

Precise Control of Process Temperature using AI-7048 Temperature Controller and Solid-State Relay (SSR) Control System

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Abstract: *Temperature is the most common process value measured in industrial processes. This paper focuses on how to accurately control process temperature without extensive operator involvement. The experiment was done in a controlled research laboratory using YUDIAN Technologies AI-7048 temperature controller, SSR, SIMATICS7-1200 PLC, STEP7 programming software. Serial communication using RS485 was established first and AI-7048 was able to automatically adjust power to the heater as temperature approached and exceeded the set point value.*

Keywords: process temperature, AI-7048 temperature controller, SSR, RS485 communication

1. Introduction

Temperature control in many industrial applications is an old science, taking off mostly during the industrial revolution [10] and spread throughout the world in the twentieth century. The control was very simple, it was mechanical in nature, involving turning a heater or cooling device on or off. Today, the techniques of temperature control are of immense importance and complex in most facets of industrial application.

The reason many process industries need precise temperature control is that, systems which cannot handle the energy's being turned on and off frequently need to be considered during the initial temperature control system design. For example, the system where the mass of the system is so great that temperature changes extremely slow for a temperature alarm, system like those used in superplastic forming machines [1].

For understanding and repeatability of this experiment, the reader should study further related material on AI-series temperature controller [8], STEP7 Professional V13 programming software (TIA Portal) [5], SIMATIC WinCC flexible and/or King View's for graphical user interfacing. General understanding of automatic control system [3] [2] and measurement and instrumentation principles [4]. Therefore, this paper focused on applying practical approach in achieving the precise control of temperature. This means that less or non-mathematical concepts will be used in this paper. Also, a simplified model of a mass of a heating system that showed how slow temperatures changes could be measured and analyzed.

The basis on which this paper is based is the irregular behavior of temperature on the large mass of system, and it therefore seek to find the solution to the question, how to control process temperature accurately without extensive operator involvement. This precise temperature control

system relies upon a AI-7048 controller, which accepts a temperature sensor as input. It then automatically compares the actual temperature to the desired set point and provides an output to a control element, the solid-state relay (SSR).

2. Method

2.1 Temperature Control System Experiment

The process setup consisted of heating the mass system, the heating plate fitted with SSR controlled heater for on-line heating. Temperature sensor (thermocouple) was used for temperature sensing. The process parameter (temperature) was controlled by AI-7048 which manipulated heat input to the process. The temperature controller was connected to the SIMATICS7-1200 PLC through shielded twisted pair RS485 communication cable.

We connected the SIMATIC S7-1200 PLC to the central control computer with up and running STEP 7 Professional programming software and KingView software. The AI-706ME5 digital indicator was connected to the current transformer (labeled CT). The RS485 communication cable was connected to the SIMATIC S7-1200 PLC. See figure 1.

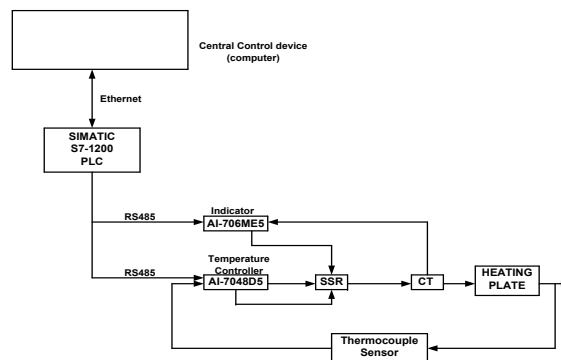


Figure 1: System schematic arrangement of a closed control loop

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The specifications of the system components are as follows;

- 1) Type of control: closed control loop
- 2) Control units:
AI-7048D5, AI-706ME5, SIMATIC S7-1200 PLC with CPU 1212C DC/DCRLY- (6ES7 212-1HE40-0XB0)
- 3) Communication: RJ45 end to end terminated Ethernet cable, shielded twisted pair RS485 cable.
- 4) Temperature sensor: type K thermocouple PT100
- 5) Heating process switching: proportional power controlled solid state relay (SSR) with input voltage 3-32V DC, 8mA, load current of 40A and voltage 24-240V AC.
- 6) Other devices include current transformer (CT input =50A AC, output=4-20mA DC), 12V DC coil relay, 240 V AC contactor and 240V AC electric heater. See figure 2.

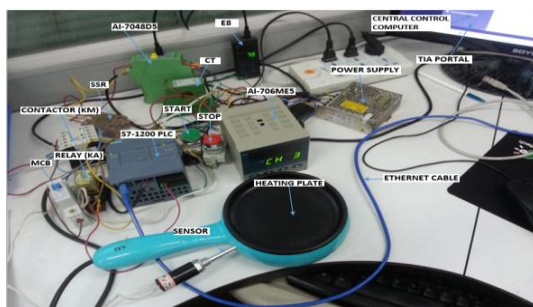


Figure 2: Photo illustrating equipment wired together

A step input was applied to SSR by AI-7048 temperature controller. AI-7048 received its signals from sensor which was displayed on AI-7048 hand-held monitor (labeled E8) and on central control computer. The system components were connected as per the designed electrical circuit shown in figure 3. This is the output from figure 4 step 2.

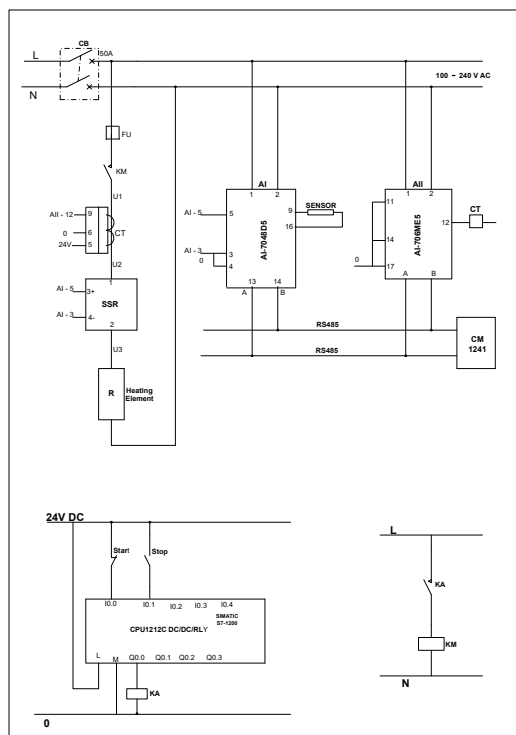


Figure 3: Schematic diagram of hardware and control circuit

2.2 Flowcharts Method

We used flowcharts in this paper to show how the circuits were designed and software configured. This methodsimplified the difficult of writing step by step instruction for workflow. Figure 4 shows steps that were followed from electrical circuit design stage to writing STEP 7 professional program was done and figure5 shows how KingView software was configured. The key results from these flowcharts are presented in results section of this research paper.

2.3 Communication

Point-to-point (PTP) communication is serial communication that uses standard UARTs to support a variety of baud rates and parity options. The RS485 communication module (CM) and RS485 communication board (CB) provides the electrical interfaces for performing the PTP communication [5].

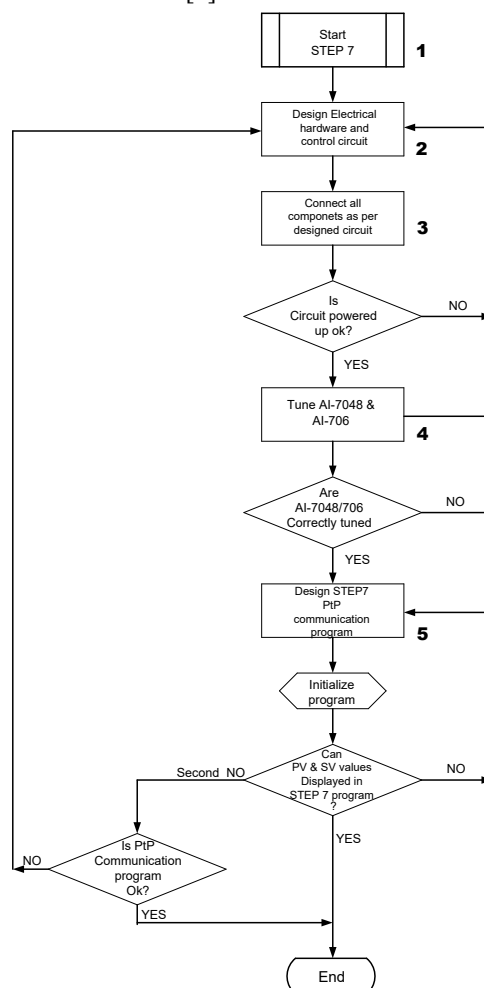


Figure 4: Flowchart showing design procedure from schematic control to STEP 7 program

a) Programming the STEP7 professional V13 software for PTP communication

The PTP configuration and STEP7 program illustrates how the CPU of S7-1200 PLC can receive a message from the programmable controller (PC) and echo the message back to the PC.

b) RS-485 Communication

The RS485 standard is the most versatile one of the RS interface standards. RS 485 permits a “multidrop” network connection on two wires (shielded twisted pair-STP cable) that is multi-transmitter and multi-receiver. It allows reliable serial data communication with data rates up to 10Mbps [5].

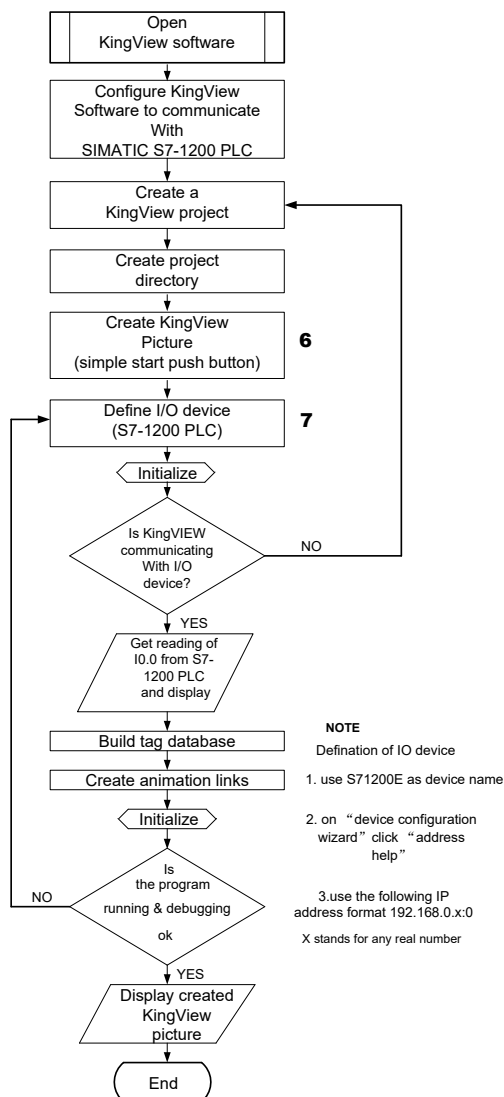


Figure 5: Flowchart showing KingView configuration procedures

We connected the communication interface of the CM1241 RS485 module to the RS485 interface of the SIMATIC S7-1200 PLC. STEP 7 professional program uses a global data block (DB) for the communication buffer, a RCV_PTP instruction to receive data from the AI-7048D5 temperature controller and a SEND_PTP instruction to echo the buffer back to the controller [5]

c) AI-BUS Communication Protocol

The AI series instruments are equipped with communication functions from the RS-485 interface and PC loader interface, which enables the transmission and reception of data between such devices as PC, PLC and HMI etc. The communication system is composed of a master and slave relationship. For security, RS 485 repeater is needed when slaves over 60 units. The master can only communicate with

one slave at a time. Therefore, each slave is specified by the “Address code” setting from “0” ~”80”. Address code is decided by the parameter “ADDR” [9]. The communication system with AIBUS protocol always operate using a method whether the master first sends a command message and the applicable slave replies with a response message. The command message and response message are composed of 4 parts: the address number, function code, parameter code, check code. Read command standard: address number+52H (82) + parameter code+0+0+check code [9] [8].

2.4 Description of Devices Used

a) SIMATIC S7-1200 PLC

The S7-1200 series is a line of programmable logic controllers that can control a variety of automation applications. Compact design, low cost, and a powerful instruction set make the S7-1200 a perfect solution for precise control of process temperature. It is window-based programming tool that gave us the flexibility we needed for the research.

b) Solid-State Relay (SSR)

An SSR is a mechanically passive version of its older counterpart the electromechanical relay (EMR), providing essentially the same performance, but without the use of moving parts. It is a totally electronic device that depends on the electrical, magnetic components to accomplish its isolation and relay-switching functions [7].

c) KingView Software

KingView software, provided by Wellin Control Technology company of China is a multifunction HMI software that can be used for automated monitoring of control process in industry. It provided us with integrated, flexible and easy to use development system, with a wide range of functions making it very easy for control system engineers to use. The system can create, test and dispose of automation applications and can quickly connect, transmit and record real-time information. This allowed us to monitor the process in real time and control the process temperature accurately.

d) AI-7048 Temperature Controller

AI-series instruments produced by YUDIAN TECHNOLOGIES of China[8] is capable of measuring and controlling four channels of temperature, and every channel can define its own input specification. AI-7048 can either work independently or cooperate with computer or PLC. It has advanced communication functions, compatible with the communication protocol of other AI series instruments. AI-7048 poses 0.1 accuracy, universal input and output, supports RS485, universal power supply of 100-240V AC or 24 V [8].

The summary description of features and capabilities of some devices/software explains why we choose to use them for precise control of process temperature research experiment.

3. Results and Discussion

The results of SIMATIC STEP 7 professional software point to point communication program. See figure 6.

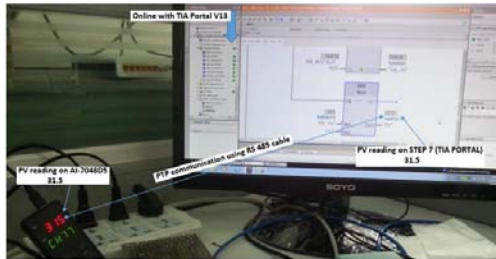


Figure 6: Photo of PV readings from E8 and CCC running TIA portal

Configuration of KingView graphical user interface software with the process in real-time. The procedure is outlined in figure 5. See figure 7.

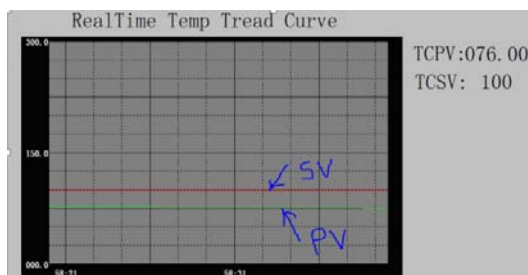


Figure 7: Photo of real-time trend curve from KingView

Precision control of process temperature.

Table1: Data set of Temp, Power & SV

time(s)	Temperature(.c)	Power(w)	Setpoint(SV)
1	50.1	1248	100
2	70.3	1224	100
3	75.2	0	100
4	100.1	0	100
5	102.1	0	100
6	99.4	1248	100
7	98.2	744	100
8	98.6	360	100
9	99.7	408	100
10	100	24	100
11	100.1	0	100

Table 1: Data set of temperature, Power and Setpoint.

The graph of table is shown in figure 8. It was drawn with microsoft office 2016 excel.

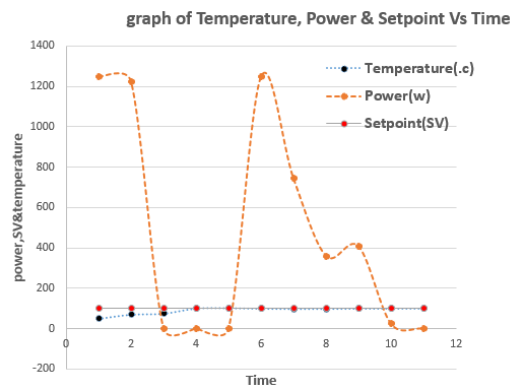


Figure 8: Graph of showing plot of data set in table 1

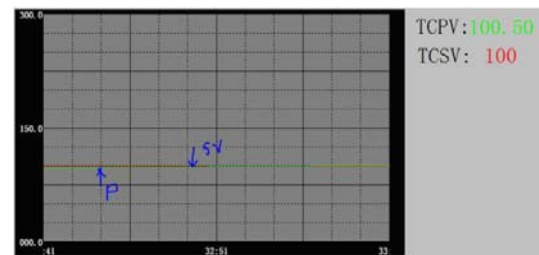


Figure 9: Real-time graph showing PV & SV against time



Figure 10: Real-Time graph showing PV exceeding SV



Figure 11: Graph showing PV being restored to SV

4. Control Algorithm

This refers to the method in which the controller attempts to restore system temperature to the desired level. If this was to be achieved, then precision control of process temperature can be achieved. For heating control, the output is on when temperature is below the set point, and off above set point since temperature crosses the setpoint to change the output state, the process temperature will be cycling continually going from below setpoint to above and back below. This on-off control is usually used where a precise control is not necessary.

To achieve precise control of process temperature communication was first configured and tested as outlined in the flowchart in figure 4. Components were wired and Siemen's SIMATIC STEP 7 professional software program. Figure 6 was the results of successful point to point communication between hardware and software. As can be

seen from figure 6, we were able to read PV and SV real-time values on both hand-held monitor(E8) and central control computer. E8 was connected to AI-7048D5 as shown in figure 3 and 1.

Figure 7 shows the result of successful configuration of graphical user interface software. The steps of configuration are shown in figure 5. Any problem in step 6 and 7 of figure 5 could not have given us results in figure 5. the software was able to quickly connect, transmit and show real-time process information.

Because the system we were investigating was subject to wide temperature cycling and since our goal was to achieve high precision of process temperature. AI-series controller that uses both proportional control and PID control algorithm was used. A proportional controller decreases the average power being supplied to the heater as the temperature approaches set point. Table 1 shows the data set that was corrected during the process at initial temperature of 50.1.C. From table 1, it can be seen, numerically that at initial temperature, power was at its maximum, 1248 wats, enough to start rising process temperature. As temperature approaches 100.C power reduced to almost zero value. The data set was plotted in the graph as shown in figure 8. From this figure, the average power being supplied to the heater fluctuated quite a lot.

Figure 9 shows the real-time graph obtained from KingView software. TCPV stands for temperature controller process value while SV stands for set value or setpoint. From figure 9 it can be seen that process temperature was precisely controlled. The result of controller decreasing average power to the heater is shown in figure 11 while figure 10 shows the PV exceeding SV values. The controller took action and brought temperature back to SV as shown in figure 10.

5. Conclusion

Serial communication between hardware and software was successful configured. RS 485 communication cable was used. From the results obtained, precise control of process temperature was achieved. Automatic recording of real-time data from KingView was not achieved because the trial version of the software was used. Close attention was paid to safety as no injuries to humans or equipment was recorded during the experiment.

6. Acknowledgements

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