Development and Application of Ship Process Measurement, Acquisition and Control System

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Abstract. Important operational parameters need to be measured, acquired, displayed in the process of ship operation, and to be controlled as the input of the control system. This article adopts NI software modules and LabVIEW (Laboratory Virtual Instrument Engineering Workbench) software, and develops the ship process measurement, acquisition and control system, it can complete the parameters’ process measurement, acquisition, display and control reliably and real-time. It verifies the system’s feasibility through the engineering’s application.

1. Introduction
We need to improve the degree of digitalization and automation in every loop system in order to reduce the crew’s labor intensity and disoperation in the ship process, and need to realize loop system’s process measurement, acquisition, display, alarm and auto control, and store significant parameters in order to process accident analysis. This paper supplies a kind of ship process measurement, acquisition and control system which can execute parameter measurement, display and control to loop systems and devices.

2. System general design
Ship process measurement, acquisition and control system can accomplish data’s acquisition, conversion, display, storage, and complete the manual and auto control of secondary circuit’s pumps and valves. This system is composed of power supply, industrial control computer, liquid crystal display, NI acquisition system (include one main chassis, three ethernet extended chassis, six kinds of acquisition modules, eight ports Ethernet switch, operation switches, button, indicator lights and buzzer). The acquisition modules have 16-Channel analog input module, platinum resistance input module, high speed digital input and output module and 32-Channel digital input module. The acquisition signals have temperature, pressure, pressure difference, vacuum, rotational speed, regulating valve and so on.

The industrial control computer and liquid crystal display complete the parameters’ display and storage. Console’s operation switches complete the manual control of the secondary circuit’s actuators. The indicator lights display state feedback of the actuators, the red lights stand for the full close of valve position, the green lights stand for the full open of valve position. The buzzer completes the parameters’ alarm function.

The schematic diagram of process measurement, acquisition and control system is shown in Figure 1.
Figure 1 Schematic diagram of process measurement, acquisition and control system

2.1. Measurement
The measurement parameters in the process measurement, acquisition and control system are the signals of temperature, pressure, pressure difference, vacuum, rotational speed, and regulating valve and so on.

a) Temperature signals’ measurement are completed by platinum resistance thermometers, and platinum resistance signals of three wire system are returned;

b) Pressure and vacuum signals’ measurement are completed by 3051 pressure transmitter, and (4-20)mA current signals are returned;

c) Pressure difference signals’ measurement are completed by 3051 pressure difference transmitter, and (4-20)mA current signals are returned too;

d) Rotational speeds signals’ measurement are completed by assembling unit or pumps with themselves through rotational speeds measurement equipment, and they send frequency signals and current signals.

2.2. Acquisition
The ship process measurement, acquisition and control system completes the all parameters’ acquisition by four kinds of acquisition modules.

a) Platinum resistance input module completes the acquisition of platinum resistance temperature signals;

b) Analog input module completes the acquisition of (4-20)mA standard current signals, it process the signals of pressure, pressure difference, vacuum, regulating valve opening,

c) Digital input and output module completes the acquisition of frequency signals, it processes the rotational speed signals;

d) Digital input module completes the acquisition of switching signals, alarm signals, status signals.

2.3. Display
Industrial control computer receives the bottom data by ethernet switch and displays the data on the
screen of liquid crystal display. Operators can know the real-time parameters information by parameter display interface, regulate and control the secondary circuit systems and devices by the regulating valve interface and pump interface.

2.4. Alarm
There are 143 parameters which are measured, acquired and displayed in this system. We set limit alarm to the significant parameters which is related to the control. The screen parameters are displayed in red if they exceed the upper limit or lower limit, and the buzzer alarm to remind the operator’s attention.

2.5. Control
The system is related to the regulating valves of secondary circuit condensation and feed-water system, exhaust steam pressure system, circulating water system, and the chain pump control of the regulating oil system. Then we introduce the control of the water level regulator of condenser as an example.

Water level regulator of condenser is needed to have the function of remote operation and auto control operation. We can choose the control mode by the regulator’s working condition selection switch.

a) Remote operation: we can process remote operation control by the regulator remote switch which is set on the console, if we set the switch on open, the water level regulating valve opening will bigger, if we set the switch on close, the water level regulating opening valve will smaller;

b) Auto control operation: the controller acquires water level, outputs (4-20) mA current signal to the input of the actuators of water level regulator of condenser, and regulates the water level regulating valve opening to maintain the water level to the normal value.

3. Hardware design
The hardware of the system are composed of direct-current power, industrial control computer, liquid crystal display, NI series products (CPU controller, main chassis, ethernet extended chassis, analog input modules, platinum resistance input modules, high speed digital input and output module, digital input modules, digital output modules, analog output modules), eight ports ethernet switch, operation switches, buttons, indicator lights and buzzer. The hardware composition of process measurement acquisition and control system is shown in table.1.

| Sequence | Equipment name                          | Quantity |
|----------|----------------------------------------|----------|
| 1        | direct-current power                    | 1        |
| 2        | CPU controller                          | 1        |
| 3        | main chassis                            | 1        |
| 4        | ethernet extended chassis               | 3        |
| 5        | 16-Channel analog input module          | 3        |
| 6        | 32-Channel digital input module         | 2        |
| 7        | platinum resistance input module        | 18       |
| 8        | high speed digital input and output module | 1       |
| 9        | 32-Channel digital output module        | 1        |
| 10       | analog output module                    | 3        |
| 11       | eight ports ethernet switch             | 1        |
| 12       | industrial control computer             | 1        |
| 13       | liquid crystal display                  | 1        |
| 14       | operation switch                        | 19       |
| 15       | indicator light(green)                  | 13       |
| 16       | indicator light(red)                    | 9        |
| 17       | buzzer                                  | 1        |
| 18       | button                                  | 1        |
The hardware diagram of process measurement acquisition and control system is shown in Figure 2.

![Hardware diagram of process measurement acquisition and control system](image)

**Figure 2** Hardware diagram of process measurement acquisition and control system

3.1. Direct-current power
We choose direct-current power which is 500W 24V 20A. It can change AC 220V input power to DC 24V power, and supply power to the every function module.

3.2. Industrial control computer and liquid crystal display
The system chooses industrial control computer which is made from Chinese Advantech Co.Ltd. and 17” liquid crystal display which is used to display and store data.

3.3. NI system
NI helps the engineers which are belonged to the field of test, control and design to deal with the challenge. Through ready-made software, such as LabVIEW, and cost-effective modular hardware, NI helps every field engineers to innovate constantly, shorten the time of product and reduce the development cost. The system mainly adopts products such as follows:
- NI cRIO-9023: Intelligent real-time embedded controller for Compact RIO;
- NI cRIO-9112: Eight-slot reconfigurable embedded chassis;
- NI 9148: Eight-slot ethernet expansion chassis for c series modules;
- NI 9208:16-Channel, ±20mA, 24-bit analog input module which is configured with 37-Pin DSUB to screw-terminal connector block NI 9923;
- NI 9217: 4-Channel, 24-bit, 100ΩRTD analog input module;
- NI 9401: 8-Channel, TTL digital input/output module which is configured with 25-Pin DSUB to screw-terminal connector block NI 9924;
- NI 9426: 32-Channel, 24V, sourcing digital input module which is configured with 37-Pin DSUB to screw-terminal connector block NI 9923;
- NI 9476: 32-Channel, 24V, sourcing digital output module which is configured with 37-Pin DSUB to screw-terminal connector block NI 9923;
- NI 9265, 4-Channel, 0-20mA, 16-bit analog current output module.
3.4. Eight ports ethernet switch
It is used to Ethernet communicate between the main chassis and ethernet extended chassises to exchange the bottom data. Industrial control computer receives the bottom data through eight ports ethernet switch, and displays and stores data.

3.5. Operation switches and indicator lights
The system includes 19 operation switches and 22 indicator lights. Operation switches are regulating valve switches mainly, they complete the manual control of secondary circuit actuators. The indicator lights display state feedback of the actuators, the red lights stand for the full close of valve position, the green lights stand for the full open of valve position.

4. Software design
We choose LabVIEW software to develop this system. LabVIEW is a developing environment [1] which has a graphical programming language, and a program compiling platform which is developed by NI, it is convenient to maintain software. Besides LabVIEW platform has many kinds of controls which can be modified by customer [2], it can prompt the design method of human-machine interface. The function of virtual instrument in LabVIEW is very strong, it is a data acquisition system which is organized by instrument, and it is used in the field of computer data acquisition and data signal process widely.

4.1. System’s function design
Software design is the center of the total system [3]. Its design is realized through hierarchical modular theory, the system is divided into several modules, modularized program architecture not only make the system clear, but also easy to be maintained. The system software architecture of data acquisition system based on LabVIEW is shown in Fig.3. The software part include system start up interface, system menu, display parameter 1, display parameter 2, display parameter 3, exhaust steam pressure regulating, gland sealing steam supply pressure regulating, water level regulating of left condenser, water level regulating of right condenser, valves and pump chain control and view history data.

Figure.3 System software architecture

4.2. System interface design
The system develops corresponding interface to eleven function modules.
a) system start up interface
System start up interface mainly refers to check every module’s power and network connection.
b) system menu and function interface
System menu interface is a flat structure, it has eight tabs which are corresponding to eight interfaces.
- display parameter 1
- display parameter 2
- display parameter 3
- exhaust steam pressure regulating
- gland sealing steam supply pressure regulating
- water level regulating of left condenser
- water level regulating of right condenser
- chain control of values and pumps
- view history data

It can display corresponding software interface when click each tab. The option of software interface is shown in Fig.4

![Figure 4](image)

**Figure 4** option of software interface

The measurement parameters are displayed in three software interfaces, the display parameter 1 interface mainly displays \((4 \sim 20)\ mA\) current signals, the display parameter 2 interface mainly displays platinum resistance signals, the display parameter 3 interface mainly displays digital signals.

The background of parameter will change to red blinking status when the parameter’s value exceed its pre-set upper and lower limit. We can change the parameter’s range, upper and lower limit through modifying the EXCEL file.

“exhaust steam pressure regulating”, “gland sealing steam supply pressure regulating”, “water level regulating of left condenser”, “water level regulating of right condenser” in the software interfaces are PID auto regulating of correspond process parameter. We can set the PID regulating parameters and display the process parameters regulating status.

c) view history data

There is a button which can open the data log file in the display parameter 3 interface. The path is “D:\Data\XXXXX”, XXXXX is the data’s date, such as “180425”, it is April 25,2018. We can open the data log file through choosing TDMS file, and also can open it by double clicking the TDMS file through the path. The view of the history data interface is shown in Figure.5

![Figure 5](image)

**Figure 5** View of the history data

Attention: we must close the EXCEL file after viewing the data log file.

5. Application
The ship process measurement, acquisition and control system is applied to accomplish the parameters measurement, acquisition, display, control of secondary circuit systems and devices. Now we give a example of exhaust steam pressure regulating to introduce the application of this system. The software interface of exhaust steam pressure regulating is shown in Figure.6.
Figure 6 software interface of exhaust steam adjustment

The top left area of interface displays the setting value and real-time value of exhaust steam pressure. We can input the setting value by keyboard. The circle status light is the alarm status display, the green light stand for normal status, if the pressure exceed the upper limit or lower limit, the light will change to red, and display “high pressure” or “low pressure” with characters.

The top center area of interface displays the status of exhaust steam regulator switch and the setting positive output valve of regulator. The status of exhaust steam regulator switch is auto when it display auto.

The top right area of interface displays the parameters setting of regulator, it need password to set the parameters.

The bottom area of interface displays the curve graph of the exhaust steam total pressure and the exhaust steam regulating valve position. We use different color to display setting value and real-time value of the exhaust steam total pressure.

6. Conclusion
The ship process measurement, acquisition and control system can accomplish the parameters measurement, acquisition, display and control of secondary circuit systems and devices, reduce the local measurement equipment and local parameter display, and provide methods for process status display and safety operation. The system also can be applied to other district of process measurement, acquisition and control.

7. References
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