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Design of a PLC Based Temperature Controlled System

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***Abstract**. Temperature control plays a critical role in various industrial applications, ensuring optimal process efficiency, product quality, and output. The programmable logic controller (PLC) has emerged as a versatile tool for implementing temperature control systems due to its advanced capabilities in computer control, communication, and automation. This work presents an approach for designing a temperature control systems using Programmable logic controller (PLC). The system employs thermostats, which is a form of temperature sensor to detect and convert temperature values into voltage signals, which are then processed by the PLC through ladder algorithms. The temperature status of the thermostats is used to switch OFF or ON electric heaters in a bid to reduce or increase the temperature of a system. The PLC technology enables continuous monitoring and control of temperature, ensuring precise regulation in industrial settings such as material processing, boiler heating, and kiln operations. Additionally, the paper highlights the advantages of PLC-based temperature control systems, including high efficiency, stability, precision, and remote monitoring capabilities. The findings suggest that PLC-based temperature control systems offer promising solutions for achieving reliable and effective temperature management in diverse industrial environments.*

***Keywords –** Temperature control, PLC, thermostat, electric heater.*

INTRODUCTION

A temperature control system plays a crucial role in various industries and applications, ensuring optimal operating conditions, product quality, and energy efficiency [1, 2]. One effective approach to temperature control is the use of Programmable Logic Controllers (PLCs), which provide robust and reliable automation capabilities. PLCs offer advanced control functionalities, precise monitoring, and flexible programming options, making them well-suited for temperature regulation tasks [3]. A temperature control system based on PLC technology involves the integration of temperature sensors, actuators, and a PLC unit. The temperature sensors detect the current temperature of the system or environment and relay this information to the PLC. The PLC then analyses the temperature data and compares it to a predefined set point [4]. Based on this comparison, the PLC activates or adjusts the connected actuators, such as heating or cooling devices, to achieve and maintain the desired temperature.

The utilization of PLCs in temperature control systems brings several advantages. Firstly, PLCs provide high-speed processing capabilities, allowing for real-time temperature monitoring and rapid response to temperature fluctuations [4]. Secondly, PLCs offer precise control accuracy, ensuring that the temperature is regulated within tight tolerances. Additionally, PLCs can be programmed to accommodate complex control algorithms, incorporating features like PID (Proportional-Integral-Derivative) control for improved stability and performance [5, 6].

Moreover, PLC-based temperature control systems provide flexibility and scalability. They can be easily customized and adapted to different environments, process requirements, and temperature ranges. PLCs offer the ability to create user-friendly human-machine interfaces (HMIs) for convenient temperature parameter adjustments and system monitoring [4]. Furthermore, PLCs can be integrated with other automation systems, such as SCADA (Supervisory Control and Data Acquisition), for centralized control and data management.

In the research paper titled "Temperature Monitoring System Utilizing PLC," Ding and Li (2013) presented a temperature control system that incorporated a Mitsubishi PLC and PID control for monitoring and regulating temperature. The system employed a temperature sensor to detect the temperature of a heating tube. The sensor's readings were converted into a digital voltage signal ranging from 0 to 10 V, which was then processed by the PLC. A comparison was made between the obtained temperature readings and a predetermined temperature set point. Through a PID operation, the deviation from the set point was calculated, and if the current temperature exceeded the set point, an alarm was activated. The researchers concluded that the system exhibited affordability, reliability, and a robust resistance to interference [7, 8].

Wei (2016) presented a conference paper titled "Design and Implementation of a PLC-based Industrial Temperature Control System." The study addressed the challenges associated with low accuracy and slow response in automatic temperature controllers used for boiler heating and material processing. To overcome these challenges, the author utilized a Siemens S7 200 PLC to develop a temperature control system. The system incorporated a heating plate and a fan for temperature regulation. The control algorithm was based on a combination of traditional PID control and fuzzy control techniques. To evaluate the system's performance, simulations were conducted using MATLAB to assess its precision, stability, and robustness. The testing of the system demonstrated its high stability, reliability, and resistance to interference.

Zhao and Wang (2021) presented a research paper titled "Implementation and Investigation of a Kiln Temperature Control System Based on PLC." The paper focused on the crucial aspect of temperature control in kilns, which are essential heat-consuming devices used for product calcination. The authors emphasized the significance of precise temperature control in ensuring system efficiency and product quality. It was observed that the existing traditional methods of temperature control could not guarantee a consistent temperature in the kiln. To address this issue, the researchers employed a PLC in conjunction with a PID control algorithm to develop a temperature control system specifically tailored for the kiln. The study concluded that the developed system exhibited efficient control capabilities, successfully achieving the objective of automated temperature control in the kiln.

This work explored the design, components, operation, and potential applications of PLC-based temperature control systems in boilers. The system developed has a unique advantage of flexibility such that the temperature ranges can be varied with respect to unique conditions of devices whose temperature is to be regulated. Its flexibility allows for incorporation into more advanced devices as this design is not tailored to a single device.

The development and implementation of the temperature control system using PLC technology offer numerous benefits, including enhanced temperature regulation, increased efficiency, reduced energy consumption, and improved product quality. By leveraging the capabilities of PLCs, industries can optimize their temperature-dependent processes, ensuring optimal performance and meeting the desired temperature conditions for various applications. dependent processes, ensuring optimal performance and meeting the desired temperature conditions for various applications.

METHODS

1. Materials Used

Thermostat

A thermostat is a device used to regulate and control the temperature of a system or space. It is commonly used in heating, ventilation, and air conditioning (HVAC) systems to maintain a desired temperature level. The thermostat contains a sensor that measures the current temperature and compares it to a pre-set temperature called the set point. When the measured temperature deviates from the set point, the thermostat triggers a response to adjust the heating or cooling mechanisms accordingly. This response can include activating or deactivating heating or cooling systems, such as furnaces, air conditioners, or heat pumps, to maintain the desired temperature. Thermostats can be analog or digital and may offer additional features such as programmable schedules, energy-saving modes, and remote control capabilities. XH-W3001 24V, 240W thermostat was used in this paper.

Electric heater

An electric heater is a device that converts electrical energy into heat energy. It is designed to generate heat by passing an electric current through a resistive element, usually made of chrome or similar materials with high electrical resistance. When the electric current flows through the resistive element, it encounters resistance, which causes the element to heat up. The heat produced is then transferred to the surrounding environment, providing warmth and increasing the temperature of the space or object in proximity to the heater. Electric heaters are commonly used in homes, offices, and various industrial applications to provide localized heating and maintain comfortable temperatures. They come in different forms, including portable heaters, wall-mounted heaters, baseboard heaters, and radiant heaters, offering versatility and flexibility in heating solutions. 240 V AC, 5A electric heater was employed in this project.

Switch mode power supply (SMPS)

SMPS stands for Switched Mode Power Supply. It is a type of power supply that converts electrical power efficiently from one form to another using high-frequency switching techniques. SMPS is widely used in electronic devices and equipment to convert AC (alternating current) power from the mains supply to DC (direct current) power required by the device. The key component of an SMPS is a power switching device, typically a transistor or a MOSFET, which rapidly switches the input voltage on and off at a high frequency. This switching action allows for efficient power conversion and regulation. The SMPS also includes a transformer, rectifier, filter capacitors, and control circuitry to regulate the output voltage and current. The advantages of SMPS include high efficiency, compact size, lightweight, and the ability to provide stable and regulated DC power. They have largely replaced older linear power supplies due to their improved efficiency and performance. 24VDC, 20A SMPS was used for this project.

FX1N32MR PLC

The FX1N32MR PLC (Programmable Logic Controller) is a model of PLC manufactured by Mitsubishi Electric. The FX1N series is a compact and cost-effective PLC designed for small to medium-scale automation applications. It offers a range of digital and analog input/output (I/O) points, allowing for flexible control and monitoring of various devices and processes. The FX1N32MR PLC, specifically, is a variant of the FX1N series that offers 32 digital input/output points. This means it can accommodate up to 32 digital signals, which can be used to interface with sensors, switches, actuators, and other devices in an automated system. The PLC is programmed using specialized software, such as Mitsubishi's GX Developer, which allows users to create logic and control programs to suit their specific application requirements. The PLC I/O ports A rated 24VDC. While the output port has maximum of 2A.

2. Method of Construction

Three thermostats, namely TR1, TR2, and TR3, each set to temperature thresholds of 80 degrees, 100 degrees, and 101degrees respectively. When the system temperature falls below 60 degrees, two electric heaters, HT1 and HT2, are activated. When the temperature reaches or exceeds 80 degrees, thermostat TR1 sends a signal to the PLC, which then deactivates heater HT1. Similarly, when the temperature equals 100 degrees, thermostat TR2 sends a signal to the PLC, resulting in the deactivation of heater HT2. However, if the temperature goes beyond 100 degrees due to malfunction or external factors, thermostat TR3 sends a signal to the PLC, causing both heaters HT1 and HT2 to be powered off. This ensures that all heaters are turned off when the temperature reaches or exceeds 80 degrees. Indicator LEDs are utilized to indicate the active heater at any given time. Table 1 and Table 2 presents the system activities and PLC address assigned to components. while Figure 1 and Figure 2 presents the system block diagram and flowchart. Respectively.

Table 1. Activities of temperature controller system

S/N	Temperature Range	Thermostat	Action
1	Less than 60°C degrees	TR1	Activate heaters HT1 and HT2
2	Equals to 80°C	TR1	Deactivate heater HT1
3	Equals to 100°C	TR2	Deactivate heater HT2
4	Above 100°C	TR3	Deactivate heaters HT1 and HT2

Table 2. Program Alias, PLC Address Assigned and Ratings of components

S/N	Components	Alias	PLC –Address	Ratings	Contact
1	Start Push button	STR	INPUT-X000	24VDC	NO
2	Stop Push button	STP	INPUT-X001	24VDC	NC
3	Thermostat 1	TR1	INPUT-X002	24VDC	NC
4	Thermostat 2	TR2	INPUT-X003	24VDC	NC
5	Thermostat 3	TR3	INPUT-X004	24VDC	NC
6	Heater 1	HT1	OUTPUT- Y000	24VDC	N/A
7	Heater 2	HT2	OUTPUT- Y001	24VDC	N/A
8	Green LED	SYS_ON	OUTPUT- Y002	24VDC	N/A
9	Red LED	SYS_OFF	OUTPUT- Y003	24VDC	N/A

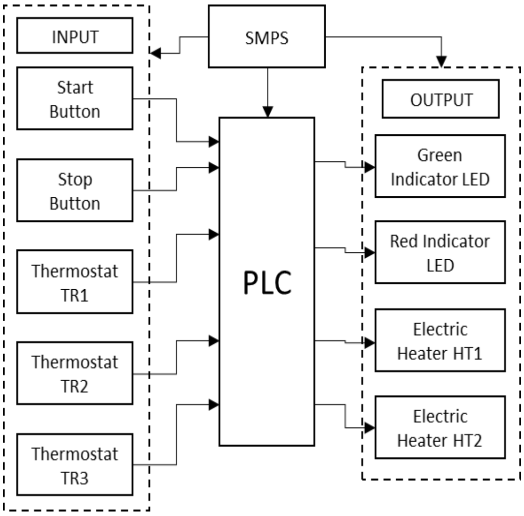

Figure 1. Block diagram

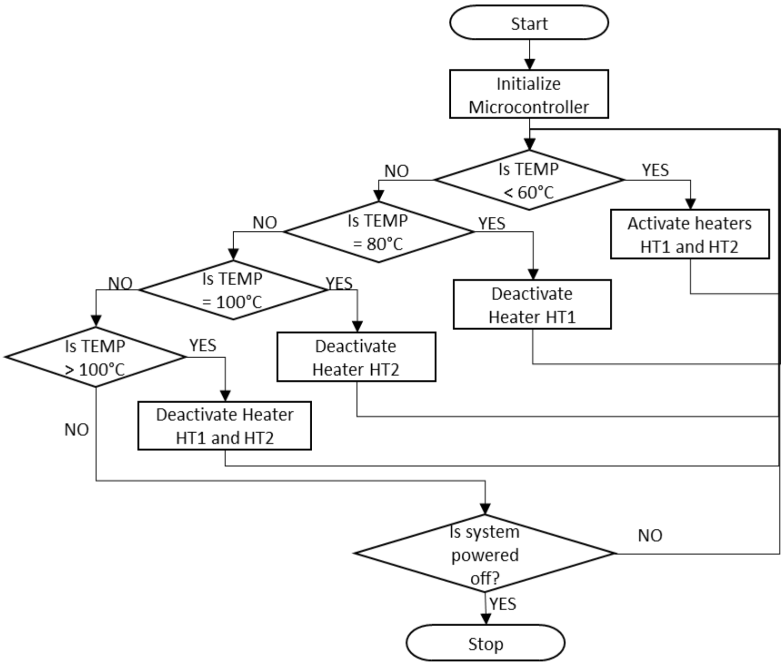

Figure 2. System Flowchart.

RESULTS AND DISCUSSION

System layout is presented in figure 3.

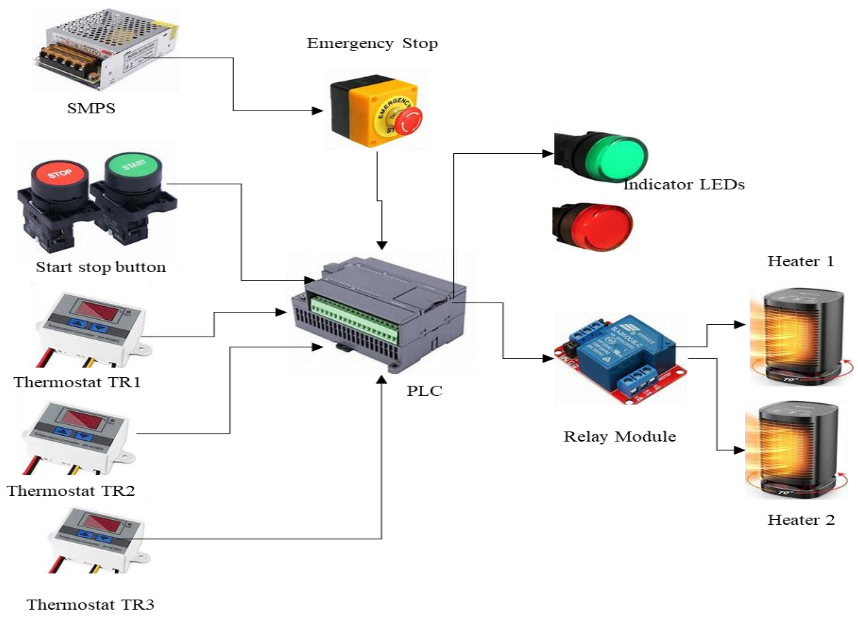

Figure 3. Physical layout of the system

Simulation Stage 1: In the initial simulation stage, the ladder logic was simulated to observe the behavior when the start button contact transitioned from logic 0 to 1. As a result, the system's red LED coil (SYS_OFF) was deactivated, while the green LED coil (SYS_ON) changed from logic 0 to 1. Figure 4 and Figure 5 illustrates the ladder logic for simulation stage 1.

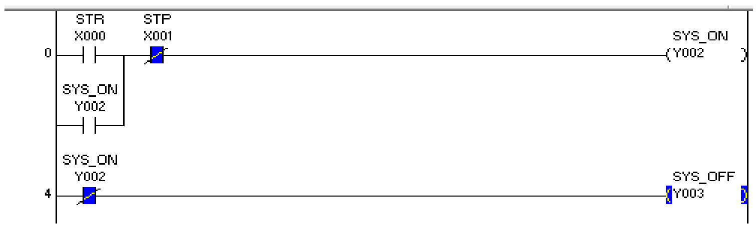

Figure 4. Simulation stage 1

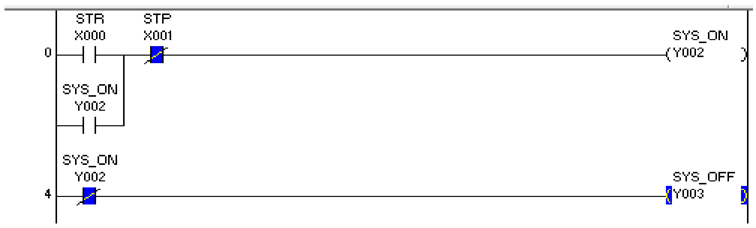

Figure 5. Simulation stage 2

Stage 2: Once the system is active, indicated by the SYS_ON coil being logic 1, the TR1, TR2, and TR3 contacts also become logic 1, signifying that the temperature is below 60, 80, and 100 degrees, respectively. Consequently, the HT1 and HT2 coils are activated and set to logic 1 (ON). Figure 6 displays the ladder logic for simulation stage 2.

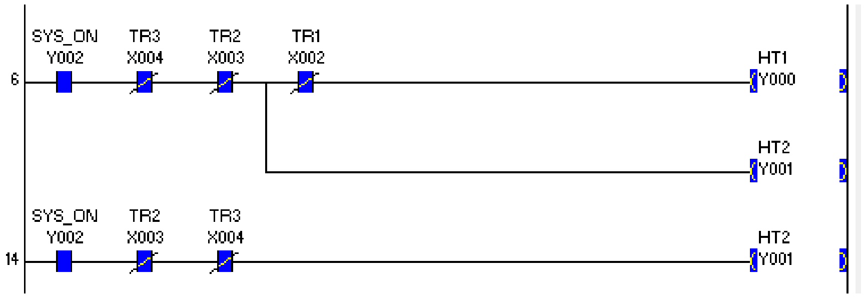

Figure 6. Simulation Stage 2

Stage 3: As the temperature of the system surpasses 80 degrees, the TR1 contact switches from logic 1 to 0. Consequently, the HT1 coil is set to logic 0, while the HT2 coil remains at logic 1. The ladder logic simulation for stage 3 is depicted in Figure 7.

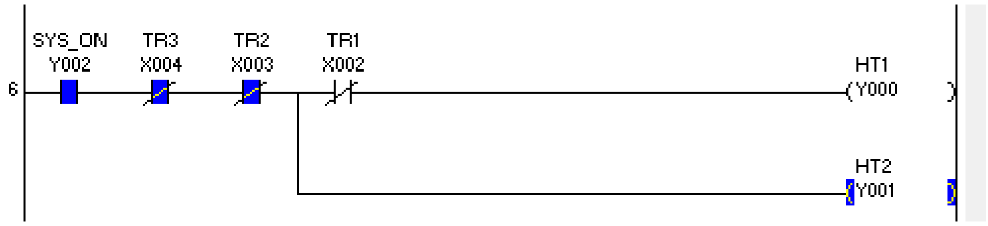

Figure 7. Simulation stage 3

Stage 4: When the temperature exceeds 100 degrees, the TR2 contact transitions from logic 0 to 1. Consequently, the HT2 coil changes from logic 1 to 0, resulting in the deactivation of heater 2. The ladder logic simulation for stage 4 is presented in Figure 8.

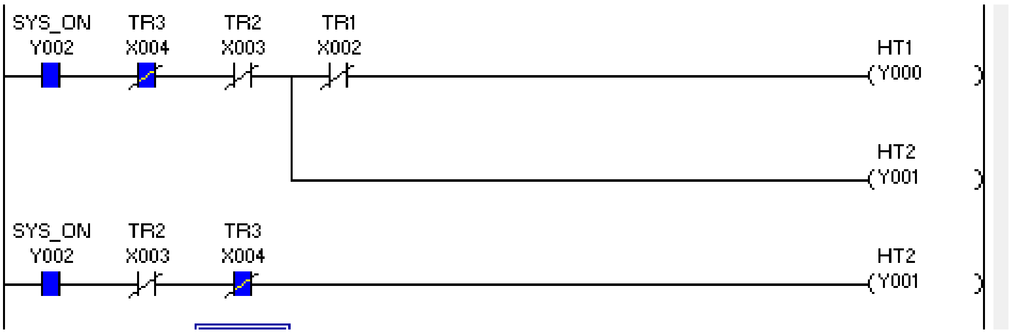

Figure 8. Simulation Stage 4

The simulation effectively demonstrated the ability to regulate the temperature of a system with speed and accuracy through timely response to signals from input devices.

CONCLUSION

In conclusion, this study demonstrates the effectiveness of using a Programmable Logic Controller (PLC) in designing temperature control systems for various industrial applications. The integration of thermostats as temperature sensors and the PLC's advanced capabilities in control, communication, and automation enable precise regulation of temperature in industrial processes. The findings highlight the advantages of PLC-based temperature control systems, including high efficiency, stability, precision, and remote monitoring capabilities. The use of electric heaters, controlled by the PLC based on the signals received from the thermostats, ensures optimal temperature management and enhances process efficiency. This research contributes to the development of reliable and effective temperature control solutions for diverse industrial environments.

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