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A Monte Carlo Model for Predicting Life and Reliability of a Lithium Ion Satellite Battery

Mark J. Isaacson
Lockheed Martin Space Systems
1111 Lockheed Martin Way
Sunnyvale, CA 94089

Introduction

Satellite batteries have demanding life and reliability requirements. Typical life requirements for a satellite battery in geo-synchronous earth (GEO) orbit are:

1. A fifteen-year on orbit life.
2. 1500-3000 cycles at DODs as high as 80%.
3. 99+% reliability.

Lithium Ion (Li-ion) batteries are now starting to penetrate the satellite market. The first GEO communications satellite with a Li-ion battery was launched in March 2004. In spite of this, there is still concern regarding the ability of Li-ion batteries to meet satellite life and reliability requirements.

This paper presents a Monte Carlo model for predicting the life and reliability performance of a Li-ion battery for a GEO satellite application. The model is used to predict battery reliability as well as explore the effects of factors such as variation in cycle-dependent cell capacity fade and calendar-dependent cell capacity fade.

Model

The simulated battery consists of forty-eight cells arranged in a 3P x 16S topology, i.e. the battery is assembled by first connecting three cells in parallel to form a thee-cell-parallel-module and then connecting 16 three-cell-parallel-modules in series to from the battery.

The beginning-of-life (BOL) average cell capacity and standard deviation are determined from experimental data. The BOL battery capacity is calculated by assuming that:

1. The capacity of a three-cell-parallel-module is equal to the sum of the capacities of the three cells that compose the module.
2. The capacity of the battery is equal to the minimum three-cell-parallel-module capacity in the battery.

In this paper, cycle-dependent and calendar time-dependent cell capacity fade are modeled by the semi-empirical relationships proposed by Borthomieu and Planchat.[1] These equations are linearly combined to replicate the charge/discharge profile that a battery would be subjected to in a GEO satellite. Eq. (1) shows the relationship for calendar-dependent capacity fade.

$$N = c_1 \exp(-c_2 D) \qquad (1)$$

In this equation, N is the number of cycles to failure, c_1 and c_2 are constants determined from cell cycle data and D is the depth-of-discharge.

Results

Selected results are shown in Fig. 1. The x-axis is the standard deviation in c_2 (see Eq.1) divided by the average c_2 for the 49 cells in the battery and the y-axis is the EOL battery capacity divided by the average BOL battery capacity. The two curves represent the 50% Battery, or average battery, and the 1% Battery, or the battery with a capacity that is less than 99% of the batteries in the simulation.

Fig. 1 clearly shows how the variation in the variation in C_2 affects battery reliability. For small standard deviations in C_s the capacity of the 1% Battery is near that of the 50% Battery but for large standard deviations the capacity of the 1% Battery is considerably less than that of the 50% Battery.

Summary

A Monte Carlo model has been developed for a Li-ion battery. The model is used to predict the life and reliability of Li-ion batteries in GEO satellite applications.

Acknowledgements

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References

(1) Y. Borthomieu and J.P. Planchat, 2000 NASA Aerospace Battery Workshop, Huntsville, Alabama (2000).

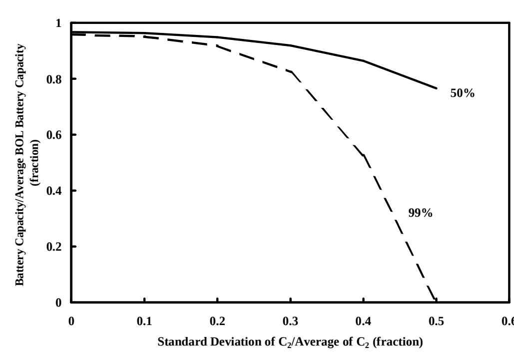

Fig. 1. Effect of the variation in C_2 on battery reliability. See text for description of figure.