International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Data Analysis of Electric Vehicle Battery

Avanti Joshi[1], Dr. Roopa R.Kulkarni[2]

[1]P.G.Student, Department of Electronics and Communication Engineering, KLS Gogte Institute of Technology, Belagavi, Karnataka,India
[2]Associate Professor, Department of Electronics and Communication Engineering, KLS Gogte Institute of Technology, Belagavi, Karnataka, India

---

Abstract: Nowadays *electric vehicle (EV) are introducing new challenges in the automotive industry. Electric vehicles are mainly beneficial from environmental health. The battery is a major aspect of the electric vehicle which is used to supply power to the vehicle. In a day to day journey, whether it is a fuel vehicle or electrically powered vehicle, it generates a huge amount of data. Electric vehicle has a major data in its battery part as it is one of the essential parameter of vehicle while running. The battery data consist of various parameters such as voltage, current, voltage charge, current charge, temperature which are responsible for estimating the health of a battery. In this paper these parameters are used for predicting the battery life and health.*

The battery data has taken from the NASA and it is stored to local server for processing. Once the data is collected the analysis starts. Battery data analysis includes detail analysis of all the parameters a dataset has. R tool is used for processing and analyzing of the parameters. Linear regression algorithm consisting of R squared value function is used for checking which parameter has major effect on battery life. Using this algorithm the data is split into train and test and then it is processed through the linear model to predict the battery life. All the parameters a dataset has are used for the prediction

R squared and adjusted r squared values are responsible for predicting the difference between predicted and actual value A voltage line is a reference line used for checking the battery life. The current charge value near to the reference voltage line shows the 100% battery life. . Data analysis of a battery data give a lot of information about its health and also it compares the two different battery data sets for predicting which battery pack is batter.

***Key Words*: Data Analysis, Electric Vehicle, Linear Regression, R squared value, R tool.**

1. INTRODUCTION

Now-a days when there is lot of development going on in the transportation and automotive industry, Electrical vehicles (EVs) are the main focused area. Electric vehicles are automobiles powered by electric energy and engine. [2] It has already introduced new challenges in the future of mobility and now it is introducing new questions which will change the way vehicles are used. When EVs come in the picture it is all about the environmental health and the feasibility. Evs have started in the mid-19th and now they have reached at the top in the automotive industry [1].When to talk about Evs, Battery is the "Heart" of an electric vehicle. The working of an EV is totally dependent on how the battery works. Battery can be used to supply power to the vehicle. It is the main part of the whole electric vehicle system which provides power and makes the vehicle start. Different batteries are used in the vehicles such as lithium ion batteries, laid acid batteries, Ni-MH batteries .The most frequently used batteries are Li-ion batteries. Because of their great efficiency and working capacity they are widely used. When batteries come in the picture, the data that batteries have is an important aspect.[6]

Analysis of data is a process in which a lot of transformation, modelling, calculations, cleansing happens to find out the information which is useful for future, and also finding out the conclusions. Data available today is very big and vast. Very few studies have been done related to data. But now every customer wants to know how the battery system works and if it has any fault, what kind of fault it has? And how to recover that fault. To do so the data monitoring is an important part. The data consists of various kind of dada such as sensor data, vehicle data, battery data, driver's data, surroundings data, etc. The data comes when some changes happens in the system and then the parameters changes accordingly. This data is real time data and it can be measured using different tools. Data analysis is the most important and developing streams now a days because it gives exact information about the system and it is easy to find out the faults and errors if any [4]. Battery related data is a major aspect in the electric vehicle. There is huge development going on in the battery technology from last 10 years ,because of which China has made progress in the battery, motor, engine etc. but still it has difficulties that needs to be overcome .Data analysis of battery system will provide an answer to such difficulties. The main point is knowing that what exactly happens inside the electric vehicle. It means that when the electric vehicle is running it produces a huge amount of data daily in the real time.[7]

In this project the main focus is on battery as it is the core of the electric vehicle. The battery data consists of the information such as voltage, current, voltage and current charge, temperature, time etc. Using this data the battery system can be monitored and analyzed to perform further analysis. This project mainly gives an idea about battery analysis depending on the measured data. The data which comes from the data logger of an electric vehicle is stored in the local server (Excel file). The main purpose why the data is stored in the local server is that it can be used offline also whenever needed. The measured data has been taken and can be processed in the R tool in such a way that it gives the information about the battery life (state of health and performance). Linear regression with R squared value is the method followed to predict the battery life [8][10] .The graphical representation of a battery parameters gives a proper visualization. Depending on this representation it can be shown that the battery life is high at certain points and low at certain points and the life of a battery is predicted. This analysis gives overall prediction of how battery works.

1.1 Prediction of Battery Life

The state of charge of an electric battery is an important parameter while predicting the battery life. To know about the end of life of batteries voltage and current are the major components used for evaluation of state of charge of a battery. SOC can be predicted using a voltage and current that is measured. It is nothing but the ratio of remaining capacity to full charge capacity. The capacity is given by measuring the voltage and current drawn from the battery. The battery life is the main issue that needs to be solved in automotive industry. As there is fast development in the automotive domain, the next step is the fully automatic and electric vehicle. So battery is the main concern and that has to be well maintained.[7] The life of battery is what the main feature of the battery. One needs to know everything about the battery, how it works, for how much time and mainly how long it can sustain in the whole trip. More the battery life, more the demand and investment also increases. Looking into all these factors battery life decides the life of a vehicle and indirectly affects the economy of the company too. So prediction of battery is highly important.[11]

1.2 Battery Data

Data is nothing but an information of that particular parameter. Battery data mainly consist of information about its parameters such as voltage, current, temperature, state of charge, discharging rate, etc. By using these basic parameters, estimation of battery performance and life is possible. Every company is asking for the records now-a–days which can be only presented when the proper data is collected from vehicle and analyzed it later. So the data is a big concern of all the automotive companies. The data of a battery has large number of values of voltage, current etc. These values needs to be checked for a proper estimation of battery working. Data storage, processing and visualization are the parameters related to data. For a proper battery monitoring one need to gather sufficient and useful amount of data.[11]

2. OBJECTIVES

The objective of this project is analysis of electric vehicle battery data and predict the battery life using measured parameters. Some of the outcomes are as follows:

i. A multi-dimensional problem (estimate life of a battery and performance of a battery) is solved in this project by analyzing battery parameters such as voltage, current, time, temperature, voltage and current charge.
ii. The battery data is collected over long period of time and under certain considerations.
iii. Electric Vehicle's battery data that comes from data logger should be locked in the local server so that we can easily access it whenever needed and also offline.
iv. Vehicle that will be travelling everyday generates huge amount of data which keeps on changing, so to collect that data and analyze and visualize it is an interesting task and also gives lot of information about vehicle's performance, behavior and status, so gathering of that data is also focused.
v. The graphical representation of the battery parameters will give exact information about the battery and in more efficient way.
vi. Processing of a measured data and extraction of the parameters of battery is really a difficult task which is done in this project.

3. METHODOLOGY

Data analysis of an electric vehicle battery using R tool depending on measured data is one of the efficient methods. The first most important step is gathering of the data that comes from vehicle data logger when vehicle runs for a long period of time. Here the datasets are taken from the DAWN MCINTOSH, NASA Ames Research Center, recorded and tested at NASA Ames Prognostics Centre of Excellence (PCoE) in 2010.The dataset for 4 different Li-ion batteries is provided by the NASA. Since the datasets has large amount of data, only one set of data is considered for analysis of battery life prediction here. The data provided was in the .mat format which is the MATLAB file. This data is 1st converted into the excel format, as it is easy to store the data in excel and even easy for reading and understanding. Here the data is stored in our local server in the excel format. The battery dataset B0006.mat is the 1st data set on which the analysis is done in this project. R tool is the best data analysis tool used here for analyzing the battery data. Once the data is stored in the local server in the excel format it is then imported to the R tool for analyzing and processing.

There are few packages in the R that needs to be installed while reading, processing and plotting the graph. The dataset is then read and imported in the R. The structure of the dataset here is in the string format. The dataset has some random values which are called as outliers. These outliers are responsible for adding noise and unnecessary data or values in the dataset. These are eliminated from the data. The boxplots are generated for confirmation of elimination of the outliers. For every parameter that the dataset has such as voltage measured, current measured, time, temperature, voltage charge, current charge, boxplot of outlier is generated. The data which is now processed is with no noise. The data is then split into two sets such as train and test data with the split ratio of 0.7. Standard values of split ratio is 0.7 as the data is split 70 and 30%. Regression algorithm is used for finding out the R squared value between train and test data. In the data, residuals are selected such as minimum, median and maximum values from test and train data. Depending on that the interpretation is done which includes estimated value, standard value and testing data value. R squared value is used to find out which parameter has major effect on the battery life. The parameter which has more effect say 100% has 3 stars in the output. Using a mathematical equation of time verses voltage measured, temperature and voltage charge, the battery life is predicted.

Equation used for analysis is:

Time ~ `.`, data = train

Where '.' Indicates all the parameters (Voltage measured, current measured, voltage charge,

Current charge, temperature).

In the backend the user interfacing program is run which involves inputs that are provided. The graphical representation needed a background color, font, margin, alignment, title etc. These parameters are provided in the user interface program. It has a server program which is also a backend program that is used for reading and executing all the packages required for execution of main program. All the input, output, session are mentioned here. The output graph that is generated is because of this backend program. It shows the predicted time for battery in the form of graph. As the input parameters are changed, accordingly it will take those values and a predicted time is displayed in the form of value and in the form of a scatter plot.

The data available here is analyzed and the relation between them is found out by regression algorithm and the battery life is predicted in the form of scatter plot.

3.1 Data Set Description

The dataset provided by NASA is carried out under some considerations, they are as follows:

A set of two Li-ion batteries (# 5, 6) were run through 3 different operational profiles (charge, discharge and impedance) at room temperature. Charging was carried out in a constant current (CC) mode at 1.5A until the battery voltage reached 4.2V and then continued in a constant voltage (CV) mode until the charge current dropped to 20mA. Discharge was carried out at a constant current (CC) level of 2A until the battery voltage fell to 2.7V, 2.5V, 2.2V and 2.5V for batteries 5 and respectively. Impedance measurement was carried out through an electrochemical impedance spectroscopy (EIS) frequency sweep from 0.1Hz to 5 kHz. Repeated charge and discharge cycles result in accelerated aging of the batteries while impedance measurements provide insight into the internal battery parameters that change as aging progresses. The experiments were stopped when the batteries reached end-of-life (EOL) criteria, which was a 30% fade in rated capacity (from 2Ahr to 1.4Ahr). This dataset can be used for the prediction of both remaining charge (for a given discharge cycle) and remaining useful life (RUL).

3.2 Data Structure

The data structure is also provided by the NASA: cycle: top level structure array containing the charge, discharge and impedance operations, type: operation type, can be charge, discharge or impedance. Ambient temperature: ambient temperature (degree C), time: the date and time of the start of the cycle, in MATLAB date vector format, data: data structure containing the measurements.

for charge the fields are: Voltage _measured: Battery terminal voltage (Volts),Current_ measured: Battery output current (Amps), Temperature measured: Battery temperature (degree C),Current charge: Current measured at charger (Amps),Voltage charge: Voltage measured at charger (Volts),Time: Time vector for the cycle (secs),

For discharge the fields are:

Voltage measured: Battery terminal voltage (Volts), Current measured: Battery output current (Amps), Temperature measured: Battery temperature (degree C), Current charge: Current measured at load (Amps), Voltage charge: Voltage measured at load (Volts), Time: Time vector for the cycle (secs), Capacity: Battery capacity (Ahr) for discharge till 2.7V.

For impedance the fields are:

Sense current:Current in sense branch (Amps), Battery current: Current in battery branch (Amps), Current ratio: Ratio of the above currents, Battery impedance: Battery impedance (Ohms) computed from raw data, Rectified impedance: Calibrated and smoothed battery impedance (Ohms),Re: Estimated electrolyte resistance (Ohms), Rct: Estimated charge transfer resistance (Ohms).

3.3 Algorithm

1) Collect the data from the electric vehicle battery which has parameters such as voltage measured, current measured, time, temperature, voltage charge and current charge.

2) Store the data in the local server and in the excel format (Database creation)

3) Import and read the database in the R tool.

4) Split the data into Train and Test data using linear regression method.

5) The algorithm for linear regression is as follows:

To find the relationship between two continuous variable simple linear regressions is used. In these two variables one is independent or predictor and other one is dependent variable. Simple linear regression uses statistical relationship than deterministic relationship. When one variable is expressed exactly by another variable then it is called deterministic relationship. Example of deterministic variable is the temperature sensed in Celsius is equal to the Fahrenheit. In the static variable two variables are not accurate. Example of static variable is relationship between height and weight [9][10].

a) Load the data in the tool

b) Initialize the split ratio 0.7

c) Simple linear regression with R squared value algorithm:

d) The error is calculated by taking summation of subtraction of predicted output from actual output whole multiplied by two. The equation of error is given by

e) This represents the difference target value and regression line i.e. predicted value. To avoid the cancellation of positive and negative points from each other the square of error is

$$\text{Error} = \sum_{i=1}^{n} (\text{Predicted\_output} - \text{average\_of\_actual\_output})^2$$

taken.

f) Above equation let us know the distance between estimated regression lines from horizontal 'no relationship' line.

g) Above equation gives information about how much data points have been moved around mean.

8) Predict the response using time verses the parameters of the battery (voltage measured, Current charge, Voltage

$$\text{Error} = \sum_{i=1}^{n} (\text{Actual\_output} - \text{average\_of\_actual\_output})^2$$

$$R^2 = 1 - (SSE/SSTO)$$

charge, time, temperature, current measured)

Time ~`Voltage measured` * Temperature * `Voltage charge * current charge * current measured `

9) Find difference between the predicted value and the actual value.

test$diff = (test$pred - actual)/60

10) Compute for the absolute value using

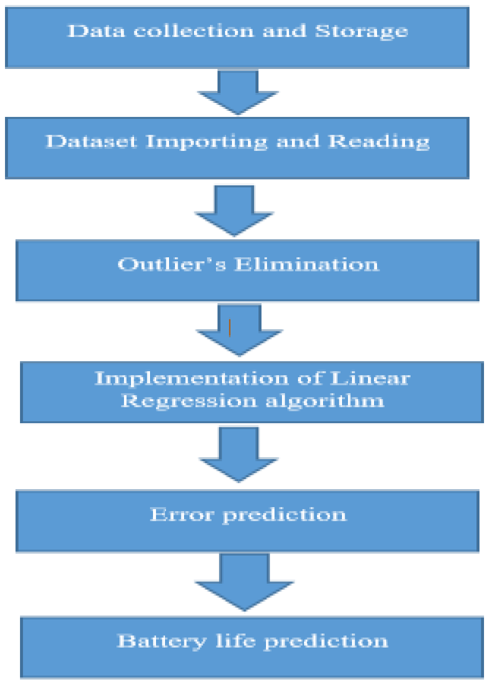
Value=[sqrt(mean((test$pred-actual)^2))

11) Visualize the output in the form of scatter plot.

12) For two different battery sets, column wise check the data and using the algorithm time is predicted which necessary parameter for finding the battery life is.

12) Depending on this analysis of the measured data (battery parameters) battery life is predicted.

3.4 Flowchart



4 RESULT AND DISCUSSION

The dataset used for analysis is as shown in figure.

	Voltage measure	Current measure	Temperature	Voltage charge	Current charge	Time
2	3.86462358	8.20E-05	24.68221382	-0.001	-0.007	0
3	3.469113384	-4.059184554	24.69540665	-4.06	1.558	2.532
4	3.99480602	1.513749505	24.71149128	1.506	4.71	5.5
5	4.005887761	1.511389489	24.73967193	1.506	4.726	8.344
6	4.012944387	1.510817458	24.75317988	1.506	4.737	11.125
7	4.018813099	1.513170287	24.74937723	1.506	4.743	13.891
8	4.023530277	1.512648683	24.75903096	1.506	4.748	16.672
9	4.028040812	1.51192691	24.76891928	1.506	4.748	19.5
10	4.031895809	1.512426695	24.76622836	1.506	4.753	22.282
11	4.035639017	1.51158267	24.77862443	1.506	4.759	25.063
12	4.038838112	1.514447611	24.77718937	1.507	4.764	27.828
13	4.042523778	1.511547725	24.79446544	1.506	4.764	30.641
14	4.045597017	1.513654364	24.80570149	1.506	4.77	33.453
15	4.048531125	1.511969467	24.81297659	1.506	4.77	36.219
16	4.051981795	1.511366399	24.82214074	1.506	4.775	39.735
17	4.054648631	1.514724956	24.82645213	1.506	4.775	42.578
18	4.057332696	1.513914456	24.83866462	1.506	4.78	45.438
19	4.060010657	1.510671072	24.84201259	1.506	4.78	48.297
20	4.062096003	1.512040393	24.85087696	1.506	4.786	51.188
21	4.06444915	1.509848421	24.8711841	1.506	4.786	54.047
22	4.066407521	1.50899717	24.86861494	1.506	4.791	56.922
23	4.068266267	1.511628992	24.88030469	1.506	4.791	59.797
24	4.070491552	1.510696464	24.88352137	1.506	4.791	62.688
25	4.07207205	1.512672275	24.88642356	1.506	4.797	65.657
26	4.074158085	1.511140263	24.90260894	1.506	4.797	68.547
27	4.075828825	1.513532762	24.9069661	1.506	4.797	71.453
28	4.077266477	1.514241355	24.91319749	1.506	4.802	74.344
29	4.078631246	1.509884918	24.92257526	1.506	4.802	77.235
30	4.080664465	1.509858394	24.93729149	1.507	4.802	80.188
31	4.081355589	1.515231541	24.93820498	1.506	4.807	83.172
32	4.083152942	1.510709438	24.9470181	1.506	4.807	86.094
33	4.084261874	1.516496394	24.96301834	1.506	4.807	89.016
34	4.085052959	1.512395993	24.97159546	1.506	4.807	91.922
35	4.086667684	1.511097475	24.97692908	1.506	4.807	94.907
36	4.087659507	1.51321153	24.98591017	1.506	4.813	97.844
37	4.088556611	1.511952731	24.99498012	1.507	4.813	100.766
38	4.090156301	1.513948279	24.9912057	1.506	4.813	103.75
39	4.09070909	1.506262564	25.01141466	1.506	4.813	106.703
40	4.091928657	1.510563444	25.02030023	1.506	4.813	109.641

Fig-1 Dataset for Battery 1

	voltage_measure	current_measure	Temperature	Current_charge	voltage_charge	Time
2	3.86612311	-0.00383003	24.43424399	-0.0006	0.002	0
3	3.644899593	-2.26186662	24.4410531	-2.2697	2.576	2.532
4	4.001099145	1.4891608	24.44572713	1.4995	4.719	5.5
5	4.011040778	1.491029463	24.4596027	1.4995	4.745	8.344
6	4.017485049	1.491413434	24.45838469	1.4995	4.745	11.125
7	4.023051376	1.489502665	24.45990751	1.4995	4.745	13.891
8	4.027731667	1.488795033	24.47089359	1.4995	4.757	16.672
9	4.031854091	1.489900798	24.47826262	1.4995	4.757	19.5
10	4.036218026	1.490721578	24.47861462	1.4995	4.77	22.282
11	4.039862568	1.488135777	24.48326775	1.4995	4.77	25.063
12	4.043032214	1.490928624	24.49048789	1.4995	4.77	27.828
13	4.046067723	1.488761182	24.50140654	1.4995	4.77	30.641
14	4.049290161	1.490963208	24.51478218	1.4995	4.783	33.453
15	4.052165475	1.488530083	24.5310489	1.4995	4.783	36.219
16	4.055849363	1.492886317	24.53501373	1.4995	4.783	39.735
17	4.058516268	1.491565695	24.54383264	1.4995	4.796	42.578
18	4.060948089	1.490567457	24.56026239	1.4995	4.796	45.438
19	4.063609206	1.488995462	24.55743579	1.4995	4.796	48.297
20	4.065760902	1.489612155	24.57249881	1.4995	4.796	51.188
21	4.06803762	1.490264967	24.58470777	1.4995	4.796	54.047
22	4.070231287	1.489399811	24.59067986	1.4995	4.796	56.922
23	4.072531168	1.487890774	24.59572209	1.4995	4.808	59.797
24	4.074273662	1.488840231	24.60993344	1.4995	4.808	62.688
25	4.076173464	1.494040942	24.61645791	1.4995	4.808	65.657
26	4.077923326	1.491323942	24.63336046	1.4995	4.808	68.547
27	4.079691623	1.489195111	24.6440776	1.4995	4.808	71.453
28	4.081465077	1.489363798	24.64444908	1.4995	4.808	74.344
29	4.082925322	1.493254705	24.65568998	1.4995	4.808	77.215
30	4.083910744	1.490410889	24.66042275	1.4995	4.821	80.188
31	4.085959001	1.490995249	24.67244805	1.4995	4.821	83.172

Fig-2 Dataset for Battery 2

```
Call:
lm(formula = Time ~ ., data = train)

Residuals:
     Min       1Q   Median       3Q      Max
-1153.31  -530.83   -98.93   442.59  2170.82

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      -50700.76    6804.84  -7.451 3.91e-13 ***
voltage_measured  20733.18    2009.57  10.317  < 2e-16 ***
Current_measured -56616.63   18971.78  -2.984  0.00298 **
Temperature       -1158.88      80.36 -14.421  < 2e-16 ***
Voltage_charge    56230.89   19067.76   2.949  0.00333 **
Current_charge     -794.20      45.83 -17.329  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 715.5 on 519 degrees of freedom
Multiple R-squared:  0.8981,    Adjusted R-squared:  0.8971
F-statistic: 914.9 on 5 and 519 DF,  p-value: < 2.2e-16
```

Fig-3 R squared value checking which parameter has major effect on battery

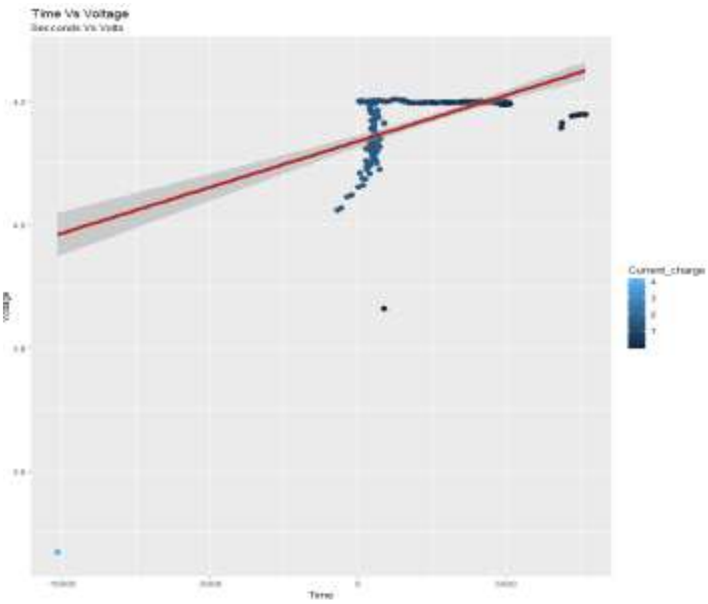


Fig-4 Time prediction based on provided parameters

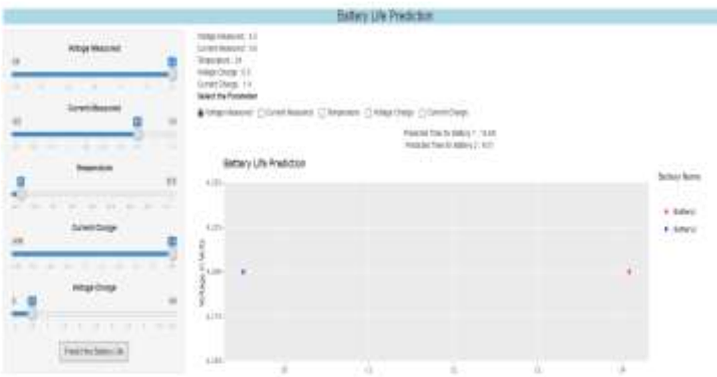


Fig-5 Battery life prediction of two batteries with respect to each parameter.

Consider,

Voltage measured: 4.2 (Maximum)

Current measured: 0.6

Temperature: 24

Current charge: 1.4(Maximum)

Voltage charge: 0.5

From the figure 4, it can be predicted that when the current charge value is maximum (high intensity point) is near to the reference line where voltage is also maximum, the time is 4800 sec ,which if taken in hours can give 4800/360=13.33 hrs.

From the figure 5, The voltage measured and current charge is kept maximum value and the battery life is predicted ,It give 14.09 which is almost same as before.

The prediction of battery life is crosschecked here. Also two different battery sets are compared as it predicts life which is different. The difference between predicted and actual value is divided by 60 to predict the battery time in hours. The graph changes with all those parameters which has major effect on the battery. The voltage line is a reference line where the maximum battery life is considered. The current charge point which is nearby to the reference voltage line has a 100% battery life.

5 CONCLUSIONS

Data analysis of an electric vehicle battery using R tool based on measured data is an effective technique used for prediction of a battery life. By applying the regression algorithm which uses Euclidian distance for classification of test and train data, prediction of battery life in terms of all the battery parameters is done. The data collected is stored in the local server so that it can be used offline also. The scatter plot shows best estimation of the battery life in terms of the given parameters.

Prediction of electric vehicle battery life results in the following conclusions:

i. Gives detailed information about a battery which results in quantitative analysis of a battery.
ii. Shows dependent and independent variables of a battery and the relation between them.
iii. Predict the effect of each parameter on a battery life when parameters varies in a given limit.
iv. R squared value and R squared adjusted values define how much variance the battery model has.
v. Higher R squared values shows that the model is batter. The adjusted R only considers important parameters and other parameters are dropped.
vi. Collection and storage of a data provided is properly done in the initial stage which results in less human errors.
vii. The battery life is predicted as per the provided data. The problem of many companies about battery life prediction and performance of a battery is solved.

6 FUTURE SCOPE

Data collection and storage can be done in a real time where data is processed online when the vehicle is running in the test cycles. Only two sets of a battery data is processed here and compared but different four sets of Lithium-Ion batteries can be processed and analyzed that can how those parameters affect the battery life. Comparison of different datasets of a battery results in selection of a proper battery pack for effective working of the vehicle.

REFERENCES

[1] Jinliang Zhang, Xuehuan Jiang, Wei Jian," Data analysis of the Electric Vehicle's Current and Speed Based on Actual Road Condition"2013 International Conference on Computational and Information Sciences, 21-23 June 2013, 1162 - 1165 ,10.1109/ICCIS.2013.308.

[2] Luca Bascetta, Giambattista Gruosso, Giancarlo Storti Gajani, "Analysis of Electrical Vehicle behavior from real world data: a V2I Architecture", 2018 International Conference of Electrical and Electronic Technologies for Automotive, 1-4, 9-11 July 2018.

[3] Vishal Vijayan Nair, Boppudi Pranava Koustubh, "Data analysis techniques for fault detection in hybrid/electric vehicles", 2017 IEEE Transportation Electrification Conference (ITEC-India), 13-15 Dec. 2017.

[4] Vamshi K. Bolly, Dr. John A. Springer, Dr. J. Eric Dietz, "A Study of Electric Vehicle Data Analytics", Computer and Information Technology, USA.

[5]Egor Kulik, Xuan Trung Tran, Alecksey Anuchin," GPS-tract Data Processing for the Optimization of the Powertrain for Hybrid Electric Vehicles", 2017 ,58th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON).

[6] Pneg Rong, Massound Pedram "An analytical model for predicting the remaining battery capacity of Lithium-Ion batteries", Processing of the Design Automation and Test in Europe Conference and Exhibition (DATE'03) 1530-1591/03 $17.00@ 2003 IEEE.

[7] Yishan Cai, Lin Yang, Zhongwei Deng, Xiaowei Zhao, Hao Deng , "Prediction of Lithium-ion Battery Remaining Useful Life Based on Hybrid Data-Driven Method with Optimized Parameter", 2017 2nd International Conference on Power and Renewable Energy.

[8] Sun Bo, Du Junping, Gao Tian, "Study on the Improvement of K-Nearest_Neighbor Algorithm", 2009 International Conference on Artificial Intelligience and Computational Intelligence, Chine 100876.

[9]Aiman Moldagulova, Rosnafisah Bte. Sulaiman "Document Classification Based on KNN Algorithm by Term Vector Space Reduction", 2018 18th International Conference on Control, Automation and Systems (ICCAS 2018) Oct. 17-20, 2018

[10] Astrid Schneider, Gerhard Hommel, and Maria Blettner, "Linear Regression Analysis", Part 14 of a Series on Evaluation of Scientific Publications.

[11] Qingxia Yanga, Jun Xua, Binggang Caoa, Dan Xua, Xiuqing Lib, Bin Wanga," State-of-health estimation of lithium-ion battery based on interval capacity " , The 8th International Conference on Applied Energy – ICAE2016.

[12] Cheng Lina, Aihua Tanga ,Wenwei Wanga , "A review of SOH estimation methods in Lithium-ion batteries for electric vehicle applications ", The 7th International Conference on Applied Energy – ICAE2015 .

[13] Yuan Zou, Xiaosong Hu, Hongmin Ma, Shengbo Eben Li , "Combined State of Charge and State of Health estimation over lithium-ion battery cell cycle lifespan for electric vehicles" , Journal of Power Sources 273 (2015) 793e803.

[14] Weiping Diao, Jiuchun Jianga, Caiping Zhanga, Hui Lianga, Michael Pecht, "Energy state of health estimation for battery packs based on the Degradation and inconsistency ", 9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK.

[15]Siqi Wu, Luca Morandini, Richard O, Sinnott," SMASH: A Cloud-based AArchitecture for Big Data Processing and Visualization of Traffic Data", 2015 IEEE International Conference on Data Science and Data Intensive System.

[16] Cheng Lina, Jilei Xinga, Aihua Tanga, "Lithium-ion Battery State of Charge/State of Health Estimation Using SMO for EVs", the 8th International Conference on Applied Energy – ICAE2016.