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# Battery Management System in PHEV

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**ABSTRACT**

*The green energy usage is becoming increasingly more important now a days due to environmental considerations. Transportation sector is one of the major contributors to air quality deterioration. Hence, electric vehicles are currently the superior choice for the environment in terms of public and personal transportation. Lithium-ion batteries are widely used in electric vehicles due to its high energy and current density. However, they have risks of fire hazard and electric shock if they are not operated within their Safe Operation Area (SOA). Therefore a battery management system (BMS) must be used in every lithiumion battery, especially for those used in electric vehicles. Lithium-ion battery (LIB) power systems have been commonly used for energy storage in electric vehicles. However, it is quite challenging to implement a robust real-time fault diagnosis and protection scheme to ensure battery safety and performance. This paper presents a resilient framework for real-time fault diagnosis and protection in a battery-power system. Based on the proposed system structure, the self-initialization scheme for state-of-charge (SOC) estimation and the fault-diagnosis scheme were tested and implemented in an actual cell series battery-pack prototype. The experimental results validated that the proposed system can estimate the SOC, diagnose the fault and provide necessary protection and self-recovery actions under the load profile for an electric vehicle.*

***Keywords**: Battery management system, state of charge, state of health, state of life.*

## I. INTRODUCTION

Electric vehicles (EV) play a key role in reducing air pollution because of its zero-emission of harmful gases and use of energy efficiently. Electric vehicles are equipped with large number of battery cells that require an effective battery management system (BMS) for providing necessary power. The battery in a electric vehicle is expected to provide long lasting energy and also a high power whenever required. Some of the most commonly used batteries for traction applications are, Lead-acid, Lithium-ion, -metal hydride. Lithium-ion is most commonly used traction batteries due to its high efficiency and high energy density. The battery capacity range for an electric vehicle is about 30 to 100 KWH or more.

One of the important parameters that are required to ensure safe charging and discharging is SOC. SOC is defined as the present capacity of the battery expressed in terms of its rated capacity. SOC provides the current state of the battery and enables batteries to safely be charged and discharged at a level suitable for battery life enhancement. Thus, SOC helps in the management of batteries. However, measuring SOC is not direct, because it involves the measurement of battery voltage, current, temperature, and other information that pertains to the battery under consideration. The finite battery efficiency and the chemical reaction that takes place during charge and discharge conditions cause temperature rise, which influences SOC estimation. Therefore, accurate

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algorithms are needed to model the battery for SOC estimation. In EVs, the number of batteries is connected in series-parallel combination to match the load requirement.

BMS is a separate entity with hardware and firmware and is connected to a battery charger rather than integrated within the charger. BMS consists of a number of sensing devices for monitoring battery parameters that will be used in the algorithm for SOC estimation. The significant block of any BMS is the battery model block, which requires detailed understanding of battery characteristics for accurate SOC estimation. The model is generally derived from the charging and discharging curves of the battery.

## II. OBJECTIVES

- To protect the cells or the battery from damage
- Using control technique to optimize the performance of a BMS
- Increase the life of the battery
- Maintains the state of the battery

## III. METHODOLOGY

Safety circuitry has long been used in BMSs. However, since more sensors are used in the proposed BMS, improvements in current safety circuitry designs can be implemented, such as the addition of accurate alarms and controls to prevent overcharge, over-discharge, and overheating. The sensor system consists of different sensors to monitor and measure battery parameters including cell voltage, battery temperature, and battery current.

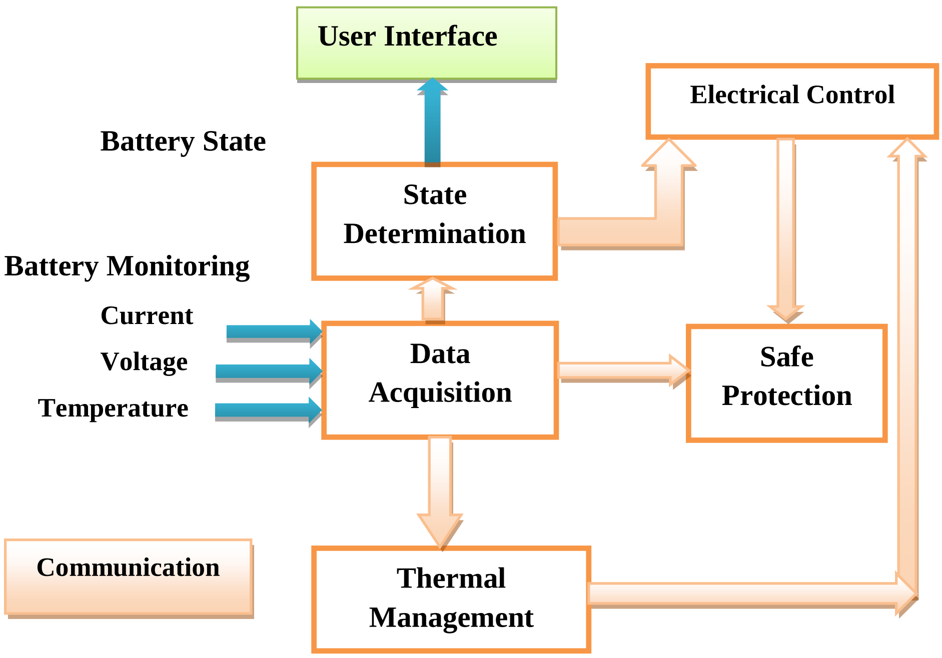


**Figure1. Block diagram of a battery management system.**

From a hardware structure perspective, three kinds of topologies have been implemented in BMSs, including centralized, distributed and modular structures. However, the functions of the BMSs in each case are similar.

**A. State of Charge (SOC):** SOC is critical, but it is not measurable given the current onboard sensing technologies. The ratio of the currently available capacity to the maximum capacity can be expressed as SOC, which is calculated by Equation

$$SOC=1-\frac{\int idt}{C_n} \quad \text{-----------------------Equation -1}$$

Where *i* is the current, and *Cn* is the maximum capacity that the battery can hold.

SOC reflects the amount of remaining charge that is available to the battery. It is used to determine the driving distance remaining in EVs, while it indicates when the internal combustion engine should be switched on or off in EVs. Due to the inherent chemical reactions of the battery and different external loads, the maximum capacity of the battery gradually decreases over time.

**B.** A Proposed Battery Management System: The weaknesses of current BMSs are identified through a comprehensive review of the existing approaches. To tackle these weaknesses, we suggest that a comprehensive and mature BMS should contain the components shown below.

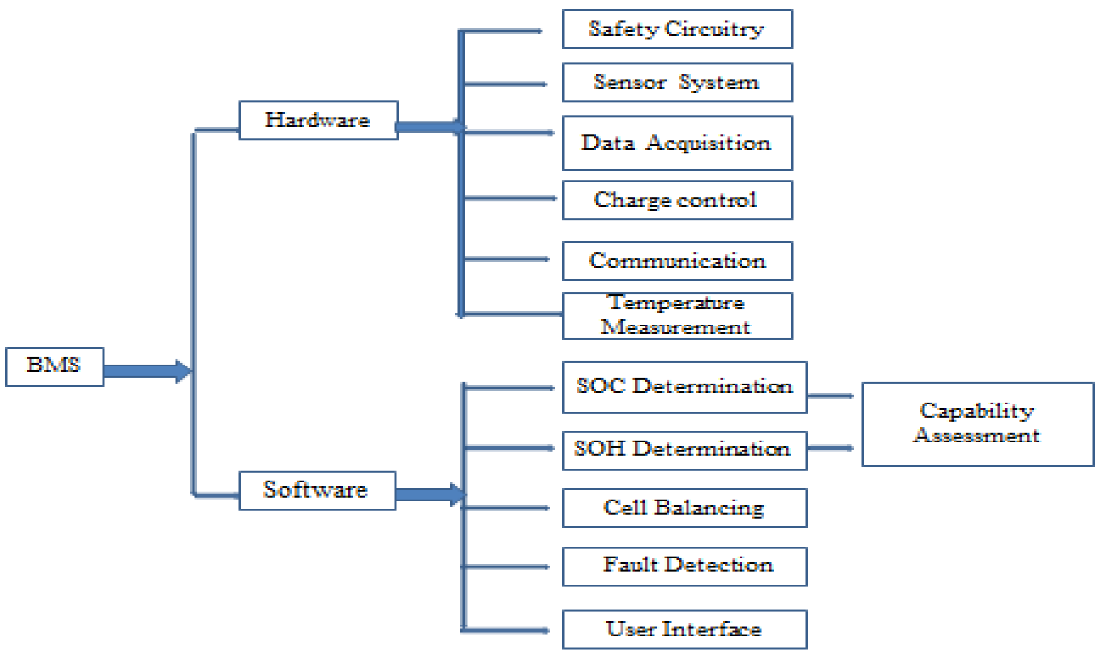


**Figure2. Components of the Proposed BMS**

Hardware: Safety circuitry has long been used in BMSs. However, since more sensors are used in the proposed BMS, improvements in current safety circuitry designs can be implemented, such as the addition of accurate alarms and controls to prevent overcharge, over-discharge, and overheating.

**Software:** The software of the BMS is the center of the whole system because it controls all hardware operations and analyses of sensor data for making decisions and state estimations. Switch control, sample rate

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monitoring in the sensor system, cell balancing control, and even dynamic safety circuit design should be handled by the software of a BMS.

Determination of SOC and SOH will be integrated into a capability assessment, which also presents the life status of the battery and sets the operating limits according to state-of-the-art algorithms, such as fuzzy logic, neural networks, state-space-based models, and so on

**Possible Solutions for BMSs:** By monitoring the sensor signals and processing real-time data from a BMS, the battery status, including SOC, State of Health, and State of Life, can be estimated and predicted to provide end users with an accurate "gauge meter" in an EV or HEV. Based on the data collected, the BMS determines the corresponding maintenance strategies. Meanwhile, abnormality detection can be used to capture signals to update the predictive results and guarantee the safety and reliability of batteries.

## C. HARDWARE DESIGN:

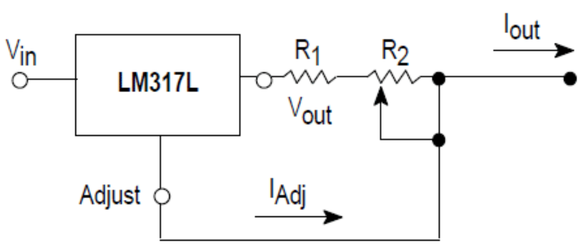
A diode bridge is an arrangement of four diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating-current input into a direct-current output, it is known as a bridge rectifier.

In fact, this is a Zener diode, which opens when a certain voltage is reached on the battery and extinguishes everything unnecessary. The circuit consists of a regulated Zener the diode on the basis of the chip TL431. At a given voltage, a power transistor opens. With the diodes in the collector circuit, it forms the equivalent of the load. That is, the excess power will be dissipated as heat on these elements, so the transistor may need a heat sink.

The board has a tuning resistor to adjust the circuit for the desired cut out voltage. The LED indicator on the collector circuit of the transistor will glow when the transistor is open, thereby indicating that the charging process is complete. In my case, 5 mm LEDs are used.

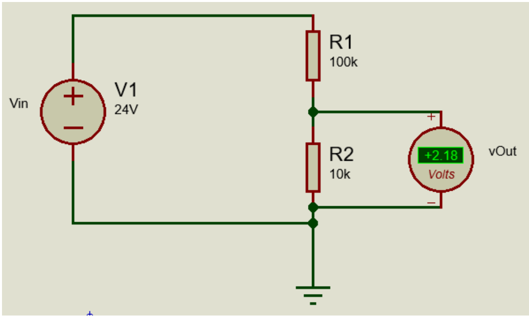
Adjustment of the circuit is a simple. Set the voltage in the region of 4.2 Volts on laboratory power supply. Then connect the board to it and slowly rotate the trimmer until the LED illuminates. We adjust all balancing units so that the current consumption or balancing current for all was the same.

**Voltage regulator:** Any electrical or electronic device that maintains the voltage of a power source within acceptable limits. The voltage regulator is needed to keep voltages within the prescribed range that can be tolerated by the electrical equipment using that voltage.




$V_{out} = 1.25V(1 + \frac{R2}{R1})$ ----------Equition-2

**Voltage divider circuit:** A voltage divider is a passive linear circuit that produces an output voltage($V_{out}$) that is a fraction of its input voltage($V_{in}$). Voltage division is the result of distributing the input voltage among the components of the divider.




$V_{out} = V_{in} * \frac{R2}{R1+R2}$ -------- Equition-3

$=24*\frac{10K}{100K+10K}$

=2.18V

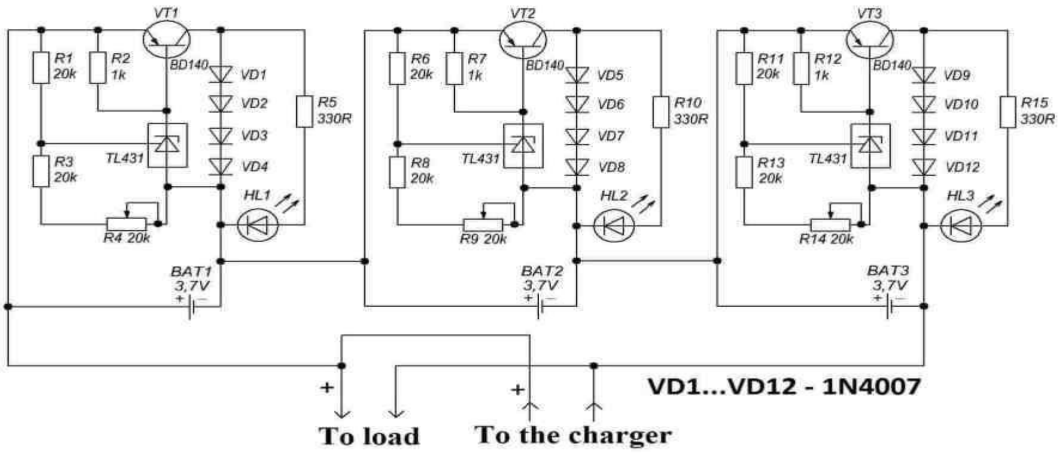



**Figure3. Circuit diagram of BMS**

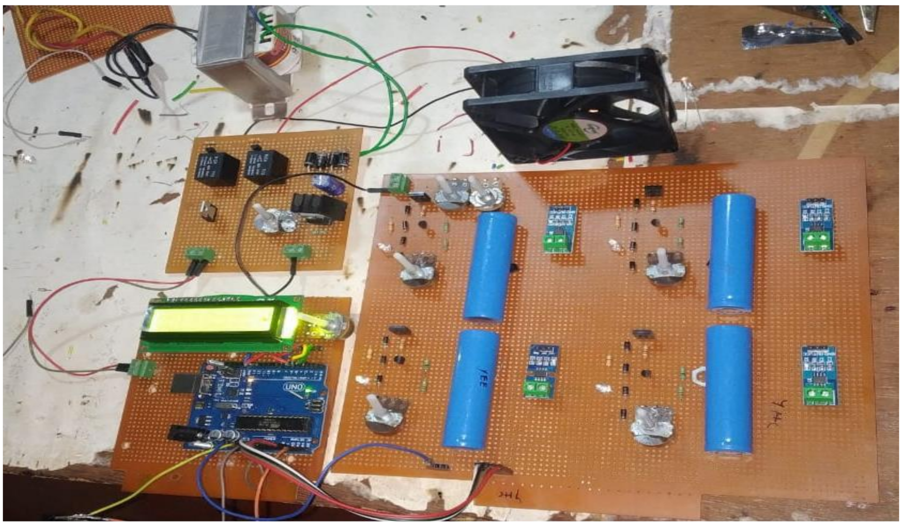


**Figure4. Hardware circuit diagram of BMS**

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**SOFTWARE USED:**

**D.PROTEUS DESING SUITE 8.6:** It is a software suite containing schematic, simulation as well as PCB designing.The simulation allows human access during run time, thus providing real time simulation.It has the feature of viewing output in 3D view of the designed PCB along with components. The designer can also develop 2D drawings for the product.

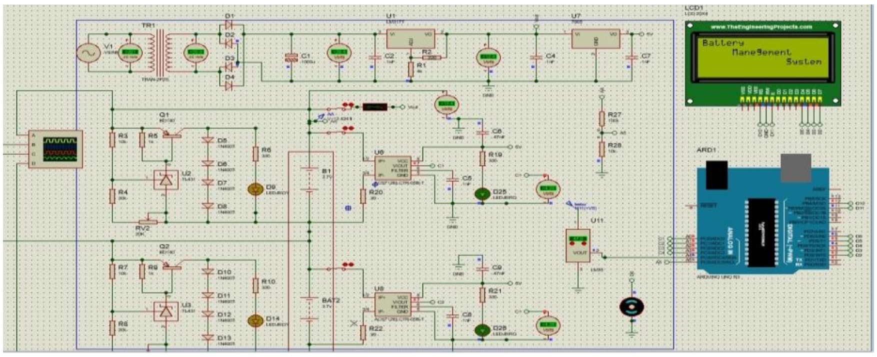

**Figure5. Simulation circuit diagram of BMS**

## IV. RESULT

**Table1: State of Charge**

| Sl No | Cell 1 | Cell 2 | Cell 3 | Cell 4 |
|---|---|---|---|---|
| 1 | 1.5 | 2.5 | 3.5 | 1.4 |
| 2 | 1.8 | 2.8 | 3.7 | 1.8 |
| 3 | 2.2 | 3.1 | 4 | 2.4 |
| 4 | 2.7 | 3.7 | Bypass supply | 2.8 |
| 5 | 3 | 4 | | 3.2 |
| 6 | 3.5 | Bypass supply | | 3.7 |
| 7 | 4 | | | 4 |
| 8 | Bypass supply | | | Bypass supply |

Table 1 shows the details of state of charge (SOC). From the table 1 we can observe that, as soon as the battery charge reaches to its rated voltage of 4V, the supply is bypassed to other battery whose charge is less than its rated voltage and it starts charging.

**Table2: State of charge (Percentage and Time)**

| Sl No | Time in Hr | Cell 1 | Cell 2 | Cell 3 | Cell 4 |
|---|---|---|---|---|---|
| 1 | 0 | 28% | 62% | 87% | 35% |
| 2 | 0.25 | 36% | 70% | 93% | 45% |
| 3 | 0.5 | 44% | 77% | 100% | 60% |
| 4 | 0.75 | 54% | 92% | | 70% |

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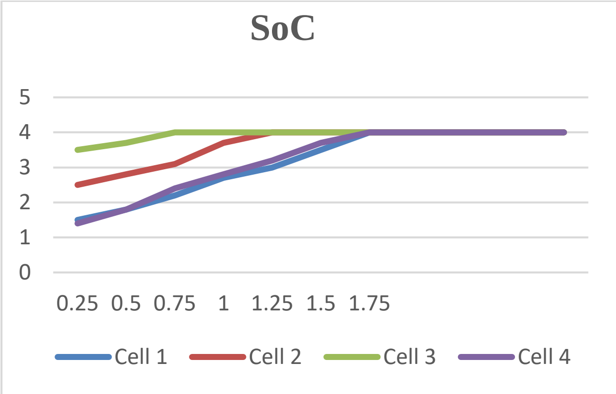
| | | | | | |
|---|---|---|---|---|---|
| 5 | 1 | 60% | 100% | | 80% |
| 6 | 1.25 | 87% | | | 92% |
| 7 | 1.5 | 100% | | | 100% |

Table 2 shows the time required to charge battery from its residual charge. It can be noticed that the time required is inversely proportional to residual charge.

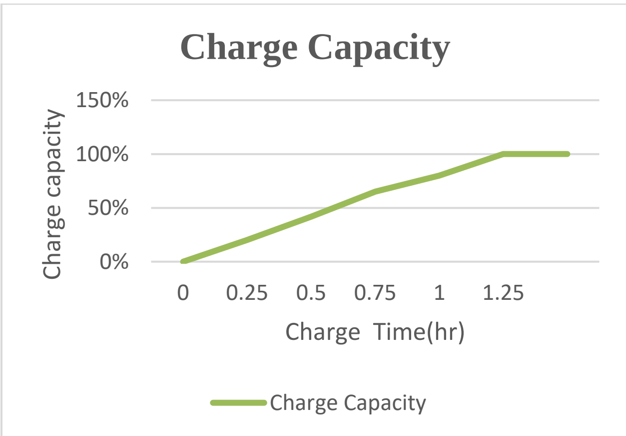



**Graph1. State of Charge**

**Table3: Charge Capacity**

| Sl No | Charge Time in Hour | Charge Capacity |
|---|---|---|
| 1 | 0 | 0% |
| 2 | 0.25 | 20% |
| 3 | 0.5 | 42% |
| 4 | 0.75 | 65% |
| 5 | 1 | 80% |
| 6 | 1.25 | 100% |

**Table3 shows total percentage of charging capacity of battery.**



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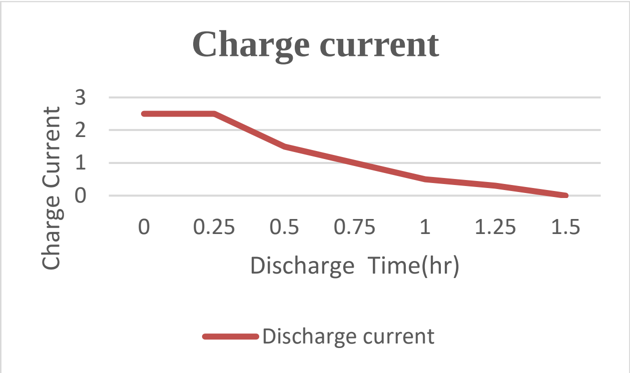
**Graph2. Charge Capacity**

**Table4: Charge Current**

| Sl No | Discharge time in Hour | Charge current (Amp) |
|---|---|---|
| 1 | 0 | 2.5 |
| 2 | 0.25 | 2.5 |
| 3 | 0.5 | 1.5 |
| 4 | 0.75 | 1 |
| 5 | 1 | 0.5 |
| 6 | 1.25 | 0.3 |
| 7 | 1.5 | 0 |

Table 4 & Graph 3 shows, the current of the battery. As the discharging time of the battery increases charge current decreases. Finally charging current attains to zero value.




**Graph3. Charge Current**

**Table5: Cell Voltage**

| Sl No | Charge Time in Hour | Cell Voltage(volt) |
|---|---|---|
| 1 | 0 | 3 |
| 2 | 0.25 | 3.5 |
| 3 | 0.5 | 3.9 |
| 4 | 0.75 | 4.4 |
| 5 | 1 | 4.4 |
| 6 | 1.25 | 4.5 |
| 7 | 1.5 | 4.5 |

Table 5 shows as charging time increases cell voltage increases.

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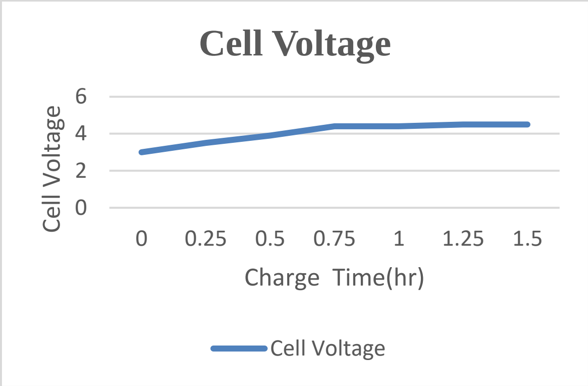


**Graph 4. Cell Voltage**

**Table 6: Temperature condition**

| Sl No | Temperature | Observation |
|---|---|---|
| 1 | 24 C | Cooling Fan OFF |
| 2 | 27 c | " |
| 3 | 28 c | Cooling Fan ON |
| 4 | 30 c | " |
| 5 | 32 c | " |
| 6 | 33 c | " |
| 7 | 36 c | Charging Supply OFF |
| 8 | 38 c | " |

As the temperature of the battery is below 27c looking fan is in OFF mode as if increases above 28c fan gets automatically ON, till 36c charging supply gets isolated.

## V. CONCLUSION

An improved battery model is proposed in this work by considering state of health, state of charge and cell balancing. The model is simulated using proteus 8 software, It improved the original system by adding temperature management system.

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