Development of remote hydraulic system based on BS framework

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Abstract. Based on the analysis of related research at home and abroad, combined with the experimental requirements of hydraulic teaching and scientific research, this paper designs a remote teaching experiment project and content for hydraulic pump performance test based on B/s network architecture. The field experiment subsystem is designed and developed, and the field experiment measurement and control software is developed based on LabVIEW. The step response tracking experiments in the field experiment and remote terminal experiment are compared and analyzed. The response speed and control accuracy of the remote terminal experimental system are slightly lower than that of the field experimental system, but both of the two systems can achieve good control of the controlled quantity, which can meet the needs of remote and field hydraulic experiments. Using construction has an important role in promoting.

1. Introduction

Colleges and universities have done some researches on the remote experimental system based on the Internet, and achieved good application results in the fields of electrical and electronic, computer network system, control system and other disciplines. Because the hydraulic system has the characteristics of high oil pressure and complex experimental conditions, there is little research on the remote system of hydraulic teaching experiment. Combined with the requirements of hydraulic teaching experiment in a university, the subject cross fusion is realized. The remote monitoring technology and hydraulic measurement and control technology are combined. The remote hydraulic experiment system based on B/S architecture is studied. The remote browser of the experimental system is analyzed and applied ASP-NET Web publishing technology, Measurement Studio and other web design technologies based on visual Studio platform for remote browser application development, based on B/s remote hydraulic teaching system operation analysis, through a series of experiments, verify the feasibility of the system, and comparative analysis of remote experimental mode and field experimental mode of the system control accuracy and response speed [1-2].

2. Design of test system

According to the analysis of the objective and functional requirements of the hydraulic teaching experimental system, the overall scheme of the experimental system based on B/S architecture is shown in Figure 1. The system consists of three parts: field experiment system layer, server layer and remote experiment system layer.
2.1 Overall scheme of remote hydraulic teaching experiment system
The system consists of a complete set of scene monitoring system. The hydraulic experimental system includes hydraulic system, electric control system and computer measurement and control system. The control structure is composed of upper computer and lower computer. PLC is used as the lower computer to collect and control the digital quantity. The industrial computer is used as the upper computer to collect and control the real-time analog signal through the data acquisition card. It has the functions of processing, displaying and saving experimental data and operating. In order to meet the needs of scientific research, the hydraulic products can be tested on the field experimental system without remote control environment. The on-site monitoring camera is responsible for collecting the field experiment images and transmitting them to the web server for remote users to observe the experimental site.

The server layer is the middle structure of remote hydraulic teaching experiment system, which is composed of web server and database server. Web server is mainly used to publish remote applications and process user requests; database server is mainly used to manage the whole system data. In this system, due to the small amount of data, the web server and database server are deployed on the industrial computer, which improves the communication efficiency between the web server and the database server, and improves the real-time data interaction between the remote client browser and the database server. Remote terminal users communicate with web server through campus Internet or wireless network.

Under the browser / S mode, the user can access the system without the installation of software. Users visit the web server through a specific IP address, and the web server will display the remote experiment interface in the form of dynamic web pages. Remote users can carry out relevant hydraulic experiments in this interface, and also carry out personnel information management, sensor parameter calibration, on-site monitoring screen view and other operations.

![Diagram of remote hydraulic teaching experiment system](image)

Figure 1 General scheme of remote hydraulic teaching experiment system

2.2 Principle design of hydraulic system
According to the determination of the experimental items, and considering the requirements of national and industrial standards for the performance test of hydraulic pump, the schematic diagram of
hydraulic pump performance experiment designed in this paper is shown in Figure 2, including main circuit, oil return circuit of oil collecting tank and circulating cooling circuit.

![Figure 2 Schematic diagram of hydraulic pump performance test](image)

1. Oil tank 2. Liquid level thermometer 3. Temperature sensor 4. Liquid level controller 5. Air filter 6. Ball valve 7. Motor 8. Torque tachometer 9. Hydraulic pump 10. Check valve 11. Pressure gauge 12. Pressure sensor 13. High pressure temperature sensor 14. Filter 15. Three way ball valve 16. Flowmeter 17. Proportional loading valve 18. Cooler

As can be seen from Figure 2, in the main circuit, the main motor 7.1 drives the tested pump 9.1 to rotate through the torque tachometer 8, sucks oil from the main oil tank 1.1, and then the booster pump comes out. The torque tachometer 8 collects the speed and torque value of the tested pump in real time, and sets the temperature sensor 13 and pressure sensor 12 at the outlet of the tested pump to collect the experimental oil temperature and the outlet pressure of the tested pump. After the oil at the outlet of the tested pump is filtered by filter 14.1, the output flow of the tested liquid pressure pump is detected by flowmeter 16, and the three-way ball valve 15 is used for overpressure protection of high-pressure flowmeter. The proportional relief valve 17 is used to adjust the system pressure tested by the tested liquid pressure pump. After overflow, the oil flows back to the main oil tank after being filtered by filters 14.2 and 14.3.

3. Design and development of measurement and control system

The measurement and control system of the field experiment system is composed of electrical control system, data acquisition system and computer control system. The hardware consists of industrial computer, S7-200 smart PLC, sensor, pci-1710u data acquisition card, proportional amplifier, digital display instrument, etc. The system takes industrial computer as upper computer and PLC as lower computer. The upper computer communicates with the lower computer through Ethernet. The data acquisition card collects the signal and transmits it to the industrial control computer through PCI bus.
According to the above analysis of the requirements of the field experiment system, the field experiment measurement and control software developed in this paper mainly includes login authentication module, data storage module, PLC communication module, data acquisition module, data display module, curve drawing module and automatic experiment module[3], as shown in Figure 3.

![Figure 3 Main test interface of field application program](image)

4. Application program design and development of remote terminal experiment system

4.1 Application development of remote terminal experiment system

System selection ASP.NET Technology for the development of remote monitoring website, Microsoft launched the visual Studio is the platform for the development of web applications. HTML and ActiveX technologies are applied in the front-end of the website to design and layout the website pages. The back-end of the website is programmed with C# and the corresponding logical operation is processed. The system database is managed by access software. The Measurement Studio tool and DSM manager of Ni company are used to realize the field experiment data in visual Real time data communication and management between studio and LabVIEW platform[4].
According to the requirement analysis of the system, the function module of remote terminal experiment system is divided into three parts: database management module, data communication module and experimental operation module. The database management module includes personnel information management, sensor parameter correction, experiment report management and other functions. The data communication module is mainly responsible for the real-time transmission and exchange of experimental data and the transmission of on-site monitoring screen. The experimental operation module includes experimental data display, curve drawing and experimental pressure control. The main functional module structure of the remote terminal experimental system is shown in Figure 4.

![Figure 4 main function module structure of remote terminal experiment system](image)

4.2 Development of experimental operation module
The experimental operation module includes experimental data display and curve drawing, as well as speed and pressure control. In the design of experimental data display function, this paper uses HTML technology and ActiveX control in visual studio to display real-time data. In the curve drawing function design, because visual studio does not provide the corresponding control, this paper uses the waveform graph control in the Measurement Studio toolbox to draw and display the curve. In the design of speed and pressure control function, this paper uses C# to program the control algorithm to realize the dynamic control of hydraulic hardware in the remote terminal experimental system.

Open windows 7 component iis6.0, function ASP.NET After the Internet information service project is enabled, register IIS server in vs2012 developer command prompt, generate solutions in Visual Studio 2012 platform, publish web applications, add and deploy the website through IIS.
manager, and configure application pool, IP address and port information. After the website is established, create a new inbound rule to open the network port [5-6].

In the field experiment system and remote terminal experiment system, the web application can be accessed by browser through the IP address of web server. The web server in this system is deployed in the industrial computer, and its IP address is 192.168.2.111. After inputting the IP address, enter the authentication interface of the remote terminal experiment system, and log in through the user name and password to enter the main interface for experiment.

5. Analysis of operation effect of remote hydraulic teaching experiment system

In order to test the feasibility and control accuracy of the remote hydraulic teaching experiment system, the remote experimental system is built for operation analysis. The controllability and stability of the remote terminal experimental system are analyzed by comparing the field experiment data with the remote terminal experimental data.

5.1 displacement verification and volumetric efficiency experiment

In the field experiment system, the motor speed is set at 1000r/min and 1500r/min for experiment. After the speed is stable, the no-load displacement is verified. After that, the system is pressurized at a constant speed and the system pressure is loaded to 250bar. The pressure flow curve drawn during the experiment is shown in Fig. 5. Repeat the experiment in the remote terminal experiment system, and the pressure flow curve is shown in Fig. 6.

![Figure 5 pressure flow curve of field experimental system](image1)

![Figure 6 pressure flow curve of remote terminal experimental system](image2)

In the field experimental system, the no-load displacement of the tested pump is 15.6 ml/R at 1000 R/min and 15.7 ml/R at 1500 R/min; in the remote terminal experimental system, the no-load displacement of the tested pump is 15.7 ml/R at 1000 R/min and 15.8 ml/R at 1500 R/min. The volumetric efficiency at each pressure is shown in Table 1.

| Experimental system | Motor speed (r/min) | 50bar (%) | 100bar (%) | 150bar (%) | 200bar (%) | 250bar (%) |
|---------------------|--------------------|-----------|------------|------------|------------|------------|
| Field system        | 1000               | 96.8      | 96.2       | 94.2       | 91.7       | 88.5       |
|                     | 1500               | 98.7      | 96.6       | 94.9       | 93.6       | 91.9       |
| Remote system       | 1000               | 96.8      | 94.9       | 94.3       | 92.4       | 89.8       |
|                     | 1500               | 98.3      | 97.5       | 96.2       | 94.5       | 92.4       |

The experimental results show that in the field experimental system and remote terminal experimental system, the verified no-load displacement conforms to the theoretical displacement of the tested pump, and the volumetric efficiency under various pressures can accurately reflect the pressure flow characteristics of the tested pump. The experimental average error of the two
5.2 Pressure step response experiment

In view of the danger caused by excessive pressure overshoot, the experiments were carried out with the overshoot controlled within 5% and without overshoot.

Adjust the motor speed to 1000r/min, set the theoretical value of pressure signal to 180bar, and then adjust the PID parameters of the field experimental system and remote terminal experimental system respectively to control the overshoot of the step response within 5%. The pressure response curve obtained is shown in Fig. 7 and Fig. 8. In the field experiment system, the overshoot is 2.8%, the rise time is 2220ms, the peak time is 3940ms, and the adjustment time is 4060ms. In the remote terminal experimental system, the overshoot is 3.9%, the rise time is 3520ms, the peak time is 5600ms, and the adjustment time is 6000ms.

![Figure 7 Speed step response curve of field experimental system (overshoot < 10)](image1.png)

![Figure 8 Speed step response curve of remote terminal experimental system (overshoot < 10)](image2.png)

Keep other parameters unchanged, then adjust PID parameters of field experiment system and remote terminal experiment system respectively to eliminate overshoot of step response. The pressure response curves obtained are shown in Fig. 9 and Fig. 10.

In the field experiment system, the rising time is 4950ms and the adjusting time is 7520ms. In the remote terminal experimental system, the rising time is 5020ms and the adjusting time is 7860ms.

![Figure 9 Pressure step response curve of field experimental system (without overshoot)](image3.png)

![Figure 10 Pressure step response curve of remote terminal experimental system (without overshoot)](image4.png)

The experimental results show that both the field experimental system and the remote terminal experimental system can effectively control the system pressure. In the control of system pressure, when the system pressure overshoot is controlled within 10%, the rise time of remote terminal experimental system is 58.6% slower than that of field experiment system, the peak time is 42.1% slower, and the adjustment time is 47.8% slower. When the overshoot is cancelled, the rise time and adjustment time of the remote terminal experimental system are 1.4% and 4.5% slower than those of...
the field experiment system. The pressure step response curve of the remote terminal experimental system fluctuates obviously.

6. Conclusion
A set of on-site hydraulic experimental system and remote hydraulic teaching experimental system are built. Taking the displacement verification, volumetric efficiency experiment and speed step response experiment of hydraulic pump as examples, a series of experiments are designed to verify the feasibility of the remote terminal experimental system and the field experimental system, and the differences in response speed and control accuracy between the two subsystems are analyzed. The experimental results show that the response speed and control accuracy of the remote terminal experimental system are slightly lower than those of the field experimental system, but the two systems can achieve good control of the controlled physical quantities, and meet the needs of teachers and students for hydraulic teaching experiment and hydraulic pump performance test.

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