The Automatic Control of the Heating System in Shangdi Zone

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I. Overview of the Heating System in Shangdi Information Industry Zone

In October 1991, the first hi-tech zone, The Shangdi Information Industry Zone, was established in Beijing China upon the approval from the State Science and Technology Commission and Beijing Municipal Government. With information industry as the core business, it features R&D, manufacturing, trade, training and service etc. The centralized heating system in Shangdi Information Industry Zone is operated and administrated by Shichuang Heat and Power Company, which provides energy service for the local residents and enterprises in this zone. When the system runs in full capacity, it can meet the requirements for manufacturing, life, and heating, cooling within the 1.8Km square meters of the zone with a total of 2,000,000 square meters of building areas. 0.6MPa saturated steam as the primary heating media: acts as the heat source the heating system for the residents in winter time, which is raised to the designed temperature via heat exchanger (mostly panel heat exchanger); during summer time, the saturated steam of 0.6MPa is cycled via lithium bromide cooler(mostly steaming dual mode) to meet the air conditioner requirements of comfortability and production process.

1. Heat Source

There are four 35 tons/hour, 1.57Mpa saturated steam boiler and three 10 tons/hour, 1.25MPa saturated steam single layer assembled boiler in the Shangdi Information Industry Zone Heating Plant boiler workshop, with a total capacity of 170 tons/hour. The primary and secondary boiler workshop are equipped with blowing and conducting machine, water bump, dust catcher and water processing equipment.

2. Regional Heating Pipe Network

A set of regional heating pipe network is built up along the inner ring of Shangdi Zone, with a total length of 5.2Km. With two steam pipes, it's both beneficial to the adaptability of the heating (cooling) load change and the improvement of the reliability of heating steam, we use the double primary pipes system. In order to save energy and recycle the condensed steam water, we installed a condensed water pipe within the heating pipe network. It's required that the users of the steam to use close back water system to pump back the condensed water using the condensed water pump and ensure the rate of the back-pumped condensed water is more than 80%.

3. Heat-to-Cool Station

When the steam arrives at the heat-to-cool station, it will be pumped into heat exchange system via the decompression valve. In summer cool water of 7～12℃ will be generated by the lithium bromide heating machines, and then fed to the air conditioning machines or blowing machines and new blowing machine terminal devices. Condensed water pump, water supply pump, condensed water tank, water supply tank and water softening devices are equipped in the station. Cooling tower is also installed in the top of the building. In winter, the warm water of 55～70℃ will be generated by panel heat exchanger, and then fed to the blowing machine and new blowing machine sets (some of which use heat radiator in the terminal) via the heating water cycling bump. Water softening devices are equipped to make softened water to be used as heating cycling water. Inflating tank is installed at the top. Activating the water supply tank will compensate the insufficiency of the water pressure. When the level of the water in the tank reaches certain position, the condensed water pump will feed water into the heating network.

Therefore, with the secondary system in the heat exchange station, only a single heat media transmission and production system is needed for the whole zone to meet the various requirements of the enterprises and residents in this area. Depending on the workload of heating and cooling in winter and summer, one type of boiler can be put into operation, while another is kept as an alternate to ensure the safe operation of the system. The difference of equipment models and work flow in the heat exchange stations may affect the operation and administration, as a result the life time and safety of the system will be affected. To be aware of the defects in the stations and resolve them timely will be important for the long term safe operation and energy savings of the system. In fact, the old administration mode depends heavily on the individual's initiative and different levels of operators make large difference for the overall running of the system. With the new system, there are many improvements both to the management and technology application.

II. System Principle

This system is a computer-based control system, or DDC system (Direct Control System). The process of data and control algorithm are both based on digital calculations and implemented by software. As well as most of the computer monitor systems, this system is composed of computer, field modules, sensors and executors.

1. Computer Controller:

Computer controller is the core for computer-based control systems. Its main features are shown below:

1) The working process of computer controller is determined by software. For the normal instruments, the process is implemented via electronic logic circuit or other mechanical hardware logic. The main difference between computer-based controller and normal instruments is whether software or hardware implements the control functionality.

2) The software for this system is implemented using VB. The various input signals are sent to the input port of the computer via digital communication bus. The data acquisition, control and administration is therefore implemented in the computer. This is different compared to the normal instruments which are implemented by individual control circuit or protective circuit. Computer controller can make use of all the related parameters of the object and implement a uniformed control, protection and administration system.

3) Computer controller can make use of graphics user interface, which is very user-friendly to exchange information with the users, such as alert message window, the statistic of running time, and make it very easy to manage the system equipments and devices.

2. Field Modules

The ICPDAS I-7000 series field modules are used to implement data acquisition and control signal transmission to the executors. RS-485 communication is used to send data to the transformer, which is then converted to the RS232 communication serial port.

3. Sensors

Sensors are used to get the physical values of the objects that need to be monitored, and then convert them to the electric signals, which can be, send to computer. They act just like the "eyes" of the computer. The status of various parameters is sent to the field modules via voltage, switch signals etc. Most of them are pressure sensors, temperature sensors, liquid level sensors and current sensors.

4. Actuators

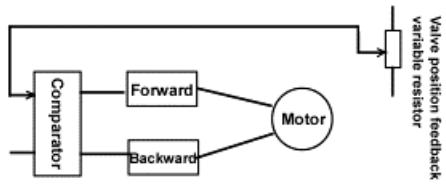
Actuators indicates the various switches and valves that can be directly controlled by computer. The computer controls the objects by adjusting the actuators, which act like the hands and/or foots. Controllers are connected to the actuators via the two types of output channels of the field modules:

1)Digital output channel (DO). The control software can set the digital output channels to high or low levels, which are used to turn on or turn off other switch components via corresponding driver circuits. They can also be used to control the light on and off state.

2)Analog output channel (AO). The output is voltage signal of the range of 0～10V. The value is determined by the control software. Because the internal information than are processed in a computer are digital values, the continuous changes of analog values are generated by a digital-analog conversion circuit (D/A).

Valve electric actuators are implemented by a connecting a motor with a mechanical speed reduction system, which is used to control the motor to rotate forward, backward and stop. It can also be used to control the valve to open large, close or keep its current position. The following figure shows the diagram

of the electric actuators.



This system chooses the electric executive valve from Lanjier Company to receive the 0~10V signals from the field modules to adjust the value open degree.

Fig. 1 Diagram of the electric actuator

5. Power Supply

There are 3 power supplies in total, which provide power supply for the electric executive valve, pressure sensor, current sensors and field modules.

6. Communication Network (Twisted-pair Wires)

To reduce the interference to the signals, we use twisted-pair wires for the transmission of signals for the whole system.

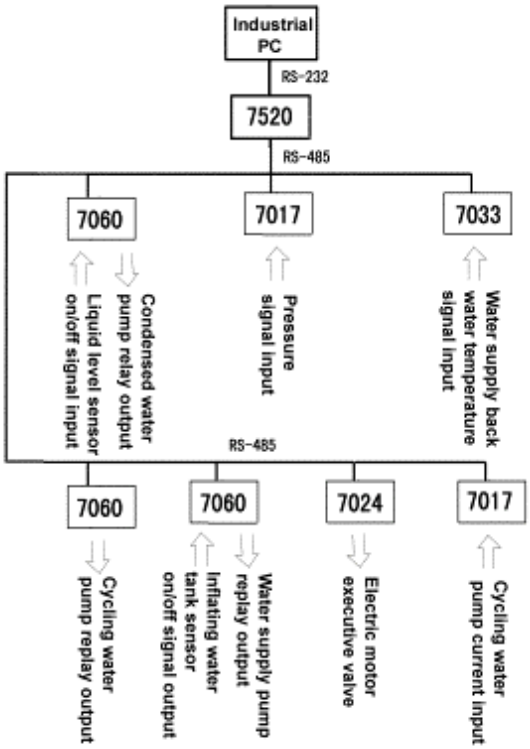
III. Hardware Architecture

1. The hardware architecture is shown in Fig. 2.

2. Main hardware: The following is the analysis for the sensors, field modules and executors:

1) Sensors

(1) Pressure sensors



The 4040PC pressure sensor is the first pressure transmitter made by Honeywell, which uses only a single chip. Its encapsulation is suitable for harsh environment with a working termperature of -45～125 ℃. The framework of this type of sensor is made up of stainless steel, glass, flux, silicon and brass. With complete adjustment and temperature compensation, the ability of providing linear output amplification, and the single chip which is based on the pressure-resistance characteristics, its long term reliability is improved significantly. The transmitter is powered with 5VDC, the range of output change is 4V, proportional to the input pressure from 0.5 to 4.5VDC.

Fig. 2 The hardware architecture

(2) Liquid level sensors

The Honeywell LL series liquid level switches can provide accurate measurement for liquid levels. One LED and one photoelectric transceiver are configured within the plastic semi-globe. According to the internal reflection principle of the light, most LED light will be absorbed by the photoelectric transceiver if there is no liquid. If the globe surface is covered by liquid, the refraction rate at the tip of the globe and the interface of the liquid will change, the LED light received by the transceiver will reduce, thus the output will change accordingly. The ON/OFF output signal and the digital input terminals of the field modules are connected in order to read data for the computer.

Power supply: photoelectric transceiver 5V

Output current: 40mA max., NPN

Output: High in the air, low in the liquid.

(3) Current sensors

The CSNE151 type of electric current sensors is based on the zero magnetic field balance principle (feedback system) and H-effect to measure the electric current. The internal magnetic field within the sensor is always below zero under the control. The current used to balance the zero magnetic field is the primary current over the conductor multiplied by the primary-sencondary coil ratio. The close loop current is the output of the sensor, which reflects the relationship of the primary current which is reduced by the sencondary coil. The output current can be converted to voltage output via external resistor.

Power supply: ±15VDC

Input/output current ratio: 25mA/25A

(4) Temperature sensors

We use thermal resistance temperature sensors, which is temperature measurement component whose resistance changes with the temperature. Its temperature increases when the temperature goes high. The thermal sensitive parts are rolled along the framework made of insulating materials using thin metal lines. The industrial thermal resistance sensors are categorized into two main classes, platinum and copper thermal resistance sensors. This system adopts the platinum class Pt100 with a working temperature range of -200～850℃. It has two wiring terminals, allowed error range is ±(0.3+0.005｜t｜). Besides the temperature sensitive components, the general thermal resistence sensors have protective sleeves, mounting devices, wiring boxes etc.. The shielded platinum thermal resistance sensors use the stainless steel as its shielding sleeves, and high density oxides as the internal insulating materials. The termperature sensor is fixed within the shields.

2)Field modules

This system uses I-7000 series as the field modules at 9600bps. Their function and address and channel allocations are shown below:

(1) I-7060

Function	Acquire the liquid level signal via the liquid level sensor. Start the condensed
Address	01
In3	Acquire the high level signal
In4	Acquire the low level signal
RL3NC	Control the stop of condensed water pump
RL1NO	Control the start of condensed water pump

(2) I-7017

Function	Acquire the pressure signal via pressure sensor
Address	02
Vin0	Water supply pressure
Vin1	Exit pressure of the water supply pump
Vin2	Exit pressure of the cycling pump
Vin3	Exit pressure of the condensed water pump
Vin5	The post-back water pressure of the cleaner
Vin6	Heat exchanger entry steam pressure
Vin7	Residential steam pressure

(3) I-7033

Function	Acquire temperature of the supply and back water via the temperature sensor
Address	03
Sense0	Supply water temperature
Sense1	Back water temperature

(4) I-7060

Function	Acquire the liquid level signal of the inflating water tank via the liquid level sensor, start the supply water pump when there is no water at low level, and stop the pump when there is water at high level
Address	04
In3	Acquire high level signal
In4	Acquire low level signal

RL3NC	Control the stop of #1 water supply pump
RL1NO	Control the start of #1 water supply pump
RL4NC	Control the stop of #2 water supply pump
RL2NO	Control the start of #2 water supply pump

(5) I-7024

Function	Send 0-10V voltage signal to control the open degree of the valve according the value calculated by the computer
Address	05
Vout0	Output voltage signal to the electric executive valve

(6) I-7017

Function	Acquire the cycling pump current via current sensor
Address	06
Vin3	current of cycling pump 1
Vin4	current of cycling pump 2

(7) I-7060

Function	Control the start/stop of cycling pump
Address	07
RL3NC	Control the stop of cycling pump 1
RL1NO	Control the start of cycling pump 1
RL4NC	Control the stop of cycling pump 2
RL2NO	Control the start of cycling pump 2

(8) I-7520

Function	Implement the conversion between RS485 and RS232

IV. Software Design

1 Overview of the software functions

1) Identification and record: Identify the users of the system by verify their password, and record the time of entry and user's name

2) Automatic acquisition of running parameters and status

(1) Display the following parameters by value

a. Pressure(MPa): water supply pressure, water supply pump exit pressure, condensed water pump exit pressure, cycling water exit pressure, back-water cleaner pressure, heat exchanger entry pressure,

residential steam pressure.

b. Temperature(℃): water supply temperature, back-water temperature.

c. Display the open digree of the valve(0~1): from full open to full close.

(2) Graphical display the following status

a. Water tank high/low liquid level: low level with water at normal state->green color, no water at abnormal state->red, high level with water at normal state->green color, abnormal state with water->red color

b. Start and stop display of the pump: red at start when switch is closed, green at stop when switch is open

3) Automatic and manual remote control of the operation status

(1) Automatic

a. Automatic control of the start and stop of the condensed water pump according to the liquid level of the condensed water tank: start if there is water at high level, stop if there isn't water at low level. As to the water supply pump, the system is not a random to start a pump. It starts the pump whose accumulated running time is the longest.

b. Manual start of the cycling water bump, or field manual start and then enter the auotmaticcontrol phase. Change the pump according to the continuous running time.

c.According to the back water temperature acquired over a period of time and activate the PID process to the electric executive valve.

(2) Remote manual

a. The water cycling pump must be started/stopped by clicking the picture.

b. Under specail cases (such as no feed back condensed water), the water supply pump, condensed water pump can be switched to manual mode by the Manual/Automatic switch button. The start and stop of the pump can be operated by cliking the picture.

4) Exception alert

(1) Alert devices: Because the temperature of the supply water need to be adjusted very often, there is no restriction on its adjustment. The other main parameters of the system are configured by users who are granted specific previliges to set the high and/or low limits.

(2) Alert functions: The details are shown in the alert list on Page 9.

5) Generate the operation record list and daily curve

6) Summary, query, print and update

(1) Summary and query

The summary of accumulated operational time for the pumps.

Query the users who enter/exit the system and the corresponding time.

Query the alerts and post-alert process logs.

The historical values of the main operational parameters

(2) Print and update: print the queried information.

Update the information that needs not to be kept.

The software flow is shown in Fig. 3.

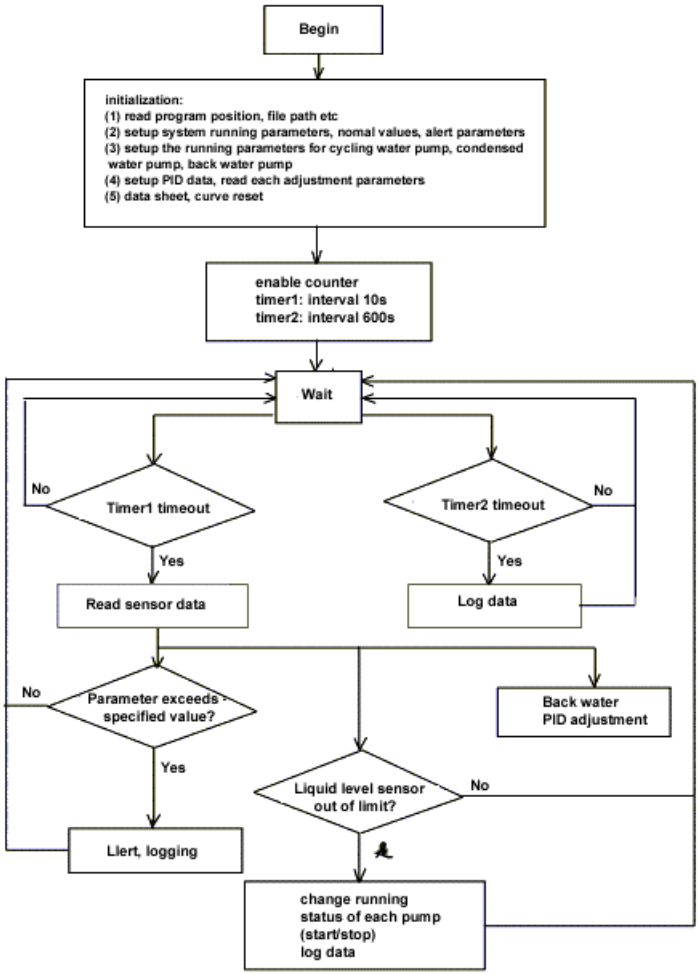


Fig.3 Software Diagram

V. Actual Results

This system has been running in good condition after some period of debug (mainly software debug) since it was first put into operation in November 1999. No operation personnel is needed in the heat exchange substation now. This system has the following actual results and long term benefits:

1. Resolve the original system shortcomings

1) Because the original design doesn't have the inflating water tank liquid level signal, the operator usually has to go up to the 8th floor to check the changes of the liquid level. If he found out the the system is in lack of water, he then come back to the heat exchange substation to start the water supply pump.

2) Because the original design doesn't have condensed water tank liquid level signal (event without a glass display of the liquid level), the operator has to start or stop the condensed water pump mainly based on his own experience or by watching the condensed water tank liquid level.

2. This system saves energy and ensures the reliable running of the system.

In the past time, the winter heating system operation is for the operator to adjust the steam valve to a certain position and start the system. In the whole wintertime, there is only a few requirements to adjust the system., and few requirements is needed to adjust the steam according to the changes of the steam pressure. The disadvantage is: when the steam pressure is high, the back water temperature tends to increase and no adjustment is performed, which results in unreliable performance and extremely waste of energy. When this system is put into operation, for an expected back water temperature, the open degree of the electric executor can change accordingly and save energy consumption. When the steam pressure is stable, the back water temperature will be within the expected range and the whole system is running steadily.

Fig. 4 Field Installation Diagram

3) Directional Effects

Because the period of the construction of Shangdi zone is very long, the centralized heating system is designed several years ago and the technology is already out of date now. In addition, the designer doesn't have practical operational experience, the automation level in the heat exchange substation is not high and the energy waste is very serious. This is not in accordance with the image of the first hi-tech development zone of China and cannot meet the needs of the enterprises in this zone. To change this situation is a key issue in the operation of our company. The leaders of the company have realized that to ensure the normal operation of the production, it's a long-term strategy to save energy and improve the operational efficiency. To save energy, it's important to improve the performance of the equipment and digitalization of the control system, we must utilize new technology. This is not only an issue of concept, it reflects the ability of the leaders in technology and management, and it's also an issue of management and science. The actual result shows that this new technology has significant advantages and benefits. It has both social benefits and financial benefits. The Ministry of Energy requires a policy that we should insist to emphasis development and saving and put the saving to the first important position. The emphasis of technical reform and energy saving is the process reform, equipment reform and production reform and then we can achieve the goal of advanced production process, reliable and economical operation. During the experimental operation period, we make the

original logic control system compatible with the reformed control system and can switch manually. For steaming system we can also switch to manual operation mode via bypassing method. In addition, the electric executive valve can also be switched to manual operation mode. After experimental operation and training, the operators have got familiar with the system and can operate the system independently. After a winter's operation, the operators have mastered the operation of the system. This can be a great help for the future success and development of the company.

#	Situation	Automatic system acknowledge action	Alert message	Operator	
1	supply water temperature high		supply water temperature too high		set appropriate supply
2	supply water temperature low		supply water temperature too low		water temperature high/low limits
3	supply water pressure high		supply water pressure too high		contact service personnel for system check,
4	supply water pressure low		supply water pressure too low		mainly from heat exchanger water supply to water distributor tank
5	difference between supply water pressure and cycling water pump exceeds certain value		pressure difference at the heat exchanger too high		maybe because the panel heat exchanger is dirty. change the heat exchanger.
6	supply water pump pressure high		water supply exit pressure too high		contact service personnel for system check mainly the water supply pump and connection pipe network
7	supply water exit pressure low		water supply exit pressure too low		
8	cycling pump exit pressure high		cycling pump exit pressure too high		contact service personnel for system check mainly cycling pump and its connection network
9	cycling pump exit pressure low	display alert message box	cycling pump exit pressure too low		
10	condensed water exit pressure high		condensed water pump pressure too high	click the alert message box which pops up	contact service people for system check mainly the condensed water pump and its

				immediately	
11	condensed water exit pressure low		condensed water pump pressure too low		connection network
12	difference between supply water pressure and back-water cleaner pressure exceeds certain value		system water loop resistance too big		contact service personnel for system check, mainly the heat panel
13	heat exchanger entry steam pressure high		heat exchanger entry steam pressure too high		if all other parameters are within normal range, set the appropriate
14	heat exchanger entry steam temperature low		heat exchanger entry steam pressure too low		high/low limits
15	residential steam pressure high		residential steam pressure too high		contact department office or boiler workshop for the reason of
16	residential steam pressure low		residential steam pressure too low		pressure change
17	back water temperature high	steam electric executive valve PID adjustment	back water temperature too high		
18	back water temperature low		back water temperature too low		
19	supply water pump single operation time exceeds 45 minutes		supply water pump operation time out		contact service personnel to check system
20	water supply pump operation 5 minutes and low water level has no water	close steam electric executive valve	system leak, check immediately!		leak or other abnormal status
21	condensed water pump single operation time exceeds 45 minutes		condensed water pump operation time out		consult service people for the small municipal condensed water valve and condensed water pump
22	power failure	close steam electric executive valve			contact electrician to restore the power

VI. The field picture is shown in Fig. 4.

VII. Experience of using I-7000 field modules

1. New ideas

Since 1999, we began to contact ICP China for the project draft design. We have found that ICPDAS makes great effort to the R&D of new products. For example, in March of the year, the only module for temperature acquisition is I--7013. And in June when we order the product, they have developed a new module named I-7033, which provides more choices of better performance/price ratio.

2. Service

During the project implementation phase, the workers in charge of the wiring of data cable and power supply cable of the field modules adopted a round trip mode. Because the central control office was under decoration at that time, the system debug process was carried out in the heat-exchanging substation. We could not find the any information from the modules when we went through the debug process. We could not find the reason for the problem after made a check over the 9 pairs of serial communication bus. After consulting Mr. Shiyong Yu of IA department from ICPDAS, he gave us lots of directions over the phone. However, because of the connection of the round trip wiring, we still could not find the signals. In the afternoon, Mr. Yu came to the local site and after some investigation, we found out the reason and solved the problem at last. Mr. Lin Yang also gave us lots of help and answered our questions using his off hours in the evening and night. After we ordered the devices and components in June, they sent personnel both from Shengzhen and Taiwan to help us. We greatly appreciate their high quality of service.

VIII. Conclusion

The total assets of Shichuang have reached about RMB 80,000,000. The implementation of this project and the use of computer control technology is only a step toward production management and marketing from basic construction in the company. As a technical professional and manager, especially the experience of working as the technical director and manager for this reform project, I realized the important role that technology plays in the production and management of the company. There is still a lot of things that need to be improved. The energy management of Shangdi Zone also has relationship to the steam heat source and power supply. The ICPDAS industrial control products have a very good future of application in such fields. The research for other technology is also an emphasis in our future development, which includes the following: frequency adjustment technology applied in large motors (such as ash pump, water supply pump etc); the electric meter reform in order to monitor and control from a central point; power supply network reconstruction in several stand-alone transformer substations (The workshop of LouHua, Factory 1, Factory

2); distributed administration of power load in transformer stations; centralized air conditioning system in the zone; heat exchanging system centralized monitor and control network, etc.

There is still a long way to go in the application of new technologies. We believe new technology will be widely used to improve the management and production in the enterprises.