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Verification of Interface Compatibility Between Pcdu And High-power Hall Electric Propulsion

Jian Li, Wentao Yu, Lei Wang, Yaoxian Jiang
Institute of Telecommunication and Navigation Satellites, CAST, Beijing, China

Abstract: For the application of high power Hall electric propulsion system on satellites, a newly developed Power Control and Distribution Unit (PCDU) is applied which owns high voltage and high power. It is used to adjust the power of the solar array and battery to form a fully regulated 100V bus. Then the bus power is delivered to the Power Processing Unit (PPU). To verify the interface compatibility between the PCDU and the PPU load, as well as the rationality of the power supply architecture design, an integrated test of PCDU and PPU has been conducted. The test results shows that the compatibility meets the requirement.

Key words: PCDU; Hall Electric Propulsion; Load Compatibility

1 Introduction

Electric propulsion technology has become a research hotspot in the aerospace field due to its high specific impulse advantage, and has been successfully applied on multiple satellite platforms abroad. The next generation of satellite platforms is mainly based on full electric propulsion technology, which can be used for various tasks such as satellite orbit lifting, station keeping, in-orbit maneuvering, attitude control, etc. [1-4].

The PPU is commonly powered by the Power Control Unit (PCU) for satellites. As a key equipment of the electrical power system on the satellite, PCU achieves automatic regulation and smooth switching of electrical energy coming from the solar array and battery. A single power bus can be obtained and the bus voltage can be maintained stable [5-6].

Compared to the station keeping task, the implementation of orbit lifting based on electric propulsion usually requires multiple electric thrusters to work simultaneously, which has higher steady-state power requirements and more significant transient effects on the power bus. Therefore, the analysis and verification of the interface compatibility between PCU and PPU has become one of the key points for the development of fully electric propulsion satellites. Regarding the compatibility issue with electric propulsion loads, there are certain limitations to conducting the verification of PCDU or thruster solely based on load characteristics. For PCU, simulating loads is difficult to fully cover the entire characteristics of the whole process including thruster starting, ignition, and stopping, while for electric propulsion systems, ground power supply is commonly used, which differs from the PCU design that integrates multiple functions and has a more complex design on board, making it difficult to fully reflect the compatibility of system interfaces.

This article focuses on the Russian Hall thruster product SPT-140 and Hall PPU product from TAS-B. A newly developed high-voltage and high-power PCDU is used to supply 100V bus for the PPU. An integrated test scheme between PCDU and Hall electric propulsion system is proposed to verify the interface compatibility between them.

2. Design of PCDU

The PCDU integrates PCU and PDU functions, effectively reducing the volume and weight of the electrical power system and improving the power density. The PCU part adopts a two domain power regulation mode, as shown in Figure 1. During the sunlight period, the electrical energy generated by the solar array can be regulated by the sequential switch shunt regulation circuit (S3R) and transmitted to the bus. The battery charge and discharge regulation module (BCDR) stores some of the bus energy in the battery. When the eclipse period comes or the output power of the solar array is insufficient, the battery energy is released to the bus through BCDR. By adjusting the power of the solar arrays and batteries, a single fully regulated bus of 100V is formed, with a maximum output power of

14.4kW. The internal schematic diagram of the PCDU is shown in Figure 2, and the module components are listed as follows:

1) 2 telemetry and remote control interface modules (TM/TC)
2) 3 sunlight regulation modules (SUN)
3) 4 battery charge and discharge regulation modules (BCDR)
4) 2 capacitor modules (CAP)
5) 1 power distribution module (PD)
6) 2 thermal control modules (PT)
7) 2 pyrotechnic management modules (PM)
8) 1 backplane module

As shown in the Figure 2, the high-power interface for the electric propulsion is set at each SUN module port to reduce the power distribution path. The electrical connector used is DAM3W3. A maximum power of 12kW can be provided by three SUN module interfaces

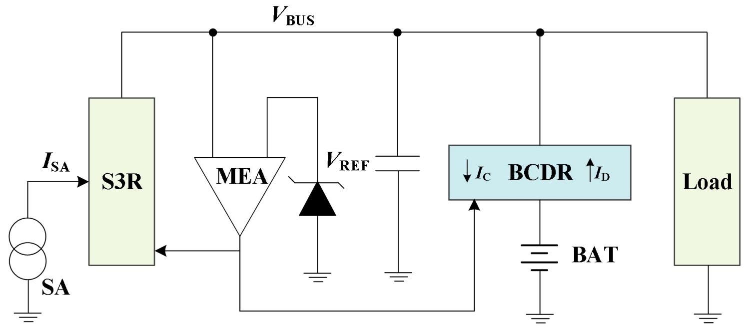

Figure 1. The Schematic Diagram of The Electrical Power System

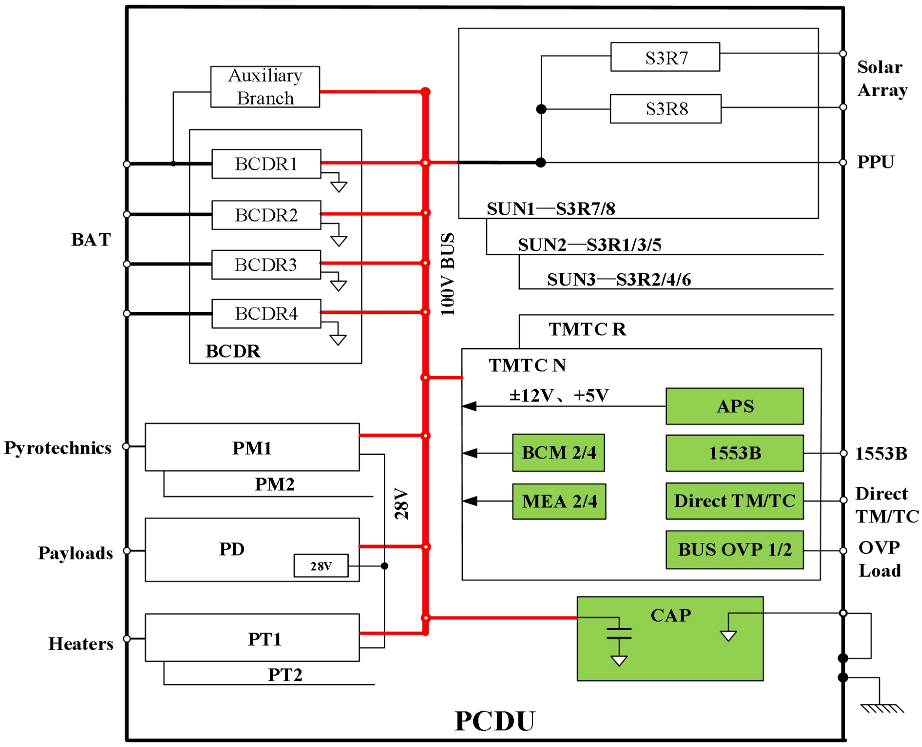

Figure 2. The Schematic Diagram of the PCDU

3 Integrated Test Scheme

3.1 Verification Purpose

The test is aimed to verify the interface compatibility between PCDU and Hall PPU, including whether PCDU can effectively respond to surge currents and the dynamic characteristics of PPU loads, and whether the ripple reflected by PPU to the PCDU bus can be effectively suppressed.

3.2 Test Equipment

The core equipment in the test includes:

1) 1 PCDU (EM)
2) 2 PPDU (EM)
3) 2 Hall PPU (FM)
4) 1 Hall thruster simulator, and 1 Hall thruster (EM).

Considering that the pin number of three SUN modules cannot meet the connection requirements for two Hall PPUs, two PPDU are used to achieve the expansion of the pin number of the electrical connector on 100V bus side. Its internal power transmission module can achieve 1 pin to 3 pins. The input and output of PPDU are short circuited inside the PPDU respectively. The number of power transmission modules can be configured according to the needs.

PCDU, PPDU and Hall PPU are placed on the desktop outside the vacuum tank, and the EM Hall thruster is placed inside the vacuum tank.

There are matched devices for the test, including solar array simulators and their power supply, industrial computer, instruction board, acquisition board, 1553B board, power analyzer, oscilloscope, etc. All devices are connected through power or signal cables.

The schematic diagram of the integrated test is shown in Figure 3.

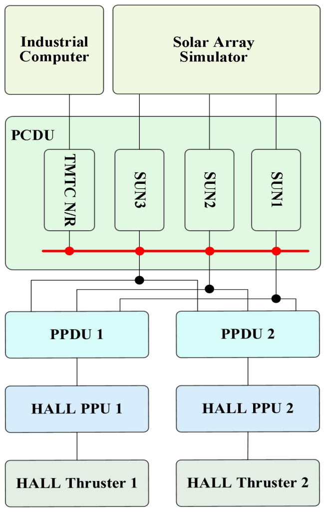

Figure 3. The Schematic Diagram of the Integrated Test

3.3 Test Projects

The integrated test projects are shown in the Table 1 below.

Table 1. Test Projects

No.	PPU and Thruster Configuration	Thruster Operating Mode
1.	PPU1+Thruster1(EM)	3kW/300V
2.		3kW/300V to 4kW/300V
3.		3kW/300V to 4.5kW/300V
4.		3kW/300V to 3kW/375V
5.	PPU1+Thruster1(EM)+PPU2+Thruster2(Simulator)	3kW/300V
6.		3kW/300V to 4kW/300V
7.		3kW/300V to 4.5kW/300V
8.		3kW/300V to 3kW/375V

4. Experimental Results

During the experimental process, the waveforms of PPU power on, thruster ignition, thruster operating condition transition, and thruster shutdown processes are observed and recorded by oscilloscopes for the test projects in Table 1. Main waveforms are shown in Figures 4-9. At the same time, an industrial computer is used to record real-time telemetry of PCDU. From the test waveform and test data, it can be seen that:

(1) When PPU is powered on, the surge current is small, while the power changes greatly during thruster ignition, operation switching, and shutdown processes. For the ignition process, the bus voltage drop is less than 0.3V, and for the transition and shutdown process, the bus voltage is not experience significant fluctuations and remains stable. The maximum ripple Vpp of the bus voltage is 1.58V, which is less than 3.7V and meets the technical requirements for the output characteristics of the PCDU bus.

(2) For the four processes of PPU power on, ignition, transition, and shutdown, the bus current changes significantly during the ignition and shutdown processes, with a current rise or fall slope of less than 1×10^3A/sec, which meets the specification requirements of less than 1×10^6A/sec.

5 Conclusion

Through the integrated test, the interface compatibility between PCDU and Hall electric propulsion PPU has been verified. PCDU can effectively respond to PPU surge current and PPU load dynamic characteristics under sole or dual thruster operation. The output characteristics of power bus under different PPU operating conditions meet the technical requirements. The system can be applied to the fully electric propulsion satellites.

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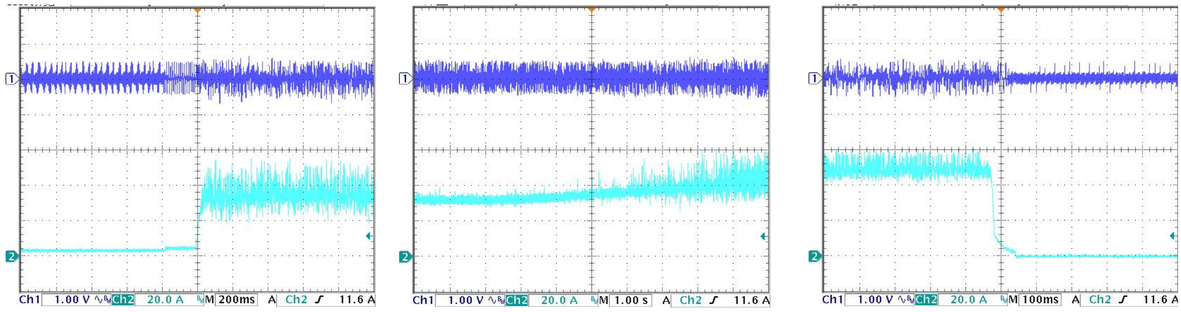
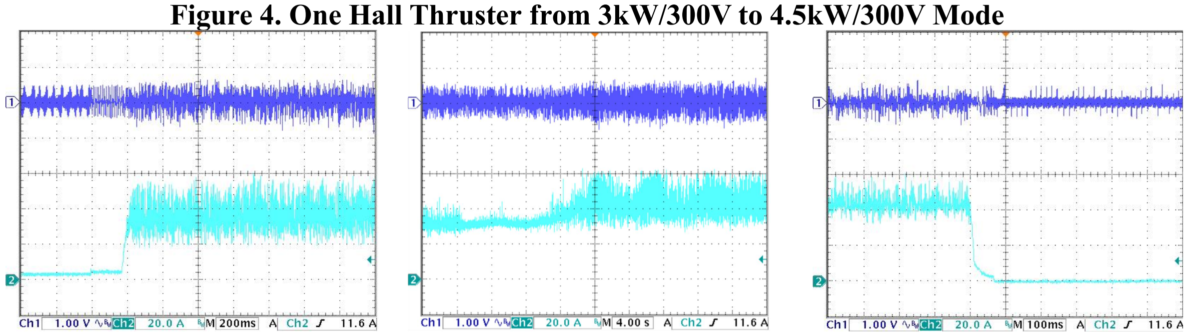


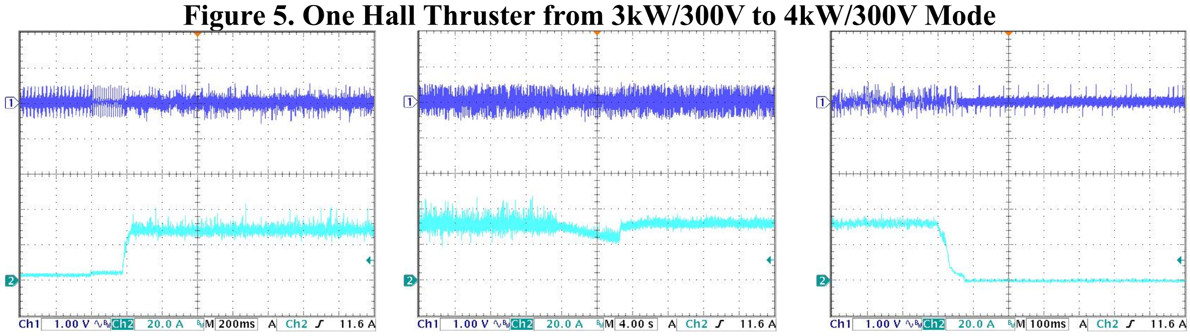
Ignite **Switching operating conditions** **Shut down**

Figure 4. One Hall Thruster from 3kW/300V to 4.5kW/300V Mode



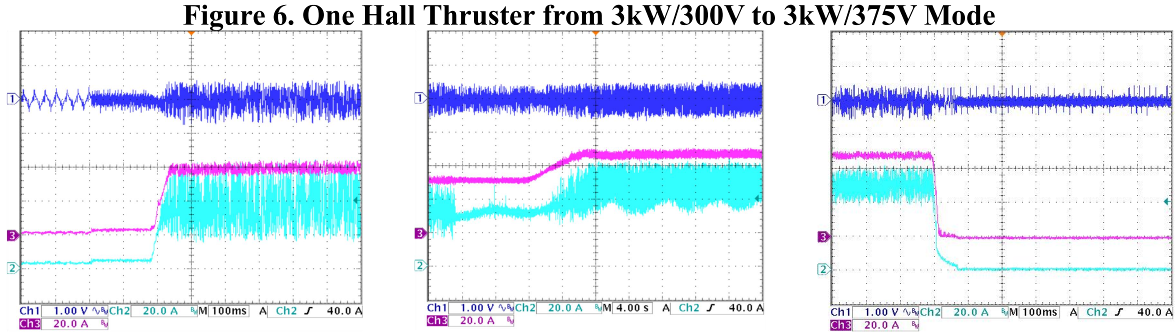
Ignite **Switching operating conditions** **Shut down**

Figure 5. One Hall Thruster from 3kW/300V to 4kW/300V Mode



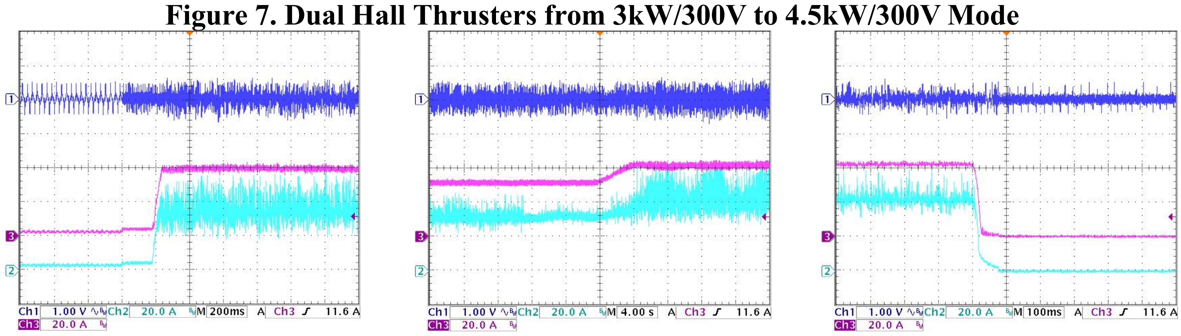
Ignite **Switching operating conditions** **Shut down**

Figure 6. One Hall Thruster from 3kW/300V to 3kW/375V Mode



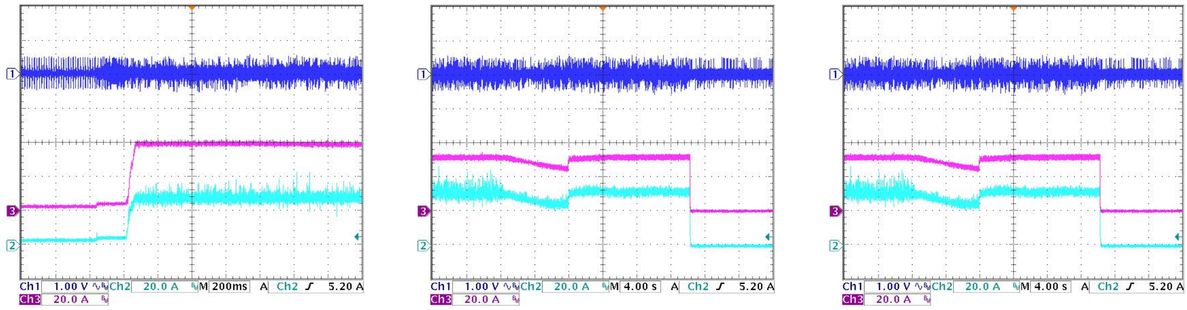
Ignite **Switching operating conditions** **Shut down**

Figure 7. Dual Hall Thrusters from 3kW/300V to 4.5kW/300V Mode



Ignite **Switching operating conditions** **Shut down**

Figure 8. Dual Hall Thrusters from 3kW/300V to 4kW/300V Mode



Ignite **Switching operating conditions** **Shut down**

Figure 9. Dual Hall Thrusters from 3kW/300V to 3kW/375V Mode

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