Design of Refrigeration Control System for Parallel Refrigerator Unit Based on PLC

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Abstract. In order to improve the refrigeration control efficiency and reduce the temperature fluctuation in the cold storage. In this paper, the refrigeration control system of the parallel unit of the cold storage is designed based on the upper and lower computers. The lower computer uses PLC to monitor the field parameters and control the execution of the field equipment. The upper computer uses HMI to realize the real-time monitoring, parameter display and alarm function during the operation of the cold storage, and uses the slide valve to adjust the energy of the compressor. The results show that the control system runs reliably and meets the control requirements of large cold storage.

1. Introduction
The cold storage is mainly used to ensure the quality and freshness of food. The temperature and humidity in the cold storage can reach certain conditions by refrigeration equipment. The change of air temperature inside and outside the cold storage and the entry and exit of food will affect the temperature in the cold storage. In order to reduce the temperature change in the storeroom and meet the temperature required for food refrigeration, it is necessary to keep the cooling capacity in the storeroom balanced with the cooling capacity of the refrigeration system[1]. As a closed system, the refrigeration system reflects its operation status through parameters such as temperature, pressure, liquid level and pressure difference. If the control efficiency is not high and the control is not timely and accurately controlled, it will affect the quality of food, and even lead to food deterioration. The parallel unit in the control system has the function of graded energy regulation, which can adjust the cooling capacity according to the change of load, reduce the fluctuation of reservoir temperature, improve efficiency and save energy[2]. Therefore, this paper uses PLC and human-computer interaction interface to realize the control of refrigeration in cold storage, and uses slide valve to adjust the energy of compressor, which improves the stability of system operation and achieves the purpose of energy saving and consumption reduction.

2. Hardware design of refrigeration control system
As an important part of the cold storage refrigeration, the control system plays a vital role in the safe and reliable work of the cold storage. In order to conveniently and quickly realize the collection of operation data, the start-stop control of equipment and the monitoring of operation state of the refrigeration system of the cold storage, so as to improve the efficiency of refrigeration of the cold
storage, the control system adopts the principle of decentralized control and centralized management and the control form dominated by the upper and lower computers. As shown in Figure 1, the structure is divided into three levels: monitoring layer, control layer, equipment layer.

![System structure diagram](image)

**Figure 1. System structure diagram**

1. **Monitoring layer**
   - This cold storage control system, the monitoring layer is mainly composed of touch screen. Touch screen shows the operation status of the whole refrigeration system, and real-time display of important parameters in the system such as the temperature between the cold storage, liquid supply valve opening and closing, reservoir level, exhaust pressure and suction pressure. At the same time, important data can be stored on the SD card, which is convenient for operators to extract at any time. Users can input control commands to the control system through the touch screen. In addition, the touch screen also has the functions of alarm and parameter setting of cold storage control system.

2. **Control layer**
   - The control layer is the core of the entire cold storage control system. The control layer adopts Siemens S7-200 SMART series PLC. PLC can receive the data information (digital input signal or analog input signal) transmitted from the scene. After the logical operation of the internal program of the CPU, the corresponding instructions are issued to act on the scene equipment, and the relevant data are sent to the touch screen by PLC through RS485 communication.

3. **Equipment layer**
   - The equipment layer is a part of the system to collect signals and execute control instructions, which belongs to the infrastructure. The equipment layer in the control system includes field pressure sensors, temperature sensors, various solenoid valves, check valves and relays.

3. **Software Design of Refrigeration Control System**
   - The software design of refrigeration control system is mainly composed of two parts, one is the design of PLC control program, the other is the design of HMI screen configuration.

3.1. **PLC control function realization**

1. **Start - stop Unloading Control of Parallel Unit**
   - The starting, stopping, increasing and unloading of the parallel unit are controlled by pressure sensors, intermediate relays, increasing and unloading solenoid valves and PLC. In normal refrigeration, the refrigerant evaporates in the evaporator, and the temperature of the cold storage is reduced by absorbing heat. When the suction pressure of the parallel unit rises continuously and reaches the pressure value set by the start-up, the contact point of the intermediate relay is closed, and the signal is input to the PLC. After comparing the running time of each compressor, the PLC starts the compressor in order of running time from less to more. When the cooling load changes, the energy is adjusted by controlling the sliding valve. When the cooling capacity demand is large, the sliding valve moves to the exhaust port of the
unit, opens the load-increasing solenoid valve, and increases the energy output of the parallel unit. When the demand for cooling capacity is reduced, the unloading solenoid valve is opened, and the sliding valve moves to the direction of the backflow hole, reducing the amount of suction, and also reducing the amount of exhaust and energy output. Adjusting the cooling capacity of the unit according to the cooling capacity in the library can reduce the temperature fluctuation in the library. When the temperature of each warehouse reaches the lower limit of the temperature setting range, the PLC sends out instructions to stop the refrigeration, closes the solenoid valve for the liquid supply, and prevents the refrigerant from entering the evaporator. At this time, the suction pressure of the parallel unit continues to decrease. When the suction pressure is lower than the set value of the shutdown pressure, the contact of the intermediate relay is disconnected, and the PLC sends out the shutdown instructions to shut down the compressor in turn. Figure 2 shows the automatic control process of compressor.

![Figure 2. Automatic control process of compressor](image)

![Figure 3. Cold storage temperature control process](image)
(1) cooled storage temperature control

The temperature of each cold storage is controlled by temperature sensor, liquid supply solenoid valve and PLC, and the temperature of each cold storage is maintained within the required range. The upper and lower temperature limits of each cold storage can be set on the man-machine interface. The temperature sensor can monitor the temperature change of the cold storage in real time. When the temperature of the cold storage reaches the upper limit of the set temperature value, the refrigeration signal is sent out for the opening of the liquid electromagnetic valve, so that the refrigerant flows to the evaporator in the room. When the temperature of the warehouse continues to decrease and reaches the lower limit of the set temperature, the refrigeration signal stops, the liquid solenoid valve closes, and the refrigerant flows into the evaporator stops. Figure 3 shows the cold storage temperature control process.

(2) level control

The liquid level of the circulating barrel and the liquid storage device is automatic control, and the refrigerant of the circulating barrel and the liquid storage device must have a stable liquid level. The automatic control of the liquid level uses the floating ball type liquid level sensor to control the opening and closing of the electromagnetic valve to automatically maintain a relatively stable normal working level. When the liquid level is super high, it can automatically alarm. If the refrigerant liquid level is lower than the lower limit of the set value, the liquid level sensor sends a signal to PLC. PLC executes the replenishment instruction, and the solenoid valve is opened to replenish the liquid in the container. When the liquid level reaches the upper limit of the set value, PLC eliminates the replenishment instruction, closes the solenoid valve for replenishment, and stops supplying liquid to the container. If a system or component fails, the liquid level in the circulating barrel rises to a high level, the PLC sends an alarm signal and instructs the compressor to shut down to avoid damage to the compressor cylinder.

(3) Fault detection and alarm

Fault detection mainly detects the fault of the compressor parallel unit. When the pressure difference between the inlet pressure and the outlet pressure is lower than the given value after the compressor starts and operates, the oil pressure difference controller delays the action, and sends this switching signal to PLC, which controls the compressor shutdown and sends out an alarm signal. When the exhaust pressure of the unit is too high or the suction pressure is too low, the unit immediately stops, PLC sends an alarm signal.

(4) Analog acquisition and conversion

The analog input signal collects the temperature of the frozen storage, the temperature of the cold storage, the current and exhaust temperature of the compressor, the return pressure and exhaust pressure of the system, the liquid level of the liquid storage device and the circulating barrel, the temperature of the oil separator and the oil cooling temperature. The current signal is converted by the transmitter and transmitted to PLC. After internal calculation, the PLC feedbacks the calculation results to the human-machine interface.

3.2. Design of Human - computer Interface

In the current automation control system, the human-computer interaction interface of the touch screen has become an indispensable part of the system[6]. Through the human-computer interaction interface, the operator can monitor the operation status of the whole system, and the system control parameters can be set. The man-machine screen includes the basic equipment of the whole refrigeration unit control system and the running state of each equipment, real-time display of the liquid level of the reservoir and the circulating barrel, and record the working time of each compressor. The man-machine interface shows the operation state of each cold storage including the state of the liquid supply valve and the fan, and the temperature of each cold storage is displayed in real time. During the normal operation of the cold storage, the upper and lower limits of temperature need to be set to maintain the temperature of the cold storage within the range required by the control system. The parameter setting is related to the normal operation of the system and the normal alarm. It must be set by the relevant technical personnel. When the operating parameters exceed the set value or failure occurs, the system will pop up the alarm message box and save the alarm message.
4. Conclusion
The refrigeration control system of parallel units designed in this paper adopts PLC and human-computer interaction interface technology to meet the control requirements of the refrigeration unit. The parallel combination of four units is used to obtain the multi-level output power combination, so as to realize the optimal energy regulation for load change, and reduce the operation cost and temperature fluctuation. PLC control and HMI configuration meet the requirements of refrigeration process, and improve the control efficiency of the refrigeration unit. The man-machine dialogue window is simple to operate without too much professional knowledge. Managers can control the equipment and reduce the labor cost after simple training.

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