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Design of Satellite Power Test Simulation Teaching Experiment System

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***Abstract*—In view of the problems existing in the current aircraft power supply design course, such as students' difficulty in understanding basic principles, lack of space imagination, inability to put what they have learned into practice and the urgent need to improve their innovation ability, based on the composition of the satellite control system, a satellite power test simulation teaching experiment system combining software and hardware is built by using semi-physical simulation technology. The aim of this report is to discuss the software and hardware of the system and the related content of the experimental course. Through the combined commissioning of the system, it is shown that the overall system is functioning properly. It can be assumed that if the teaching experimental system is put into use, it will be able to meet the teaching and testing needs of relevant courses and achieve good teaching results.**

Keywords—teaching experiment system; semi-physical technology; test simulation; satellite power control system

I. INTRODUCTION

With the continuous expansion of social demand in the new era, the development of satellite-related technologies has entered a period of rapid growth. These technologies have not only created extremely substantial benefits in scientific research, economy, national defense, military and other fields, but also have considerable development prospects. In general, we define an unmanned spacecraft orbiting the earth as a satellite [1]. In the satellite system, the power system is an important part of generating, exchanging, storing, distributing and regulating the satellite voltage within the rated range, as well as protecting the internal components of the power system in case of emergency [2]. As a part of the satellite platform, the safety performance and technical level of the power system will affect the design of the whole satellite [3]. Satellite power system usually includes power control system, battery and solar array [4]. In the design of the satellite power system, the power control system needs to be simulated and tested to detect whether the power control system can work normally, whether all components can communicate normally, and whether the design requirements of the entire satellite power supply meet the requirements [5].

It is known that there are some problems in the actual teaching process of the satellite power control system. (1) It is not easy for students to learn this knowledge, because it involves too many abstract theoretical concepts and complicated mathematical derivation. (2) As is not possible to intuitively demonstrate the satellite's spatial motion and positioning results in class, most students will find it difficult to understand these concepts. (3) If students only rely on their spatial imagination without actual experiments, some students who lack this ability may be tired of learning. (4) Traditional teaching experiments are mostly demonstration and verification, which are isolated and lack of integrity. Therefore, it may lead to the failure of cultivating students' creativity in analyzing and solving problems [6].

In view of the above problems, the satellite power control system adopts semi-physical simulation technology to build a set of experimental teaching simulation test platform. The platform can simulate the real power supply system of spacecraft to verify the results on the ground, and greatly mobilize the learning enthusiasm of students through the software interface as well as achieve good teaching results.

II. DESIGN PROCEDURES

A. *Requirements Analysis*

- To output test variations by simulating solar panels in different spatial states (orbit, sun angle, temperature, input shadows, output shadows, etc.);
- To observe whether all parts of the power control system work normally by simulating various variations of the spacecraft load (average load, short time load, pulse load);
- To realize simulation test and teach tasks of the entire power control system through data collection and command functions.

B. *Environment Construction*

The whole system works as follows: STK software simulates the output of umbra/plenum shadow file, light angle, start/end simulation time and number of calculation cycle number; The solar cell simulator simulates the operating parameters of the solar cell by inputting test orbit information such as illumination angle and occlusion; The output data from the solar cell simulator is imported into the system for testing and then fed into a programmable electronic load. Thus, a cycle is formed. The electronic loads simulate various variations of spacecraft loads; Then the voltage, current, temperature and internal state of the system under test are input into the simulation test software through the data acquisition card. Through above steps, it is possible to judge whether the power control system can achieve the expected ideal function. The structure of the semi-physical simulation is shown in Fig. 1.

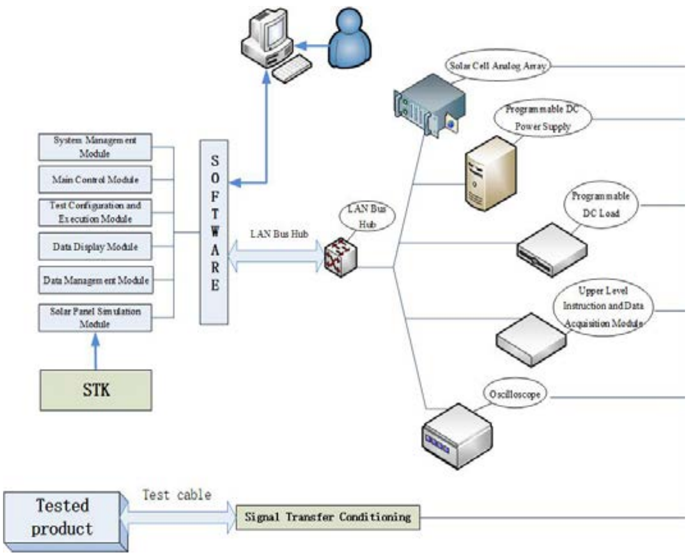

Fig. 1. Structure of the system

III. SOFTWARE AND HARDWARE

A. Hardware System

The whole system is divided into system control host, LAN bus hub, solar battery analog array, programmable DC power supply, programmable electronic load, command and data acquisition module, oscilloscope and signal transmission conditioning board and other hardware. Fig. 2 is a block diagram of the entire system.

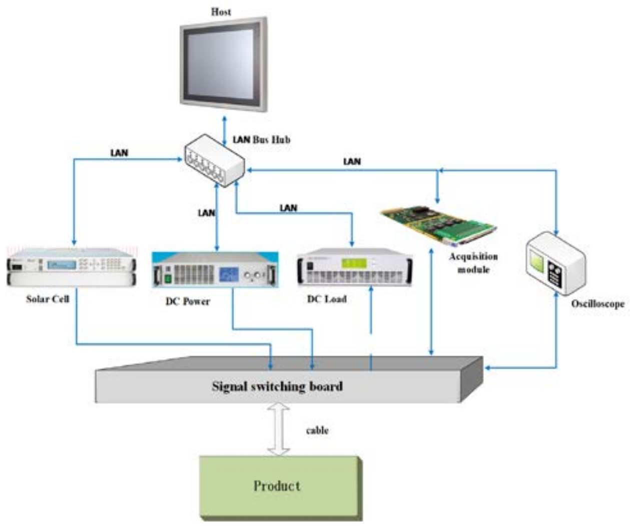

Fig. 2. System composition

- Control System Host: to complete the setting of the system instrument, to command application of the tested product, to control the simulation and data processing. The industrial tablet SHP-170TA is selected, and its appearance is shown in Fig. 3.

Fig. 3. Master computer appearance

- LAN Bus Hub: to integrate all the devices of the system through the LAN bus, so that each instrument can communicate with the host conveniently and flexibly.
- Solar Cell Analog Array: according to the simulation result of the simulation software, the solar cell simulation array outputs the IV curve of the solar cell on the simulated satellite. The double-channel photovoltaic simulator E4361A produced by Keysight was selected, and its appearance is shown in Fig. 4.

Fig. 4. E4361A appearance

- Programmable DC Power Supply: to simulate the output function of on-board battery system. The programmable DC power supply produced by the EA Company is selected, and its appearance is shown in Fig. 5.

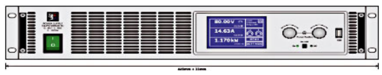

Fig. 5. EA-PSI 9080-60 appearance

- Programmable DC Load: to simulate the on-board load. The N6102 multi-channel programmable DC electronic load produced by NGI Company is selected, and its appearance is shown in Fig. 6.

Fig. 6. N6102S product appearance

- Upper Level Instruction and Data Acquisition Module: to complete the collection of the temperature, voltage and current output of the product under test.
- Oscilloscope: to collect bus voltage, solar array voltage, battery voltage, and other test points that need to be observed and collected.

B. Software Design

The software design of the simulation system is to realize the overall coordination and cooperation among the subsystems. The software functional block diagram is shown in Fig. 7.

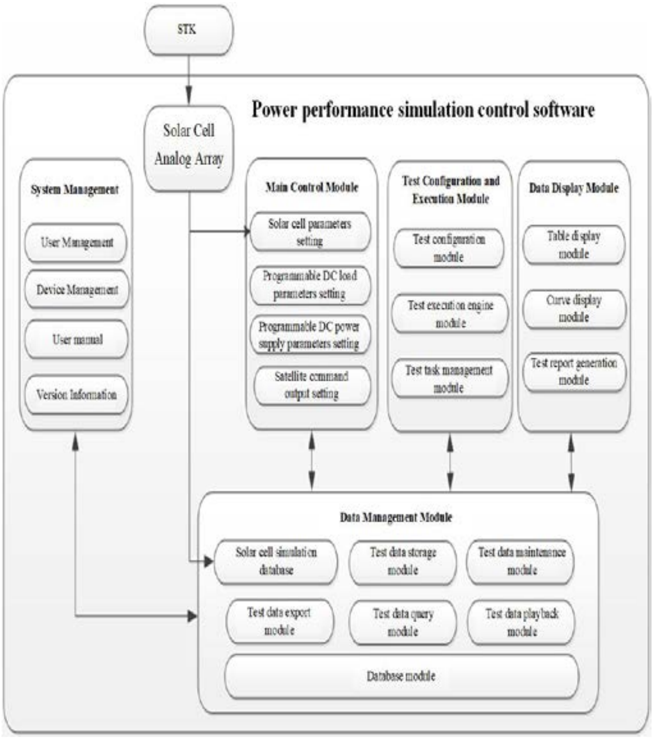

Fig. 7. System software block diagram

- System Management Module: to control registration and level authority for system users to ensure system operation security.
- Solar Panel Simulation Module: to simulate the operation state of the solar panel, to generate the I-V curve of the entire orbital period automatically according to the parameters of the solar cell's orbit information, windsurfing size, material, etc.
- Main Control Module: to configure the configuration resources of the system. Users can set the input and output of each submodule according to different needs and form a system test sequence based on this module.
- Test Configuration and Execution Module: provides a graphical interface that allows developers to enter test programs to complete the tasks of testing and developing test configurations. The test configuration and execution module flow are shown in Fig. 8.

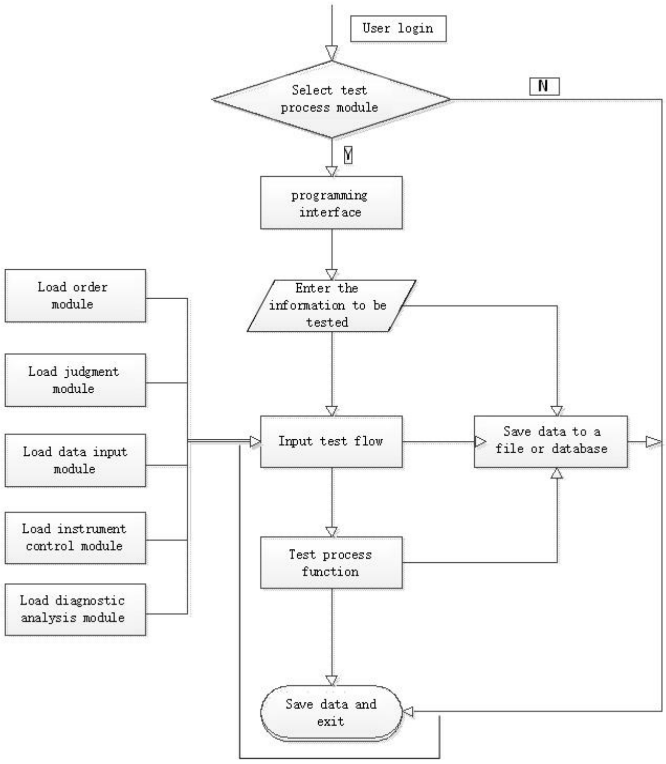

Fig. 8. Test configuration and execution module flow

- Data Display Module: in the process of data presentation, the system provides users with the application mode of “built on demand”. According to the requirements of online monitoring, the function of quickly creating monitoring pages is realized to show component management, data binding and other operations.
- Data Management Module: SQL database is used to centrally manage system hardware information, tester information, software configuration information, test data and solar cell data curve.

In this experiment system, STK calculates shadow files, ray angles, simulation start times and cycles. In this experiment system, information return method is adopted to collect output information from STK. The process is shown in Fig. 10, and the teaching simulation example is shown in Fig. 11.

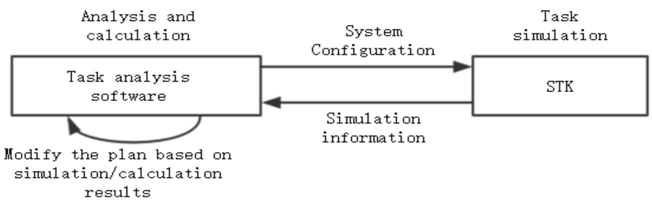

Fig. 9. process

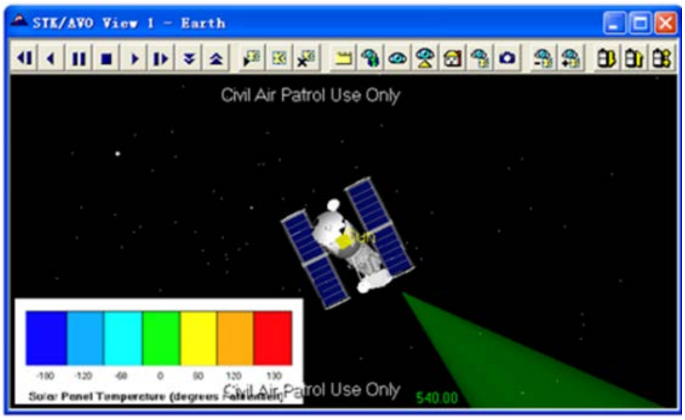

Fig. 10. 3D interface

IV. Teaching Experimental Arrangement

A. Basic experiment.

The purpose of the basic experiment is to make students familiar with the operation process of the experimental platform. To simulate the running track and operation of the power manager, use the platform to simulate the working process of the satellite power control system, test the responses that the power manager can make according to different conditions, and check the corresponding results which are dynamically displayed in real time on the designed software interface, students' understanding of the satellite power control system are deepened.

B. Comprehensive experiment

The purpose of the comprehensive experiment is to deepen students' understanding of the semi-physical test simulation and get familiar with the use of STK software. STK software combines satellite communication sensor or device simulation with satellite orbit modeling function. Through analysis of related objects, STK completes 2D and 3D modeling tasks. After the STK completes the simulation, the preset parameters are returned to the platform program, and then the solar array's illumination characteristics are simulated, and the results are analyzed and verified by combining with the parameter characteristics of the solar cell.

C. Extended experiment

Extended experiment, focus on cultivating students' creativity and innovation ability, aims to guide students to think independently, discover problems and solve problems on their own. This experimental platform has designed some open experiments, such as the exploration of the best working efficiency mode, the influence of different variables such as solar illumination area on the satellite power control system, exploration of the practicability and efficiency of its engineering practice, etc.

V. Conclusion

At present, in the field of aeronautics and astronautics, the speed of electronic equipment updating is getting faster and faster. Combined with the actual teaching needs, this paper analyzes the functional requirements of the test model and the working principle of the satellite power supply control system, and deeply studies the important technology of the system software and hardware.

The research results of this paper mainly include the following aspects:

1. Completed the overall design of the satellite power test simulation teaching experiment system, and built the platform of semi-physical simulation, which has the value of practical teaching application;
2. Complete the hardware selection and design integration of the teaching experiment system, reasonably select each hardware, ensure that the hardware not only meets the basic requirements, but also can effectively realize the simulation task;
3. Complete the development of the software platform of the teaching experiment system, and realize the user's independent configuration and secondary development;
4. STK software is used to simulate the running state of solar cells and realize the simulation detection function;
5. Realized the software and hardware integration of the simulation test system, which has the prospect of teaching application.

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