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MODELLING AND SIMULATION OF BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLE

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ABSTRACT: Battery Management Systems (BMS) are essential for ensuring that rechargeable batteries operate safely and effectively. An overview of BMS and its significance in many applications, such as electric vehicles, renewable energy systems, and portable electronics, is given in this abstract. In order to improve performance, lengthen battery life, and avoid potentially harmful circumstances like overcharging or overheating, the BMS monitors and controls important battery characteristics like voltage, current, temperature, and state of charge. In this study, we provide a protection to over voltage, under voltage and temperature of battery and comprehensive analysis of the purpose, functions, and topologies of BMS. Finally, simulation data are used to illustrate how well the improved battery model performs. The design and experimental results of a novel BMS hardware system are then described. A list of suggested improvements for the battery model and BMS hardware is provided in the section on conclusions and future work.

KEYWORDS: Electric Vehicles, Simulation of Battery Management System, Protection of Battery, Batter Electric Vehicles, State of Charge (SoC).

I. INTRODUCTION OF BMS

Wall clocks, alarms, and smoke detectors are just a few examples of devices that require batteries. Cars, trucks, and regular motorcycles use relatively big rechargeable batteries, whereas wall clocks, alarms, and other devices use little disposable batteries rechargeable batteries require a Battery Management System (BMS) to function and be maintained. It is in charge of keeping an eye on and managing the battery's different properties, including voltage, current, temperature, and state of charge. By using sophisticated algorithms and control techniques, the BMS maintains the battery's optimum performance, safety, and life. It stops the battery from being overcharged, over discharged, or overheated, which can cause deterioration and pose safety risks. The BMS also performs cell balancing to balance the charge between individual cells, increasing the battery pack's total capacity and longevity. A strong and trustworthy BMS is essential for effective and safe battery operation in applications including electric cars, renewable energy systems, and portable devices, increasing the life and increasing the battery system's overall performance and increasing its longevity.

II. CELL AND BATTERY

BATTERY: A battery is an example of an electrochemical device since it useschemical processes to store and transmit electrical energy. One or more electrochemical cells are linked to one another in a series or parallel configuration. A positive electrode (cathode) and a negative electrode (anode) are the two electrodes that make up each cell. The electrolyte sits between the two electrodes. Chemical processes take place inside the battery's cells when it is linked to an outside circuit, converting chemical energy into electrical energy. A current of electricity is produced by the movement of electrons from the anode to the cathode in the external circuit.

CELL: Anode (negative electrode), cathode (positive electrode), and electrolyte make up a cell, which is the fundamental component of a battery. It is a standalone electrochemical device that can generate electrical energy through chemical processes. The electrolyte, which can be a liquid, gel, or solid, acts as a barrier between the anode and cathode, which are normally formed of different materials, frequently metals or metal compounds.

Electrons are released during discharge as a result of a chemical reaction at the anode, and they go to the cathode through an external circuit. In order to balance the charge, ions from the electrolyte go through it and toward the cathode at the same time. A current of electricity is produced by this electrochemical process, which may be utilized to power a variety of systems or devices.

1. DIFFERENT TYPES OF BATTERY

Batteries may be broadly divided into two types:

1. Primary battery2. Secondary battery

PRIMARY BATTERY: One form of battery that cannot be recharged after being fully depleted is a main battery, commonly referred to as a non-rechargeable battery. It is not intended to be recycled or refilled but rather for single-use applications. Primary batteries often offer a steady and dependable power source for a certain amount of time before needing to be replaced. They are frequently employed in gadgets and uses when prolonged use or recharging are not necessary, such as remote controls, smoke alarms, calculators.

SECONDARY BATTERIES: A secondary battery, often referred to as a rechargeable battery, is a type of battery that has numerous recharging cycles after being depleted. Secondary batteries, in contrast to primary batteries, may be recharged with electrical energy and are made for repeated usage. They are often employed in gadgets and programs that need rechargeable power sources, such as mobile phones, computers, electric cars, and renewable energy storage systems. Multiple charges and discharges are possible with secondary batteries because they use reversible chemical processes to store and release energy.

2. BATTERY APPLICATIONS: Small sealed batteries have seen an exponential increase in use in consumer products during the past few decades. Numerous appliances employ primary or rechargeable batteries with tiny form factors. The following lists a few of them.

- Batteries are often used to power portable electronics, including computers, tablets, smartphones, smartwatches, and handheld game consoles. Without a direct power source, these batteries supply the energy required for these gadgets to function.
- Electric Vehicles (EVs): Battery technology is essential to the

development of the electric vehicle market. Electric vehicles such as motorbikes, automobiles, and other modes of transportation are all powered by large-capacity batteries. The vehicle's propulsion energy is stored in these batteries, providing a greener option to conventional fossil fuel-powered automobiles.

- Energy produced from renewable sources, such as solar panels and wind turbines, is stored using batteries. There will be a more consistent and dependable supply of energy thanks to the use of this stored energy at times of high demand or low renewable energy output.
- Uninterruptible Power deliver (UPS): UPS systems frequently employ batteries to deliver momentary backup power during power outages or variations in the primary power source. For applications including data centers, hospitals, telecommunications, and other locations where continuous power is necessary to prevent data loss, equipment damage, or service interruption, UPS systems are crucial.

3. BATTERY MANAGEMENT SYSTEM (BMS)

In today's battery-powered products and electric cars, a battery management system (BMS) is essential. It is in charge of keeping an eye on and managing the lifetime, performance, and safety of the battery pack. Cell balancing, determining the level of charge, controlling temperature, and providing safety from over- and under voltage are just a few of the crucial jobs that the BMS does. The BMS makes sure that everything runs smoothly and efficiently by continually gathering data from individual battery cells. By using the proper management techniques, it employs sophisticated algorithms to recognize and avoid potentially dangerous circumstances including overcharging, over discharging, and thermal runaway. The BMS extends the battery's life while improving overall performance, dependability, and safety through efficient battery pack management.

4. COMPONENTS AND TOPOLOGY:

In contemporary battery systems, a BMS is essential because it performs monitoring and control tasks to guarantee the batteries' optimum performance, safety, and longevity. A few essential parts of the BMS are as follows:

- Various battery metrics, including voltage, current, temperature, and state of charge (SoC), are continually monitored by the battery monitoring unit (BMU). The battery's condition is updated in real-time.
- Cell Balancing Circuit: In a battery pack with several cells, the cell balancing circuit makes sure that the voltage levels of individual cells stay balanced. In order to avoid overcharging or over discharging of any one cell, this circuit redistributes charge among the cells.
- The voltage and current levels going into and out of the battery pack are measured by the voltage and current sensing circuit. It aids in assessing the charge and health states and finds any unusual behavior, such as overcurrent or short circuits.
- Temperature Monitoring Circuit: The BMS has temperature sensors placed throughout the battery pack to avoid overheating. In order to provide input to the BMS for thermal management, these sensors detect the temperature

of the cells and the components in their immediate vicinity.

- The BMS uses algorithms to estimate the state of charge (SoC), which is a measure of how much charge is still in the battery. This estimate is based on past battery data as well as inputs from voltage, current, and temperature sensors.
- State of Health (SoH) estimate Algorithm: The SoH estimate algorithm determines the battery's overall condition and rate of deterioration over time. It evaluates the battery's state by taking into account elements including capacity fading, internal resistance, and cycle behavior.
- Circuitry for safety and protection: The BMS has a number of safety elements to safeguard the battery and its surroundings. These characteristics include of heat protection, short circuit protection, overcurrent protection, under voltage protection, overvoltage protection, and protection against overcurrent.
- Communication Communicate: To communicate with other battery system components or external devices, the BMS frequently incorporates communication protocols as CAN (Controller Area Network), RS485, or Ethernet. Data sharing, control commands, and diagnostics are made possible through this.

- Data Processing: The BMS's control unit processes data from various sensors, algorithms, and protective circuits. Based on this knowledge, it takes judgments and transmits control signals to other parts, including the external charging system or the cell balancing circuit.
- User Interface: A user interface, such as an LCD screen or LED indications, may be included in certain BMS systems to display battery information, allow users to modify settings, or display diagnostic data.

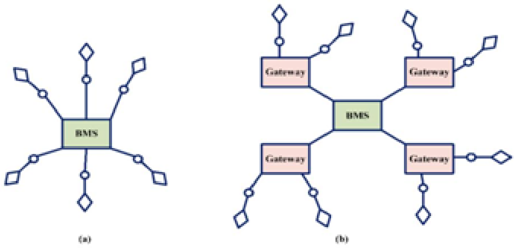


Figure1 BMS implementation topology: (a) centralized, (b) distributed.

5. SOFTWARE ARCHITECTURE: A key element responsible for monitoring and managing different elements of battery performance, safety, and longevity is the software architecture of a BMS. It has a number of crucial layers and parts that work together to guarantee effective operation. Hardware interfaces enable connection with specific battery cells at the most fundamental level, gathering vital information including voltage, temperature, and current. These data are organized and processed by the data collection layer before being used as inputs by the control layer. The control layer conducts algorithms for state estimation, cell balance, and thermal management, thereby enhancing battery performance and avoiding problems like overcharging or overheating.In order to integrate and coordinate, the communication layer makes it possible to interface with other systems like energy management systems or vehicle controllers without any interruption. Last but not least, the user interface layer provides a graphical interface with an easy-to-use user interface for controlling and monitoring battery condition. Overall, the BMS software design strives to improve battery safety, lengthen its lifespan, and maximize its efficiency across multiple applications including electric cars, renewable energy storage, and portable gadgets.

1. Estimation of the state of charge (SoC)
2. State of Health (SoH) Monitoring
3. Cell balancing
4. Protection against Overvoltage and Under voltage
5. Thermal management
6. Current Monitoring

6. FUNCTIONALITIES:

7. FUNCTIONS OF BMS

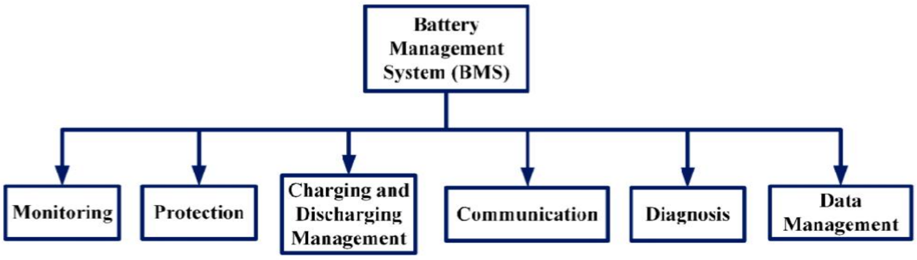


Figure 2Function of BMS

MONITORING: Monitoring of the BMS is essential for guaranteeing the effective and secure functioning of batteries. It entails monitoring and analyzing battery metrics in real-time, including voltage, current, temperature, and state of charge. The BMS can identify abnormalities, avoid overcharging or over discharging, and improve battery efficiency by continually monitoring this data. Additionally, it offers maintenance and problem detection alerts and notifications, enabling prompt interventions to avoid battery damage and lengthen its lifespan. As it improves battery dependability, safety, and overall performance, BMS monitoring is crucial for many applications, including electric cars, renewable energy systems, and portable gadgets.

PROTECTION: For the protection of batteries, BMS are essential. They offer voltage, current, and temperature monitoring and control to guard against problems including overcharging, over-discharging, and overheating. BMS also make sure that each cell in a battery pack has an equal charge across all of its cells, which promotes consistent performance and lengthens battery life. Additionally, while putting safety first, BMS allow effective charging and discharging procedures. BMS enhances the efficiency and dependability of battery systems in a variety of applications, such as electric cars, renewable energy storage, and portable devices.

CHARGING AND DISCHARGING MANAGEMENT: The management of battery charging and discharging requires the use of BMS. To guarantee safe and effective functioning, they keep an eye on important characteristics including voltage, current, temperature, and state of charge. To avoid overcharging and overheating during the charging process, the BMS controls the charging voltage and current. In a similar manner, while the battery is being discharged, it regulates the discharge current to prevent over-discharging, which might harm the battery. To keep battery cell charge levels consistent, BMSs can include capabilities like cell balancing. All things considered, BMSs are essential for improving battery performance, increasing battery life, and assuring safety during charging and discharging activities.

DIAGNOSIS: For batteries to work at their best BMS are essential. In order to evaluate various parameters, such as depth of discharge (DOD), state of charge (SOC), battery capacity, cell temperature, state of fitness (SOF), available energy, charging time, remaining useful life (RUL), remaining runtime, inner impedance of the cell, and current capability, they perform calculations and monitoring tasks. Any possible problems or anomalies in the battery system are also found and identified by the BMS. The BMS works to increase battery efficiency, lengthen its lifespan, and ensure dependable performance by continually tracking and evaluating key factors

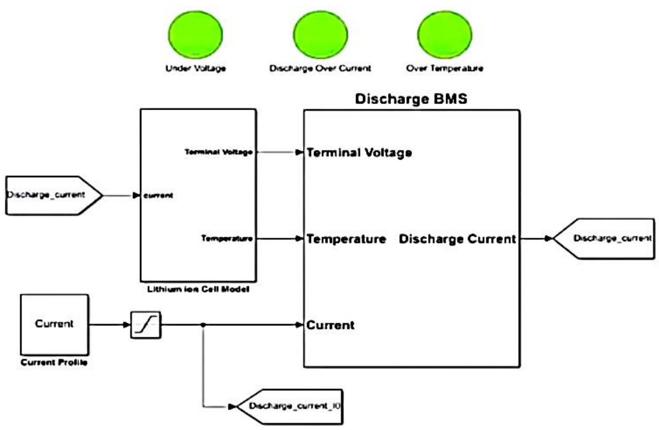
III. SIMULATION AND RESULTS

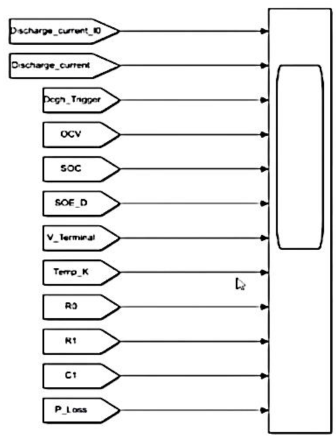
1. CELL SPECIFICATION: We have used cell specification to build a BMS blocks

Cell Specification

Typical Capacity[1]		31.0 Ah
Nominal Voltage		3.7 V
Charge Condition	Max. Current	62.0 A
	Voltage	4.2V ± 0.03 V
Discharge Condition	Continuous Current	155.0 A
	Peak Current	310.0 A
	Cut-off Voltage	2.7 V
Cycle Life [@ 80% DOD] [2]		> 800 Cycles
Operating Temp.	Charge	0 ~ 40 ℃
	Discharge	-20 ~ 60 ℃
Dimension	Thickness (mm)	8.4 ± 0.5
	Width (mm)	215 ± 2.0
	Length (mm)	220 ± 2.0
Weight (g)		860 ± 40

2. BATTERY MANAGEMENT SYSTEM: This is a BMS Model which we have inserted in this to operate the terminal voltage the temperature the current other is a cell model we have made and here is the output here are the indicators for display purpose it is green which means it is in the condition which we have said is in turn red it means it will exceed the limit which we have said so let run it.

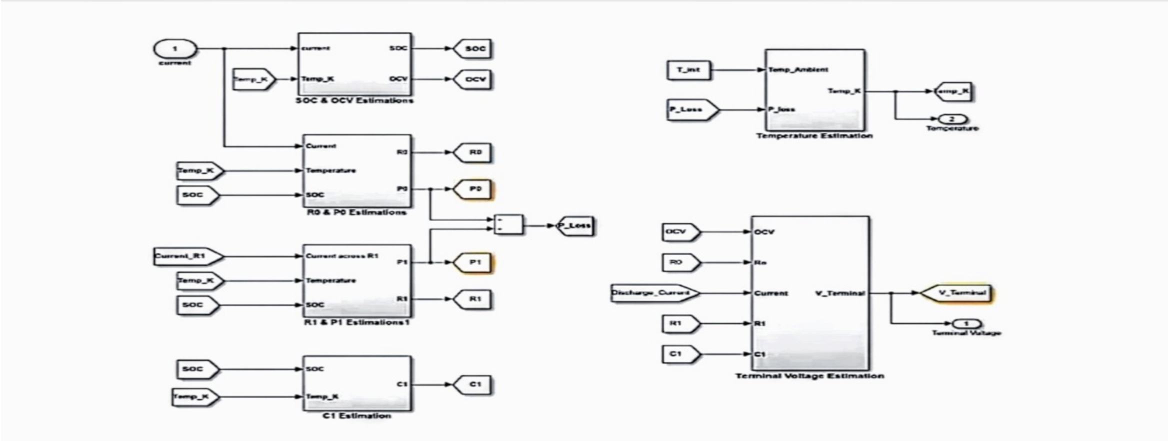




Current profile: As we are designing the model for discharge currently is any DC profile is for both purpose. Here we have two insert the current as any DC current profile. Input as this cycle is used for both purpose charging and discharging and it for the discharging we have to set the limits for current positive current based discharge current and negative current which is showing in the graph means the charging current.

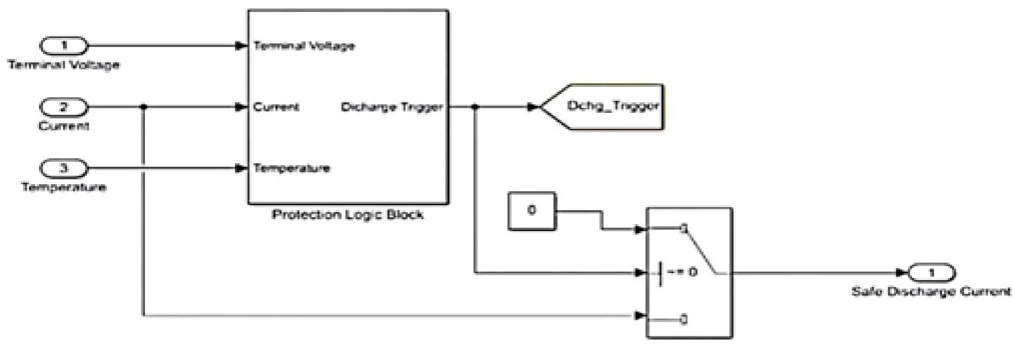
3. LITHIUM ION SUBSYSTEM:

This is a Lithium ion subsystem two build lithium ion subsystem we need three Terminals First is Discharge terminal it is used as a input terminal and other We need two output terminals first is terminal voltage and second is temperature. Both Output terminals connect to the protection subsystem block.



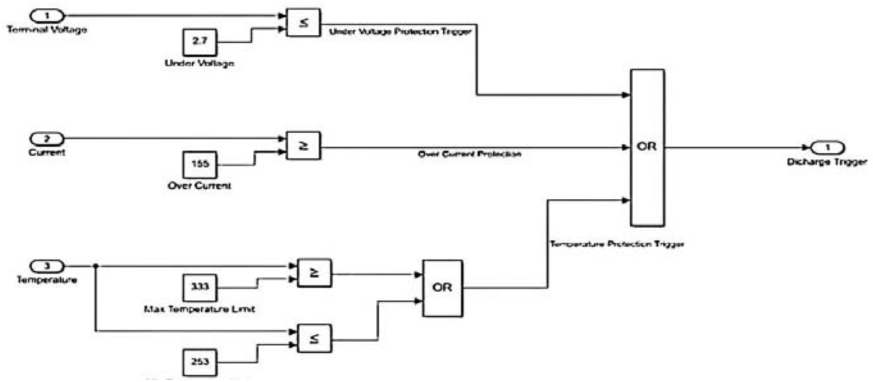
4. PROTECTION SUBSYSTEM:

This is a protection logic block. We need three terminals first is voltage then current and last need the temperature and the output which we want is current. So this is a protection logic block so it will basically give us a discharge trigger yes or no to continue further. If it is yes then it will proceed with our current which we have given it as input so our voltage as we want to give the condition which means it has not exceeded below the unbounded switches which has been specified in the data sheet which is 2.7 volts. Then for the current it should not exceed 155 amps. Hot temperature here is two limits minimum limit being -20 degree and maximum being 60 degrees so we required two relational blocks a constant block to set the limit.

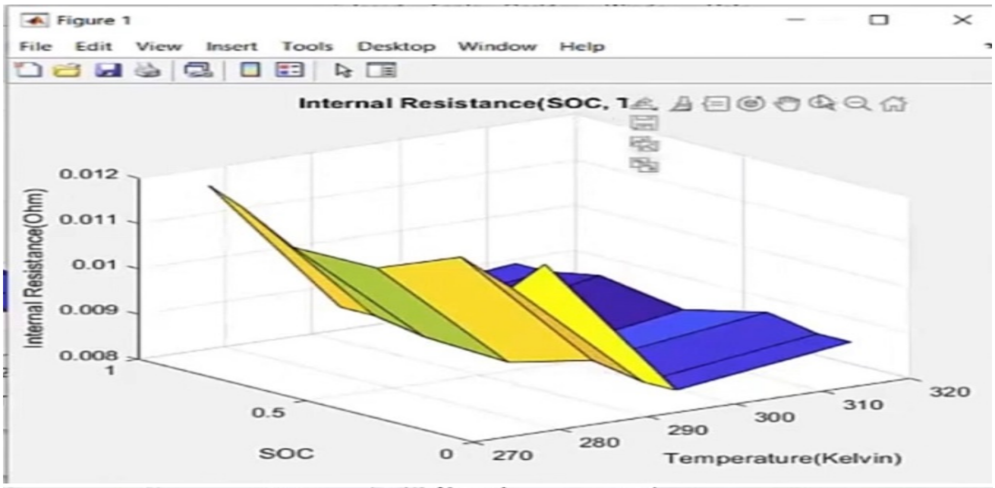


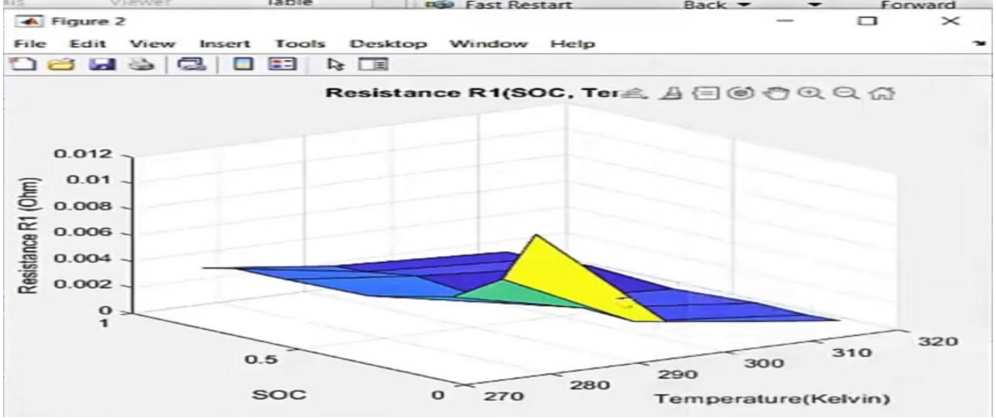
5. DISCHARGE BMS SUBSYSTEM:

It is a discharge BMS subsystem. So basically we are building model for three conditions that is under voltage, over voltage and temperature so we require three inputs. First we need a terminal voltage then current and last need the temperature.



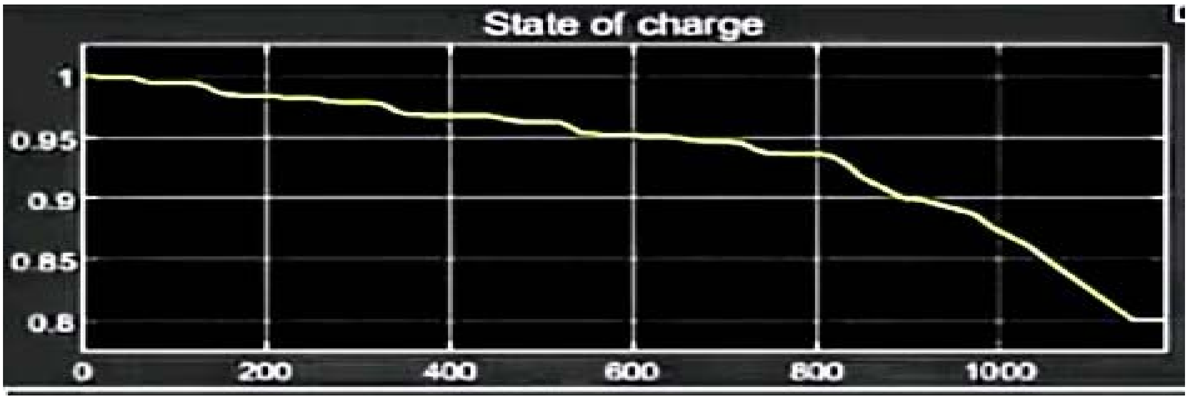
6. RESULTS: Here is all the graph of the parameters which we are inserting in the cell modelling like internal resistance which is the function of state of charge this is a 3D graph.





Then this resistance variation with respect to SOC and temperature this voltage radiation with respect to SOC and temperature and third is for the capacitance of the cell.

Here shown below all the graphs of the protection of battery.



It is an open circuit voltage it is not giving or it is not going below 2.7 volts which we have set. The temperature is not going above 333 Kelvin so the discharge trigger is zero. The initial current is also not exceeding the maximum current that is 80 amperes. So we want to check whether our BMS model is working properly or not we change the current to the value of 60 ampere. We will again run it and check. So here we can see it is going above 80 amperes the initial discharge current is going above 75 and now the final discharge current from the BMS Model is not exceeding 80 amperes. We can also see from discharge figure when it exceeds 60 amperes is shows discharge figure is one and here it is dropping suddenly and again rising because as in a switch it is given and it is zero then our discharge current will be same as input current but if it is not zero the discharge figure is one and we get zero as an output.

IV. CONCLUSION

This report's major thing is to have an in-depth debate on BMS and BMS safety for different operations. The paper compiles and evaluates the present norms geography and, where applicable, suggests specialized and safety preventives for the new BMS standard. BMS is among the abecedarian factors of electrical energy storehouse systems. We have successfully done to protect the under voltage, over voltage and temperature of the battery with the help of simulation. And deeply analyze how to build a BMS simulation model. It is an open circuit voltage it is not giving or it is not going below 2.7 volts which we have set. The temperature is not going above 333 Kelvin so the discharge trigger is zero. The initial current is also not exceeding the maximum current that is 80 amperes.

REFERENCE

[1]. Einhorn, Markus, Werner Roessler, and JuergenFleig. "Improved performance of serially connected Li-ion batteries with active cell balancing in electric vehicles." IEEE Transactions on Vehicular Technology 60.6 (2011): 2448-2457.

[2]. Xing, Yinjiao, et al. "Battery management systems in electric and hybrid vehicles." Energies 4.11 (2011): 1840-1857.

[3]. Palihawadana, A. S. Battery Cell Monitoring and Balancing System for a Track Day Electric Car. Diss. University of Wolverhampton, 2016.

[4]. Ribbens, William. Understanding automotive electronics: an engineering perspective. Butterworth-heinemann, 2017.

[5].Barsukov, Yevgen, and Jinrong Qian. Battery power management for portable devices.Artech house, 2013.

[6].Abedinia, Oveis, et al. "Electricity price forecast using combinatorial neural network trained by a new stochastic search

method." Energy Conversion and Management 105 (2015): 642-654.
[7]. Chen, Dafen, et al. "Comparison of different cooling methods for lithium ion battery cells." Applied Thermal Engineering 94 (2016): 846-854.
[8]. Andrea, Davide. Battery management systems for large lithium-ion battery packs.Artech house, 2010.
[9]. Rakhmatov, Daler. "Battery voltage modeling for portable systems." ACM Transactions on Design Automation of Electronic Systems (TODAES) 14.2 (2009): 1-36.
[10]. Pistoia, Gianfranco. "Battery operated devices and systems: From portable electronics to industrial products." (2008).
[11]. Weicker, Phil. A systems approach to lithium-ion battery management.Artech house, 2013.
[12]. Shearer, Findlay. Power management in mobile devices.Elsevier, 2011.
[13]. Rakhmatov, Daler. “Battery voltage modeling for portable systems.” ACM Transactions on Design Automation of Electronic Systems (TODAES) 14.2 (2009): 1-36.
[14]. Bhovi, Ravi P., et al. “Modeling and Simulation of Battery Management System (BMS) for Electric Vehicles.” Journal of University of Shanghai for Science and Technology 23.06 (2021): 805-815.
[15]. Zhang, Mingyue, and Xiaobin Fan. “Design and implementation of software and hardware of battery management system based on a novel state of charge estimation method.” International Journal of Electric and Hybrid Vehicles 14.3 (2022): 171-202.