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# An Effective and Low Cost Based Hybrid Model of Heater Control for Process Control Applications

Dr. S. Anthony Jesudurai[1], Deepak Raj S[2], Jaganadithyan M[3], Selvakarthik S[4]

[1]*Professor Electrical and Electronics, Dr. Mahalingam College of Engineering and Technology, Coimbatore, India*

[2,3,4]*Department of Electrical and Electronics, Dr. Mahalingam College of Engineering and Technology, Coimbatore, India*

***Abstract*—The prototype IoT-based efficient temperature monitoring and control system for a heater using a PT100 sensor and an operational-amplifier-based control circuit. The system is engineered to operate in two distinct modes— Electronic Control Mode and PLC Mode—ensuring high reliability, flexibility, and uninterrupted operation. A mode- switching mechanism is incorporated using a 24 V relay for automatic transition and a manual on/off switch for user- controlled switching. In automatic mode selection, the PLC energizes the relay, connecting the controller to the relay's normally open (NO) contact and enabling PLC-based temperature regulation. If a PLC fault occurs, the loss of the 24 V signal forces the relay to deenergize, shifting the controller to the normally closed (NC) contact, thereby activating the standalone Electronic Control Mode. The PT100 sensor provides accurate temperature feedback, which is processed through an op-amp based signal conditioning and control circuit to regulate the heater precisely. Additionally, an IoT support system is integrated to enable real-time monitoring, data logging, remote parameter configuration, and control through cloud connectivity. This enhances system visibility, user accessibility, and maintenance capability. Overall, the project provides a robust and intelligent temperature controller with dual mode operation, fault-tolerant design, making it suitable for industrial heating applications that require high accuracy, reliability, and remote operability.**

## I. INTRODUCTION

In many industrial operations, including chemical processing, manufacturing, and thermal systems, where maintaining accurate temperature levels directly affects product quality, safety, and efficiency, temperature control is a crucial necessity. A single control unit is frequently used in conventional temperature control systems, which might result in system failure or downtime in the event that a controller malfunctions. As a result, the demand for accurate, dependable, and fault-tolerant temperature control systems is rising. The capabilities of monitoring and control systems have been greatly improved in recent years by the integration of Industrial Automation technologies.

Automation Technologies improves system performance and lowers operational risks by enabling real-time data capture, remote supervision, and predictive maintenance. Analog electronic circuits offer quick and independent backup control, whereas programmable logic controllers (PLCs) are commonly employed in businesses for reliable and adaptable control

Using a PT100 temperature sensor, an operational amplifier-based control circuit, and a PLC-based control mechanism, this project offers an automatic-based effective temperature monitoring and control system for a heater. The system may operate in either a solo electronic control mode or under PLC control thanks to its dual-mode design.

The system's automatic fault-tolerant switching mechanism, which guarantees continuous functioning, crucial component. The system is controlled by the PLC under normal circumstances, but in the event of a PLC breakdown, a relay- based architecture allows the system to smoothly transition to the electronic control mode. By doing this, process interruptions are avoided and system reliability is improved.

Additionally, real-time monitoring, remote access, and data logging are made possible by the incorporation of PLC technologies, giving users better system visibility and control. The suggested system is very effective and appropriate for contemporary industrial applications because to its automation, redundancy,

and connectivity.
Additionally, a PT100 sensor is perfect for industrial settings because it guarantees great accuracy and stability across a broad temperature range. By boosting and filtering the sensor output, the signal conditioning circuit that makes use of operational amplifiers improves measurement accuracy. Additionally, the system is scalable and reasonably priced, making it adaptable to various industrial needs.

Its modular architecture makes maintenance easier and allows for simple integration with current systems.
Additionally, having a manual override option gives operators flexibility in emergency or maintenance scenarios. The platform can help industries save operating costs and increase energy efficiency by supporting data analytics and performance improvement. Overall, by integrating connectivity, intelligence, and dependability into a single solution, the project advances smart industrial control systems.

## II. PROPOSED SYSTEM

The proposed system is a temperature monitoring and control solution designed for efficient heater operation in industrial applications. It focuses on achieving precise temperature regulation while ensuring uninterrupted performance under fault conditions. The system integrates sensing, signal conditioning, control, and switching mechanisms into a unified architecture. The main objective is to overcome the limitations of conventional single-controller systems by introducing redundancy. This design enhances system reliability and operational safety. The architecture is simple yet effective, making it suitable for practical implementation.

Each unit in the system is designed to perform a specific function while maintaining coordination with other units. The system ensures stable operation even under varying conditions. It also minimizes the chances of system failure. Thus, the proposed system provides a dependable temperature control solution.
The temperature sensing unit is based on a PT100 resistance temperature detector, which is known for its high accuracy and stability. The PT100 sensor operates on the principle of resistance variation with temperature. As the temperature increases, the resistance of the sensor changes proportionally.
This characteristic makes it suitable for precise temperature measurement. It offers excellent repeatability and reliability in industrial environments. The sensor is capable of measuring a wide temperature range with minimal error. Proper installation ensures accurate heat detection from the heater. Shielded cables are used to reduce electrical noise interference. The sensor output is stable and consistent. Hence, the PT100 sensor serves as a reliable input element in the system.

The signal conditioning circuit is implemented using operational amplifiers to process the sensor output. Since the PT100 produces a small resistance change, it cannot be used directly for control.
Therefore, an op-amp-based circuit is used to convert this change into a proportional voltage signal. The circuit may include a Wheatstone bridge configuration for accurate detection of resistance variation. Amplification is performed to increase signal strength. Filtering components are used to remove noise and unwanted disturbances. This ensures that the output signal is clean and stable.

Proper calibration aligns the output voltage with temperature values. The circuit maintains linearity across the operating range. This improves control accuracy. Thus, signal conditioning is essential for proper system functioning.
The proposed system combines accurate sensing, effective signal processing, reliable control, and automatic fault handling into a single framework. The dual-mode operation ensures continuous performance even during PLC failure. The relay- based switching mechanism provides seamless transition between modes. The use of a PT100 sensor enhances measurement accuracy. The op-amp circuit improves signal quality and control precision. The system is designed with a focus on safety and reliability. It is suitable for various industrial heating applications. The modular design allows easy maintenance and upgrades. Overall, the system offers a robust and efficient temperature control solution. It improves performance compared to traditional systems.

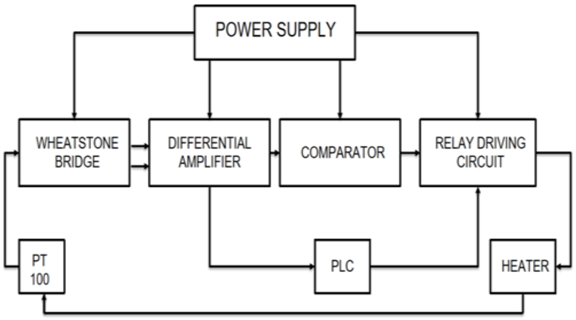


Fig 1: Block Diagram of Proposed System

## III. EXISTING SYSTEM AND ITS LIMITATIONS

The majority of temperature control systems currently in use in industrial settings are built on single-controller designs, such as PLC-based systems or standalone analog controllers. Temperature sensors, such as thermocouples or RTDs, are used in these systems to detect temperature and regulate heaters using simple ON/OFF or PID techniques. Because of their straightforward design and ease of usage, they are widely utilized. Nevertheless, the majority of these systems rely just on one control unit to function. The system as a whole cease working if the controller fails. Continuous industrial processes suffer greatly as a result. Lack of backup control results in lost productivity and downtime. Operations may be delayed while troubleshooting. As a result, system reliability is decreased. Therefore, important applications that need continuous performance are not appropriate for traditional systems.

The PLC serves as the primary controller for processing sensor inputs and managing the heating system in PLC-based temperature control systems. PLCs offer greater control techniques, flexibility, and programmability, but they heavily rely on hardware and software operating properly. Complete system shutdown can result from any issue, including internal hardware damage, program errors, or power outages.

Because of this, the system is susceptible in crucial situation. PLC systems also need qualified workers for maintenance, troubleshooting, and programming. This raises the cost and complexity of operations. Internal processing delays may also have a minor impact on response time. The majority of PLC systems lack an integrated backup control system.

As a result, total reliance on PLC lowers system reliability. Another kind of current system that regulates temperature using operational amplifiers, comparators, and discrete components is an analog electronic control system.

These systems are renowned for their straightforward design and quick response times. They don't need software or programming to function on their own. But once designed, they are rigid and difficult to change. Circuit components must be manually adjusted whenever control parameters change. This procedure is less accurate and takes more time. Over time, accuracy may be impacted by environmental changes and component drift in analog systems. Complex control strategies are not supported by them. They also lack switching and automatic fault detection. As a result, the functionality of isolated electronic systems is restricted. The lack of a fault-tolerant mechanism is a significant drawback of current systems.

The majority of systems lack the capability to automatically transition between control modes in the event of a malfunction. When a problem arises, system operation must be restored manually. Reduced efficiency and more downtime result from this. Overheating and possible damage can result from improper temperature control in heating applications. In these circumstances, safety hazards also rise. Redundancy and backup control mechanisms are typically absent from current systems. Seldom is integration between various control techniques used. As a result, the overall robustness of the system is decreased. As a result, a better system that guarantees continuous operation, increased safety, and greater reliability is required.

## IV. PLC ALGORITHM IMPLEMENTATION

The temperature input from the signal conditioning circuit attached to the PT100 sensor is first read by the PLC algorithm. Scaling is used to transform the analog signal into a temperature value. The PLC stores the setpoint temperature so that it can be compared. The setpoint value and the measured temperature are compared by the PLC. The heater is activated if the temperature falls below the setpoint. The heater is shut off if it reaches or beyond the setpoint. To avoid frequent switching, a hysteresis is employed. In order to retain control mode during regular operation, the PLC activates the relay. For real-time temperature control, the procedure is continuously repeated.

The PLC keeps an eye out for any problem circumstances, such as aberrant readings or signal loss.

The relay automatically de-energizes in the event of a PLC or power supply malfunction. As a result, the NC contact forces the system to enter Electronic Control Mode. Additionally, the PLC limits temperature within predetermined ranges to guarantee safe operation.

System functioning and fault states can be displayed via status indicators.
To ensure precision and stability, the control logic is carried out cyclically. As a result, the PLC implementation guarantees consistent and dependable temperature control.

```
PROGRAM PlcProg VAR
Temp: REAL; Sensor: REAL;
Heater_0ff AT: BOOL; END_VAR
```

## V. PROPOSED SYSTEM ADVANTAGES AND LIMITATION

*A. Advantages:*

Because of its dual-mode operation, which enables it to operate in both PLC Control Mode and Electronic Control Mode, the suggested system delivers great reliability. In the event that one control unit fails, this guarantees ongoing operation. Manual involvement during faults is eliminated by the relay-based automatic switching mechanism. System downtime is thereby greatly decreased. The precision and stability of temperature measurements are increased when a PT100 sensor is used. Signal conditioning based on operational amplifiers improves control action precision.
The technology ensures effective heater regulation by reacting swiftly to temperature fluctuations. Additionally, it increases safety and reduces the possibility of overheating. It is appropriate for industrial use because of its strong and straightforward design. As a result, the system offers consistent and reliable performance.
The system's adaptability and ease of maintenance are two other significant benefits. Without altering hardware, the PLC mode makes it simple to change control parameters. Additionally, the electronic control mode offers a dependable backup that functions without the need for software. This combination increases the adaptability of the system. It is simple to troubleshoot and replace individual components thanks to the modular architecture.
Relay-based switching guarantees a seamless mode change without interfering with operation. By offering redundancy, the system also lowers operational risks. The heater's effective regulation maximizes power usage. The overall design improves durability, performance, and safety. As a result, the suggested method is more sophisticated and effective than traditional temperature control systems. Despite its strengths, the system has certain limitations that provide opportunities for future research.

*B. Limitations:*

Due to the addition of dual control modes and switching methods, the suggested solution increases total system complexity even if it improves reliability. Careful design and integration are necessary when using both PLC and electrical control circuits. Compared to simpler systems, initial setup and calibration could take longer. Despite its effectiveness, the relay-based switching technique may cause minor transitional delays. Over time, mechanical relays can also experience wear and tear. If improperly maintained, this may have an impact on long-term dependability. Periodic inspection is therefore necessary.
The higher cost of extra parts such relays, signal conditioning circuits, and backup control units is another drawback. Temperature and component aging may potentially cause slight drift in the analog circuit. Additional hardware may result in somewhat greater space needs. As a result, even though the system is dependable, it requires more money and upkeep than simple controls.

## VI. CONCLUSION

In industrial heating applications, the suggested temperature monitoring and control system offers a practical way to maintain precise and steady temperatures. High accuracy and dependable temperature measurement are guaranteed when a PT100 sensor is used. The control signal's stability and quality are enhanced by the operational amplifier-based signal conditioning circuit.
The technology is built to react fast to changes in temperature. This aids in preserving steady heating performance. The general layout guarantees effective energy use. Additionally, it lessens temperature

swings. As a result, accurate and dependable temperature management is achieved by the system. System dependability and fault tolerance are improved by the dual-mode operation that uses PLC Control Mode and Electronic Control Mode.

In the event of a PLC failure, the relay-based automated switching mechanism guarantees continuous operation. This enhances operational continuity and lowers system downtime. An independent control path is by the backup electronic control. System performance is unaffected by the seamless changeover process. In heating applications, the design improves safety. Additionally, it reduces the possibility of system failure or overheating. As a result, the system guarantees consistent and reliable operation.

In summary, the suggested approach performs better than traditional temperature control techniques. In a single system, it integrates precise sensing, efficient control, and automated problem handling. It is simple to maintain and troubleshoot due to its modular nature. It can be modified for a number of industrial heating uses. The system lowers operating hazards and increases efficiency. It offers a dependable and affordable option. Its powers can be further improved in the future. All things considered, it is a reliable and useful temperature control system.

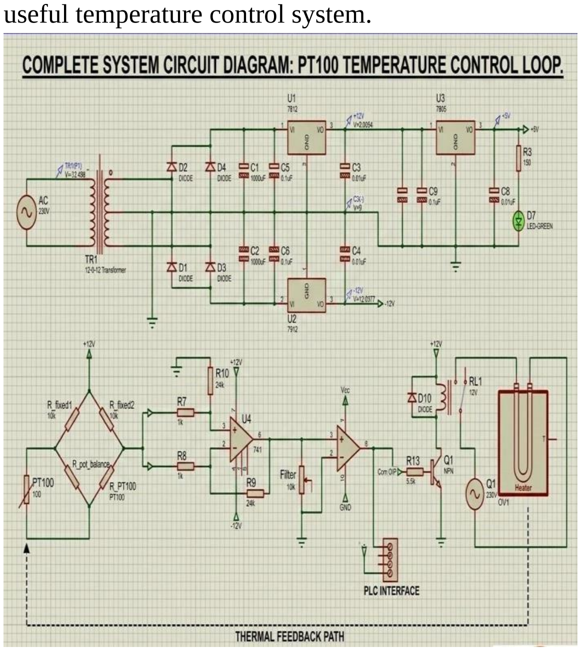


Fig 2: Circuit Diagram of Proposed System

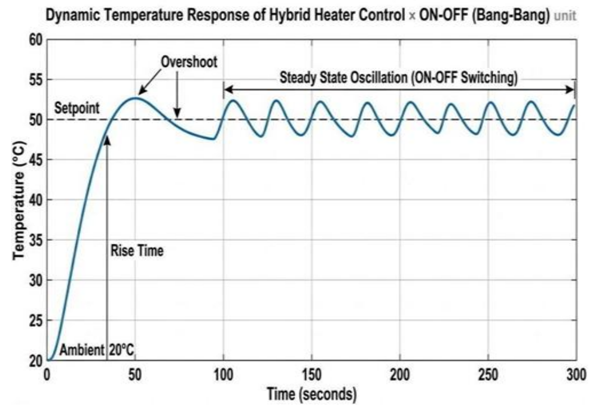


Fig 3: Result: Temperature Control Response

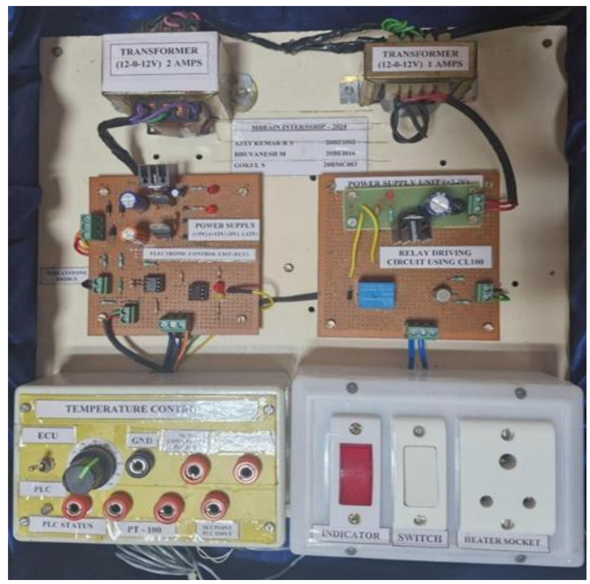


Fig 4: Prototype of the System (ECU Unit)


Fig 5: Prototype of the System (PLC Unit)

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