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Temperature Monitoring System based on PLC

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Abstract

The programmable logic controller (PLC) is an industrial control computer; it is the new automatic device inherited computer, automatic control technology and communication technology. System temperature signal detected by the temperature sensor. The temperature transmitter will be the temperature value converted into a voltage signal of 0-10V into PLC. PLC voltage signal setting compared to the temperature deviation after PID operation; the system will issue a temperature control signal to reach the electric heater voltage control. So that it implements a continuous monitoring and control of the temperature. The temperature monitoring system in the industrial field has a certain value.

Keywords*: temperature monitoring, PID, control, configuration software, PLC*

1. Introduction

The temperature is commonly used in the industrial production process parameters, while closely related to people's lives. In many fields of scientific research and production practice, the temperature control occupies a very important position, especially in metallurgy, chemical industry, building materials, food, machinery, petroleum and other industries, has a pivotal role. Programmable Logic Controller (PLC) is an industrial control computer; inherit computer, automatic control technology and communication technology as one of the new automatic device. It has strong anti-interference ability and cheap price, reliability, programming is simple, easy to learn and use, by the project operator, like in the industrial field, the PLC has been widely used in various areas of industrial control.

The configuration software is an automatic control system monitoring layer a software platform and development environment. Its flexible configuration will provide users with software tools to quickly build industrial automatic control system monitoring and general level.

Before the appearance of the configuration software, the industrial areas of the user by hand or entrust a third party to write HMI (Human Machine Interface software), it has developed a long time, low efficiency and poor reliability shortcomings; or buy a dedicated industrial control systems. It usually is a closed system, the choice of small, often can not meet the demand, and it is difficult to exchange data with the outside world, upgrade and add functionality to be severely restricted. The emergence of the configuration software configuration software allows users to build a system which best suits their own applications.

With the rapid increase in the level of industrial automation, computer widely used in the industrial field, a wide range of control equipment and process monitoring devices in industrial applications, industrial control software has been unable to meet the diverse needs of the user. In the development of the traditional industrial control software, once the industrial controlled object changes, it is necessary to modify the source code control system, leading to long development cycle; industrial control software has successfully developed so that each control different repeated low usage, it's expensive. General industrial automation configuration software can be a good solution to the problems of traditional industrial control software, enables users to any configuration of objects and control purposes, the completion of the final automation control engineering [1].

This paper designed a temperature monitoring system based on Mitsubishi PLC. This system through the analog input module capable of temperature changes in the amount of conversion to digital into the PLC, PID controller temperature reaches the set value, it compares the current temperature and set temperature, if beyond the set value the system will

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alarm. At the same time, the system was adopted MCGS upper monitoring system, to achieve human-computer integration.

2. System Hardware Block Diagram

The temperature control system hardware block diagram is shown in Figure 1. System controlled object is a signal of the temperature, and the temperature sensor detects the temperature of the heating tube. Through the output module, the temperature value is converted to a digital signal fed to the PLC module. PLC to the temperature signal obtained with the temperature settings are compared, and then get the temperature deviation after PID operation, it will issue a control signal and the corresponding operation, such as higher than 50 degrees Celsius, and the alarm [2].

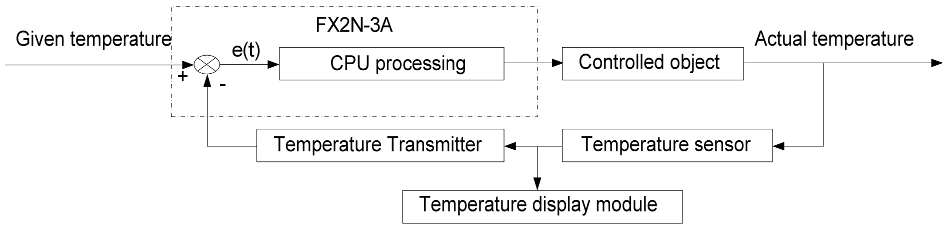

Figure 1. System hardware block diagram

2.1. I/O Assignment

Input interface: (X0) button, start button; (X1) button, stop button.

Output interface: (Y0) start indicator; (Y1) stop light; (Y2) the normal operation of light; (Y3) alarm indicator; (Y4) heating lamp; Y5-Y14: LED lights a segment-h segment. Y15-Y17: LED chip select signals.

2.2. PID Control System

PID is the abbreviation of proportion, differentiation, integration, and PID controller is the most widely used closed-loop controller. PLC analog PID control, the use of the following methods:

(1) PID process control modules: process control module contains the A/D converter and D/A converters, PID control procedures designed PLC manufacturers, and stored in the module, the user use only need to set some parameters, very convenient to use, a module can control a few road or even dozens of road closed loop. However, the relatively high value of this module, generally used in large and medium-sized control system.

(2) PID instruction: many PLC has for PID process control module and the PID control function instruction, for example FX2N PID instruction. They are actually used for PID control subroutine used in conjunction with analog input / output modules, you can get a similar process with PID control module effect, but the price is much cheaper.

(3) The edited program PID closed-loop control: Some PLC PID process control module and the PID instruction. Although it can use the PID control instructions, but hope the other improvements PID control algorithm. In the above case, it requires the user to the preparation of the PID control program.

(4) closed-loop control of the inverter: Inverter does not generally have a PI controller or PID controller. For this type of closed-loop control system of constant pressure water supply, the feedback signal can be received feedback signal input terminal of the inverter, inverter internal control its closed-loop control [3]. PLC through communication or switch signal to the inverter frequency reference signal and the start and stop commands. If the feedback signal is sent to the PLC analog input module with PLC PID closed-loop control, analog signal as a D/A converter output inverter frequency of a given signal, the need to increase the PLC analog input modules and analog output module, will increase the cost of hardware.

2.3. PID Algorithm

In engineering practice, the most widely used regulator control law for the proportional, integral, differential control, PID control for short. When not fully understand a system and the controlled object, or can not be measured through effective means to obtain the system parameters, the most suitable PID control technology. PID controller is based on the error of the system, using a proportional, integral, differential, the calculated control amount is controlled.

Proportional (P) control: proportional control is one of the most simple, the most commonly used control mode, the controller output and input error signal proportional relationship. When only a proportional control system output, there is a steady-state error.

Integral (I) control: integral control, the controller output and input error signal proportional to the integral relationship. An automatic control system, steady-state error into the steady state, this system is called steady-state error of the system. In order to eliminate the steady state error, must refer to the integral term in the controller. The integral term for the calculation of the error depends on the time integral of the increase over time, the integral term increases. Thus, even when the error is small, the integral term will increase over time to increase, he pushed the controller output is increased, so that the steady state error is further reduced until it is equal to zero. Therefore, using proportional + integral controller can make the system into the steady-state is no steady-state error [4, 5].

Derivative (D) control: differential control, the controller output is proportional to the input. The automatic control system in the adjustment process to overcome the error may oscillations and even instability. The reason is the presence of large inertial assembly or after assembly having suppression error of the role change; the variation is always behind the error. The solution is to inhibit the role of the error changes ahead. That is, in the control wherein the reference only the proportional term is often not enough, the role of the proportional term only enlarge the amplitude of the error term, and the current increase of the differential term, it can predict the trend of change in the error. Thus, proportional + derivative control to advance so that the role of suppression error equal to zero, or even negative, thus avoiding the serious overshoot of the amount charged. Proportional + derivative controller can improve the dynamic performance of the system in the mediation process [6].

PID controller can adjust the loop output, so that the system reaches a steady state. The relationship of the deviation e, the input amount r and the output c is given by:

$$e(t) = r(t) - c(t) \qquad (1)$$

PID control loop block diagram is shown in Figure 2.

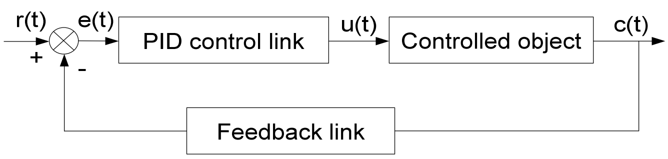

Figure 2. PID control loop

The output of the controller is given by:

$$u(t) = K_p[e(t) + \frac{1}{T_i}\int_0^1 e(t)dt + T_d \frac{de(t)}{dt}] \qquad (2)$$

In the where:
u(t)-PID loop output
K_p-Proportionality coefficient
T_i-Integral coefficient
T_d-Differential coefficient
PID regulator transfer function is given by:

$$D(s) = \frac{U(s)}{E(s)} = K_p[1 + \frac{1}{T_i s} + T_d s \quad (3)$$

Digital computer processing function relationship must be discretized continuous function the sampling deviation cycle, and then calculate the output value. The PID discretization law is as shown in Table 1.

Table 1. PID Discretization Law

Analog form	Discrete form
$e(t) = r(t) - c(t)$	$e(n) = r(n) - c(n)$
$\frac{de(t)}{dT}$	$\frac{e(n) - e(n-1)}{T}$
$\int_0^t e(t)dt$	$\sum_{i=0}^{n} e(i)T = T\sum_{i=0}^{n} e(i)$

The discrete PID output equation is given by:

$$u(n) = K_p\{e(n) + \frac{T}{T_i}\sum_{i=0}^{n} e(i) + \frac{Td}{T}[e(n) - e(n-1)]\} = u_p(n) + u_i(n) + u_d(n) + u_0 \quad (4)$$

In the formula, Proportional is given by:

$$u_p(n) = K_p e(n) \quad (5)$$

Integral term is given by:

$$u_i(n) = K_p \frac{T}{T_i}\sum_{i=0}^{n} e(i) \quad (6)$$

Differential term is given by:

$$u_d(n) = K_p \frac{T_d}{T}[e(n) - e(n-1)] \quad (7)$$

In the above formula, the integral term is including a first sampling period to a cumulative value of all the errors of the current sampling cycle. Calculation, there is no need to retain all the error term of the sampling period, and only need to retain the integral sum. It can use the PID instruction in the PLC to control algorithm amount.

PID parameter tuning method is to determine the regulator proportion coefficient P, integration time T_i and derivative time T_d to improve the system's static and dynamic characteristics of the system transition process to achieve the most satisfied with the quality indicators requirements generally can by theoretical calculations to determine but the error is too large. Currently, the most widely used engineering tuning method, as the empirical method, the attenuation curve method, critical proportions and reaction curve method. The experience method called trial and error method, it does not require the prior calculations and experiments, but using a set of empirical parameters, based on operating experience, the constantly changing parameters in accordance with the effect of the response curve for a temperature control system, and PID parameters law is shown in Table 2.

Table 2. Temperature Control PID Experience Parameters

Controlled variable	regular	Proportionality	Integration time (minutes)	Derivative time (minutes)
Temperature	Lag larger	20-60	3-10	0.5-3

2.4. PID Controller Circuit

PID controller circuit is shown in Figure 3. The arithmetic circuit of the controller is a concatenation of the two arithmetic circuits of the PD and PI. Operational amplifier A1, A2, A3, 24V single power supply, the same phase and the inverting input can not work around at 0V input measurement signal is based on the starting 1-5V voltage to zero volts, the input circuit to conduct voltage level shifting, the deviation level of the voltage is raised to 10V as a starting point of the change, so the signal voltage u01, u02, u03 are to 10V starting reference. In the amplifier A1 proportion differential circuit, the derivative action is needed to introduce or excision.

When the differential action is not required, the switch K1 is in the disconnected position, the amplifier A1 is proportional amplifier. Without disturbance introduced differential, differential capacitance C_D will not work through the switch K1 is connected to the voltage divider on charging the capacitor C_D. So, the need to introduce a differential effect, the switch K1 can be readily turned "on" position, without causing a sudden jump of the output voltage u_{02} of the impact, i.e. without the process being controlled [7, 8].

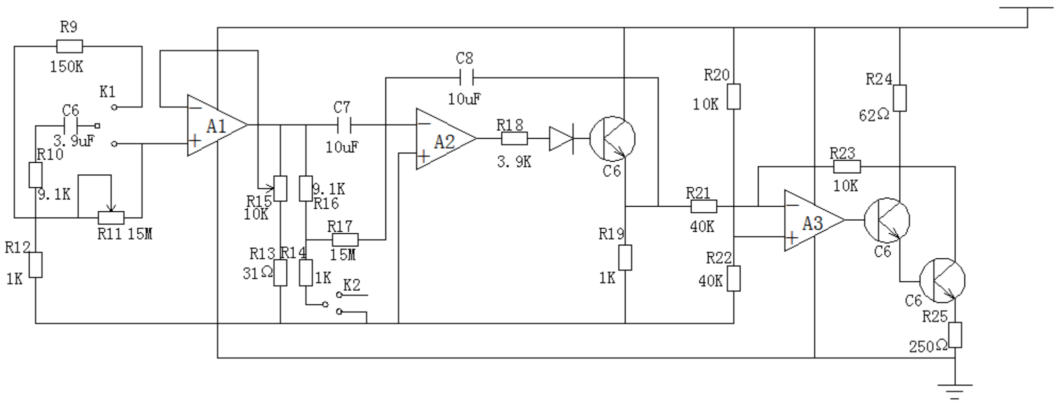

Figure 3. PID Control Circuit Diagrams

In Figure 3, the differential gain K_d=n=10 the differential time T_d = n$C_D R_D$, C_D = 3.9μF, R_D= 62 kΩ-15MΩ then to T_d =0.04-10min, a range of variation of the feedback voltage ratio is 1-250. In amplifier A2 proportional integral circuit, switch K2 is a integration time multiplied switch. When placed "× 1" position, 1kΩ resistor one end open. K2 placed in the position of the "× 10", input voltage u_{02} after 1/10 partial pressure connected to the integrating resistor R_1. Integral velocity slows m times, because no change in the proportion of degree, so the integral time T_i =$m R_1$C, consider to add to the R_2 signal amplitude m times, the ultimate limits of the integral output amplitude will drop, so in this case the integral gain is also decreased to m times. In the circuit C_1=C_M=10μF, R_1= 62kΩ-15MΩ, set A2=10^5, when m= 1, T_i =0.01-2.5min, K_i=10^5.

Resistor connected to the output terminal of amplifier A2, a diode D1 and the emitter of the transistor T_1 constituting plate follower. The amplifier A3, the transistors T_2 and T_3 form a voltage-current conversion of the output circuit, it PID circuit 1-5V between the change in output voltage u_{03} converted to a current output of 4-20mA, 250Ω resistor R_{14}, then the 4-20mA converter 1 -5V voltage output. u_{03} based changing voltage (10V) is as a starting point, while the SCR trigger voltage control signal is connected between the output terminal and the ground, therefore the output circuit must also assume the task of level shifting [9].

3. System Software and Configuration Software

Software flow chart of the system consists of four parts, and they are the main program flow chart, flow chart of temperature setting, alarm subroutine flowchart and interrupt the program flow chart. The main program flow chart is shown in Figure 4.

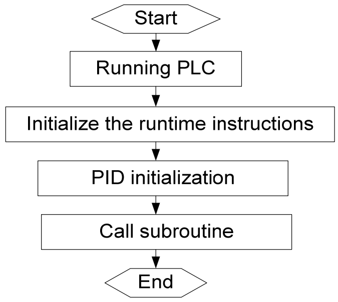

Figure 4. Main program flowchart

With the rapid increase in the level of industrial automation, computer widely used in the industrial field, one of the requirements of industrial automation is increasing, a wide range of control equipment and process monitoring devices in industrial applications, making the traditional industrial control software Unable to meet the diverse needs of the user. MCGS the emergence of industrial control configuration software provides a new way to solve some practical engineering, because of its ability to solve the problems of traditional industrial control software, allowing users to any group under the control object and control purposes state, completed the final automation control engineering. MCGS Chinese industrial automation control configuration software is a set of 32 engineering software, stable operation in Window95/98/Me/NT/2000 other operating systems, set animation, process control, data acquisition, equipment control and output, data transmission network, hot standby, engineering reports, data and curves and many other powerful functions in one, and support at home and abroad many data acquisition on the output device, and is widely used in the petroleum, power, chemicals, iron and steel, mining, metallurgy, machinery, textile, aerospace, construction, materials, refrigeration, transportation, communications, food, manufacturing and processing industry, water treatment, environmental protection, intelligent buildings, laboratories and other engineering fields [10].

MCGS to provide users with a complete program to solve practical engineering problems and development platform, able to complete on-site data acquisition, real-time and historical data, alarm and security mechanisms, process control, animation, trend curve and statements output, as well as enterprise monitoring network functions. MCGS, users do not have the knowledge of computer programming can be developed in a short period of time easily completed a run stable, full-featured, low maintenance and a highly specialized computer monitoring system [11].

MCGS has a simple, good visibility, maintainability, the salient features of the high-performance, high reliability, and has been successfully used in the petrochemical industry, steel industry, electric power systems, water treatment, environmental monitoring, machinery manufacturing, transportation, energy, raw materials, agricultural automation, aerospace and other fields, the actual operation of the various field of long-term, stable and reliable system.

MCGS configuration software top five part, MCGS configuration software created works by the master window, the device window, the user window, the real-time database and run strategy in five parts, each part of the configuration operation to complete the work, has different characteristics. MCGS is shown in Figure 5.

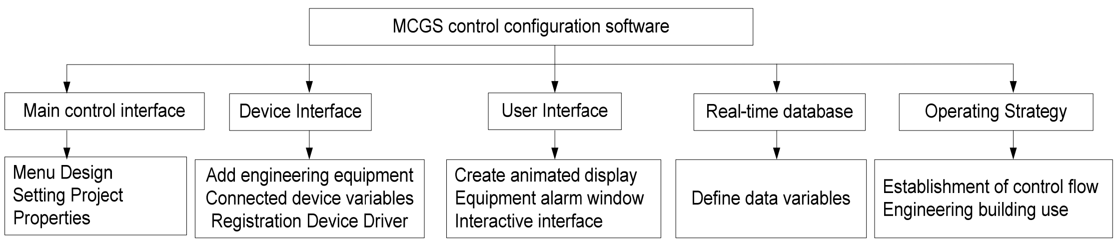

Figure 5. MCGS composition

Host monitoring, temperature monitoring system, it needs to create the following variables: the start button, stop button, start light, stop light, normal indicator, stop lights, alarm indicator and temperature display. Where in the temperature display type is numeric.

Graphical interface system ride by the graphic object is stationary, these graphic object animation design, truly describe the state of the outside world objects change, achieve process real-time monitoring purpose. MCGS graphics animation designs the user window graphic objects and data objects in the real-time database to establish the correlation connection and set the animation properties. The system is running, the appearance and state of the graphics object, driven by the real-time collection of data objects in order to achieve the graphics animation. MCGS the alarm processing as a data object attributes, encapsulated in data objects from the real-time database automatically processed. When the value or state of the data object is changed, the real-time database to determine whether an alarm or the alarm has been generated corresponding data object has ended, and the generated alarm information to the rest of the system, the same time, the real-time database according user configuration settings, the alarm information is stored in the specified save the database file.

The defined alarm operation is as follows: temperature variable in the real-time database, double-click the "temperature", select "Allow alarm processing, alarm attribute; alarm settings, select" limit alarm, the alarm value is set to: 50 degrees; alarm Note: the temperature exceeds the upper limit of 50 degrees when the alarm; check alarm information automatically saved to disk properties. Real-time data reports real-time data variables for the current time display and printing certain report format (user configuration): reflect the amount of instantaneous, real-time data reports through the MCGS system real-time form components configured to display real-time data statements [12, 13].

Analog devices MCGS software to generate a set of the simulation curve data, according to the parameters set for the user commissioning works. The member can generate standard sine wave, square wave and triangle wave; saw tooth wave signal and its amplitude and period can be set arbitrarily.

4. Conclusion

The programmable controller has strong anti-interference ability and cheap price, reliability, programming is simple, easy to learn and use by the project operator, like in the industrial field. This article is designed temperature monitoring system based on Mitsubishi PLC. PID controller allows the temperature reaches the set value, and the system compares the current temperature and set temperature, temperature control; beyond the set value, the system will alarm. The system has good stability, high reliability, and broad application prospects.

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