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# Single Inductor Multi Port Power Converters for EV Battery Monitoring System

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***Abstract* - This project deals with battery modeling and simulation. The main aim of this is to know the mathematical relationship between the input and output parameters of the battery by the simulator using MATLAB. At present, we see that the accumulation of energy increases the interest in the electrical system such as electrical utilities, energy service companies, automobile manufacturers, etc. This paper describes the development of an intelligent safety system for batteries which is there in applications from last over the past hundred years, electricity has been the most versatile and widely used form of energy in the world. With the help of batteries, we can store electrical energy in the form of chemical energy and we can reuse this chemical energy in the form of electricity. These batteries have very strict requirements regarding safety, power density (acceleration), energy density (runtime), high efficiency, deep discharge cycles, or low self-discharge rates a name a few. From the chemicals available for building EV batteries. However, it cannot be directly measured from the battery and have a strong dependence on temperature and operating conditions. Several SOC estimation techniques are mentioned in the literature that requires cell models with different complexity and computer process requirements. In this work, an electrical equivalent The circuit model (EEC) was adopted, with its parameters estimated on the basis of experimental data collected through in-cell tests at different temperatures and charge / discharge current profiles. This is all done with the help of MATLAB software using all its different module types.**

***Keywords:*** Battery Management Systems (BMS), Li-ion Batteries, State of Charge (SoC), State of Health (SoH), Simulation.

## I. INTRODUCTION

The world suffers from many problems without electricity. In day-to-day life electric power is important in many applications such as mobile, laptop, camera, sensors, bionic implants, satellites and oil platforms. In 1891, Nikola Tesla has proposed an idea of wireless power transmission and he demonstrated the first wireless power transfer system for illumination. Sometimes connecting too many wires in small power sockets becomes inconvenient and hazardous. The First electric vehicle practically implemented by Thomas Parker in 1884. Until 1859 rechargeable batteries are not available for storing electricity, French physicist Gaston Plant invented lead- acid battery and reduced the drawback. Electric vehicles are more popular in many countries, the electric vehicles are small or large in size such as buses, car is large and two wheelers, electric bicycles are small. Electric vehicles are same as like normal vehicles, but electric motor is used in electric vehicle for propulsion purpose, for power supply of that motor battery is used.

The history of battery management systems (BMS) dates back several decades, evolving alongside the development of rechargeable battery technologies. Here is a brief overview of the history of BMS:

- **Early Development:** In the early days of rechargeable batteries, basic monitoring and protection systems were implemented to prevent overcharging and over discharging. These systems used simple voltage sensors and switches to control charging and discharging processes.
- **Nickel-Cadmium Era:** In the 1970s and 1980s, nickel-cadmium (NiCd) batteries gained popularity. BMS for NiCd batteries focused on basic voltage monitoring and thermal protection. They employed rudimentary circuits to prevent overcharging, over discharging, and overheating.
- **Nickel-Metal Hydride Advancements:** In the 1990s, nickel-metal hydride (NiMH) batteries emerged as an alternative to NiCd batteries. BMS for NiMH batteries introduced improved voltage monitoring and protection circuits. These systems incorporated more advanced microcontrollers to accurately measure voltage, current, and temperature.
- **Rise of Lithium-Ion Batteries:** With the advent of lithium-ion (Li-ion) batteries in the 1990s, BMS technology experienced significant advancements. Li-ion batteries offered higher energy density and greater efficiency, but they required more complex monitoring

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and control systems due to their sensitivity to operating conditions.

- **Integration of Electronics:** As Li-ion batteries became the primary choice for various applications, BMS evolved to integrate more advanced electronics. Microcontrollers, digital signal processors (DSPs), and application-specific integrated circuits (ASICs) were employed to enable precise monitoring, state estimation, and active control of battery parameters.
- **Safety and Performance Optimization:** In the 2000s, safety concerns associated with Li-ion batteries led to further advancements in BMS technology. BMS systems were enhanced with additional safety features such as overcurrent protection, short-circuit detection, and thermal runaway prevention. State of charge (SoC) and state of health (SoH) estimation algorithms were developed to optimize battery performance and extend lifespan.
- **Smart BMS and Connectivity:** Recent years have seen the emergence of smart BMS, incorporating connectivity features and advanced communication protocols such as CAN (Controller Area Network) and LIN (Local Interconnect Network). Smart BMS enables real-time data monitoring, remote diagnostics, and over-the-air updates. It also facilitates integration with other vehicle or system control units.
- **Future Trends:** The future of BMS is expected to focus on enhancing energy efficiency, extending battery life, supporting advanced cell chemistries, and integrating with emerging technologies like solid-state batteries. BMS will continue to evolve to meet the demands of electric vehicles, renewable energy systems, and other applications relying on rechargeable batteries.

Overall, the history of BMS reflects the continuous efforts to improve battery safety, performance, and longevity. Advancements in BMS technology have played a crucial role in enabling the widespread adoption of rechargeable batteries in various industries.

## II. LITERATURE REVIEW

A battery is a portable electrochemical device capable of converting stored chemical energy in high efficiency and gaseous emission-free electricity. Based on this concept, Lithiumion batteries (LIB) were first developed by Armand in the late 1970s, but the first commercialized cells appeared in 1991 by Sony, after countless research on the electrode materials, safety issues, economically sustainable processes, and performance optimization.

The typical composition of LIBs, net of the variability due to the various producers consists of two electrodes wound by lamination to a polymer separator and impregnated with a suitable electrolyte, allowing the ionic conductivity of the Lions. During the use of LIB, Li + is generated through reversible negative reactions electrode, they travel to the cathode, where they combine to form metal oxides. Conversely, during the charging mechanism, an external power supply supplies electrons which combine with Li + a form of Lithium (Li) metal, stored between layers of anodic graphite by intercalation mechanisms.

Due to the inherent properties of the materials, LIBs operate between 1.5 and 4.2V: a lower voltage degrades the copper (Cu) foil, while higher forms of reactive Li dendrites increase the potential safety risks of the product. In addition to the active material of the electrodes, key components of LIB are the highly dielectric solvent that allows the transfer of ions through polymeric separator that protects the electrodes from direct contact and from the current of Cu and Aluminum (Al). Collector sheets, on which the active powder is made to adhere through an organic binder.

Thanks to its bass atomic weight and high energy density (120 Wh / kg) guarantee lightness of the product, low self-discharge speed, good longevity (500-1000 cycles), absence of heavy metals (lead or cadmium), and ample operating temperature range (−20/60 ° C), LIB applications have increased significantly in recent years (Al-Thyabat et al., 2013). The use of LIB in portable electronic devices, such as cell phones, laptops, cameras, toys, e-cigarettes, and electric and garden tools, doubled from 2014 to 2019, of which 37.2% lithium cobalt oxide (LCO), 29% cobalt oxide lithium nickel manganese (NMC) and 5.2% lithium iron phosphate (LFP). The LIB market also shifts from a small-scale application to large capacity sectors, such as electric vehicles (EVs) and energy storage systems (ESS), to reduce greenhouse gas emissions and dependence on oil or to resolve the intermittency of alternative green energy sources. In EV applications, for example, LIB sales will increase by 5 million in 2015 to 7 million in 2020, reaching 180 million in 2045 Although production is mainly located in Asian countries (40% of production is in Japan, followed by South Korea and China), the highest consumption is in the USA (28.4%) and in the EU (27.2%), where the battery sector is located represents the fastest growing waste stream due to increasing electrification in the automotive sector.

According to the short, estimated duration of LIB (3-8 years), it was predicted that more than 25 billion units and 500,000 tons of LIBs will become a waste in 2020, albeit a strong harvest a consolidated recycling system and the process is still missing (Yu et al., 2018). In the case of portable batteries, only 30-50% of the population, in fact, properly dispose of LIBs, being unaware of the potential harmfulness

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of post-use products. The presence of metallic Li due to an error battery cycle, highly reactive with moisture, and the internal presence of a flammable electrolyte could cause explosive reactions and the emission of harmful gases (such as hydrogen Fluorine, HF) in case of mechanical damage, overheating or degradation phenomena, exposure people with serious injuries.

Whereas in the medium and near future only lithium-based batteries could meet the automotive needs and the large power demand of portable devices, the goal of this work is the analysis of current processes for the treatment of postuse LIB, highlighting the potential of a circular approach and underlining the importance of recycling LIBs along with redesign, reuse and remanufacturing. A comprehensive view of progress in each phase of the process allows overcoming the peculiar fragmentation of post-use treatments, where waste preparation is studied separately from the hydrometallurgical or pyrometallurgical phases. Furthermore, along with a thorough literature review, actual industrial processes are critically analyzed in order to highlight their advantages and disadvantages through the use of comparison tables. Along with that, the legislative and economic barriers related to the development of sustainable and innovative waste management solutions are reported.

## III. BATTERY MANAGEMENT SYSTEM

There are various Battery Management Systems available, either by the available Integrated IC or even customize our own battery management system (BMS) and have three different types of the battery management system (BMS) available. They are differentiated based on their topology. The three available battery management system (BMS) are,

- Modular battery management system (MBMS)
- Centralized battery management system (CBMS)
- Distributed battery management system (DBMS)

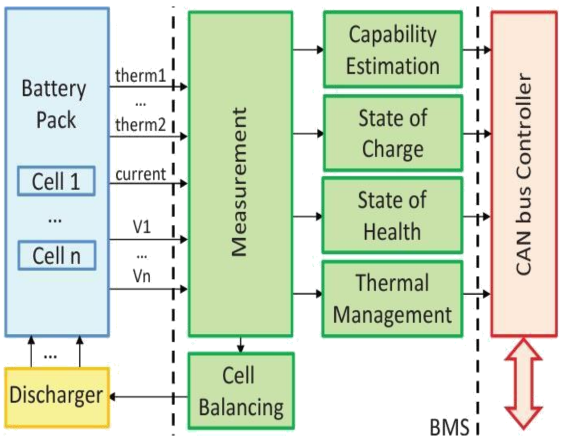


**Figure 1: Block diagram of BMS system**

The CAN bus is the single serial bus communication medium connecting all the Electronic control units across the vehicle. As we know the BMS is the primary control unit for the battery torque and rpm for the wheels to rotate and thereby generating motion [5]. The can bus is responsible for all the information and command to transmit from the electric vehicle control unit (ECU) to other systems or subsystems. The important part is the pedal subsystem which is connected via can bus to motor controller ECU and dashboard ECU. This subsystem work when the fault or error signal occurs then the immigrant driver stop or restarts the vehicle. The main purpose of the BMS is the monitoring, control, safety, of the battery life and the system performance. in a data system, a few things are monitored or observed:

- Monitor individual cell voltages in the battery.
- Measure overall battery voltage and current output.
- Measure the temperature of the battery and its surroundings.
- Control the charging of the battery.
- Monitor the discharge of the battery.
- Monitor overvoltage or under voltage conditions.
- Determine the condition of the battery.

### A) State of Charge (SOC)

State of charge (SoC) is a relative measure of the amount of energy stored in a battery, defined as the ratio between the amount of charge extractable from the cell at a specific point in time and the total capacity.

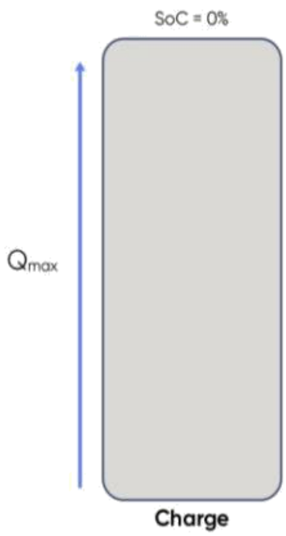


**Figure 2: Battery during Charge and Discharge**

Accurate state-of-charge estimation is important because battery management systems (BMSs) use the SOC estimate to inform the user of the expected usage until the next recharge, keep the battery within the safe operating window, implement control strategies, and ultimately improve battery life.

 

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### B) State of Health (SOH)

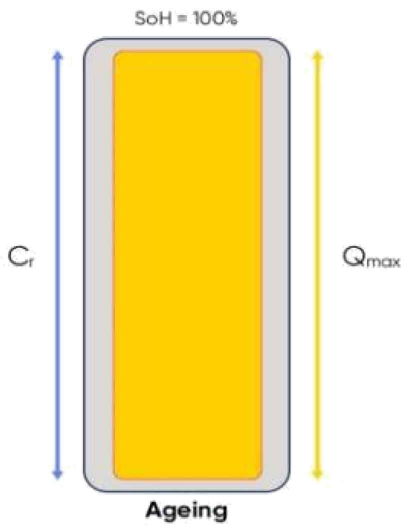


**Figure 3: Battery during Aging**

State of Health Definition (SoH) with advancing battery degradation, the internal resistance of the battery increases while the capacity of the cell fades. This leads to drastic changes in cell behavior and might make a cell unsuitable to be used for its primary application, such as in an EV. Therefore, it is necessary to track the cell degradation, using the parameter state of health (SoH). The battery SoH characterized by the slow-changing parameters, such as capacity fading and resistance increasing, varies with cycles and hence it needs to be monitored in a long timescale.

### C) Thermal Management

The BMS monitors the battery pack temperature through four (4) thermistors directly connected to the main unit. If additional thermistor monitoring is necessary, the Thermistor Expansion Module can be connected to monitor up to 80 additional thermistors, and as many as 10 thermal modules can be used together to monitor 800 thermistors total. The thermal interface also includes the ability to control an external fan. The controller can be configured for on/off operation or for a variable fan speed using a PWM output. For reliability reasons, the fan driver is external to the BMS and is optional. The fan controller interface includes a fan monitoring circuit which monitors for a malfunctioning cooling fan and can set error codes if a fault is detected. The fan can be configured both to cool the battery when hot and to warm the battery when warmer ambient air is available. All thermal settings are programmable.

### D) Cell Balancing

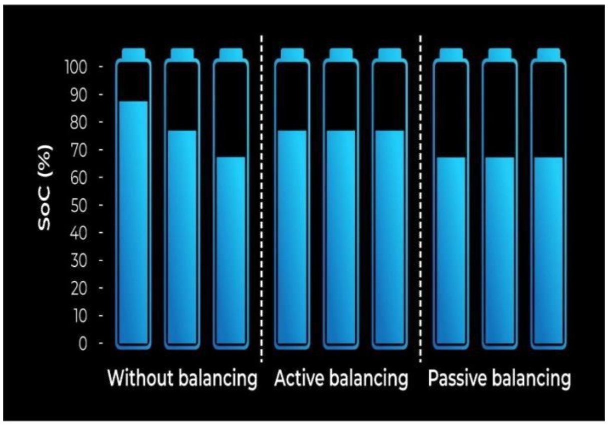


**Figure 4: Cell Balancing**

Cell balancing is a technique that improves battery life by maximizing the capacity of a battery pack with multiple cells in series, ensuring that all of its energy is available for use. A cell balancer or regulator is functionality in a battery management system that performs cell balancing often found in lithium-ion battery packs electric vehicles.

Typically, individual cells of a battery pack have different capacities and are at different SOC levels. Without redistribution, discharging must stop when the cell with the lowest capacity is empty, even though the other cells are still not empty. This limits the energy delivering capability of the battery pack.

## IV. SYSTEM DESIGN

There are 24 Batteries are taken, 12 are connected in series and 12 are connected are in parallel there is also resistor connected as a load.

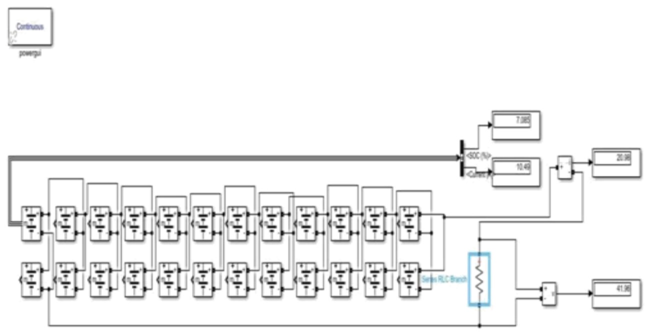

**Figure 5: Simulation Design 1**

This simulation are taken for the engaging the battery pack using different nominal voltage and rated voltage in this simulation 25volt battery pack is taken and through the load resistor it state of charge and current has been shown. There is

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also a current measurement block which is connected across a resistor which shows the resistor.

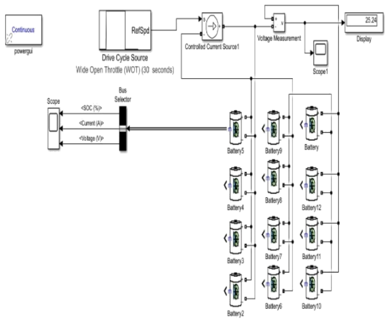

**Figure 6: Simulation Design 2**

**Procedure:**

- Connect all blocks as per simulation diagram in MATLAB SIMULINK.
- Put all the Parameters values in the block.
- Select a parameter & update simulation time.
- Run a simulation for a given time, if error occurs it will show error.
- After successful simulation, we will get output results on scope.
- Compare three drive cycles and see variations.

## V. RESULTS

### A) Output of Battery

Output of Battery we measured in three ways we measure state of charge, current and voltage, on an instant firstly we measure the state of charge when vehicle is not working at that movement soc is 100% on a running condition the state of charge slightly start decreasing at is consume battery from the battery pack.

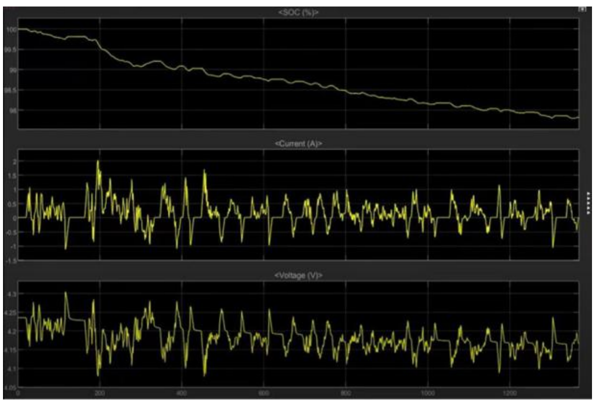

**Figure 7: Output of Battery**

Current is fluctuating when we accelerate or de-accelerate the vehicle on a running condition, as vehicle is accelerating at that movement battery will be discharge so current will discharge the above graph is go on downward direction also voltage has its similar movement as current and state of charge when vehicle is not accelerating or de-accelerating vehicle is shown the straight line.

### B) Drive Cycle Source Voltage

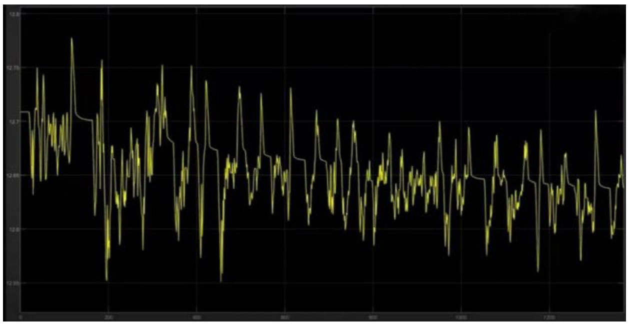

**Figure 8: Drive Cycle Source Voltage**

This is the drive cycle source voltage when vehicle is at running condition the starting at generating path its analyses its surroundings and according to them battery management system adapt himself as the road conditions because of its versatility in the road condition drive cycle is fluctuate the voltage.

## VI. CONCLUSION

Battery electric vehicle (BEV) and its components were simulated in this study to examine energy flow, production, life span and efficiency of Li-ion cells used in EV. Using MATLAB Simulink, good results were shown for battery voltage, current, power, and state of charge. There are still many possibilities ahead of them to build a better BEV model that will be the basis for future studies.

In to find the best voltage, current, capacity, battery state of charge and exact part size and minimize for automotive designers, the use of electricity, modelling and simulation are very important. This project shows the parameterization of the charging / discharging behaviour of the battery using MATLAB –Simulink and this report helped study the dynamic characteristics of lithium ions batteries. The capacity, open-circuit voltage (OCV), and internal resistance of the battery cell (Lithium ions) were measured at the state of charge (SOC) and load currents. In further research, the model can be updated and implemented according to the different loads or needs and includes all parameters.

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