AN EFFICIENT POWER MANAGEMENT SYSTEM FOR BATTERY MANAGEMENT SYSTEM IN ELECTRIC VEHICLES

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ABSTRACT: A novel power management strategy (PMS) for a small urban electric vehicle is presented in this study. By developing a PMS that is more effective for battery electric vehicles, it is possible to extend their driving range and extend the lifespan of their batteries. The power control unit (PCU) of the battery management system is proposed to be controlled by fuzzy logic control (FLC). Using the MATLAB software, the utilized control devices are verified and experimented with through simulations to evaluate their performance. The results of the simulations show that FLC performs well in terms of settling time and peak overshoot. The results of the simulations indicate that the proposed PCU can extend the battery's lifespan and reduce energy loss within the battery.

KEYWORDS: Sliding mode controller, Permanent magnet synchronous machine, Power management

I INTRODUCTION

Because they are extremely efficient, do not generate any local pollution, are silent, and can be used to regulate power by the network operator, electric vehicles (EVs) are frequently regarded as the cars of the future.However, there are still serious issues with EVs that must be resolved. Limited driving, a lengthy charging period, and the high cost are the three primary obstacles. Each of the three significant difficulties are connected to the battery bundle of the vehicle. The battery pack must have sufficient power for acceleration and deceleration as well as for a specific driving range. It is critical to have a suitable vehicle model in order to accurately estimate EVs' power consumption [1–3]. To address the aforementioned issues, it is essential to develop an efficient power management strategy (PMS) for battery electric vehicles (BEVs). There are a lot of studies on the design of the PMS for hybrid EV

(HEV)/plug-in HEVs, but few on the power management of pure EV energy. This could be because of the simplest powertrain structure and limited power distribution freedoms. The optimal power distribution between ultra-capacitors and batteries for hybrid electric vehicles equipped with ultra-capacitors has been the subject of a number of studies [4, 5]. This will improve both the driving range and the energy storage system's life cycle. Because BEVs only use batteries for power, there are more restrictions on how PMS can be strengthened. Kachroudi et al., in [6], utilized the particle swarm optimization technique to control the energy flow between the powertrain and other vehicle aids for a particular BEV in the most effective manner. By making some suggestions to the driver, they attempted to reduce the amount of energy used by the vehicle while maintaining the passengers' comfort. Utilized a power control for the cooling system in [8] and [7] to reduce overall energy consumption and improve battery health from BEVs, respectively. In order to maintain comfort and reduce fuel consumption, these strategies do not guarantee the best power distribution under various conditions. Additionally, the driver cannot adjust it to select between various operating modes, including fuel economy or convenience.

In the literature, there are basically three different models of batteries: electrochemical, electrical, and experimental models. Estimating the state of a battery's charge (SOC) necessitates the use of electrochemical and experimental models that are not well-suited to represent cell dynamics. However, models based on electric circuits can be helpful in illustrating the electrical properties of batteries.An ideal voltage source in series with internal resistance is the simplest electric model [9]. However, the SOC battery is not included in this model. Another model is based on resistive capacitive circuits parallel to the so-called Warburg resistance and an open-circuit voltage (OCV) in series [10]. The ID of the multitude of boundaries of this model depends on a somewhat intricate procedure called opposition spectroscopy [11].

Shepherd developed an equation to directly describe the battery's electrochemical behavior in terms of terminal voltage, OCV, internal resistance, discharge current, and charge state [12]. This model can be used for both the charge and discharge processes.

Although the Shepherd model is intriguing, the closed-loop simulation of standard models encounters an algebraic loop issue. In [13, 14], SOC battery models are only discussed as a case variable.

Shepherd's models are very similar, but they don't have an algebraic ring. Therefore, accurate battery models that are simple to use with power system simulators and onboard electronic power systems are crucial. Nickel-metal hydride (NiMH) or lithium-ion (Li-ion) batteries make up the majority of today's electric and hybrid electric vehicles' typical electrical energy storage. The capacity is frequently designed to have driving ranges of up to 250 kilometers in order to replace conventional automobiles, as with the Tesla Roadster and the BMW Mini-E [15]. This results in energy storage that is heavy, expensive, and bulky. Secondary cars used for commutes or short trips are another common type of business. The driving range is only about 30 kilometers on average, and 80% of trips are shorter than 60 kilometers [16]. The storage's energy capacity can be significantly reduced for these automobiles.

To find the best fuzzy logic controller (FLC) for controlling a battery management system (BMS), a strategy based on modeling and design is proposed in this paper. In comparison to the sliding mode controller (SMC) system, the simulation results demonstrate promising performance. In addition, specific reference values are provided by the improved FLC for use in future research into the intelligent BEV controller design. In addition, it has a separate logical control for energy flow management that was made to handle the particular electrical load. Research on PMS systems continues because commercial PMS systems are expensive and unable to meet the requirements of large electric vehicles. For urban electric vehicles, it is necessary to develop a low-cost and fully compatible PMS system that can safeguard the lithium battery and extend its lifespan.The following is a list of the main contributions made by this work:

- Ensure that the battery power is sufficient for vehicle operation.
- Make certain that there is a low likelihood of battery damage.
- Control the battery's charging and discharging.
- Keep battery cells safe from damage and abuse.

- Make sure the battery lasts as long as possible.

- Make certain that the battery is always accessible for use.

II BATTERY EV MODEL

The electric vehicle's heart is the battery pack. Lead-acid, NiMH, Li-ion, and other battery types are just a few of the many options available. The battery pack for an electric vehicle (EV) needs to be able to be recharged and also be able to withstand the harsh operating conditions. In this paper, a Li-ion battery was selected as the type of battery: The family of rechargeable batteries includes this category. Due to its relatively high specified energy and power, the Li-ion battery is the most popular choice. A battery is designed with a simple controlled voltage source in series and a constant resistance, as shown in Fig. 2.It is demonstrated that the circuit equivalent loop adheres to Kirchhoff's voltage law and generates the following terminal voltage:

$$V_{\text{batt}} = V - R_{\text{i}} \times I_{\text{batt}} \qquad (1)$$

where V_{batt} is the battery voltage (V), V is the no-load voltage (V),Ri is the internal resistance (Ω), and I_{batt} is the battery current (A), where both V and R_i depend on the instantaneous battery charge status. Internal resistance R_i can be expressed as a function in the battery charge status, operating temperature as well as particular currents for charging and discharging.

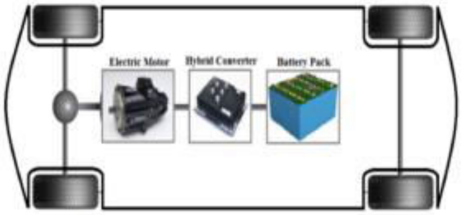

Fig. 1 *Block diagram of BEV powertrain*

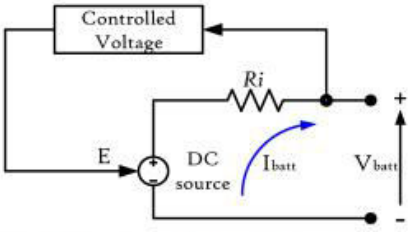

Fig. 2 *Basic equivalent circuit of the generic battery model*

III POWER MANAGEMENT STRATEGY

Under constant vehicle power requirements, the PMS must determine how power is distributed among multiple energy systems. The PMS then has to put these decision-making rules and constraints into action to create these orders or procedures for power distribution. Fig. 2 provides a Simulink model illustration of the PMS.

It is desirable for the load power requirements to be lower than the maximum amount of battery power that is specified by the battery itself. On account of a framework with batteries as an energy source, a PMS that decreases top power from the battery to the ultra-capacitors expands the energy effectiveness of the batteries, accordingly adding to the extension of vehicle independence. Preventing high-frequency power fluctuations in the battery system and preventing overcharging and over discharging beyond the established power limits may also be part of the strategy. However, a PMS's primary goal is to consistently meet load requirements. The skyline time window is, as a matter of fact, the PMS choice age, which is time-compelled to create reference power ways. Fig. 4 displays power rate limits (dPb/dt) and battery power limits (Pbatt max, Pbatt min) as functions of battery charge status. In Fig 5. The (PMS) limits on power discharge and charge within a predetermined time frame for PMS resolutions are represented by 5a and b, the battery's discharge power limit and the battery charge limit, respectively. Because of this, controlling the step change for both the discharge and shipping levels is made possible by including these restrictions in the definition of PMS.

In short, the energy system's content is processed by the EMS, power distribution is processed by the PMS, and voltage and current are processed by the PCU system. The electronic power converter's operating cycle commands come from the PCU's outputs.

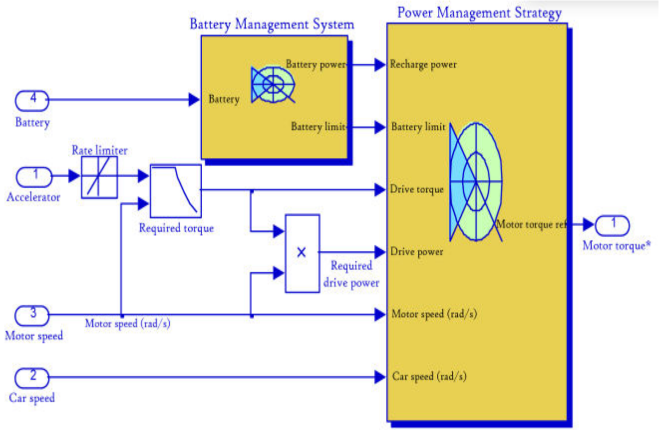

Fig 3 : Schematic diagram of the PMS in a Simulink model

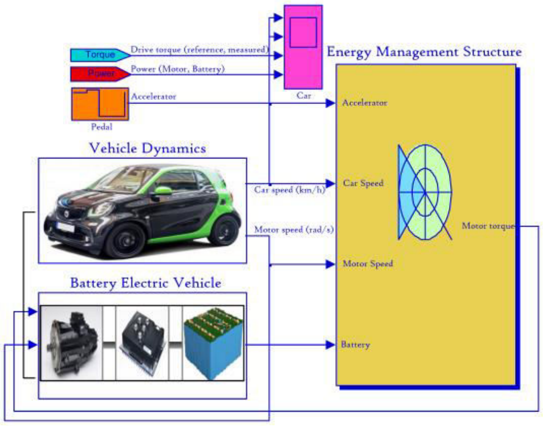

Fig 4 : *BEV simulation model*

IV PROPOSED MODEL

The proposed power controller's primary function is to connect or disconnect the battery from a load or charger. In addition, it controls the inrush current and measures the battery pack's voltage and current. Fig. A block diagram of the proposed power controller is provided in Figure 7. The power controller model relies on the specifications of the battery pack to monitor its state, calculate secondary data, report that data, control its environment, authenticate it, and/or balance it, and control its environment.

As a technique execution device, FLC is utilized. The FLC controller typically consists of four main parts: a rule base unit, a defuzzification unit, a fuzzy inference engine unit, and a fuzzification unit. [21–23] provides additional information about these groups.

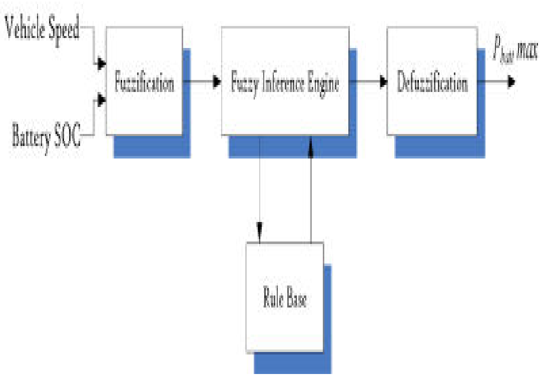

Fig 5: depicts the fuzzy inference control system as a block diagram.

The FLC within the BMS operates in a cycle that can be summed up as follows. Through a fuzzification practicability, measured variables and derived parameters were mapped into fuzzy sets that also account for the measured values' uncertainty. After that, a fuzzy logic rule base's control rules are evaluated by a fuzzy inference engine in accordance with the fuzzy sets. A fuzzy set output is created based on the rule-based evaluation. The control action that is carried out on the input variables is represented by a single-valued value that is the controller's final output. This feature is utilized to generate the battery maximum power (Pbatt max) of the BMS due to the fact that fuzzy logic permits systems to be controlled by the experimental representation of how the system behaves.

There are three membership functions that define the vehicle speed input: "Slow," "Medium," and "Fast." Similarly, "Low, Medium, High" defines the battery SOC membership function. The fuzzy inference system (FIS) is depicted as a single output system consisting of two inputs in the following general form of common rules, with x_1 and x_2 serving as status variables and y_i serving as the output variable:

$$\text{IF } x_1 \text{ is } A_{i1} \text{ and } x_2 \text{ is } A_{i2} \text{ then } y_i = \Psi_i(x_1, x_2)$$

FLC is used to control the rates of charge and discharge. The SOC for each EV and the voltage conditions in the node to which the charging station is connected are the input factors to the charging controller in this instance. The EV battery will be charged if the SOC is low and the node's voltage is high; however, if the SOC is higher and the voltage is lower for the node, the EV battery will be discharged. However, there are occasions when both the SOC and node voltages are either high or low. A specific charge/discharge rate is used in these situations. To keep voltage fluctuations in the distribution node within standard limits, FLC must be modified to handle critical situations as well.

V CONCLUSION

In this paper, the MATLAB/Simulink environment was used to set up the dynamic model and design of a BEV and PMS. The battery in EVs is selected in such a way that it meets both the power and energy needs for a given driving cycle. The design process is an iterative one in which the parameters of each power system component between the grid and the steering wheels determine how energy flows inside the vehicle. The interior states of the vehicle, such as voltages, currents, speed, torque, and charging status, determine the loss of each component. To ensure that the vehicle's energy calculation was accurate, these scenarios were incorporated into the modeling process. The power management controller in the same BMS is based on an effective battery logic control.Using this battery model makes it possible to accurately represent temporary cases, as demonstrated by the outcomes. After that, it can be analyzed for adjusting various control devices. In addition, this model contributes to the development of the PMS system, which limits the battery's maximum power by controlling all converters in addition to the PMSM motor. Finally, precise control over the battery's charging and discharging is possible. Because all other systems are dependent on this one battery, this model serves as the center of the electrical battery components. The completion of the initial version of the BEV control system and verification of its desired behavior were one of this paper's primary responsibilities.Although the initial version has been completed, the BEV control system still needs to be implemented in a variety of ways. Additionally, it is suggested that total cost and efficiency be included in the design parameters. Additionally, it offers recommendations for reducing the loss of additional loads, which will be the subject of a subsequent paper.

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