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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Battery Management using Machine learning

A Minor Project Report

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RV College of Engineering®, Bengaluru

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Department of Electrical and Electronics Engineering

CERTIFICATE

Certified that the minor project work titled ***'Battery Management system using Machine Learning,*** carried out by **Harshika Singhal (1RV20EE018), Mansi Ganotra (1RV20EE030), Shashank Sharma (1RV20EE049)** and **Usha K N (1RV20EE059),** the bonafide UG students of RV College of Engineering®, Bengaluru, submitted in partial fulfilment of the requirements for the degree of **Bachelor of Engineering in Electrical and Electronics Engineering** of the Visvesvaraya Technological University, Belagavi during the year 2022-2023. It is certified that all corrections/suggestions indicated for the Internal Assessment have been incorporated in the minor project report deposited in the department library. The minor project report has been approved as it satisfies the academic requirements in respect of minor project work prescribed by the institution for the said degree.

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DECLARATION

We, **Harshika Singhal (1RV20EE018)** ,**Mansi Ganotra (1RV20EE030),Shashank Sharma T.R (1RV20EE049)** and **Usha K N (1RV20EE059),**students of 5th semester B.E., Department of Electrical and Electronics Engineering, RV College of Engineering®, Bengaluru, hereby declare that the minor project titled ***"Battery Management system using Machine Learning"*** has been carried out by us and submitted in partial fulfilment for the award of the degree of **Bachelor of Engineering** in **Electrical and Electronics Engineering** during the year 2022-2023.

Further we declare that the content of the dissertation has not been submitted previously by anybody for the award of any degree or diploma to any other university.

We also declare that any Intellectual Property Rights generated out of this project carried out at RVCE will be the property of RV College of Engineering®, Bengaluru and we will be one of the authors of the same.

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ABSTRACT

The management of battery systems has become increasingly important as more and more applications rely on battery power. To ensure optimal battery performance and longevity, it is critical to accurately monitor the state of the battery, predict its behavior, and control its charging and discharging processes. In case if there is any fault in the Battery Management System(BMS), thermal runaway can occur due to hardware failures.

This paper proposes a battery management system (BMS) that utilizes machine learning techniques to achieve these goals. The BMS integrates sensor data from the battery with machine learning algorithms to accurately predict the battery state, including its state of charge (SoC) and state of health (SoH). The proposed BMS also employs machine learning-based control algorithms to regulate the charging and discharging processes, ensuring the battery operates at its optimal performance while avoiding overcharging or over discharging. The experimental results demonstrate the effectiveness of the proposed system in accurately predicting the battery state and extending its lifetime. The proposed BMS offers a promising approach for managing battery systems with improved efficiency, reliability, and safety.

The main aim of the project is to give fully predetermined , accurate and efficient details on BMS of the battery using the pretested and pre analysed dataset for the determination of the same. The comparative analysis on different algorithms of machine learning has been done to make the best use of the required algorithm for the required parameter. The BMS without using ML has also been quoted to state and observe the error percentage of the algorithm.

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Abbreviation

SoC-State of charge

SoH-State of health

ML- Machine Learning

BMS-Battery management system

RMSE-Root mean square error

LSTM -Long short term memory

Introduction

Chapter 1

CHAPTER 1

INTRODUCTION

Battery management systems (BMS) are critical components in battery-powered devices, ensuring their safe and efficient operation. Traditionally, BMS have been designed using rule-based algorithms, which can be effective but lack the flexibility and adaptability of machine learning (ML) models. In recent years, there has been an increasing interest in applying ML techniques to BMS to improve their performance and accuracy.

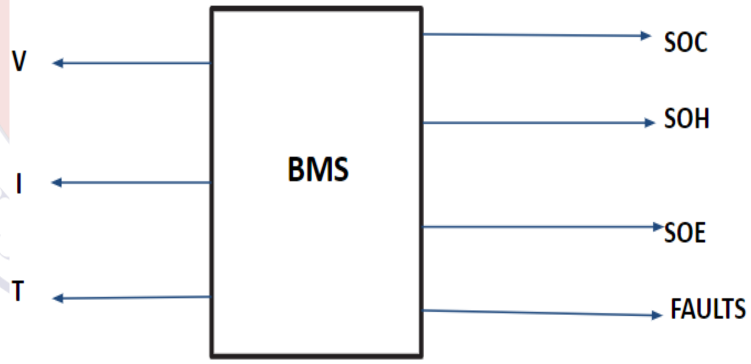

Fig 1.1 Black Box model

ML-based BMS typically involves training a model on a dataset of battery characteristics, such as voltage, current, temperature, and state of charge (SOC). The model learns to predict battery behavior based on these characteristics and can make more accurate predictions than rule-based systems. ML models can also adapt to changing battery behavior over time, which can be challenging for rule-based systems.

1.1 Literature Review

The battery management system is presented within sections i.e., Accuracy of BMS and BMS determination using data driven ML algorithms.

1.1.1 Accurate State-of-Charge Indication for Battery-Powered Applications

Valer Pop stated that the SoC information of the battery only allows it to work according to the design limits, hence the battery pack does not require any complicated engineering. Instead smaller batteries or lighter batteries which cost less can be used.

1.1.2 Predicting the Current and Future State of Batteries using Data-Driven Machine Learning

J. Zhao used machine learning enabled SoC estimator which was installed in a LI-ion battery which was used in EV's. During the conduction of the experiment the model with the help of SoC information had a satisfactory tracking precision.

1.1.3 Advanced Machine Learning Approach for Lithium-Ion Battery State Estimation in Electric Vehicles

Xiaosong Hu successfully implemented machine learning through two steps the first step is genetic fuzzing clustering and the back propagation this ML method can overcome the the challenges of model topology determination and parameter optimization.

1.2 Motivation

- Monitoring the battery requires many types of sensors, this increases the cost, inaccuracy in the system traditionally.
- Using an ML based approach provides flexibility, predictive maintenance and real time monitoring with ease.

1.3 Problem statement

Overcharging and over discharging can damage the batteries and reduce the lifespan of the battery. The BMS must monitor the battery's SoC and SoH and prevent it from going beyond safety limits. But sometimes due to failure of sensors the BMS would turn inaccurate.

Providing real-time monitoring of battery's SoC and SoH to detect any abnormalities and issue alerts to prevent any potential issues. It must ensure the safety of the battery and surrounding environment such as preventing short circuits, leak detection.

Most of the sensors used are passive elements which rely upon external battery source which inturn takes power from the battery. Inorder to avoid these ML approach can be used to determine BMS with enhanced accuracy, improved safety, increased efficiency, scalability and also reduced maintenance cost.

1.4 Objectives

Battery Management Systems (BMS) play a crucial role in ensuring the safe and efficient operation of battery systems. Machine learning techniques can be utilized to enhance the performance of BMS in several ways. Here are some advantages of BMS using machine learning:

- To improve battery life
- To enhance safety
- To achieve better performance
- To reduce maintenance cost

1.5 Organization of report

Chapter 1 - Introduction

Chapter 2-Theory and concept of Battery Management system

Chapter 3- Methodology to implement machine learning algorithms.

Chapter 4- Comparative analysis of SoC

Chapter 5- Comparative analysis of SoH

Chapter 6- Comparative analysis of SoH

Chapter 7- Result and Discussion

Chapter 8- Conclusion and Future scope

Theory and Concept of Battery management system

Chapter 2

CHAPTER 2

THEORY AND CONCEPT OF BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) is an electronic system that manages and monitors rechargeable batteries, ensuring their safe and optimal operation. The BMS typically consists of hardware components, such as sensors, electronic control units, and communication interfaces, as well as software components that analyze and interpret the data from the sensors.

The primary goal of a BMS is to maximize the performance and lifespan of the battery while ensuring safe operation. To achieve this, the BMS performs several functions, including:

- Cell Balancing: The BMS ensures that the individual cells in a battery are balanced in terms of their charge level. This is important to prevent overcharging or undercharging of any one cell, which can lead to premature battery failure.

- State of Charge (SoC) and State of Health (SoH) Estimation: The BMS estimates the SoC and SoH of the battery based on the voltage, temperature, and current measurements. This information is critical to the user, as it helps to determine the remaining battery capacity and expected lifespan.

- Temperature Monitoring: The BMS continuously monitors the temperature of the battery to ensure that it stays within safe operating limits. This is important, as high temperatures can cause thermal runaway, leading to battery failure.

- Overcurrent and Overvoltage Protection: The BMS protects the battery from overcurrent and overvoltage events, which can damage the battery or cause safety hazards.

- Communication: The BMS can communicate with other devices, such as a charger or an electric vehicle controller, to ensure that the battery is charged and discharged optimally.

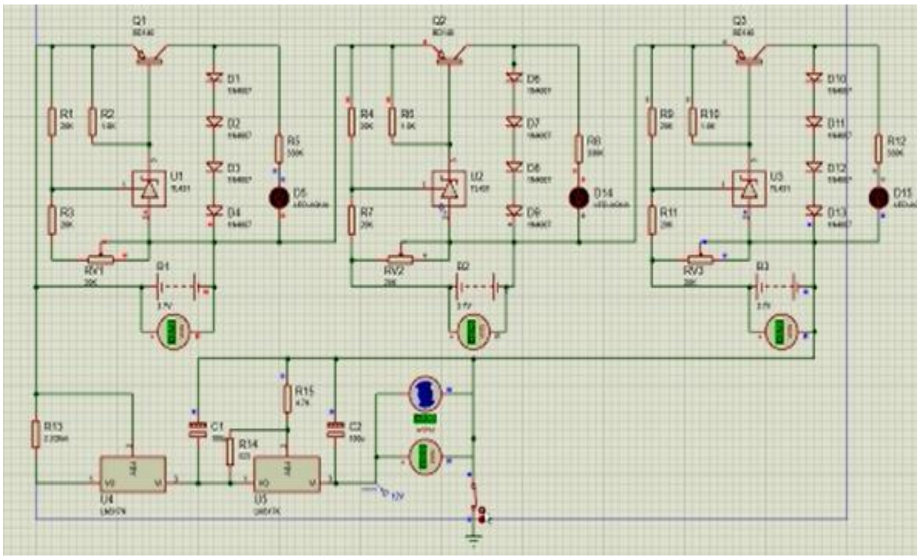

Fig 2.1 Battery management without using machine learning

The Battery management system in a traditional method is depicted in Fig 2.1 . The model includes many types of passive elements to determine the SOC and SOH of the system.Overall, the BMS plays a critical role in managing and monitoring rechargeable batteries, ensuring their safe and optimal operation. By performing cell balancing, SoC and SoH estimation, temperature monitoring, overcurrent and overvoltage protection, and communication, the BMS helps to maximize the performance and lifespan of the battery, while also ensuring safety.

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Methodology to implement machine learning algorithm

Chapter 3

CHAPTER 3

METHODOLOGY TO IMPLEMENT MACHINE LEARNING ALGORITHM

To implement any type of machine learning technique it is very crucial to understand how the technique works . Thereafter the selection of the right algorithm which gives maximum efficiency ,less mean deviation error and has good memory and longevity. The basic operation of the machine learning technique has been depicted in Fig 3.1

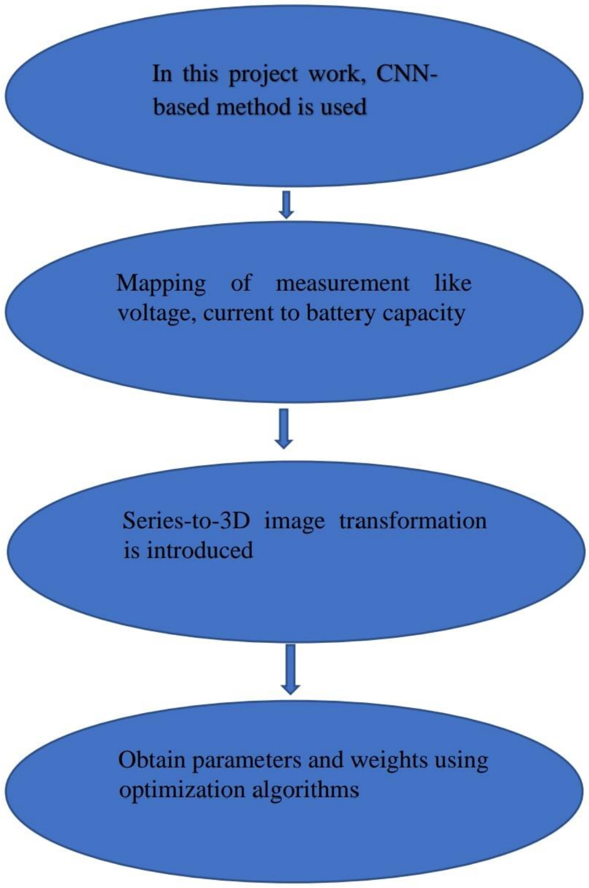

Fig 3.1 Overview of methodology

3.1 Process to implementation of the algorithm

Implementing ML in a BMS can help improve the performance and longevity of battery systems. Here is a suggested methodology to implement ML in a BMS:

- Define the problem: Identify the battery management problem that you want to solve using ML. For example, you may want to predict battery SoH, optimize charging and discharging profiles, or detect faults and anomalies in the battery system.
- Gather data: Collect and prepare the relevant data for analysis. This may include battery voltage, current, temperature, and impedance data, as well as environmental and usage data. You may also need to acquire data from battery testing and monitoring equipment.
- Choose the algorithm: Select the appropriate ML algorithm that will best address your battery management problem. This may include regression, classification, clustering, or deep learning models. Consider factors such as the size and complexity of the data, the desired level of accuracy, and the available computational resources.
- Train the model: Use the prepared data to train the selected ML algorithm. This involves splitting the data into training and testing sets, defining the model parameters, and iteratively refining the model until it achieves satisfactory performance.
- Evaluate the model: Evaluate the performance of the trained model using relevant metrics, such as prediction accuracy, false positive and false negative rates, and receiver operating characteristic (ROC) curves. This step will help identify potential issues or biases in the model and determine if it meets the desired performance criteria.
- Integrate with BMS: Once the model has been tested and validated, integrate it with the BMS. This may involve developing an API or a plugin that allows the BMS to communicate with the ML model.
- Monitor and optimize: Continuously monitor the performance of the ML model and update it as necessary. This may involve retraining the model with new data, adjusting the model parameters, or adding new features to improve its accuracy and effectiveness.

Overall, implementing ML in a BMS requires careful planning, data preparation, algorithm selection, model training, evaluation, integration, and ongoing monitoring and optimization. By following this methodology, battery manufacturers and energy storage system operators can improve the performance and reliability of their battery systems, leading to better efficiency, reduced costs, and increased safety.

Comparative analysis of SoC

Chapter 4

Chapter 4
Comparative analysis of SoC

Firstly, a training set is constructed which uses the battery current, battery voltage, battery temperature and other correlation factors as the model's training input and the corresponding battery SoC as the model's training output. Then, the model was trained with the below algorithms. Finally, the trained model was applied to the battery SoC estimation.

Chapter 4.1 Using the Random Forest Algorithm for SoC

The Random Forest Algorithm works well to determine the SoC. This is because the Random Forest is capable of performing both Classification and regression tasks. It is capable of handling large datasets with high dimensionality. It enhances the accuracy of the model and prevents the overfitting issue. The below figure Fig 4.1 shows the SoC using Random Forest algorithm.

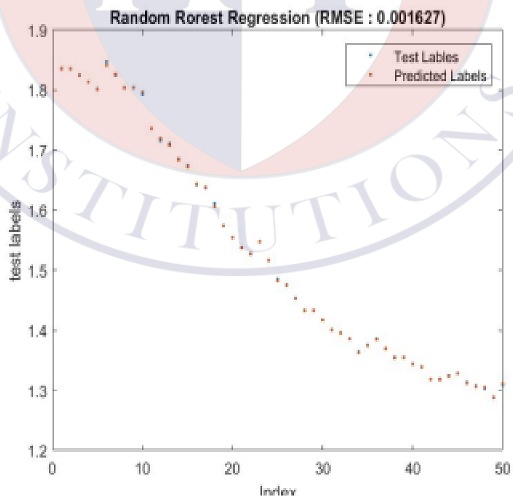

Fig4.1 Random forest regression

Chapter 4.2 Using the Neural Network for SoC

This series of algorithms mimics the operation and recognises the vast data relationship . This algorithm helps make computer intelligent decisions with less human interference. The below following figures i.e., Fig 4.2 shows us the mode result of the SoC estimation and Fig 4.3 shows the test result of the same.

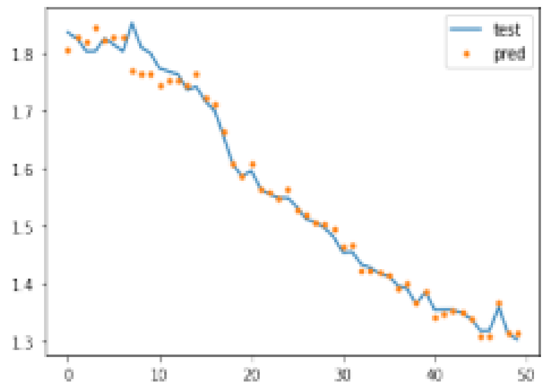

Fig 4.2 Model result of neural network

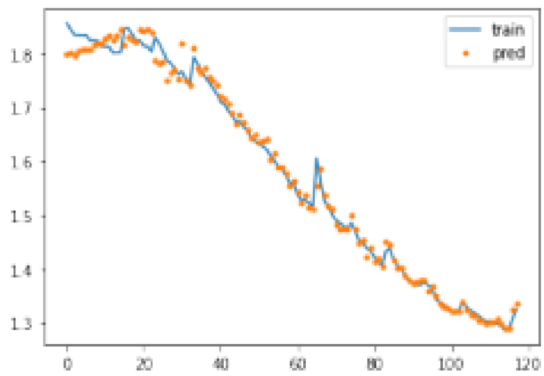

Fig 4.3 Test result of neural network

Chapter 4.3 Using the Line regression for SoC

This is a simple equation which makes the point best fit to a line as per the data available . The formula for simple linear regression is Y= mX+c where Y is the dependent variable parameter, X is the independent variable, m being the slope of the curve with best fit and c is constant. The below figure shows Fig 4.4 shows us the result of SoC estimation using the same algorithm.

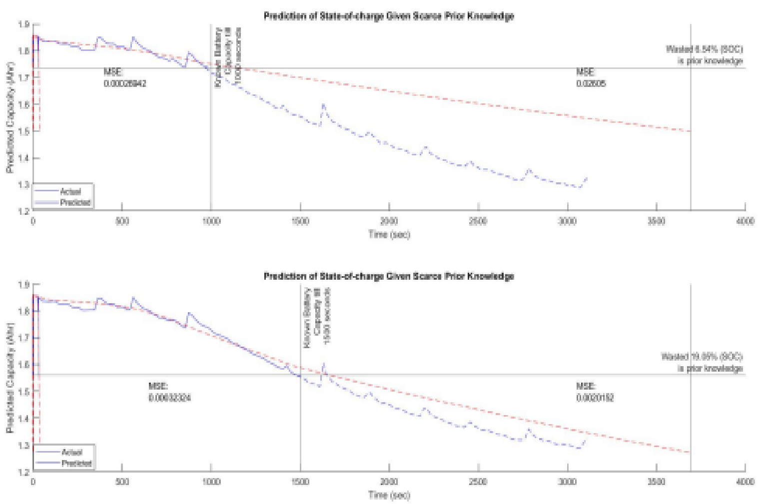

Fig 4.3 Line regression

Comparative analysis of SoH

Chapter 5

Chapter 5
Comparative analysis of SoH

The calculation and visualisation of SoH parameters is trained and implemented using the LSTM and line regression algorithm. Same as in SoC, SoH also needs the creation of a training set.The temperature is the major parameter in the determination of the SoC. In the below estimation we can see the SoH statement of the battery also varying with the temperature.

5.1 Linear regression model for SoH

Linear regression is the simplest machine learning adaptive way. But this gives us the major error due to the best fitting technique involved. The result of temperature can be seen by observing the graphical plots of the batteries B07 and B47. Fig 5.1 shows the change of SoH of the battery state with number of charge and discharge cycle starting at 50% . Fig 5.2 shows the same starting at 70% of the data.

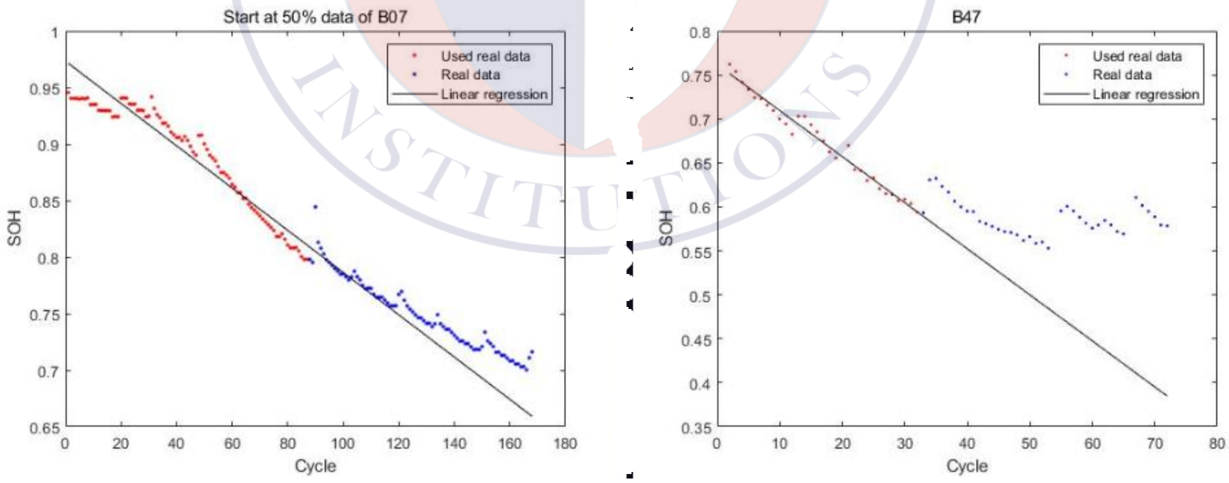

Fig 5.2 Linear regression 70% cycle

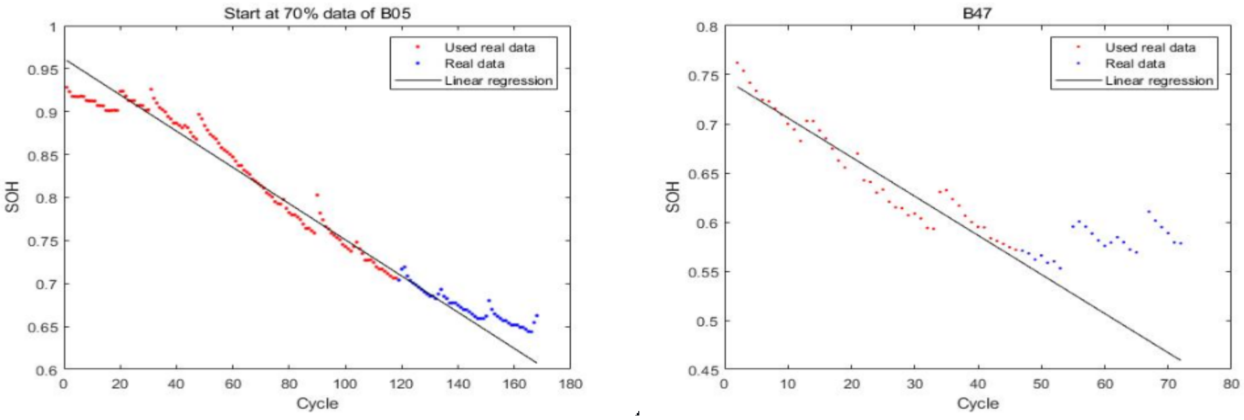

Fig 5.2 Linear regression 70% cycle

5.2 Long short term memory for SoH

Long short-term memory (LSTM) is an artificial neural network used in the fields of artificial intelligence and deep learning. The LTSM algorithms are better at handling long term dependencies. This is due to their ability to remember information for extended periods of time. The Fig 5.3 shows us the 50% cycle of the LTSM trained algorithm for determination of SoH and Fig 5.4 shows us 70% start cycle for the same .

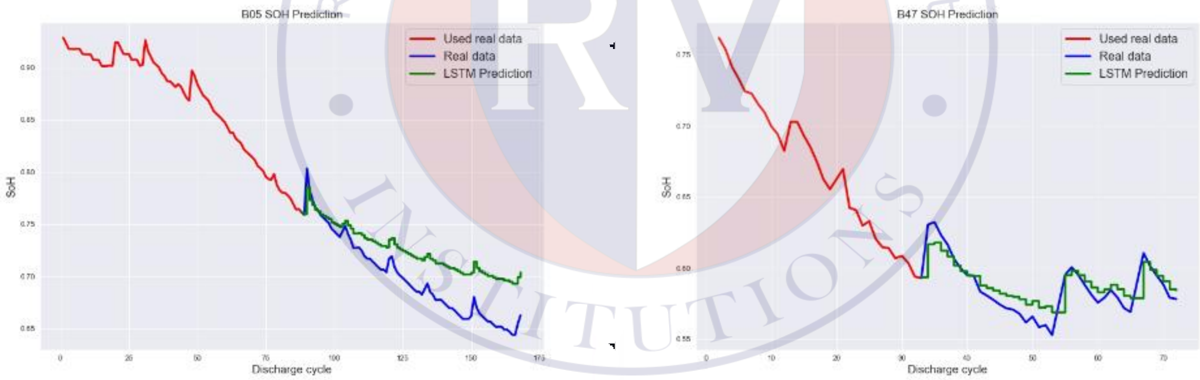

Fig 5.3 LSTM 50%Cycle

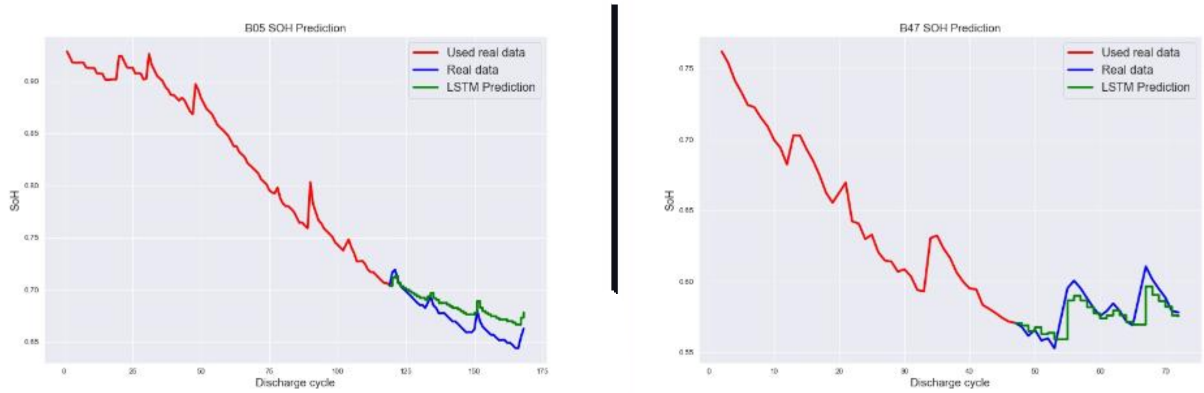

Fig 5.4 LSTM 70%Cycle

Results and Discussions

Chapter 6

Chapter 6
Results and Discussion

As per the observations drawn by all the above discussion and proper interpretation of the graph and finding out the error in each step of the algorithm.We can tabulate the errors . Table 6.1 shows us the Root mean square error of the different algorithms used to determine the SoC of the battery.

Table 6.1 Error analysis of the battery SoC

	Random forest regression	Neural network	Line regression
RMSE	0.0188	0.0707	0.0231
Training time (sec)	6.743	5.60	4.464
Prediction speed (obs/sec)	5427	6250	2100

Through the above result obtained it can be clearly said that the Random Forest algorithm works best in determining battery SoC parameters.

Error estimated fo SoH parameters at different temperature for the different algorithms has been tabulated in Table 6.2

Table 6.2 Error analysis of the battery SoH

	A						B				C					
	B05		B07		B18		B33		B34		B46		B47		B48	
	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%
Linear regression	0.1599	0.1431	0.1190	0.1315	0.1389	0.1231	0.0303	0.0351	0.0255	0.0273	0.0654	0.0385	0.1129	0.0543	0.0973	0.0470
LSTM	0.030	0.014	0.026	0.015	0.056	0.009	0.024	0.016	0.008	0.011	0.018	0.007	0.008	0.006	0.009	0.009

Conclusion and Future scope

Chapter 7

CHAPTER 7
Conclusion And Future Scope

6.1 Conclusion

In conclusion, the integration of machine learning algorithms with battery management systems (BMS) has the potential to revolutionize the performance, efficiency, and reliability of battery-based energy storage systems. Machine learning algorithms can learn from past battery performance data, optimize battery cycling, and predict maintenance needs, among other things, thus improving battery life and reducing maintenance costs. Additionally, machine learning algorithms can improve the accuracy of state of charge and state of health estimation, detect battery faults in real-time, and optimize energy management in complex systems with multiple batteries and energy sources.

Demand for battery-based energy storage solutions continues to grow, the future of BMS technology with machine learning looks promising. However, challenges remain, including the need for standardized testing protocols, the need for large amounts of data to train machine learning algorithms, and the need for robust communication protocols to ensure compatibility between different BMS technologies. Nonetheless, the potential benefits of using machine learning in BMS technology are significant, and continued research and development in this area will be crucial to unlocking the full potential of battery-based energy storage systems

6.2 Future scope

- Predictive maintenance: Machine learning can be used to analyze data from batteries and predict their performance, degradation, and failure. This can help prevent unexpected downtime and reduce maintenance costs.
- Optimal control and scheduling: Machine learning algorithms can optimize the charging and discharging of batteries to minimize their degradation and maximize their efficiency. This can improve the battery's performance and extend its lifespan.
- Capacity estimation: Machine learning algorithms can estimate the capacity of batteries in real-time based on their usage patterns, temperature, and other parameters. This can help prevent overcharging and over-discharging of batteries, which can lead to reduced lifespan.

- Improved SOC and SOH estimation: Machine learning algorithms can learn from past battery performance data to improve the accuracy of SOC and SOH estimation, even under changing operating conditions.
- Real-time fault detection: Machine learning algorithms can detect and diagnose battery faults in real-time, based on patterns and anomalies in battery performance data. This can help prevent catastrophic battery failures and improve system safety.
- Optimal battery cycling: Machine learning algorithms can optimize battery cycling to maximize battery life, by learning from past performance data and adjusting charging and discharging cycles accordingly.

6.3 Learning Outcomes

Studying BMS using machine learning gained a deeper understanding of how batteries perform under different conditions, and how different algorithms and techniques can be used to improve battery performance and extend battery life. Development of a solid understanding of machine learning algorithms and techniques, including supervised and unsupervised learning, regression analysis, and neural networks and also strong foundation in the principles and technologies used in energy storage systems, including battery chemistry, energy conversion, and power electronics.

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