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Design of Onboard Emulational Power Supply Exciter based on Virtual Instrument

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Abstract

In the validation process of power supply subsystem of aviation electro-mechanical system, connecting the power supply equipment directly can lead to accidents caused by current overload or voltage overload. In order to prevent such accidents, this paper designed a kind of emulational power supply subsystem exciter based on virtual instrument technology. The design scheme uses AC and DC programmable power supplies and PXI series analog output devices which produced by National Instrument as power sources and analog signal sources representing lubricating oil temperature, oil surplus and so on. It uses PXI data acquisition devices as signal collectors. It accomplishes the data transmission between the hardware system and the principal computer software programmed by LabVIEW through PXI-8375 optical fiber communication interface devices. The software achieves functions of the real-time acquisition and the display of signals such as the power supply, the oil temperature, the oil surplus, the alarm and so on. The test shows that the system has good stability, high reliability in data transmission and strong versatility. This system has realized functions of data collection, storage and playback of the power supply, alarm signals and so on.

Keywords: *virtual instrument, emulational exciter, data acquisition, aviation power supply, PXI data acquisition devices, GPIB communication manner, LabVIEW*

1. Introduction

Aviation power supply subsystem plays an important role in the aerospace vehicles. It is of great significance to flight security in detecting whether the performance meets the design requirements. However, in the aircraft design and test process, when connecting the power supply equipment to mechanical and electrical management system directly, equipment damage may be caused due to a design flaw or misoperation. To avoid these risks, this paper designed a set of onboard emulational power supply exciter. It can validate the function of the power supply subsystem in a safe, reliable and cost-effective condition. Combining stable programmable power supply and powerful PXI series data acquisition devices, the onboard emulational power supply exciter can accurately simulate various performances of the power supply subsystem.

2. Hardware Design of Emulational Power Supply Exciter

In order to truly simulate the function of ac power subsystem, dc power supply subsystem, emergency dc power systems, the battery system, ac/dc power distribution system of the power supply system, in this design, we use programmable ac power supply to simulate alternator and ground power supply. We also use dc programmable power supply, Phoenix connector and relay to simulate dc power supply and battery, distribution equipment bus-bar and ac/dc power supply system topology. Then we can set up data acquisition and master control module by the related NI PXI board with PXI IPC. The MCC (main control computer) controls the whole simulation system through the optical

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fiber communication interface card. The overall structure of the hardware system is shown in Figure 1.

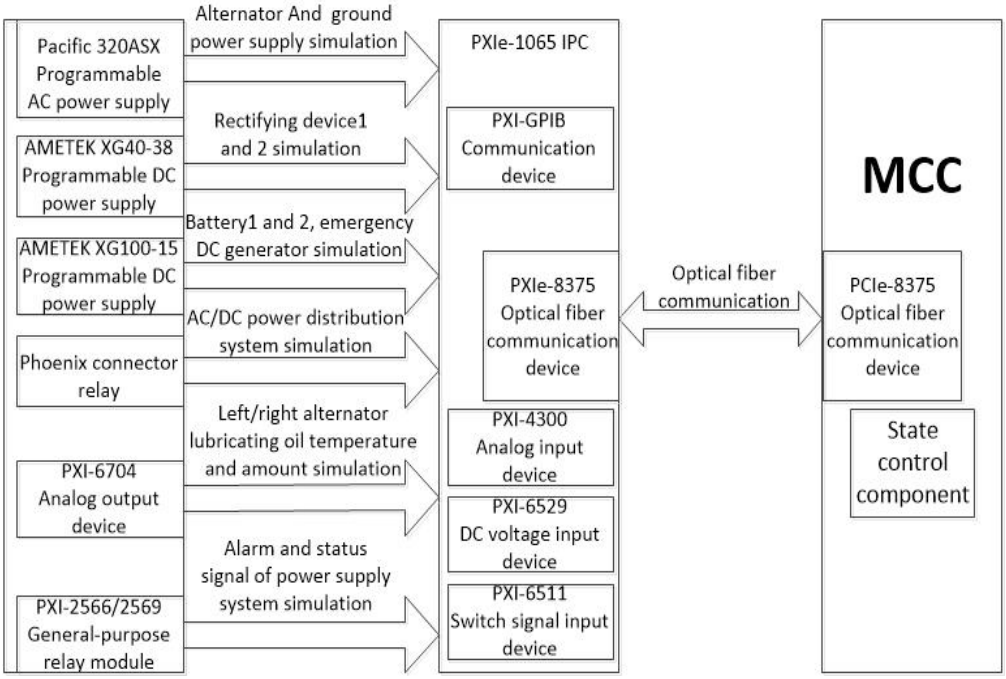

Figure 1. Hardware Structure Diagram

2.1. Programmable Power Supply

The reason why we chose programmable power to simulate the ac/dc power supply equipment is that the programmable power supply can provide stable voltage, constant current, phase shift, frequency conversion sine signal. Voltage, current, phase, frequency, power meter can be tested and verified in the same time. Coordinate with the standard power watt-hour meter, the basic error, shunt, starting of watt-hour meter can be checked and verified. Controlled by the internal computer, program-controlling realizes the software start and software stop, so as to avoid the impact and damage of instrumentation. When the misoperations such as short circuit, open connection or wiring error happen, it can automatically stop outputting and send alarm to prompt you to correct. The instrument is total key operations. All keys are set by program and interlocking software. Any operations will not damage the device. It uses pure digital waveform synthesis and pure digital amplitude modulation, phase shift and frequency modulation. It is working accurate, stable and reliable. Its power amplifier adopts imported high-power VMOS device, working absolutely reliable. Here are introductions of programmable ac and dc power supply.

2.1.1. Pacific 320ASX Programmable AC Power Supply

Type 320-ASX-2.0kVA device can operate in single phase, split-phase and three-phase condition. Single-phase and three-phase standard output voltage range is 0-150VAC_{1-n} while the output power is 2kVA. Split-phase standard output voltage range is 0-300VAC_{1-n} while the output power is 2kVA. The output frequency range is 15-1200Hz while typical distortion is less than 0.25%. In order to get a higher output voltage, special customized external output transformer can be selected. Equipment front panel is shown in the left side of Figure 2.

2.1.2. AMETEK Programmable DC Power Supply

Type AMETEK XG40-38 dc programmable power supply standard output voltage range is 0-40V. It standard output current range is 0-38A. It has a power output of 1520 kVA. The power regulation is 4mV/5.8mA. The load regulation is 4mV/12.6mA. The output voltage noise is 50mV. The power transfer efficiency is 87%.

Type AMETEK XG100-15 dc programmable power supply standard output voltage range is 0-100V. It standard output current range is 0-15A. It has a power output of 1500 kVA. The power regulation is 7mV/3.5mA. The load regulation is 7mV/8mA. The output voltage noise is 80mV. The power transfer efficiency is 87%. The response time of program from sending to read back is less than 300ms.

AMETEK power is shown in the right side of Figure 2.

Figure 2. Programmable POWER SUPPLY

2.2. NI-PXI Series Device

PXIe-1065 chassis, coordinate with various PXI/PXIe interface card, composes power supply subsystem simulation exciter control system. It has nine PXI slots, four mixed slots, three PXI Express slot and a PXI Express timing system slot. It is compatible with PXI, PXI Express, Compact PCI and Compact PCI Express module. Each slot has up to 1 GB/s dedicated bandwidth and more than 3 GB/s system bandwidth.

GPIB controller card PXI-GPIB is used to control the ac/dc programmable power supply. Its main technical indicators are as follows: (1) NI custom TNT ASIC can achieve the optimal performance of IEEE 488.2; (2) When using the IEEE 488.1 handshake protocol, maximum transmission rate can reach 1.5 MB/s. When using HS488, maximum transmission rate is up to 7.7 MB/s.

Master control computer remotely control and operate the PXI system by using PXIe-PCIe8375 remote control suite. PCIe8375 is installed in the main control computer. PXIe8375 is installed in PXIe chassis. They are combined by using optical fiber. In this way we can realize the remote control from master computer to PXIe system. It has a last data processing ability up to 838 MB/s. Lightweight and flexible fiber optic cable can be as long as 100 m and is equipped with electrical isolation. It supports PXI Express configuration of multiple types of chassis.

PXIe-4300 analog input device is used in acquire ac voltage, monitoring power supply system simulation network. It has 8 synchronous sampling analog input channels. It has a sampling rate of 250kS per second per channel. Each channel has analog to digital converter. The input range is 30, 60, 150 and 150V. Multiple equipment's trigger and synchronous can be achieved by PXI Express.

Discrete quantity acquisition card PXI-6529 is used for collecting dc voltage. 48 channels inside are light isolated drain/source input (plus or minus 60VDC). Its industrial function settings are change detection, programmable input filter and isolation. High voltage is inputted to PXI triggered bus.

Discrete quantity acquisition card PXI-6511 is used to acquire output switching value and status of various kinds of relay, contactor of power supply topology. 64 channels inside are light isolated drain/source input (plus or minus 30VDC). Its industrial function

settings are change detection, programmable input filter and isolation. High voltage is inputted to PXI triggered bus.

Analog output card PXI-6704 is used for simulating lubricating oil temperature and flow rate of left and right alternators. It has 16 static simulation output with user-defined power on status. Among which are 16-way output voltage and 16-way output current, outputting plus or minus 10V or 0.1-20mA.

Relay output card PXI-2566 with 16 independent single pole double throw relay can be fully software programming. It can switch 150VDC/125VAC. It can 2A switching current/5A current-carrying. Its scan rate can be up to 115 rounds per second.

Relay output card PXI-2569 with 100 independent single pole single throw relay and 50 independent double pole single throw relay can be fully software programming. It can switch 100VDC/100VAC. It can 1A switching current/1A current-carrying. Its scan rate can be up to 145 rounds per second.

All the PXI series devices are shown in Figure 3.

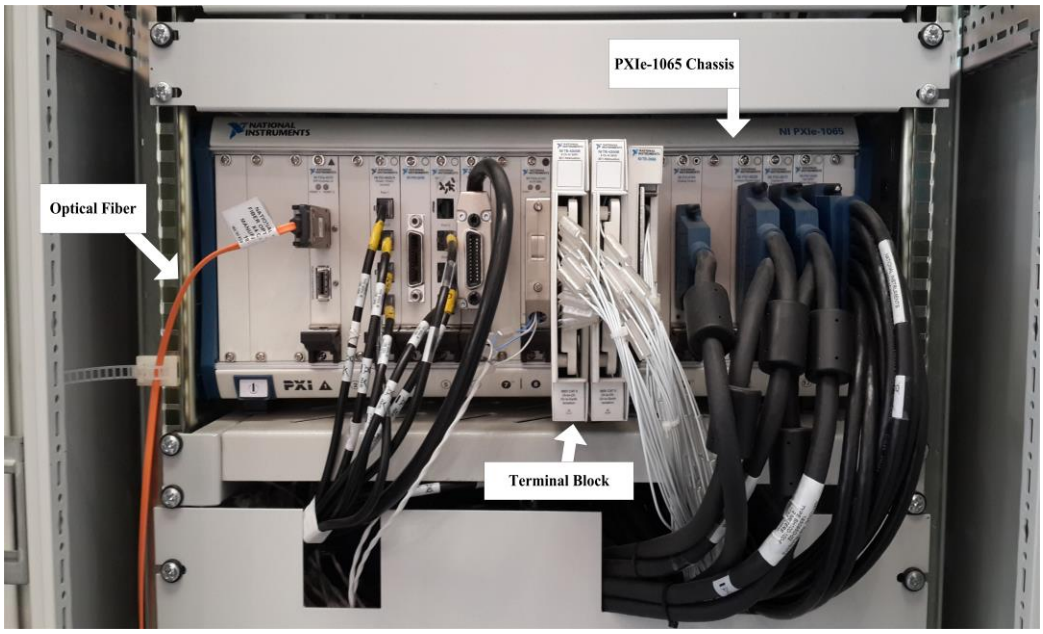

Figure 3. PXI Series Devices

2.3. Phoenix Connector and Relay

Power supply subsystem simulation exciter system topology and control rate are the same as the aircraft power supply system. It is requested for simulating various ac/dc bus-bar, contactor and circuit breaker such as EPC1, EPC2, MLC1, MLC2, ILC2, ILC3, and BTB3. This project uses Phoenix connectors to simulate all kinds of ac/dc bus-bar, contactor of aerospace relay and circuit breaker.

3. Software Design of Emulational Power Supply Exciter

The software running on the main control computer is in the form of state control component. Its main functions are the power supply system topology monitoring and display, power supply signal acquisition, signal sampling simulation, discrete quantity acquisition, report fault diagnosis and alarm, the system state storage and playback and provide help. The structure diagram is shown in Figure 4. Its function in detail and part of the LabVIEW program and the front panel display are introduced as follows.

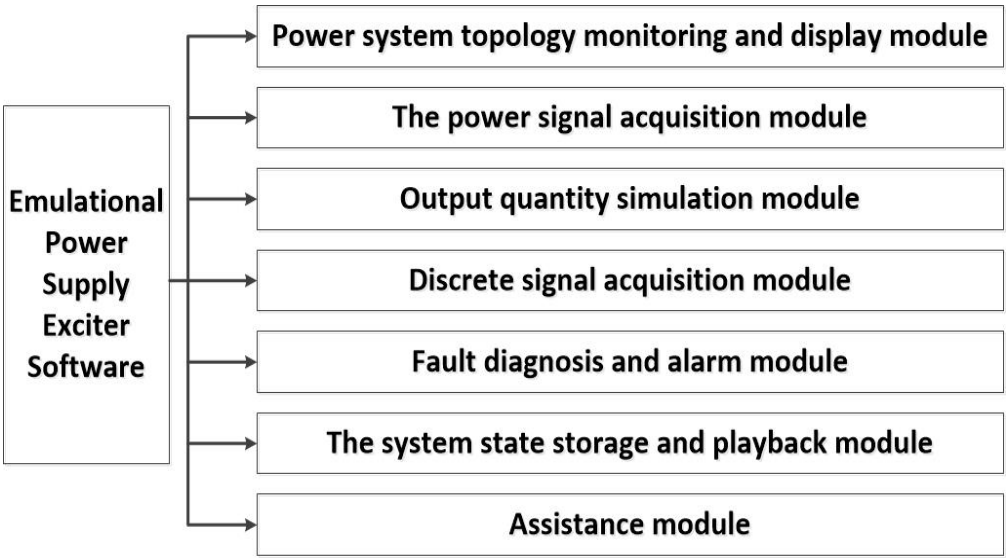

Figure 4. Software Structure Diagram

3.1. Power System Topology Monitoring and Display Module

This module is used for power supply system simulation network monitoring and topology network display, including display power system simulation topology network structure. It also monitors and displays the simulation network key points such as the status of programmable ac power supply output voltage, current, frequency, programmable dc power supply output voltage, current, ac main bus-bar voltage, dc main bus-bar, emergency bus-bar, uninterrupted bus-bar voltage, the each relay of topology structure. It determines whether the main, emergency bus-bar conversion control logic is correct. It is shown in Figure 5.

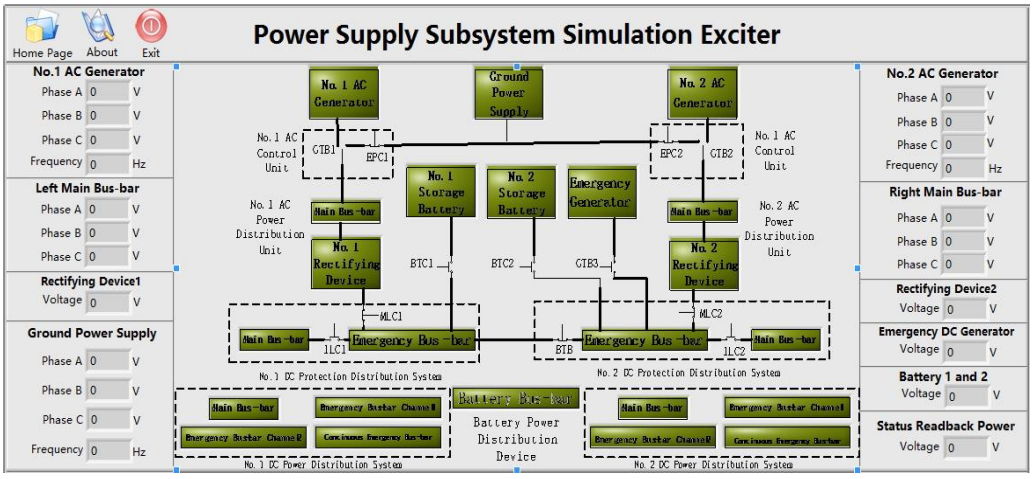

Figure 5. Power System Topology Monitoring and Display Panel

3.2. The Power Signal Acquisition Module

The module achieves the GPIB communication with two ac programmable power supplies and three dc programmable power supplies. Through software, control logic and strategy, it makes ac programmable power supply output voltage, current, frequency and dc programmable power supply output voltage as set before. And return program-controlled power measurements to display.

GPIB is short for the General Purpose Interface Bus. It is a kind of protocol in engineering control. First put forward by HP Company, it has now become an international standard. It complies with the agreement for IEEE488 which is generally used to any programming language to realize the computer control of the instrument. GPIB annotation includes two parts: interface and bus. Interface section is composed of all sorts of logic circuits, which install together with each instrument equipment. It is used to send, receive, encoding and decoding transmittal information. The bus part is a passive multi-core cable, used for transmitting messages.

3.2.1. AC Power Signal Acquisition Module

As the device we use is made by the NI Company, we use VIs in the DAQmx data acquisition palette to program to acquire ac voltage, current, frequency. Program diagram is shown in Figure 5.

3.2.2. DC Power Signal Acquisition Module

As the device we use is made by the NI Company, we use VIs in the DAQmx data acquisition palette to program to acquire dc voltage, current. Program diagram is shown in Figure 6.

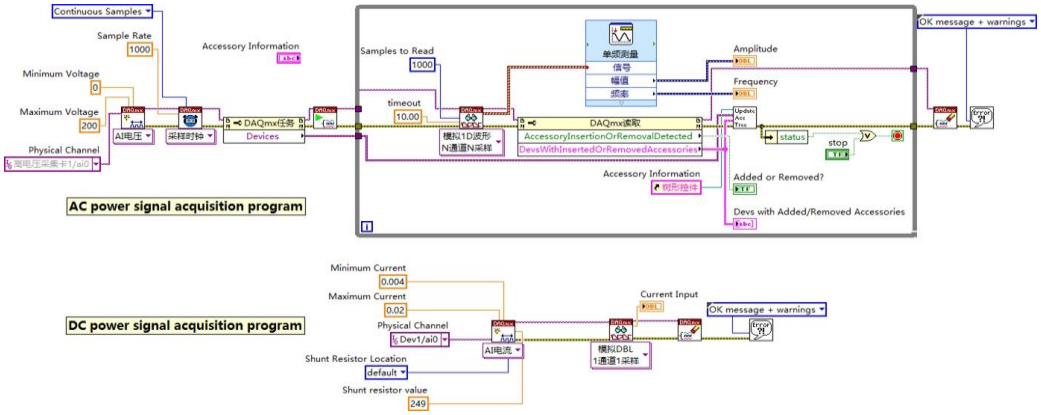

Figure 6. Power Signal Acquisition Program

3.3. Output Quantity Simulation Module

3.3.1. The Discrete Output Simulation Module

The module is to make the relay output card PXI-2566 simulate left/right generator switch, ground power switch, the battery power distribution device switch, battery 1 and battery 2 switch signal. It makes the relay output card PXI-2569 simulate left/right ac generator channel fault, battery 1 and battery 2 failure, emergency dc generator failure, No.1 and No.2 dc power distribution equipment main bus-bar fault, left/right generator control box fault protection, No.1 and No.2 rectifying device fault, No.1 and No.2 dc power distribution equipment emergency bus-bar fault, No.1 and No.2 dc power distribution device uninterrupted bus-bar fault. The specific acquisition program diagram is shown in Figure 6.

3.3.2. The Analog Output Simulation Module

The module makes analog output card PXI-6704 simulate left/right generator imported oil temperature, left/right generator lubricating oil flow and exported oil temperature. Due to the analog output card set output current range 4-20mA but we need left/right generator

import and export oil temperature range of 0-200℃, generator oil flow around 0-20L/min, so we do the proper conversion on output value, as is shown in Figure 7.

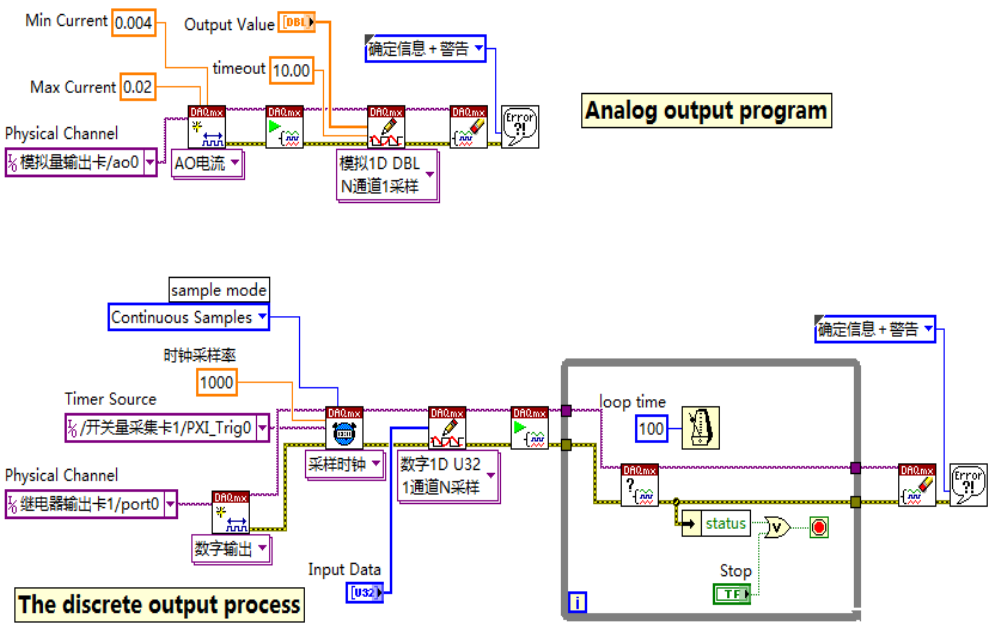

Figure 7. Output Quantity Simulation Program

3.4. Discrete Signal Acquisition Module

To monitor whether the corresponding dc voltage normally output, the module uses discrete quantity acquisition card PXI-6529 to monitor output status of No.1 and No.2 rectifying device output voltage, No.1 and No.2 battery voltage, emergency dc generator output voltage, No.1 and No.2 dc protection emergency bus-bar voltage distribution equipment, No.1 and No.2 emergency bus-bar voltage of No.1 and No.2 battery power distribution equipment, No.1 and No.2 dc power distribution unit continuous bus-bar voltage .Using discrete quantity acquisition card PXI-6511 to monitor emergency dc generator control box reset signal and engine starting signal. The specific acquisition program is shown in Figure 8.

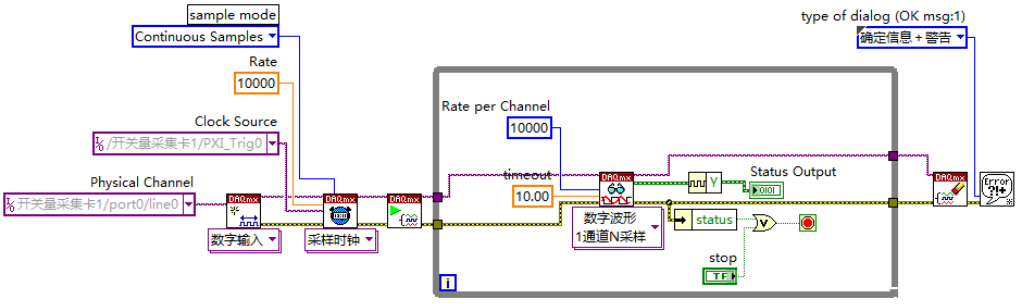

Figure 8. Discrete Signal Acquisition Program

3.5. Fault Diagnosis and Alarm Module

The module verifies the fault diagnosis, fault isolation and fault alarm of mechanical and electrical management system to power supply subsystem. By means of analyze fault which mechanical and electrical management system can diagnose, it establishes fault

diagnosis function. Set the embody output fault form through fault simulation interface and send fault alarm.

3.6. The System State Storage and Playback Module

The module mainly complete the data storage of working state of power supply system simulation exciter, including the particular moment status of power supply system simulation network, alarm information, a variety of analog and switch quantity. It is able to read the stored data later, replaying the working state of the specified period of time. It is convenient for later analysis. Binary TDM file storage and read back program block diagram is shown in Figure 9.

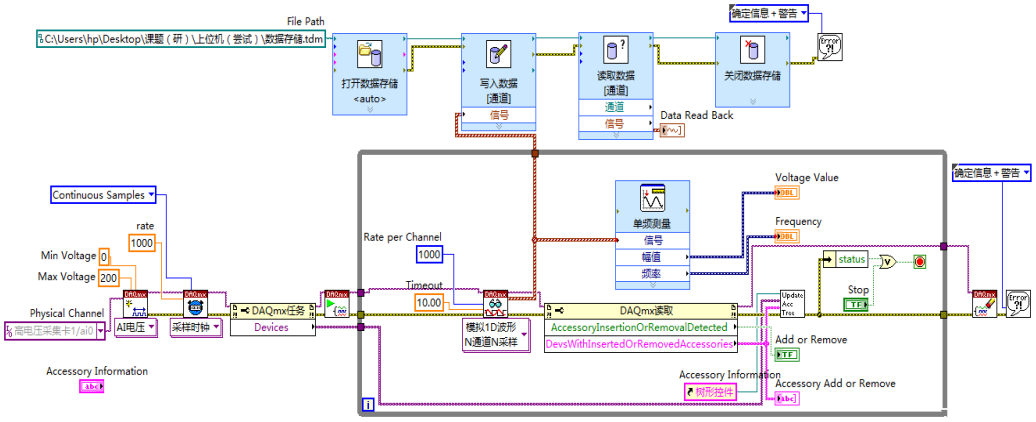

Figure 9. System States Storage and Playback Program

3.7. Assistance Module

This module provides users with convenient help information. It guides the user to correct operation of the software. Assistance module is designed according to the specific function and operating mode of each module. It provides specific operation tips and shortcuts help, making it easy to use.

4. Experimental Results

As Figure 10 shows that comparing to requested simulated ac power equipment ac voltage 115V the result ac voltage RMS error is less than 0.7826%.The frequency error is less than 0.0025% with the requested 400Hz. Each simulated dc power supply equipment dc voltage error is not more than 0.1328% compare to 28V dc voltage. All dc voltages are normally outputted. The reset signal and relay actions are in accordance with the default logic. Normal Simulated switch output normally. Import and export of oil temperature and oil mass are simulated reasonably.

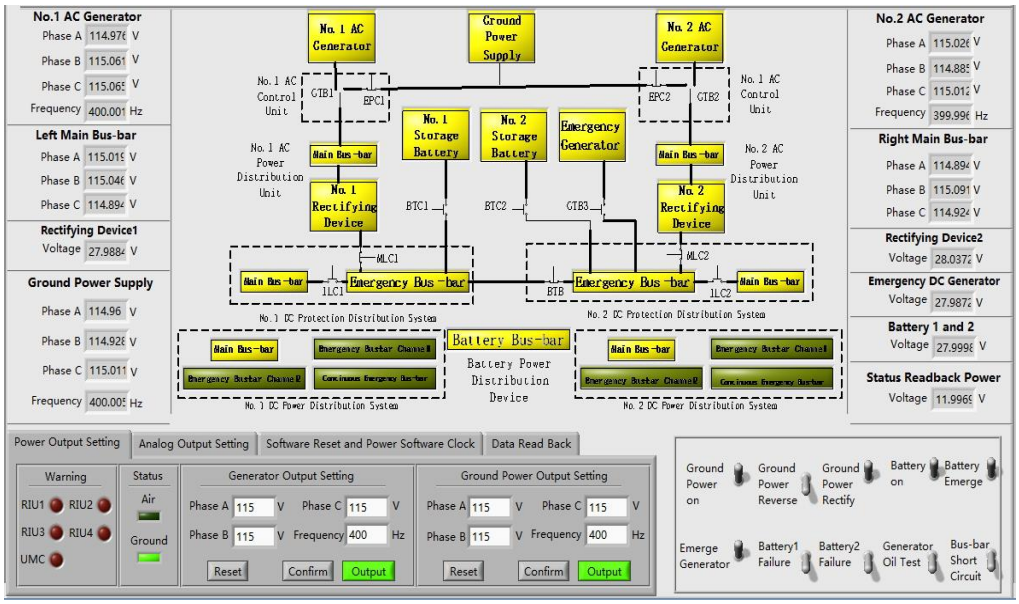

Figure 10. Experimental Results

5. Conclusions

Aiming at the particularity of the power supply subsystem validation test, this paper puts forward the way to measure programmable power supply, analog output interface card, relay signals of the power supply, reset and the alarm based on virtual instrument technology. Its innovation point，which is also the advantage compared with traditional instrument test system lies in with the demand of aviation electromechanical management system; we use LabVIEW software to design the simulation of the power supply subsystem. It conveniently and effectively realizes the various power supply parameters online real-time monitoring, data storage and fault alarm. The experiment shows that the system has high efficiency, complete functions, simple operation, good portability and scalability. In real application, this system provides data to verification of a kind of UAV designed by a research institute of China National Aviation Corp. In order to make the prototype production, this system ensures the design is correct to be produced. Because of this, the simulation of the exciter thinking not only can be used in power supply subsystem validation test, it also can be used to guide the design with no physical device test platform support or should not be directly connected to the physical equipment test model, such as fuel measurement conversion system and engine parameter conversion system authentication and so on.

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