Framework for Real-Time Monitoring of Battery Performance in Electric Vehicles and Locating Charging Facilities Nearby

Pranay Jain, Sanjana Kumari, Shreenivas B

Abstract: Electric vehicles (EVs) are becoming more prevalent in the market. In a world where all vehicles are electric, it will be necessary to provide infrastructure on average highways that is similar to the energy consumption of the automobiles on that highway. As a result, a large transition from one type of energy carrier to electrical energy would be required. In comparison to where we are now, this translates into a significant increase in the carrying capacity of the power grid. Electric vehicles are in increasing demand because they have several advantages over gasoline-powered vehicles. On the other hand, limited battery power stations and a lack of infrastructure giving real-time vehicle performance parameters such as battery efficiency, durability, total distance travelled before being totally depleted, and so on should be considered. As a result, an embedded system is being developed in our project to address the aforementioned restrictions. The suggested research demonstrates all of the mathematical calculations of battery characteristics (including but not limited to battery efficiency and percentage durability), which aids in evaluating real-time batter performance. The system was tested and verified in laboratories using acceptable methodologies. In addition, a mobile application for the end-user is being created to provide information on battery parameters as well as the maximum distance it can travel till full discharge.

Keywords: Electric Vehicles, Battery, Charging stations, Mobile.

I. INTRODUCTION

An electric vehicle (EV), also called electrics is a vehicle that uses one or more electric motors or traction motors for propulsion. The powering of EV is done through a collector system by electricity from off-vehicle sources or may be self-contained with a battery, fuel cells or an electric generator to convert fuel to electricity. A battery electric vehicle's propulsion system is driven by an electric vehicle battery and traction battery specialised systems used for commercial vehicles. These batteries are commonly rechargeable and are lithium-ion in nature.

Manuscript received on July 15, 2021.
Revised Manuscript received on July 19, 2021.
Manuscript published on August 30, 2021.
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Major transport vehicles, land and underwater vessels, electric aircraft, and electric spacecraft are all examples of electric vehicles. EVs are typically paid from standard power outlets or dedicated charging stations, a process that takes hours but can be accomplished overnight and often provides enough charge for regular daily use. All recharging could be achieved overnight if EVs crossed the 800 km range barrier in production vehicles at reasonable rates, and a major part of the range-anxiety issue will be solved. Taxi services, driving, local transportation, and so on are all excellent use cases for EVs today, and going electric makes more sense than doing so with ICEs in those circumstances.

The battery is the heart of the electric vehicle as it helps the vehicle move by pumping energy in the form of voltage and current. Just like the human body, batteries also need good care and hence monitoring battery parameters will enhance the productivity of an electric vehicle. This paper proposes a system that helps the user, to take necessary actions considering the battery performance, by providing real-time monitoring of battery parameters in a user-friendly mobile application.

This paper will first review the previous works along parallel lines and present their findings in II. It will go on to give a brief overview of the methodology of our system in III. We will not go into much depth but enough to get a lucid background of each of the parameters covered in our work. IV will give out the proposed work and V will present the testing of the model and provide experiment results.

II. LITERATURE SURVEY

With the boom of electric vehicles, the demand for energy storage with better lifetime, energy efficiency, and mileage has become a necessity. This has led to a lot of research and fieldwork over the past few decades. One of the key technologies for current and future energy storage, whether they are used for mobile or stationary applications is Lithium-ion batteries. These batteries have high charge density and discharge time although when used for large-scale applications they must be introduced to temperature control and over current and voltage control to avoid damage and explosion [1].

Longevity remains one of the key issues for Lithium-ion (Li-ion) battery technology. When it comes to the ageing and degradation mechanism in a battery it is a complicated process that depends on many factors like environment or utilization mode.

Therefore, to increase the lifetime while maintaining the performance, the battery management systems implement health-conscious control algorithms which use Remaining Useful Life (RUL).

[2] Estimates the RUL by predicting the battery capacity fade over the cycles utilizing the identified ageing model from a thermal perspective and least-squares algorithm. A combination of sliding mode observers and nonlinear least-squares algorithms is utilized for designing the estimators.

[3] predicts battery RUL using a linear ageing model constructed based on the capacity data within a moving window, combined with Monte Carlo simulation to generate prediction uncertainties in a real battery management system used in electric vehicles. Whereas,[4] predicts RUL using nonlinear stochastic degradation because the degradation process of the battery exhibits strong nonlinearity, the use of linear models based on the Wiener-based method would produce large errors, and the prediction results would deviate significantly from the true value. This paper predicts RUL with a 95% confidence level.

[5] Analyses and estimates the life of the Li-ion batteries for different kinds of cycles. Mileage of 200 km for a mid-size city car was estimated when under working temperature voltage. The lithium-polymer battery has higher energy efficiency which is over 95% (between +20ºC and +40ºC) is a large improvement when compared to lead-acid, nickel-metal hydride, and nickel-cadmium batteries whose energy densities lie between 80 to 85%. This comes close to satisfying the ALABC long-term criteria for electric vehicle batteries and is suitable for electric cars. It has a very high energy density of over 350 Wh/L, which is the highest energy as mentioned above.

However, [6] shows that it can work over a wide range of temperatures with high efficiency and it does not need cooling during summer, but will need heating at temperatures below freezing. The End-of-life of this battery is about a 20% loss in its capacity.

[7] proposes a novel system to overcome the limitations of standard electric storage systems designed as a hybrid concept between Vanadium Redox Flow Battery and Hydrogen Fuel Cell, for energy management in an electric vehicle, with zero-emission. Here they measure parameters like electric current drawn from the ultra-capacitors battery, electric current drawn from the Li-ion battery, electrical current drawn from the charging system of Li-ion battery and electrolyte pH of ultra-capacitors and using the circuit Fig.1 transmits the measured data to a PC.

[8] Analyses the relation between the whole efficiency of a hybrid system and the total energy loss. The significant result is that the total energy loss of the hybrid system is irrelevant to the efficiency of the system. The key factor which affects the total system energy loss is the ratio of time while the fuel cell system runs in a high-power area. High performance and reliable battery health management systems are required to tackle the new transportation challenges and to ensure the safety and durability of electric vehicles as well as hybrid electric vehicles.

[9] Mentions three major indicators of SOH which are the battery internal resistance, the battery impedance and its capacity. The battery capacity reflects the amount of energy the battery can store, while the internal resistance and impedance are indicators of its power capability. The battery SOH can be calculated using the ratio between the actual indicator value (capacity, impedance or resistance) and its initial one. Among various methods to calculate SOH model-based methods are highlighted due to their accuracy and compatibility with onboard and online applications. [10] shows a detailed overview of the main techniques for charge balancing, state of charge estimation and monitoring system using the 8-bit ATMEL AT90CAN128 microcontroller. Functions requiring more calculation power are implemented on a 32-bit Infineon TriCore TC1797 microcontroller PMU board. In an electric vehicle application, the balancing act can be done while the vehicle is not used for driving or using a low balancing current, which is a prerequisite for single-chip integration.

III. PROPOSED SYSTEM

The best way to resolve issues is to have a monitoring system that enables the system to acquire battery parameters wireless or wired technology to make the field more and more intelligent. We created a module that relays the data to the end-user devices.

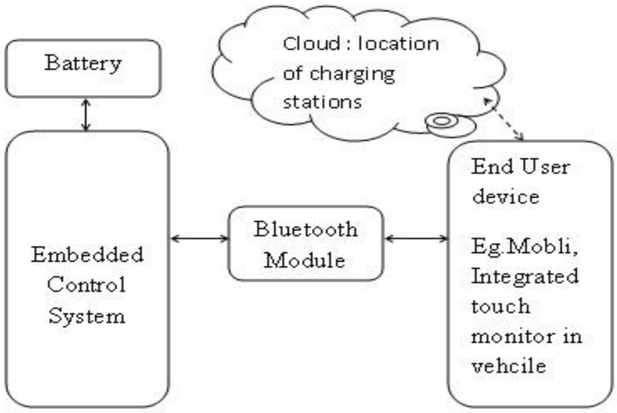

Fig. 3.1. The proposed architecture of the system

The work aims to build an embedded control device (Fig. 3.1) with a microcontroller that will be connected to the battery and monitor the battery's power in real-time. All battery parameter information is not just limited to battery percentage, efficiency, and serviceability, all the relevant parameters will be displayed on a mobile app for Android or iOS. A Bluetooth module will be used to link the hardware and software. Along with battery parameter details, the app will alert the user about the concerning nearby charging stations and how far the vehicle can go with the remaining battery charge. The charging station location and coordinates will be saved on a cloud server.

IV. IMPLEMENTATION

A. Hardware Implementation:

The hardware design of this project consists of an Arduino connected to the battery by an electronic circuit using resistors, MOSFET, opAmps. As shown in Fig. 4.1, the battery is connected to a voltage divider consisting of R1 and R2, having resistance values depending on the maximum voltage of the battery, for providing value falling under the acceptable voltage range of the microcontroller (0-5V in case of Arduino).

Retrieval Number: 100.1/ijeat.F29800810621
DOI:10.35940/ijeat.F2980.0810621
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The divided voltage is then passed through a voltage follower (U1) for avoiding loading effects. Finally, the output of U1 is provided as an input to the ADC port of the microcontroller. These readings are adjusted in the microcontroller by suitable code and then sent to the mobile application via Bluetooth module.

To keep the system safe, an operation amplifier (U2) with a reference voltage (usually equal to VCC of the microcontroller) input, designed with positive feedback, is connected to the base of the MOSFET (Q1). If the voltage at the emitter of Q1 exceeds VCC, the MOSFET will operate in a saturation state and thereby turn off the microcontroller.

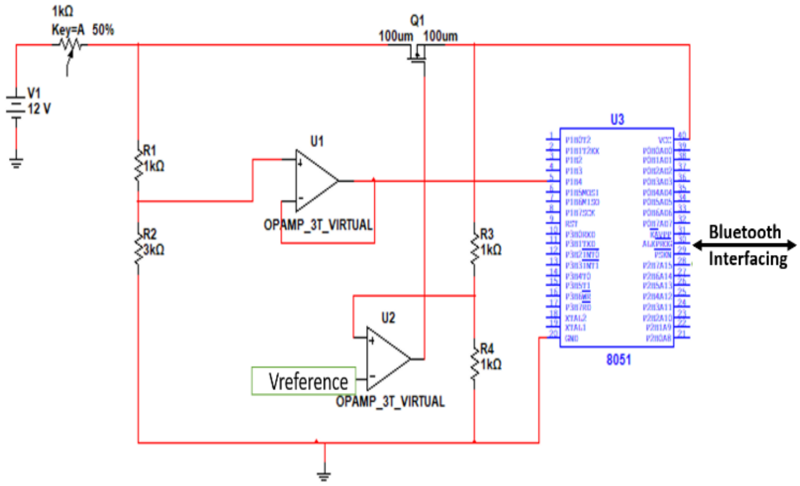

Fig. 4.1. The electronic circuit system

The system (Fig. 4.1) is simulated in MULTISIM [11] using an 8051 Microcontroller to verify the designed electronic circuit.

The following battery parameters have been calculated in our system:

i. **Battery percentage:** The amount of power a battery can deliver as compared to its maximum delivered power is known as the percentage of the battery. In our application, we have obtained the battery percentage by taking the difference of the altered input battery voltage at the Arduino port and the minimum voltage offered by the battery.

Battery Percentage is obtained by using the following equation

$$Battery\ Percentage = \left[\frac{(Voltage_{final} - \mathrm{Battery_{min}})}{(\mathrm{Battery_{max}} - \mathrm{Battery_{min}})}\right] \times 100$$

In the above equation:

- $Voltage_{final}$ = The real-time voltage of the battery.
- $Battery_{min}$ = The minimum voltage provided by the battery.
- $Battery_{max}$ = The maximum voltage provided by the battery.

ii. **Battery efficiency:** The efficiency of a battery is the ratio of the amount of power discharged by the battery to the amount of power delivered to the battery. The loss of energy to heat, which in turn warms up the battery, is also taken into consideration.

Battery Energy Efficiency is obtained by using the following equation

$$Battery\ Efficiency = \left[\frac{(V_D I_D T_D)}{(V_C I_C T_C)}\right]$$

In the above equation:

- VD/VC= Battery voltage during discharging/charging.
- ID/IC = Battery current during discharging/charging.
- TD/TC= Time taken by the battery to discharge/charge.

iii. **Battery durability:** Durability of the battery can be defined as the time taken to deplete the battery of one charge at certain operating conditions or the number of charge cycles until the end of useful life.

Battery system	Estimated self-discharge
Primary lithium-metal	10% in 5 years
Alkaline	2-3% per year (7-10 years shelf life)
Lead Acid	5% per Month
Nickel Based	10-15% in 24h, then 10-15% per Month
Lithium-ion	5% in 24h, then 1-2% per month (plus 3% for safety circuit)

State of charge	0ºC(32º F)	25ºC(77º F)	60ºC(140º F)
Full Charge	6%	20%	35%
40-60% charge	2%	4%	15%

Table. 4.1. Estimated self-discharge Table [12]

The above table (table 4.1) shows the estimated self-discharge in the percentage of different types of batteries which are used to calculate the shelf life of the battery which determines the durability.

B. Software Implementation:

This part of the project is to design a mobile application that can retrieve data from the hardware component and display it on a mobile screen. The application is designed using Adobe XD and the framework used is react native. The application is created for android and iOS and is used for the following:

i. **Retrieving data from the user**- We are using a form with input fields like user name, password, battery type they want to monitor and related information.

ii. **Displaying the current battery details-** Different details related to the battery efficiency is displayed to the user in a user-friendly manner retrieved from the Bluetooth module.

iii. **Shows the nearest station locations-** Showing the users their current location and the nearest charging stations retrieved from the cloud storage.

The application's login screen shows information such as the type of battery, distance travelled, name and password. Then it retrieves data from the hardware where the efficiency and durability are calculated and displays on the screen the values of these parameters and whether it is connected to the charger or not. For the calculations, the backend coding is done using nodeJS and express. Along with that it also shows the nearest approachable power station by locating the user's current location and comparing it with the coordinates of the charge stations which are stored in the cloud storage. We have used MongoDB as the cloud server.

C. Interfacing Hardware and Software

The interfacing is done using a Bluetooth module, HC-05. Wireless communication is swiftly replacing the wired connection and simplifying the domain of electronics and communication. Designed to replace cable connections with better technology, HC-05 uses serial communication to communicate data from one device to another. Generally, it is used to develop a connection between small devices like mobile phones using a short-range wireless connection to exchange information.

In our application, the Rx and Tx pins of HC-05 are connected to Tx and Rx pins of Arduino respectively to enable the transfer of information to the device connected to Bluetooth. Once the mobile phone is linked to Bluetooth, all the calculated battery parameters are being forwarded from the Arduino to the mobile. Hence, the real-time condition of the battery is being tracked on the mobile application via wireless communication.

V. RESULTS

The proposed model is implemented in MULTISIM and is coded using Arduino IDE. The mobile application is designed using Adobe XD and the framework used is react native. A personal computer on a windows 10 environment having an 8GB Ram and Intel I7 7th Gen processor was used to simulate the model. The time taken for encoding, decoding, encryption, and the decryption processes were the parameters observed. Apart from this, the percentage of space saved was also calculated.

The system is tested using a portable power bank (Model PLM-10003) with 0V and 5V as its lowest and highest output voltage respectively. The capacity of the power bank is 10000mAh.

The following are the results obtained from the model:

i. The design for the hardware section is successfully converted to a working embedded circuit using Arduino (Fig. 5.1).

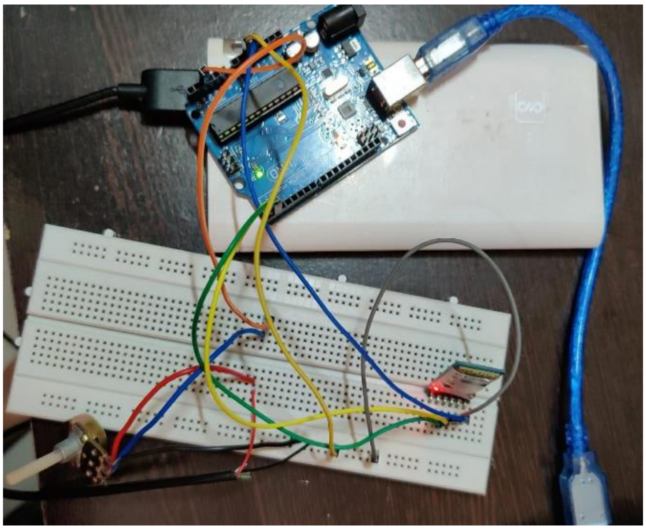

Figure 5.1: Working Embedded circuit using Arduino

ii. The design for the application is designed (UI/UX designs) and converted front-end code to create a seamless experience for both Android and iOS operating systems. The application displays the required information (Fig. 5.2) and (Fig.5.3) displays the location of the charging stations.

Retrieval Number: 100.1/ijeat.F29800810621
DOI:10.35940/ijeat.F2980.0810621
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Fig. 5.2. Mobile application – displays the information of battery

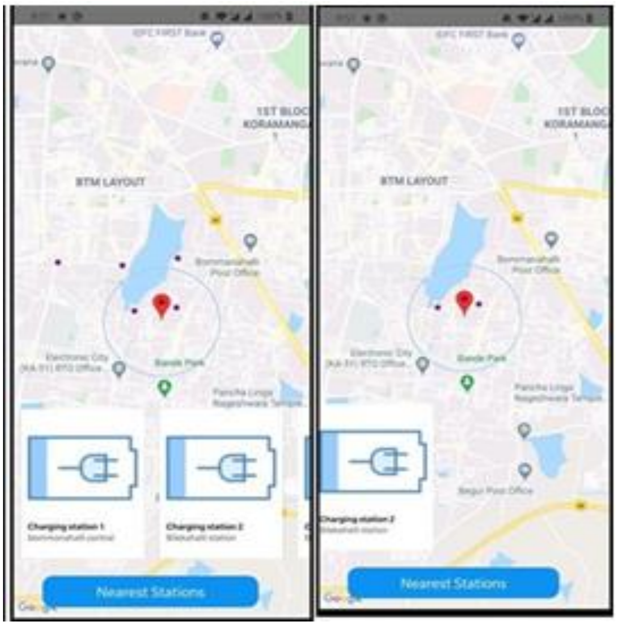

Fig. 5.3. Mobile application – displays the information of stations

VI. CONCLUSION

We can conclude that the recent development in electric vehicles has been proved advantageous in numerous ways. It is good for pollution control, easy to operate and energy-efficient. But there are some drawbacks of these vehicles. There are fewer charging stations, no information about the battery power and durability. Through our model, we have tried to overcome some of these issues by designing a system calculating the real-time battery parameters including battery efficiency, percentage, durability. Additionally, a maximum distance that can be covered by the vehicle before the complete discharge of the battery, along with the location of the nearest battery charging stations has been obtained by our system. Our system overcomes current limitations by making it user-friendly and providing real-time monitoring of battery conditions.

The following can be considered as the future scope of our system:

a) The developed mobile application can be simplified. If any wrong information is given by the user the whole procedure will be affected so simplifying the app would solve this issue.
b) In future, we aim to build a large database of the power stations that will cover the maximum area and will give out the most accurate results.
c) A circuit for fast charging at the charge stations will make these vehicles more time-efficient.

ACKNOWLEDGMENT

The authors acknowledge the support and encouragement of the management of BMS College Engineering, Bengaluru.

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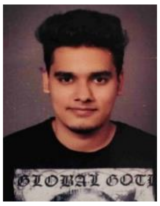

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