A Novel Dual-bus Satellite Electrical Power System

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Abstract

The traditional satellite electrical power system (EPS) scheme is difficult to satisfy the high power needs of the new generation synthetic aperture radar (SAR) satellite. In this paper, a novel dual-bus satellite EPS with high density, high efficiency, and high reliability is proposed. The EPS consists a 30V fully-regulated bus and a 100V unregulated bus. An isolated bi-direction DC/DC converter is used between the 42V bus and the 100V bus. To validate the feasibility and effectiveness, a prototype of the proposed EPS has been developed and tested.

Background

With the continuous capability promotion of the SAR satellite, the power requirement continues to increase. The power demand of the platform load may reach 2kW, and the payload peak power may exceed 20kW or even reach 50kW. This raises a new problem for the EPS design of the new generation SAR satellite operating in the low earth orbit. Moreover, the density, efficiency and reliability of the EPS are need to be improved.

EPS Design

The proposed EPS has two power bus, a 30V fully-regulated bus and a 100V unregulated bus, as shown in Fig 1.

The 30V fully-regulated bus powers the platform load, which usually consumes constant power no more than 2kW. The low voltage bus is generated by the solar array, high energy density Lithium-ion battery, and a integrated power conditioning unit (PCU). The triple junction 32% solar cells with thinned substrates are selected, and the semi-rigid solar array substrate is adopted to reduce the weight of the solar array. The newly developed solid state Lithium-ion battery cells with energy density of more than 300Wh/kg are used to improve the battery density significantly. A three-port PCU is designed to promote the power density by integrating the function of solar array regulation, battery charging and discharging in one power module.

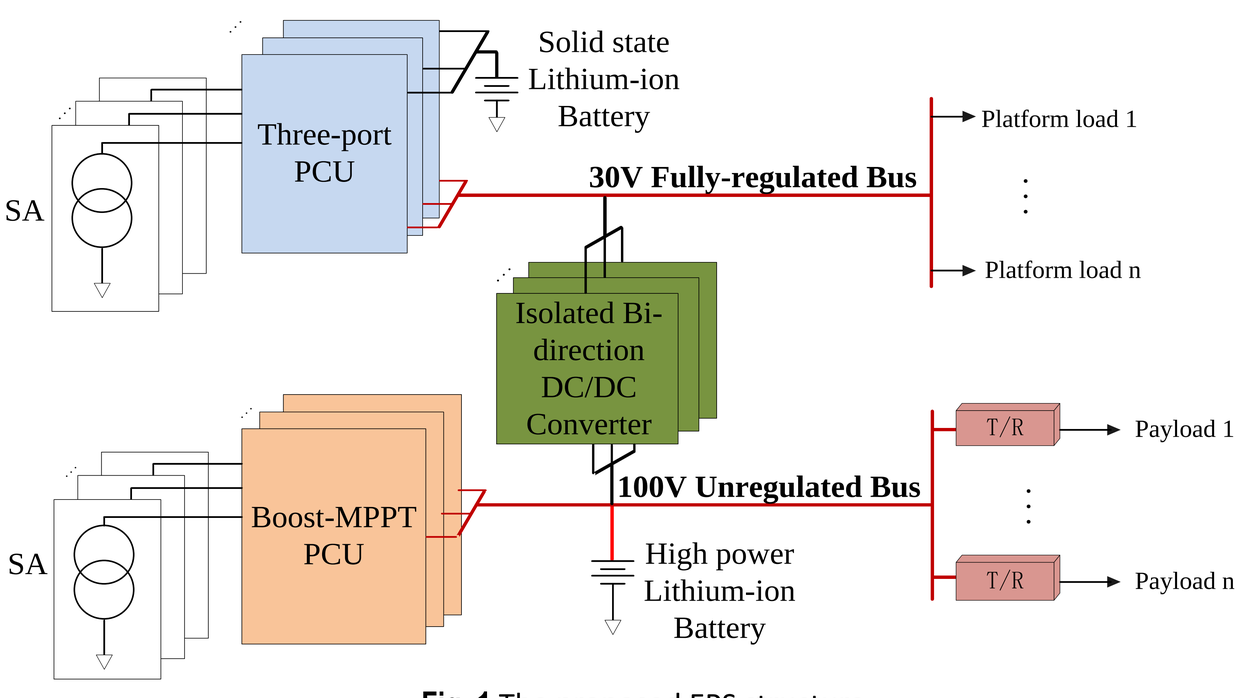


Fig. 1 The proposed EPS structure

The 100V unregulated bus powers the SAR load, which usually works intermittently depending on the satellite operation mode. The peak power absorbed from the 100V bus may reach 50kW. The solar array design is similar to the 30V bus, but the working voltage is higher. The high power Lithium-ion battery cells with 10C～30C high discharge rate are used to satisfy the peak power demand from the T/R power supply. A Boost-type PCU is designed with the maximum power point tracking (MPPT) technique. The incremental conductance method is implemented with analog circuits to extract the maximum power of the solar array.

To ensure the EPS reliability and power quality, an isolated bi-direction DC/DC converter is used between the 30V bus and the 100V bus. The DC/DC converter provides needed current from one bus to the other according to the command signal. To achieve high power conversion efficiency, the dual active bridge topology and the phase-shifting modulation are adopted.

Results

An EPS prototype has been developed according to the proposed design scheme. Currently, the solar array simulator and battery simulator are used. It is expected the power density of the solar array is about 150W/kg. The energy density of the solid state Lithium-ion battery is about 230Wh/kg. The energy density of the high power battery is about 130Wh/kg. From the test results, the power density of the 30V/2kW PCU is about 120W/kg. The tracking accuracy of the Boost-MPPT circuit is about 99%, and the power conversion efficiency is greater than 95%. Moreover, the efficiency of the isolated bi-direction DC/DC is better than 93%.

Reference

[1] Toni Fabio Catalano, Stefano Costantini and Giorgio Daprati. Sentinel-1 EPS Architecture and Power Conversion Trade-Off. 9th European Space Power Conference, 2011.

[2] E. Scorzafava, G. Gianninoto, M. Cantamessa, et al. The Cosmo-Skymed Second Generation SAR Antenna Electrical Power Chain and Platform Power Distribution. 11th European Space Power Conference, 2016.

[3] Young-Jin Wona. The Electrical Power Systems Design and the Performance Analysis for the Second Korean SAR Satellite. 70th International Astronautical Congress, 2019.

[4] Zhang Running and Jiang Xiupeng. System Design and In-orbit Verification of the HJ-1-C SAR Satellite. Journal of Radars, 3(3), 2014.(in Chinese)

[5] Zhang Qingjun. System Design and Key Technologies of the GF-3 Satellite. Acta Geodaetica et Cartographica Sinica, 46(3), 2017.(in Chinese)

[6] Yang Shuangjing and Zhao Changjiang. Design of Power Supply System for High Power SAR Satellite. Spacecraft Engineering, 26(3), 2017.(in Chinese)

[7] Li Xiaofei, Zhang Xiaochen, Liu Yihong, et al. Design and Verification of Power Distribution System for SAR Satellite. Spacecraft Engineering, 26(6), 2017.(in Chinese)