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Effect of Discharging Current on Battery Ageing

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Abstract*- Growing environmental concerns has led to the tremendous growth in electric vehicle market and batteries play a major role in these vehicles. Improving the efficiency as well as the life of battery is the major concern in improvement of electric vehicles. This paper explains the effect of high discharging current on the ageing of battery and other parameters. Simulation results are obtained with the help of MATLAB. A number of cycle life tests have been performed at different discharge current rates. The results reveal that higher value of discharging current results in faster ageing of battery and also cause rise in battery temperature.

***Keywords*— Battery, discharge current, ageing, temperature, capacity.**

I. INTRODUCTION

Electric vehicles are the new era in market of vehicles and batteries are the fundamental component of these vehicles. Growing environmental concerns and pollution issues have attracted population towards electric vehicles. Battery electric vehicles (BEV) are growing day by day and are taking over the gasoline powered vehicles. Eco-friendliness, noise free operation, more responsive with high torque and charging facility at home are some of the major advantages of using BEVs on gasoline powered vehicles [1-2]. These advantages of using BEVs are growing the market of electric vehicles and so the need of an efficient and cost effective battery with longer useful life is also increasing. Some of the batteries used in commercial electric vehicles are listed in the Table I. Among the various available batteries Lithium-ion battery are proven to be more suitable for transportation sector [3-4].

TABLE I

TYPES OF BATTERIES USED IN ELECTRIC VEHICLES

Battery Type	Lead Acid	Lithium-ion	Ni-Cd
Energy Density (J/m^3)	30-50	110-160	45-80
Power Density (W/m^3)	180	1800	150
Cycle Life (days)	200-300	500-1000	1500
Operating Temperature (℃)	20-60	20-60	40-60

Batteries usually have the property of high energy density and low power density which means they can store high energy in less mass but can supply stored energy at slow rates [5]. This property of low power density makes it less efficient mainly in the cases when sudden power is needed to meet the high dynamic load demand. Battery age also decreases with number of cycles and is affected by rate of discharging current [6]. A hybrid system is a better way to reduce stress on battery as the auxiliary device like super-capacitor can share peak loads whenever required [7-8].

The presented paper focuses on the issue of battery ageing and shows the effect of discharging current on battery ageing and temperature profile. The rest of the paper is structured as follows: section II presents the modeling of battery; section III deals with the simulation results, when battery undergoes various charging and discharging cycles; section IV summarizes and concludes the presented work.

II. MODELING OF BATTERY

Various equivalent models of batteries are used for electric vehicle's studies. In the present work most common electric model of electrochemical batteries based on Thevenin equivalent is used. The equivalent circuit is shown in Fig. 1. This model uses two RC time constant which is particularly suitable for control applications. The model includes the following parameters:

1. R_o is the battery input resistance characterizing the charge/discharge energy losses of the battery cell.
2. R_1 and C_1 are the resistance and the capacitance that model the fastest electric dynamics behavior (mostly during charging and discharging phases).
3. R_2 and C_2 are the resistance and the capacitances that model the slowest electric dynamics behavior (mostly during slow charging and discharging phase and relaxation phase)
4. E_o is the electromotive force of the battery which can be measured as open circuit voltage.

All the equivalent circuit parameters are non linear and depends on the state of charge (SOC) and temperature [9-10].

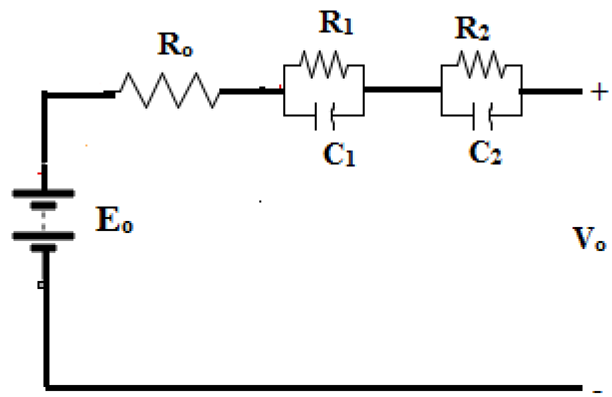

Fig. 1.Equivalent Circuit of Battery

The depth of discharging (DOD) of battery is given by:

$$DOD = 1 - SOC \tag{1}$$

The state of charge is 1 when it is fully charged and is 0 when fully discharged. Thus it can be said that DOD is 0 when battery is fully charged and is 1 when fully discharged.

Battery capacity decreases when high current flows from it in short time. This type of load is mainly found in case of electric vehicles because of its high dynamics. The affect of current on the battery capacity can be understood by using the Peukert model of battery behavior. Although not very accurate at low currents, for higher currents it models battery behavior well enough. There is a capacity, called the Peukert Capacity, which is constant, and is given by the equation:

$$Cp = I^k T \tag{2}$$

where k is constant. The battery is considered to be discharged until it is flat with a discharging current of I A and that it takes T time. The depth of discharge of a battery is the ratio of the charge removed to the original capacity. So, at the n^{th} step of a step-by-step simulation we can say that:

$$DOD_n = \frac{CR_n}{C_p} \tag{3}$$

Here Cp is the Peukert Capacity, as from equation above. This value of depth of discharge can be used to find the open circuit voltage, which can then lead to the actual terminal voltage.

III. SIMULATION RESULTS

Simulations are carried out for 1000 hours period in which battery undergoes various charging and discharging cycles at different depth of discharge and discharging current values. Initially for first 600 hours discharging and charging currents are kept at 20A and 60 A respectively. From 600 hours to 800 hours discharging current and charging current are increased to 80A. After 800 hours charging current is set at 40A and discharging current at 60A. The effect of charging and discharging current variation on the other parameters is shown through the graphs below. The positive section of current graph show discharging current and negative section show charging current.

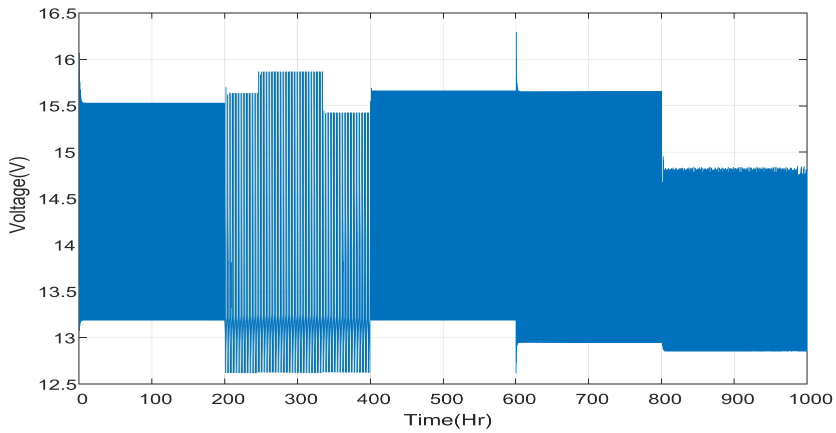

Fig. 2. Voltage Profile of Battery

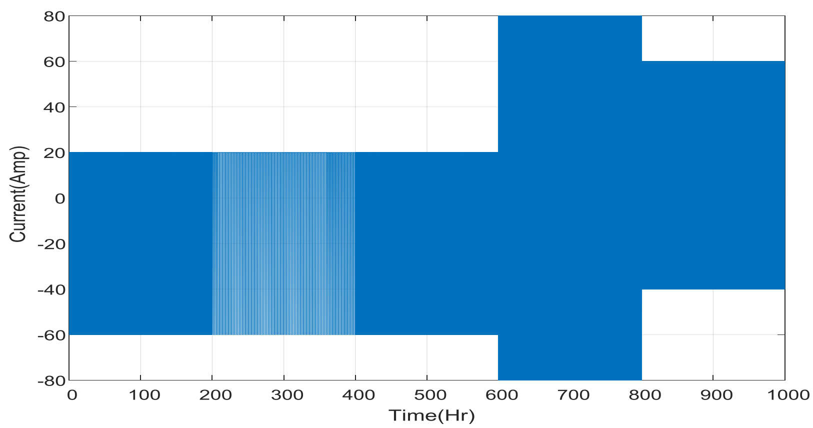

Fig. 3. Current Profile of Battery

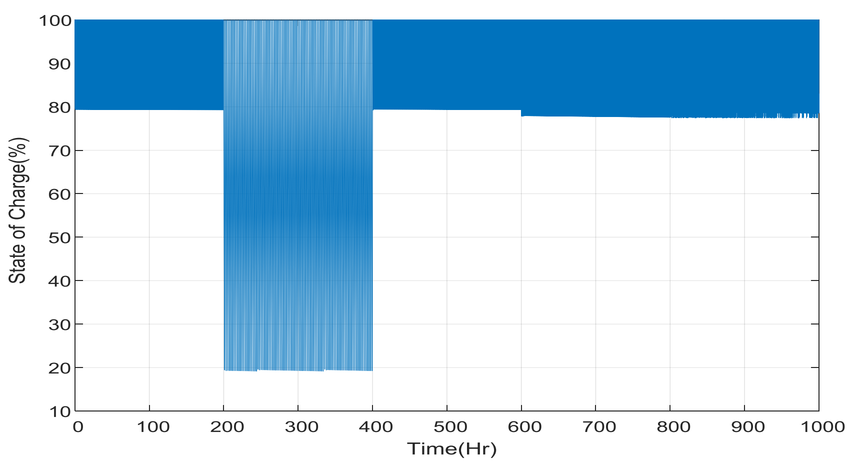

Fig. 4. State of Charge of Battery

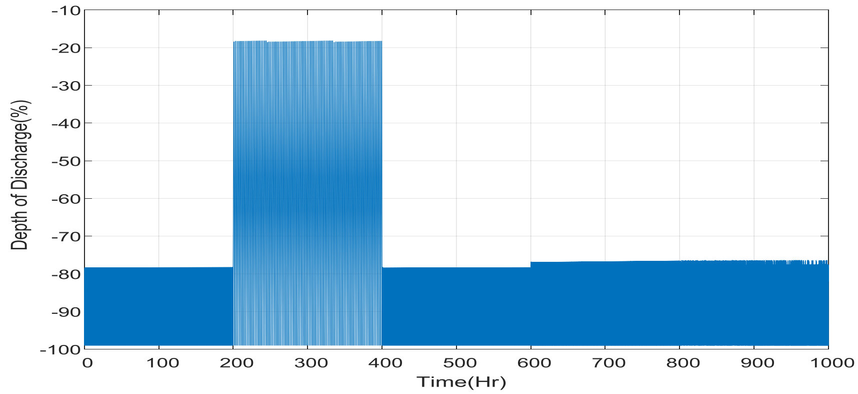

Fig. 5. Depth of Discharge of Battery

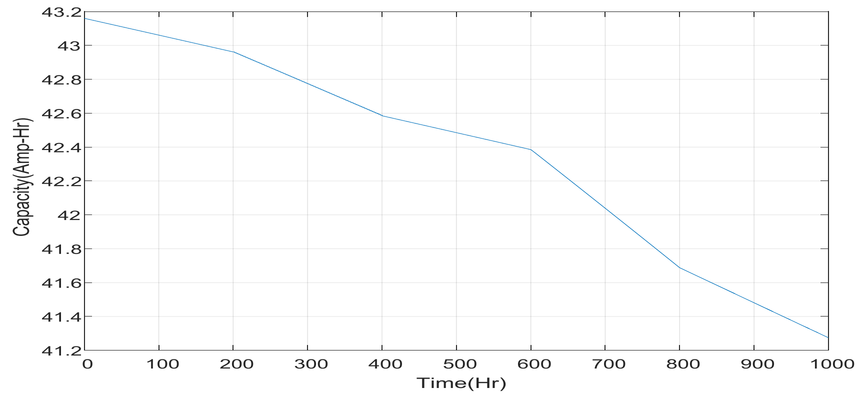

Fig. 6. Capacity of Battery

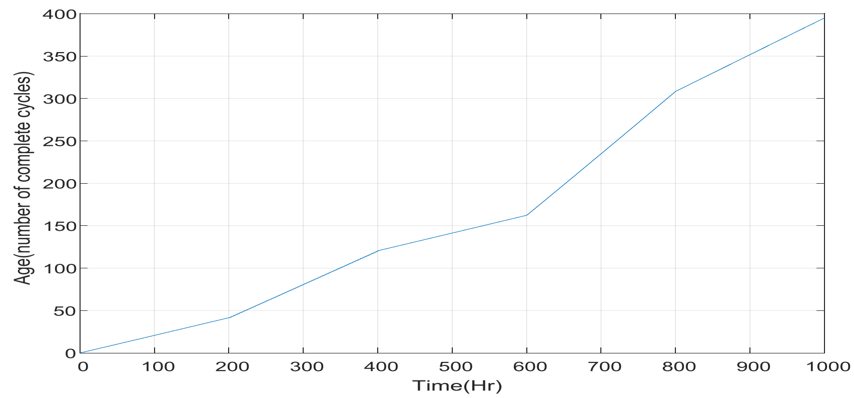

Fig. 7. Profile of Battery Ageing

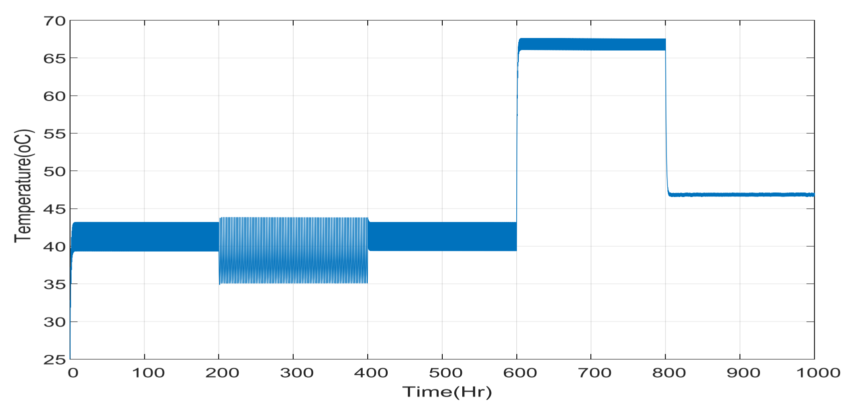

Fig. 8. Temperature profile of Battery

The above simulation results show how battery's parameters alter when it undergoes various charging and discharging cycles for different discharging currents. The charging current as well as discharging current is increased and decreased during these cycles and results show that when the discharging current is increased battery ages rapidly and when it is decreased rate of ageing decreases. The effect of increasing current can be seen on the temperature profile also. When current is increased temperature increases and when decreased temperature also decreases. High temperature is not preferable in battery and can be very harmful for its health. Thus it can be said that high discharging current is not preferable for batteries. Battery should be discharged at low currents for long time rather than in short time with high current.

IV. CONCLUSION

From the above simulation results it can be concluded that higher value of discharging current results in faster ageing of battery. Taking high current from battery results in decrease in capacity, increase in temperature which is harmful for its life. Thus, it is better to take low current from battery for long time rather than high current for short time. It is better to use a high power density source such as ultra capacitor with battery in hybrid manner for supplying instantaneous high load demand in electric vehicle applications. This would definitely reduce stress on the battery and improves the battery life.

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