

# PLC and Configuration Software Based Supervisory and Control System for Oil Tanks Area

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**Abstract** - A supervisory and control system for oil tanks area based on PLC S7-300 and configuration software ForceControl is introduced in this paper. The hardware structure of the system and the software design are both described in detail. In this system, Superior computers communicate with PLC through Industrial Ethernet. The superior computers system adopts duplex redundancy and the PLC adopts software redundancy. This monitoring system integrates the merit of PLC and computer and improves the reliability.

**Keywords** - PLC, configuration software, supervisory and control system, software redundancy

## I. INTRODUCTION

With the increasing competition of the oil market, oil depots are playing a more and more important role, and it has become a long-term important job to supervise and control the operation state of oil depots. This paper designs a supervisory and control system for a oil depot in Shandong Province. This oil depot collected tank information and controlled valves manually before. There were some shortcomings in it such as slow supervisory, great error and low reliability. So it is necessary to establish a better supervisory and control system that is timely, accurate and reliable.

Programmable logic controllers PLCs have been widely used in the industrial control fields because of its merits such as simple structure, flexible functions, high reliability and strong ability in communication. Computers have advantages in the data display and storage, as well as in human-computer communications.

This paper designs a supervisory and control system for oil tanks area based on PLC and computer. PLC is the control centre and it completes all the details of the control task. It connects with digital and analog signals of field devices through general I/O interfaces, collects and processes field data accurately and quickly, and completes the logic, timing, counting and mathematical operations easily. Computers provide human-machine interface, display the field working state dynamically, and makes the operation easy. The system combines the advantages of PLC and computer, provides a remote real-time monitoring for the tanks area, ensure safety and reliability and improves the work efficiency. Considering oil depot's high requirements on reliability and continuity, redundancy scheme is designed to improve the reliability further.

## II. HARDWARE OF THE SYSTEM

### A. the Overall structure and functions

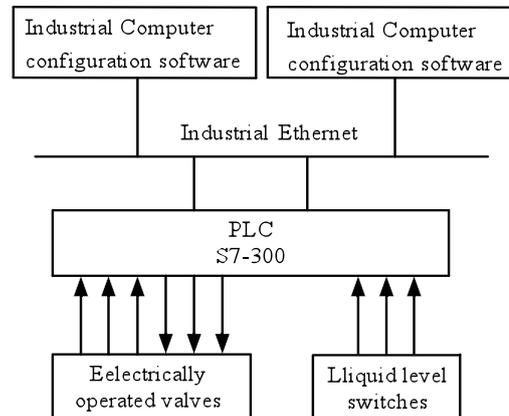


Fig. 1 Overall structure diagram of the system

The structure of the supervisory system is shown in Fig. 1. There are three levels in the system: the first level is superior computers. They consist of dual redundant Industrial Computers installed with configuration software ForceControl and placed in the monitoring center room, the second level is S7-300 PLC that adopts software redundancy and is placed in the local control rooms, and the field devices including electrically operated valves and liquid level switches form the third level. Industrial Computers are connected to the Industrial Ethernet through general network cards and PLC is connected to the same net by Ethernet communication module, so they could accomplish the communication by using TCP/IP protocol.

PLC collects feedback data of electrically operated valves, collects the status of liquid level switches and opens or closes valves according to the command from superior computers and the control program in the CPU module. In addition, PLC completes the interlock control of valve and liquid level switch. By exchanging data with PLC, superior computers installed with ForceControl, monitor electrically operated valves and liquid level switches in real time and give command to PLC to control the valves.

Redundancy structure is adopted in the system. ForceControl has taken the lead in providing complete support for redundancy among the China-made configuration software products, and it supports device redundancy, network redundancy and superior computer redundancy. There are two superior computers in the system, primary station and secondary station. In normal conditions, only the primary station communicates with PLC and the data in the secondary station synchronize with the primary station to make a backup. If the primary station fails, the secondary takes over the job. And the job

could come back to the primary station automatically or manually after the primary station returns normal. ForceControl supports PLC redundancy and normally communications with the master station of the PLC. If the master system of PLC is in the event of failure, the control job would be taken over by the reserve system, ForceControl would disconnect the communication according to the switch flag and turn to the reserve station to exchange dates.

*B. Hardware Design of PLC System*

Before selecting PLC modules, analyze the controlled object to count out I/O points. The current requirement and 20% -30% margin should be considered, allowing the system to expand. According to this principle, I/O points are as follows:125 digital inputs,21 analog inputs,84 digital outputs.

Based on the analysis of control task, the system choses Siemens S7-300 series of products. This series PLC could meet requirements of the medium-performance control system and adopt modular structure. Many different modules can be combined together and users should select appropriate modules according to the actual need. PLC modules selected are shown in Table 1.

**Table 1: Hardware of PLC**

Module	Type	Quantity
CPU	CPU315-2DP	2
Industrial Ethernet Processor	CP 343-1	2
Interace Module	IM153-2	4
Digital Input Module	SM321/32	4
Analog Input Module	SM331/8	3
Digital Output Module	SM322/32	3
Power Supply	PS307 5A	4

PLC in the system consists of two S7-300 stations each with a CPU 315-2DP and two ET200M slave stations. Its structure is shown in Figure 2. The Ethernet communication module CP343-1 provides a standard RJ45 interface, one of the functions is to connect the PLC to Industrial Ethernet to communicate with computers, and the other function is to provide redundant backup link for master CPU and reserve CPU to realize redundant communication between the two CPUs.

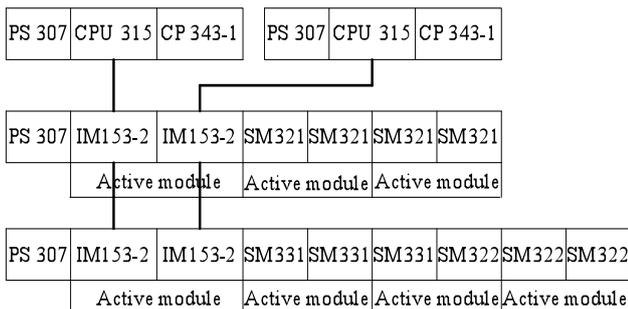


Fig. 2 Hardware structure of PLC

CPU315-2DP provides DP master interface and IM153-2 of ET200M provides two DP slave interfaces ,one is connected to the master station and the other to the reserve station through PROFIBUS-DP networks. PROFIBUS-DP could be Shielded Twisted Pair(RS485) network physically. Normal ET200M consists of a rail, a interface module and some general modules .The modules except power supply are connected through bus connectors. This structure does't support redundancy functions. There is another configuration that is suitable for redundancy. It uses a special rail that can take active bus modules and two interface modules. The modules except power supply are mounted on the active bus modules and it is possible to change modules during running.

*C. Connections of the Electrically Operated Valve*

Hengchun CKD series electric operators are used and Fig. 3 shows its connection method. The feedback of electrically operated valve includes four digital signals and one analog signal. Digital signals are remote mode indicating contact, full open indicating contact, full off indicating contact and common alarm contact. The analog feedback, a 4-20mA current, shows the valve's opening value .When the valve is in the remote control mode, digital outputs of PLC drive the relays and then control the valves. Four output control signals include open-valve signal, close-valve signal, stop signal and emergency protection signal esd.

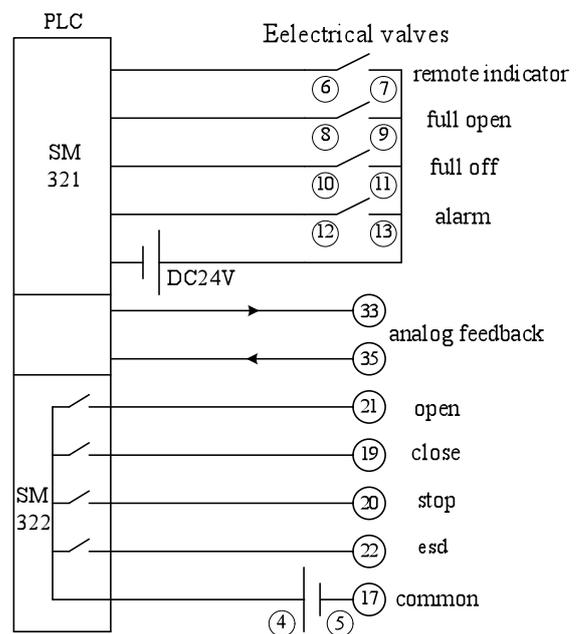


Fig. 3 Valve connection diagram

III. SOFTWARE OS THE SYSTEM

Software in the system includes two major parts, PLC programming software STEP7 V5.4 and superior computer configuration software ForceControl V6.0.

*A. Communication between Superior Computer and PLC*

ForceControl develops a special driver for the S7-300 PLC,

therefore it is not necessary for the users to be familiar with the communication protocol between them, and neither necessary to program or configure network in the PLC, the communication between PC and PLC can be achieved easily. The main problem in this system is that due to PLC's soft redundant structure, when the control task switches to reserve CPU from the master one, ForceControl should switch to the correct communication object to exchange datas. For this purpose, when device PLC is created in ForceControl ,it should be configured properly and a data point should be defined in the real-time database as a redundancy switching flag.

Fisrt configure I /O device for ForceControl, create PLC whose equipment address is set to 2, if set to 1, ForceControl will not be able to connect to the PLC. The standby channel is enabled and the device IP address and standby IP address should correspond with PLC's two Ethernet communication modules CP343-1.

After I/O device PLC is created , define a a data point in real-time database whose data type is selected as " redundancy switching flag ". The flag's value is 0 in normal state, when its value is 1, ForceControl will switch to PLC's another IP address, then the value 1 will be cleared automatically. Here the data point is linked with MW16 of PLC. Corresponding program is loaded into PLC ,when the CPU is working as master station, MW16 is set to 0, when the CPU is working as reserve station, MW16 is set to 1, program in PLC is as follows:

```
L   DB5.DBB9
L   W#16#2
AW
SRW 1
T   MW16
```

*B. Software of Superior Computer*

ForceControl configuration software solves problems:

- (1) Creating a I/O device PLC;
- (2) Creating a real-time database and linking the data points with datas in PLC;
- (3) Drawing graphical interfaces to display the work state of tank area and the state of alarm signals and to display the operation buttons;
- (4) Interconnecting the graphics with the variables so that graphics will change with the datas to make sound and light alarms;
- (5) Programming action script to control valves. When the button is pressed ,a mouse event will be triggered and then the corresponding script program will be executed to set open-valve flag, close-valve flag or stop flag to 1 or 0.

*C. Software of PLC*

Functions that STEP7 completes in the system are :

(1)Hardware configuration.

Create a project with two stations(e.g. station A and station B) and then open station A . Select a module rack for station A ,insert the power supply unit, the CPU 315-2DP

and CP343-1, establish a PROFIBUS DP network and an Ethernet network, insert and configure ET200M. Open station B,create a new PROFIBUS DP network, connect CP343-1 to the same Ethernet network with A, copy ET200M of station A because the configuration of ET200M must be identical on both stations.

(2)Network configuration.

Open the network configuration window Netpro, create a connection between station A and station B, select connection type ISO.

(3)Writing software redundancy program.

Software Redundany Package provides the library SWR\_LIB that contains special FB and FC. Invoke these FB and FC in corresponding OB according to the requirements of the Siemens software redundancy manual;

(4) Writing the program for valve control

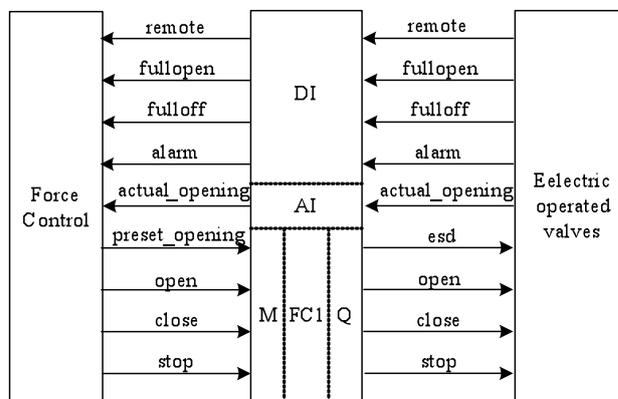


Fig. 4 Variable relation

Fig. 4 shows the relationship among variables in ForceControl, in PLC and in electric valves. Because there are a large number of valves to control in the system and the control methods are the same, a special function FC1 for valve controll is written in order to simplify the structure of the program. Fig.5 is the flowchart of FC1.

The valve has two control modes, local control mode and remote control mode.It is necessary to judge whether the valve is in the remote mode because only in this mode can the valve be controlled by the PLC. Valve opening process is as follows: click the mouse on open-valve button in ForceControl's graphical interface, the open-valve flag in PLC is set to 1 if mouse is down,then return to 0 if mouse returns up, PLC energizes the open-valve relay for 1 second according to the rising edge of open-valve flag, compares the actual valve opening with the preset value, once the former is equal to or greater than the latter, energizes the stop relay for 1 second immediately. Valve off process is similar with the above process. When the high-level switch alarms, PLC drives the esd relay, then valve will open.

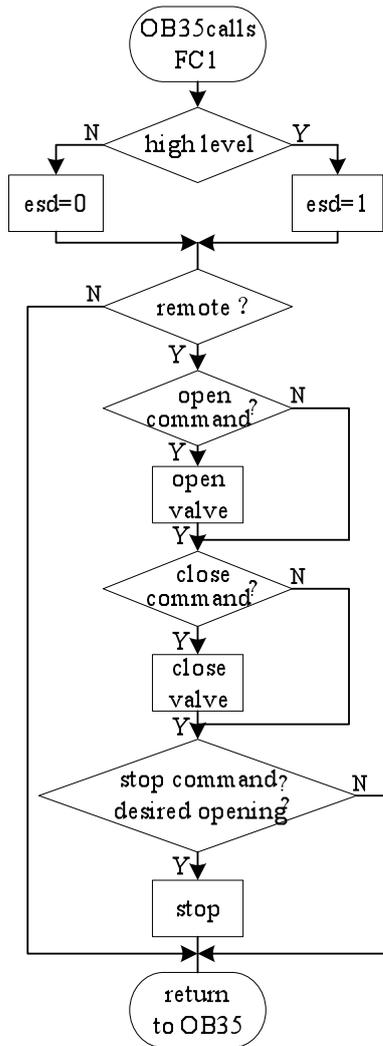


Fig. 5 Valve control flowchart

#### IV. CONCLUSION

Superior computers in which ForceControl configuration software are installed provide good human-machine interface, communicate with PLC through Industrial Ethernet, then supervise and control the system. PLC perform reliable and effective control. Dual redundancy and software redundancy is adopted, improving the reliability of the system greatly. This system combines the advantages of computer and PLC, provides simple interface and high reliability, makes operation easy, and improves the automatic level of the oil depot.

#### REFERENCES

- [1] Liu Meijun. Siemens S7-PLC Application and Maintenance, China Machine Press, 2008
- [2] Beijing Sunway ForceControl Technology Co.Ltd..Graphical interface and development system, Beijing,2007
- [3] Siemens Ltd., China.Software Redundancy for SIMATIC S7-300 and S7-400,Siemens Ltd., China, Industry Sector, Industry Automation & Drive Technologies, 2008
- [4] Siemens Ltd., China. ET 200M Distributed I/O operation manual,Siemens Ltd., China, Industry Sector, Industry Automation & Drive Technologies, 2004