Design and Research on Temperature Control System of Electric Furnace Based on PLC Touch Screen Integrated Machine

Haiyu Zhao¹, Jiashuo Zheng²
¹School of Electrical and Electronic Engineering, North China Electric Power University, Beijing, 102206
²School of Mathematics and Physics, North China Electric Power University, Beijing, 102206

Abstract. With the development of science and technology in China, temperature control system has been widely used in many fields. The emergence of PLC effectively improves the shortcomings of PID control system, optimizes the performance of PID control system, and plays a very important role in promoting industrial production and construction. In view of the design of temperature control system of heating furnace, configuration software and PLC can be used the combination of technology can achieve the goal of furnace temperature control, and it can also monitor the furnace temperature in real time and comprehensively, and then adjust the furnace temperature according to the application requirements. The investment in the process is less, which can reduce the cost to a certain extent, and also has the application advantage of high accuracy. The temperature control system of electric heating furnace is designed in this paper. PLC is mainly used, and the temperature system is controlled intelligently with touch screen. According to the actual situation and cost budget, the controller of this paper chooses Mitsubishi FX2N-48MR series PLC. In order to achieve intelligent control, it needs to use digital PID control algorithm, which is convenient for the staff to operate Gt1040-qbba-c series touch screen is used to realize human-computer interaction. The system can be started and stopped. The touch screen for temperature setting can be very simple to operate. The temperature change can also be visually displayed and monitored, and the whole system can be automatically set.

1. Introduction
The use of resistance furnaces in industry began in 1920. With the rapid development of science and technology in the world, resistance furnaces are very common in industrial production. In many production processes, whether the working environment of factory staff is safe, whether the products produced meet the market quality requirements, whether the production efficiency can be improved, and whether energy can reduce waste are closely related to the technology and economy of temperature control [1]. The accuracy of resistance furnace temperature control, whether the system can operate stably, whether the system is reliable and other requirements are the key indicators in various fields. The improvement and optimization of temperature control technology has become a hot issue for researchers all over the world. The theoretical technology of temperature control has roughly
experienced three stages from the constant value switch control to PID control and then to the current popular intelligent control [2-3].

(1) Constant value switch control: if the actual temperature value measured by the system is lower than the given value, the system needs to raise the temperature, then start the control switch to heat the system, and when the measured temperature value is higher than the given value, the control switch turns off heating. But in the actual operation of the system, the temperature control error will be very high.

(2) PID control temperature: temperature control with PID algorithm. Proportion, integral and differential are the core contents of the design and they determine the quality of the system. The working principle of the resistance furnace depends on the electric heating of the resistance wire to increase the temperature. The temperature of the resistance furnace is reduced naturally due to the influence of the external temperature. If the actual temperature of the resistance furnace exceeds the maximum limit, the control means can no longer operate normally. In the large-scale industrial production process, the biggest problem is that using PID controller for temperature control can not be very accurate [4]. Instability may occur when disturbed, which is a thorny problem at home.

(3) Intelligent control: in short, it can be thought and operated by computer instead of human brain without human participation. It can get rid of the technician's operation and automatically command the machine control object to realize the expected function. The rapid progress of scientific theory in modern countries has made a new breakthrough in the field of temperature control, in which intelligent calculation should be used. For multi-objective can be optimized, in a complex environment can learn to adapt.

The object of study is tunnel electric heating furnace. It is 5.2m long, 1.5m wide and 1.8m high. It is heated by resistance heating tube. The resistance heating pipe is divided into three groups, one group is composed of 10 electric heating pipes of 1 meter long (37.4 ohm each, with a power of about 1.3KW) in parallel, the other two groups are composed of 1.5 meter long (45 ohm each, with a power of about 1.075kw each) in parallel, with a total power of about 34.5kw. The original electric heating and insulation furnace is controlled by temperature control meter, with temperature control range of 180℃~ 220℃. In view of the design of temperature control system of heating furnace, configuration software and PLC technology can be used Combined with the way to achieve the goal of furnace temperature control, it can also monitor the furnace temperature in real time and comprehensively, and then adjust the furnace temperature according to the application requirements. In the process, less capital is invested, which can reduce the cost to a certain extent, but also has the application advantage of high accuracy. In the industrial production, the equipment operation is relatively stable and safe, and the energy waste is greatly reduced.

2. Design scheme of temperature control system of electric furnace based on PLC

2.1. Overall design scheme
The overall plan is mainly composed of the following parts:

(1) Touch screen: it is mainly used to set and display the temperature value of the corresponding electric heating furnace, stop and start, set the holding time, and display the temperature curve in real time.

(2) PLC: it mainly completes PID adjustment function, data transformation, field equipment and process control.

(3) Temperature measurement circuit: the thermocouple is connected with PLC, and PLC processes the temperature measurement signal and outputs the control signal. The heating resistance bar is connected with the thyristor according to the principle of three-phase symmetry.

(4) Output regulating circuit: the main function is to pass the control signal sent by PLC processing operation through the pulse width

The modulation device outputs pulse signal to the thyristor and controls the conduction time of the thyristor to control the heating of the heating tube. The thermocouple is connected with PLC, and the
deviation between the constant temperature setting value $Q_0$ and the actual heating pipe temperature $Q_e$.

2.2. Working principle
(k) According to the integral separation PID control algorithm, the output control quantity $U(k)$ is obtained, the conduction time of the thyristor is controlled, and the temperature of the heating tube is adjusted so that it is consistent with the given constant temperature value to achieve the purpose of constant temperature control. When the constant temperature value is reached, the constant temperature indicator light will be on, so that the number of trigger pulses is 0, and the thyristor is not on, at this time, the system will not heat the resistance furnace. In case of input error or system failure, the system will send an alarm signal. At the same time, GT1040-QBBD-C screen is used for real-time display of heating tube temperature and input of temperature setting value.

3. Hardware design of temperature control system of electric furnace based on PLC

3.1. PLC module
PLC is generally divided into integral type and modular type, but its logical structure is basically the same. In terms of hardware structure, PLC is composed of CPU, memory, I/O interface unit, extension interface and extension part, peripheral interface and peripheral and power supply, etc. all parts are connected by system bus.

Mitsubishi FX2N series PLC is small in size, moderate in price, powerful in performance and high in cost performance. Compared with other PLCs, Mitsubishi programming is easy and convenient. Mitsubishi PLC provides many expansion modules to meet the needs of different users. In line with the practical and cost-effective situation, Mitsubishi FX2N Small PLC is selected. There are many kinds of Mitsubishi PLC, among which FX2N series is ahead of other models and the processor has powerful performance. If users have other special process requirements, they can also add special function modules for most occasions. Most of FX2N consists of three parts: basic unit, expansion module and expansion unit. The user memory capacity can be expanded to 16K steps. I/O points can be expanded up to 256. It has 27 basic instructions. Compared with other large-scale PLC FX2N, it is far ahead in basic instruction operation speed. Mitsubishi FX2N-48MR is Thermocouple Input relay output type, with 24 input and output points.

The number of points available for the expandable module is 48-64, with 8000 steps of ram. The interrupt number of the timer is as follows:

| Enter number | Interrupt period (ms) | Interrupt inhibit special auxiliary relay |
|--------------|-----------------------|------------------------------------------|
| I6XX         | In the XX part of the pointer name, enter an integer of 10-99. I610 executes timer interrupt every 10ms | M8056                                     |
| I7XX         | 10-99                  | M8057                                     |
| I8XX         | 10-99                  | M8058                                     |

3.2. Analog module
Because the Mitsubishi FX2N PLC selected in this paper needs to consider the matching between the selected analog module and Mitsubishi PLC in determining the analog quantity. FX2N-2AD has two analog quantity inputs, FX2N-4AD has four analog quantity inputs, and FX2N-8AD has eight analog quantity inputs. Combined with practical experience, FX2N-4AD is compared with FX2N-4AD It is more convenient to operate, cost-effective and has more spare parts. Finally, it is decided to use FX2N-4AD. It’s an analog input module matched with Mitsubishi PLC. The analog input module consists of four analog input channels (CH1, CH2, CH3, and CH4). Any channel can transform the analog into digital. The resolution of FX2N-4AD is 12 bits.
3.3. Touch screen module
In this paper, the constant temperature setting value of the resistance furnace adopts GT1040-QBBD-C series Mitsubishi touch screen and switch key to control the input, and the software (GT designer 3) is used to edit the touch screen interface, as shown in the figure below, including the temperature setting input of the resistance furnace, real-time display of the touch screen temperature, start and stop control buttons of the touch screen, constant temperature and alarm indicators. In order to enable the user to input the given temperature value of the system through multiple ports, 10 switch buttons are added to achieve the above functions. This port can receive decimal number. Touch screen program and switch key circuit are shown in the figure below. The given temperature value shall not be more than 100°C and less than 0°C. If the input value is greater than or less than the above range due to misoperation, the red alarm light will start to alarm (red light is on). The system temperature setting input is realized by touch screen: (the temperature setting input is the number in the first row of the right figure):

4. The circuit design of the temperature control system of electric furnace based on PLC

4.1. Temperature detection circuit
In this paper, the function of temperature detection in electric heating furnace is realized by thermocouple (the temperature of heating tube is measured by the hot end of thermocouple, and the cold end of thermocouple is placed at 0°C). The most commonly used temperature sensor is thermocouple. Generally, the thermocouple used in industry will be equipped with display instrument, and the recording instrument and electronic regulator will be added according to the situation. Thermocouple temperature measurement range can be from zero to one thousand three hundred degrees, and the industry often needs to measure the object of liquid steam, gas medium or solid surface temperature can be directly measured by thermocouple.

Thermocouple structure is simple, it is a passive sensor that can directly measure temperature and is a primary instrument. Its working principle is to transform the temperature signal into millivolt signal. The medium temperature to be measured can be obtained by secondary instrument.

Thermocouple temperature measurement is made of thermoelectric phenomenon. Two kinds of different wires are welded together to form the working end, and the two ends are connected with the measuring instrument to form the circuit. Put the working end at the temperature to be measured, because of the temperature difference between this end and the free end, electromotive force will be generated, and current will pass through the circuit. Through the measurement of electrical quantity, the temperature at the other end can be measured by using the known temperature. It can be used between two substances with large temperature difference. Some thermocouples can measure the high temperature of 3000°C and others can measure the low temperature close to absolute zero.

In order to prevent adding the third metal conductor to change the thermoelectric potential generated by the couple and reduce the accuracy, it is necessary to ensure that the temperature at both ends of the third metal conductor is the same, so that the thermoelectric potential generated by the thermocouple circuit will not be affected by the newly added metal. Therefore, the temperature of the target medium can be calculated by connecting the measuring instrument with the thermocouple and obtaining the thermal potential.

4.2. Zero crossing detection circuit
The trigger needs to input a synchronous signal, which can be provided by a pulse generated by the zero crossing detection circuit at the beginning of each power cycle. The voltage is divided and filtered by resistance, and a zero crossing comparison circuit is formed by four differential comparators to obtain the square wave signal synchronized with the input voltage signal of the power grid. The GND is the ground LM339, which is the four differential comparator. There are four independent voltage comparators in the LM339 integrated block, the common mode range is very large, from zero voltage to power voltage minus one to two volts; the differential input voltage range
is also very large, even equal to VCC. Four way differential comparator uses diode to protect its input. The working waveform of the design is shown in Figure 1.

![Working waveform of zero crossing detection circuit](image)

**Figure 1.** Working waveform of zero crossing detection circuit

4.3. **PID control circuit**

In this design, PID control algorithm of integral separation is used to realize constant temperature automatic control of resistance furnace. In practical application, engineering tuning is generally used to determine the parameters of PID. Proper increase of $K_P$ can speed up the adjustment and reduce the error. However, $T_i$ and $T_d$ continue to optimize the control level when $K_P$ regulation is not ideal. The increase of $K_P$ will decrease the stability of the system, increase the overshoot and even produce unstable oscillation. If it is very difficult to adjust only $K_P$ to achieve the desired control effect, then $T_i$ and $T_d$ are needed to help adjust.

$T_i$ is introduced to eliminate the static error of the control system and improve the accuracy of the system control. However, the addition of $T_i$ will cause some problems. For example, when the constant temperature value of the system is set at the beginning and the end or before and after a very large difference, the system may have a large error due to handling this change. At this time, the deviation has exceeded the adjustment range of the controller, but PID It is still in operation. With the accumulation of time, the system will have a large overshoot, or even an unstable oscillation. The introduction of $T_d$ can reduce overshoot and regulation time, but it can amplify noise interference.

5. **Conclusion**

The temperature control system of electric heating furnace is designed in this paper. The main hardware used is PLC (programmable controller) and touch screen to control the temperature system intelligently. According to the actual situation and cost budget, the controller of this paper chooses Mitsubishi FX2N-48MR series PLC. In order to achieve intelligent control, digital PID control algorithm is needed, and GT1040-QBBD-C is used for the convenience of staff operation Series touch screen to achieve human-computer interaction, the start and stop of the system, temperature setting with the touch screen can be very simple operation, temperature change can also be intuitive display monitoring and the whole system can be automatically set. In the industrial production, the human-computer interaction interface of the control system designed in this paper is easy to learn and operate, and it is very convenient. The whole temperature control system self-tuning shows great advantages.
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