Electric Battery Life State of Health Models for Electric Vehicles

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Abstract— **An electric vehicle (EV) is one that is driven by an electric motor rather than an internal-combustion engine that burns a mixture of fuel and gases. The state of health (SOH) of a battery (or a cell, or a battery pack) in comparison to its ideal conditions is a figure of merit. The SOH of a battery is ideally taken as 100 percent when it is manufactured and gradually decreases with time and use. However, a battery's output at the time of manufacture can fall short of its requirements, resulting in an initial SOH of less than 100%. So, this research aims to obtain the state of SOH or for the estimation of SOH by the prediction from the actual values of battery' SOH. This research predicted the electric battery's SOH by taking 200 datasets and analysing the state of EV's SOH. It is predicted by this research, whether the state of the battery's SOH is acceptable, or low for predicted reading according to the threshold value decided. The threshold value of the battery's SOH decided according to the predicted readings. If the electric battery's SOH value is below threshold value, then, the state of the battery's SOH is low otherwise SOH of the battery is acceptable.**

Keywords—Component; formatting; style; styling; insert (key words)

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) organisation [1] the transportation industry alone accounted for 27% of overall European Union greenhouse gas emissions. 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 [2],[3]. GM Chevy-Volt, BMW Mini E, Tesla Model S, Renault Zoe, Nissan Leaf EV, Chrysler 200 C EV, and Mitsubishi iMi EV almost all EVs on the road [4],[5]. EV batteries must be handled more efficiently to expand driving range, optimise power consumption, prolong battery life, boost battery efficiency, and ensure safe operations. In general, electric vehicle uses a dedicated module called a battery management system (BMS) to ensure that the battery is safe and efficient. Improper battery maintenance can contribute to safety problems such as rapid battery ageing and excessive heat, which can lead to an explosion [3,6]. One of the most important BMS operations is the precise measurement of the battery's state-of-health (SOH). This ensures that LIBs behave in a healthy and predictable fashion by calculating their remaining lifespan and forecasting their failure state [1].

II. ELECTRIC VEHICLES

EVs (Electric vehicles) and HEVs (hybrid electric vehicles) have been recognised 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 [1]. 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 optimised 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.

A. Types Of Electric Vehicles

(1) BEV– AEV: For the propulsion, all electric vehicle (AEV) or a battery-electric vehicle (BEV) uses high-density batteries and an electric motor (Figure1.1a). It has no fuel tank, fuel cell, or internal combustion engine, and receives all its power from its battery pack. The only way to recharge the car's battery is to attach it to a charging station. [4-8]. This is the case of Mercedes-Benz B-Class and the Chevy Spark Electric vehicle.

(2) HEV: The Hybrid Electric Vehicle (HEV) is the second type, which utilises a mechanical combination of an electric motor (EM) for low-speed in-city traffic and a conventional internal combustion engine (ICE) for use in the outside of urban areas (Figure.1.1b). When the ICE mode is engaged, the EM is switched off, and the batteries are charged with an alternator operated by the same ICE. The HEV is converted to a Plug-in Hybrid Electric Vehicle (PHEV), which includes an externally pumped modern battery charging system. When the batteries are drained and the driver is unable to brake for charging, the combustion engine takes over. Porsche launched the Panamera Plug-in S E-Hybrid, a substitute for the conventional Panamera Hybrid that provides increased driving responsiveness and fuel economy [8, 9].

(3) RPEV: In the third category Extended Range Electric Vehicles (EREV or REEV) are the most important in the given structure (Figure.1 c), vehicle propulsion is solely provided by an electric motor powered by high-capacity batteries. A small motor-generator unit is used to hold these powered batteries. [10]. The all-new 2014 Cadillac ELR, the AUDI A1 e-Tron, and Jaguar's Limo-Green range are the first REEVs to enter in the market this year.

(4) FCEV: Aside from these three main types, a long-distance fuel cell electric vehicle (FCEV) has been produced. A fuel cell module drives the on-board electric motor (Figure1.1 d). Proton Exchange Membrane (PEM) fuel cells, often recognized as Polymer Electrolyte Membrane (PEM) fuel cells, are being used in FCEVs to produce energy from hydrogen contained on board and oxygen from the atmosphere. FCs, like conventional ICEs, keeps generating energy as long as there is a fuel supply [11-13].

(5) SEV: A solar electric vehicle (SEV) is a type of electric vehicle that runs partially or entirely on solar power. Solar arrays installed on top of the vehicle, which are normally photovoltaic (PV) batteries, turn solar energy directly into electric energy. Photovoltaic modules are commercially used as auxiliary power units for various electric vehicles, especially plug-in hybrid electric vehicles [17]. Sensors help the driver in the same way as conventional vehicles do. The data gathered here is used to monitor the car's energy usage, solar energy recovery, and other parameters. SEVs can be packed with a battery pack that allows for continuous driving on rainy days or at night, granting users more autonomy.

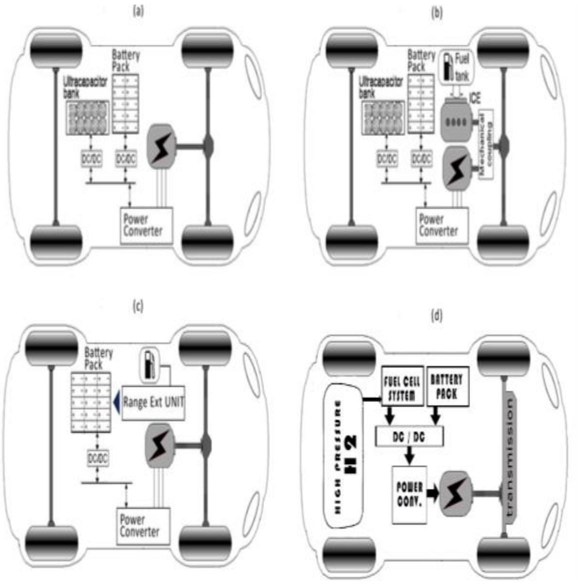

Fig.1. Key Electric Vehicle Drivetrain Architectures Simplified: (a): Battery Electric Vehicle (b): Hybrid Electrical Vehicle (c): Range Extended Electric Vehicle (d): Fuel Cell Electric Vehicle

III. RESEARCH METHODOLOGY

In the current research from the list of limitations for SOH methods and also for the methods which relied over the data driven techniques are considered. As in the literature, current voltage and temperature data for further analysis are obtained from a battery's complete life cycle. We also introduce compared with the CV charging duration; the current time constant is a more stable characteristic parameter relevant to battery ageing in the current job. The CV charging current is represented in a recursive manner dependent on the employed ECM to achieve a comprehensive expression of the current time constant. The task of calculating by constructing a novel function vector consisting of variations in derived voltage values and average battery temperature, SOH is approached using the partial charging info. For each partial loop, we used about 15 minutes of charging data to produce the function vector. A feature vectors respect to various SOH levels are created from 100 percent to 80 percent for training purposes.The architectural block diagram of the whole methodology is described in Figure 2. A total of six blocks are there and have individual descriptions or their own tasks; we can see the architectural representation below.

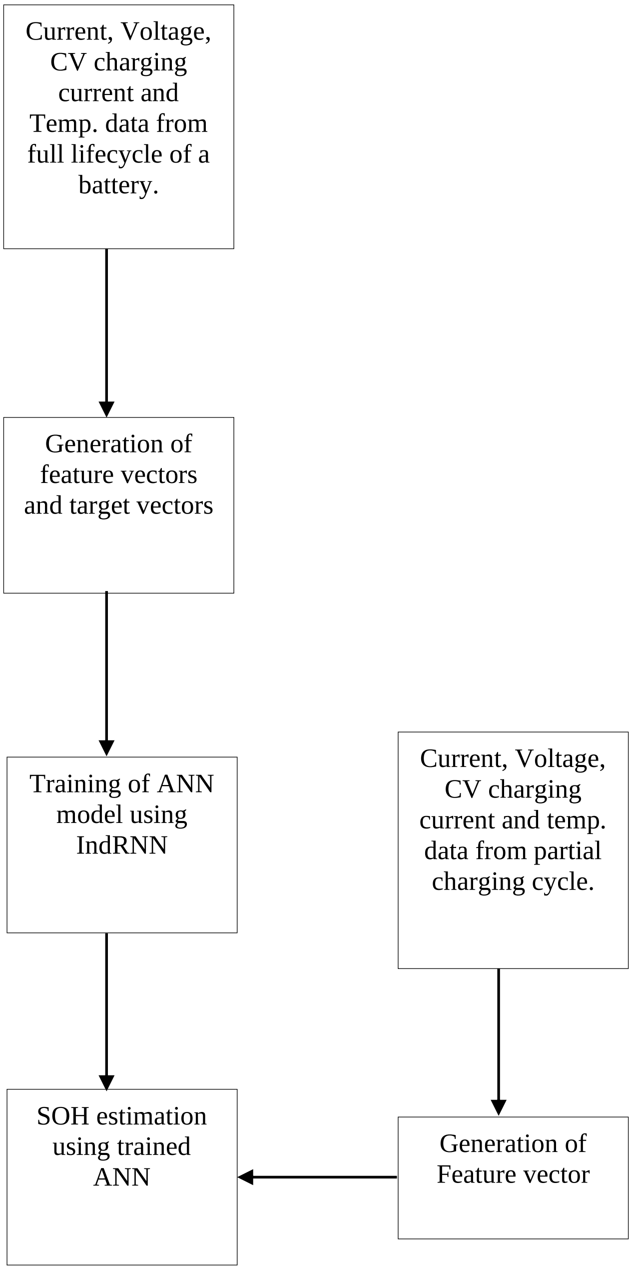

Fig.2. Architecture Block Diagram of Proposed Methodology

A. Independently Recurrent Neural Network (IndRNN)

IndRNN is a new form of RNN. Neurons in the similar layer are independent of one another in IndRNN, but they are related across layers. Although letting the network for learning long-term dependencies, an IndRNN can be easily supervised to avoid gradient exploding and disappearing problems. Furthermore, an IndRNN can be trained robustly using non-saturated activation functions like the rectified linear unit. To build a network that is greater than the current RNNs, several IndRNNs can be stacked. When compared to conventional RNN and LSTM, IndRNNs have shown to perform better on a variety of tasks. Figure 3 shows diagrammatical representation of IndRNN.

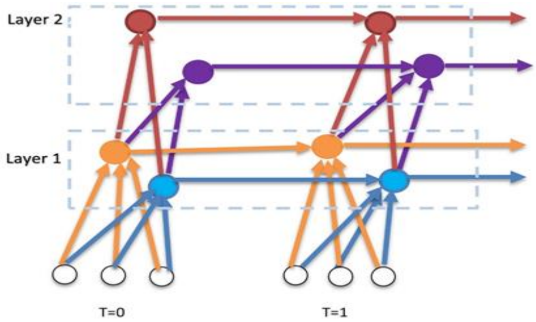

Fig.3.IndRNN

B. Artificial Neural Network (ANN)

ANN is a high-performance computing device whose core theme is inspired through biological neural networks. Parallel distributed processing systems, connectionist systems and artificial neural systems are all terms utilized to describe ANNs. ANN collects a larger number of units that are linked in several way to enable contact between them. These modules, also recognized as neurons or nodes, are basic processors that work in a parallel manner. A connection relation connects every neuron to another neuron. Every communication link has a weight associated with it that contains data about the input signal. Since the weight normally excites or prevents the signal being communicated, this is the greatest valuable knowledge for neurons for solving a particular issue. An activation signal is an internal state that each neuron has. The output signals produced through combining input signals with the activation rule can be sent to other units[25]. The architectural representation of ANN is shown in Figure 4.

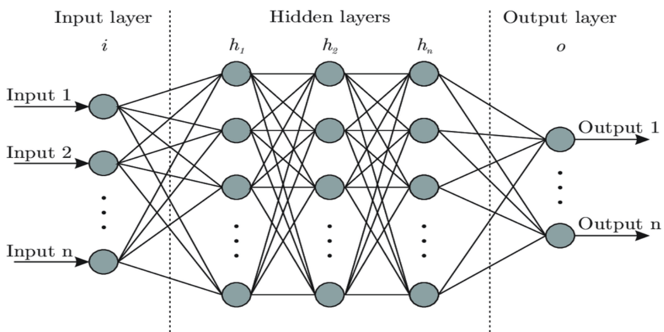

Fig.4. Artificial neural network architecture (ANN i-h1-h2-hn-o)

C. State-of-Health (SOH)

SOH refers to the current state of an ageing battery's ability to deliver specific output as opposed to its ability to deliver specific performance when it was in its initial state. SOH notifies you of the battery's age and state of deterioration, as well as when it's time to replace it. The battery is no longer available for vehicular applications once its performance has degraded to 80% of its rated capacity. It should be replaced. The battery SOH is calculated by dividing the real power by the nominal capacity.

IV. RESULTS

Firstly, the input data of the battery's SOH have been taken for the prediction. The input data of the battery's SOH is shown in the below Figure 5.The readings of input data are taking place between 0 to 200 and the readings of SOH are between 50 to 100. The varying lines in the graph which is shown in the below figure are the input data of State of Health of the battery. The state of health (SOH) is varying for every battery as seen in the below graph. These readings of SOH are varying between 50 to 100 of 200 datasets.

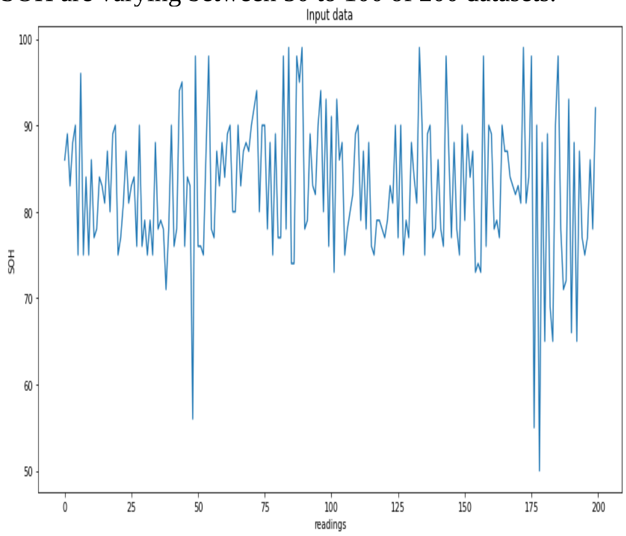

Fig.5. Input Data of SOH

The eleven values or predicted readings of battery's SOH which have been taken for the estimation are 88.31448966, 88.79806674, 88.77619416, 89.37145895, 89.4401083, 89.77072042, 90.14114654, 90.45027453, 90.55070615, 90.8250699 and 90.79064447, respectively. According to these values the threshold value is taken or decided by which the estimation of SOH of battery will be obtain. In the estimation of SOH according to the threshold, the state of SOH will be describing that SOH of battery is low for predicted reading or acceptable.

The graph between predicted input and actual input of battery's SOH is shown below in Figure 6. A total of 200 datasets have been taken in this prediction. The blue colour varying line is of actual value, it represents the input value of SOH of battery. The orange colour varying lines shows the predicted value of Soh of battery. The actual or real value of the battery's SOH is shown by blue colour and the predicted value is shown by orange colour.

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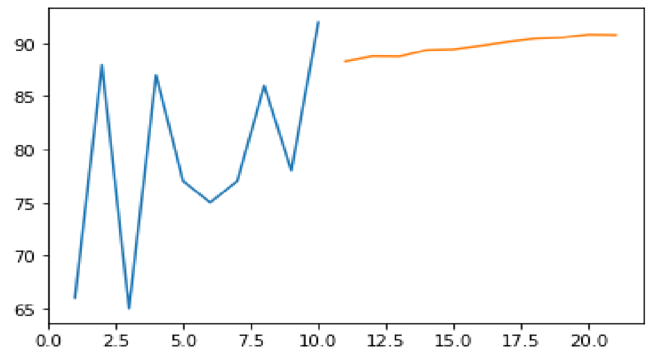

Fig.6. Difference of Predicted Input and Actual Input

From this prediction, certain errors such as mean absolute error (MAE), mean squared error (MSE) and root mean squared error(RMSE) is obtained. In statistics, MAE is a method for comparing errors between paired observations that describe the same phenomenon. Comparisons of predicted versus observed are examples of Y versus X. MSE is used to see how accurate predictions or projections are to real values. The lower the MSE, the closer the prediction is to reality. The RMSE is the square root of the mean of all the errors.

V. CONCLUSION & FUTURE DIRECTIONS

This paper primarily concentrated on the estimation of the Battery's SOH. Adaptive approach, Data-driven approach, direct evaluation approach, and Others are the four basic methods for estimating SOH. These approaches can be combined with other parameters or systems, such as Open circuit voltage, Impedance spectroscopy, and Coulomb counting in the Direct assessment approach, Adaptive approach with Particle filter, Kalman filter, and Least square in the Adaptive approach, Data-driven approach with Fuzzy logic, Neural network, and Support vector machine systems in the Data-driven approach, and in other approaches. In this research, an ANN is used to estimate SOH, i.e., a data-driven approach.

In this research, the prediction of the Electric battery's SOH is made and analyzed the state of battery's SOH. This research predicted that the battery's SOH is acceptable or low for predicted readings according to the threshold value taken. Prediction is made based on 200 datasets for the SOH of the battery. A total of 11 reading of the battery's SOH is predicted for analysing the state of SOH or for the estimation of battery's SOH. According to these readings, the threshold value has been decided. So, by doing this whole process, it has been observed that the utilized prediction method gives great accuracy with fewer errors in predicting values concerning the actual values of SOH.

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