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A Brief Survey on Modelling of Batteries for Hybrid Electric Vehicles

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Abstract: The present scenario is focused on Hybrid electric vehicles (HEV) because of rise in global environment issue so, in HEV state of charge of the batteries are very important factor. As far as the electric vehicle concern so mileage of vehicles and life of the battery plays a vital role in automobile industry. To find accurate SOC an accurate model is necessary and there are various method which can find the accurate SOC of batteries. The SOC is mainly dependent on various parameters, some are here: open circuit voltage, temperature, age and internal resistance etc. As we know that batteries are storing element and having non-linear characteristics so, here we discuss some modeling of battery techniques like simple battery, resistive thevenin model and modified thevenin equivalent model.

Keyword: SOC, Battery modelling, Hybrid Electric vehicles, Equivalent Circuit Model and Electric vehicles.

I. INTRODUCTION

The automobile industry is growing continuously because there are increasing the number of vehicles all around the world and due to this air pollution touches the height we have to find the alternate solution of this problem. As we know that electrical vehicles are non-polluted vehicles because their fuel is electricity. But it is also very known factor that electrical vehicles are not so popular because for their poor performance and they cannot travel long distance without being charged. If we want that this problem get dissolve so we introduced the hybrid electrical vehicles (HEV). In HEV the engine is design to run on gasoline and electrical mode. During gasoline mode is run and stores the power in battery and when needed it can run in electric mode. Various famous car manufacturer industries are working and launched some model of hybrid electrical vehicles but the problem is the life and state of charge of batteries. So in this chapter we introduce the modeling of battery and my next paper contains the concept of state of charge (SOC) of battery. Before going further let discuss some hybrid electric vehicle configurations.[1]

II. HEV CONFIGURATIONS

There are several configurations present in market but here we discuss three main configuration say series, parallel and advanced mode configuration.

(a) In ***series configuration*** of hybrid electric vehicles the internal combustion engine (IC engine) drives an alternator (which is nothing but an AC generator) and alternator supplies the power to motor as well as battery. In this configuration only electrical motor is connected to the drive train.

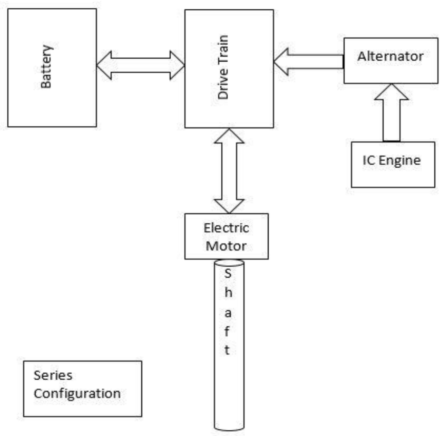

Fig.1 Series Configuration of HEV

Once the battery gets charged fully then engine will turn off and vehicle gets power from battery and in some cases vehicle gets power from both the sources say battery and engine-generator set. The advantages of series configuration is low emission (when vehicle runs on battery) but for this we need full size motor, alternator and engine which is disadvantages of series configuration.

(b) In ***parallel configuration*** the IC engine is mechanically coupled with the drive train and electric motor. So, there are two way for the drive

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train, one is from electric motor and other is from IC engine. In this configuration there is no need of alternator and vehicle can be connected to electric grid for charging and recharging purposes. These type of configuration categorized in two ways one is short trips and long trips, the vehicle is derived with electric motor and IC engine respectively.

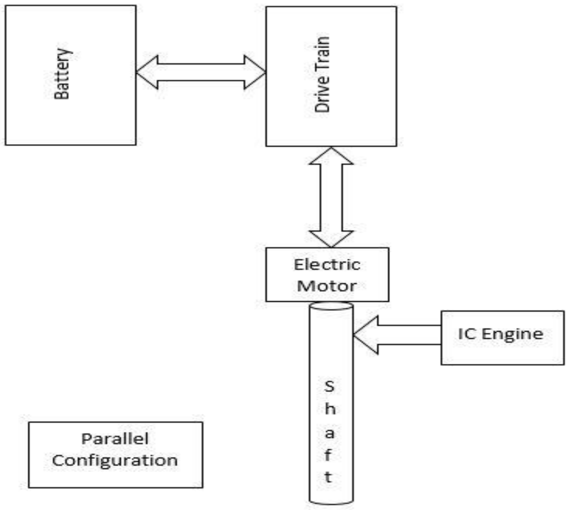

Fig.2 Parallel Configuration of HEV

Advantages of this type of configuration is that low emission and small size battery required due to engine and motor both are connected to drive train. Disadvantages of this configuration is that vehicle is not completely accelerated due to battery pack charge is law.

(c) In ***advanced configuration*** the alternator is mechanically coupled with shaft and IC engine and through engine battery gets charged. So, basically this configuration is similar to parallel type of configuration. In normal condition engine fed alternator and drive train thus battery gets charged. And during fully accelerated condition the motor gets power from the battery. The basic advantage of this configuration is that it has both type of advantage say series and parallel.

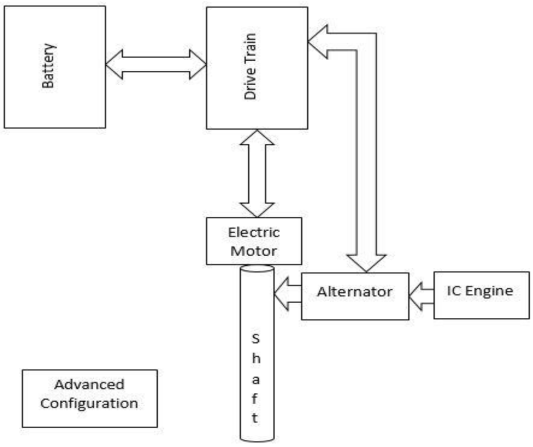

Fig.3 Advance Configuration of HEV

III. BATTERY

Wherever we need portable thing like cell phones to space equipment which are very high tech all we need battery. A battery stores energy in chemical form and converted it into electrical and gives us back when needed. Battery consist of one or more electro-chemical or electrolytic cell from converting purposes which are connected electrically. There are two electrode one is positive and other is negative, a separator and electrolytic. As mention above electrolytic connected electrically due to transfer the electrons. A schematic diagram is shown in figure. [2]

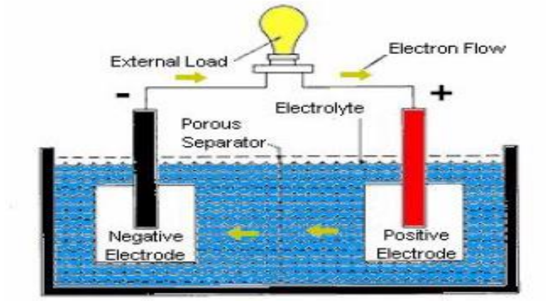

Fig.4 Schematic Diagram of Battery

In battery there are following chemical reaction takes place:

Positive electrode side:

$$PbO_2 + SO_4^{-2} + 4H^+ + 2e^- \leftrightarrow PbO_4 + 2H_2O \ (1.685V)$$

Negative electrode side:

$$Pb + SO_4^{-2} \leftrightarrow PbSO_4 + 2e^- \ (0.356V)$$

Complete reaction:

$$PbO_2 + Pb + 2H_2SO_4 \leftrightarrow 2PbSO_4 + 2H_2O \ (2.041V)$$

If we use single lead acid cell battery so, 2.041V is developed as maximum open circuit voltage. If we need more voltage so we have to connect these electro-chemical cells in series and parallel accordingly. For example if we want 8V battery so, use series connection of 4 batteries of 2V.

IV. PARAMETERS OF BATTERY

There are several parameters of battery

(a) Internal Resistance
(b) Polarization Capacitance
(c) Discharging Characteristic
(d) Rate of Charge and Discharge

- ***Internal resistance***: This resistance is inversely proportional to the temperature. The resistance is a

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form of water of electrolytic is called internal resistance of a battery. [3]

- ***Polarization Capacitance***: It depends upon the state of charge of a battery and need not to present a purely electric capacitance. It is produces due to chemical diffusion of battery.
- ***Discharging Characteristic***: There are two types of discharging process, one is continues discharging where battery continuously delivers energy to the load. Second is Intermittent discharging, in this case battery delivers energy at regular and irregular intervals. The second process is involved in hybrid electric vehicles.
- ***Rate of Charge and Discharge***: If we want the good life span of a battery so, rate of charge and discharge should not be too high. This simply means that the frequency of charging and discharging is as high as possible.

V. MODELLING OF A BATTERY

In this paper we focused three types of modelling as follows:

(a) Simple battery model
(b) Resistive thevenin battery model
(c) Modified thevenin equivalent model

- ***Simple Battery Model***: In this model of battery an open circuit voltage V_0 is connected in series with internal resistance $R_{internal}$ and terminal voltage V_t. Terminal voltage and internal resistance can be found by connecting necessary metering. Because this model is very simple so, it is not taken in account for hybrid electric vehicles and electric vehicles.

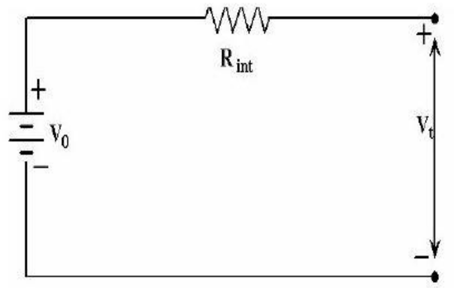

Fig.5 Simple Battery Model

- ***Resistive thevenin battery model:*** This model is similar to the simple model of a battery but differ in the following manners: Electrolytic resistance and current are constant during discharging process, polarization is linear function and electrodes are made up of porous materials. [4]

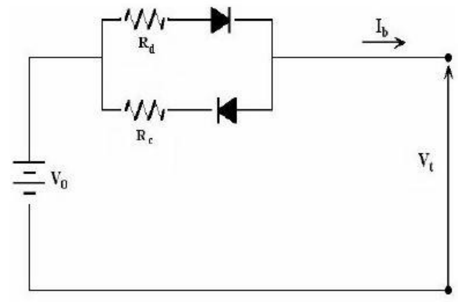

Fig.6 Resistive Thevenin Model

In this model there are two types of resistances are present charging resistance (Rc) and discharging resistance (Rd) which are associated with charging and discharging process respectively. Here one diode is conducting at a time because if one diode will be forward wise so, other will be reverse wised. These diode are present here for only modelling purpose and have not physical significance in a battery.

- ***Modified thevenin equivalent battery model:*** This is modified model of previous model. For this model the charging and discharging equations are given by: [5]

$$V_p = \frac{dV_p}{dt} = -V_p \frac{1}{R_d C} + V_0 \frac{1}{R_d C} - I_b \frac{1}{C}$$

$$Where\ V_p \leq V_0$$

$$V_p = -V_p \frac{1}{R_c C} + V_0 \frac{1}{R_c C} - I_b \frac{1}{C}$$

$$Where\ V_p > V_0$$

$$I_b = \frac{V_p - V_0}{R_b}$$

Where, Vp is polarization voltage

Rd is discharging resistance

C is polarization capacitance

Ib is battery current

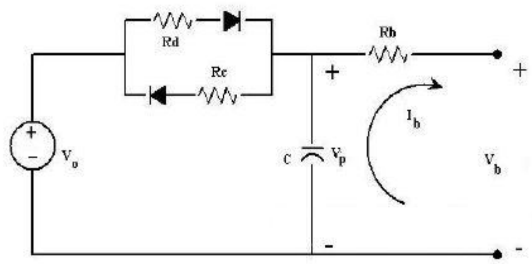

Fig.7 Modified thevenin Equivalent Model

VI. SUMMARY

In this paper we represent the basic of battery like introduction of battery, chemical reaction of battery, parameter of battery, modelling of battery and about hybrid electric vehicles. The motive of this paper is to define some

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basic so that next paper will have some techniques of estimation of state of charge for HEV example extended kalman filter (EKF) and adaptive extended kalman filter (AEKF). If we want to find state of charge so, first we should know the open circuit voltage which is described in this paper. This paper shows the energy losses during charging and discharging process with circuit parameter Rd and Rc. The relationship between open circuit voltage and state of charge is given by:

$$V_{oc}(t) = aS(t) + b$$

And

$$S(t) = \frac{V_{oc}(t) - b}{a}$$

These equation will help us to determine SOC of a battery.

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