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Design and Analysis of Battery Management System for Electrical Vehicles

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***Abstract:** The quantity of pollution that is emitted into the atmosphere will only continue to climb as the number of people who drive automobiles powered by internal combustion engines continues to rise. To reduce emissions of greenhouse gases, academics and companies on every continent are now focusing their attention on the research and development of more sophisticated technologies for electric cars. During this investigation, we are going to model and create a two-way power converter for electric automobiles. Batteries, a dc-dc converter, and a dc motor are just a few of the many diverse parts that make up the power electronics module. It is advised that the starting battery be charged to about 90% of its capacity before using the motor mode, which has a discharge current of 44.5 A. The battery stack has a maximum capacity of 100 ampere-hours, and its nominal voltage is 350 volts. This is the greatest amount of energy that it can store. Direct current (DC) machines have the potential to generate up to 250 horsepower, provided that the armature voltage is 500 volts and the field voltage is 300 volts, respectively. The mode of operation for the power converter is determined by the readings of torque that are obtained by the DC machine when it is operating in the motor mode and the generator mode, respectively. The processes of charging and discharging batteries have been monitored and handled in relation to the wide variety of modes of operation that may be found in DC machines. This was done in order to make full use of the capabilities of these machines. The bidirectional dc-dc converter, which may operate in either direction, is managed by a fuzzy logic controller. This allows the converter to work in either direction. It's likely that the converter and controller that's been shown here are all that's needed for charge management and running the motor in electric automobiles.*
***Keywords:** Electric Vehicles, Greenhouse gas (GHG), Internal Combustion Engines (ICE); Battery Management, Simulation, Driving Cycles, and Energy Efficiency.*

I. INTRODUCTION

The transport sector is crucial to the smooth running of modern society. Greenhouse gases including carbon dioxide, carbon monoxide, and methane are produced when traditional vehicle technology burns fossil fuels. These gases are a major cause of climate change. Air pollution, climatic shifts, and increased global warming are all results of the over use of these gases. More and more people are turning to the technology underlying electric cars (or EVs) as a way to lessen the severity of these consequences. Electric vehicles have substantially lower running costs than their fossil fuel counterparts since its main components are things like batteries, power electronics, and an electric motor. When it comes to charge managementand driving range, the battery system of an electric vehicle is the single most important component [1,2]. Unlike traditional cars powered by Internal Combustion Engines (ICE), electric vehicles may put their electric motors to work in both the motor and generator modes of operation thanks to a feature known as regenerative braking. Therefore, it is possible for electric devices to recharge their batteries by regenerative braking by entering generator mode [3,4].

A. *Objective of the Project*

According to the definition, the basic tasks of the BMS are identical to its objectives. Although different types of BMS have different objectives, the typical BMS follows three objectives:

1) It protects the battery cells from abuse and damage
2) It extends the battery life as long as possible
3) It makes sure the battery is always ready to be used.
4) Identifying dominant function parameters of BMS that mustappear in a BMS interface of an EV.
5) Identifying dynamic display of BMS function parameters for anEV.
6) Getting expert's judgement regarding display alternative for BMSfunction parameters.

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B. Research Background

Dynamic visualization is simply defined asthose representations that go beyond traditional static forms, such as printed media.It can be characterized by either animation, interaction, or real-time circumstances. Powerful visualizations of scientific phenomena and more abstract information canbe produced by using current advanced information technology and graphics. It makes perception that there should be a benefit of dynamic over static media stated that dynamic media allow us to show processes explicitly. There are several strengths possessed by dynamic visualization The greatest strength of dynamic visualization is its ability to create different views to the same data. Besides, the real-time nature become another strength of dynamic visualization. In addition to become a tool for communication, dynamic visualization plays role as a tool for exploration which are grouping and regrouping of variables, highlighting and filtering support decision-making.

However, Hegarty revealed that the first phase of research examining differences between dynamic and static displays failed to show a clear advantage for dynamic displays. From over 20 studies that compared static and animated graphics, most of them indicated that there was no advantage of animations over static graphics. A small number of studies showed such an advantage, but in these studies, more information was presented in the animated graphics than in the static graphics, i.e., they were not informational equivalent. This leads us to the much more interesting and challenging issues of understandingwhat conditions must be in place for dynamic visualizations to be effective.

II. LITERATURE REVIEW

A. K. M. Ahasan Habib, Lithium-Ion Battery Management System for Electric Vehicles: Constraints, Challenges, and Recommendations, (2023), Flexible, manageable, and more efficient energy storage solutions have increased the demand for electric vehicles. A powerful battery pack would power the driving motor of electric vehicles. The battery power density, longevity, adaptable electrochemical behavior, and temperature tolerance must be understood. Battery management systems are essential in electric vehicles and renewable energy storage systems. This article addresses concerns, difficulties, and solutions related to batteries. The battery management system covers voltage and current monitoring; charge and discharge estimation, protection, and equalization; thermal management; and battery data actuation and storage. Furthermore, this study characterized the various cell balancing circuit types, their components, current and voltage stresses, control reliability, power loss, efficiency, size and cost, and their benefits and drawbacks. Secondly, we review concerns and challenges in battery management systems. Furthermore, we identify problems and obstacles that need additional attention for optimal and sustainable battery management systems for electric vehicles and renewable energy storage systems. Our last topic will be on issues for further research.

Tsung-Hsun Wu, Design of Battery Management System For Electric Vehicles (2021), The battery management system is one of the key technologies for electric vehicles. This system is mainly used to monitor the status of the battery, improve the efficiency and reliability of the battery, prevent the battery from overcharge and over discharge, and to extend the battery life. This research uses NUVOTON's Coretex-M4 chip M487SIDAE as the control core to construct a set of "low-cost and high-efficiency battery management system", for the electric vehicles. With self-designed battery monitoring and sensing circuits to measure various important parameters of the battery module, A set of C# real-time monitoring screens is constructed on the computer interface to facilitate the monitoring of the personnel, and to make the battery information in real time. Recording and data accumulation are convenient for users to perform subsequent battery health status diagnosis and analysis offline, which can be used to effectively judge the battery life.

Akshay Shrawan Shambharkar, Design & Analysis of smart battery management system for Electric Vehicle (EV's), (2022), The amount of exhaust gases increases with the increasing use of vehicles with internal combustion engines. To reduce CO_2 emissions, researchers and industry are working to improve electric vehicle technology around the world. This paper deals with the design and simulation of a bidirectional power converter for electric vehicles. The electronics block consists of batteries, a bidirectional DC-DC converter and a DC motor.

The initial state of battery charge is set at 90% where the discharge current is 44.5 A in motor mode. The nominal voltage of the battery stack is 350 V and the maximum capacity is 100 Ah. The rated power of the DC machine is set at 250 HP with 500 V armature voltage and 300 V field voltage.

The operation mode of the power converter is determined according to the torque value of the DC machine which is operated in motor and generator mode. Battery charging and discharging conditions have been controlled with respect to DC motor operating modes. The bidirectional dc to dc converter is controlled by fuzzy logic in both modes. The proposed converters and controllers are designed to meet the charging control and motor drive requirements for electric vehicles.

III. METHODOLOGY AND BATTERY STORAGE SYSTEM

Explains the methodology of research. The methodology of this research consists of the sequential step to do this research. The step is systematicallyarranged according to research and battery storage system. Energy storage systems, usually batteries, are essential for all-electric vehicles, plug-inhybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs).

Types of Energy Storage Systems

The following energy storage systems are used in all-electric vehicles, PHEVs, and HEVs.

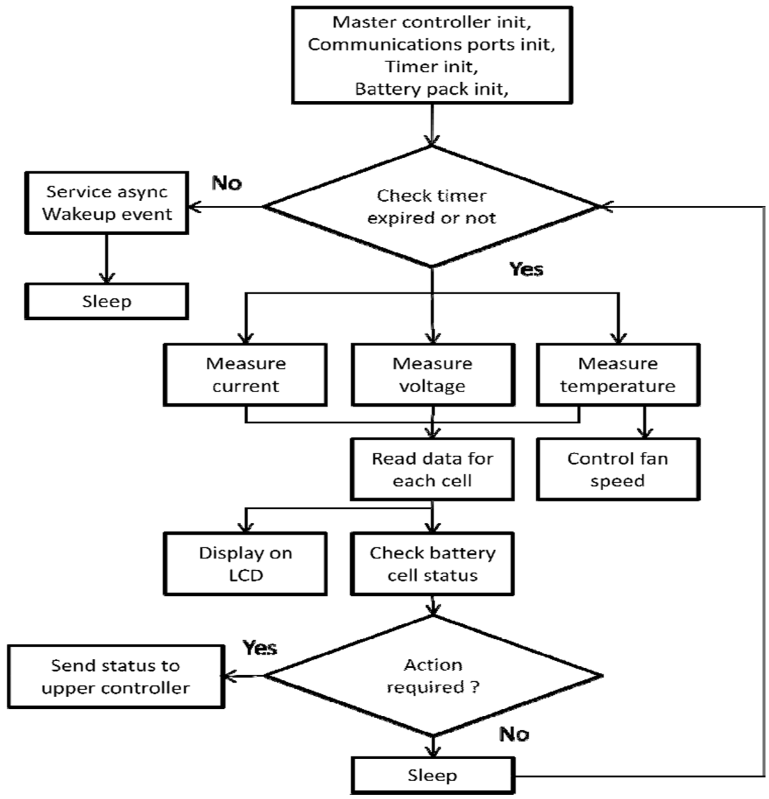

Fig 1: Flow chart diagram

IV. POWER ELECTRONICS TECHNOLOGY FOR EVs

Power converter structures need to be dependable and lightweight for automotive applications with minimal electromagnetic interference and low current/voltage ripples to meet the automotive industry standards for high reliability and efficiency. A proper interface between energy storage systems (ESSs) and power electronics converters is required for effective EV operation. There are numerous varieties of ESSs that are coupled to different types of power electronic converters in electric vehicles. AC/DC converters are typically used to charge ESSs through charging stations or grids. To accelerate the vehicle, ESSs transmit the necessary energy from a battery to the motor. However, the energy provided by ESSs is unreliable and suffers from significant voltage dropouts. As a result, DC/DC converters are crucial in transforming uncontrolled power flow into controlled/regulated power flow to support various electrical loads and auxiliary power supply in EVs

Electric vehicle has the basic meaning of all vehicles driven by electrical energy source. Aside from the other definitions available, in this research electric vehicle is a system with the power source of battery which is charged by activating one or more of the automobile’s electric motors

According to Volkswagen Group of America, Inc. (2013), the electric drivesystem generally consists of:

1) High-voltage battery with control unit for battery regulation andcharger
2) Electric motor/generator with electronic control (power electronics)and cooling system
3) Transmission including the differential
4) Brake system
5) High-voltage air conditioning for vehicle interior climate control.

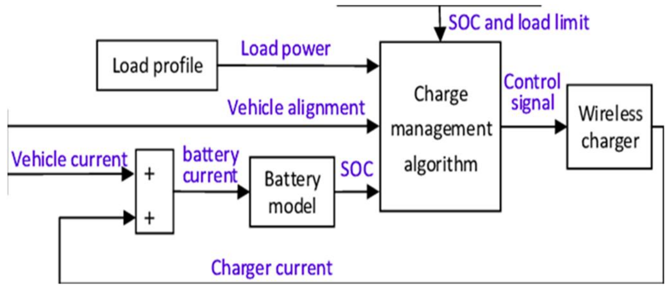

Fig 2: EV'S conducting charging

A. *Battery Management System*

Battery management system (BMS), which is installed on an EV dashboard, plays as the connector between the battery and the vehicle. It portrays a vital role, such as improving battery performance and optimizing vehicle operation in a safe and reliable means. It is crucial to develop a comprehensive and mature BMS, as itis with an engine management system in a gasoline car. The battery's state of the safety, usage, performance, and longevity should be presented in BMS indicators (Xing, 2011). The battery is risky to ignite when overcharged due to its volatility, flammability and entropy changes. In additional, over-discharge leads the cell capacity to reduce because of irreversible chemical reactions. It becomes a seriousproblem, since an explosion could cause a fatal accident (Stuart, et al., 2002 at (Xing, 2011).

1) Data acquisition
2) Safety protection
3) Ability to determine and predict the state of the battery
4) Ability to control battery charging and discharging
5) Cell balancing
6) Thermal management
7) Delivery of battery status and authentication to a user interface
8) Communication with all battery components
9) Prolonged battery life

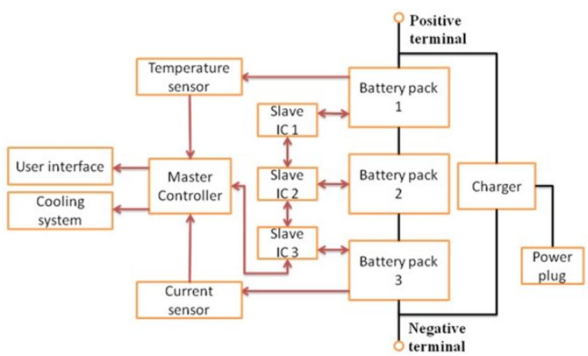

Fig 3: BMS system block diagram

B. *Fuzzy Working Procedure*

It maps the input to an output in a very efficient and the mapping can be very easily controlled without much complex knowledge about the process. Steps to be performed in Fuzzy control:

1) First, study how the rule base system and the operator can be applied to this control.
2) Understand the concept of membership functions and linguistic variables.
3) Analyse the power system to be controlled and decide the state variables to be considered as inputs to the system.
4) Form an understanding as how to control the state variables to get the required control in the plant.
5) Now form the Rule base for the linguistic variables of inputs and outputs.
6) Try to optimize the membership functions to make the control more efficient.
7) Integrate the fuzzy controller into the plant and check the result

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V. RESULTS AND ANALYSIS

After discussing the methodology that will be used in order to achieve this capstone project. I will be focusing on the battery model. As many alternatives could be used, I chose the model thatI am more familiar with which is Chen Mora. One of major the reasons behind choosing this model is that there is a whole library on SIMULINK dedicated to this specific design. In addition, the coding part on MATLAB will not take much time to implement using SIMSCAPE (coding language of SIMULINK). The following part will be dedicated to the design of this mentioned model in MATLAB.

Before discussing the results generated by the model. I will first illustrate the final design of theChen mora battery model including all the inputs and outputs needed. The figure below illustrates the final design on MATLAB before implementing

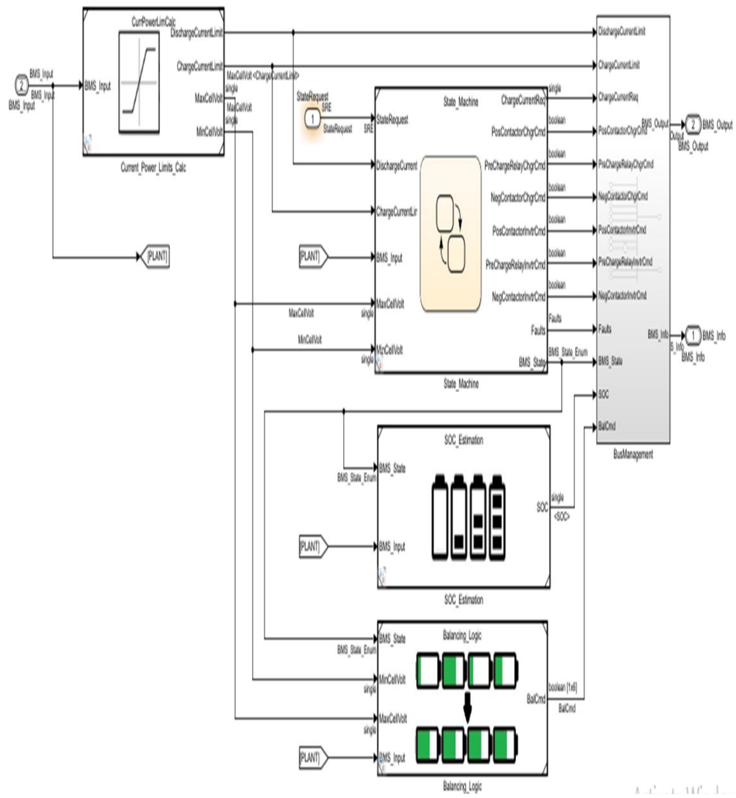

Fig 4: Final design of the BMS on MATLAB

A. Performance Evaluation

An isolated DC-DC converter is a type of power converter that provides electrical isolation between the input and output sides of the circuit. It is commonly used to step up or step-down DC voltage levels while maintaining galvanic isolation between the input and output.

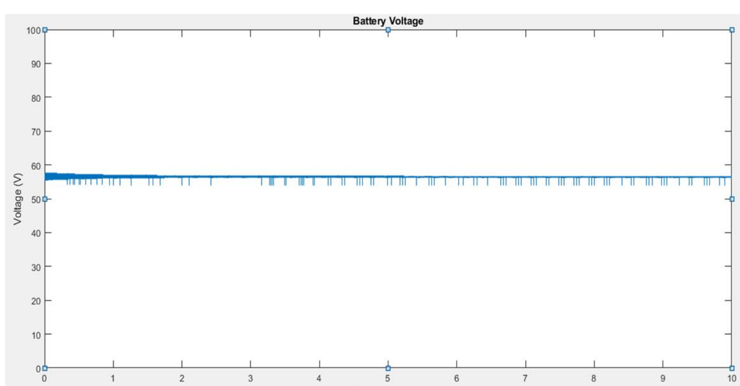

Fig 5: Battery voltage

The basic operation of an isolated DC-DC converter involves converting the input DC voltage to an AC waveform using a high-frequency switching circuit, such as a PWM converter. The AC waveform is then fed into a transformer, which transfers the energy from the primary side (input) to the secondary side (output) while providing galvanic isolation.

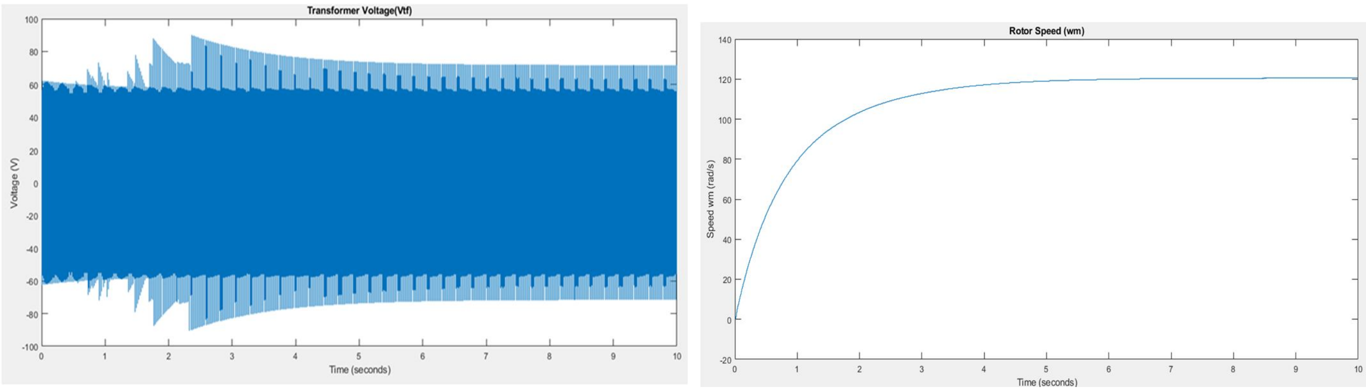

Fig 6: Transformer primary voltage, Dc Motor speed

On the secondary side of the transformer, the AC waveform is rectified back into DC using diodes or synchronous rectifiers. Additional filtering components such as capacitors and inductors are used to smooth the output voltage and reduce any remaining ripple. A non-isolated DC-DC converter, also known as a buck or boost converter, is commonly used in electric vehicles (EVs) for various power conversion tasks. These converters are responsible for efficiently converting the high-voltage DC power from the battery to the required voltage levels for different vehicle subsystems.

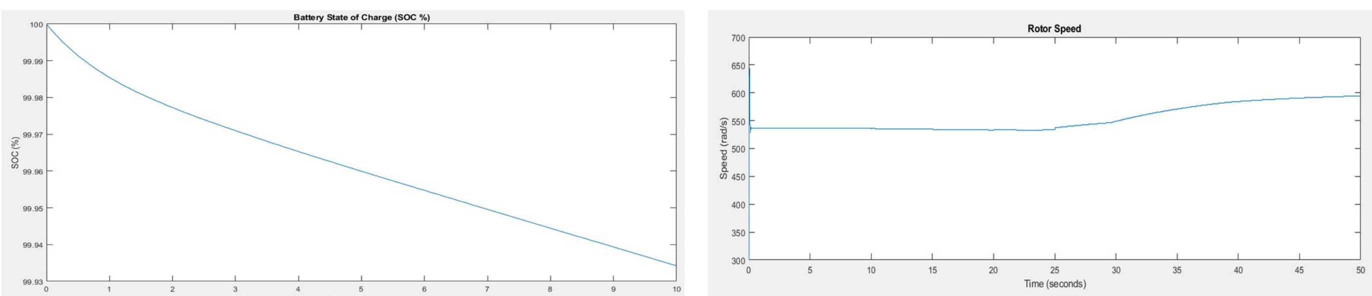

Fig 7: Battery SOC vs time, Rotor Speed vs Time

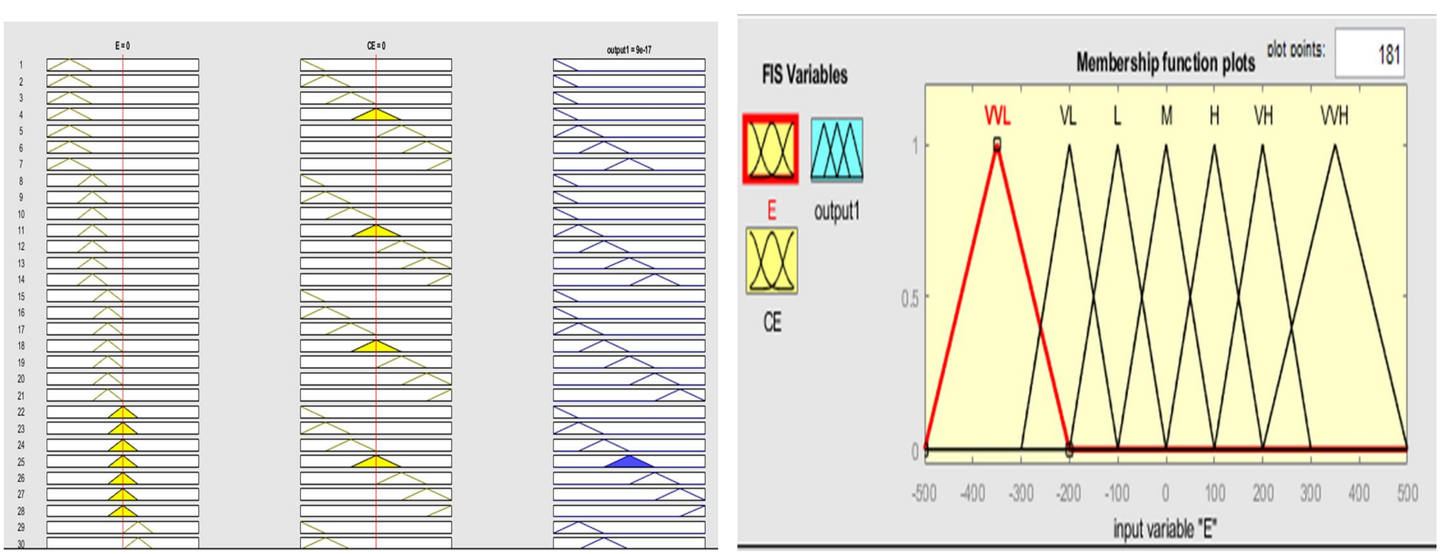

Fig 8: Fuzzy Rule Viewer, Member ship functions

VI. CONCLUSIONS

This work first introduced the background of electric vehicles, lithium-ion batteries and the BMS. The details of the BMS, including its definition, objectives, functions, and topologies were then discussed. The literature on battery modeling and BMS hardware system design were reviewed in the following section. The limitations of early battery models and the disadvantages of other BMS hardware systems were also reviewed. The objectives and outline of this thesis were then presented. The battery management system (BMS) is widely recognised as the central control unit responsible for overseeing and regulating various parameters inside the battery pack of an electric vehicle. Furthermore, the performance of the batteries is a matter of responsibility. Furthermore, the level of charge is a significant factor that influences battery efficiency. The objective of this study is to provide a precise assessment of the level of charge. This report presents a comprehensive literature assessment of the progress made by Morocco in the adoption and implementation of e-mobility. In the pursuit of acquiring knowledge on this subject matter, I had the privilege of attending a conference. The literature study included an examination of the operational mechanisms of Li-ion batteries as well as an exploration of the rationale for selecting this technology over other options. Furthermore, I was able to comprehend the underlying reasoning behind the neural network.

The state of charge is widely recognised as a significant factor influencing battery performance. In order to achieve this objective, I successfully developed a model that offers users a precise assessment of the condition of the charge. The neural network's performance was then evaluated by comparing it to the data obtained from the SIMPOWER battery, which was developed based on the Chen Mora battery model. Subsequently, the neural network underwent optimisation in order to enhance the precision of the obtained values. In addition, the protein application was used to create a 3D model of the battery management system. Furthermore, the battery management system was constructed with MATLAB, with the state of charge estimator being customised through the use of a neural network. Ultimately, the capstone project presented significant challenges due to the need to acquire proficiency in a comprehensive software package for the purpose of designing both the neural network and the battery management system.

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