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AN028
This document defines the State of Charge (SoC), Stage of Health (SoH) and State of Power (SoP) in batteries

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Application Note – AN028

State of Charge, Health and Power in batteries. Definition

Introduction

Different types of batteries have entered the industrial market in the last 20 years being the Lithium based batteries the most promising and studied so far. Lithium batteries have many advantages, such as small volume, light weight, long cycle life and self-discharge rate which make them ideal for different applications in the industrial market that were filled by other technologies before.

On the other hand, their small variations and non-linearity between the remaining energy and the voltage measured in the battery makes its monitoring more complex than with the widely used lead-acid chemistries.

Algorithms to obtain the state of charge and the state of health of batteries can provide very useful information to the user of the energy storage. Other states such state of power, which rely on the previous states, can also play an important role in some applications.

To be able to simulate and estimate the response of batteries in a real application, batteries must be modeled. The most common and widely used models are shown below in Fig. 1 and Fig. 2.

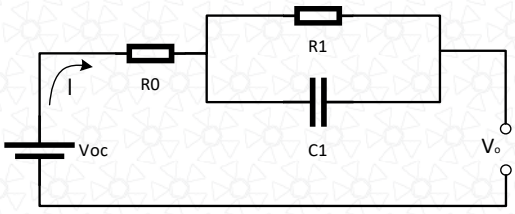

Fig. 1: First order RC Model

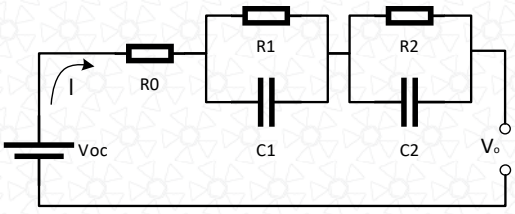

Fig. 2. Second-order RC Model

State of Charge (SoC)

The state of charge (SoC) can be described as the level of charge of a battery relative to its capacity. The units of SoC are percentage points and it is calculated as the ratio between the remaining energy in the battery at a given time and the maximum possible energy with the same state of health conditions.

$$SoC(t) = \frac{Q_{remaining}(t)}{Q_{max}(t)} * 100\ [\%] \qquad (1)$$

The obtention of the SoC is key for every application and sets base for the other states' estimation. There are many algorithms to obtain the SoC but the most widely used are the Coulomb Counting method, the voltage method and the Kalman filter method. Each one of them has their benefits and limitations depending on the application, type of battery, computation availability and precision.

State of Health (SoH)

The estimation of the maximum level of charge of a battery relative to its initial value when it is first used is called state of health (SoH). The units of SoH are percentage points and it is calculated as the ratio between the maximum energy storing capacity in the battery at a given time and the maximum energy it was able to store initially (nominal capacity).

$$SoH(t) = \frac{Q_{max}(t)}{Q_{nominal}(t)} * 100\ [\%] \qquad (2)$$

The state of health is a very useful indicator of the life expectancy of the batteries and helps to decide when to change the battery because the minimum requirements are not achieved.

Also, by having an accurate state of health algorithm, the model of the battery used and its usage in the application it is possible to estimate the life that the battery will have under a specific use.

State of Power (SoP)

A battery's state-of-power (SOP) is defined as the ratio of peak power to nominal power. The peak power, based on present battery-pack conditions, is the maximum power that may be maintained constant for T seconds without violating preset operational design limits on battery voltage, SOC, power, or current.

$$SoP(t) = \frac{P_{max}(t)}{P_{nominal}(t)} * 100\ [\%] \qquad (3)$$

This indicator is very important to ensure that the charge or discharge power does not exceed certain limits with the aim of using the battery as good as possible to

extend its life expectancy. Also, in peak power applications this indicator can turn useful to define conditions in the battery to be able to make big charges or discharges.

The state of power depends highly on the state of charge, the capacity of the battery and its initial features, chemistry and battery voltage so it is obtained in a second step of a battery study.