The research and development of platform of process instrument and control

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Abstract. Process instrument and control experiment platform was researched, designed and developed. The controlled object was extracted from typical unit of process industry. In the platform the water and air were used for heat exchanging and recycling. The water and air can be recycled. The platform is easy to maintain. The real industrial instruments and distribute control system were used. The platform is close to the real industry. Many experiments about instrument and control can be supported. Good teaching and experiment environment can be supplied by the platform for the courses of process control and measuring instrument. The teaching standard can be improved.

1 Introduction
The professional courses of automation, monitoring and control and other discipline in the current college, such as process control, detection instrument, belong to the core curriculum. These courses are used to give students the basic knowledge of control, instrument type, principles. With the development of computer technology, control technology and detection technology, there have been many experimental platforms for the education of process control, instrument. Software experimental platforms which use computer software simulation of the process and control system have been used for process control experimental teaching. For example, MATLAB is used to simulate process objects in the platform. In order to improve the intuition of the object and the consistency with the real scene, the real equipment began to be introduced into the experimental platform. For example, water tanks are used as the controlled object in the experimental platform\cite{1}\cite{2}. In order to further enrich the experimental content, some simple instruments and equipments are introduced into the process control experimental platform\cite{3}\cite{8}. In the pipeline detection and power systems, some researchers have also developed an experimental platform\cite{10}\cite{11}. At the same time, intelligent instruments began to be introduced into some platforms, providing intelligent instrument related knowledge teaching\cite{12}. Hardware-in-the-loop simulation technology is also used in the development of experimental platform, combining the simulation technology and the actual equipment to complete the development of the platform\cite{13}\cite{14}.

The above experimental platforms have their own focus, and also can basically meet needs of teaching of the process control, detecting instruments and others, but there are also some problems, including:

(1) The objects were mostly in the form of sink containers, and the objects were relatively simple, and the knowledge points available for teaching were limited.
(2) Some of the platforms use some equipment for temperature control, such as boilers, reactors,
but it is inconvenient to use or maintain the platform, and it may be difficult to continue teaching, and it can even lead to the occurrence of security incidents when the experiment failed.

3) Most of the platforms which are mainly used to verify the control algorithm, are lack of process instrumentation teaching function, even if there are some instruments, the number and the number of type of which are both small, at the same time, the gap between actual industrial field and platform is too large to meet the needs of instrument teaching [18].

4) The number of types of experiments that can be carried out is small.

In view of the above problems, combined with the experience of practical teaching, a good experimental platform for teaching the process control, detecting instruments and other courses should have the following characteristics:

1) The objects are summarized and abstracted from the actual industrial scene to reflect the characteristics of industry; and the objects have a certain degree of complexity.

2) The experimental platform needs to be easily used and maintained.

3) It can provide more types of instruments, and the using of the instrument and transmission should be consistent with the actual industrial site to meet the teaching needs.

4) It can provide more experimental projects.

According to the above characteristics, the process instrument and control experiment platform was designed and developed, and the process of heat transfer with water and air is used in the platform. In the platform the self- circulation is realized and the platform can be easily maintained. The real instrument s and distributed control system are used in the platform. By the platform a large number of process control, detecting instruments and other related experiments can be carried out. The paper structure is as follows: the first part is the introduction, then the second part is the design of the experimental platform, the third part is the realization of the experimental platform, and the last part is conclusion.

2 The design of process instrument and control experimental platform

2.1 Process design

The platform uses air and water as the medium for heat transfer process, and this process is widely used in the area of intelligent buildings, engines, air conditioning and so on. The overall process is shown in Figure 1.

Figure 1: flow chart of the process

Each tag is shown in Table 1.
| Tag   | Equipment name                          |
|-------|-----------------------------------------|
| V101  | Sink                                    |
| V102  | Water tank                              |
| E101  | Hot air blower                          |
| E102  | Heat Exchanger                          |
| A101  | Air Cooler                              |
| P101  | Centrifugal pump                        |
| K201  | Blower                                  |
| TT101 | Sink thermometer                        |
| TT102 | Heat exchanger cold water outlet        |
| TT201 | Hot air blower air outlet thermometer   |
| TT202 | Heat exchanger hot air outlet thermometer|
| PT101 | FT101 after the cold water pressure     |
|       | transmitter                             |
| PT201 | FT201 rear hot air pressure transmitter |
| FT101 | Cold water flow transmitter             |
| FT201 | Hot air flow transmitter                |
| LT101 | V102 level differential pressure        |
|       | transmitter                             |
| TG101 | Sink bimetallic thermometer             |
| PG101 | P101 export pressure gauge             |
| PG201 | K201 export pressure gauge             |
| LG101 | V102 glass plate level gauge           |

The process is divided into the tank level system and the heat transfer system. In the tank level system, the water is conveyed from the water tank V101 to the top of the tank V102 by the centrifugal pump P101 and then the water circulates from the bottom of the tank V102 to the tank V101, that form a self-circulation system, as shown in picture 2.

In the heat transfer system, the water is pumped out of the water tank V101 by the centrifugal pump P101, and after entering the plate heat exchanger E102 to exchange heat with hot air, the temperature of water rises to a certain value, and water enters into the air cooler A101 to be cooled down by a certain program, finally the water returns to V101. Air through the blower K201 first enters into the hot air fan E101 to be heated, when the temperature rises to a high level, the air enters into the heat exchanger E102 and exchange heat with water, when the temperature drops to a certain value, the air is discharged into the atmosphere. It is shown in Figure 3.
2.2 Experimental platform system structure

On the basis of the above process, the design and structure of whole system are shown in Figure 4.

![Figure 4: Process instrument and control platform system structure](image)

As it shown in Figure 4, the entire platform consists of the real DCS control system and the host computer and the controlled object. The control object includes water tank, water tank, heat exchanger, pump, air cooler, various instruments, blower and so on, among them, pumps, air cooler, instruments and valves communicate with PLC by 4-20mA signal and internal bus, and the fan communicates with PLC by the three-phase power and DP bus. Any PLC that supports the bus protocol can be used in this
control system.

The whole platform contains the controller and the controlled object, including the device equipment, materials, instruments, actuators, controllers and other basic elements of process control. A complete experimental environment is supported by the platform forms.

3 The realization of process instrument and control experiment platform

According to the design of the platform, the control experimental platform is developed.

3.1 Equipment and Instruments

The main equipments of the platform include: centrifugal pumps, sinks, water tanks, heat exchangers, air coolers, blowers, hot fans and so on.

1. Centrifugal pump. Horizontal centrifugal pump, with 220V power supply, has a lift of 19m, and the maximum outlet pressure is 190kPa.

2. Sink. Sink’s size is 800 * 600 * 500 (mm), and the maximum storage capacity is 2.4 cubic meters, and the sink covers can be removed to clean the sink inside. The upper surface of the sink has a square mouth for the return of the pipe, and on the side of the sink has a water inlet for irrigation and a drain at the bottom. At the same time the sink also has two temperature detection points, one of which is a bimetallic thermometer for local display and the other is a thermal resistor thermometer for remote transmission.

3. Water tank. The water tank is 400 mm high, which is cylindrical, and upper and lower bottom are semi-circular, and water enters into the top of the tank, and is discharged from the bottom of the tank. The left side of the tank is equipped with a differential pressure level transmitter for the remote level signal; the right side of the tank is equipped with a glass plate level gauge for local display.

4. Heat Exchanger. The heat exchanger is a plate heat exchanger that provides heat transfer for water and hot air. It has the characteristics of high heat transfer efficiency, small heat loss, compact structure, small footprint, easy installation and cleaning, wide application and long service life. In the case of the same pressure loss, the heat transfer coefficient is higher 3-5 times than the tube heat exchanger, and it covers an area of one-third of the tube heat exchanger, and heat recovery rate of the heat exchanger can be as high as 90% or more.

5. Air Cooler. Air cooler uses the ambient air as a cooling medium to cool the high temperature fluid in the air cooler tube. In the platform, the water heated by the heat exchanger first enters into the air cooler to be moderate cooled, and then back to the tank to control the heating rate of the cycle water in the entire device. The fan in the air cooler is 220V power supply, and the corresponding button in the cabinet is used to control the start action and stop action of the air cooler.

6. Blower. Blower is the high-pressure blower, and the maximum outlet pressure is 37kPa, using 380V three-phase power supply. The air first enters into the blower through the filter and then accelerates into the hot air blower to be heated. The motor of the blower is controlled by the inverter. The position of the inverter is located at the hot air blower. There are knobs on the hot air fan to adjust the input power frequency of the motor.

7. Hot air blower. Hot air blower is the heat source of the device, using 220V resistance wire to heat, and the maximum air can be heated to 80 ℃, hot air with a thermostat, can adjust the heating process to ensure that the air outlet temperature meets the corresponding requirements. The hot air blower is equipped with two knob switches, as well as the corresponding power supply, heating indicator.

The real instruments are used in the platform and includes local display instruments and remote transfer instruments.

Local display instrument:

1. Bimetallic thermometer. It is used to measure the water temperature of the sink.

2. Pressure gauge. It is used to measure the outlet pressure of the pump and blower. This device is made of stainless steel seismic pressure gauge, because the pump and fan outlet pressure along with
the pump and fan start and stop is a sudden change, and often fluctuate, so fill in the dial silicone oil to protect the pressure gauge pointer is not damaged.

(3) Glass plate level gauge. It is used to measure the level of the sink.

Remote instrument:

(1) Thermal resistance temperature transmitter. It is used to measure the temperature of the tank, the cold water outlet temperature of the heat exchanger, the hot air outlet temperature of the heat exchanger, and the outlet temperature of the hot air blower.

(2) Pressure transmitter. It is used to measure the cold water pressure, hot air pressure.

(3) Vortex flow transmitter. It is used to measure the flow of hot air.

(4) Electromagnetic flow transmitter. It is used to measure the flow of cold water.

(5) Differential pressure level transmitter. It is used to measure the level of the tank.

On one hand, the real industrial instruments and more types of instruments can ensure that the teaching is true and intuitive; on the other hand, it is possible to ensure that the student is exposed to as many instrument types as possible.

3.2 Distributed control system

Siemens 314C-2PN / DP compact PLC is used as the controller in the platform control system, and the controller integrates two IO modules, namely DI8 / AI5 / AO2 (that is, the module has 8 digital input, 5 analogy input, 2 analogy output), DI16 / DO16 (that is, the module has 16 digital inputs, 16 digital output), and platform expands another two 8-channel AI module 331-7KF02-0AB0 and another one four-channel AO module 332-5HD01-0AB0.

Each channel is shown in Table 2.

| modules    | channel | Instrumentation | Description |
|------------|---------|-----------------|-------------|
| 7KF02 AI (NO.1) | 1       | TT101           | Two wire    |
|            | 2       | TT102           | Two wire    |
|            | 3       | TT201           | Two wire    |
|            | 4       | TT202           | Two wire    |
|            | 5       | FT201           | Two wire    |
|            | 6       | LT101           | Two wire    |
|            | 7       | PT101           | Two wire    |
|            | 8       | PT102           | Two wire    |
| 7KF02 AI (NO.2) | 1       | FT101           | Four wire   |
|            | 2       | ZT101           | Valve signal |
| 5HD01AO    | 1       | FV101           | Two wire    |

Real industrial-grade control systems provide the most suitable software and hardware systems for industrial applications. In addition, the IO module can provide consistent with the real field of the wiring environment, and students can practice wiring to improve operation ability.

3.3 Experimental Project

The platform can provide equipment operation, process control, signal acquisition and other types of experiments. Specifically include:

(1) Experiments of equipment operation. Startup, shutdown, exception handling and so on.

Specifically include:

A. Normal startup operation and normal shutdown operation of device.

B. Basic operation in the steady state.

C. Exception handling.

Through these experiments, students can understand and learn the equipment characteristics of the entire platform, process, operational requirements, alarm handling, precautions and so on.
(2) Process control experiments. The platform object includes the liquid level system and the heat exchange system. The flow, level, temperature and pressure can be used for control of single circuit, cascade and advanced.

A. Flow control of cooling water.
B. Flow control of hot air.
C. Level control of sink.
D. Level control of tank.
E. Temperature of outlet hot air control of heat exchanger.
F. Temperature of outlet cooling water control of heat exchanger.
G. Pressure control of cooling water.
H. Pressure control of hot air.

(3) Instrument disassembly experiments. The platform can provide all kinds of instrument disassembly experiments, including: local display instrument, remote instrument, bimetallic thermometer, pressure gauge, glass level gauge, thermal resistance temperature transmitter, pressure transmitters, vortex flow transmitters, electromagnetic flow transmitters and differential pressure level transmitter.

(4) Signal acquisition experiment. According to the International Electro technical Commission (IEC) standards, 4-20mA DC, and the 1-5V DC are used. Through the signal acquisition experiment, students can learn the actual field signal transmission principle and at the same time, students can understand the wiring way and cultivate independent thinking and practical ability.

4 Conclusion
The experimental platform of process instrument and control was designed and developed to overcome the shortcomings of existing platforms, such as experiment object is too simple, the platform is difficult to be maintained, and the gap between the actual industrial fields is too large and so on.

Water and air are used as the medium for heat transfer process in this platform to achieve cooling flow, heating flow and self-circulation. On one hand, a reasonable process design ensure that the object can reflect the characteristics of industrial processes and have a certain degree of complexity, on the other hand, the design can ensure that equipment can be easily used and maintained; The platform uses a variety of real instruments and real distribution control system to close to the actual industrial environment. The platform can provide lots of experiments of process control and instruments. Practical application shows that the platform can be a good experimental teaching environment, which can improve the teaching level.

References
[1] Liu Ying. “An Experimental Teaching System for Chemical Instrumentation and Process Control”, HIGHER EDUCATION OF SCIENCES, 2009,5: 145-147.
[2] Zhu Ta, Li Hong. “Research and Practice of Instrument Automation Experiment Device”, Chemical Engineering & Equipment, 2013, 7:258-260.
[3] Qi Zhitao, TianZhong, Qi Jin.“Development of experiment system for chemical industry meters and automatic control”, EXPERIMENTAL TECHNOLOGY AND MANAGEMENT, 2007, 24(10):62-64.
[4] Wang Xiaofang, Zhang Jiyan, Jin Lulu. “Development of Advanced Control System Based on SMATIC System”, Research and Exploration in Laboratory,2008,27(8):207-209.
[5] Yu Yali, Wu Li.“Design and Implementation of process control experimental platform”, MECHANICAL & ELECTRICAL ENGINEERING MAGAZINE,2010,27(8):36-38.
[6] Yuan Mei,Zhang Lijun,DongShaopeng. “Development of temperature control experimental platform based on semiconductor refrigerator”, EXPERIMENTALTECHNOLOGY AND MANAGEMENT,2010,27(12):73-76.
[7] Zhu Jianing, Shu Huailin. “The research of the comprehensive experiment platform of computer control and automation instrumentation”, *Industrial Instrumentation & Automation*, 2012, 2:52-54.

[8] Ai Hong. “Function development and application of process control experimental device”, *Experimental Technology and Management*, 2013, 30(8): 50-53.

[9] Zhu Mingqiang, Sun Xuan, Li Haixia. “The design of instrument measure and process control experimental system based on industrial air-conditioning”, *Microcomputer & its Applications*, 2015, 34(14): 84-86.

[10] Wang Mingda, Xu Changhang, Fu Jianmin.“Design and development of experimental platform for pipeline leakage detection”, *Experimental Technology and Management*, 2014, 31(11): 104-106.

[11] Zhang Mingrui, Lin Xianqi. “Teaching Application of the Power System Automation Experimental Platform”, *Research and Exploration in Laboratory*, 2015, 34(1): 226-229.

[12] Zhang Qian, Ou Yangling, Wen Shengjun, Wang Aihui. “The Design of Open Experimental Platform Based on Intelligent Measurement and Control Instrument”, *China Modern Educational Equipment*, 2015, 3:4-6.

[13] Tang Jian, Chai Tianyou, Pan Jinxiang, Yue Heng. “A Hardware - in - the - loop Simulation Platform for optimized Intelligent Control of Industrial Process”. *Journal of NortheasternUniversity(Natural Science)*, 2009, 30(11): 1530-1533.

[14] Zhu Tao, Zhou Tianpei, Li Hong, Ling Qidong. “Development of instrumentation automation experimental system based on combination of simulation and prototype realization”, *Experimental Technology and Management*, 2015, 32(4): 136-140.

[15] Cheng Dengliang, Jiang Weirong, Huang Zhiwen, Zhang Kai, Wang Weihua. “Design of measurement-control platform by using water temperature sensor based on equilibrium point increment fuzzy control”. *Experimental Technology and Management*, 2014, 31(2): 77-81.