An automatic control and measurement system of Compressor experimental operation platform

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Abstract. According to actual needs of measurement system, the virtual instrument with functions of automatic acquisition and automatic control was built by NI data acquisition card. Then, automatic control and measurement system with modular features was set up using LabVIEW software. The mode of autonomous configuration is flexible and convenient, which can greatly improve the adaptability of the device in the actual measurement. The experimental efficiency was enhanced, and the experimental data was reliable.

Introduction

In order to adapt to the diversity of market needs, more and more enterprises are increasingly demanding high-speed of product development and laboratory testing. Then, the requirements of the efficiency and compatibility for the automatic test system are also greatly improved. Traditional customized automatic testing system model has limited to speeding up the pace of product development and product testing [1]. The modular automatic testing control system program, which can achieve rapidly develop, has become the development trend of future automation systems.

The development of virtual instrument technology has laid a solid foundation for the realization of modular automated test system. Automated test platform based on design and implementation of virtual instrument technology mainly contains the following contents: the overall design of the platform, the hardware design of the test platform, the software architecture of the platform and the design of the test module [2].

Principles and design of the overall system

Automatic control and measurement system for the compressor is mainly used for testing the performance of the compressor and comparing the model design performance with the actual performance of the compressor. For compressor testing laboratory with multiple testing sets bit, the versatility and compatibility requirements of automatic control testing system are relatively high [3].

As a general automatic control testing system of compressor experimental operation platform, the hardware should meet the requirements of hardware interface and control testing rate. This automatic control test system has good scalability. The space was reserved for increasing the functionality of the compressor automatic control test system [4].

NI-PXI programmable board, NI- SCXI programmable board and CompCRI O real-time controller were chosen as the hardware of the automatic control testing system. The hardware system can achieve the acquisition of analog current, analog voltage, pulse signal and digital signal, and also can achieve the control of 4-20 mA equipments. The hardware system with scalable industrial fieldbus communication interface and Ethernet interface can meet the needs of most of the expansion equipments. And the card slots of PXI and SCXI programmable board were reserved for expansion of the hardware equipments.

LabVIEW development operator interface and universal control module were used as the software of the automatic control testing system, which can achieve the functions of system parameter settings, automatic control testing, data backtracking, data analysis and report generation. The software
modularity and parameterization were given full consideration in the design, which is easy to system expansion. At the same time, the user can achieve different purposes of testing experiments by parameter settings.

The design of hardware system

In order to achieve the laboratory bench-bit multiplexed and meet the requirements of high-precision, high-performance and high-reliability, National Instrument (NI) production PXI programmable board, SCXI programmable board and CompcRIO controller were chosen as the hardware devices. The hardware diagram of the entire system was shown in Fig.1.

(1) Hardware interface

In order to ensure the system reliability and easy maintenance, the hardware interface of the system is divided into analog interface and digital interface.

The existing collection devices are analog output, such as pressure transmitters, thermocouples, flow meters, tachometers, atmospheric sensors and so on. And the output format is not unified. The air plugs were used as acquisition interface terminal. And the different collection volume was connected to the different collection areas. In order to achieve the versatility of the test system, the different analog signals are respectively collected. This is not only to meet the versatility of test system in each station bit, but also ease to system expansion.

Figure.1 Hardware diagram of automatic control and measurement system

(2) The measure synchronization method

The data acquisition synchronization of automatic measuring system consists of NI data acquisition system synchronization and the synchronization between NI data acquisition system and data acquisition of electronic pressure scanning valve.

Multi-device synchronization of data measurements are the strengths of the NI test system. In this system, all the data acquisition cards were inserted in the PXI and SCXI mixed mainline backplane of main chassis. The synchronous operation of multiple devices was achieved by configuration these devices work under a unified backplane clock. The relevant configuration function was integrated in the device driver. In order to achieve the synchronous operation of DAQ equipment, all measurement acquisition channels were set to a unified soft trigger signal of data acquisition. Take advantage of the
above synchronization mechanism, controller module that could support real-time capability was chosen, which can achieve the simultaneous measurement and data acquisition of all thermocouples and pressure measuring devices connected to the NI data acquisition system.

Electronic pressure scanning valve can provide timestamp function of external trigger and transferring data. Analog output of NI devices emitted trigger signal to electronic pressure scanning valve. According to the timestamp of the scanning valve returns data, the synchronous correction was carried out. And the synchronization between NI data acquisition system and data acquisition of electronic pressure scanning valve was also achieved.

This design feature of automatic measuring system is using minimal hardware resources to achieve more test function and more the number of test channels, high integration, and reserve enough space for system expansion.

The design of software system

According to the application requirements of the model-level automatic measurement system, the entire application software is designed under LabVIEW. LabVIEW is a graphical programming environment, which contains functions such as signal gathering, data display, data analysis and data storage. Software system mainly consists of run-time monitoring module, operating point crawling module, basic parameters management module, data analysis and report generation module, and system configuration module. The software system can meet a variety of complex test and control needs.

The software design and development of automated measuring system based on model-level test bench, including the user application layer software design, data acquisition system software design and the underlying hardware device driver software design. The NI LabVIEW software was used for software design, including NI Developer Suite Core, NI Real-Time Testing, HIL Simulation Option and LabVIEW-based device driver. The software architecture of the entire system was shown in Fig.2.

![Figure 2 Software architecture of automatic control and measurement system](image)

(1) User layer

The user layer is mainly to achieve communication between the acquisition device and the top-level operator station computer, including receiving control information, sending data acquisition information and so on.
The top-level computer can achieve real-time communication with PXI data collection card and SCXI data collection card by industrial Ethernet switches. The test system can complete sampling rate settings, acquisition channel settings, storage channel settings, interface configuration settings and data storage settings.

Fig. 3 The user interface

The user interface was shown in Fig. 3. It contains real-time data acquisition interface, real-time data display interface, real-time data acquisition curve display interface and online real-time analysis of results interface.

(2) Functional layer

The functional layer is the main part of the software system design. Modular design was used in the design of software system, which is easy to debug system and expand performance. It contains data acquisition module, data analysis and processing module, data display module and data storage module [5].

Data acquisition module. For different sets of experiments, the number of data acquisition and control channels was different. At the same time, instrumentation was also different. All the same type of channels was numbered. For the same type of data input and output, the user can set the sampling rate and the channel number of the acquisition channels according to the actual needs of the experiment [6]. According to the acquisition channel configuration, display interface framework was established.

Data display module. According to the user configuration, the information needed to display was sent to the display module. The display module provided two data display modes, which are table display and curve display respectively. The table display shows the experimental real-time data. The curve display shows the continuous curve of the present experimental data.

Data storage module. According to the user configuration, the data was stored by the appropriate format in the database.

Data analysis and processing module. According to the user configuration, online or off-line data analysis and processing was carried out. Data information was classified. And the legends and reports were generated.

(3) Driver layer

PXI and SCXI device drivers were provided by NI. The hardware device driver was used to achieve mapping and calling of device configuration and hardware device on functional layer, and filtering process during data acquisition [7]. The device driver layer was mainly used to achieve synchronous acquisition of the compressor experimental operation platform.

Pressure scanning valve with LabVIEW driver and data interface was chosen, which was directly connected to the system by Ethernet. Pressure scanning valve was integrated in NI system, which can achieve the synchronization of data between pressure testing system and data acquisition system.
Conclusions

Automatic control test system has passed the acceptance tests, and it has been used 1 year in Shengu compressor laboratory. The automatic control test system has achieved the main functions such as multiple-bit shared, flexible custom settings, automatic test and data analysis. The test efficiency of the compressor laboratory is greatly improved. This automatic control test system has good scalability. The hardware and general test module of automatic control test system can be extended according to the actual situation, in order to adapt to future testing needs.

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