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Circuit Based Battery Model Used in Mathematical Modelling for Automotive Application

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Abstract - With the aid of any form of modelling analysis, it is vital to comprehend the non-linear dynamics of any type of battery model. Analysing battery performance and state of charge circumstances mostly relies on mathematical modelling. Any electrically powered vehicle, as is common knowledge, needs a battery to function in order to go from one location to another. Understanding a battery's functional characteristics, such as its charging and discharging durations, life expectancy, and cost-effectiveness in design, is crucial. Only via mathematical computations and equations could all these parameters be examined. From this point on, the focus of this study has been on the mathematical treatment of battery model analysis. In addition The circuit-based models are usually not scalable and are accurate only for the narrow ranges of specified parameter values. Any changes in the battery parameters such as capacity, thermal, applied current, etc., would cause large distortions in the simulation results..

Key Words: Battery model, mathematical modeling, non-linear dynamics, state of charge

1.INTRODUCTION

The definition of a battery as an electro-chemical device, which essentially transforms chemical energy into electrical energy, is well recognised [1]. The rated capacity (abbreviated Q) and voltage rating (V) of a battery are generally considered to be its distinguishing characteristics. In order to build theoretical as well as practical related tools to summarise the features of batteries, mathematical prototyping is required to estimate the battery working [2]. In recent years, numerous models have been put forth and developed [3-5]. However, these models are thought to be composite in nature and difficult to use. In order to learn about the characteristics of a battery using mathematically based equations, a straightforward model is needed.

Traditionally, many battery-powered devices

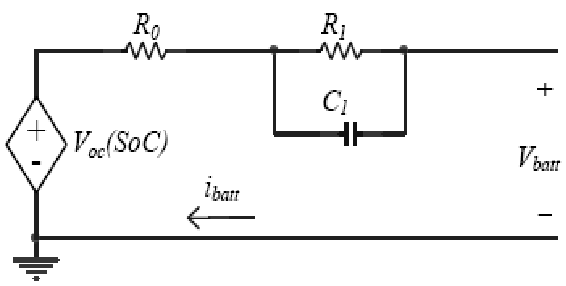

Fig. 1: battery powered Devices

Figure 1 **shows** one of the **circuit-based** (electrical) battery **models.** These models **provide** details **such as** state of charge (SOC) and

charge/discharge time. Figure 2 shows **a runtime-based circuit-battery** model.

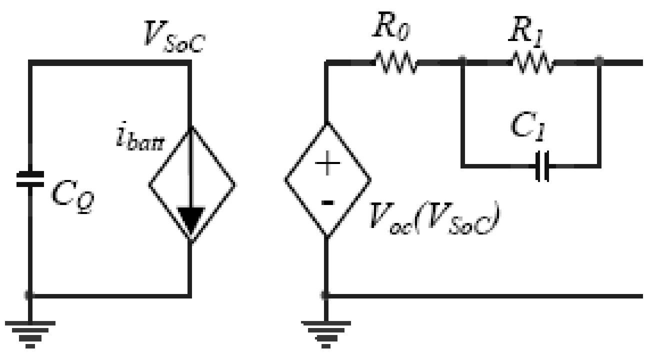

Fig. 2: Runtime based Battery model

II. ELECTRICAL BATTERY MATHEMATICAL ANALYSIS

Based on the essential points selected from the manufacturer's battery steady state related data characteristics, a mathematically based battery model's parameters could be extracted. As a result, computing the battery equations could be used to get additional model parameters. The regression approach is the alternative strategy for extracting model parameters..

$$V_{battery}(x) = f(Y,\alpha) \text{ ------------------ (1)}$$

Where 'x' represents the observation, 'Y' represents a variable to predict the values and 'α 'represents battery vector.

Any of the curve fitting technique should be employed in order to find the value of 'α'. One can find error in 'α' with the help of following relation given below respectively:

$$err(\alpha) = \sum_{x=1}^{K} (V_{battery}(x) - f(Y_x - \alpha))^2$$

------------------------- (2)

The complete mathematical battery model normally consists of many sub-models respectively. The important sub model is the voltage & current model. This sub model basically explains about the variation of output terminal voltage with the changes in the value of current parameter.

The well known current & voltage model pertaining to constant current discharge application is the Shepherd model. One can find the value of voltage of the battery by the relation mentioned below:

$$V_{battery} = V_0 - \alpha\left(\frac{Q}{(Q-it)}\right)i - R_0 i$$

------------------------ (3)

The above equation can also be represented in terms of SOC as follows:

$$V_{battery} = V_0 - \left(\frac{\alpha}{SOC}\right)i - R_0 i$$

------------------------ (4)

The flow chart of battery model can be analyzed as given below:

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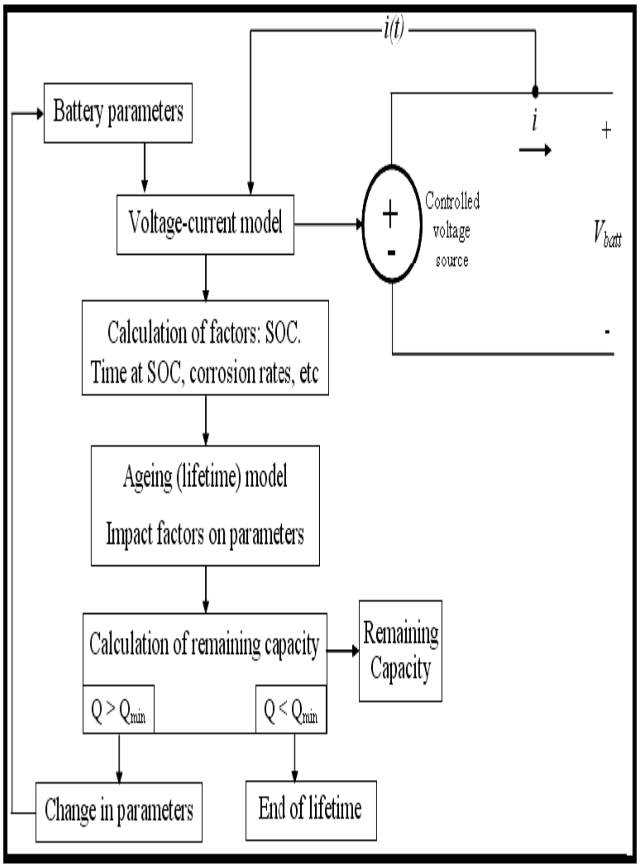

Fig. 3: Model using a mathematical battery and flowcharts

The aforementioned flowchart makes it easy to evaluate and compute the SOC parameter, life-cycle assessment, Q rate computation, terminal voltage, and current flowing through the battery.

By connecting a generic battery model to a bidirectional DC-DC converter, a simulation was run in the MATLAB/SIMULINK environment to better understand the battery charging and discharging curves, and the resulting charts are displayed below.

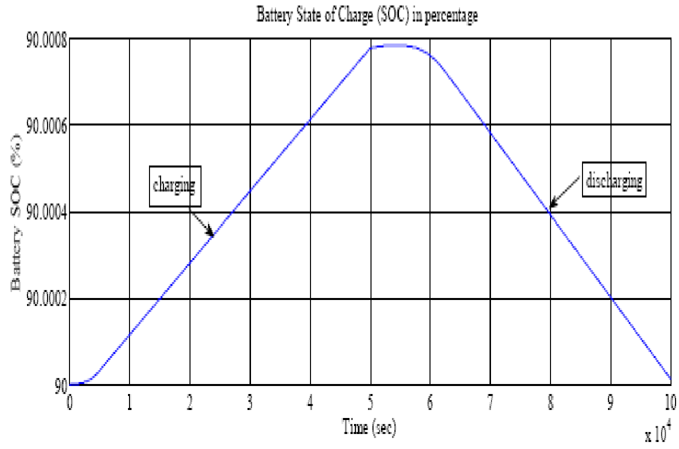

Fig. 4: Battery SOC curve

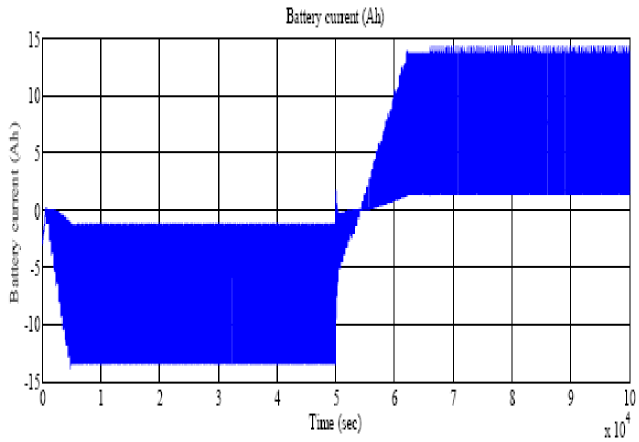

Fig. 5: Battery current plot

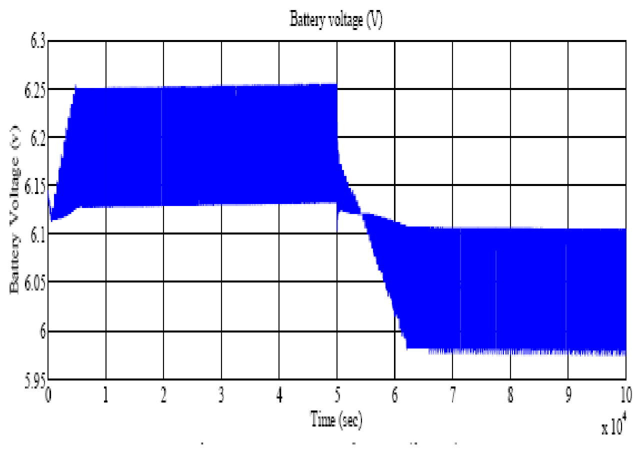

Fig. 6: Battery voltage plot

III. CONCLUSION

This work presents a mathematical approach for simulating a battery model. After modelling the generic battery model, this paper also provides some insights into determining the values of SOC, battery voltage, and battery current. Additionally, it shows a few simulation plots on battery SOC, as well as variations in battery current and voltage, for a particular bidirectional converter, to demonstrate that the battery model is in usable condition, indicating that it can be connected to any type of circuitry and be used to further analyse the battery characteristics..

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