACK1	Normal	52.47	3.28	3.283	3.268	0.015	-22.53	100	44641	44700	44700	13	355

Discharging End

NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
7956	10/9/2024 11:55:46 AM	PACK1	SOC Low alam	46.54	2.909	2.926	2.889	0.037	-22.53	0	0	44700	44700	1	355
7957	10/9/2024 11:55:47 AM	PACK1	SOC Low alam	46.52	2.908	2.924	2.888	0.036	-22.53	0	0	44700	44700	1	355
7958	10/9/2024 11:55:48 AM	PACK1	SOC Low alam	46.5	2.906	2.923	2.886	0.037	-22.53	0	0	44700	44700	1	355
7959	10/9/2024 11:55:49 AM	PACK1	SOC Low alam	47.17	2.948	2.963	2.931	0.032	-22.53	0	0	44700	44700	1	355
7960	10/9/2024 11:55:50 AM	PACK1	SOC Low alam	47.29	2.955	2.968	2.939	0.029	-10.33	0	0	44700	44700	1	355
7961	10/9/2024 11:55:50 AM	PACK1	SOC Low alam	47.4	2.963	2.976	2.947	0.029	0	0	0	44700	44700	1	355
7962	10/9/2024 11:55:51 AM	PACK1	SOC Low alam	47.45	2.966	2.978	2.951	0.027	0	0	0	44700	44700	1	355
7963	10/9/2024 11:55:52 AM	PACK1	SOC Low alam	47.51	2.97	2.981	2.955	0.026	0	0	0	44700	44700	1	355
7964	10/9/2024 11:55:53 AM	PACK1	SOC Low alam	47.55	2.972	2.982	2.958	0.024	0	0	0	44700	44700	1	355
7965	10/9/2024 11:55:54 AM	PACK1	SOC Low alam	47.59	2.975	2.985	2.961	0.024	0	0	0	44700	44700	1	355

75% DOD Charging Test at 16 A

CC (Constant Current) Starts

O.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
44	10/16/2024 2:40:49 PM	PACK1	DOCAlarm	52.23	3.264	3.267	3.262	0.005	0	0	0	34937	35000	2	355
45	10/16/2024 2:40:51 PM	PACK1	DOCAlarm	52.3	3.269	3.271	3.266	0.005	0	0	0	34937	35000	2	355
46	10/16/2024 2:40:52 PM	PACK1	DOCAlarm	52.34	3.272	3.275	3.268	0.007	3.46	0	0	34937	35000	2	355
47	10/16/2024 2:40:54 PM	PACK1	DOCAlarm	52.43	3.277	3.28	3.274	0.006	4.45	0	1	34937	35000	2	355
48	10/16/2024 2:40:56 PM	PACK1	DOCAlarm	52.48	3.28	3.285	3.276	0.009	6.39	1	4	34937	35000	2	355
49	10/16/2024 2:40:58 PM	PACK1	DOCAlarm	52.55	3.284	3.29	3.281	0.009	8.32	1	9	34937	35000	2	355
50	10/16/2024 2:41:00 PM	PACK1	DOCAlarm	52.62	3.289	3.294	3.285	0.009	10.25	1	14	34937	35000	2	355
51	10/16/2024 2:41:02 PM	PACK1	DOCAlarm	52.71	3.294	3.3	3.291	0.009	12.21	1	21	34937	35000	2	355
52	10/16/2024 2:41:04 PM	PACK1	DOCAlarm	52.76	3.298	3.304	3.295	0.009	14.24	1	28	34937	35000	2	355
53	10/16/2024 2:41:05 PM	PACK1	DOCAlarm	52.81	3.3	3.308	3.297	0.011	15.81	1	33	34937	35000	2	355
54	10/16/2024 2:41:07 PM	PACK1	DOCAlarm	52.84	3.303	3.311	3.299	0.012	15.83	1	41	34937	35000	2	355
55	10/16/2024 2:41:09 PM	PACK1	DOCAlarm	52.86	3.304	3.312	3.3	0.012	15.82	1	50	34937	35000	2	355
56	10/16/2024 2:41:11 PM	PACK1	DOCAlarm	52.88	3.305	3.312	3.301	0.011	15.82	1	59	34937	35000	2	355
57	10/16/2024 2:41:13 PM	PACK1	DOCAlarm	52.88	3.305	3.313	3.301	0.012	15.82	1	68	34937	35000	2	355

CC Ends

	A	B	C	D	E	F	G	H	I	AR	AV	AW	AX	AY	AZ	BA
1	NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
45	4144	10/16/2024 4:48:49 PM	PACK1	DOCAlarm	55	3.437	3.455	3.427	0.028	15.68	96	33417	34937	35000	2	355
46	4145	10/16/2024 4:48:51 PM	PACK1	DOCAlarm	54.99	3.437	3.457	3.426	0.031	15.68	96	33426	34937	35000	2	355
47	4146	10/16/2024 4:48:53 PM	PACK1	DOCAlarm	54.99	3.437	3.456	3.426	0.03	15.68	96	33430	34937	35000	2	355
48	4147	10/16/2024 4:48:55 PM	PACK1	DOCAlarm	55	3.437	3.456	3.426	0.03	15.68	96	33439	34937	35000	2	355
49	4148	10/16/2024 4:48:57 PM	PACK1	DOCAlarm	54.99	3.437	3.457	3.427	0.03	15.68	96	33448	34937	35000	2	355
50	4149	10/16/2024 4:48:58 PM	PACK1	DOCAlarm	55.01	3.438	3.458	3.427	0.031	15.71	96	33457	34937	35000	2	355
51	4150	10/16/2024 4:49:00 PM	PACK1	DOCAlarm	55.02	3.439	3.457	3.428	0.029	15.71	96	33465	34937	35000	2	355
52	4151	10/16/2024 4:49:02 PM	PACK1	DOCAlarm	55.02	3.439	3.459	3.428	0.031	15.63	96	33474	34937	35000	2	355
53	4152	10/16/2024 4:49:04 PM	PACK1	DOCAlarm	55.02	3.439	3.459	3.428	0.031	15.6	96	33483	34937	35000	2	355
54	4153	10/16/2024 4:49:06 PM	PACK1	DOCAlarm	55.01	3.438	3.458	3.427	0.031	15.56	96	33491	34937	35000	2	355
55	4154	10/16/2024 4:49:08 PM	PACK1	DOCAlarm	55.02	3.438	3.459	3.428	0.031	15.45	96	33496	34937	35000	2	355
56	4155	10/16/2024 4:49:10 PM	PACK1	DOCAlarm	55.02	3.439	3.458	3.428	0.03	15.4	96	33504	34937	35000	2	355

CV Ends

	A	B	C	D	E	F	G	H	I	AR	AV	AW	AX	AY	AZ	BA
1	NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
15	4514	10/16/2024 5:00:23 PM	PACK1	DOCAlarm	55.02	3.439	3.455	3.422	0.033	1.57	99	34839	34937	35000	2	355
16	4515	10/16/2024 5:00:25 PM	PACK1	DOCAlarm	55.01	3.438	3.455	3.421	0.034	1.57	99	34840	34937	35000	2	355
17	4516	10/16/2024 5:00:27 PM	PACK1	DOCAlarm	55.01	3.438	3.455	3.421	0.034	1.57	99	34840	34937	35000	2	355
18	4517	10/16/2024 5:00:29 PM	PACK1	DOCAlarm	55.01	3.438	3.455	3.42	0.035	1.45	99	34841	34937	35000	2	355
19	4518	10/16/2024 5:00:30 PM	PACK1	DOCAlarm	55	3.438	3.454	3.42	0.034	1.49	99	34842	34937	35000	2	355
20	4519	10/16/2024 5:00:32 PM	PACK1	FOV	55.02	3.439	3.455	3.421	0.034	1.49	100	34937	34937	35000	2	355
21	4520	10/16/2024 5:00:34 PM	PACK1	FOV	54.96	3.435	3.452	3.417	0.035	0	100	34937	34937	35000	2	355
22	4521	10/16/2024 5:00:36 PM	PACK1	FOV	54.93	3.433	3.449	3.416	0.033	0	100	34937	34937	35000	2	355

75% DOD Charging Test at 20 A

CC Starts

NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
34	10/16/2024 9:36:43 PM	PACK1	DOCAlarm	52.41	3.275	3.28	3.272	0.008	13.45	1	26	34923	35000	3	355
35	10/16/2024 9:36:45 PM	PACK1	DOCAlarm	52.49	3.281	3.286	3.277	0.009	15.42	1	35	34923	35000	3	355
36	10/16/2024 9:36:47 PM	PACK1	DOCAlarm	52.58	3.286	3.292	3.283	0.009	17.39	1	44	34923	35000	3	355
37	10/16/2024 9:36:49 PM	PACK1	DOCAlarm	52.67	3.292	3.3	3.288	0.012	18.35	1	49	34923	35000	3	355
38	10/16/2024 9:36:51 PM	PACK1	DOCAlarm	52.7	3.294	3.302	3.29	0.012	19.81	1	60	34923	35000	3	355
39	10/16/2024 9:36:53 PM	PACK1	DOCAlarm	52.73	3.296	3.307	3.291	0.016	19.81	1	71	34923	35000	3	355
40	10/16/2024 9:36:55 PM	PACK1	DOCAlarm	52.75	3.297	3.307	3.292	0.015	19.81	1	82	34923	35000	3	355
41	10/16/2024 9:36:56 PM	PACK1	DOCAlarm	52.77	3.298	3.308	3.294	0.014	19.81	1	93	34923	35000	3	355
42	10/16/2024 9:36:58 PM	PACK1	DOCAlarm	52.79	3.299	3.306	3.295	0.011	19.81	1	104	34923	35000	3	355
43	10/16/2024 9:37:00 PM	PACK1	DOCAlarm	52.82	3.301	3.308	3.298	0.01	19.81	1	115	34923	35000	3	355
44	10/16/2024 9:37:02 PM	PACK1	DOCAlarm	52.83	3.302	3.31	3.296	0.014	19.82	1	126	34923	35000	3	355

Table CC (constant current) starts for 75% DOD at 20 A

CC Ends

NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
3193	10/16/2024 11:18:38 PM	PACK1	DOCAlarm	54.99	3.437	3.464	3.43	0.034	20.31	97	33779	34923	35000	3	355
3194	10/16/2024 11:18:40 PM	PACK1	DOCAlarm	55	3.438	3.463	3.43	0.033	20.32	97	33791	34923	35000	3	355
3195	10/16/2024 11:18:42 PM	PACK1	DOCAlarm	54.99	3.437	3.464	3.43	0.034	20.32	97	33802	34923	35000	3	355
3196	10/16/2024 11:18:44 PM	PACK1	DOCAlarm	55	3.437	3.463	3.429	0.034	20.32	97	33813	34923	35000	3	355
3197	10/16/2024 11:18:46 PM	PACK1	DOCAlarm	55.01	3.438	3.464	3.431	0.033	20.3	97	33819	34923	35000	3	355
3198	10/16/2024 11:18:48 PM	PACK1	DOCAlarm	55.01	3.438	3.465	3.429	0.036	20.3	97	33830	34923	35000	3	355
3199	10/16/2024 11:18:50 PM	PACK1	DOCAlarm	55	3.438	3.463	3.429	0.034	20.28	97	33841	34923	35000	3	355
3200	10/16/2024 11:18:51 PM	PACK1	DOCAlarm	55.01	3.438	3.464	3.43	0.034	20.3	97	33853	34923	35000	3	355
3201	10/16/2024 11:18:53 PM	PACK1	DOCAlarm	55.01	3.438	3.465	3.43	0.035	20.29	97	33864	34923	35000	3	355
3202	10/16/2024 11:18:55 PM	PACK1	DOCAlarm	55.02	3.439	3.465	3.431	0.034	20.26	97	33875	34923	35000	3	355
3203	10/16/2024 11:18:57 PM	PACK1	DOCAlarm	55.02	3.439	3.465	3.432	0.033	20.22	98	33886	34923	35000	3	355

CV Ends

	NO.	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCap	FullCap	DesignCap	CHGInterval	MaxCHGInterval
10	3609	10/16/2024 11:32:11 PM	PACK1	DOCAlarm	55.02	3.439	3.456	3.417	0.039	1.49	99	34923	34923	35000	3	355
11	3610	10/16/2024 11:32:13 PM	PACK1	DOCAlarm	55.03	3.439	3.456	3.417	0.039	1.42	99	34923	34923	35000	3	355
12	3611	10/16/2024 11:32:15 PM	PACK1	DOCAlarm	55.02	3.439	3.455	3.416	0.039	1.48	99	34923	34923	35000	3	355
13	3612	10/16/2024 11:32:17 PM	PACK1	DOCAlarm	55.02	3.439	3.454	3.416	0.038	1.45	99	34923	34923	35000	3	355
14	3613	10/16/2024 11:32:19 PM	PACK1	DOCAlarm	55.01	3.438	3.454	3.416	0.038	1.47	99	34923	34923	35000	3	355
15	3614	10/16/2024 11:32:21 PM	PACK1	FOV	55.01	3.438	3.455	3.415	0.04	1.38	99	34923	34923	35000	3	355
16	3615	10/16/2024 11:32:23 PM	PACK1	FOV	54.97	3.436	3.452	3.414	0.038	0	100	34923	34923	35000	3	355
17	3616	10/16/2024 11:32:25 PM	PACK1	FOV	54.95	3.435	3.45	3.412	0.038	0	100	34923	34923	35000	3	355
18	3617	10/16/2024 11:32:27 PM	PACK1	FOV	54.93	3.433	3.448	3.41	0.038	0	100	34923	34923	35000	3	355
19	3618	10/16/2024 11:32:29 PM	PACK1	FOV	54.92	3.432	3.447	3.41	0.037	0	100	34923	34923	35000	3	355
20	3619	10/16/2024 11:32:31 PM	PACK1	FOV	54.92	3.432	3.447	3.409	0.038	0	100	34923	34923	35000	3	355

75% DOD Discharging Test

CC Starts

NO	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCa	FullCa	DesignCa	CHGInterva	MaxCHGInterva
43	10/17/2024 10:31:51 AM	PACK1	DOCAlarm	53.27	3.329	3.332	3.328	0.004	0	100	34844	34916	35000	6	355
44	10/17/2024 10:31:52 AM	PACK1	DOCAlarm	53.26	3.329	3.331	3.327	0.004	0	100	34844	34916	35000	6	355
45	10/17/2024 10:31:54 AM	PACK1	DOCAlarm	53.26	3.329	3.331	3.327	0.004	0	100	34844	34916	35000	6	355
46	10/17/2024 10:31:56 AM	PACK1	DOCAlarm	53.26	3.329	3.332	3.327	0.005	0	100	34844	34916	35000	6	355
47	10/17/2024 10:31:58 AM	PACK1	DOCAlarm	52.61	3.288	3.292	3.276	0.016	-19.66	100	34839	34916	35000	6	355
48	10/17/2024 10:32:00 AM	PACK1	DOCAlarm	52.52	3.283	3.287	3.271	0.016	-22.52	100	34826	34916	35000	6	355
49	10/17/2024 10:32:02 AM	PACK1	DOCAlarm	52.47	3.279	3.284	3.267	0.017	-22.52	100	34814	34916	35000	6	355
50	10/17/2024 10:32:04 AM	PACK1	DOCAlarm	52.4	3.275	3.279	3.263	0.016	-22.52	100	34801	34916	35000	6	355
51	10/17/2024 10:32:05 AM	PACK1	DOCAlarm	52.37	3.273	3.277	3.261	0.016	-22.52	100	34795	34916	35000	6	355
52	10/17/2024 10:32:07 AM	PACK1	DOCAlarm	52.33	3.271	3.275	3.259	0.016	-22.52	100	34782	34916	35000	6	355
53	10/17/2024 10:32:09 AM	PACK1	DOCAlarm	52.31	3.269	3.273	3.257	0.016	-22.53	100	34770	34916	35000	6	355
54	10/17/2024 10:32:11 AM	PACK1	DOCAlarm	52.27	3.267	3.271	3.254	0.017	-22.53	100	34757	34916	35000	6	355
55	10/17/2024 10:32:13 AM	PACK1	DOCAlarm	52.26	3.266	3.27	3.254	0.016	-22.52	100	34745	34916	35000	6	355

CC Ends

NO	Time	Pack	state	TotalVol	AverageVol	MaxVol	MinVol	Voldif	Current	SOC	RemainCa	FullCa	DesignCa	CHGInterva	MaxCHGInterva
3019	10/17/2024 12:04:44 PM	PACK1	DOCAlarm	50.85	3.178	3.183	3.163	0.02	-22.54	0	1	34909	35000	7	355
3020	10/17/2024 12:04:46 PM	PACK1	DOCAlarm	50.84	3.178	3.182	3.162	0.02	-22.54	0	0	34909	35000	7	355
3021	10/17/2024 12:04:47 PM	PACK1	DOCAlarm	50.84	3.178	3.182	3.162	0.02	-22.54	0	0	34909	35000	7	355
3022	10/17/2024 12:04:49 PM	PACK1	DOCAlarm	50.84	3.178	3.183	3.163	0.02	-22.54	0	0	34909	35000	7	355
3023	10/17/2024 12:04:51 PM	PACK1	DOCAlarm	50.84	3.177	3.182	3.163	0.019	-22.54	0	0	34909	35000	7	355
3024	10/17/2024 12:04:53 PM	PACK1	DOCAlarm	50.84	3.178	3.182	3.162	0.02	-22.54	0	0	34909	35000	7	355
3025	10/17/2024 12:04:55 PM	PACK1	DOCAlarm	51.47	3.217	3.219	3.213	0.006	-10.24	0	0	34909	35000	7	355
3026	10/17/2024 12:04:57 PM	PACK1	DOCAlarm	51.55	3.222	3.224	3.218	0.006	0	0	0	34909	35000	7	355
3027	10/17/2024 12:04:59 PM	PACK1	DOCAlarm	51.59	3.225	3.227	3.221	0.006	0	0	0	34909	35000	7	355
3028	10/17/2024 12:05:01 PM	PACK1	DOCAlarm	51.64	3.227	3.23	3.223	0.007	0	0	0	34909	35000	7	355

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