STATE OF CHARGE ESTIMATION OF BATTERY MANAGEMENT SYSTEM

AFIQ ANWAR BIN AKMAL

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS

UNIVERSITI MALAYSIA PAHANG
2022

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : AFIQ ANWAR BIN AKMAL

Date of Birth : 23/20/1997

Title : STATE OF CHARGE ESTIMATION OF BATTERY MANAGEMENT SYSTEM

Academic Session : 2022

I declare that this thesis is classified as:

- ☐ CONFIDENTIAL (Contains confidential information under the Official Secret Act 1997)*
- ☐ RESTRICTED (Contains restricted information as specified by the organization where research was done)*
- ☑ OPEN ACCESS I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

(Student's Signature)	(Supervisor's Signature)
971023-01-6913	Hamzah bin Ahmad
New IC/Passport Number	Name of Supervisor
Date: 17/2/2022	Date: 19.2.2022

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Engineering in Electrical and Electronics Engineering.

(Supervisor's Signature)

Full Name : DR. HAMZAH BIN AHMAD
Position : Supervisor
Date : 19.2.2022

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____
(Student's Signature)

Full Name : AFIQ ANWAR BIN AKMAL
ID Number : EC18019
Date : 17/02/2022

STATE OF CHARGE ESTIMATION OF
BATTERY MANAGEMENT SYSTEM

AFIQ ANWAR BIN AKMAL

Thesis submitted in fulfillment of the requirements
for the award of the Bachelor
of Electrical Engineering with Honours

College of Engineering
UNIVERSITI MALAYSIA PAHANG

Febuary 2022

ACKNOWLEDGEMENTS

Alhamdulillah to the only one God, the God that the most merciful for giving me the strength to complete this thesis. I would like to give this token of appreciation to Universiti Malaysia Pahang (UMP) for financial support for this project.

I would like to express the sincerest appreciation to my supervisor, Dr Hamzah bin Ahmad for his outstanding guidance and encouragement. As a supervisor, he is always giving out ideas and responsive to every question upon completing this project. I am beyond grateful for his unwavering support. I am also incredibly grateful for all of lecturers of Universiti Malaysia Pahang (UMP) who are willing to help in so many ways every time I reached for their help and guidance.

A special thanks goes for my beloved family and friends for the constant moral support and motivation. Their motivation keeps me going and bring the out the potential in me to give my all for this project.

Lastly, I want to express my heartfelt gratitude to anyone who contributed to the process of succeeding this project. I hope that all the research done on putting this project into words would be one of a great use and would bring about a great inspiration.

ABSTRACT

Battery Management System (BMS) is the essential section which has a fundamental occupation in controlling and getting the electric vehicle. The significant elements of BMS incorporate assessing battery state of charge (SoC) utilizing different calculations and propose highlights towards fostering a smart BMS. Battery checking is indispensable for most electric vehicles (EVs) on the grounds that the security, activity, and, surprisingly, the existence of the traveller relies upon the battery system. This trait is by and large the significant capacity of the battery-management system (BMS to check and control the situation with battery inside their predefined safe working circumstances. The state of charge (SOC) assessment has been executed utilizing Kalman Filter Method, consequently wiping out the restriction of the independent Coulomb counting technique. By displaying the battery with SOC as one of the state factors, SOC can be assessed, which is additionally remedied by the Kalman filtering strategy. The battery boundaries from test results are coordinated in the model, and re-enactment results are approved by try. This examination will apply the Kalman Filter in battery model to appraise the battery SoC in light of reproduction model. Recreation will be done through MATLAB Simulink and the examination will zero in on the blunder and state covariance investigation on the consistency and dependability.

TABLE OF CONTENT

LIST OF TABLES

No table of figures entries found.

LIST OF FIGURES

LIST OF SYMBOLS

LIST OF ABBREVIATIONS

SoC	State of charge
BMS	Battery management system
KF	Kalman filter
EKF	Extended Kalman Filter
EV	Electric Vehicle
HEV	Hybrid electric vehicle
V	Voltage
I	Current
OCV	Open circuit voltage
FM	Formal Method
AI	Artificial Intelligence
RuL	Remaining useful life
EoL	End of life
LTV	Linear time varying
SoC	State of charge
BMS	Battery management system
KF	Kalman filter
EKF	Extended Kalman Filter
EV	Electric Vehicle
HEV	Hybrid electric vehicle

CHAPTER 1

INTRODUCTION

1.1 Electric Vehicle

An electric vehicle (EV) is a vehicle that involves at least one electric engines for drive. It tends to be controlled by a gatherer system, with electricity from extravehicular sources, or it very well may be controlled independently by a battery (in some cases charged by sunlight-based chargers, or by changing fuel over to electricity utilizing power devices or a generator). EVs incorporate, however are not restricted to, street and rail vehicles, surface and submerged vessels, electric airplane and electric shuttle's initially appeared during the nineteenth century, when electricity was among the favoured strategies for engine vehicle drive, giving a degree of solace and simplicity of activity that couldn't be accomplished by the fuel vehicles of the time. Gas powered motors were the prevailing impetus technique for vehicles and trucks for around 100 years, however electric power stayed typical in other vehicle types, like trains and more modest vehicles of

In the 21st century, EVs have seen a resurgence in view of mechanical new developments, and an extended focus on maintainable power and the conceivable lessening of transportation's impact on ecological change and other normal issues. Project Drawdown depicts electric vehicles as one of the 100 best contemporary solutions for keeping an eye on climate change. Government inspirations to grow gathering were first introduced in the last piece of the 2000s, recollecting for the United States and the European Union, provoking a creating business area for the vehicles during the 2010s. Expanding public premium and care and fundamental catalysts, for instance, those being fused into the green recovery from the COVID-19 pandemic, is depended upon to staggeringly assemble the electric vehicle market. The International Energy Agency said in 2021 that state run organizations should do more to meet climate destinations, including approaches for profound electric vehicles. Electric vehicle arrangements could increase from 2% of overall offer in 2016 to 30% by 2030. Quite a bit of this improvement is ordinary in business areas like North America, Europe and China; a 2020 composing review suggested that advancement being utilized of electric 4-wheeled vehicles appears financially fantastical in making economies, but that electric 2-wheeler advancement is reasonable. There are more 2 and 3 wheel EVs than another sort.

1.2 Battery Management System

A battery pack of lithium-particle cells is likened to a little dangerous. Watching out for boundaries like voltage, charge, and temperature turns out to be profoundly significant. An uncontrolled warm rampant can cause blast or fire which can be deadly for the vehicle inhabitants. Following are the standard capacities that an ordinary Electric Vehicle BMS performs.

Cell Monitoring: When charging or releasing, the battery cells should be checked consistently. Any out-of-spec circumstance should be recognized and announced alongside the setting off of the security instrument. There are incorporated circuits furnished with cell observing calculations that fill this role. There is a hierarchy of leadership where the phone checking circuit records the cell voltage and temperature and gives the information to a cell management regulator.At this stage, a few calculations hurry to compute the state of charge (SOC) and state of wellbeing (SOH). Not entirely set in stone to guarantee that the battery is rarely finished or undercharged. SOC can likewise be viewed as a fuel sign of an electric vehicle as it demonstrates the energy staying in the battery. Utilizing this data extra calculations can be hurried to decide the distance the EV would cover before the battery needs a recharge. The SOH is a mark of generally soundness of the battery and gives a knowledge into the working states of the battery. In view of this data, battery life expectancy and support timetable can be anticipated. Diagnostics is one more significant aspect to cell checking. UDS based diagnostics software help the EV BMS to recognize and report the mistake codes and indicative information. Such information focuses can be utilized to fix the issue or trigger ISO 26262 based security component.

Power Optimization: The immediate result of cell observing is the enhancement of battery power. While the phone observing usefulness decides SOC and SOH, the EV battery management system's responsibility is to keep the SOC and SOH boundaries inside the predetermined qualities. At the point when the battery is charging, the EV battery management system decides how much current can be permitted in the singular cells. During the EV activity when the EV is releasing, the BMS guarantees that the voltage level doesn't get excessively low. It speaks with the engine regulator to guarantee that.

Wellbeing of Electric Vehicle: Safety is the essential concern when EV power supply and battery management system is in the image. An undetected warm out of control can cause significant setback. As referenced before, the BMS catches information, for example, voltage, temperature and current to upgrade the power. Comparative arrangement of information is additionally used for guaranteeing security. Norms like ISO 26262 have specific necessities that should be satisfied to guarantee that the BMS is created as a safeguard system. One more part of wellbeing is the protection of vehicle body/body from the battery pack to stay away from electric shock to vehicle tenants.

Battery Charging Optimization: The battery cells break down over the long haul. A canny EV BMS factors in this weakening that outcomes in change on battery boundaries such voltage, current, and so on For example, a battery cell gets marginally harmed by hotness and starts getting charged at a lower voltage than the other cells. Battery management system is liable for distinguishing this shortcoming and upgrading the charging system with the goal that all cells are charged at the lower voltage. This diminishes the weight on the general battery pack and improves its life. Obviously, the BMS diagnostics will likewise store this issue as a difficulty code with the goal that it is fixed at a later stage. Additionally, oxidation in the battery terminals might prompt decrease in voltage and the BMS adjusts to these progressions to separate best execution from the battery.

1.3 Project background

Battery are the most well-known electrical energy as stockpiling gadgets in EVs. The presentation of a battery when it is associated with a heap or a source depends on the compound responses inside the battery. The synthetic substances corrupt with time and utilization that mirror the slow decrease in the energy stockpiling limit of the battery. The battery devaluation process should be diminished by moulding the battery in a reasonable way by controlling its charging and releasing profile, much under different burden conditions. By and large, the battery lifetime will be reduced when the battery is worked under a wide scope of warm circumstances and regular charge and profound discharge cycles, especially at high-beat current circumstances. Batteries are protected, notwithstanding reports of blast or disappointment, when utilized with a power-molding system that joins security elements and programmed closure. Regular minimal expense battery chargers utilize not many defensive highlights planned for that battery, subsequently inadequate with regards to adaptability and undeniable assurance. Henceforth, BMS, which is adaptable to safeguard batteries of various sorts and can give all the wellbeing highlights, has been the subject of late turn of events/research in EV and elective energy systems. One of the significant boundaries that are expected to guarantee safe charging and releasing is SOC. SOC is characterized as the current limit of the battery communicated as far as its evaluated limit. SOC gives the present status of the battery and empowers batteries to securely be charged and discharged at a level appropriate for battery life improvement. Along these lines, SOC helps in the management of batteries.

1.4 Problem Statement

Batteries utilized in EVs ought not be overcharged or over-discharged to abstain from harming the battery, shortening the battery life, and causing fire or blasts. The battery management system (BMS), with the elements of battery displaying, battery state assessment, battery adjusting, and so forth, is one of the central issues to safeguard the battery and streamline the use of the battery in EVs. Electric vehicle battery is a significant job in electric vehicle to continue onward out and about, hence the electric vehicle battery pack should be secure from harm in view of lopsided temperature.

Contingent upon the electrochemical utilized in battery, the ideal reach is unique, however the ideal temperature of electric vehicle battery is 45°C in request to save the exhibition and life for the battery.

Energy and natural issues are the most hazardous issues looked by the world auto industry.to conquer these issues world has sped up to the new energy improvement. Cars fueled by gas motors represent almost 25% of the worldwide energy utilization. Rechargeable batteries guarantee a method for supplanting them by electric vehicles (EVs) sooner rather than later. Notwithstanding EVs, rechargeable batteries have been broadly embraced in convenient electronic gear, domestic devices, power devices, aviation hardware and sustainable power stockpiling systems. A battery management system (BMS) guarantees the wellbeing, proficiency and unwavering quality of a battery controlled system. Research on BMS has been extremely extraordinary over the most recent twenty years and huge enhancements were accomplished in the security, proficiency and unwavering quality of battery systems. An arising challenge for battery management systems comes as battery reuse. It is anticipated that the electric vehicle deals are going to develop by almost 500% in the following 10 years. The state of the craftsmanship BMS calculations vigorously rely upon earlier portrayal did in research centers. Thus, they are just powerful for first time utilization of batteries. Considering the way that the primary utilization of the battery changes its electrochemical qualities in remarkable ways, customary BMS moves toward that depend on observational displaying, under the suspicion that batteries of a similar science and size have comparable attributes, will be insufficient to oversee utilized batteries.

1.5 Objective

This research are to determine an accuracy estimation of SOC prevents battery damage or rapid aging by avoiding unsuitable overcharge and over discharge. The conventional SOC estimation using the Coulomb counting method suffers from error accumulation glitch, leading to inaccurate estimation. In addition, the finite battery efficiency and the chemical reaction that takes place during charge and discharge conditions cause temperature rise, which influences SOC estimation. Therefore, accurate algorithms are needed to model the battery for SOC estimation. In EVs, the number of batteries is connected in series-parallel combination to match the load requirement. Due to manufacturing procedures, not all batteries simultaneously attain full voltage during charging. This condition results in voltage imbalance among different batteries and, consequently, lower capacity from the entire battery string. Therefore, a cell with 100% SOC may not necessarily indicate the actual SOC. Therefore, accurate calculation of SOC must be accompanied by a continuous monitoring of the actual capacity of the cell with a number of measurements of the cells to reflect the actual and practical capability of the cell to fit the different road conditions and driving patterns of EVs.

1.6 Scope of project

The exploration will be completed utilizing the state of charge (SoC) addresses the accessible battery limit with battery management system (BMS). It is one of the main states that should be observed to advance the exhibition and broaden the lifetime of batteries. This exploration are to read up the techniques for SoC assessment for batteries. SoC assessment strategies that introduced zeroing in on the depiction of the methods and the elaboration of their shortcomings for the utilization in on-line battery management systems (BMS) applications. SoC assessment is a difficult assignment obstructed by significant changes in battery attributes over its lifetime because of maturing and to the particular nonlinear conduct. These assessments are significant for the legitimate working of ideal charging calculations, charge and warm adjusting methodologies, and battery security instruments. Way to deal with hearty battery management comprises of exact portrayal, vigorous assessment of battery states and boundaries, and ideal battery control systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There have been various distributions distributed on the practicality investigation of carrying out SoC assessment of battery management system. Electric vehicles are set to be the predominant type of transportation sooner rather than later and rechargeable battery packs have been generally taken on in them. Battery packs should be continually checked and overseen to keep up with the security, productivity and unwavering quality of the general electric vehicle system. The examination about SoC, battery management system, State of wellbeing of the battery and electric vehicles

2.2 Battery-Management System (BMS) and SOC Development for Electrical Vehicles

One of the significant boundaries that are expected to guarantee safe charging and releasing is SOC. SOC is characterized as the present limit of the battery communicated as far as its appraised limit. SOC gives the present status of the battery and empowers batteries to securely be charged and dis charged at a level reasonable for battery life improvement. Subsequently, SOC helps in the management of batteries. Be that as it may, estimating SOC isn't immediate, on the grounds that it includes the estimation of battery voltage, current, temperature, and other data that relates to the battery viable. Precise assessment of SOC forestalls battery harm or fast maturing by keeping away from unsatisfactory overcharge and over discharge. The traditional SOC assessment utilizing the Coulomb counting technique experiences mistake gathering error, prompting incorrect assessment. Furthermore, the limited battery proficiency what's more the synthetic response that happens during charge and discharge conditions cause temperature rise, which impacts SOC assessment. Along these lines, exact calculations are expected to model the battery for SOC assessment. In EVs, the quantity of batteries is associated in series-equal mix to coordinate the heap prerequisite. Because of assembling systems, not all batteries all the while accomplishes full voltage during charging. This condition brings about voltage unevenness among various batteries and, therefore, lower limit from the whole battery string. Thusly, a cell with 100 percent SOC may not really show the genuine SOC. Subsequently, exact computation of SOC should be joined by a ceaseless observing of the real limit of the cell with various estimations of the cells to mirror the genuine and functional ability of the cell to fit the different street conditions and driving examples of EVs. BMS is a different element with equipment and firmware and is associated with a battery charger rather than coordinated inside the charger. BMS comprises of various detecting gadgets for observing battery boundaries that will be utilized in the calculation for SOC assessment. The huge square of any BMS is the battery model square, which requires nitty gritty arrangement of battery attributes for precise SOC assessment. The model is for the most part gotten from the charging and releasing bends of the battery. One progressed battery model in light of a state-space procedure is carried out in this paper.

2.3 Battery Management System In Electric Vehicle

Electrification in the vehicle (charged transportation) is the most suitable method for accomplishing perfect and proficient transportation that is pivotal to the manageable improvement of the entire world. Sooner rather than later, electric vehicles (EVs) including cross breed electric vehicles (HEVs), module half and half electric vehicles (PHEVs), and unadulterated battery electric vehicles (BEVs) will rule the perfect vehicle Market. By 2020, it is normal that more than a big part of new vehicle deals will probably be EV models. The key and the empowering innovation to this progressive change is battery. Electric vehicles (EVs) are fueled by an enormous number of battery cells, requiring a powerful battery management system (BMS) to keep up with the battery cells in a functional condition while giving the important power effectively. Battery management systems (BMS) settle on choices on charge/discharge rates based on load requests, cell voltage, current, and temperature estimations, and assessed battery SOC, limit, impedance, etc.

2.4 State of Charge Estimation Using Extended Kalman Filters for Battery Management System

As innovation propels, numerous electric vehicle batteries are presently likewise expected to speak with different parts inside the vehicle, for example, the engine regulator to maximize reach and speed increase. A precise assessment of the energy accessible inside the battery is fundamental to great powertrain activity and forestall abandoning the rider. Ultimately, realizing the excess energy likewise forestalls overcharge furthermore over discharge of batteries, crucial to safe use and long life of lithium-particle batteries. Lithium-particle batteries have turned into the battery of decision for mixture and electric vehicle, yet in addition for electric bike and bike applications. The key drivers are their high explicit energy, energy thickness, cycle/schedule life as well as their decreased requirement for support when contrasted with overflowed lead corrosive batteries. One of their couple of disadvantages is the trouble assessing how much excess energy. This author has been created for assessing battery state of charge (SoC). Following the Coulomb counting definition, SoC is assessed as the proportion between the current limit, as the basic of the battery current, and the ostensible limit of the battery. This approach shows the downsides connected with the basic activity processed on the current estimation: it is exceptionally delicate to the SoC beginning condition not generally known unequivocally, and the coordination can undoubtedly separate if there should arise an occurrence of extra clamour. Consequently, different strategies have been researched, particularly for vehicle on-board application in light of genuine estimation, as the instance of e-bicycles considered in this paper. Broadened Kalman filter (EKF) is a strong model-based assessor appropriate with the end goal of this work. In roundabout strategies, SoC is assessed utilizing data from other assessed amounts. SoC can be figured starting from open circuit voltage (VOCV) estimation. In truth, Lead-Acid and Li-particle batteries VOCV is immediate function of SoC and this relationship is generally tentatively assessed. For Lead-Acid batteries specifically, the SoC assessment is straight-forward because of the direct abatement of the VOCV regarding SoC. Paradoxically, Li-particle batteries doesn't present a straight connection among VOCV and SoC, so it is more diligently to make an interpretation of the VOCV estimation to SoC. A few comparative circuitous techniques are created utilizing reduced state space electrochemical models, which give a great portrayal of the cycle inside the battery, together with EKF, in a structure that can be utilized for online SoC and boundaries assessments. Other sort of strategies have been utilized in writing as well counterfeit neural organizations and impedance spectroscopy. These techniques ordinarily require a more noteworthy computational exertion contrasted and EKF and extremely exact estimations this make them appropriate for research centre application. EKF is a fruitful model-based strategy for state estimation, broadly utilized additionally for battery application. SoC assessment with EKF is acted in. In this take care of the issue of SoC assessment with EKF is tended to for a Li-particle battery produced for e-bicycle application. The primary intention is to plan a solid and complex calculation as EKF for a precise identification of SoC for the new classes of light vehicle, for example, hybrid car. The battery pack structure is talked about and the numerical model is presented. The model boundaries are recognized: for the battery obstruction a dependence on SoC is characterized. The SoC assessment calculation is introduced in this paper where and versatile form of EKF.

2.5 Summary of Literature review

In light of study that has been distributed, to execute the SoC assessment of battery management system, electric vehicles (EV) are assuming a key part as a result of its zero-outflow of destructive gases and utilization of effective energy. Electric vehicles are prepared by an enormous number of battery cells which require a compelling battery management system (BMS) while they are giving vital power. In light of Juan Pablo Rivera-Barrera, Nicolás Muñoz-Galeano and Henry Omar Sarmiento-Maldonado, battery management system (BMS) is the essential system in electric vehicle since batteries utilized in electric vehicle ought not be get overcharged or over discharged.[1] If that occurs, it prompts the harm of the battery, ascend in temperature, decreasing the life expectancy of the battery, and once in a while likewise to the people utilizing it. It is additionally used to amplify the scope of vehicle by appropriately utilizing how much energy put away in it. Diminishing oil utilization has been a worry for decreasing the green house impact. As per I. Priyanka, R. Sandeep, V. Ravi and O. Shekar, Electric and mixture vehicles usage is one of the answer for take care of the issue. Challenge in this space is connected with batteries use. Most batteries require battery management system (BMS). One of the significant central questions in BMS configuration is the precision of state of charge (SoC) estimation.[2]

According to Dickson N. T. How, M. A. Hannan, M. S. Hossain Lipu, Pin Jern Ker Department of Electrical Power Engineering, College of Engineering, University of South Asia, the successful operation of EV is highly dependent on the operation of battery management system (BMS). State of charge (SOC) is one of the vital paraments of BMS which signifies the amount of charge left in a battery. A good estimation of SOC leads to long battery life and prevention of catastrophe from battery failure. Besides, an accurate and robust SOC estimation has great significance towards an efficient EV operation. However, SOC estimation is a complex process due to its dependency on various factors such as battery age, ambient temperature, and many unknown factors.

Estimation using battery models are powerful to approximate nonlinear behaviour of battery. This idea is conducted by entering gauged battery signals to battery model. Afterwards, the terminal voltage of battery is calculated by taken measurement signal into account parameters as well as current and old states of battery. In order to keep the estimation updated, gaps among values derived from calculation and measurements are then inputted into an observer.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, we collect the data about precise estimation of SoC can prevent battery from damage or premature aging by avoiding over charge or discharge. Due to the limited capacity of a battery, advanced methods must be used to estimate precisely the SoC in order to keep battery safely being charged and discharged at a suitable level and to prolong its life cycle. We review several existing effective approaches such as Coulomb counting, Open Circuit Voltage (OCV) and Kalman Filter method for performing the SoC estimation. Then we investigate both Artificial Intelligence (AI) approach and Formal Methods (FM) approach that can be efficiently used to precisely determine the SoC estimation for the smart battery management

3.2 Flow of methodology

Based on **Error! Reference source not found.** shown, the flow chart of the p rocess of using SOC estimation of BMS. Before we start do the study, we need to understand what growing shift towards the green-energy transportation such as Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) that require support from CPS. Moreover, battery-powered electronic devices have become ubiquitous in modern society

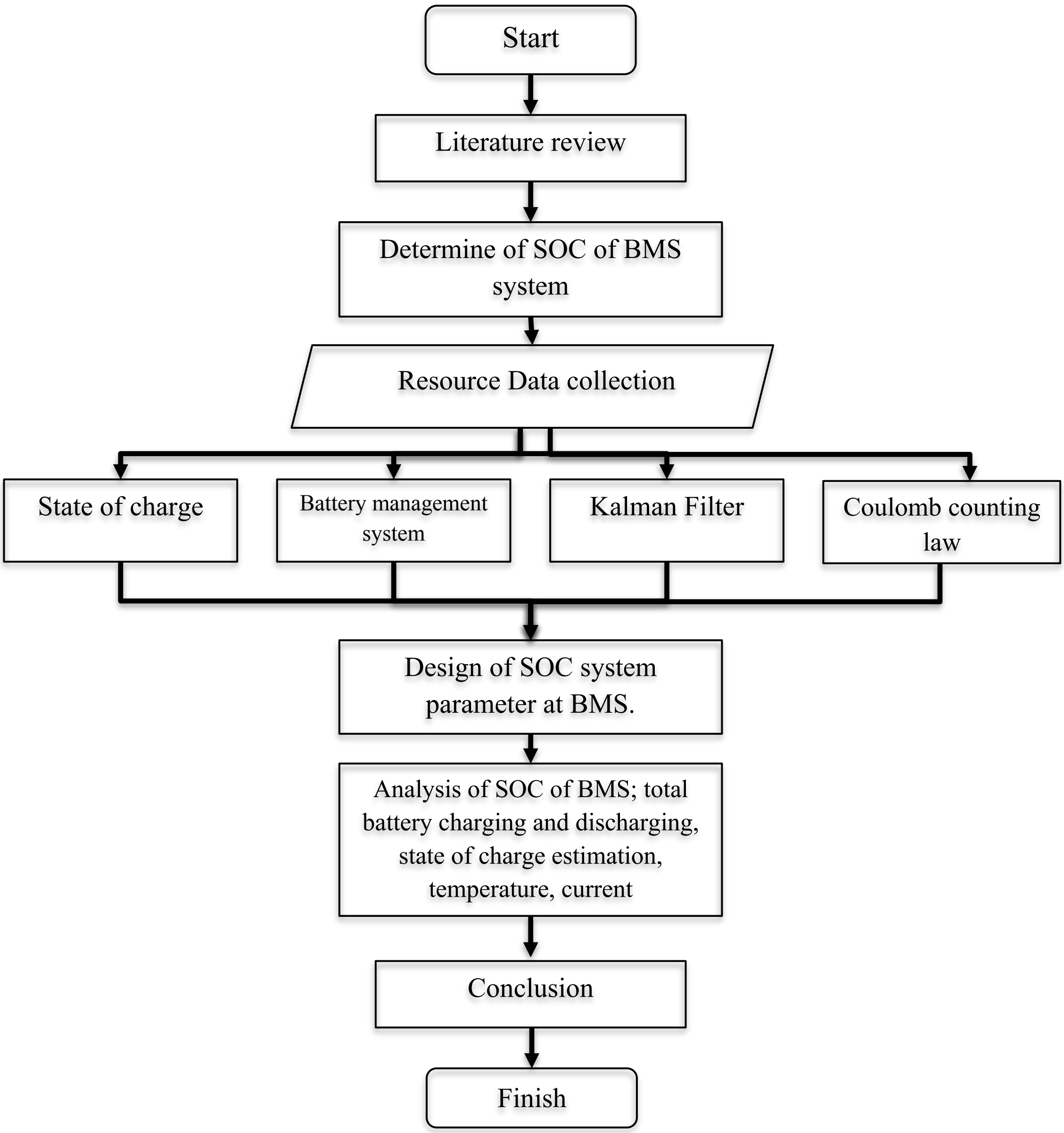


Figure 1 Flow chart of the methodology of this project.

3.3 Resource data collection

To continue this study, I conduct this research and gather data from a variety of sources. Battery management system (BMS), battery charging and discharging rates, state of charge estimation, state of health estimation, cell voltage, temperature, current etc.

3.3.1 Battery management system (BMS)

Battery management system (BMS) is the vital system in electric vehicle since batteries utilized in electric vehicle ought not be get overcharged or over discharged. Assuming that occurs, it prompts the harm of the battery, ascend in temperature, lessening the life expectancy of the battery, and at times likewise to the people utilizing it. It is likewise used to amplify the scope of vehicle by successfully utilize how much energy put away in it. Battery management system is fundamental for following reasons:

- Maintain the safety and the reliability of the battery
- Battery sate monitoring and evaluation
- To control the state of charge
- For balancing cells and controlling the operating temperature
- Management of regenerative energy

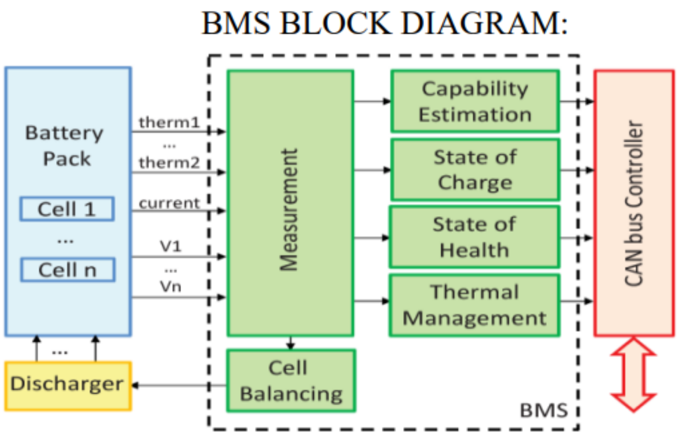


Figure 2 BMS block diagram

A BMS is a gadget that is worked with equipment and software that control the functional states of the battery to drag out its life, ensuring its security and giving an exact assessment of the various states of the battery for the energy management modules. To meet this, a BMS has a few highlights to control and screen the states of the battery at various battery cell, battery module, and battery pack levels. The capacity of a battery to store energy diminishes over its lifetime. State of wellbeing (SoH) is a sign of this disintegration. The excess valuable life (RUL) is the leftover time or number of burden cycles until the battery arrives at its finish of life (EoL). A BMS should be a security circuit as well as an intensive and exact gadget that can anticipate the SoC, SoH, RUL, limit, and accessible power, to expand the effectiveness and the wellbeing of the battery.[3] By consistently estimating current, voltage, and temperature in batteries, the previously mentioned boundaries can be assessed. The assessment of the SoC is key in a BMS, however its on the web and precise assessment stays a test because of solid nonlinear and complex electrochemical responses in the battery and in light of the fact that battery attributes change with maturing.

3.3.2 State Of Charge (SoC)

State of charge is characterized as the accessible measure of battery as the level of appraised limit of the battery. State of charge gives a pivotal help to battery management system to evaluate the state of the battery which assists the battery with working inside the safe working reach by controlling charging and releasing. It likewise builds the life expectancy of the battery.[4] State of charge can't be assessed straightforwardly. It is determined by utilizing the condition

$$\mathrm{SOC} = 1 - \frac{\int \mathrm{idt}}{\mathrm{c_n}}$$

Where,

I =current and

Cn= maximum capacity that the battery can hold

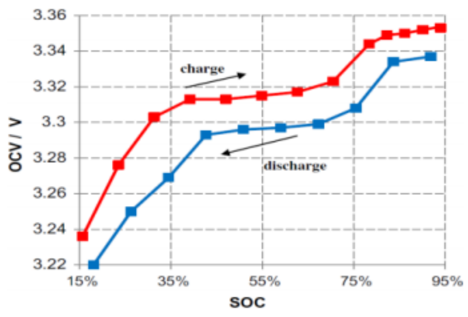


Figure 3 SOC during charging and discharging

There are various methods to estimate the state of charge. Following are the list of state of charge estimation method:

- Coulomb counting SOC estimation method
- 2. Fuzzy logic SOC estimation method
- 3. Impedance spectroscopy SOC estimation method
- 4. Kalman filtering SOC estimation method
- 5. Open circuit voltage SOC estimation method

Among all these various methods Kalman filtering method has been successful for the estimation of SOC for EV'S.

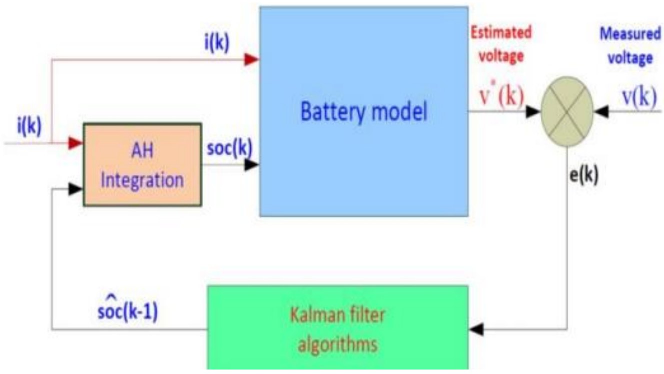


Figure 4 Kalman filtering SOC estimation model

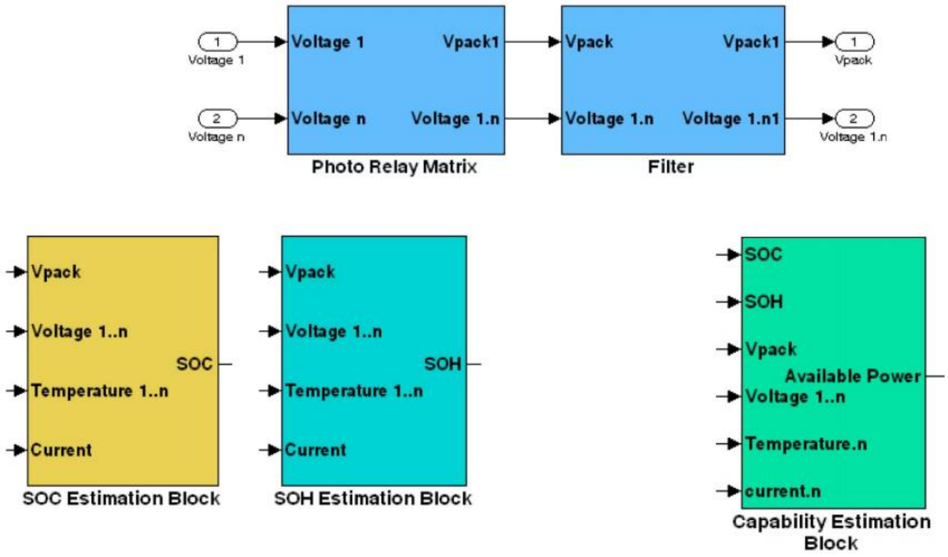


Figure 5 SOC and SOH estimation block.

3.3.3 Kalman Filter

The Kalman Filter is an exceptionally uncommon calculation, in that it is one of a handful of the that are provably ideal. It was first distributed by Rudolf E. Kalman in his fundamental 1960 paper named A New Approach to Linear Filtering and Prediction Problems. It is utilized in regions as different as aviation, signal handling, and fates exchanging. At its center, it proliferates a state portrayed by a Gaussian dissemination involving direct progress capacities in an ideal way.[5] Since it is ideal, it has remained generally unaltered since it was first presented yet has gotten a huge number to apply it to something other than straight Gaussian systems.

One significant constraint of the Kalman Filter is the severe arrangement of issues to which it applies: issues with straight state change and direct estimations with added Gaussian noise.[6] While a large number of issues can be displayed along these lines, it would be great to apply the Kalman Filter to different issues, because of its optimality. The Extended Kalman Filter was designed only for this reason. It deals with a course of linearization, where the nonlinear progress and perception capacities are approximated by a Taylor Series development.

The Extended Kalman Filter is a notable calculation to a great extent utilized gauge the state of a powerful system described by uproarious estimations. Simultaneously, this technique may likewise be utilized to perform system boundaries recognizable proof beginning from trial data.[8]

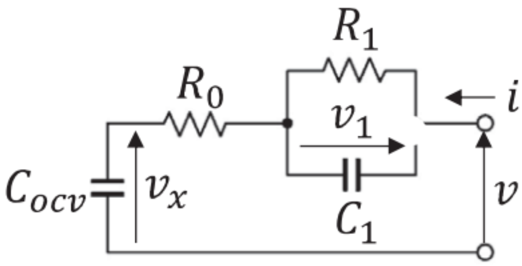


Figure 6 Simplified model

For boundary assessment, I initially determine the exchange capacity of the same circuit model in. Then, at that point, the assessment of the boundary ends up being assessment of the coefficients of the exchange work utilizing the Kalman filter, which is an augmentation of the recursive least-squares strategy. For the worked on model in Figure 6, the exchange work from the info current to the result voltage is given by

$$V(s) = \left(R_0 + \frac{R_1}{R_1 C_1 s + 1} + \frac{1}{C_{ocv} s} \right) I(s),$$

where I(s) and V(s) denote the Laplace transforms of i and v, respectively. Discretization by the Euler method yields

$$V(z) = \frac{b_0 z^2 + b_1 z + b_2}{(z - a_2)(z - 1)} I(z),$$

where I(z) and V(z) denote the z-transforms of i and v, respectively, and

$$a_2 = 1 - \frac{T_s}{R_1 C_1},$$

$$b_0 = R_0,$$

$$b_1 = T_s\left(\frac{1}{C_{ocv}} + \frac{1}{C_1} + \frac{R_0}{R_1 C_1}\right) - 2R_0,$$

$$b_2 = \frac{T_s^2}{R_1 C_1 C_{ocv}} + R_0 - T_s\left(\frac{1}{C_{ocv}} + \frac{1}{C_1} + \frac{R_0}{R_1 C_1}\right)$$

From that, we see that this system contains an integrator, which might adversely affect the exactness of boundary assessment. This issue is kept away from by a strategy that thinks about the time subordinate of the result as another result. That is, the voltage contrast is characterized as

$$\Delta V(z) = \frac{b_0 z^2 + b_1 z + b_2}{z(z - a_2)} I(z).$$

3.3.4 MATLAB & Simulink software

This project is required MATLAB Simulink as a platform to run this project. I have design all the Battery Management System with State of Charge with two battery pack in this MATLAB Simulink.

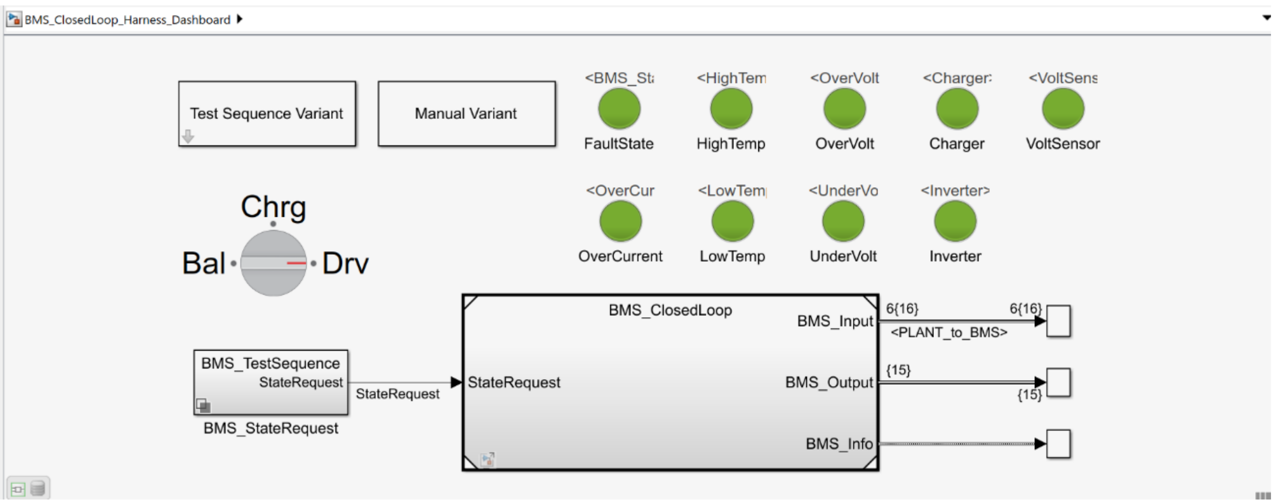


Figure 7 BMS Closeloop Harness Dashboard

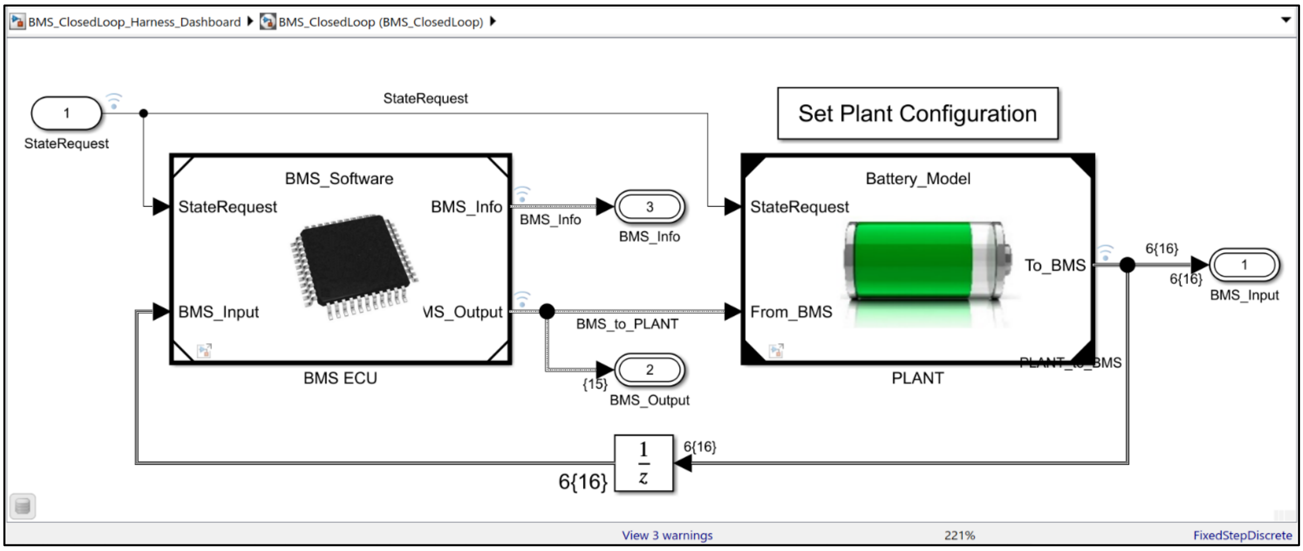


Figure 8 Battery Management System

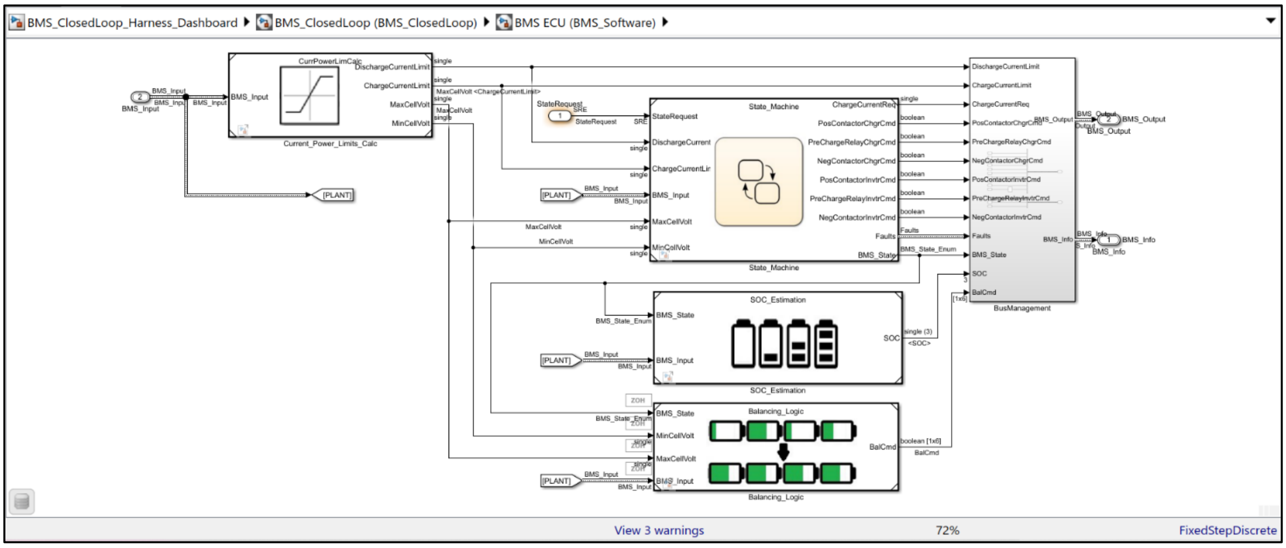
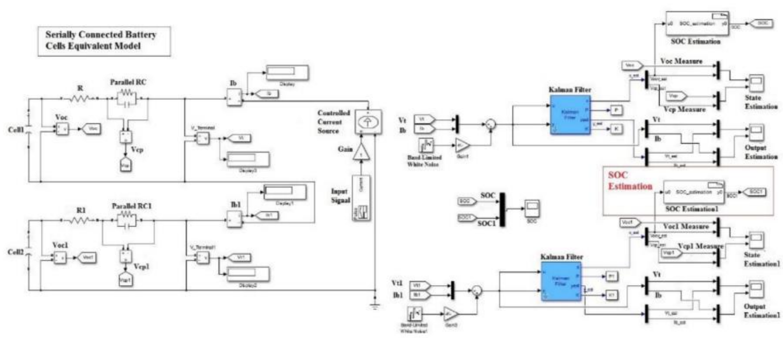


Figure 9 BMS ECU



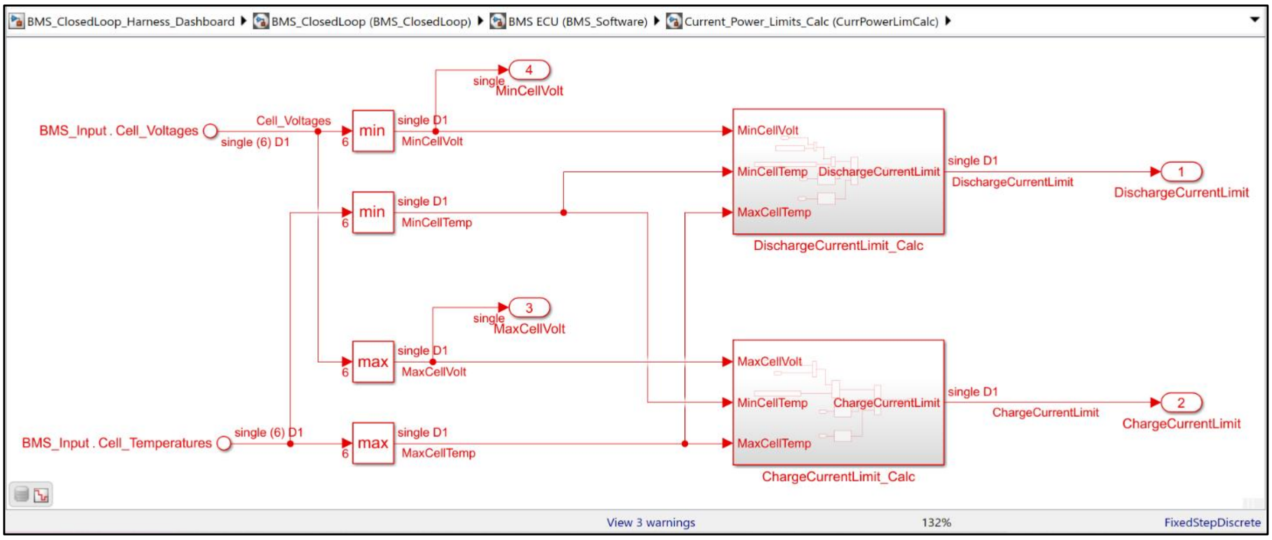


Figure 11 Current Limit Power Calculation

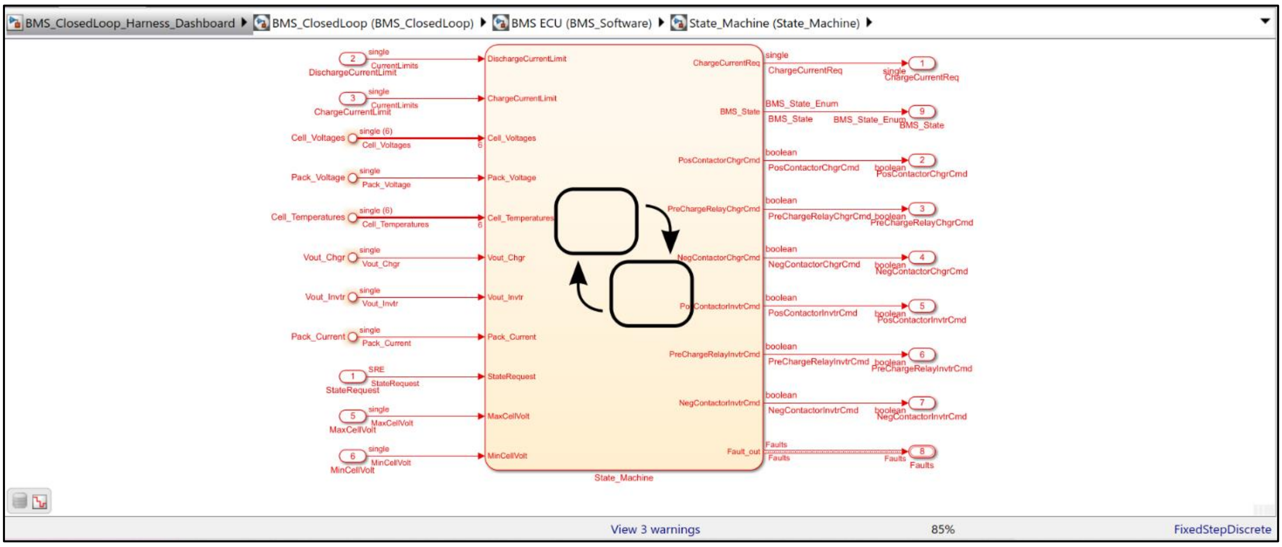


Figure 10 State Machine

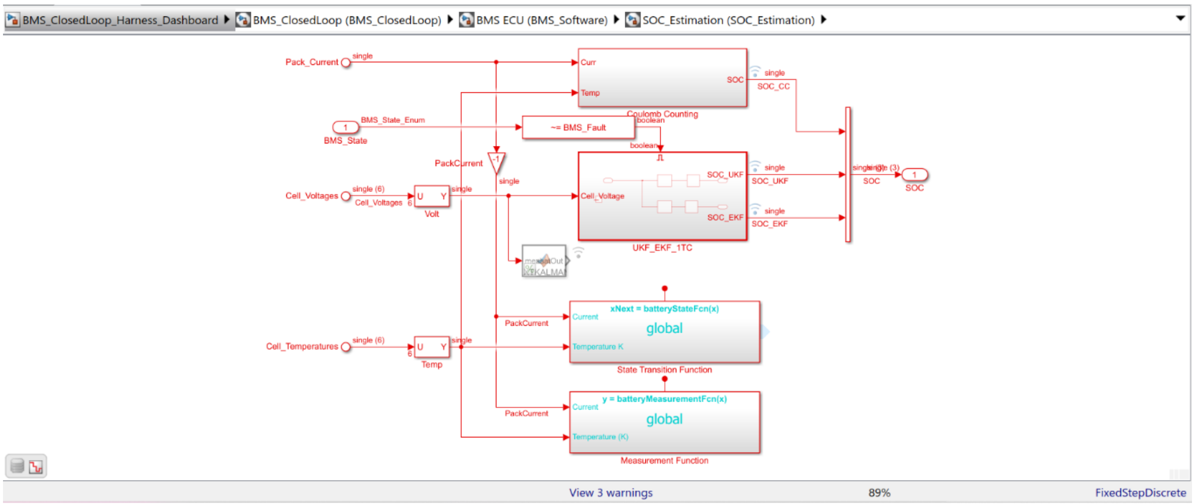


Figure 13 State Of Charge Estimation

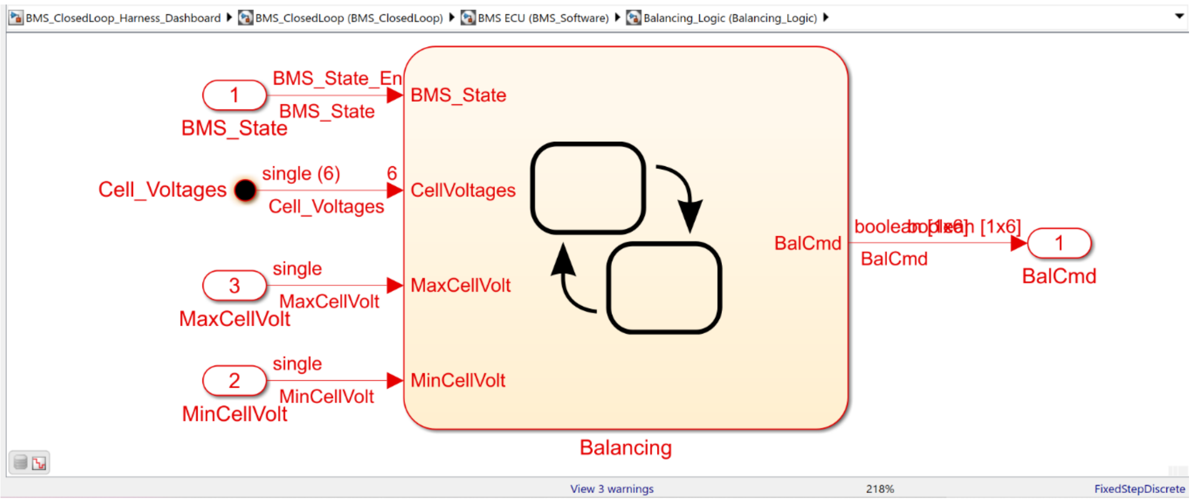


Figure 12 Balancing Logic

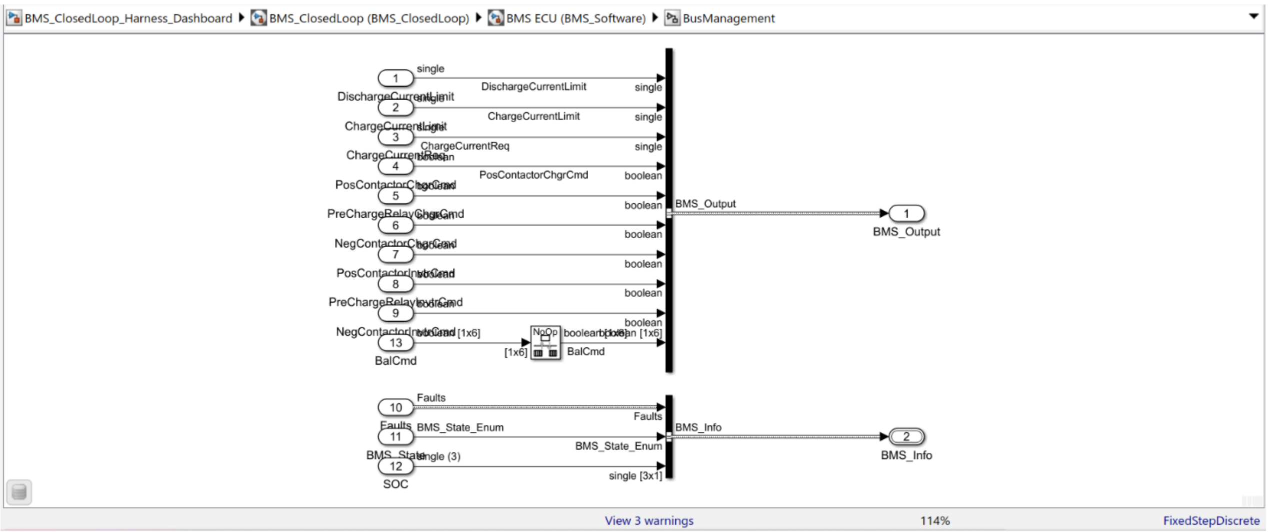


Figure 14 Bus Management

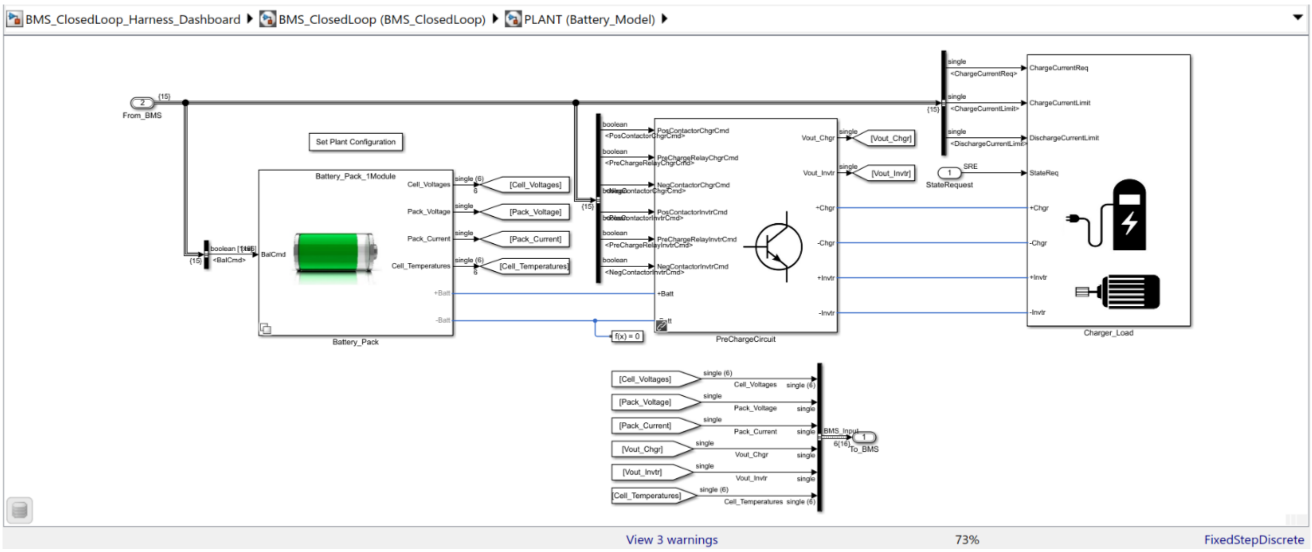


Figure 15 Battery (Plant)

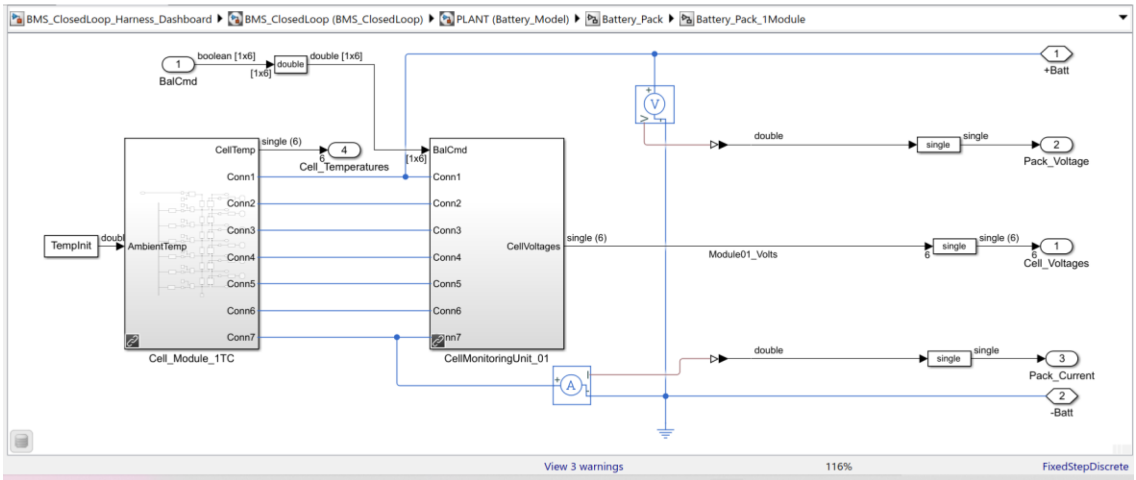


Figure 16 Battery Pack

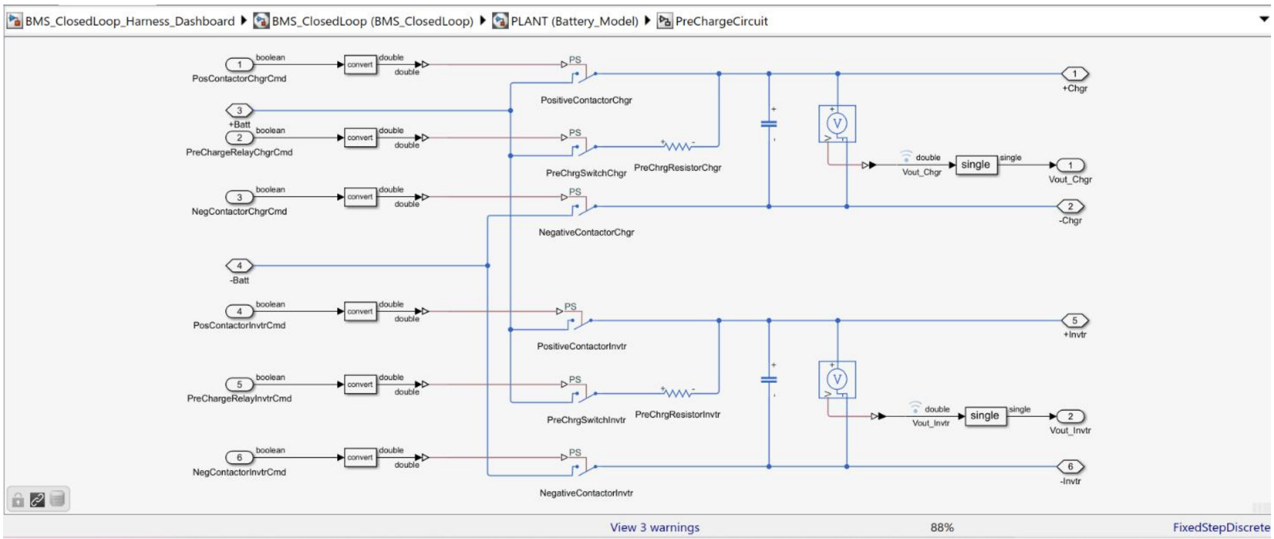


Figure 17 PreCharge Circuit

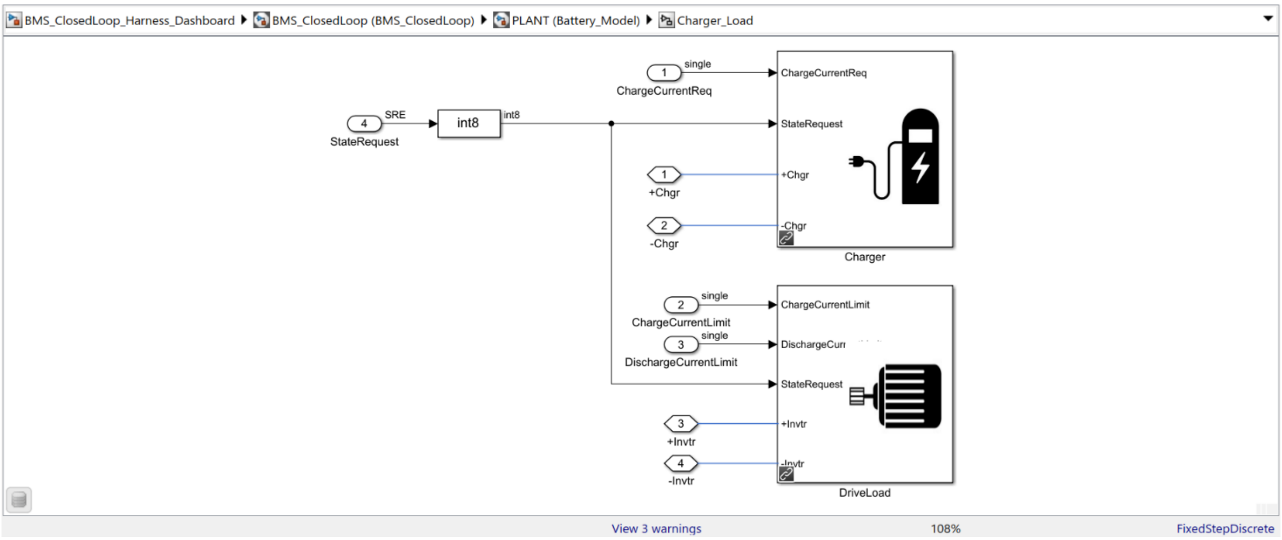


Figure 18 Charger Load

These are my design for my project using MATLAB. These design are complete that can get BMS and all SOC and SOH. The most important part are that I am using Extended Kalman Filter to get the accurate SOC for BMS.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This paper proposes a method of precisely assessing the state of charge (SOC) of rechargeable batteries in high eco-friendliness vehicles, like half breed electric vehicles (HEVs) and electric vehicles (EVs) utilizing Battery management system (BMS). In spite of the significance of precisely assessing the SOC of batteries to accomplish greatest proficiency and security, no strategy so far has had the option to do as such. This paper centers around the improvement of an assessment of time-fluctuating battery boundaries, and assessment of SOC within the sight of estimation commotion. To resolve these three issues, a model-based methodology that utilizes a fell blend of two Kalman filters, "series Kalman filters," is proposed and carried out. This approach is confirmed by playing out a progression of recreations in an EV working climate.

The ultimate goal is to design a state estimator capable of accurately estimating the state of any kind of batteries under every possible user condition.

4.2 SoC estimation of battery management system results

Using real-time measurement road data to estimate the SOC of battery would normally be difficult or expensive to measure. In application of the Kalman filter method is shown to provide verifiable estimations of SOC for the battery via the real-time state estimation.[7]

Yatsui and Bai in research paper introduced a Kalman filter based SOC assessment technique for lithium-particle batteries. Test results approve the adequacy of Kalman filter during the web-based application. Barbarisi et al introduced a lengthy Kalman filter (EKF)[10] to gauge the centralizations of the super compound species which are found the middle value of on the thickness of the dynamic material to get the SOC of the battery, by utilizing the terminal current and voltage estimations.

In view of unscented Kalman filter (UKF) hypothesis and a thorough battery model, an original SOC assessment strategy is proposed in [35]. The outcomes show that UKF strategy is better than expanded Kalman filter technique in SOC assessment for battery. Sun et al. introduced a versatile UKF strategy to assess SOC of a lithium-particle battery for battery electric vehicles. The versatile change of the commotion covariance in the SOC assessment process is carried out by a thought of covariance matching in the UKF setting.

In this examination work, powerful and precise Battery State of Charge (SOC) assessment system is proposed. Precise assessment of state of charge should be visible in the reenactment results taken by utilizing assessed open circuit voltage. It tends to be seen that the two cells with various inside attributes have slight distinction between assessed states of charging bends. Kalman filter technique is astoundingly precise in assessing non-straight systems with commotion sources. Reproduction result showed that proposed system can used to gauge SOC successfully which can be utilized to anticipate battery attributes like lifetime and wellbeing. [11]

4.3 Results in Simulink

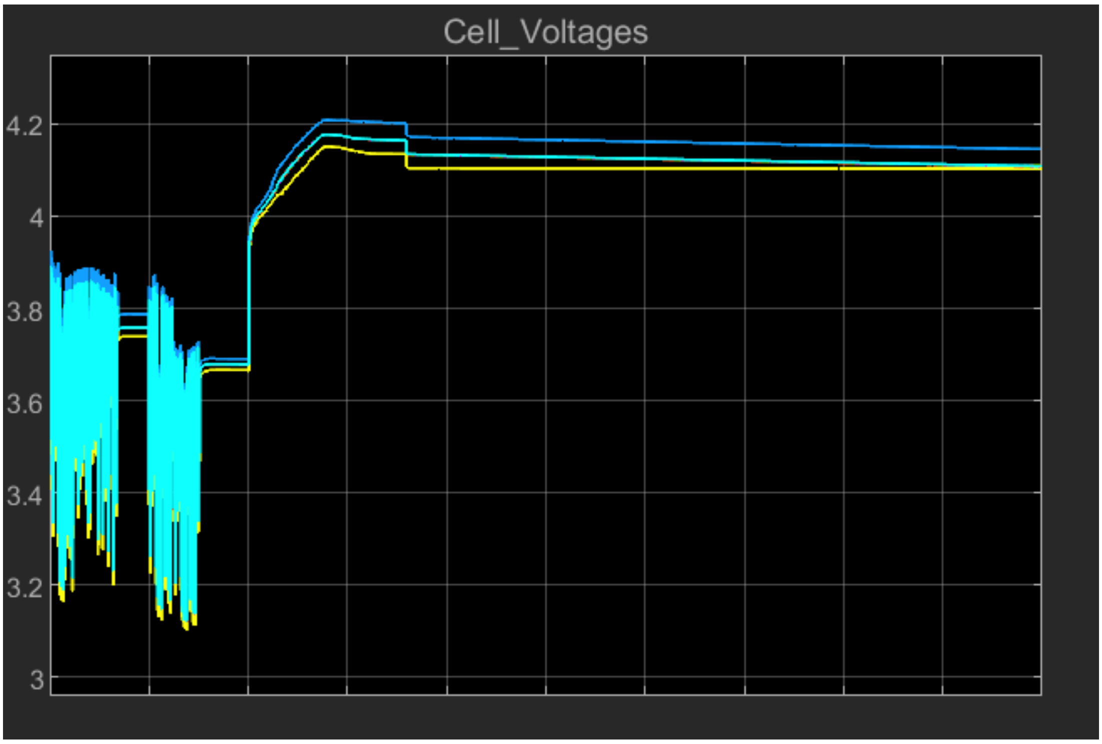


Figure 19 Cell Voltage

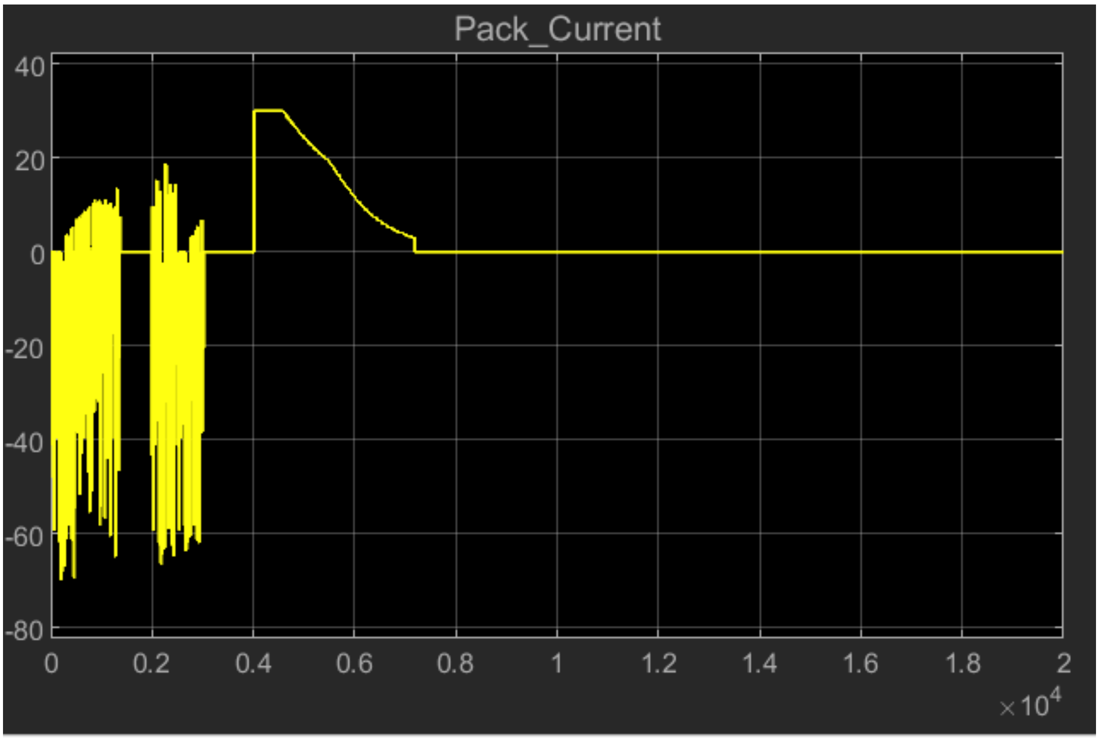


Figure 20 Pack Current

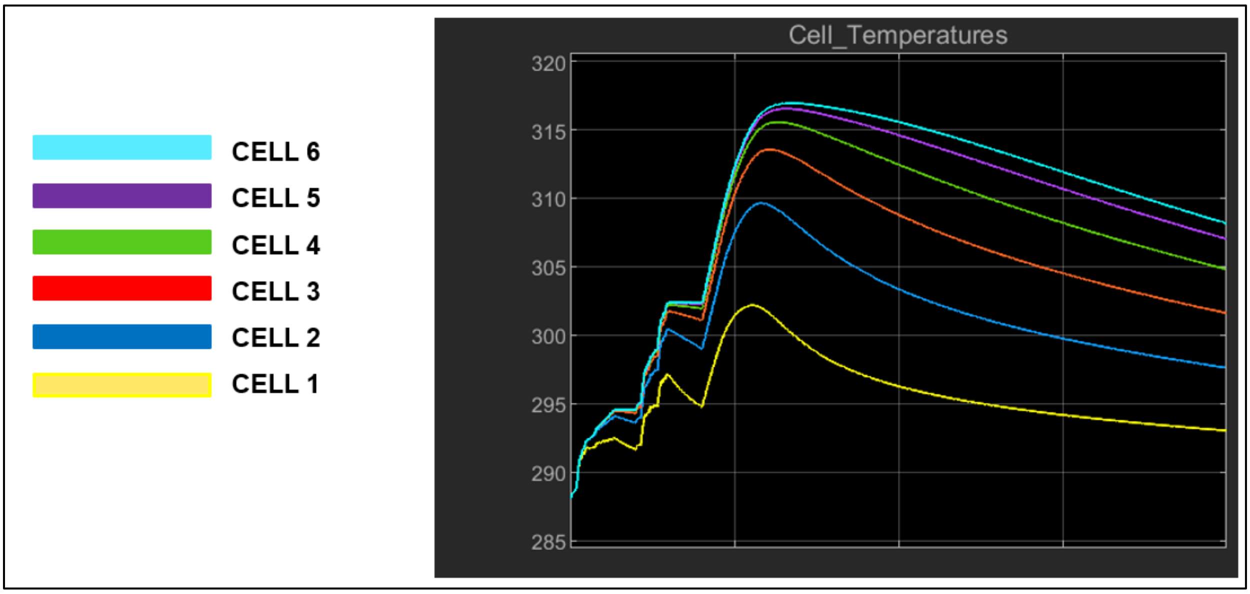


Figure 22 Cell Temperatures

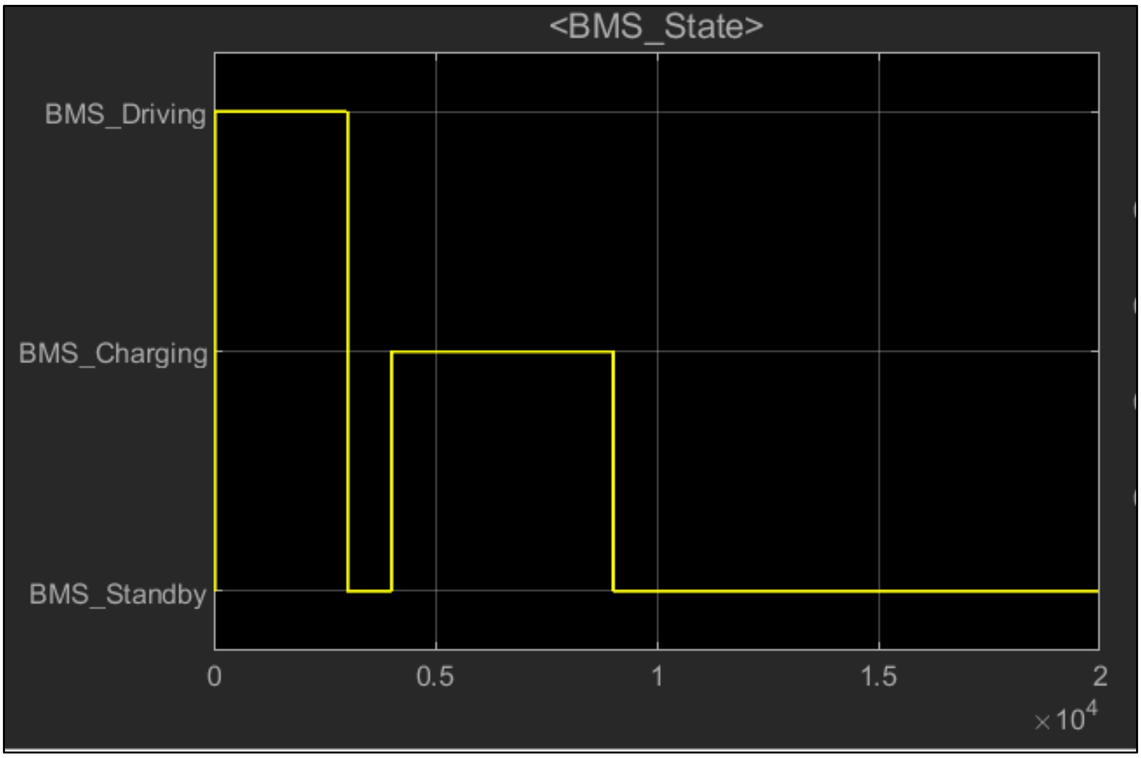


Figure 21 BMS

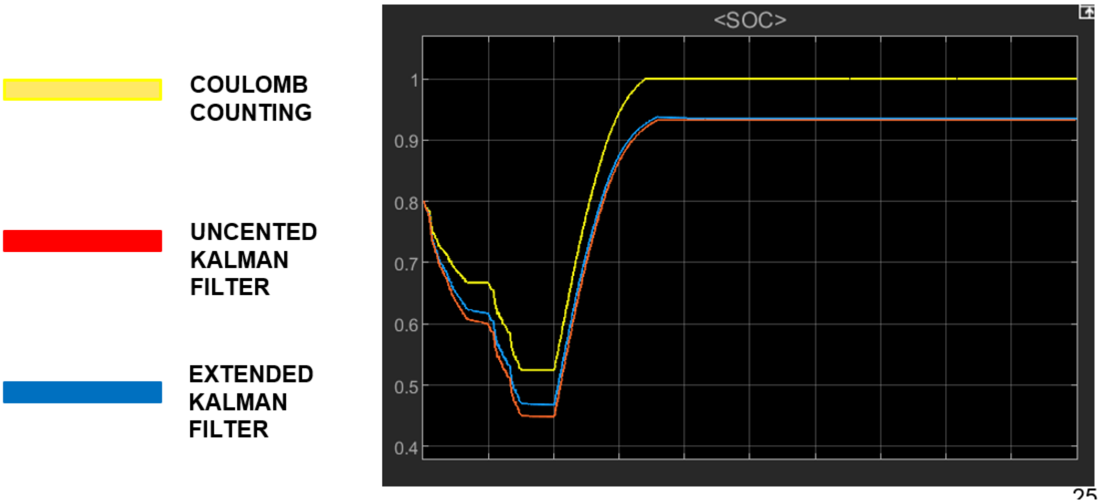


Figure 23 SOC Results

The SOC estimation technique is based on online closed-loop observers such as Kalman filter algorithms. This technique is the most popular and frequently used for real-time battery management systems, due to its higher level of computation compared to coulomb counting or artificial intelligence techniques. On account of the nonlinear behavior of the battery, extended Kalman filter is chosen for SOC estimation, which is a nonlinear version of the classical Kalman filter used for linear systems. Many previous works have addressed SOC estimation using EKF [3, 4]. The operation principle of the Kalman filter is the same as any other observer, it consists of estimating the outputs γ of the real system from its model by minimizing the difference between the measured and estimated outputs, in order to adjust the quantities of the variable χ Kalman filter is characterized by a gain K that allows the correction of the estimated states and tunes the performance and dynamics of the filter. Due to prediction error alongside measurement uncertainties (noise), this gain changes in each iteration. A good adjustment of the filter's dynamics is determined by good initialization of the measurement covariance matrix (R) as well as the error covariance matrix values P. In this work, a complete design and implementation process of EKF for SOC estimation is proposed, starting with modeling and identification of battery internal parameters, in addition to the choice of the appropriate embedded card and performance evaluation.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this paper, I have proposed the technique for battery management system and Kalman filter to appraise the SOC of a battery for HEV/EV use. The proposed technique includes the utilization of a Kalman filter in MATLAB Simulink. In this paper, the useful squares of a BMS have been created. The different practical squares, e.g, battery model, warm management, and battery ability assessment, are incorporated and mimicked in the Simulink stage. The SOC assessment has been executed utilizing Kalman filter with the SOC reset system utilizing the OCV strategy, accordingly disposing of the impediment of the independent Kalman filter technique. The Kalman filtering strategy was utilized to further develop the SOC assessment procedure. The utilization of the Kalman filtering strategy in the battery calculation altogether works on the precision of the SOC assessment, which is checked by test and re-enactment results.

REFERENCES

[1] J. P. Rivera-Barrera, N. Muñoz-Galeano, and H. O. Sarmiento-Maldonado, *Soc estimation for lithium-ion batteries: Review and future challenges*, vol. 6, no. 4. 2017.

[2] K. W. E. Cheng, B. P. Divakar, H. Wu, K. Ding, and H. F. Ho, "Battery-management system (BMS) and SOC development for electrical vehicles," *IEEE Trans. Veh. Technol.*, vol. 60, no. 1, pp. 76–88, 2011, doi: 10.1109/TVT.2010.2089647.

[3] H. J. (Hendrik J. Bergveld and University Press Facilities), "Battery management systems : design by modelling," *Int. J. Eng. Res. Technol.*, vol. 9, no. 5, pp. 605–607, 2020, [Online]. Available: https://www.ijert.org.

[4] W. Chang, "The State of Charge Estimating Methods for Battery : A Review," vol. 2013, no. 1, 2013.

[5] C. Taborelli and S. Onori, "State of Charge Estimation Using Extended Kalman Filters for Battery Management System."

[6] Z. Yu, R. Huai, and L. Xiao, "State-of-Charge Estimation for Lithium-Ion Batteries Using a Kalman Filter Based on Local Linearization," pp. 7854–7873, 2015, doi: 10.3390/en8087854.

[7] K. L. Man and C. Chen, "Towards a Hybrid Approach to SoC Estimation for a Smart Battery Management System (BMS) and Battery Supported Cyber-Physical Systems (CPS)," no. September 2014, 2012, doi: 10.1109/BCFIC.2012.6217989.

[8] F. Asghar, M. Talha, S. H. Kim, and I. Ra, "Simulation Study on Battery State of Charge Estimation Using Kalman Filter Simulation Study on Battery State of Charge Estimation Using Kalman Filter," no. November, 2016, doi: 10.20965/jaciii.2016.p0861.

[9] C. Montella, “The Kalman Filter and Related Algorithms : A Literature Review The Kalman Filter and Related Algorithms A Literature Review,” no. May 2011, 2014.

[10] A. Nugroho, E. Rijanto, F. D. Wijaya, and P. Nugroho, “Battery State of Charge Estimation by Using a Combination of Coulomb Counting and Dynamic Model With Adjusted Gain,” no. October, 2016, doi: 10.1109/ICSEEA.2015.7380745.

[11] A. Baba and S. Adachi, “SOC Estimation of HEV / EV Battery Using Series Kalman Filter,” vol. 187, no. 2, pp. 907–914, 2014, doi: 10.1002/eej.22511.