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Industrial Machine Overheat Detection System

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ABSTRACT

Industrial machines are highly specialized equipment used in manufacturing and production processes. However, malfunctions or deterioration in their electrical, pneumatic, or hydraulic systems can lead to overheating, posing risks to the working environment and causing production downtime and financial losses. The objectives of this study are to develop an industrial machine overheat detection system using a microcontroller, monitor and control machine temperature, and measure the response rate of the system for overheat detection. The project implemented various components, including programmable logic controller (PLC) Siemens S7-1200, Thermocouple K-type, Max 6675 module, Arduino Uno, buzzer, relay, light crystal display (LCD) with I2C module, cooling fan, Arduino Ethernet shield, and project structure, to ensure the successful operation of the industrial machine overheat detection system. The results of the project focused on analysing the response rate of the temperature sensor when an overheat event occurs. By measuring this response rate, insights can be gained into the effectiveness of the system in promptly detecting and responding to overheat conditions. This research study aims to contribute to the understanding of overheating consequences, implement preventive measures, and address the issues associated with industrial machine overheating.

Keywords:
Overheating; Industrial Machine; Microcontroller

1. Introduction

Industrial machines play a vital role in manufacturing, optimizing tasks and improving product quality while minimizing labor costs [1]. However, the reliance on electric motors in these machines can lead to overheating, posing risks to both performance and user safety [2]. The lack of proper ventilation exacerbates this issue, creating a potential fire hazard and hindering heat dissipation [3].

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Shih, Horng, and Lee (2016)'s research underscores the connection between machinery overheating and fire casualties, with root causes often traced to component failures like heaters [4]. In response, the proposed Industrial Machines Overheat Detection System aims to prevent overheating, utilizing a microcontroller to monitor real-time temperatures and alert users to potential issues before they escalate. This proactive approach enhances overall industrial safety, protecting machine components, prolonging lifespan, and ensuring optimal functionality.

1.1 Issues Existed in Equipment

In a recent study, researchers conducted an investigation into equipment failures and presented their findings in a pie chart, as depicted in Figure 1 [4]. Utilizing root cause analysis, the study collected data to identify key factors contributing to equipment failures, with a specific focus on incidents leading to fires. The data highlighted four primary issues: malfunction, overheating machinery, oil leakage, and poor machine operation.

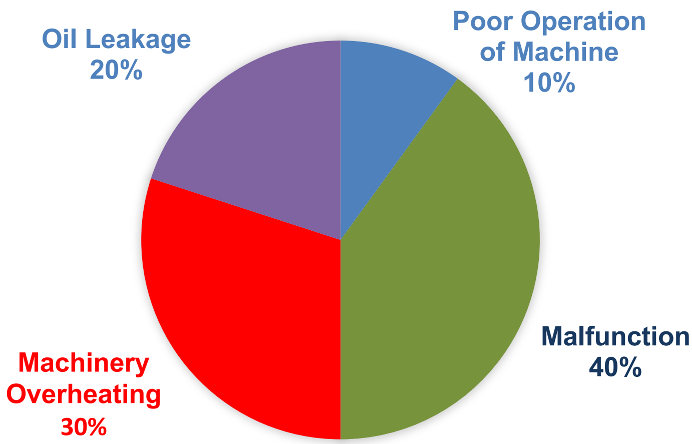

Fig. 1. Equipment Failure Fire Casualty Based on Root Causes Breakdown in Percentages

Based on the provided data, it can be inferred that overheating machinery is the second most significant issue in equipment that contributes to equipment failure, potentially leading to fire incidents. Hence, it is appropriate to undertake this project aimed at developing an overheating detection system to effectively prevent such accidents from occurring.

1.2 Consequences of Overheating

Machine or equipment malfunctions pose various risks with outcomes contingent upon factors like severity and machinery type [5]. Particularly, unanticipated mechanical failures in rotating machinery can have severe consequences, and overheating exacerbates the risks. Overheating in machines can lead to safety hazards, causing fire accidents and jeopardizing worker's well-being [4]. A case study in agriculture highlighted that machine parts' overheating poses a significant fire risk, impacting worker safety [6]. In industrial settings, overheating electrical motors can result in machinery damage, incurring substantial downtime and repair costs [7]. A study analyzing downtime in vibrating screen machines found that extensive repairs, lasting 75.8 hours, led to a production loss of 5,269.85 tons, valued at Rp. 580,382,000 [8]. Financial losses due to overheating underscore the critical importance of addressing these issues promptly. Additionally, overheating in electrical components can compromise long-term sustainability by diminishing equipment performance and the durability of wires [9]. For instance, the operation of a computerized numerical control (CNC) milling machine induces heat in its electrical components, contributing to temperature elevation and potential performance degradation. Overall, addressing overheating issues is imperative to mitigate safety risks, financial losses, and long-term sustainability concerns in diverse industrial contexts.

1.3 Preventive Measures to Overcome the Overheating Machinery

To prevent harmful accidents resulting from machine overheating and to minimize financial losses associated with machinery damage, proactive measures are crucial. Temperature monitoring in induction motor drives poses a challenge, with variations affecting the machine's lifespan and control performance [10]. To address this, an online monitoring technique for tracking rotor and stator temperature in field-oriented induction motor drives can be employed to prevent hazardous overheating, emphasizing the importance of preventive measures.

Additionally, to avoid excessive heat build-up in large industrial motors, the implementation of a cooling system can be explored to reduce critical temperatures in wires, enabling superconducting capabilities [11]. A study evaluating a cooling system during the conceptual design phase of a 100-HP high-temperature superconducting synchronous motor highlights the potential for preventing overheating through innovative engineering solutions. Furthermore, an Ant Colony Optimization (ACO) technique was utilized to establish an optimal maintenance schedule, minimizing the risk of machine failures and disruptions in production by strategically implementing preventive maintenance intervals based on historical breakdown data [12]. By incorporating these strategies, including temperature monitoring, cooling systems, and optimized maintenance schedules, organizations can effectively prevent overheating issues, ensuring both worker safety and sustained machinery performance. Machine or equipment malfunctions pose various risks with outcomes contingent upon factors

2. Methodology

This project runs controller and microcontrollers, PLC and Arduino Uno, to support the detection system. Thermocouple k-type is a temperature sensor that senses the machine's heat and sends data into Arduino using the Max 6675 module connection Uno. After the Arduino received the temperature data, it could be monitored through the LCD. Besides that, PLC that interfaces with Arduino Uno would receive data if the temperature is heating up. It could switch on the cooling fan to minimize the heat. When the machine overheated, PLC sent a signal to the relay and cut off the supply voltage, which acts as an emergency shutdown. Also, the buzzer was switched on to indicate that the machine is overheating. Therefore, this project controls the machine's heat and power supply to reduce the impact of overheating on the machine.

In this project, both Arduino and PLC were utilized for programming development. The programming flow established the input temperature threshold for overheating based on the machine's temperature limit. The input temperature was also set to control the temperature using a cooling fan. A thermocouple was employed to gather machine temperature data, which was then displayed on an LCD screen for user monitoring. The programming logic used conditional statements (if-else) to check if the reading temperature matches the set input temperature. Arduino sent a signal to the PLC when the two temperatures are equal or more than. Subsequently, the PLC performed several actions, including activating the cooling fan, cutting off electricity through the relay, and triggering an alert using a buzzer to notify the user. Figure 2 displays the process flowchart of the project.

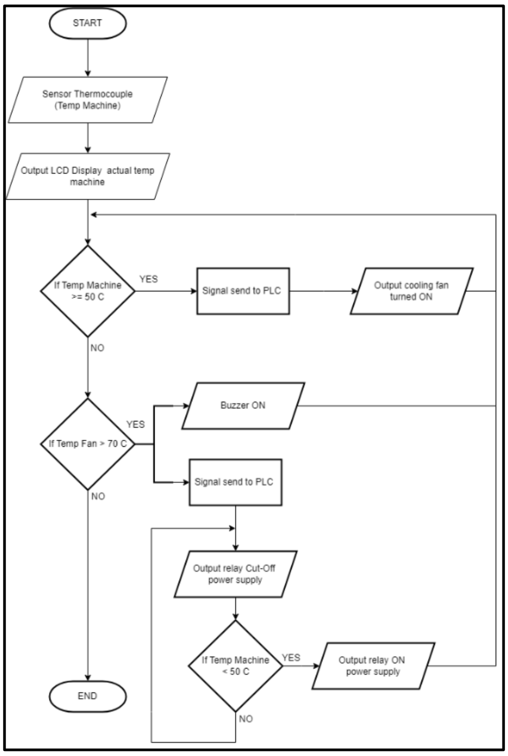

Fig. 2. Process flowchart of the project

3. Results

3.1 The developed prototype

The electrical wiring for this prototype involved the interconnection of PLC S7-1200, Ethernet shield, and Arduino Uno. All the connections were made in a terminal block, and they were extended to other devices and instruments. To ensure the integrity of each connection, a testing process was implemented using a multimeter to check for continuity. This was done to confirm the smooth flow of electricity without any leaks or broken wires. As a safety measure and for a tidy arrangement of wires, cable lugs were employed to establish better connections in the terminal block. Electronic devices are soldered together in one PCB board which the connection for LCD, MAX6675 module, buzzer, 5V and ground that connected to Arduino Uno. This is shown in Figure 3.

3.2 Response rate of the system when overheating occurs

Table 1 presents the results obtained indicating the response of the system when detecting overheating. This reflects the conditions under which the system reacts, activating the cooling fan and cutting off the power supply when necessary.

The graph illustrated in Figure 4 indicated that the increase and decrease in temperature for the equipment exhibit similar time durations. This observation suggests that the cooling fan efficiently works to rapidly cool down the equipment when transitioning from an elevated temperature to a working temperature state.

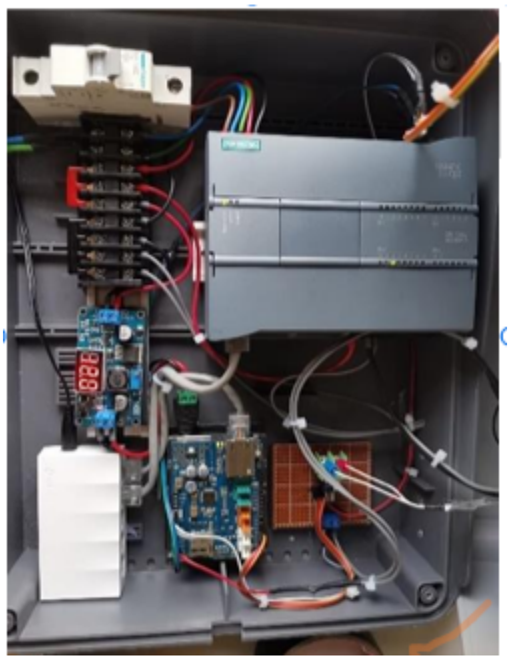

Fig. 3. Electrical setup and arrangement for the prototype

Table 1
Collected data on response of the system when overheating occurred

No.	Time machine on	Initial Temp. (°C)	Time Fan on	Temp. machine (Fan On) (°C)	Time Machine Off	Temp. Machine Off (°C)
1	2:50 PM	34	3:04 PM	50	3:55 PM	70
2	4:50 PM	45	4:55 PM	50	5:45 PM	70
3	6:40 PM	45	6:45 PM	50	8:08 PM	70
4	8:55 PM	45	8:59 PM	50	9:59 PM	70

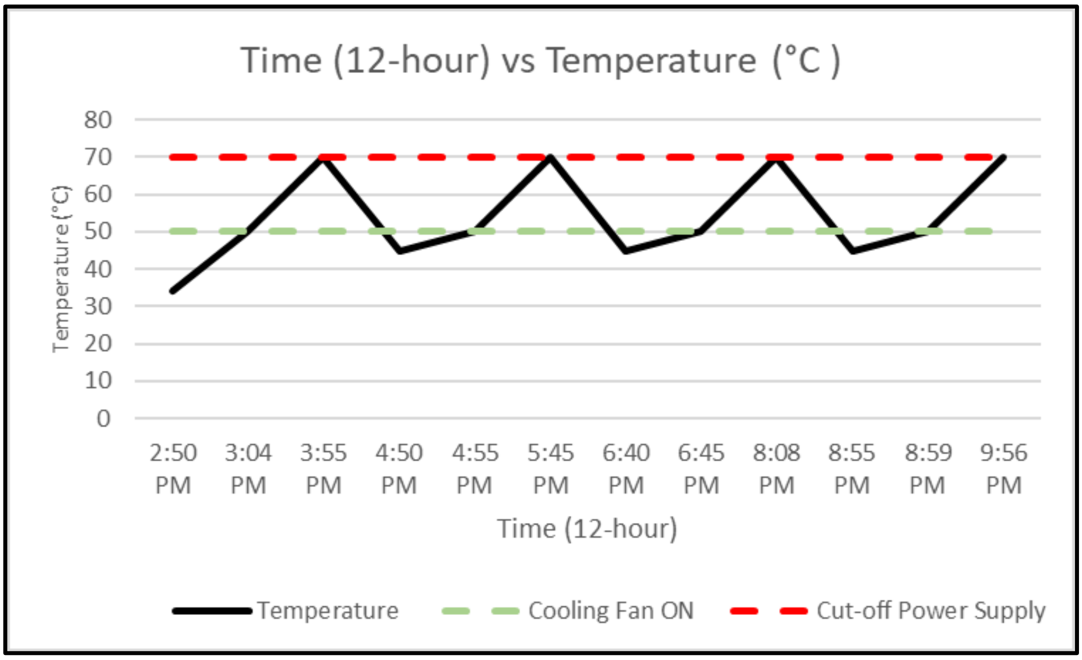

Fig. 4. Graph reflecting the response of the system when overheating occurred

4. Conclusions

The development of the industrial machine overheat detection system has been a resounding success. The objectives in this project have been achieved by creating a robust and reliable system that not only detects overheating but also actively monitors and controls industrial machine temperatures. The measured response rate showcases the system's efficiency in handling overheat scenarios, highlighting its potential to significantly contribute to industrial safety and machine performance. Moving forward, further optimization and integration with existing industrial systems could enhance the scalability and applicability of this technology across various sectors. The successful completion of this project marks a significant step towards ensuring the reliability and longevity of industrial machines through temperature monitoring and control systems.

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