

# “MATLAB/SIMULINK BASED MODEL AND SIMULATION OF A BATTERY CHARGING & DISCHARGING”

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**Abstract:** This project deals with modeling and simulation of the battery. It needs to know the mathematical relationship between battery input and output parameters and simulator by using MATLAB. At present, we see energy storage increases interest in the power system such as electric utilities, energy service companies, automobile manufacturers, etc. In this paper, describes that simulate the charging or discharging by using MATLAB / Simulink. As we know that development over the past one hundred years, Electricity is the most versatile and widely used form of energy in the world. With the help of batteries, we can store electrical energy in the form of chemical energy and we can use again this chemical energy in the form of electricity.

**Keywords:** Battery, Open Circuit Voltage (OCV), State Of Charge (SOC), Simulation

**1. Introduction.:** This project is a very basic model to calculate battery charging and discharging behavior by using MATLAB/Simulink. To establish links with drag and drop, annotate diagrams with requirements context, analyze requirements traceability, and navigate between requirements, designs, generated code, and tests. It helps too when changes occur to linked requirements, designs, or tests and according to requirements; it calculates the implementation and verification status.

In the battery system model and simulate algorithm is using Simulink and Stateflow including:

- Monitoring current & voltage
- State of Charge (SOC) estimation
- Supervisory logic
- Limiting power input and output for overcharge and discharge protection, etc.

The method for battery parameterized, plan of the proposed battery model which results from the complete battery portrayal tests are depicted in the accompanying areas.

## 2. Principle and Structure of Battery Charging / Discharging Characteristics:

An accurate battery model is the first step in the development to build and parameterize an equivalent circuit that reflects the battery behavior. By using MATLAB, estimation technique, and measured lithium-ion or Ni-MH or lead-acid battery data. In this project, we use the lithium-ion battery because they have several benefits such as high specific energy densities, high energy density, and long cycling life. Discharging and charging current pulses are used to parameterize. Mathematical models for forecasting and optimizing the behavior of the complex system can be built with the help of MATLAB. Following steps are considered for the model development are:

- Develop models using data fitting and first principle modeling techniques
- Identify parameters that optimize system performance
- Simulate models and develop custom post-processing routines
- Generate reports the document model derivation and simulation results

- Share the developed models

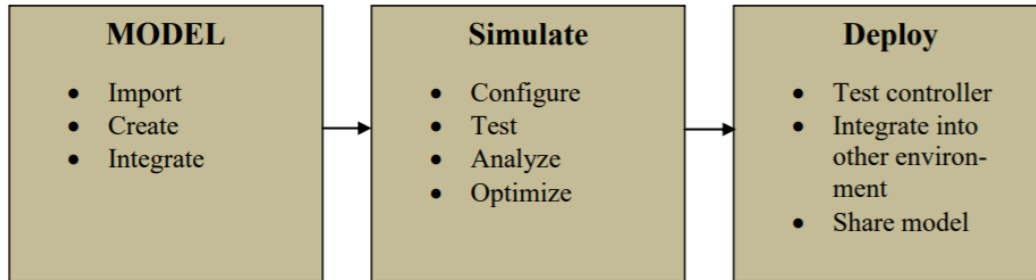
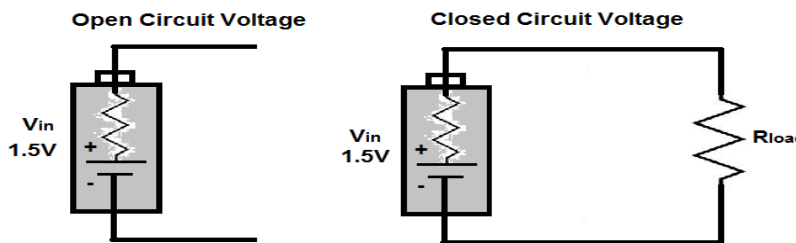


Fig.1: MATLAB Model

According to the block diagram of the MATLAB model of rechargeable battery are shown various steps. These steps include may include defining model, simulation, and deployment of the developed system in a controller or share the developed model. By using the MATLAB model, collected from the experimental data in this project or research will be also used to determine the influence of load and its behavior charging/discharging. The construction of each subsystem is described in the following parts: Open Circuit Voltage (OCV) Calculation and State of Charge (SOC) Calculation.

2.1. OCV Calculation:

The difference of electrical potential between two terminals of a device is connected and when the device is disconnected from any circuit, called Open Circuit Voltage. As shown in fig.2.:  $v(t)=OCV$ , there is no external load connected even no external electric current flows between the terminals.



(a) circuit without load (b) circuit with load

Fig.2

For Lithium-ion batteries, OCV is important characteristic parameter. It is used to analyze the changes of electronic energy. The simplest model of an ideal battery is modeled as an ideal voltage source. In this model (Fig.2.(a)), voltage is not function of current & past usage and (in ideal condition) voltage is constant. So, the voltage between the battery terminals when a load is applied, called terminal voltage on the other hand the voltage between the battery terminals when there is no load applied, called OCV (Open Circuit Voltage). Example of battery open circuit voltage: As show in fig.3. , here we use a multi-meter to measure the voltage of the battery terminals; we have read the OCV even there is no current is flowing in the circuit.

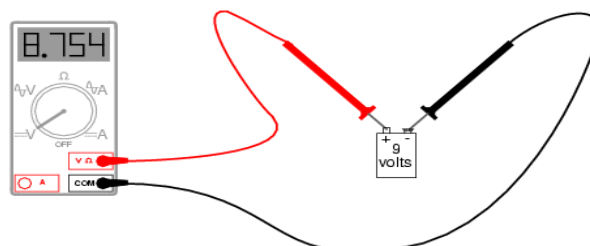


Fig.3 Example of OCV

The open circuit voltage (v) changes with state of charge (SOC).

### 2.2. State Of Charge (SOC):

The level of charge of an electric battery relative to its capacity is called state of charge. SOC is the capacity that remaining in a battery and an important parameter as well which control strategy. SOC characteristics show the battery charging and discharging and its depend on their level or range. If the voltage is high then the battery is fully charged and if the voltage will reach at its lowest point that mean battery is empty. It has two most common and easier methods to estimate SOC of a battery: (a) SOC estimating OCV method and (b) SOC estimating coulomb counting method.

#### SOC Calculation for the battery model:

$$SOC(t) = Q_t / Q_n$$

SOC is the most important battery parameters and SOC of a battery is the ratio of its current capacity ( $Q_t$ ) to the nominal capacity ( $Q_n$ ). The nominal capacity ( $Q_n$ ) is given by the manufacturer, which represents maximum value of charge that can be stored in the battery. Capacity was considered as a function of current and to determine the effect of capacity on the current of the battery cell. Then the calculation of SOC is

$$SOC = SOC|_o - \frac{1}{C_n} \int_0^t I(t) dt$$

Where,  $C_n$  is capacity  $I$  is the current  $SOC|_o$  is the initial SOC

### 3. Battery Capacity:

The energy stored in a battery is called a battery capacity. It's measured in ampere-hours(Ah) or watt-hours(Wh) or Kilowatts hours (kWh). Battery capacity is one of the battery parameters. We can explain it with an example: Let us have a voltage  $v_b$ , and flowing current is  $i_b$ . then the energy is

$$\int v_b \cdot i_b \cdot dt = \text{Energy capacity in Wh}$$

or

$$\int i_b \cdot dt = \text{Charge capacity in Ah}$$

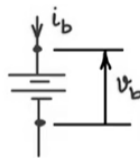


Fig.4:

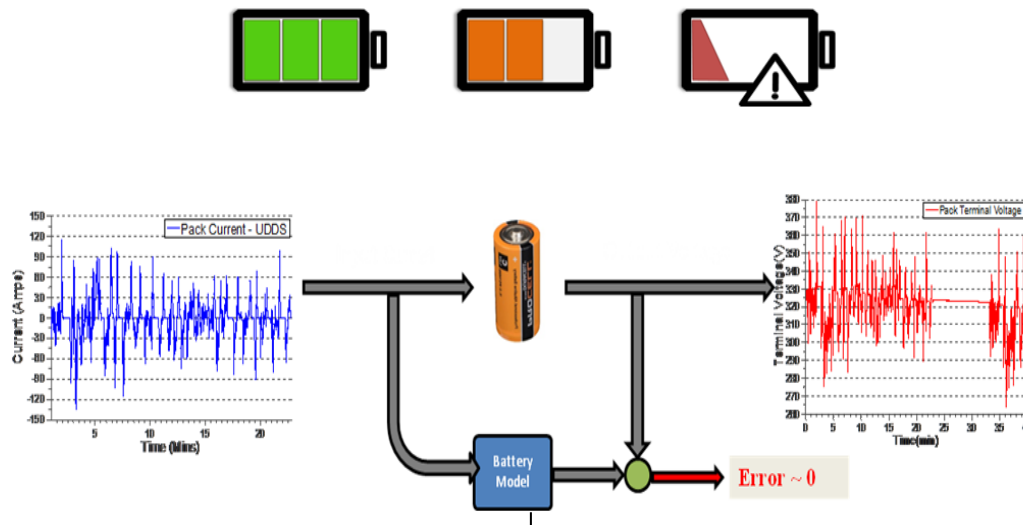
- If  $i_b$  is positive that means it is flowing into a positive terminal and charging the battery. Then the calculated energy will be charging energy.
- If current  $i_b$  is flowing out of the terminal and reverse in the direction which indicates discharge of energy.

So, the capacity of battery is the amount of energy that battery can hold or discharge to the load. Wh capacity or energy capacity gives the true capacity of the battery. If  $v_b$  is constant, then charge capacity (C) or Ah gives a measure of Wh. So, Charge Capacity (C) or Ah battery is most commonly used for commercial purposes. The capacity of a battery is measured by discharging a fully charged battery through an applied load at a constant current rate.

#### 4. Modeling and Simulation of Battery:

Modeling and simulation of the battery is required to know mathematical relationship between battery input and output parameters and simulator. Here a controlled voltage source dependent on the actual state of charge (SOC). The modeling and simulations are required for capacity determination and optimum component selection in the electrical system and also play an important role in the approximation of battery performance and in design. Battery modeling described with all the concept of extracting parameters from manufactures discharge characteristics. This characteristics gives fast accurate and effective solution which will be useful for the batteries. The general model for charge and discharge is in this form:  $E_{charge}=f_1(it, i^*, Exp, Batt\ Type)$  and  $E_{discharge}=f_2(it, i^*, Exp, Batt\ Type)$

Where,  $E_{charge}$  and  $E_{discharge}$  are the function of it (Extracted Capacity (Ah))  $i$ =Low frequency current(A)  $Exp$ =Dynamics Exponential zone(V) Batt type=types of battery (presently, Lithium-ion battery used) So, the battery model is required to monitor battery parameter such as SOC



**Fig.5: Battery Model: used to monitor battery parameters**

The first step in designing a battery management system (BMS) is to develop a high fidelity battery model. In order for a BMS to estimate the battery critical parameters such as the battery state of charge and state of health, an accurate battery model has to be implemented on board of the BMS along with a robust estimation strategy. So a battery model is a list of mathematical equations that describe what’s physically happening inside the battery. In simple terms, as shown in the figure, if we apply the same current profile to the battery and the battery model, both should generate the same voltage profile and the error between the two signals should be close to zero. The model can predict the behavior of the battery in a way that if we applied an estimator, we can predict critical parameters such as the battery SOH and remaining useful life.

#### 4.1 Simulation of Battery Model:

In the MATLAB/ Simulink is built a simulation model of the battery which includes a cell parameters module for a lookup in the charging and discharging process.

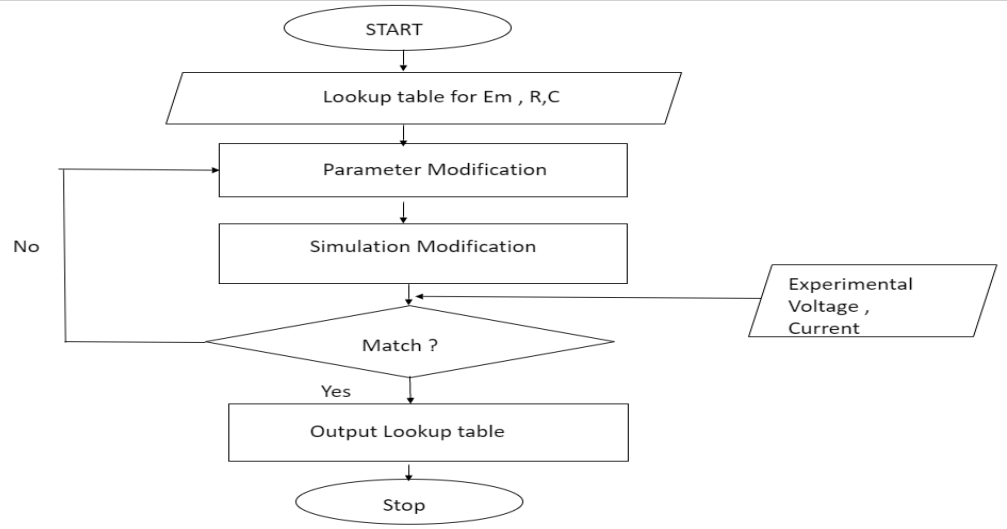


Fig.6: Flow Chart to obtain simulated parameters in equivalent circuit elements.

**5. Mathematical Model of the battery:** According to methodology, there are various mathematical methods of estimation are classified and the classifications of these estimation methods in the various literatures are divided into four categories:

- Direct measurement: This method uses battery physical features such as terminal voltage or impedance. Following methods are mentioned below, which are commonly used:
  - Open circuit Voltage method
  - Terminal Voltage method
  - Impedance method
  - Impedance spectroscopy method
- Book-keeping estimation: To this method, Charging or discharging of the battery is taken as input. Accuracy of the coulomb counting depends on the accuracy of the current measurement of the battery system. It is basically two types:
  - Coulomb counting method
  - Modified Coulomb counting method
- Adaptive systems: It is also called an indirect method of measurement because of their ability to deal with the nonlinearities of battery systems. It can be classified into five types:
  - BP neural network
  - RBF neural network
  - Support vector machine
  - Fuzzy neural network
  - Kalman filter
- Hybrid Method: This method constructed with the order of accuracy by the different- different scientists from different countries for solving the equations. In this battery model, it can three types mainly :
  - Coulomb counting and EMF combination
  - Coulomb counting and Kalman filter combination
  - Per-unit system and EKF combination

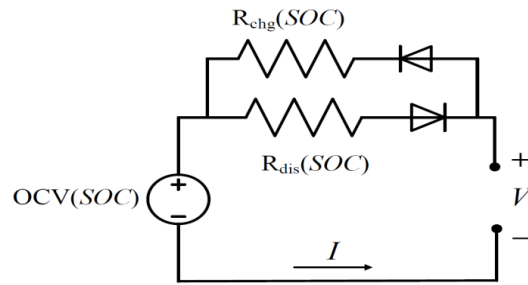


Fig.7: Equivalent circuit

Here we describe relationship between state of charge (SOC) and terminal voltage ( $V_t$ ).

$$V_t = OCV(SOC) - I * R_{dis}(T, SOC) \text{ at time of discharging}$$

$$V_t = OCV(SOC) + I * R_{chg}(T, SOC) \text{ at time of charging}$$

$V_t$  is actual terminal voltage where actual load is connected.

Open circuit voltage is function of SOC. Every battery have some internal resistance which oppose current at the time of battery charging and discharging. Behave of resistance at time of charging is different than at the time of discharging. These internal resistance is also cause of heating of battery.

Change in SOC can be calculated by how much current is going inside of battery or coming from battery. mathematically we can represent

$$SOC = SOC|_0 - \frac{1}{C_n} \int_0^t I(t) dt \text{ at the time of discharging}$$

Where  $SOC|_0$  is initial state of SOC and  $C$  is capacity of battery

In equivalent circuit we can easily see the actual circuit of battery with the internal charging and discharging resistance.

If we concluded these two equation is represent the actual condition what happening inside battery

$$V_t = OCV(SOC) - I * R_{dis}(T, SOC)$$

$$SOC = SOC|_0 - \frac{1}{C_n} \int_0^t I(t) dt$$

These equation is in continuous time domain. In discrete time domain equation are

$$V_k = OCV(SOC_k) - i_k * R$$

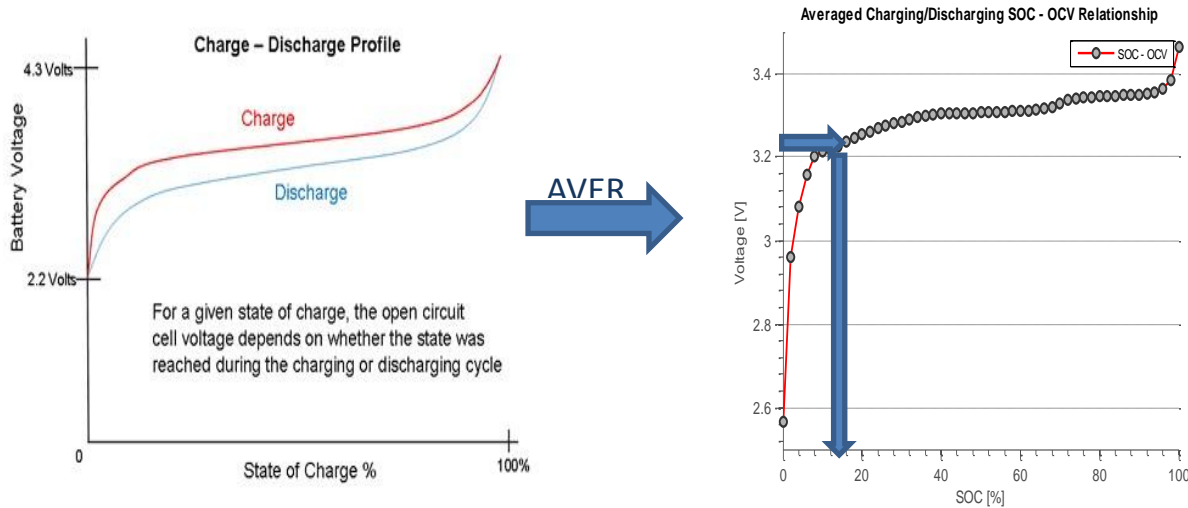
$$SOC_{k+1} = SOC_k - \Delta t \frac{i_k}{C_n}$$

**6. System Parameters:** Some obscure parameters of dynamic scientific model in Fig. (1) we're not sure on account of SOC, the temperature of the environment, and the cycle life of the battery. Be that as it may, considering the impact of SOC in a steady situation temperature and for a few days.

### 6.1. The Relationship between OCV and SOC:

There is a relationship between the battery Open-circuit voltage (OCV) and State of Charge (SOC), which is depends on the battery chemistry and the direction of charging and discharging. Lets we start with a completely discharged a battery and start to charging it, the battery OCV starts at voltage 2.2V and keep ramping up until it reach its in the maximum voltage at 4.3V, as it shown in the fig. with red line. So, we set the battery SOC to 100% when the battery is fully charged. After that start discharging the battery, it start from a fully charged state then it showed a different path indicated by the blue line until it fully

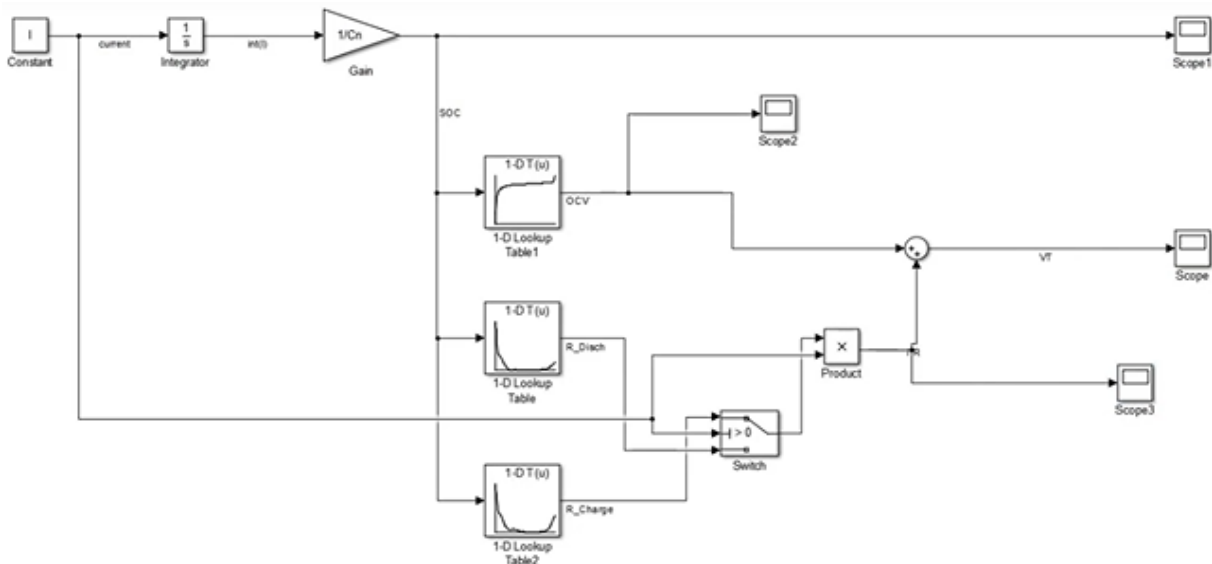
discharge the battery at 0% SOC. Due to hysteresis, we can see the difference between the charging and discharging paths. In the following section we will know how to experientially derive the battery open circuit voltage-state of charge relationship from experimental data.



(a) (b)  
**Fig.8: (a)Charge-Discharge profile (b) Averaged charging/ discharging SOC-OCV relationship**

### 6.2. Identification of the Dynamic Parameters:

In this project, we need to estimate the battery we can explain which is the amount of remaining charge in the battery. On the other hand, we can say that we have to know the battery behavior that it is fully charged, in the middle means 50% state of charge or completely discharge. Now, form a model to observe and try to understand battery behavior. In the basic, we know the sign of the current. If its +ve that means charging and discharging mean -ve. Now we simulate it with Mathwork.



**Fig.:9. Complete model of battery charging & discharging**

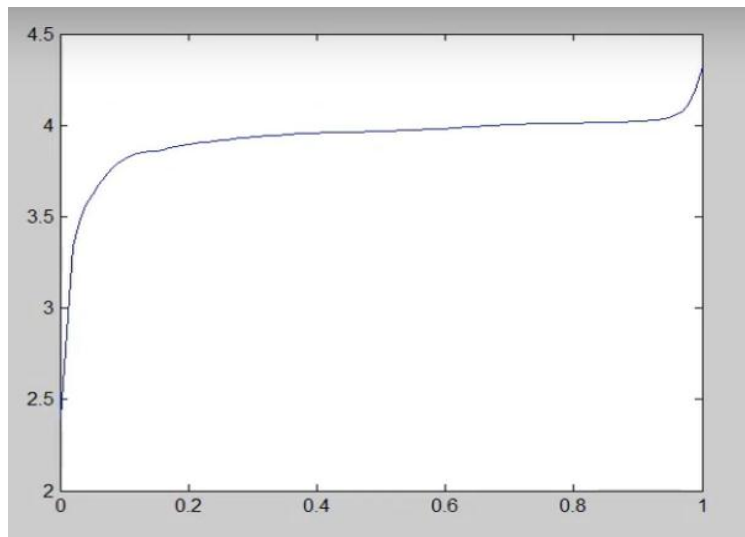
**Methodology:**

This research is applied research because as we faced lots of problems with the extensive use of different types of fossil fuels in automobiles as well as in industries. It has adverse effects on global warming and on greenhouse gas (GHG) emissions. Today's, all over the world battery had rule or we can say that a wide range of electrical equipments, such as mobile phone, MP3 players, EV's etc. are operated by batteries. In this project, MATLAB/ Simulink becomes the most used software for modeling and simulation of the dynamic systems.

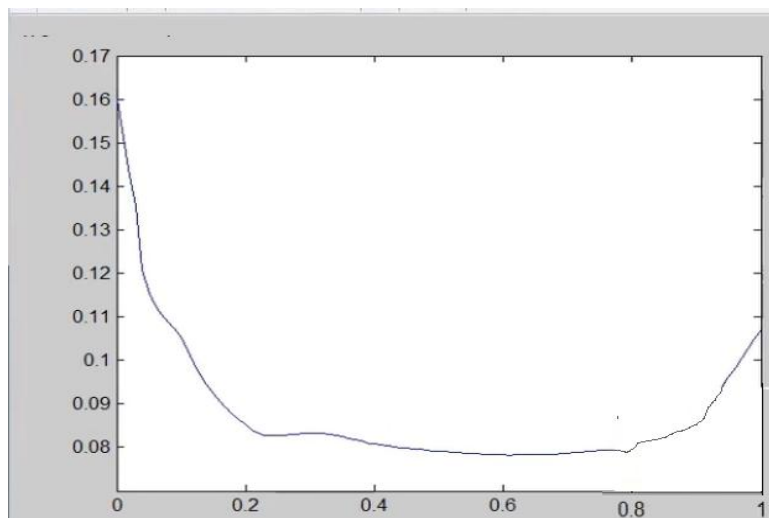
**Result:**

MATLAB programming based battery test system with consistent current source has been created and utilized for knowing battery limit and battery charging and releasing time for its various burdens. In a dynamic burden, the releasing current of the battery is kept steady and battery voltage is diminished by the heap.

After Simulation the battery model, its output of battery parameters with fig.10, fig.:11 & fig.:12 can be represented with the plot the graphs which are mentioned below:



**Fig: 10 Output of SOC which is OCV**



**Fig.11: Output of Charge Resistance of Battery**



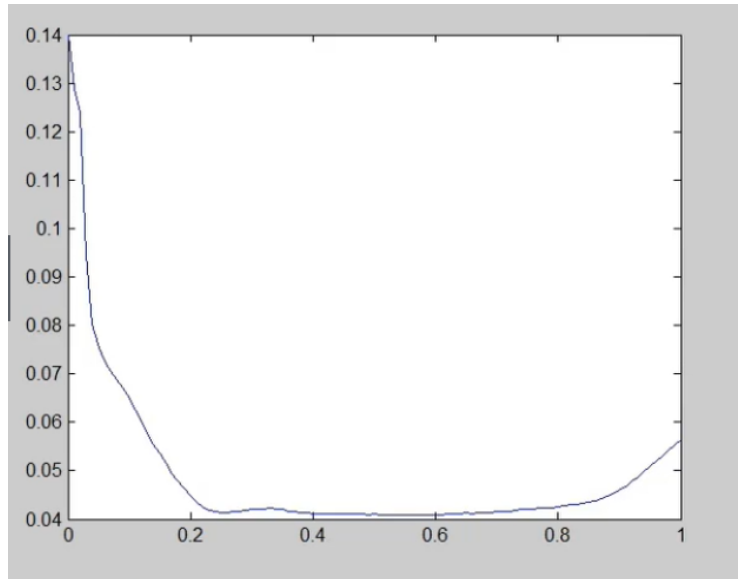


Fig.12: Output of Discharging Resistance of battery

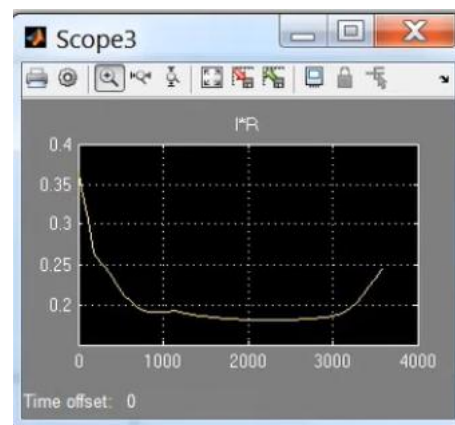
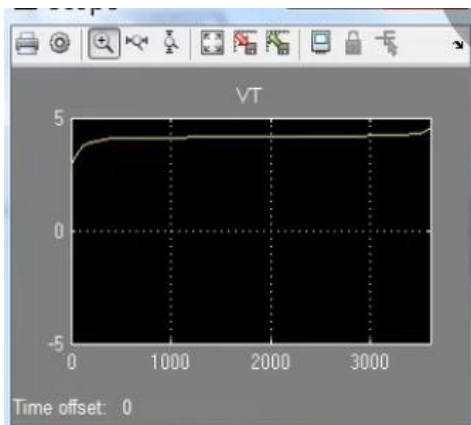


Fig.:13 (a) Fig.:13 (b)

The terminal voltage rises and falls during charging and discharging of batteries can be characterized by measurements of voltage under constant charge and discharge inputs.

### 7. Future Scope:

According to studies, we can see that humans always trying to make better with new inventions and accept new challenges. We have lots of challenges for our future like a pacemaker battery charging model by using MATLAB/Simulink with wireless power transmission. As well as the study of a new type of battery that will be coming soon and that Japan still research on Sodium-ion battery.

### 8. Conclusion:

This project shows the parameterization of the battery charging / discharging behavior by using MATLAB –Simulink and this report helped to study the dynamic characteristics of Lithium-ion battery. The capacity, open-circuit voltage (OCV) and internal resistance of the battery cell (Lithium-ion) were measured at the state of charge (SOCs), and load currents. In further research, the model can be upgraded and implement according to their different loads or its requirements and it includes all the parameters.

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