EFFECT OF DIFFERENT BATTERIES ON BATTERY MANAGEMENT SYSTEM IN ELECTRIC VEHICLES

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EFFECT OF DIFFERENT BATTERIES ON BATTERY MANAGEMENT SYSTEM IN ELECTRIC VEHICLES

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BY

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ABSTRACT

Electric Vehicles are one of the highly important possible means of transportation in our future life. They have ability to reduce the use of petrol which emit CO_2 in atmosphere and cause air pollution. For best performance of an Electric Vehicle one needs a proper battery management system. Battery is an essential part of battery management system. The most important concern is how much efficient these batteries can be. They have different properties that should be controlled to maximize the life of a battery cell and due to that control the performance as well as life of electric vehicle is made longer and better. Such type of control on battery cell is provided by battery management system of that electric vehicle. By proper working of battery management system, the safety as well as reliability of operations and durability of electric vehicles enhances. All the components of battery management system were discussed in this research work along with best type of batteries to be used in it. Two different models were produced in order to compare charging and discharging properties of four different types of batteries. Those four batteries are Lithium Ion battery, Nickel Metal Hydride (NiMH) battery, Lead Acid battery and Nickel Cadnium battery. MATLAB Simulink was used to build and test different models. With different constant variables of those models following parameters were calculated: SOC % (state of charge), charging time and discharging time. From the results it was observed that lithium ion battery is the best choice for making an efficient battery management system. Lead acid battery can be used as second option because it also provides a better performance, as it has the best discharging time among all the batteries.

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"EFFECT OF DIFFERENT BATTERIES ON BATTERY MANAGEMENT SYSTEM IN ELECTRIC VEHICLES"

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List of Abbreviations

Mpg	Miles per gallon
BEVs	Battery Electric Vehicles
PHEVs	Plug-in Hybrid Electric Vehicles
HEVs	Hybrid Electric Vehicles
AC	Alternate-current
DC	Direct current
SOC	State of charge
SOH	State of health
OCV	Open circuit voltage
Wh	Watt-hours
Dcfc	Direct-current fast charging
GUI	Graphical user interface
NiMH	Nickel Metal Hydride Battery

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CHAPTER 1

INTRODUCTION

1.1Vehicles

A Vehicle is a machine which is used to transport people or cargo from one place to another. Vehicles are of many types specified according to their structure. Vehicle with two wheels can be either a bicycle or a motor bike, where vehicle with four wheels can be a car, bus, truck or a wagon. By use of modern technology vehicles without wheels are also produced such as ships in sea and airplanes in air [1].

Modern technology has worked a lot to make vehicles best up to the mark. In present era, vehicles are manufactured with best performing equipment's and systems. The modern technology used in automotive industry is as following:

- Cruise Control

The basic function of cruise control is to control the speed of vehicle automatically with help of sensors. By help of cruise control there is no need of changing gears or hit brakes every time [2].

- Automatic Lift-Gates

With help of automatic lift-gate, driver can easily unlock the doors of the vehicle without touching it. As the key would be brought closer to the vehicle, the sensors build inside the keys will be sensed by the vehicle and hence it will open up automatically. This feature helps the driver extremely when his hands are fully loaded [2].

- GPS Car Track

To get the regular updates regarding position of the car, a GPS tracking system is used in modern vehicle. It also provides an indication regarding over speed of the

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vehicle, as well as it also informs the owner if a specified geographical location is crossed by the vehicle [2].

- Backup Cameras

In present era majority vehicles have backup camera which helps a lot during reverse or parking the car. It has several advantages; the most important one is saving costs because with help of these cameras driver will avoid hitting trash bins or walls when reversing. Additionally, they can park easily in tight place [2].

- Automatic High Beam Control

Most modern cars which are manufactured by leading companies such as Volkswagen, Toyota, and Hyundai have a system that automatically turn on the lights when it starts getting dark and dims the high-beam headlights when they sense an oncoming vehicle [2].

There are basically two type of mechanism on which a vehicle runs. On behalf of these two mechanisms vehicles can be categorized in two form, fuel vehicles and electric vehicles [2].

1.2 Fuel Vehicles

Fuel Vehicles works with either gas or diesel. Both work on same mechanism of internal combustion engines. A gasoline vehicle works with spark ignited internal combustion engine, where vehicle using diesel works with compression ignited systems. In spark ignited system, first the fuel is injected to combustion chamber and then it is combined with air. Then this fuel mixture with air is ignited by a spark produced by a spark plug. Gasoline is the most common transportation fuel but there are also many other alternative fuel options present that use similar components and engine systems [1].

1.3 Electric Vehicles

Electric vehicles are that type of vehicles which runs fully or partially by electric power. First electric vehicle was introduced in 1884 by Thomas Parker after the invention of lead-acid batteries. Electric vehicle is one of the best upcoming technologies in this world as it has great number of advantages regarding

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consumption of fuel, reduction in harmful gases and better efficiency. Such automobiles run by a battery, which is needed to be recharged. Many companies are working on construction of electric vehicles, as the only drawback is their speed, as they cannot reach the high speed and long ranges as compared to that of conventional vehicles. So nowadays work is done on making their speed high and distance covered large by making advancement in their electric motor and batteries. The time during which their battery gets charged is long as compared to the time they are in work, so due to that reason they are still not up to the mark [1]. Electric Vehicles consist of many components such as charging module, converters, controllers, batteries and electric motor. All components perform different actions regarding their requirement and use [2].

1.4 Comparison between Fuel Vehicles and Electric Vehicles

Electric Vehicles and Fuel Vehicles have a great resemblance in terms of outer structure just for an exception that electric vehicles don't have a tail pipe. When internal system is examined both are quite different from each other. 70% of electric vehicle parts are quite different from fuel vehicle [3].

When moving parts are brought into consideration, electric vehicle has only one moving part, the motor, where in case of fuel vehicle it has number of moving parts. Due to less moving parts electric vehicle is more reliable and requires less periodic maintenance. The fuel vehicle requires more maintenance which starts from frequent oil changes, replacement of filters, repairing of exhaust system and periodic tune ups, and ends at less frequent actions such as replacement of water pump, fuel pump and alternator etc. [4].

As electric vehicle has only one moving part so its maintenance is less costly as compared to that of a fuel vehicle. With advancement of technology the batteries used in electric vehicles are produced in such a manner that not only they extend the range of vehicle but also extend the life of battery pack which may eliminate the need of replacing the battery pack during the life of the vehicle [3].

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Electric Vehicles are more efficient then Fuel Vehicles. An electric vehicle efficiency will travel about 43 miles for $1.00. Based on an average of 22 mpg (miles per gallon) for fuel vehicles and a fuel cost of $1.25/gal, the fuel-powered vehicle will go about 18 miles. Thus, the distance that can be traveled for a fuel cost of $1.00 is more than twice as far with an electric vehicle [3].

With all these advantages, challenges still exist for the owner of an electric vehicle. Some of these challenges are, the battery charging which is a time consuming process, the weight of an electric vehicle which is heavy due to overloaded batteries with in it, it cannot climb quickly on height and it causes indirect pollution [3].

1.5 Type of Electric Vehicles

The three basic types of electric vehicles are categorized on basis of their working principal. These are as following:

- Battery Electric Vehicles (BEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs)
- Hybrid Electric Vehicles(HEVs)

Battery Electric Vehicles or in short BEV's are the type of electric vehicles which only works on rechargeable battery and no gases are present inside. The battery is recharged by the grid and so the vehicle performs its action after getting fully charged. BEVs do not produce any harmful gasses in atmosphere, so they are extremely environment friendly vehicles [2].

Plug in Hybrid vehicles or in short PHEV's have dual engine, which means they consist of a gasoline engine as well as electric motor to run the car. The fixed batteries can be recharged by regenerative braking. They are different as compared to regular hybrid vehicles as they have a larger battery which can be recharged by plugging it into a grid. A hybrid vehicle can only travel 1 to 2 miles at a slow speed before converting into gasoline engine, where a PHEVs can travel 10 to 40 miles without converting to gasoline engine. When the electric range is reached, plug-in hybrid-electric vehicles act as a normal hybrid car and can travel hundreds of miles

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on the gas tank. An EVgo L2 charger is used for charging plug-in hybrid-electric vehicles, but most PHEV's can't support quick charging [2].

Hybrid Electric Vehicles or in short HEV's, work on both the electric motor and the gas power engine to run the car. The energy in these types of vehicles is gained by regenerative breaking otherwise the lost energy may affect or damage the gasoline engine. HEVs can't be recharged by grid or any EVgo charger [2].

1.6 Charging Technologies in Electric Vehicles

There are three types of charging technologies used in electric vehicles which are as following:

- Alternate-current (AC) charging, also known as level 1 or level 2

In this type of system, an inverter present within the car converts alternate current (AC) to direct current (DC), which then charges the battery at either level 1 or level 2. It operates with at powers approximately equal to 20 kilowatts [5].

- DC charging, also known as level 3 or direct-current fast charging (DCFC)

In this type of charging system, the current is converted before it enters the car which means that the alternating current is converted from the grid to direct current and charges the battery without use of an inverter. Usually called direct-current fast charging or level 3, it operates at powers ranging from 25 kilowatts to more than 350 kilowatts [5].

- Wireless charging

In this type of charging system electromagnetic waves are used in order to charge the batteries. Usually a charging pad is connected to the wall socket and a plate which is attached to the vehicle. Current technologies range same as that of level 2 chargers and can provide power up to 11 kilowatts [5].

1.7 Battery Management System in Electric Vehicles

Management system for battery plays an important part for the management of batteries in electric vehicles. Batteries have different properties which should be controlled to maximize the life of a battery cell; such control is performed by

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battery management system due to which the safety as well as reliability of operations and durability of electric vehicles enhances. In electric vehicles, the battery management system has to perform many complex tasks for better working as compared to other applications and this is the greatest reason why modern technology is trying hard to make battery management system best [3].

There are many different cells in battery management system. Some of them are connected in combination of series and other are connected in parallel combinations. Each cell has its own characteristic which is checked and controlled by Battery management system. Battery cells have some limits for its long term lifetime such as temperature, charging and discharging rate and most extreme as well as least cell voltage. These all limitations are managed by battery management system. A gripping battery management system will protect the electric vehicle from physical damage, it will manage the charging and discharging of batteries, life cycle limit of battery and it will also estimate the life of a battery cell. Battery management system is also connected with the engine controller, heat controller, the common bus bar and other monitoring systems to maintain as well as perform different functions [3].

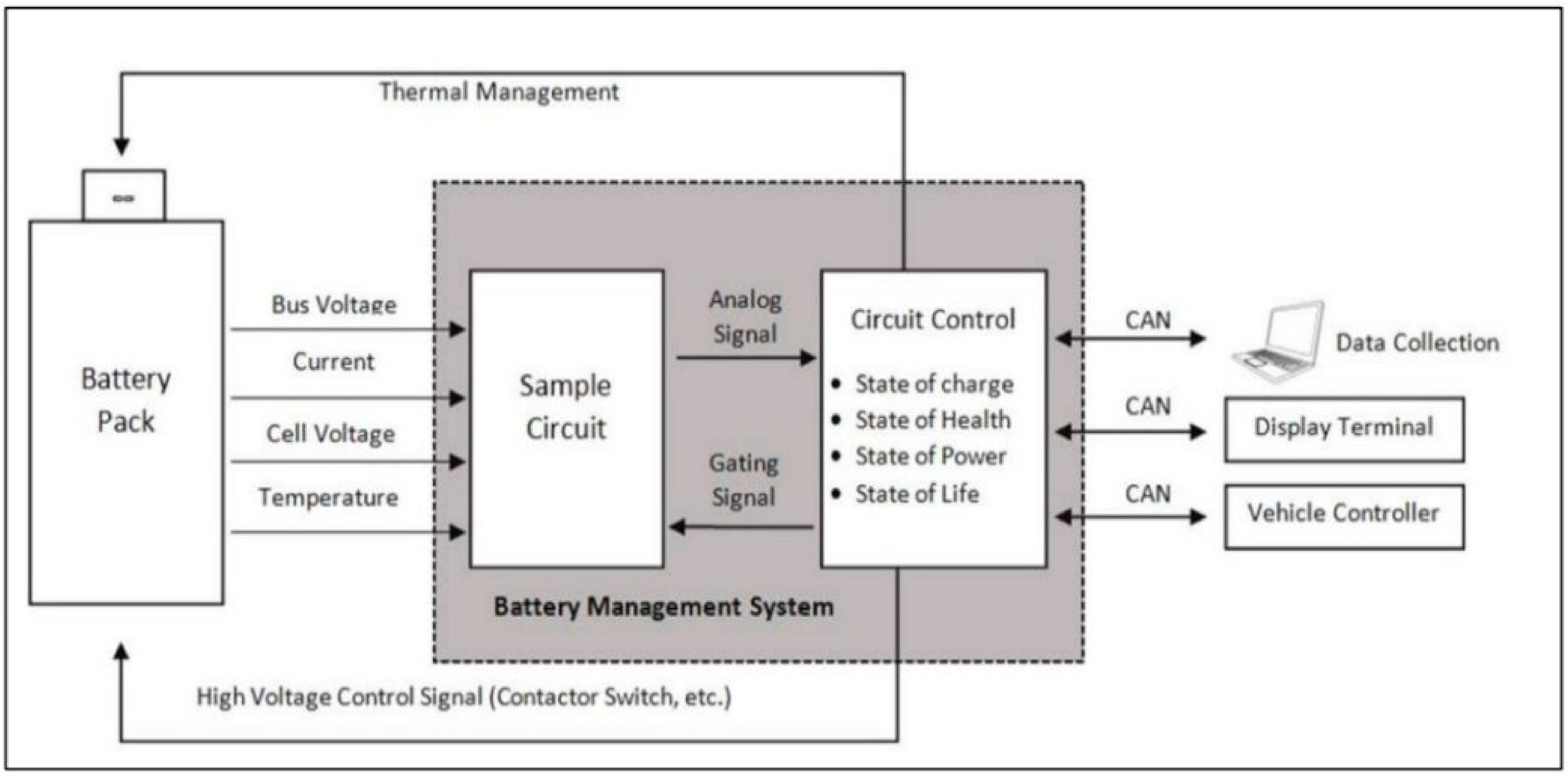

Figure 1.1 General Battery Management Systems [3].

It can be viewed from figure 1.1, that a battery management system consists of a battery pack, which is connected to a circuit control. This circuit control is further connected to a sample circuit which deal with the basic parameter of the battery pack such as bus voltage current, cell voltage and temperature. The signal by the sample circuit is detected by the circuit control and send to the display terminal as well as vehicle controller which control the vehicle. So in this way battery management system protect the vehicle life time and its performance by monitoring it continuously.

1.7.1 Architecture of a Battery Management System: -

Architecture of battery management system is divided into two portions, hardware and software. Hardware components are present inside the car to manage the following parameter of batteries voltage, current and temperature etc. Software components are responsible for the managing alert, performance of internal and external communication, monitoring of active variables and performing different types of estimation [3].

1.7.2 Block diagram of Battery Management System: -

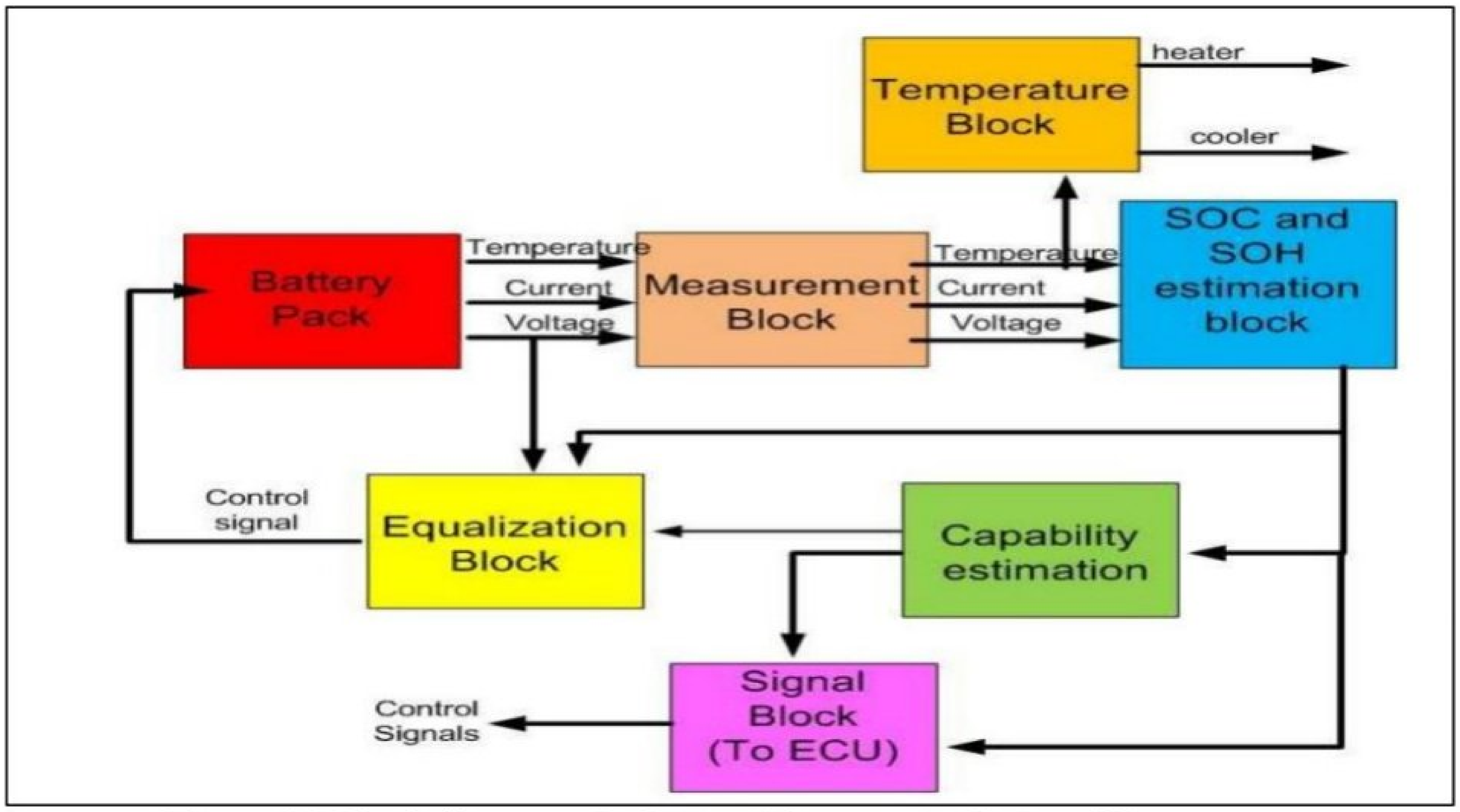

Figure 1.2 Block diagram of a Battery Management System [3]

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The basic blocks of battery management system are explained as following:

- Measurement Block

The main working of a measurement block is to have a look at cell voltages, currents, temperatures, ambient temperatures, as well as all the necessary data. Once the values of all the factors are calculated then they are converted into digital signal for processing. Placing sensors at a cell level is advantageous because at the lowest level they provide cell balancing but its cost is very high [17].

- Battery Algorithm Block

The main function of the battery algorithm is to estimate the SOC (State of Charge) and SOH (State of Health) of battery management system using data provided in the measurement block. State of Charge (SOC) of a battery is defined as the amount of current, battery has a capacity to keep. Charging mode varies with temperature, charging and discharge cycles. Therefore, such factors should be considered by the algorithm used. The cost ratio is very helpful in avoiding the risk of overcharging and undercharging. Due to charging, the disposal cells may be overcharged mainly due to regenerative brakes. In such cases the battery management system should monitor the conditions and control all parameters to avoid damage to the battery. The most common method of calculating the cost condition is to measure the open circuit voltage (OCV) and to output the charge status on the previously stored output components. But in this way the effect of heat is not taken into account. It is therefore important to use a method that takes into account all the consequences [17].

- Capability Estimation Block

This block is used to determine the maximum amount of charging and discharging of current at any point during calculation of state of charge and state of health. The output value which is obtained by this block is then calculated by the Electronic Control Unit. Hence battery management system is now fully able to have control

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over the charging and discharging of the battery and it also works on other measures necessary to protect the battery [17].

- Cell Equalization Block

All cells present in battery management system are not ideal and hence they will have variation in characteristics. So even from cell to cell charging level may vary. The balancing of state of charge and state of health is performed by this portion, in order to protect the system from damage. It provides comparison of different voltages of cell and their state of charge and also provides the differences in between them [17].

- Heat Management Block

It monitors the cell temperature so that no damage can occur during the operation. Cooling system and the heating system is then provided with the output. These systems then work collectively to maintain the temperature within working limits which are safe in nature. A control signal is sent to the Electronic Control Unit (ECU) if the temperature rises abnormally which can cause permanent battery damage [17].

1.7.3 Functions of Battery Management System: -

Following are the common functions performed by battery management system:

- Cell Monitoring

When the battery is charging or discharging, its cells should be monitored at all times. Any unusual action or situation must be identified on the spot and reported along with the solution in order to make safety of electric vehicle sure. This action is performed by the integrated circuit equipped with algorithms of cell monitoring. There are large numbers of commands through which cell voltage and temperature are recorded and maintained as a data for cell management controller [4].

State of charge is calculated to ensure that the battery is charged or discharged perfectly, which means they are not over or undercharged. State of charge is also

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used as fuel indicator in electric vehicle as it shows the remaining energy in the battery and with this information we can also know the range of distance which can be covered by the electric vehicle before recharging its battery [4].

State of health is an indicator of overall health of the battery and gives an internal look into the operating conditions of the battery. With the help of this information, battery lifespan and maintenance schedule can be projected [4].

- Power Optimization

When the cell is monitored, the first basic outcome of this action is optimization of battery power. As the cell monitoring determines SOH and SOC, so one of the jobs performed by battery management system of electric vehicle is to keep SOH and SOC values within the specified range. During charging, the battery management system keeps an eye on how much current should be allowed to transfer into each cell, and during discharging it take care of the voltage level, so that it does not decrease to a very low rate. This function is performed with help of communication motor controller [4].

- Safety of Electric Vehicle

The most important function in any system is to provide safety of a device. Battery management system, make sure that electric vehicle is working safely. Any unwanted thermal operation can cause a great damage with in the electric vehicle, so battery management system keeps a strict eye on the temperature of batteries in electric vehicle. Another way of safety is to make insulation over the battery pack, so that electric shock can be avoided [4].

- Battery Charging Optimization

The battery cell present within electric vehicle decay with passage of time, due to this decay a large impact is experienced on factors such as voltage, current, etc. Battery management system identify and reduce its effect, when the battery cells shows change in working, mostly one of them start producing heat and get charged at a lower voltage. So battery management system optimizes the charging process,

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so that the entire cells get charged at lower voltage. Due to this action battery stress is reduced and life of battery increases [4].

1.8 Batteries used in Electric Vehicles: -

There are four types of batteries which are most commonly used in electric vehicles. They are named as

- Lithium Ion battery
- Nickel Metal Hydride (NiMH) battery
- Lead Acid battery

The additional batteries which can also be used for better performance are Super-capacitor and Nickel Cadnium battery.

All of these batteries have different effect on working of battery management system of electric vehicle.

1.8.1 Lithium Ion Battery: -

Lithium Ion battery was first commercially used in 1991 for consumer electronics sector. The working principle of lithium ion battery is the circulation of electrons by means of creating potential difference between two electrodes, out of which one is positive and one is negative. These electrodes are immersed in a conductive ionic liquid called the electrolyte. When power is supplied to a device by battery, the electrons present in the negative electrode travel to the positive electrode by external circuit (it is the discharging phase). When the battery is charging, these electrons move from positive to negative electrode [5].

A lithium-ion battery inside a car is designed as a combination of individual battery units (cells), connected to each other and monitored by an electronic circuit. The number of cells, the size of each cell, and the way it is organized, determines the amount of voltage that a battery can supply and its capacity, which means the amount of electricity it can store. In the automotive industry they are usually referred to as watt-hours (Wh), or kilowatt-hours (kWh) [5].

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Lithium ion batteries are commonly used in electric vehicle due to its high storage density. This density lies on the ratio of storage capacity and the weight or size of battery. If a comparison is made between lithium ion battery and a lead acid battery, then it is notice clearly that density of lithium ion battery is 300 to 500 Wh/Kg, which is ten time more than lead acid battery. Lithium ion battery provides high voltage, easy recharging and durability. Its use in hybrid vehicles is relatively new, but it could move the car for 150,000 miles which is a battery life of 15 years. This longevity is longer than other hybrid battery packs, a desirable feature for consumers who are aware of the cost. Lithium-Ion batteries can also be used and provide a quick charging time of up to 30 minutes [6].

With so many advantages lithium ion batteries also have some disadvantages, for example there is limitation produced in size of lithium ion battery. They work best in small size because when the size of lithium ion battery is increased, heat is produced due to improperly absorbed electromagnetic waves. More over cost of lithium ion battery is very high (some as much as $5,000) [6].

1.8.2 Nickel Metal Hydride Battery (NiMH): -

Another type of battery use in electric vehicle is Nickel Metal Hydride Battery (NiMH). This type of battery uses hydrogen to store energy, plus nickel and another metal, such as titanium, to secure the hydrogen ions. The working range of NiMH is 4 to 5 miles kilowatt hour and so they produce more energy. They can be recharged easily but low amount of energy is stored inside them as compared to lithium ion battery packs [5].

The cost of Nickel Metal Hydride Battery is less, and they are more compatible and versatile. The disadvantage of Nickel Metal Hydride Battery is that it has higher discharge rate. Which means it loses a large amount of their charge during discharging. As it has high level of toxicity, it is harmful to the environment when improperly disposed of [6].

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1.8.3 Lead-Acid Battery: -

Lead-acid batteries are used in electric vehicle due to its high power. It is inexpensive, safe, and reliable. They have a longer battery life and are less in weight. It is the oldest auto battery which was used in electric vehicle [6].

However, some disadvantages of lead acid battery are low energy, poor temperature performance, and short cycle life. An electric vehicle with a lead acid battery can travel up to 10 miles in fully electric mode and 20 miles in hybrid mode [6].

1.8.4 Super-Capacitor: -

Super capacitor is a best alternative source which can be used in battery management system for promising working as compared to conventional batteries. The working principle of super capacitor is same as that of conventional capacitor. The only difference between both the capacitor is in charge accumulation mode. In super capacitor the charge is accumulated at the interface between electrolyte solution and conductor surface, where in case of conventional capacitor or classical capacitor the charge is accumulated on the two armatures [17].

There are many advantages of using super capacitors, for example

- They don't contain any polluting material in their chemical composition.
- They can store electric charge in very large quantity.
- They allow charging and discharging of current in large value which might be hundreds of amperes.
- The most efficient and greatest advantage of super capacitor is that it decreases the size and weight of the proposed system [17].

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RATIONALE

Nowadays, electrical vehicles are becoming a popular technology, due to the existing environmental problems. They reduce emissions to a great extent and help us to conserve natural fuel resources. To attain these features, electrical vehicles require proper functioning of battery management system. A battery plays a critical role in battery management system of electric vehicles; as the driving range of electric vehicle depends upon the efficiency of battery. Modern technology is working on making battery management system better and efficient. The main focus of this work is to compare how different batteries can affect the efficiency of battery management system for making electric vehicle best for drive.

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OBJECTIVES

Following are the objectives of this study:

- To comprehend and compare the potential utilizations of different batteries for making the battery management system better.
- To understand different strategies used for making better battery management system.
- To highlight the future perspectives of electric vehicles by using different batteries and new components

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CHAPTER 2

LITERATURE REVIEW

Guangxu Zhang et al. (2021) presented a paper on comprehensive study about the internal short circuit of lithium-ion battery and its importance regarding electric vehicles. It includes the formation mechanisms, evaluation, experimentation, and advantages of lithium-ion battery in order to be used in battery management system. It provides the information that lithium ion batteries have high energy and high power density, with long term life time service. From 2013 china is using lithium ion battery in electric vehicles and its ratio is increasing day by day, due to its better efficiency. According to their work, by making better active invention, the temperature range of lithium ion battery was so adjusted that it become protected from sudden rise in temperature. For batteries, high current charging and low temperature are extremely dangerous, so in order to solve these issue the latest solution are AC heating and optimizing charging algorithm. AC heating working during low temperature warm up the cells and make them reach their normal operating temperature improving electrode kinetics. Optimizing charging algorithms can reach the fast charging without affecting the life of cell and its safety [7].

R. Sreedhar et al. (2021) studied that battery management system is one of the essential part of electric vehicles for its smooth working and long life. In this paper they provided four different batteries which can be used in battery management system by different simulation design. These batteries are of Nickel-Metal-Hydride, Nickel-Cadmium, Lithium-Ion and Lead-Acid. That design of system is in such a way that it controls the instantaneous values of current, power consumption, battery voltage and state of charge. The system proposed by them continuously look over the battery parameters especially during the state of charge with high efficiency. The simulation for model

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formation was done using MATLAB. Their work proved that lithium ion battery possesses best performance in most of the battery parameter when evaluated with other four battery type [8].

Rohullah Tofan et al. (2021) examined that after so many advancements in battery system of electric vehicles, there are still many lags due to which it cannot satisfy the energy demands required by electrical vehicles for electricity usage. The major problem is the Non-monotonic energy consumption during the time when battery discharges. This action is very dangerous for the battery's electrochemical operations. A solution was provided that if a super capacitor which is an electrochemical cell but with higher rate capability and greater cyclability is used this problem can be solved. Super capacitor will provide the additional energy which is required in such scenario when the battery fails. The simulation for this method was done on MATLAB. Super capacitor was connected with lead-acid battery. Through his paper a controller model was developed. The function of the controller is to maintain the vehicle's constant speed with the proper power distribution within the battery and super capacitor, as well as to prevent sudden changes in the flow of battery power to protect it. Their Future efforts are focused on building a final machine that will work with all modes of driving [4].

Muhammad Uzair et al. (2021) studied the different parts of battery management system in detail. They provide the comprehensive explanation of all those aspects and development in them.one important task perform by battery management system is the cell monitoring. The paper includes a proposed model for cell balancing and different techniques for cell balancing. The comparison of these cells take place by eight cell battery pack and the simulation is done by using MATLAB. Their work provides us information that active cell balancing technique enhances the energy balancing better as compared to that off passive cell balancing techniques. Due to the proposed technique the life of lithium ion batteries increases and efficiency of electric

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vehicles also become better. Their work mentioned that battery management system is still in an early stage. Management for safety, high-efficient operations and good maintenance are still challenges for future electric vehicles as battery management system has to perform many enlightened functions in real time to manage difficult nature of batteries, which can deal with harsh environments and fulfill the requirements of future electric vehicles [3].

Nitika G. Panwar et al. (2020) published an article which explains the recent advancements done in battery management system of electric vehicles. According to them there are still some issues in battery management system of electric vehicles such as be it range anxiety, slow charging or the performance/cost of the battery, so they discussed those issues which are mainly faced due to problems of methods use for cell balancing, type of battery used and its protection against charge and over current, thermal management system and estimation of State of health (SOH) and estimation of state of charge (SOC) of the battery in battery management system. Their work explains the advancement in development of advance and intelligent technologies which can be used to make battery management system work fast and more efficient. For such purpose non-destructive testing of batteries was performed. Their work provides a frame work for upcoming researchers and experts, which they can use to develop comprehensive systems comprising of advanced battery management system with real-time battery monitoring and battery reusability and recycling; etc. as a whole complete unit [9].

Yujie Wang et al. (2020) provided a systematic review of most commonly used battery modeling and the state estimation approach for battery management system. There model consist of physics based electrochemical model, integral and fractional order based chemical model. The state emission approaches are made according to the health prognoses, energy estimation, power capability prediction and life span and many other crucial indexes in battery management system. According to them the main reason why battery management system cannot be developed is that lithium batteries are highly non-linear with

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multispatial scale (such as nanometer active materials, millimeter cell, and meter battery pack, etc.) and multi-time scale aging, making it difficult to accurately modeling. They discussed the outcomes as a result of these modeling and challenges faced by them. The data-driven battery management scheme provided by them was based on big data and cloud computing, so it seems to be a trending one in future [10].

Aishwarya Muralidharan et al. (2020) presented a paper which consists of the introduction of all the pervious algorithms present in battery management system estimation method, and the information of particular battery required for electric vehicles. A model was proposed by them with its outcome. According to their study lithium ion battery are the best choice for battery management system, due to its property of high density and high power, its low cost and large life time. It has high single-cell voltage, high specific energy; high energy efficiency more over Lithium is the third lightest element following Hydrogen and Helium so due to these reasons they are most suitable for electric vehicles [11].

V Karkuzhali et al. (2020) presented a paper in which they discussed that for a safe and reliable operations, electric vehicles require high power batteries with extreamly suitable battery management system. The main topic of their interest was discussion of electric vehicles batteries and issues faced by battery management system of electric vehicles. They also compared Lithium ion (Li-ion) battery & Nickel metal hydride battery by considering terms of aging and effect of temperature using their state of charge (SOC) and open circuit voltage (OCV) [12].

Muhammad Umair Ali et al. (2019) presented a paper in which they discussed that energy storage system is still a problem faced in electric vehicles. In order to solve this problem, the only solution is use of a smart battery management system. As nowadays lithium ion batteries are most commonly used in electric vehicles, but their accurate estimation of state of charge is bit difficult because

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they are highly time variant, non-liner and have a complex electrochemical system. So they explained the detail of all those problems which can be faced during use of lithium ion batteries including their merits, limitations and estimation errors. They also provide some solution to the problems faced during online estimation, based on development in technologies [13].

Achary Bosire Omariba et al. (2019) studied on various battery cell balancing methodologies for optimizing battery pack performance. Most of the time failure is caused in batteries due to its wrong connection either in series or in parallel, which need to be properly corrected in real time manner. By their study they explored that there are many schemes named as active and passive, which can solve these problems. All those schemes have their own advantages and disadvantages, so by critical analysis the proper scheme for the problem faced can be selected. Studies have shown that the hybrid system will be much better because it is in line with the benefits of all systems. Their research examines the relationship between those strategies and battery performance. Currently there are very few studies dealing with the vibration of battery measurement performance. Their research suggests that long-term battery durability should be evaluated from a wide range of temperatures and vibrations [14].

Ming Shen et al. (2019) presented a paper which explains the detailed study of research and developments of multi-physics model simulation and multi-function integrated battery management system technology. Due to progress in battery technology, advancement is achieved in battery management system, as it is converted into an integrated one. According to their study effective control of battery management system can be achieved by implementation of an effective model which needs to be established as a beginning step. On basis of this reason, some important technologies which are based on the model are more advanced in function of ensuring battery safety, power, and durability. Some of them are battery state estimation, energy equalization, thermal management, and fault diagnosis. It is an essential to consider the

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communication of interactions between battery management system and vehicle controllers, motor controllers, etc., for optimizing driving and improving vehicle performance. So from their work it was proved that a cooperative and collaborative battery management system is the base for green-energy vehicles should be intelligent, electric, systemized, and shared [15].

Mao LI et al. (2018) proposed a design through which different parameters of battery thermal performance can be studied. These parameters deal with flow rate of cooling air, heat flux produced from the battery cell to the cooling air, and passage spacing size. These three parameters are used to evaluate the battery thermal management system, its thermal performance which includes high temperature in the battery module, temperature similar to the battery module, and pressure drop. Through their research they found that increasing the amount of bulk flow would result in an uneven distribution of the flow rate between the corridors, and the large size of the passage space could adversely affect the temperature similarity to the battery walls. In their experiment, optimization was also performed to reduce the passage spacing size [16].

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CHAPTER 3

METHODOLOGY

Different models were simulated on MATLAB SIMULINK in order to compare and study the effect of individual type of batteries in battery management system. Simulation is basically used to examine the behavior of a circuit under variety of different circumstances without implementing them in real life. Simulations are very useful when used for following circumstances, for example: to study the performance of newly generated system by subjecting them to a variety of different situations. Design issue can also be found and fixed by using simulations. Also, different simulation work can be stored and we can begin our work right from where we left it last time.

3.1 MATLAB

MATLAB is an abbreviation whose full form is matrix laboratory. MATLAB is a synergistic system in which data element are expressed in form of array and do not depend upon dimensioning. It will make you able to solve many technical problems associated with computing, mostly the one which deal with formulation of matrix and vector. The language used for writing a program in MATLAB is C or Fortran [18].

Formation of MATLAB was a solution to get easy access to software in which the basic dealing is done with matrix; this software was developed by the LINPACK and EISPACK projects [18].

MATLAB has being introduced in many years and now it deals with multiple user input. In universities, it is the standard instructional mechanism used by students to learn introductory and advanced courses of basic science such as

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mathematics and engineering. MATLAB is used for implementation of high productivity research, development and analysis in field of industry [18].

MATLAB deal with many features of solutions which are specific to application called as toolboxes. It is very important for the users. Specialized technology can be learn and applied using these toolboxes. These are basically broad collection of MATLAB functions (M-files) and it enhances the MATLAB environment by which particular problem can be solved. Toolboxes are available in areas which include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others [18].

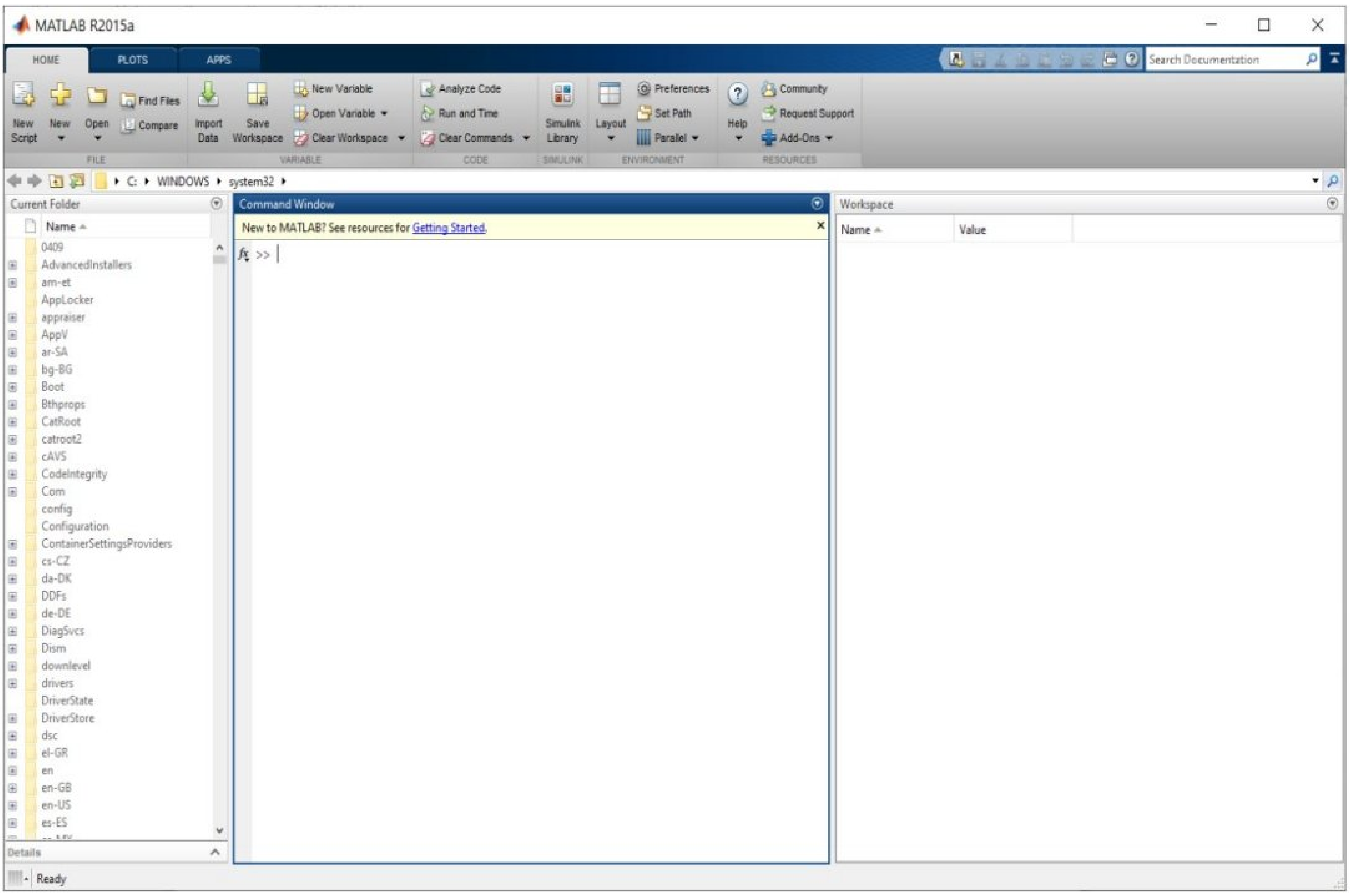

Figure 3.1 Main window of MATLAB [18]

3.1.1 Uses of MATLAB

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MATLAB is one of the high-performance languages, which is used for technical computing. It integrates computation, visualization, and programming in an easy-to-use way, where problems and solutions are expressed by mathematical notations. Typical uses include:

- Solution to math problems and the computation analysis.
- For the development of algorithm
- For the modeling of a design and its respective simulation, and prototyping
- For the analysis of data and exploration of new components, and visualization of models
- Dealing with graphics of science and engineering
- For the development of application, including the building of Graphical User Interface

3.1.2 MATLAB System

The MATLAB system is built on following main parts:

1) The MATLAB Language

Language which is used in MATLAB is an effective one in order to deal with matrix, it has control on flow statements, the function with which we deal, structures of data, input and output of data and object oriented program features [18].

2) The MATLAB Working Environment

MATLAB working environment is the area in which all the tools and facilities are provided for the user. It deals with importing and exporting of data and manages all the variables of the workspace. Tools used in developing and managing of M files as well as MATLAB applications are also provided by this area [18].

3) Handle Graphics

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Handle graphics is the part which deals with graphic system of MATLAB. Two-dimensional and three-dimensional visualization of data can be done by handle graphics. The commands use for processing of image, animation, and presentation of graphics are also provided by it. Commands dealing with modification of the appearance of graphics are also provided by it, and also the command which deal with building complete Graphical User Interfaces on MATLAB applications [18].

4) The MATLAB Mathematical Function Library

It deals with the collection of computational algorithms such as summing of data, application of trigonometric functions including sine, cosine, and more complex arithmetic. It also deals with complicated functions such as taking inverse of a matrix, finding eigenvalues of a matrix, Bessel functions and the Fourier transformation within seconds [18].

5) The MATLAB Application Program Interface (API)

The C and FORTRAN programs which interact with MATLAB can be written with help of application program interface. There are many advantages of this program as it can be used to call any function in MATLAB; it also calls MATLAB as a computational engine, which can be used for reading and writing of MAT-files [18].

3.2 Simulink

Simulink is software which makes us able to work on an interactive graphical environment for making models, simulation of those models and analysis of those dynamic systems. It is basically a product which is additional in MATLAB. It makes the user to understand the concepts regarding the minor details of design and construction of virtual prototypes. Graphical user interface (GUI) is used by Simulink for the purpose of making models in form of block diagrams. Simulink consists of a detailed library which already consists of predefined blocks, so due to that reason construction of model is

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very easy. Drag-and-drop mouse operations are used in order to construct graphical models. By help of Simulink, quick running models can be produced which normally take hours when build in a laboratory. It provides support to linear as well as nonlinear systems, the systems with continuous time or sampled time. It can also work with combination of both sampled and continuous time. With help of these features students learn efficiently with frequent feedback. User can try new things due to the cooperative nature of software, they can change parameters very quickly and obtain the results immediately, for "what if" exploration. Simulink is integrated with MATLAB and due to that reason data can be easily shared between the programs [19].

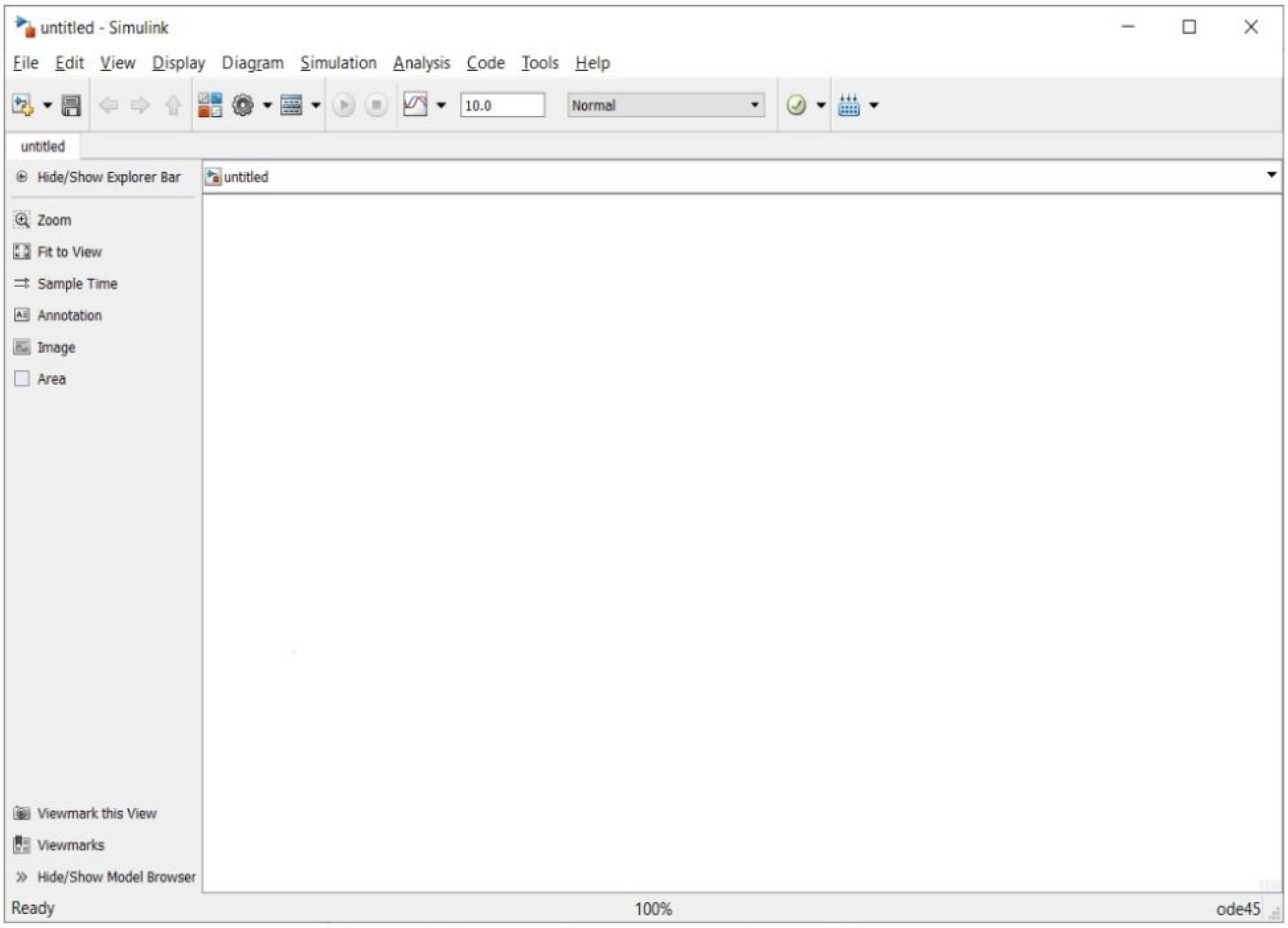

Figure 3.2 Basic Simulink windows [19].

3.2.1 Basic Elements of Simulink

Simulink is divided into two major portions which consist of:

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• Blocks

• Lines

Blocks are used for the preparation of models, their modification and combination. Output is also produced and displayed in form of signals by Simulink. The connection between one block and another is made by lines [19].

Blocks

Blocks include following parameters:

• Sources:

Various signals are generated with the help of sources. Only outputs are dealt by sources and have no effect over the inputs. Different type of inputs such as constant input, Sine Wave, a Step, a Ramp, a Pulse Generator, or a Uniform Random number can be used by user to simulate noise. Clock may be used for plotting by creating a time index. [19].

• Sinks:

Sinks are used to provide output signals. Sinks blocks deal with values of inputs and none of outputs.

Examples are Scope, Display, Floating Scope, XY Graph, etc.

• Discrete:

It consists of Discrete Filter, Discrete State-Space, Discrete Transfer Fcn, Discrete Zero-Pole, Unit Delay, etc.

• Continuous:

It includes Integrator, State-Space, Transfer Fcn, Zero-Pole, etc.

• Signal routing:

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It deals with Mux, Demux, Switch, etc.

• Math Operations:

It deals with Abs, Gain, Product, Slider Gain, Sign, Sum, etc. [19].

Lines

Lines transmit signals from one block to another in the direction indicated by the arrow. Lines always work in a manner of transmitting signals from the output terminal of one block to the input terminal of another block.one line can also be connected to another line. This is a way by which the original signal can be transmitted to two (or more) destination blocks. A signal used can be either a scalar signal or a vector signal [19].

3.3 Simulink Models Simulations

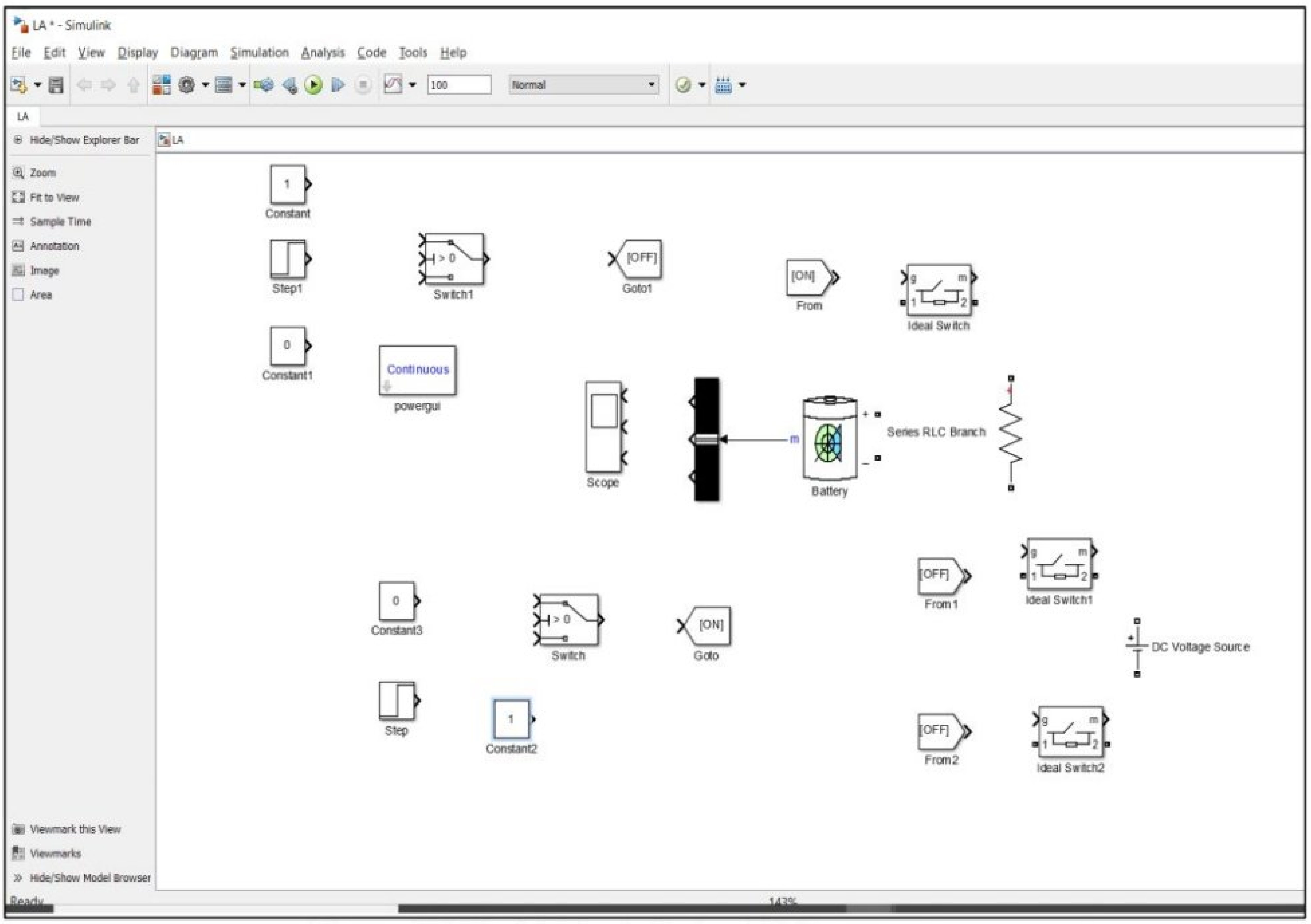

Figure 3.3 Model Blocks before Wiring.

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The model for simulation in MATLAB Simulink as shown in Figure 3.3 is created by following steps:

- In Simulink window new model is drawn.
- Create a new model.
- Add all the require components for the model from the Simulink library browser. It includes build in blocks, all sources, components, batteries.
- The values and type of battery are changed from edit properties.
- Place all the block elements on their positions.

All the blocks are wired together to make a proper battery pack model as shown in Figure 3.4.

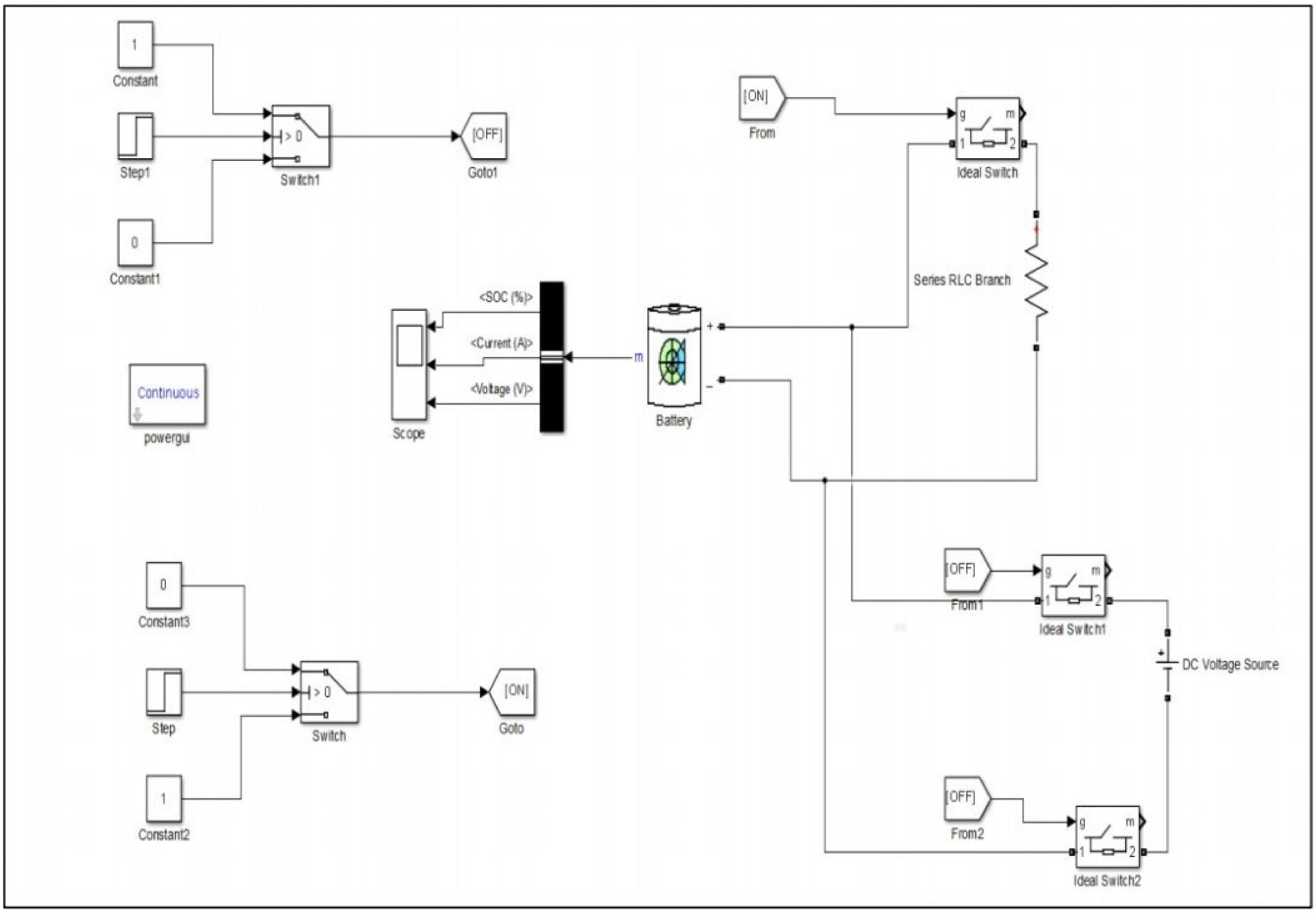

Figure 3.4 Model Blocks after Wiring.

- Continuous simulation was added in order to get the continuous charging output waveform for the provided battery.
- Run model is clicked in order to carry out the simulation. Stop time is fixed according to own wills.
- Graphs can be viewed by clicking the scope.
- Results will be formed based on time taken by different batteries for charging and discharging.

  Same steps are taken for running the model of discharging batteries.

3.4 Proposed Models in Simulink

Two different models were drawn for charging and discharging of four different batteries named as

- Lead acid battery
- Lithium ion battery
- Nickel cadmium battery
- Nickel metal hydride battery

3.4.1 Charging Model for Batteries

The model shown in Figure 3.5, was built in order to study the charging characteristics of batteries

All the batteries were provided with following parameter provided in Table 3.1:

Table 3.1 Values of the internal parameters of batteries used in Charging Model

Nominal Voltage (V)	12
Rated Capacity (Ah)	30
Initial State-Of-Charge (%)	100

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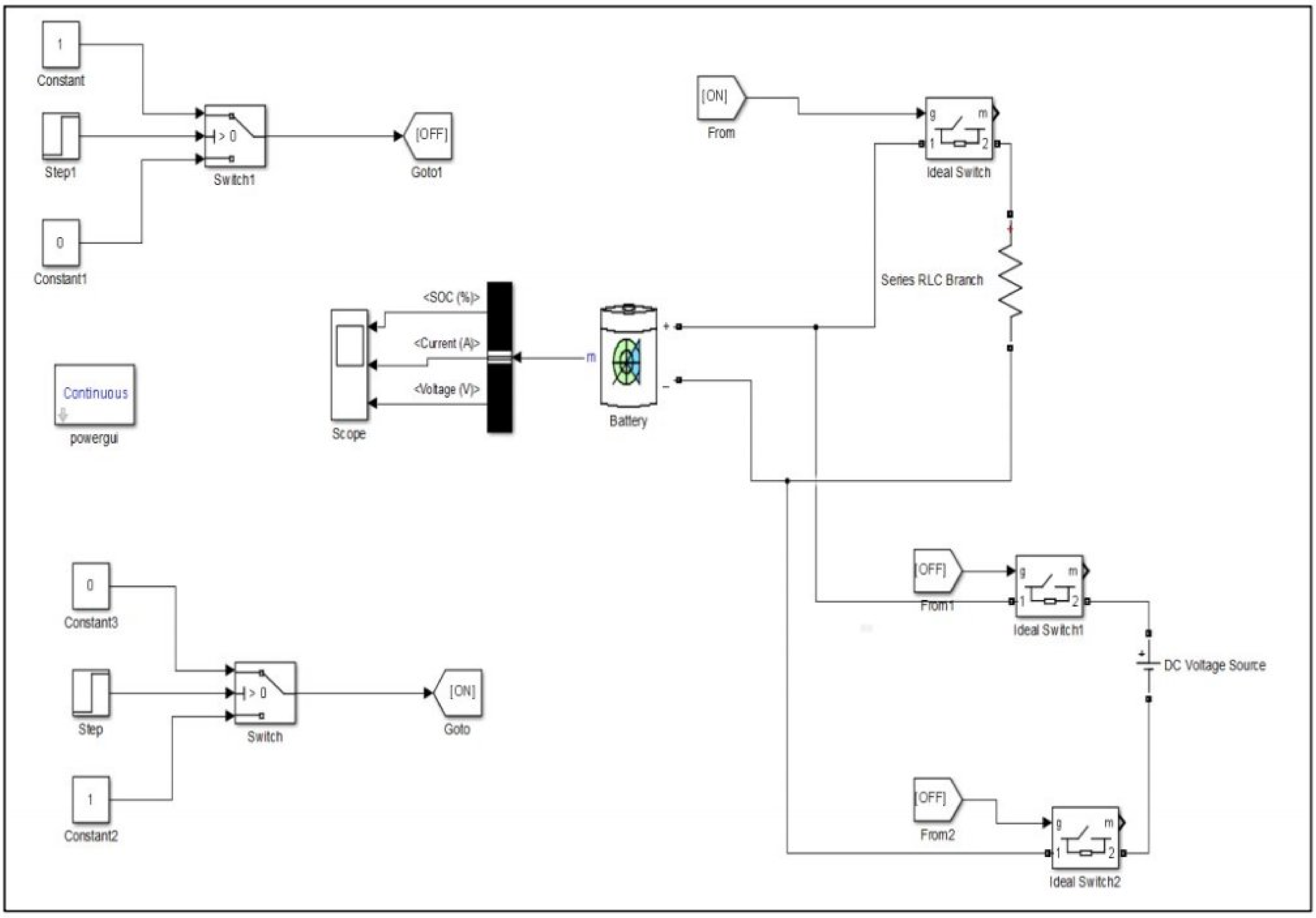

Figure 3.5 Basic Charging Models for Batteries.

Load Resistance was set to 0.5 Ohms. Ideal switch was set with following parameters shown in Table 3.2.

Table 3.2 Values for the Internal Parameters of the Ideal Switch used in charging model

Internal resistance Ron (Ohms)	0.001
Initial state (0 for 'open', 1 for 'closed')	0
Snubber resistance Rs (Ohms)	1e5

Simulation stop time for charging model was set as 6000 seconds.

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3.4.2 Discharging Model for Batteries

Following model shown in Figure 3.6 was built in order to study the discharging characteristics of batteries.

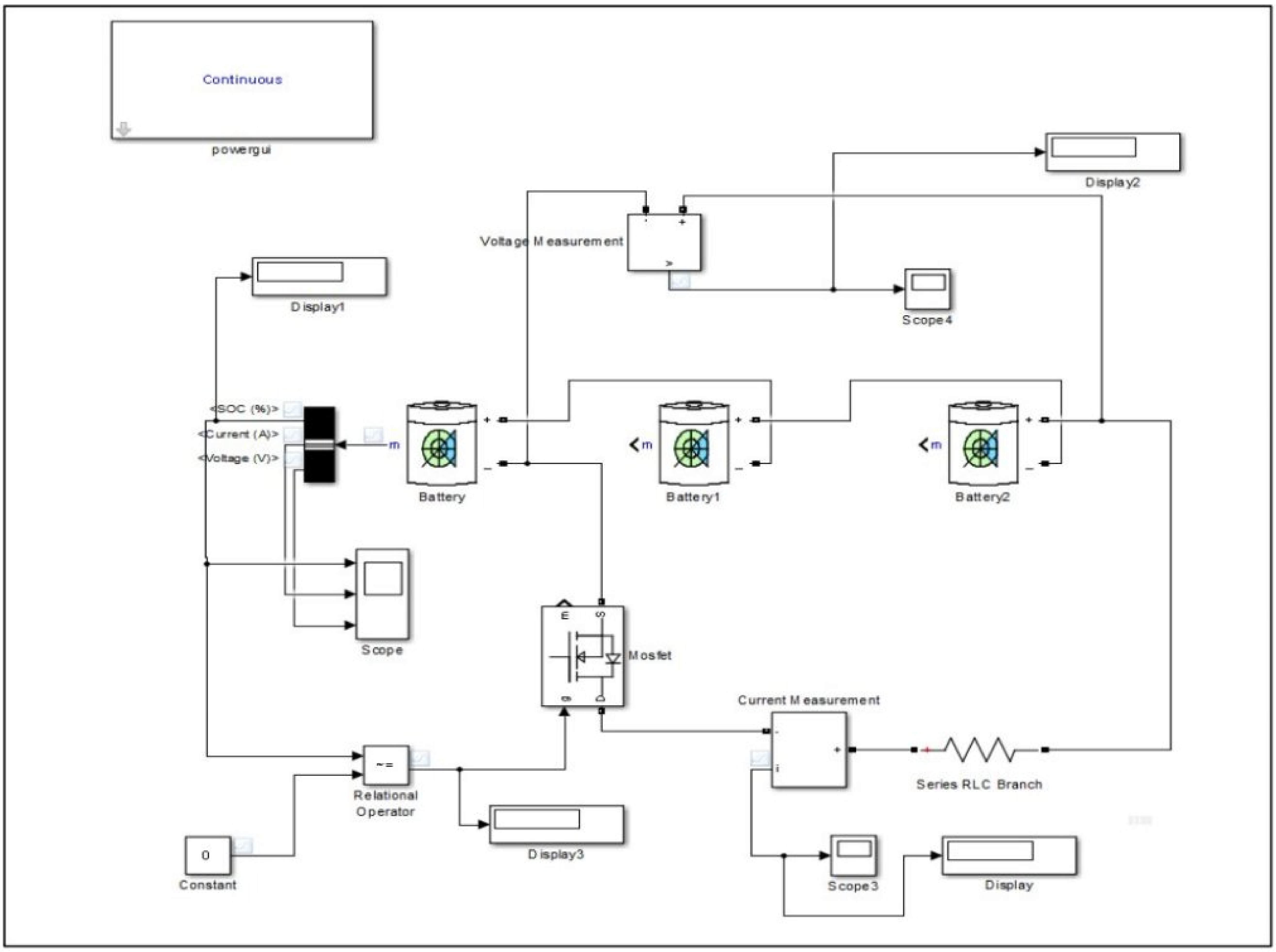

Figure 3.6 Basic Discharging Models for Batteries.

All the batteries used in this model were provided with following parameter provided in Table 3.3.

Table 3.3 Values of the internal parameters of batteries used in Discharging Model

Nominal Voltage (V)	3
Rated Capacity (Ah)	2.1
Initial State-Of-Charge (%)	96

Load Resistance was set to 4.4 Ohms.

MOSFET was set with following parameters provided in Table 3.4.

Table 3.4 Values of the internal parameters of MOSFET used in Discharging Model

FET resistance Ron (Ohms) :	0.01
internal diode inductance Lon (H) :	0
Internal diode resistance Rd (Ohms)	0.1
Snubber resistance Rs (Ohms)	1e5
Internal diode forward voltage Vf (V)	0

Simulation stop time for charging model was set as 6000 seconds or 100 minutes.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Performance Analysis of Lead Acid Battery by Charging Model

By use of charging model shown in figure 3.5, charging time was calculated for Lead Acid Battery when simulation time was set at 100 minutes where discharging time was kept constant at 50 minutes. Following graph was obtained by the scope window.

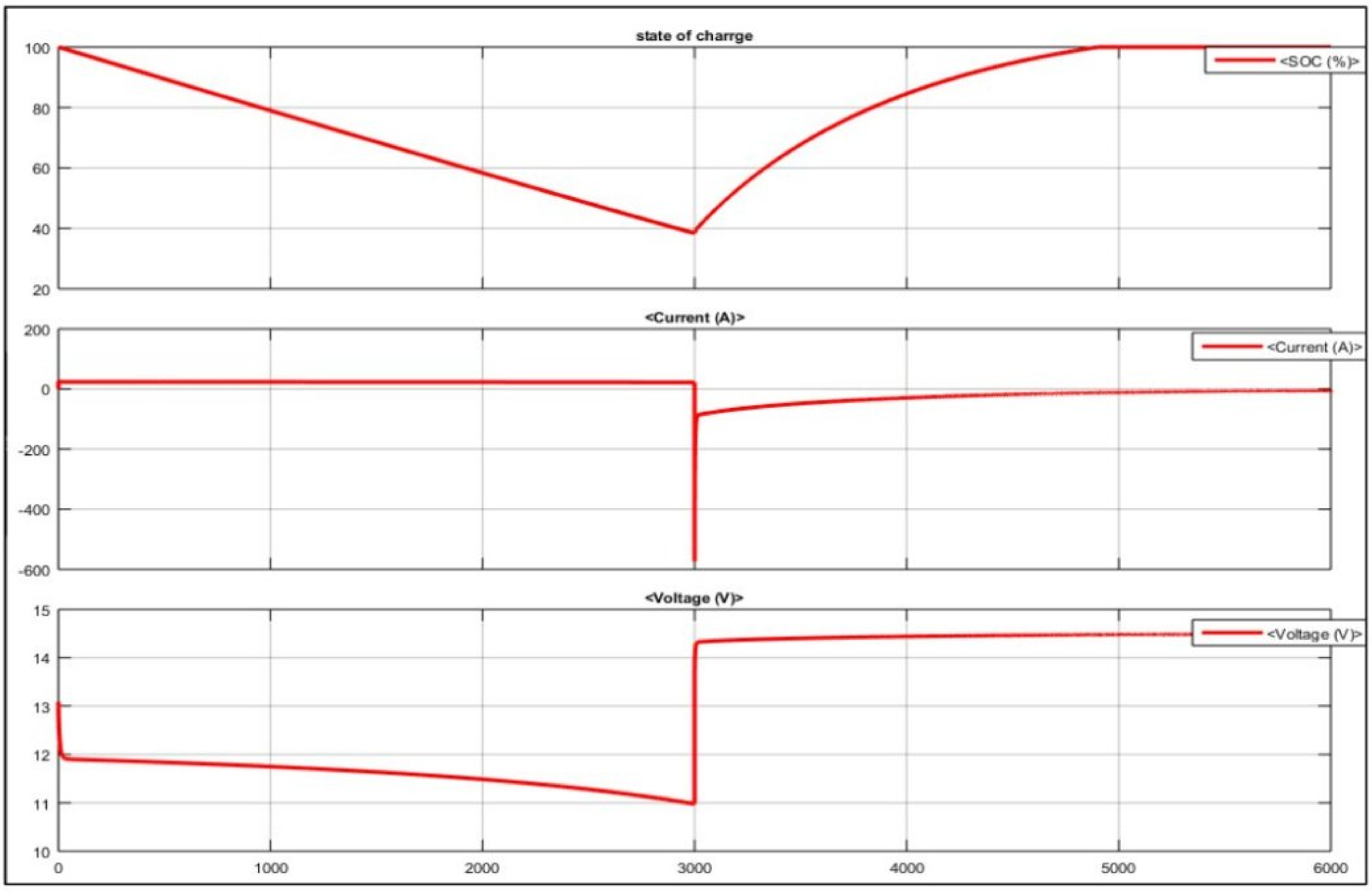

Figure 4.1 Performance Analysis of Lead Acid Battery by Charging Model

It is clear from the graph in Figure 4.1 that the state of charge or simply the time taken by the lead acid battery to get fully charged after a constant discharge time is approximately 30 minutes. During discharge, currents drops immediately when it reaches the discharge time, which was kept constant at 3000 seconds, after this it increases but in a slow manner. In case of voltage, a sudden rise is experienced. During charging cycle voltage reaches approximately equal to the total capacity of voltage available in the battery cell which is 14 volts in this case

4.2 Performance Analysis of Lithium Ion Battery by Charging Model

Charging time was calculated for Lithium Ion Battery by use of charging model shown in figure 3.5. The simulation time was set at 100 minutes where discharging time was kept constant at 50 minutes. Following graph was obtained by the scope window.

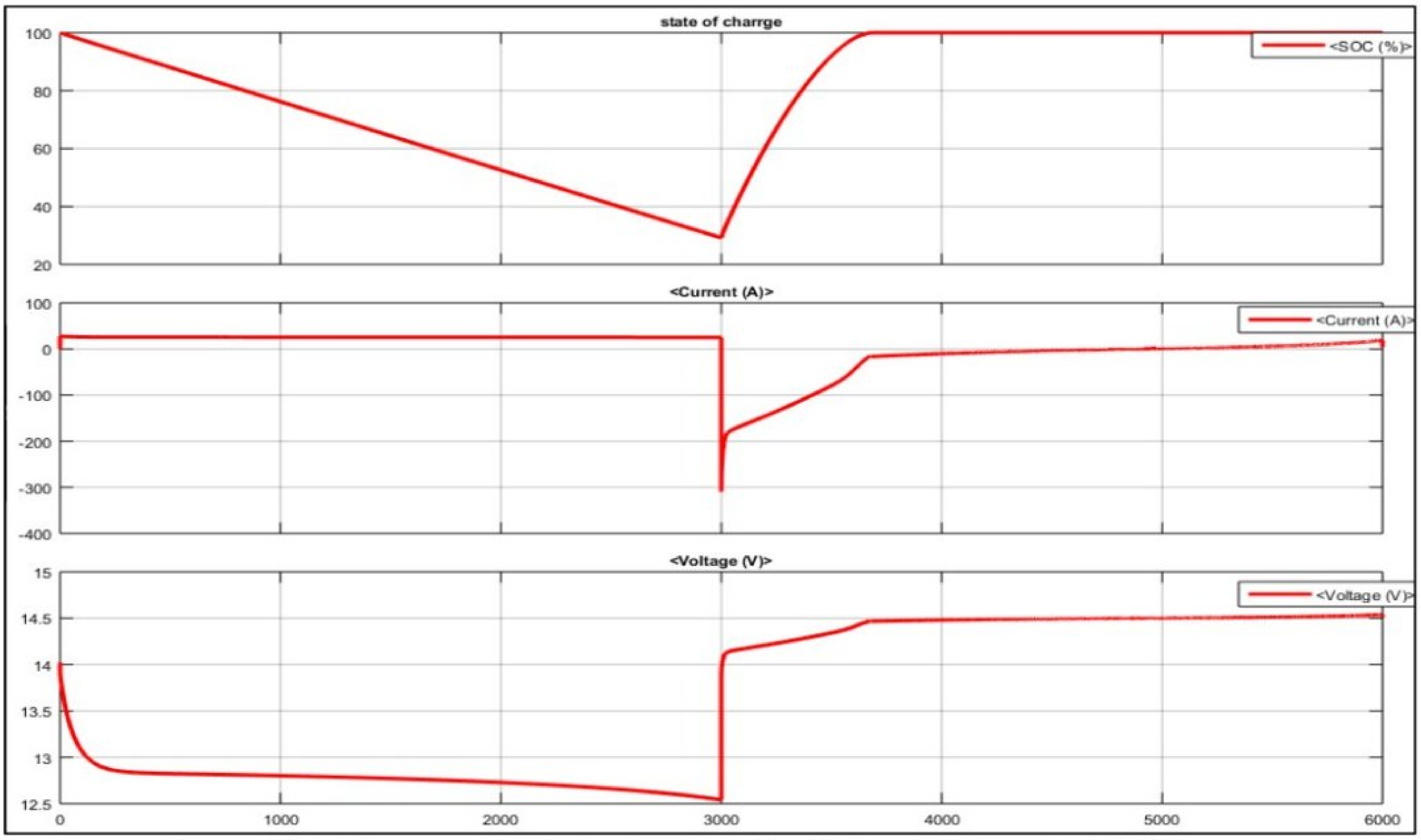

Figure 4.2 Performance Analysis of Lithium Ion Battery by Charging Model

It is evident from the graph in Figure 4.2 that the state of charge or simply the time taken by the lithium ion battery to get fully charged after a constant discharge time is approximately 10 minutes. During discharge, currents drops immediately when it reaches the discharge time, which was kept constant at 3000 seconds, after this it increased but very slowly. In case of voltage, a sudden rise is experienced. During charging cycle voltage reaches to a level of 14.5 volts which is more than the total capacity of voltage available in the battery cell which is 14 volts.

4.3 Performance Analysis of Nickel Cadnium Battery by Charging Model

For Nickel Cadnium Battery charging time was calculated with help of charging model shown in figure 3.5. The simulation time was set at 100 minutes where discharging time was kept constant at 50 minutes. Following graph was obtained by the scope window.

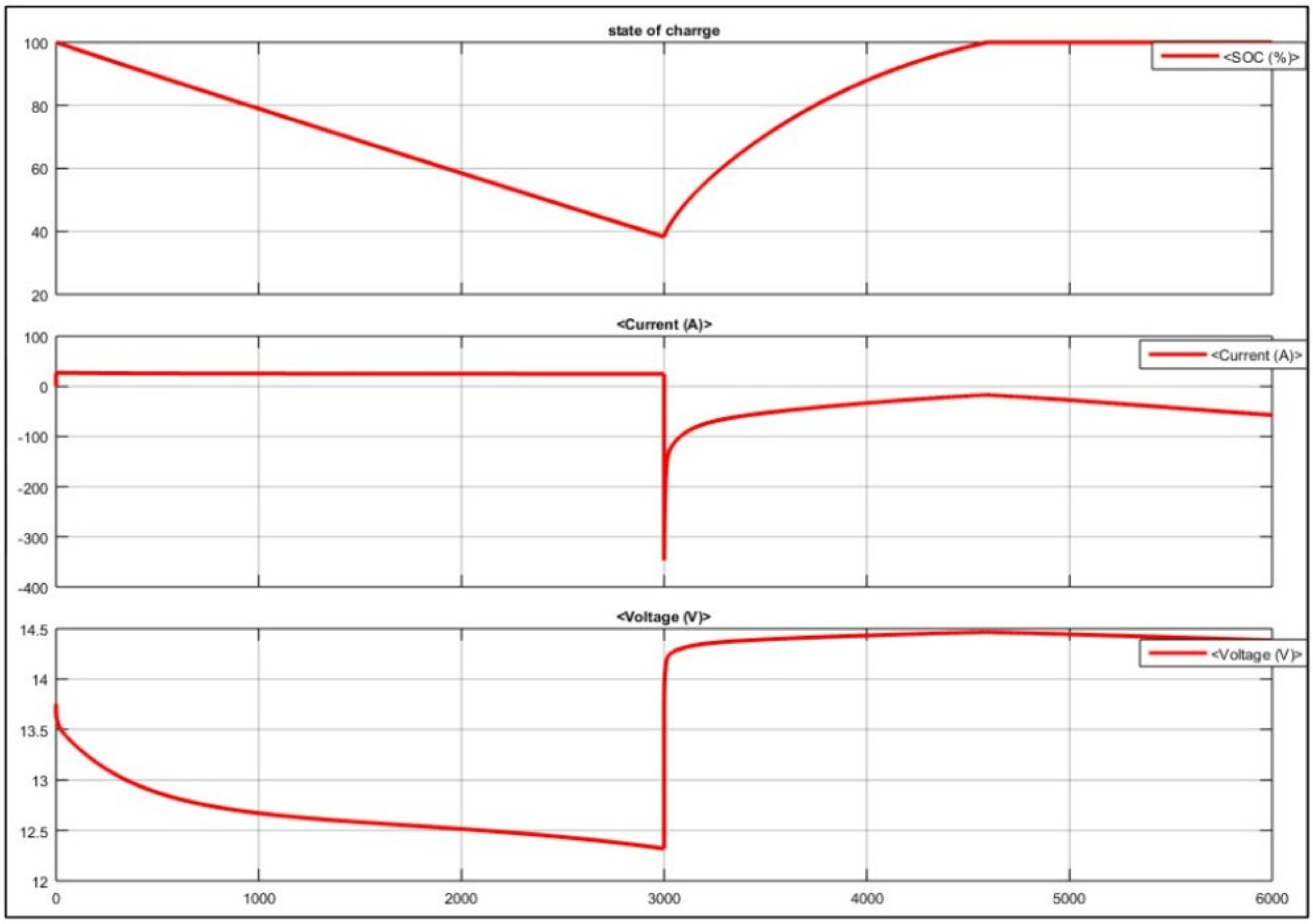

Figure 4.3 Performance Analysis of Nickel Cadnium Battery by Charging Model

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It is clear from the graph in Figure 4.3 that the state of charge or simply the time taken by the Nickel Cadnium battery to get fully charged after a constant discharge time is approximately 25 minutes. During discharge, currents drops immediately when it reaches the discharge time, which was kept constant at 3000 seconds, after that it increased. In case of voltage, a sudden rise is experienced. During charging cycle voltage reaches to a level of 14.3 volts which is more than the total capacity of voltage available in the battery cell which is 14 volts.

4.4 Performance Analysis of Nickel Metal Hydride Battery by Charging Model

By use of charging model shown in figure 3.5, charging time was calculated for Nickel Metal Hydride Battery when simulation time was set at 100 minutes where discharging time was kept constant at 50 minutes. Following graph was obtained by the scope window.

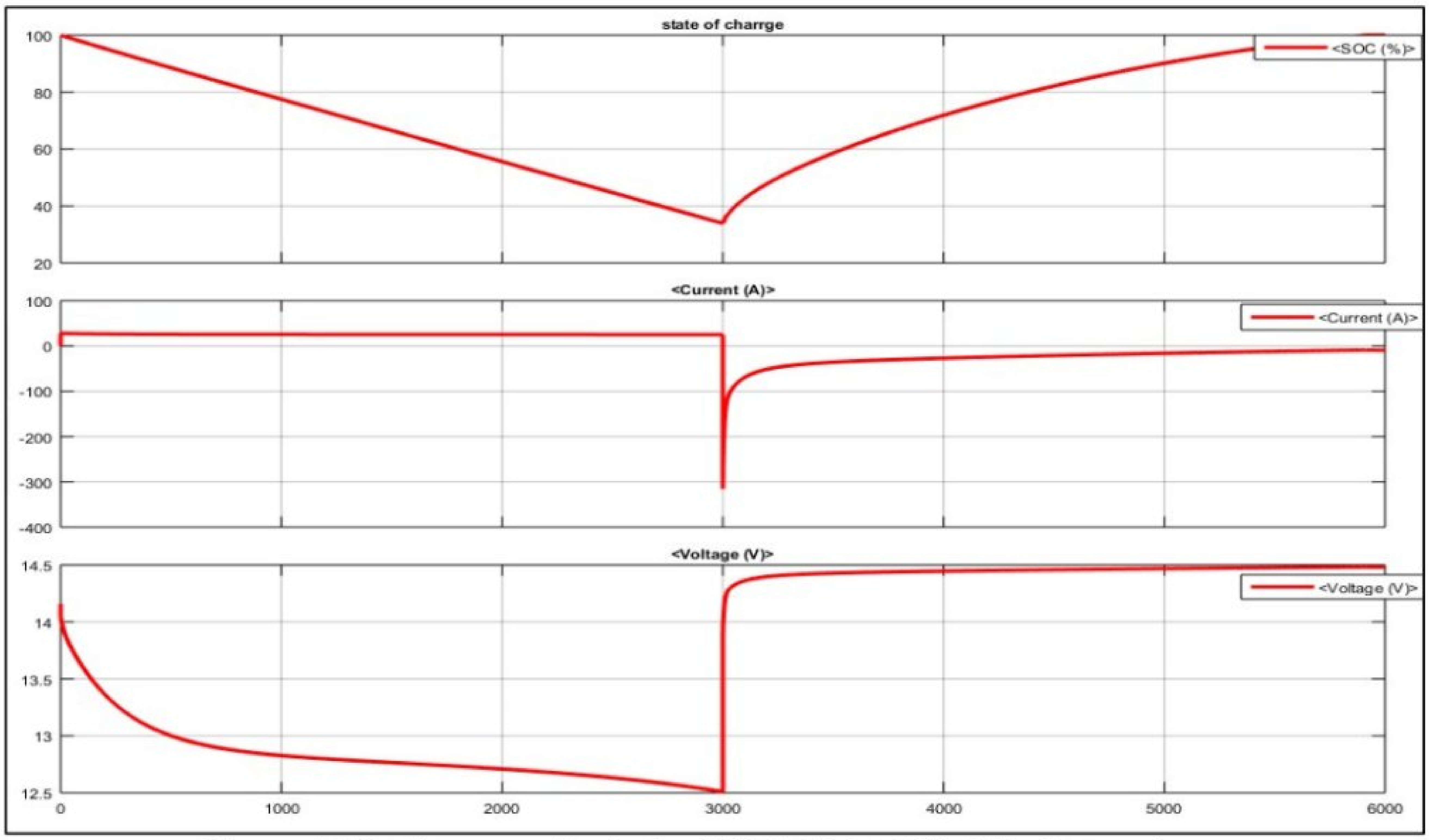

Figure 4.4 Performance Analysis of Nickel Metal Hydride Battery by Charging Model

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It is evident from the graph in Figure 4.4 that the state of charge or simply the time taken by the Nickel Metal Hydride battery to get fully charged after a constant discharge time is approximately 47 minutes. During discharge, currents drops immediately when it reaches the discharge time, which was kept constant at 3000 seconds, after that it increased in a slow manner. In case of voltage, a sudden rise is experienced. During charging cycle voltage reaches to a level of 14.3 volts which is more than the total capacity of voltage available in the battery cell which is 14 volts.

4.5 Comparison of Performance Analysis of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery by Charging Model

For making the comparison of performance analysis of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery during charging, results were found by charging models, Table 4.1 shows a clear image of the time taken by Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery to get fully charged. It also explains the maximum charge which can be stored in the battery as well as the fully charged voltage. Nominal discharge current was also calculated which means the amount of current which a fully charged battery can provide to the system.

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Table 4.1 Comparison of Parameters found by Charging Model

Batteries	Total time to get fully charge (minutes)	Maximum charge stored (SOC %)	Fully charge voltage (Volts)	Nominal discharge current (Amperes)
Lead acid	30	99.64%	13.25 V	6 A
Lithium ion	10	99.72%	13.97 V	13.04 A
Nickel Cadnium	25	99.67%	13.73 V	6 A
Nickel metal hydride	47	99.67%	14.14 V	6 A

Hence from the above table it is clearly seen that Lithium ion Battery takes the least time to get charge and have the highest charge storing capacity.

4.6 Performance Analysis of Lead Acid Battery by Discharging Model

By use of discharging model shown in figure 3.6, discharging time was calculated for Lead Acid Battery when simulation time was set at 100 minutes. Initially the battery was set at fully charged condition. Following graph was obtained by the scope window:

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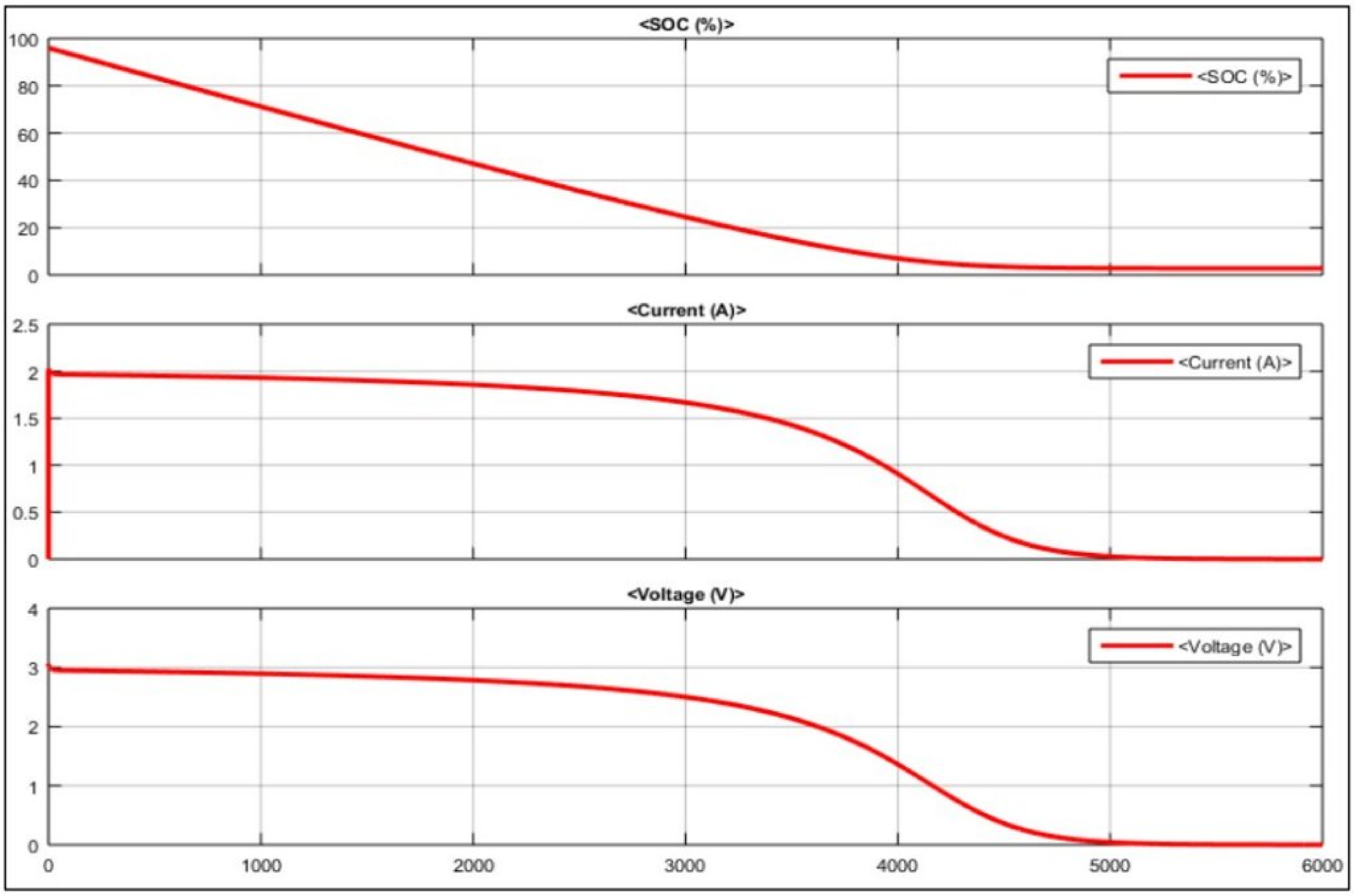

Figure 4.5 Performance Analysis of Lead Acid Battery by Discharging Model

It is evident from the graph in Figure 4.5 that the state of charge or simply the time taken by the Lead Acid Battery to get fully discharged is approximately 75 minutes. During discharge, current drops in a slow and liner manner and took approximately 82 minutes to get at zero amperes. Voltage also drops slowly and took 82 minutes to get at 0 volts.

4.7 Performance Analysis of Lithium Ion Battery by Discharging Model

The discharging time for Lithium Ion Battery was calculated with help of discharging model shown in figure 3.6. The simulation time was set at 100 minutes. Initially the battery was set at fully charged condition. Following graph was obtained by the scope window:

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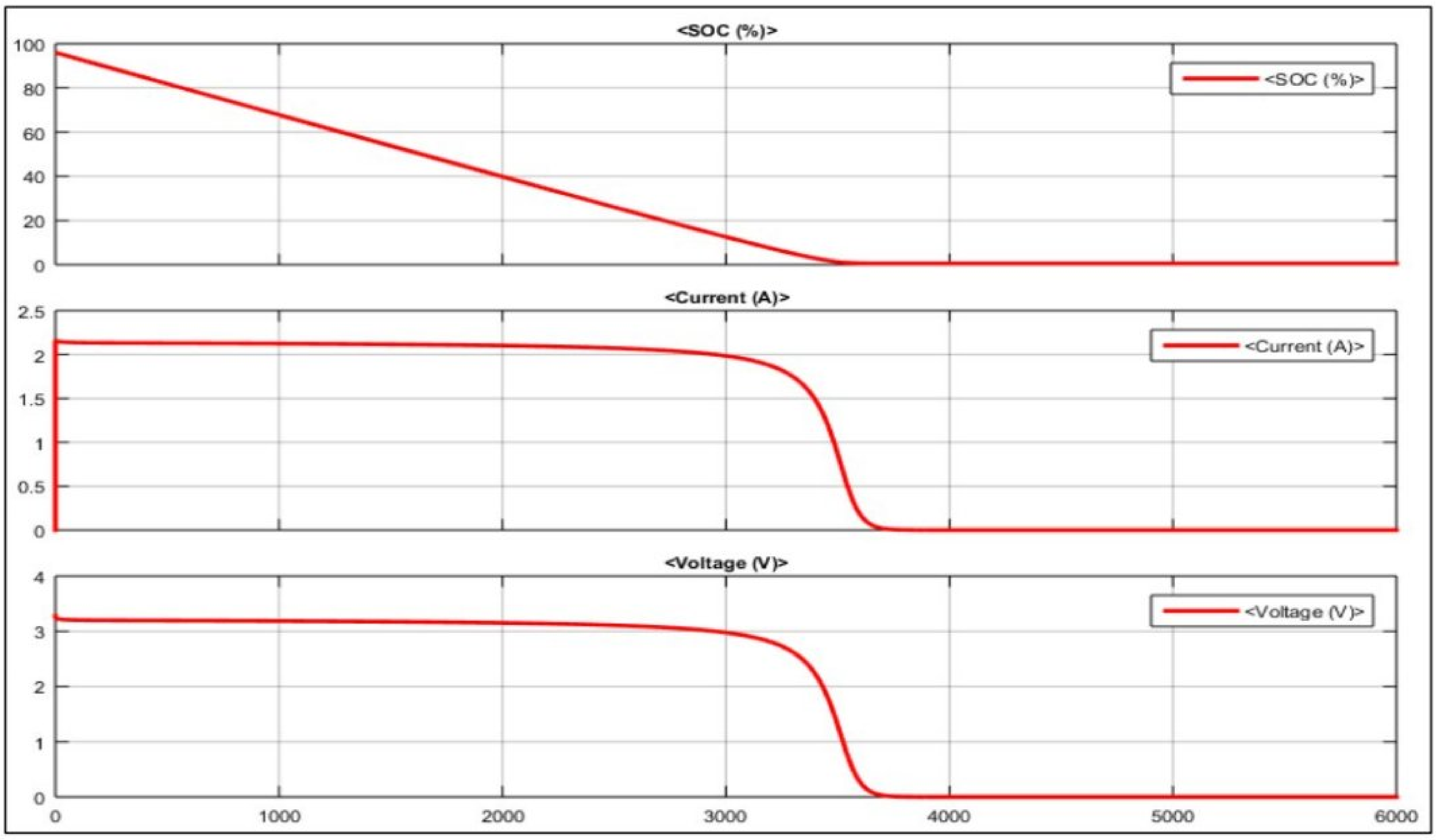

Figure 4.6 Performance Analysis of Lithium Ion Battery by Discharging Model

It is clear from the graph in Figure 4.6 that the state of charge or simply the time taken by the Lithium Ion Battery to get fully discharged is approximately 59 minutes. During discharge, current drops in a slow and liner manner and took approximately 61 minutes to get at zero amperes. Voltage also drops slowly and took 63 minutes to get at 0 volts.

4.8 Performance Analysis of Nickel Cadnium Battery by Discharging Model

By use of discharging model shown in figure 3.6, discharging time was calculated for Nickel Cadnium Battery when simulation time was set at 100 minutes. Initially the battery was set at fully charged condition. Following graph was obtained by the scope window:

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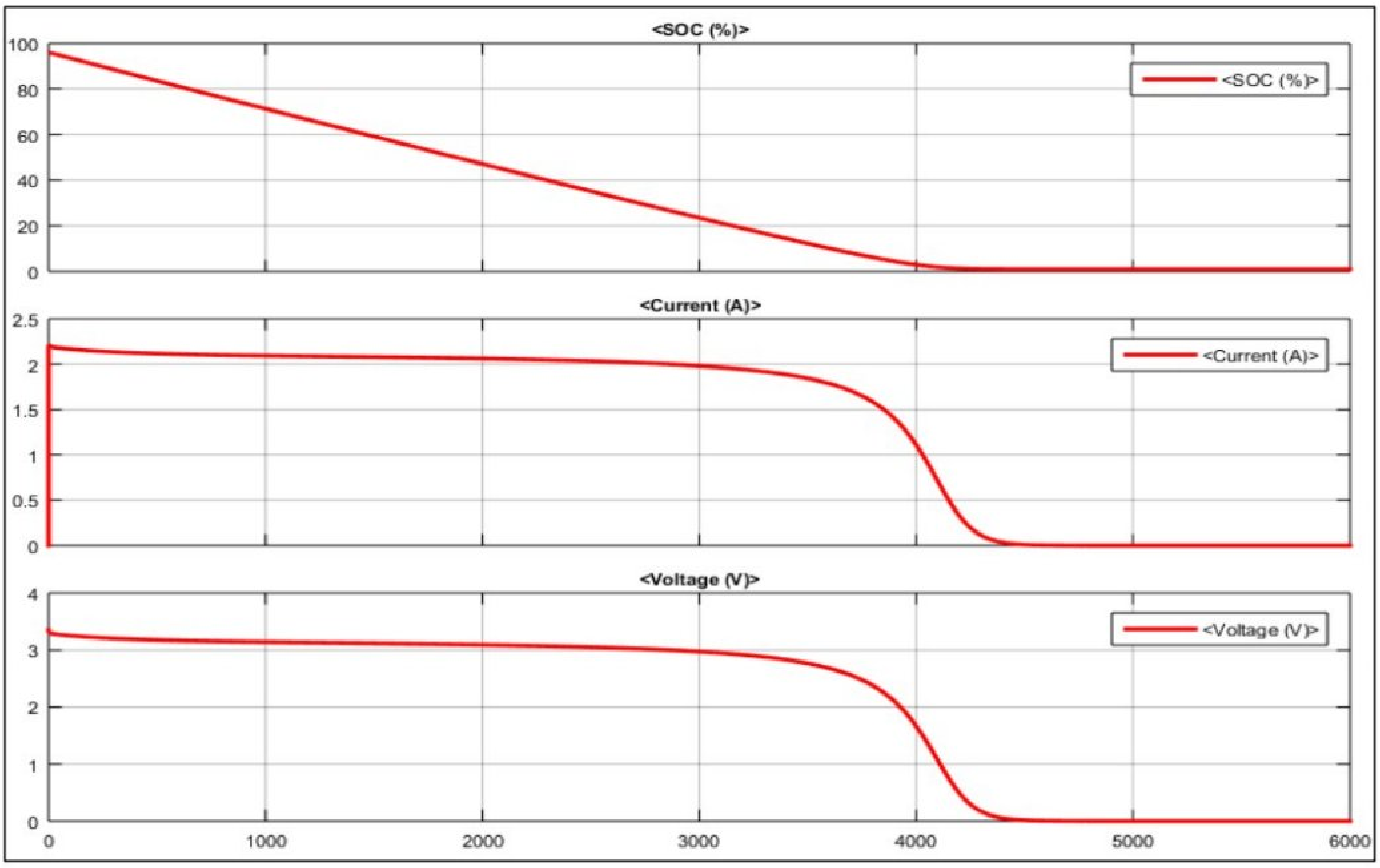

Figure 4.7 Performance Analysis of Nickel Cadnium Battery by Discharging Model

It is evident from the graph in Figure 4.7 that the state of charge or simply the time taken by the Nickel Cadnium Battery to get fully discharged is approximately 70 minutes. During discharge, current drops in a slowly and took approximately 80 minutes to get at zero amperes. Voltage also drops slowly and took 72 minutes to get at 0 volts.

4.9 Performance Analysis of Nickel Metal Hydride Battery by Discharging Model

By use of discharging model shown in figure 3.6, discharging time was calculated for Nickel Metal Hydride Battery when simulation time was set at 100 minutes. Initially the battery was set at fully charged condition. Following graph was obtained by the scope window:

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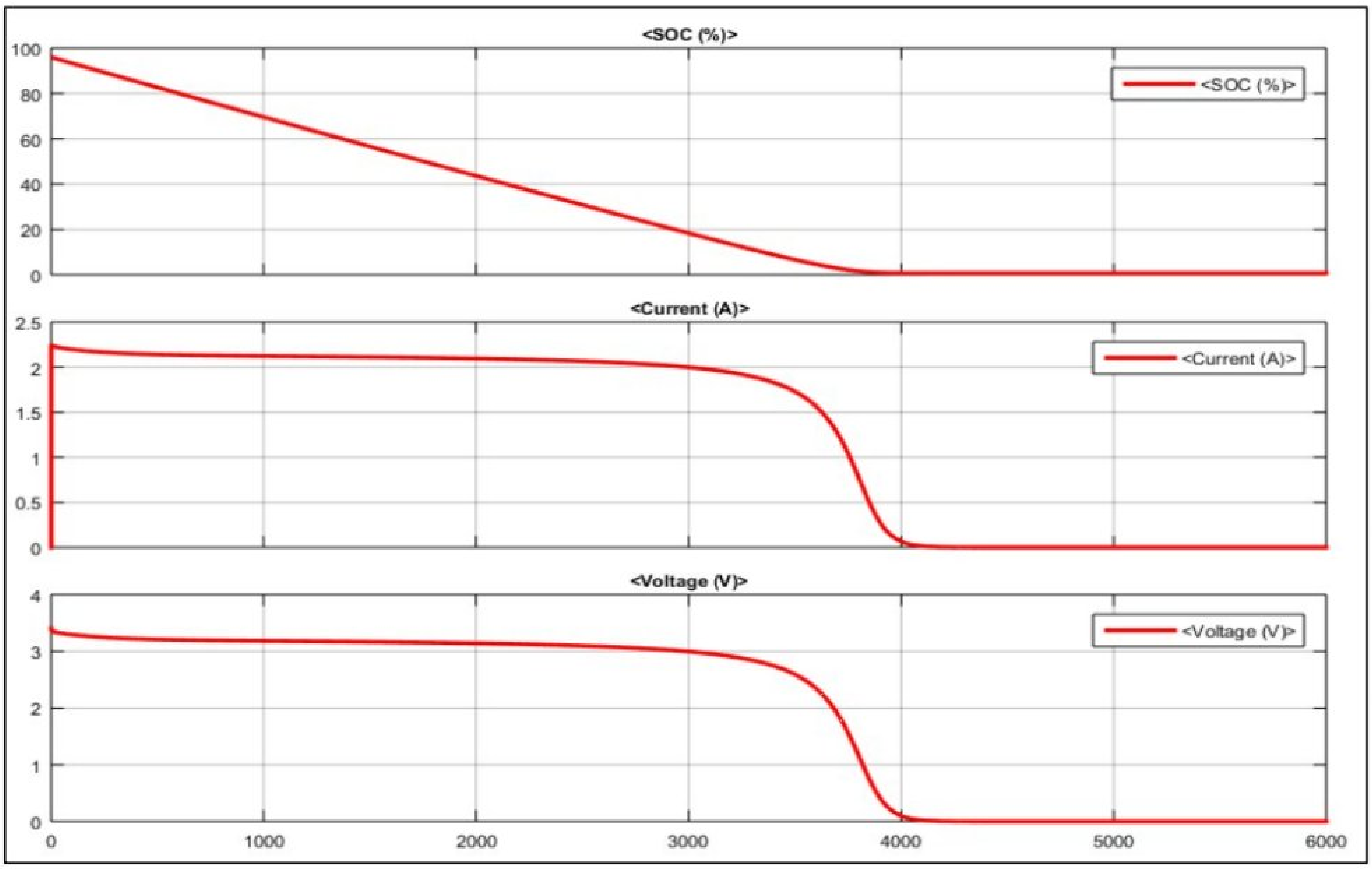

Figure 4.8 Performance Analysis of Nickel Metal Hydride Battery by Discharging Model

It is clear from the graph in Figure 4.8 that the state of charge or simply the time taken by the Nickel Metal Hydride Battery to get fully discharged is approximately 64 minutes. During discharge, current drops in a slow and liner manner and took approximately 66 minutes to get at zero amperes. Voltage also drops slowly and took 66 minutes to get at 0 volts.

4.10 Comparison of Performance Analysis of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery by discharging Model

For making the comparison of performance analysis of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery during discharging, results were used found by discharging model, Table 4.2 shows a comparison of the time taken by Lead Acid Battery, Lithium Ion Battery, Nickel

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Cadnium Battery and Nickel Metal Hydride Battery to get fully discharge. It also provides the amount of charge left in batteries even if it is fully discharged.

Table 4.2 Comparison of Parameters Obtained by the Discharging Model

Batteries	Fully discharge time (minutes)	Time to get Zero Current (minutes)	Time to get Zero Voltage (minutes)	Available charge SOC (%) (minutes)
Lead acid	75	82	82	2.783
Lithium ion	59	61	63	0.518
Nickel Cadnium	70	80	72	0.964
Nickel metal hydride	64	66	66	0.761

Hence from the above table it is clearly seen that Lead Acid Battery takes the longest time to get fully discharged and have the highest charge stored in it even after getting discharged.

4.11 Comparison of Charging and Discharging time of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery

For a better comparison, an individual table is created (Table 4.3) which shows charging and discharging time of Lead Acid Battery, Lithium Ion Battery, Nickel Cadnium Battery and Nickel Metal Hydride Battery.

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Table 4.3 Comparison of Fully Discharged time and Fully Charged time of Batteries

Batteries	Fully discharge time (minutes)	Total time to get fully charge (minutes)
Lead acid	75	30
Lithium ion	59	10
Nickel Cadnium	70	25
Nickel metal hydride	64	47

From this table it can be seen clearly that Lithium ion battery shows an overall best performance regarding charging and discharging time as it took only 10 minutes to get fully charge and 59 minutes to get fully discharged. Lead acid battery is also a good option as it took 75 minutes to get fully discharged. According to the manufacturing of battery management system, 12 cells in parallel combine to make one module, and six modules combine to form a battery pack in an electric vehicle so the total time taken by an electric vehicle to get charge would be as following as shown in Table 4.4:

Table 4.4 Total Charge time and Total Discharge time for a Battery Pack in Electric Vehicle

Batteries	Charge time	discharge time
Lead acid	6 hours	15 hours
Lithium ion	2 hours	11.2 hours

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Nickel Cadnium	5 hours	14 hours
Nickel metal hydride	9.4 hours	12.8 hours

For a further better comparison, a table was formed (Table 4.5) for the state of charge when the battery was close to fully charged state and when it was almost close to fully discharged state. From this table we could easily concluded that how much charge could be stored in a battery when it is in charging mode, and how much it could have with in it after it is discharged to almost zero

Table 4.5 SOC (%) for Fully Charged state and Maximum Charge Stored SOC (%) when fully discharged for Batteries.

Batteries	Maximum charge stored SOC(%) when fully discharged	SOC (%) for fully charged state
Lead acid	2.783	99.67%
Lithium ion	0.518	99.72%
Nickel Cadnium	0.964	99.67%
Nickel metal hydride	0.761	99.64%

From Table 4.5, it is clearly viewed that lithium ion Battery is a best choice as it can store 99.72% charge. Lead acid Battery is also a good choice because it has 2.783% charge present inside it, even when it is approximately equal to fully discharged state.

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CONCLUSION

Four different types of batteries were compared for making a choice of best battery to be used in battery management system of an electric vehicle. On behalf of their charging and discharging time as well as the charged stored in them when they are close to fully discharged, results were found. Those four batteries are Lithium Ion battery, Nickel Metal Hydride (NiMH) battery, Lead Acid battery and Nickel Cadnium battery. The charging time for Lead acid battery is 6 hours and discharging time is 15 hours, where for Lithium ion battery charging time is 2 hours and discharging time is 11.2 hours, for Nickel Cadnium charging time is 5 hours and discharging time is 14 hours and Nickel metal hydride battery take 9.4 hours to charge and 12.8 hours to discharge. A lead acid battery can store up-to 99.67% of total provided charge, where lithium ion stores 99.72%, Nickel Cadnium can store 99.67% and Nickel metal hydride can store 99.64%.

From all these numerical values it is concluded that lithium ion battery is the best choice for making a best battery management system for an electric vehicle. As it takes the smallest time to get fully charged and much better time to get fully discharged. Second option after lithium ion battery is lead acid battery, as it took the longest time to get fully discharged. Hence lead acid battery could also be used for making a good battery management system.

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LIMITATIONS

- There was lack of tutorials and example about different models in MATLAB SIMULINK.
- Better version of MATLAB SIMULINK should be used for research conduction.
- Lack of model information and simplification for making a better version of battery model.

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RECOMMENDATIONS

- In future the research work should be enhanced in order to make a better battery management system by choosing a best battery.
- More accurate models can be used to compare the working characteristics of provided battery type.
- In future the proposed model can be used to study effect of these batteries in other type of appliances.
- For better results more batteries can be connected in series or parallel connections.

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