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State-of-Health Estimation of Li-ion Batteries in Electric Vehicles

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ABSTRACT: Lithium-ion batteries have a limited lifetime and cannot be used after they have reached their end of life. Using a lithium-ion battery after it has reached its end of life can lead to serious consequences and can sometimes cause catastrophic battery explosion. Also, range anxiety among drivers and potential customers has become a barrier in the sales of electric vehicles. Hence, accurate prediction remaining useful life of lithium-ion batteries is of utmost importance in the domain of electric vehicles. In electric vehicles (EVs), battery management systems (BMS) carry out various functions for effective utilization of stored energy in lithium-ion batteries (LIBs). Among numerous functions performed by the BMS, estimating the state of health (SOH) is an essential and challenging task to be accomplished at regular intervals. Accurate estimation of SOH ensures battery reliability by computing remaining lifetime and forecasting its failure conditions to avoid battery risk.

The above-mentioned issues can be addressed using accurate RUL prediction models. Thus, as part of this research, machine learning models such as Support Vector Machine (SVM), Long Short-Term Memory (LSTM) network and Similarity based Model (SBM) are implemented to predict the remaining useful life of a set of lithium-ion batteries. The effect of resting of batteries (calendar aging) is also considered. It is observed that the LSTM models perform better than the SVM models and they take much less time to train than the latter. SBM performs better than both LSTM models and SVM models and they can be trained faster than LSTM and SVM models. It is also observed that the resting of batteries impacts their remaining useful life

KEYWORDS: Lithium-ion batteries, Electric vehicles, Battery management systems, State of health (SOH), State of Charge(SOC).

I. INTRODUCTION

The growing number of fossil-fuel-powered internal combustion engines (ICEs) has a major impact on global climate change, energy use, greenhouse pollution, and health threats. As a result of this worrying situation, several countries have begun to put a greater focus on renewable and green energy sources to replace fossil fuels. According to a report by the Transport and Environment (T&E) organization the transportation industry alone accounted for 27% of overall greenhouse gas emissions in India. In fact, passenger vehicles account for 41% of total transportation pollution. The car industry has identified electric vehicles (EVs) as the perfect solution to emerging challenges and issues related to climate change and increasing energy demands. Because of their high electric capacity, high specific energy, high charging efficiency, long lifespan, low maintenance, and low self-discharge, lithium-ion batteries (LIBs) are a favoured choice for the automotive industry.

EVs (Electric vehicles) and HEVs (hybrid electric vehicles) have been recognized as the most feasible alternatives to existing internal combustion (IC) engine-based vehicles and their production has been increased in recent years. Due to several advantages such as high energy capacity, low environmental emissions, and long cycle life, batteries have become a common power source for EVs and HEVs. A well-thought-out charging technique would safeguard batteries, reduce temperature variations, and improve energy conversion efficiency. Slow charging limits the availability of EV usage, whereas charging too quickly results in substantial energy loss and temperature increase. As a result, the battery management system (BMS) is important for preserving battery safety and performance. Battery simulation, internal state measurement, and battery charging are all relevant developments in the BMS of electric vehicles.

Battery state monitoring, thermal management, real-time controller tuning, battery behaviour research, and fault diagnosis all benefits from an optimized battery model. Furthermore, some of the internal battery states such as state of charge (SOC), state of health (SOH), and internal temperature are difficult to determine explicitly despite the fact that these states play essential roles in regulating battery operation and must be monitored using effective estimation methods.

II. RELATED WORK

Dincer et al (2017: 78) state of Health (SOH) is defined as the internal capacity degradation of the batteries with highly temperature in exterior aspects. There is not any specified specification for SOH estimation overall major consideration will be ability to power comparisons to the initial with present condition of the batteries. Among different parameter we can consider any one or combine of battery internal resistance, capacity, power density, stationary power losses, impedance and how long the battery operate. This degradation is often found due to short circuit, collusion, cell aging, increased internal resistance.

Ang Yang et al (2019) estimate the SOH with fault detection using dynamic Peukert's law which works under the capacity of the battery degradation with degradation cycle. In this research they used current capacity degradation from the initial and recent battery capacity. This was estimated using the different parameters including internal resistance, power density, capacity and discharging rate.

H. Zhang et al (2015) sets the experiment considering the measurement of SOH depends on Depth of Discharge and which is the charging and discharging nearby to lower and higher SOC batter level but often for the EV is operated with 10 to 90% for charging and discharging which lead depth of charge to neglect and consider external temperature effects which was found that higher the temperature capacity fading will be higher than at lower temperature in running mode. Whereas, for Plug in Electrical vehicle mode external temperature has greater effects on chemical process and strain-stress so maintain lower the battery will increase the longevity of battery which refer to better health of battery.

III. METHODOLOGY

An embedded system is a combination of software and hardware to perform a dedicated task. Some of the main devices used in embedded products are Microprocessors and Microcontrollers. Microprocessors are commonly referred to as general purpose processors as they simply accept the inputs, process it and give the output. In contrast, a microcontroller not only accepts the data as inputs but also manipulates it, interfaces the data with various devices, controls the data and thus finally gives the result. The project "State-of-Health Estimation of Li-ion Batteries in Electric Vehicles" using IOT and PIC microcontroller is an exclusive project.

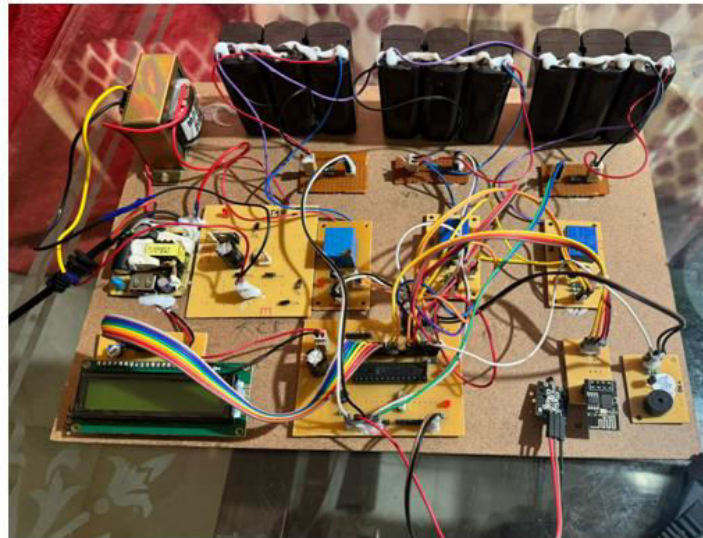
A new approach is adopted to identify and extract a set of input features associated with the battery degradation process. A data-driven based SOH estimation using an independently recurrent neural network (IndRNN) is developed with the help of vital battery parameters collected from LIBs. The effectiveness of the proposed IndRNN based SOH estimation approach is verified by comparing it with similar RNN architectures, and the IndRNN resulted in having a much lower mean square error (RMSE) rate

The MICROCONTROLLER measure the SOC(State-of-Charge) and (SoC)State-of-Health from voltage sensors and based on that it will switch on the relays for battery charging. Here relay works as a switch to on/off the charging connection. And also it will send the voltage,temperature,soc and soh values into the thingspeak cloud through esp8266 Wi-Fi module. The status of the project will display on LCD module

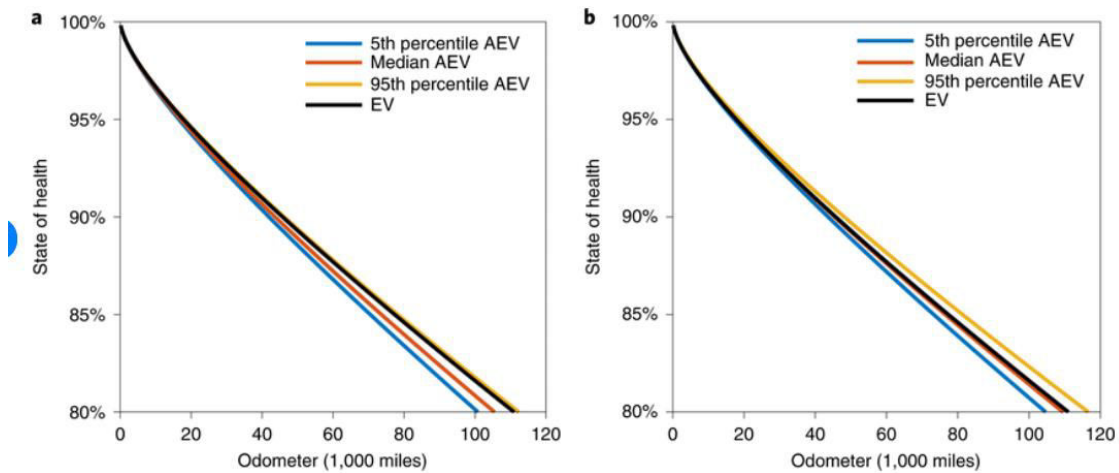
IV. EXPERIMENTAL RESULTS

The project "Battery-Management System (BMS) and SOC Development for Electrical Vehicles" an improved battery model is introduced in an advanced method than the existing process. The controlling device of the whole system is PIC Microcontroller. The integrated modules to the controller are ESP8266 WI-FI, temperature sensor, Battery packs along with relays, Charger, DC Fan,Load and LCD Module. When any of the battery pack get drained, that battery pack get charged from the charger through relay and the voltage values of each battery pack data is displayed on LCD module as well as it displays the temperature continuously. If the temperature value crosses the set limit then PIC microcontroller active the buzzer for alerts.The microcontroller measure the SOC(State-of-Charge) and (SoC)State-of-Health from voltage sensors and based on that it will switch on the relays for battery charging. Here relay works as a

switch to on/off the charging connection. And also it will send the voltage, temperature, SOC and SOH values into the thingspeak cloud through esp8266 Wi-Fi module.



(a)



(b)

Fig. 1. SOH of batteries-(a) Prototype experiment module picture (b) SOH result graph of 2 cells.

V. CONCLUSION

This research work proposed an IndRNN based SOH estimation model to estimate the SOH of LIBs used in EV applications. To emulate the dynamic driving behavior of a real-world EVs with non-uniform variable load requirement, randomized battery usage datasets were chosen. This dataset represents the dynamic load condition of an EV with the help of the Random walk (RW) cycle, in which the battery is allowed to operate under variable load condition for every 5 min. Then, a series of reference benchmarking tests were carried out to evaluate the battery capacity. From the RW cycle and reference discharge cycle, a set of 18 input features (including V, I and T) which affects battery capacity are identified and extracted to develop the IndRNN model.

To verify the capability of the proposed IndRNN based SOH estimation approach, different experimental analyses were carried out. Results obtained from each test reveals IndRNN with a time-step size of 15 is optimal time step size for accurate SOH estimation with 80% of SOH is considered as end of battery life (EOL). Due to the lower error rate

provided by this approach, this is more appropriate for BMS of EV applications. The major strength of this method includes real-time estimation, suitable for different LIBs, and robust and accurate SOH estimation. Meanwhile the limitation of the approach is that, a detailed analysis is required on experimental dataset to understand and identify input parameters for different battery chemistries. The proposed model is developed with the help of a dataset produced from three battery cells, but to increase the SOH accuracy further additional datasets with real-world EV driving patterns, operating under different temperatures and high-current discharge conditions is required.

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