



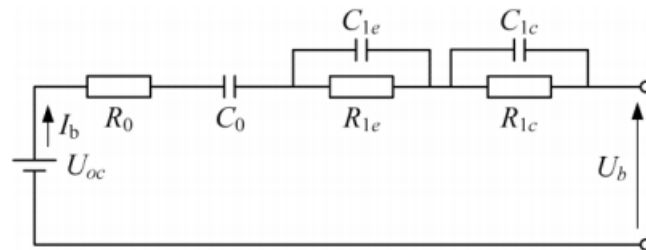
## MODELING LEAD-ACID BATTERY SYSTEMS

Eduado Baima Monteiro de Paula<sup>1</sup>, João Paulo Modesto Damiano<sup>2</sup> and Daniel Guzmán Del Río<sup>3</sup>

### ABSTRACT

It is of interest in the use of lead-acid batteries, as the main energy storage devices that by operating these devices it is possible to know, and predict, their operation in the most accurate way possible, with a focus on the main parameters of interest for the system external to the battery, these being: State of Charge, abbreviated to SOC, and its operating voltage, both in Open Circuit Voltage (OCV) and under load. There is great difficulty in predicting these parameters reliably. The relationship between the voltages produced by the battery and its state of charge occurs in a non-linear manner, changing severely throughout this state of charge and operating temperature, among other factors.

For the correct and direct modeling of these devices, then, several methods are used, here we present two of the main ones, with an electrical approximation, called General Nonlinear (LNG) and another with an approximation by the Padé method of rational functions. It can be observed, then, first:



Source: Bašić et al. 2022

Where the current supplied by the battery ( $I_b$ ) is modeled from a voltage in capacitor  $C_0$  over time, given by:  $(dC_0)/dt = I_b/C_0$ . It is important to note that these capacitances are given in tens of Kilofaradays, and are highly sensitive to frequency changes.

Another method of obtaining is through Padé approximations, which result in similar outputs, but in the Laplace plane, being computationally intense due to the number of possible iterations, being an example of second-order approximation:

$$\frac{-2 - \frac{2}{5}s - \frac{3}{320}s^2}{s(1 + \frac{3}{40}s + \frac{1}{1920}s^2)}$$

**Keywords:** Battery, State of Charge, Voltage, Modeling: Padé Approach, LNG.

<sup>1</sup> University of the State of Amazonas – AM

<sup>2</sup> University of the State of Amazonas – AM

<sup>3</sup> University of the State of Amazonas – AM