

Monitoring and Prediction of Battery Life in Electric Vehicle: A Comparative Study

Deepu.S.R.¹, Dr.N.Karthick² and Neethu.U³

^{1,3}Research Scholar, School of Electronics & Electrical Engineering, Lovely Professional University, Punjab
Email: mail2deepusr@gmail.com, neets7r@gmail.com

²Associate Professor, School of Electronics & Electrical Engineering, Lovely Professional University, Punjab
Email: karthick.23586@lpu.co.in

Abstract—In electric vehicles, battery management systems (BMS) are used to monitor and control the charging and discharging of rechargeable batteries, making the operation more efficient. The battery management system keeps the battery safe and reliable while increasing senility without causing damage. Lithium-ion batteries are frequently employed in electric vehicles due to their high energy and current density. Unfortunately, if lithium-ion batteries are not used within their Safety Operation Area, they can be harmful (SOA). As a result, every lithium-ion battery, especially those used in electric vehicles, must have a battery management system (BMS). The focus of this research is to monitor and predict the battery health condition using a machine learning algorithm and hence to improve the performance of the battery management system and hence extend the battery life. To improve the performance of the battery life three models are used to find out the battery's health condition. Models used are Random Forest classifier, logistic regression, and KNN is used to find out the accurate model in which KNN with machine learning algorithm is used to predict battery heath condition.

Index Terms— electric vehicle, battery management system, safety operation area, random forest classifier, logistic regression and KNN algorithm.

I. INTRODUCTION

Electric mobility has emerged as a critical component of the transportation industry's future. Detection, prognosis, and diagnosis of faults in electric drives increase the reliability of electric vehicles (EVs). To include safety elements that reduce the frequency of accidents and fatalities on the roads, on-board electronics systems must perform properly in all operational scenarios [1]. The effectiveness of electric vehicles is determined by the appropriate performance and diagnostics of battery storage systems, as well as a detailed assessment of key elements. Electric vehicles often have a limited range of travel due to battery size and body design. One of the key challenges restricting the deployment of electric vehicles is the current battery technology's safety.

An electric vehicle's key components include an electric motor, a motor controller, a traction battery, a battery management system, a plug-in charger that may be operated independently from the vehicle. One of the most significant components, especially when employing lithium-ion batteries, is the battery management system.

There are three types of traction batteries on the market right now: lead-acid, nickel-metal hydride, and lithium-ion. Lithium-ion batteries have several advantages over the other two types of batteries, and they work well when used with a good battery management system.

II. LITHIUM-ION BATTERY

Lithium is the lightest metal in nature, with the greatest electrochemical potential and the highest energy density per weight. Rechargeable batteries with lithium as the anode might give high voltage, high capacity, and a remarkable high energy density.

Unlike conventional batteries, the lithium-ion battery requires essentially minimal maintenance over its lifetime. There is no requirement for scheduled cycling, and the battery has no memory effect. Furthermore, because its self-discharge rate is less than half that of lead-acid and NiMH batteries, lithium-ion batteries are highly suited for electric cars.

Despite their benefits, lithium-ion batteries have several disadvantages. Ions of lithium are fragile. A safety mechanism must be built into each pack to ensure the safe operation of these batteries. The battery management system (BMS) is a device that regulates the peak voltage of each cell during charging and prevents the cell voltage from falling below a threshold while discharging. The BMS also monitors the cell temperature and controls the maximum charging and discharging currents.

III. BATTERY MANAGEMENT SYSTEM

Figure 1 shows battery management system. Though batteries used in electric vehicles should not be overcharged or over drained, the battery management system (BMS) is a critical system in electric vehicles. If this happens, the battery will be damaged, the temperature will rise, the battery's life span will be reduced, and the people who are using it will be affected. It's also utilised to extend the range of a vehicle by efficiently utilising the energy stored in it.

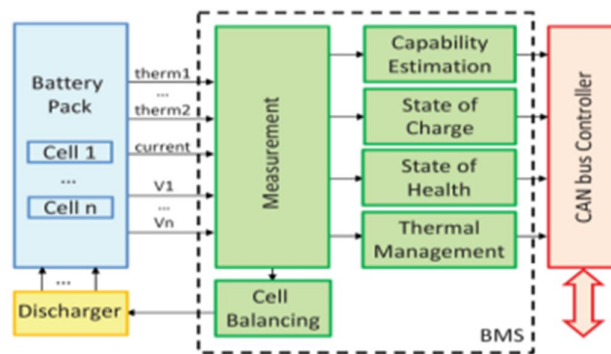


Figure 1. BMS block diagram

To avoid battery failures, various types of BMSs are employed. A battery monitoring system, for example, records essential operational characteristics such as voltage, current, and the battery's internal temperature, as well as the ambient temperature, while charging and discharging. If any of the parameters exceed the values defined by the safety zone, the system delivers inputs to the protective devices, which can create warnings and even disconnect the battery from the load or charger.

IV. LITHIUM-ION BATTERY MANAGEMENT

Electric vehicles have the potential to benefit the global economy and the environment. EV systems, including the safe operation of the ESS in the vehicle, which is vital to EV technology, must be carefully maintained to increase their performance over time. All charging and discharging functions, as well as battery cell voltage monitoring and balancing, battery charge equalisation, input/output current and voltage monitoring, temperature control, battery protection, and fault diagnosis and assessment, are all handled by the battery management system (BMS) in electric vehicles.

V. STATE-OF-CHARGE DETERMINATION

The available amount of battery expressed as a percentage of the battery's rated capacity is known as the state of charge. State of charge assists the battery management system in determining the state of the battery, allowing it to run within a safe operating range by controlling charging and discharging. It also extends the battery's useful life. It is impossible to estimate the state of charge directly.

VI. BATTERY MODEL

Because the charging and discharging behaviour of rechargeable batteries is dependent on factors such as temperature, self-discharge rate, and capacity, it is vital to carefully create models that appropriately represent this behaviour.

VII. SELF-DISCHARGING

A significant resistance in parallel with the battery terminals can easily depict the battery's self-discharging activity. Figure 2 depicts the electrical circuit that takes self-discharging into account. The self-discharging resistance is determined by the specific battery type's self-discharging time, which can be found on the battery data sheet.

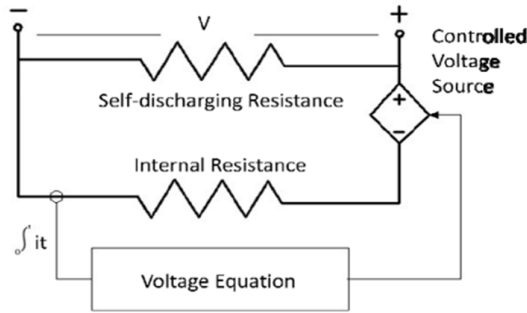


Figure 2. Self-discharging of battery

Open circuit voltage,

$$V = E - (R + R_r)i \quad (1)$$

VIII. EFFECT OF TEMPERATURE

The effects of temperature and humidity on battery performance are also possible. When the ambient temperature exceeds the suitable operating range, batteries do not work according to their usual and planned parameters. This is not a flaw in the product, but rather a result of the extreme weather. As a result, a battery should not be utilised in an environment that it was not intended for.

Extreme weather conditions occur when the ambient temperature and relative humidity of a certain environment are adjusted beyond the ordinary. These problems can strike practically anywhere and at any moment. Severe conditions can occur outside, in a room with no air conditioning, or in a closed car on a hot day, for example. Severe weather can cause the battery to cease working, bulge, bubble, melt, get damaged, produce smoke, sparks, and flames, expand, contract, or even explode in extreme situations.

Extreme weather can also happen when relative humidity raises the ambient temperature above the battery's acceptable working range. The operation of batteries is influenced by temperature because electrons become more or less energetic as the temperature rises or falls.

IX. FADING CAPACITY EFFECT

Lithium-ion batteries are known to have a finite lifespan since their capacity to hold a charge degrades over time and is irreversible. The amount of time a battery can power a gadget (also known as run time) reduces as its capacity decreases. The battery's overall performance degrades over time as the system cycles through repeated repetitions of charge and discharge.

A lithium-ion battery's usual life expectancy is two to three years, or 300 to 500 charge cycles. In high-performance applications like electric automobiles, it's critical to have a precise understanding of the battery's current state and remaining lifespan.

X. BMS HARDWARE

The BMS design for tiny applications that use lithium-ion batteries, such as laptop computers, could be as basic as an application-specific integrated circuit (ASIC) that performs all BMS operations. These chips have two

constraints when it comes to huge lithium-ion battery packs. The first constraint is that these chips are built for low battery currents, which are normally measured by a PCB-mounted resistor, rather than high currents, which are often detected by a Hall-effect sensor or a current shunt in big packs. Without knowledge of the battery current, any powerful intelligence in the chips would be useless. The second constraint is that these chips can only handle a series of cells. Electric vehicles should employ BMSs designed for large packs rather to those designed for small packs to avoid these restrictions.

XI. ANALYSIS AND DISCUSSIONS

Li-ion batteries are used in EVs with a number of series-connected battery cells in a pack for energy storage. (as shown in fig.3) EV batteries can be charged and discharged from an external source to power the EV driving motor and systems. Because of changes in their physical features, a successive charge-discharge cycle may generate a voltage and charge imbalance among the battery cells. Manufacturing, temperature, and cell ageing issues all contribute to this mismatch. The overall performance and endurance of energy storage devices may be harmed by unbalanced voltage and charge profiles. Undercharging can degrade the chemical properties of the battery and limit the life of the battery cells, while overcharging can cause cell explosion.

When the battery is out of the functioning range, the BMS may stop charging and discharging it. As a result, the battery pack may lose its rated charge level, which is required for functioning. As a result, the charge equalisation controller for the series connected battery pack is critical for protecting the battery cells as well as maintaining storage capacity and operation ratings.

Lithium-ion batteries are the most reactive, lightest, and have the most energy. Lithium-ion batteries charge and discharge much more quickly than traditional batteries. To avoid a cascade of chemical reactions, a rise in temperature, cell venting, and fire, lithium-ion batteries should be run beyond their safe operating voltage range. As a result, a battery management system (BMS) is used, allowing the battery to function within its safe operating range.

Figure 3 shows discharging voltage of Lithium-ion battery, the battery operates in the safe zone when a load is applied and thus extend the lifetime of the battery.

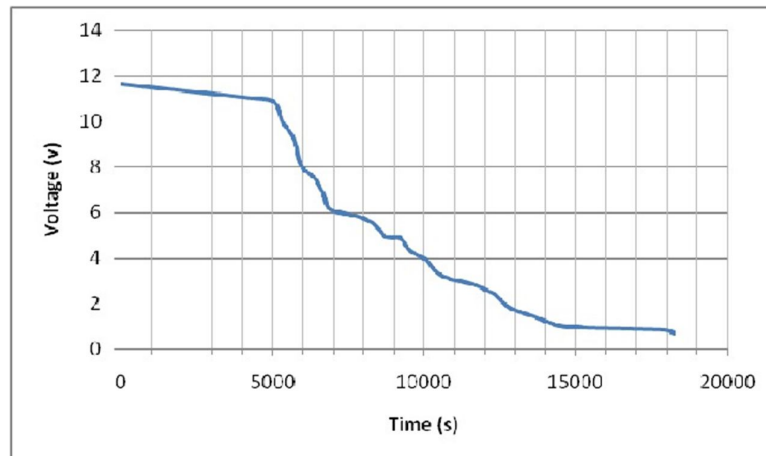


Figure 3. Discharging of Lithium-ion battery

Figure 4 shows the program to predict the battery health condition. To improve the performance of the battery life three models are used to find out the battery's health condition. Models used are Random Forest classifier, logistic regression and KNN is used to find out the accurate model in which KNN is used to predict battery health condition with machine learning algorithm. This improves the life time of the battery.

XII. CONCLUSION

This paper provides a thorough explanation of the battery management system in electric vehicles. Battery is modelled by controlling the values of voltage, current, SoC, temperature. It is critical that the BMS is carefully maintained in terms of battery reliability and safety. State of charge is estimated using deep convolution method which will optimize the range of transportation of EV and improves system performance. To improve

```

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
get_ipython().run_line_magic('matplotlib', 'inline')
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')

df = pd.read_csv('Battery AI.csv')
df.head()

df.info()
df.shape
df.isnull().sum()

df['Energy Consumption'].value_counts()
df['Energy Consumption'].replace('Battery unhealthy', 0, inplace=True)
df['Energy Consumption'].replace('Battery healthy', 1, inplace=True)
df['Energy Consumption'].replace('Battery healthy', 1, inplace=True)
df['Energy Consumption'].value_counts()
plt.figure(figsize = (50,25))
sns.set(font_scale = 5)
plt.subplot(331)
sns.countplot(df['Energy Consumption'])
from sklearn.model_selection import train_test_split
from sklearn import metrics
X = df.iloc[1:200,1:3].values
y = df.iloc[1:200,3].values
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=2)
from sklearn.linear_model import LogisticRegression
model = LogisticRegression()
model.fit(X_train, y_train)
prediction = model.predict(X_test)
print('Logistic Regression accuracy = ', metrics.accuracy_score(prediction, y_test))

from sklearn.ensemble import RandomForestClassifier
clf = RandomForestClassifier()
clf = clf.fit(X_train, y_train)
prediction = clf.predict(X_test)
print('RandomForestClassifier accuracy = ', metrics.accuracy_score(prediction, y_test))

prediction = model.predict(X_test)
print('Knn accuracy = ', metrics.accuracy_score(prediction, y_test))

result = prediction[0]
if (result == 0):
    print("Battery unhealthy")
else:
    print("Battery healthy")

```

Figure 4. Machine learning algorithm to estimate battery health condition

the performance of the battery life three models are used to find out the battery's health condition. Models used are Random Forest classifier, logistic regression and KNN is used to find out the accurate model in which KNN with machine learning algorithm is used to predict battery health condition. This improves the life time of the battery. Furthermore, by utilising a battery management system, the goal of minimising greenhouse gas emissions can be considerably achieved.

REFERENCES

- [1] Aiello, Orazio. "Electromagnetic susceptibility of battery management systems' ICs for electric vehicles: Experimental study." *Electronics* 9.3 (2020): 510.
- [2] Lipu, MS Hossain, et al. "Intelligent algorithms and control strategies for battery management system in electric vehicles: Progress, challenges and future outlook." *Journal of Cleaner Production* (2021): 126044.
- [3] Abd Wahab, Mohd Helmy, et al. "IoT-Based Battery Monitoring System for Electric Vehicle." *International Journal of Engineering & Technology (IJET)* 7.4.31 (2018): 505- 510.
- [4] Caliwag, Angela, et al. "Design of Modular Battery Management System with Point-to-point SoC Estimation Algorithm." *2020 International Conference on Artificial Intelligence in Information and Communication (ICAIIIC)*, 2020.
- [5] Heydari, Shoeib, et al. "Maximizing regenerative braking energy recovery of electric vehicles through dynamic low-speed cutoff point detection." *IEEE Transactions on Transportation Electrification* 5.1 (2019): 262-270.

- [6] El Din, Menatalla Shehab, Ala A. Hussein, and Mamoun F. Abdel-Hafez. "Improved battery SOC estimation accuracy using a modified UKF with an adaptive cell model under real EV operating conditions." *IEEE transactions on transportation electrification* 4.2 (2018): 408-417.
- [7] Sivaraman, P., and C. Sharmeeela. "IoT-Based Battery Management System for Hybrid Electric Vehicle." *Artificial Intelligent Techniques for Electric and Hybrid Electric Vehicles* (2020): 1-16.
- [8] Wang, Weida, et al. "Unscented Kalman filter-based battery SOC estimation and peak power prediction method for power distribution of hybrid electric vehicles." *IEEE Access* 6 (2018): 35957-35965.
- [9] Chandran, Venkatesan, et al. "State of charge estimation of lithium-ion battery for electric vehicles using machine learning algorithms." *World Electric Vehicle Journal* 12.1 (2021): 38.
- [10] Wei, Chun, Mouhacine Benosman, and Taesic Kim. "Online parameter identification for state of power prediction of lithium-ion batteries in electric vehicles using extremum seeking." *International Journal of Control, Automation and Systems* 17.11 (2019): 2906-2916. 23
- [11] Martinez, D. A., J. D. Poveda, and D. Montenegro. "Li-ion battery management system based in fuzzy logic for improving electric vehicle autonomy." *2017 IEEE Workshop on Power Electronics and Power Quality Applications (PEPQA)*, 2017.
- [12] Florea, Bogdan Cristian, and Dragos Daniel Taralunga. "Blockchain IoT for smart electric vehicles battery management." *Sustainability* 12.10 (2020): 3984.