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MICRO-SATELLITE'S ENERGY BALANCE ANALYSIS BASED ON THERMAL-ELECTRICAL MODELING

Abstract

A satellite Electrical Power Subsystems (EPS) is a highly critical subsystem with complex nonlinear behavior, a strong dependence of thermal environment fluctuations and with a wide range of power levels operation. The modeling, simulation and virtual-prototyping of such a complex subsystem is an efficient approach to help engineers optimize system architectures, components and performance in terms of efficiency, power density, lifetime and cost. Therefore, a design approach that handles modeling in a comprehensive and efficient way by using orbit propagators, thermo-mechanical, electrical and general-purpose state-flow simulators are necessary.

This paper presents an EPS energy balance analysis and validation based on a thermal-electrical model of Beihang University micro-satellite in Low Earth Orbit (LEO). This approach combined the STK for orbit propagation, ANSYS for thermal modeling and MATLAB/SIMULINK for electrical and signal-flow analysis. The worst-case hot and cold influence on the micro-satellite EPS behavior performance will be investigated. A Direct Energy Transfer (DET) architecture with a single stage PWM shunt regulator was simulated to investigate in detail the power flow between the solar arrays, the Li-ion battery, and the loads. Regulated buses were also included in the model by simulating the operation of a DC/DC converter tuned by a Proportional-Integral (PI) controller.

The incident radiation fluxes on the solar arrays were analyzed based on the orbit environment and acted as the inputs in the satellite thermal modeling. The solar arrays and battery temperature fluctuations impact on the electrical performance of these devices. Hence, these fluctuations were inputted in the EPS power flow analysis by properly evaluating their distortion on the arrays and battery ideal behaviors.

Moreover, the loads were simulated both as static and dynamic loads. In the static case, the satellite average power consumption per orbit was obtained based on the duty cycle estimation for each load. While in the dynamic approach, the switching operation of the loads was implemented. The battery voltage and Deep-of-Discharge (DoD) were examined in each case, as well as its charge and discharge behavior. The EPS energy balance simulation and investigation proved the availability and feasibility of the proposed model.