Design & Simulation of Battery management system in Electrical Vehicles Using MATLAB

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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. Electric vehicle (EV) is already on the roadmap of every major car manufacturer and is seen as the solution to another sustainable transport system, contributing to the reduction of greenhouse gas emissions. The Energy Storage System (ESS) is a key component for electric vehicles. [1-5] This includes the battery and all management and monitoring systems that make up the Battery Management System (BMS). 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. The SOC of the battery is vital information to the EV user. It can be displayed as a percentage of full charge capacity that is still available from the battery or to be used to estimate vehicle range based on additional information from previous driving cycles. 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. [6-9]*

Key Words: Battery Management Systems (BMS), Li-ion Batteries, Open Circuit Voltage (OCV), State of Charge (SOC), Simulation.

1. INTRODUCTION

It is now unanimous that swift action is needed to reverse the negative effects of climate change caused by massive emissions of greenhouse gases (GHG) and CO2 in particular. Road traffic is heavily dependent on fossil fuels and therefore is a major contributor to those emissions. On the other hand, more and more people are living in urban areas with a negative impact on air quality. The electric vehicle (EV) is seen as a potential solution to minimize its effects due to its high efficiency and zero emissions during the use phase. [1]

In addition, electric vehicles can actively interact with the electrical grid since they can be used as an energy bank for the storage of energy from renewable sources, known as a vehicle to the grid interaction. Another interesting application is the use of electric vehicles as controllable loads in demand response programs. However, there are still some restrictions related to autonomy and price that limit its scope acceptance. The main reason for this lies in the batteries, the bulkiest and most expensive component of an EV. The EV is already on the roadmap of every major car manufacturer.

There is a continuous evolution in the different fields that will lead to lighter materials (such as composites materials), batteries with higher energy density and longer life, faster and more efficient load. The price should also decrease, favoring the adoption of efficient systems sustainable electric mobility solutions. EV is seen as the solution to a more sustainable solution. [3]

This project is a very simple model for calculating the charging and discharging behavior of the battery using MATLAB / Simulink. To establish links with drag and drop, annotate diagrams with the context of requirements, analyze requirements, traceability and navigate requirements, projects, generated code, and tests. It also helps when changes to related requirements occur, drawings, or tests and according to the requirements; it calculates its implementation and verification state. It uses Simulink and State flow in the battery system model and simulation algorithm, including:

- Current and voltage monitoring

- State of charge estimate (SOC).
- Supervisory logic
- Input and output power limitation for overload and discharge protection, etc.

The method for the parameterized battery, plan of the proposed battery model resulting from the full drum performance tests are illustrated in the accompanying areas. [4]

1.1 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, Lithium-ion 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 Li-ions. 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. [5]

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).[6]

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. [7]

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 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. [8]

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 post-use 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. [9]

1.2 METHODOLOGY

Following are the major problems in current batteries used in EV: -

SHORT LIFE. How can it improve the life cycle of batteries?

OVERHEATING They overheat and explode if charged too quickly.

SHORT LIFE Die after less than 1,000 charge/discharge cycles. FLAMMABLE They use flammable chemicals. This causes electric cars to explode when hit in certain ways (among other problems).

TOXIC These chemicals are toxic and require special care when disposed of.

EXPIRY AT EXTREME TEMPERATURES Chemicals performs poorly when temperatures are below 0 ° C (32 ° F) or above 50 ° C (122 ° F), limiting applications.

EXPENSIVE BODYWORK Chemicals are liquid and require an expensive, hard case to prevent leakage.

EXPENSIVE TO TRANSPORT Additional precautions are required to avoid explosions and additional approval is required to ship these batteries. A transport system that can contribute to the reduction of GHG emissions and the import of crude oil, due to much higher efficiency, from 28-30% of an internal combustion engine (ICE) vehicle to 74-85% of an electric vehicle and zero tailpipe emissions.

In Portugal, even with the current energy mix, electric vehicles can provide an overall reduction in GHG emissions. During these works, two electric platforms were equipped with lithium-ion battery packages. For one, a full battery pack and commercial BMS were installed. After testing the system, it lacked some flexibility to implement different balancing algorithms. It was also impossible to modify the simple procedure of estimating the state of charge (SOC) based on the coulomb count voltage drift which must be fully programmable by the user.[10]

2. EV BATTERY OPERATING REQUIREMENTS

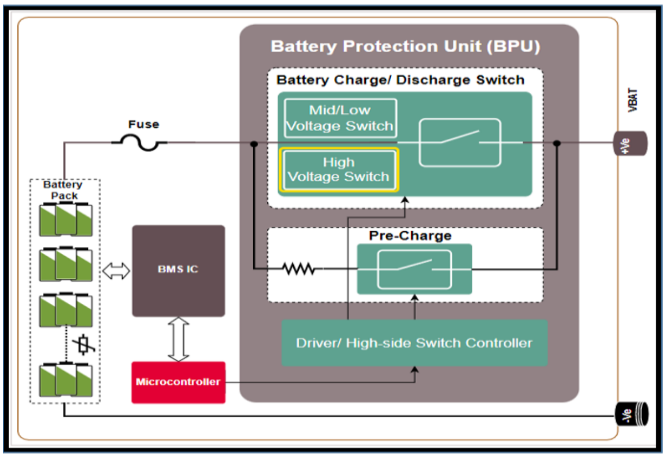

Fig -1: Block Diagram of BMS

On the basis of research studies represented in reference papers [11-15], we have the following points: -

• Large capacity batteries are required to achieve reasonable autonomy. A typical electric vehicle consumes 100 to 150 Wh per kilometer depending on the design of the power train and driving style.

• The battery must be able to function regularly with a deep discharge (80% depth of discharge (DOD) or greater);

• It is designed to maximize energy content and provide full power even with deep discharge to ensure a long-range;

• A range of capabilities will be required to meet the needs of vehicles of different sizes and usage patterns;

• Must accept very high repetitive pulsed charge currents when regenerative braking is applied;

• Without regenerative braking, controlled charge conditions and lower charge rates are possible • Regularly receives a full charge;

• Often also reaches almost complete discharge;

• Fuel level indicator near the "empty" point;

• Requires a Battery Management System (BMS); • Requires thermal management;

• Typical voltage> 300 V; • Typical capacity> 20 - 60 kW

2.1 INTRODUCTION TO BMS

As electric vehicles evolve rapidly, batteries need to improve and adapt to the stringent requirements of automotive electric vehicles requirements. The BMS is a key part of electric vehicles, to ensure that the batteries operate safely and last longer. In fact, the total cost of ownership of an electric vehicle is affected by the installed capacity is required but also when it remains usable. BMS costs only a fraction of the total investment but guarantees its duration. [16] The BMS architecture can be divided into two key parts & explained in Fig -1 Block diagram of BMS as follows: -

• The hardware that acquires the battery status variables: voltage, current, and temperature. It should guarantee the simultaneous acquisition of the measurements in order to improve the accuracy of the estimates. It needs a high sampling rate to ensure that the dynamics of the system can be monitored and must be carefully control & measure the electrical and thermal variables in order to avoid the propagation of the error to allow a reliable estimate of all parameters that cannot be measured directly.

• The software that actively monitors all the variable manages the battery protections and alerts manages the internal communication within the various hardware blocks, manages communication with peripheral systems, and makes estimates or cell balancing algorithms. There are several approaches to the hardware with which you can centralize or deploy advantages and disadvantages for every situation. [17]

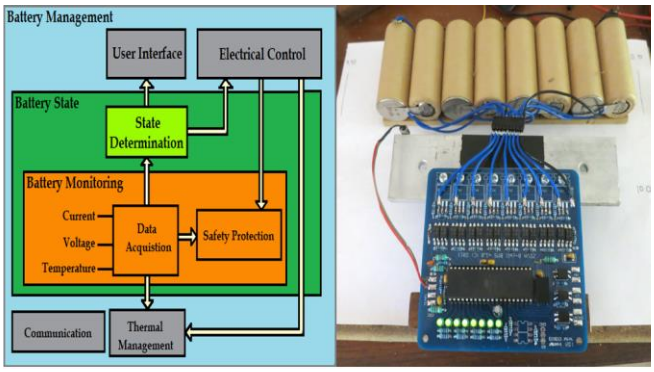

Fig -2: Architecture & Hardware representation of BMS

Cell modeling is also an important part of the BMS. Patterns can be simple or complex as required. Since a simple voltage generator and series resistor for electrochemical models represent all the interactions on the molecular structures of the battery. The author's experience reveals that most of the commercial BMS available are more based on simple estimation procedures to calculate most parameters. The Coulomb counting technique and the offset of the voltage drift is used on the BMS.

The main disadvantage of the coulomb counting method is the fact that it always needs a known starting point because the current integration over time will accumulate errors which can become substantial if fully charged or discharged does not occur. Lithium-ion batteries have already been available for many years for portable devices such as laptops and cell phones of the example is shown in Fig 2. Architecture & Hardware representation of BMS for these devices are also available from various IC manufacturers and they are already ripe. [18]

These ICs are not suitable for the EV battery pack because they can vary from tens to more than a hundred cells to provide a high-power system needed for traction. Those systems with high voltage and high currents require additional isolation of the communication signal for devices interface and are still in strong development by companies, car manufacturers, research institutes, and universities the energy crises of the 1970s and 1980s brought a renewed interest in electric vehicles. They were reintroduced in the early 1990s and went mainstream in the 2000s leading to breakthroughs in battery technology.

Lithium-ion technology has been widely adopted for EV / HEV applications due to its high energy density and power density, low self-discharge, and long life [Tao et al., 2011]. It has faced a huge improvement over the last decade. Unfortunately, the BMS developments could not follow those developments hampered by the following difficulties, inter others. [19]

• Battery modeling;

• Estimation of the state of the battery (SOC, SOL, SOH);

• Cellular balance.

Hence The basic functions of a generic BMS can be summarized as follows in short described in more detail in reference articles:

• Measure battery status parameters such as individual cell voltages, pack current and temperature;

• Activate alarms in case of abnormal conditions or even take action to disconnect the batteries in order to avoid harmful failures.

• Check the charging and discharging conditions.

• Cell balancing.

• Thermal management;

• Estimation and communication of important battery parameters like SOC, SOH, SOL.

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2.2 MODELING AND SIMULATION OF EV BATTERY LITERATURE REVIEW

Battery modeling and simulation are required to know the mathematical relationship between battery input and output parameters and the simulator. Here a controlled voltage source is dependent on the actual state of charge (SOC). Modeling and simulations are required for the capability determination and optimal selection of components in the electrical system and also carry out an important role in approximating battery performance and design.

Battery modeling is described with the whole concept of extracting parameters from the manufacturer's exhaust characteristics. This feature provides a quick, accurate, and effective solution that will be helpful for batteries. The general model of charge and discharge is in this form represented in Fig -3 Mathematical MATLAB Simulation Model for BMS. This modeling work is done by combining two BMS for multiple functions. [20]

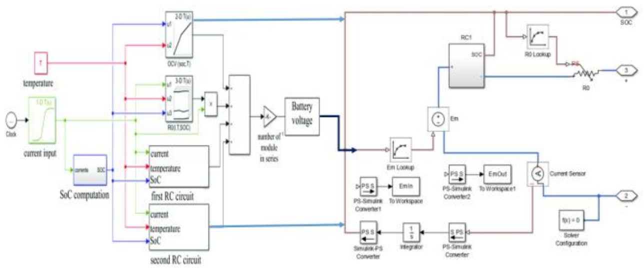

Fig 3-: Mathematical MATLAB Simulation Model for BMS

The first step in designing a battery management system (BMS) is the development of a high-fidelity battery template. In order for a BMS to estimate critical battery parameters such as battery status charge and health, an accurate battery model must be implemented aboard the BMS along with a solid estimation strategy. So a battery model is a list of mathematical equations that describe what is physically happening inside the battery.

Put simply, as shown in the picture, if we apply the same current profile to the battery and the battery model, both should generate the same voltage profile and the error between the two signals should be close to zero. The model can predict the behavior of the battery in such a way that, if we apply an estimator, we can predict the criticality parameters such as the SOH of the battery and the remaining useful life. According to the methodology, various mathematical methods of estimation are classified and the classifications of these methods of estimation in the various literature are divided into four categories explained in detail [20-25]:

• Direct Measurement: This method uses physical characteristics of the battery such as terminal voltage or impedance. The following methods are mentioned below, which are commonly used: - Open circuit voltage method

- Terminal voltage method

-Method of impedance

-Method of impedance spectroscopy

• Accounting estimate: with this method the charge or discharge of the battery is taken as input. The accuracy of the coulomb count depends on the accuracy of the current measurement of the battery system. They are basically of two types:

- The coulomb counting method

- Modified Coulomb counting method

• Adaptive systems: it is also called the indirect measurement method due to its ability to address the non-linearity of battery systems. It can be classified into five types:

- BP neural network

-RBF neural network

- Vector machine support

-Focused neural network

- Kalman filter

• Hybrid method: This method is built with the order of accuracy by different scientists from different countries to solve equations. In this battery model, can three types mainly:

- Coulomb count and combination of electromagnetic fields

-Coulomb count and Kalman filter combination

- EKF unit and combination system.

2.3 SIMULATION RESULTS

The basic power flow is from the battery (72v) ,2kwh, 20Ah with Direct voltage source, DC to DC converter, Common load for two sources Powerful - Discrete simulation type, Sampling time -5e-6, 48v-Vcc source.

-The model for this When the voltage source is disabled, the battery will supply the load & when the voltage source is enabled, the battery will charge, and the load will be powered by a voltage generator. -We have two cases a) Load & b) unload

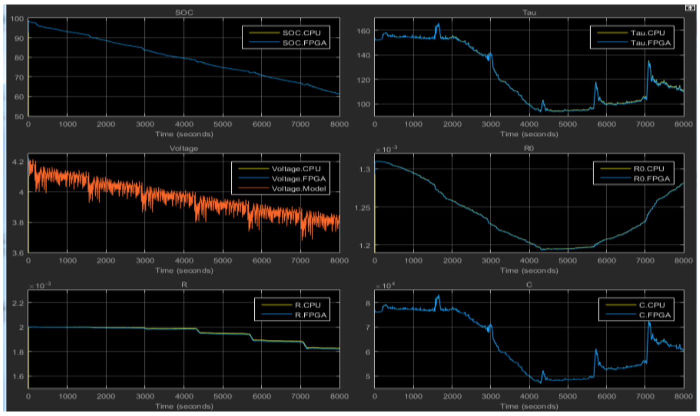

Fig 4-: Simulation Results for Battery parameters monitoring by BMS

Let's start with the charging mode PI controller Integra- 0.54 (Maximum employment ratio -0.95 PWM generation 5 because the battery is a charging mode, the current control strategy seems to be known as battery charging 2 two modes explained on basis of references [21-22]: -

1) Constant current

2) Constant voltage

Maximum current allowed for constant current. It is the maximum current for both cases (22A). Some battery companies separate the sides of constant current and constant voltage at 80%. Open circuit voltage to 80% but battery charges up to 80% SOC May require a different checking algorithm. [21] BMS wants to show a voltage-based control effect of up to 80% so needs the PI controller to determine the reference current is at the maximum level because the battery voltage is less than 48.98. Then it has been reduced by the voltage control PI and the battery is charging with 48V and 16A While the battery is charging, the battery voltage will rise due to their charging current it should decrease. Now we can check the result for when the reference current of the battery charge will be reduced. If we still supply 72V we should check the discharge mode. Our references are 72v for the load We used a different PI controller for the discharge mode. [22]

SOC which decreases the position of the battery current, this system works separately for both cases, but we have combined these two modes with the switch help. Determine the mode (charge or discharge) We determine the modes based on the voltage source. The voltage source allows the battery to charge from the power source Once disabled, it will drain our battery (discharge time) from which the load is supplied battery. [23]

3. CONCLUSIONS

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, modeling and simulation are very important. [24] This project shows the parameterization of the charging / discharging behavior 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. [25]

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BIOGRAPHIES

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