Development of A Real-Time Monitoring and Overcurrent Protection System For Industrial Air Compressors

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Abstract.
Compressors are vital equipment in the manufacturing industry that generate pressurized air to support various production processes. A common issue encountered in compressors is elevated operating temperatures and premature component failure caused by delayed replacement of consumable spare parts, such as oil, filters, and maintenance kits. This study aims to design and implement an Arduino Nano-based monitoring system for operating temperature, electric current, and running hours to support predictive maintenance routines on compressors. The system integrates a temperature sensor, a current sensor, and an hour meter with an Arduino Nano as the central controller, coupled with a buzzer alarm for early warnings whenever operating parameters exceed predefined threshold limits. The current sensor was evaluated by comparing system readings against a clamp meter across five electrical load variations, showing an average deviation of 0.09 A with a maximum error of 8.11%. Meanwhile, the temperature sensor testing against a ThermoGun as a reference instrument yielded measurement discrepancies of 1–3 °C under ambient and heated conditions. Furthermore, the system successfully provided real-time alerts whenever temperature, current, or operating hours exceeded set limits. The results demonstrate that the developed system reliably and effectively monitors compressor health as an economical preventive and predictive maintenance solution with substantially lower implementation costs compared to conventional industrial monitoring systems.

Keywords: *Compressor, Arduino Nano, Real-Time Monitoring, Predictive Maintenance, Current Sensor and Temperature Sensor.*

I. INTRODUCTION

Compressors are essential equipment widely utilized in the manufacturing industry as a source of pressurized air to operate pneumatic systems, actuators, production machinery, and various other automated devices [1, 2]. The reliability of a compressor crucially dictates the continuity of the production process, as disruptions in the compressed air supply can lead to reduced productivity or even complete production shutdowns. Therefore, a compressor condition monitoring system capable of detecting potential anomalies at an early stage is essential to ensure that maintenance actions can be carried out in a timely manner.

A common problem frequently encountered in compressor units is the rise in operating temperature due to delayed replacement of consumable components, such as lubricating oil, air filters, oil separators, and maintenance kits [3]. These components have a finite service life, typically measured in operating hours. If replacement is not carried out on schedule, the operational efficiency of the compressor decreases and poses a risk of damaging critical components, such as the drive motor, screw element, oil cooler, and control system. Furthermore, an electrical current draw exceeding normal operating limits can serve as an indicator of underlying mechanical or electrical malfunctions within the compressor.



Fig. 1. BOGE Compressor

Generally, modern compressors are equipped with internal monitoring systems that display temperature, pressure, and operating hour information on a local control panel. However, these systems have inherent limitations because the operational data can only be viewed directly at the compressor unit. In industrial environments characterized by expansive production floors and numerous operating machines, this constraint frequently causes operators to overlook warning indicators or alarms triggered on the machine panel. Consequently, corrective maintenance and component replacements cannot be executed promptly, thereby escalating the risk of more severe equipment failure.

Various studies have developed monitoring systems based on the Internet of Things (IoT), Supervisory Control and Data Acquisition (SCADA), and Programmable Logic Controllers (PLCs) to improve the effectiveness of industrial equipment surveillance [4, 5, 6]. These systems are capable of displaying real-time data and transmitting remote notifications to operators. Nevertheless, the implementation of such technologies requires relatively high capital investment as well as more complex communication infrastructure, rendering them less feasible for all industrial facilities, particularly for enterprises operating with constrained maintenance budgets.

Given these conditions, a monitoring system that is simple, cost-effective, and easy to deploy yet fully capable of delivering real-time compressor health status is essential. One viable solution is the utilization of an Arduino Nano microcontroller, which offers low procurement costs, low power consumption, and seamless integration with a wide variety of sensor types.

This study aims to design and implement an Arduino Nano-based monitoring system for operating temperature, running hours (hour meter), and electric current protection on compressors. The developed system utilizes a temperature sensor to monitor compressor operating temperature, a current sensor to track the electric motor load, and an hour meter to calculate the cumulative operating time of the machine. All acquired sensor data are processed by the Arduino Nano and displayed on a monitoring panel in real time. In addition, the system is equipped with a buzzer alarm that automatically activates whenever any monitored parameter exceeds its predetermined threshold value.

The primary contribution of this research lies in the development of a low-cost compressor monitoring system that integrates temperature, electric current, and running-hour monitoring into a single centralized platform. Beyond serving as a monitoring device, the system directly reinforces the implementation of predictive maintenance paradigms by providing early warnings based on the actual operating conditions of the machine. Consequently, maintenance workflows can be conducted more effectively, thereby minimizing the risks of unexpected breakdowns, production downtime, and unscheduled repair expenses.

II. METHODS

This study employs an engineering research methodology aimed at designing, building, and evaluating an Arduino Nano-based monitoring system for operating temperature, running hours (hour meter), and electric current protection on compressors. The research process is carried out across several systematic stages: system requirements identification, hardware design, software development, system implementation, and device performance testing and evaluation.

System Requirements Identification

The initial stage of this research was conducted by identifying prevalent issues occurring in industrial compressor units, specifically delayed replacement of spare parts, elevated operating temperatures, and abnormal motor current loads. Based on this identification, the critical parameters requiring monitoring were established, including compressor oil temperature, motor electric current, and operating time (hour meter).

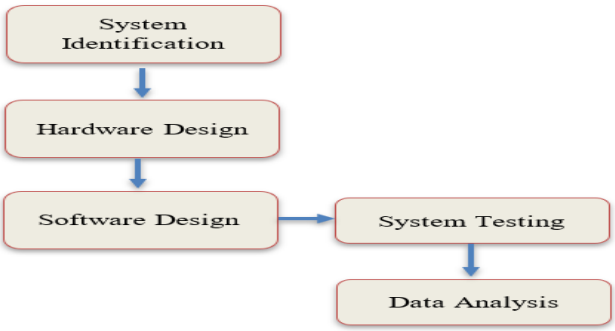


Fig. 2. Research Flowchart

System Design

The monitoring system was designed using an Arduino Nano as the central controller. Input data were acquired from a temperature sensor to measure the compressor's operating temperature, a current sensor to detect the electrical load of the motor, and an hour meter to track the total operating hours of the machine.

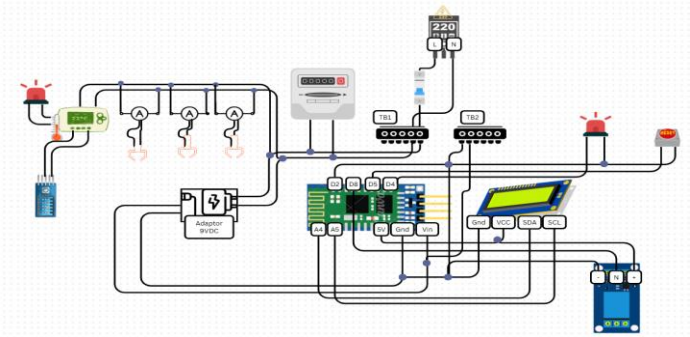


Fig. 3. Device Wiring Diagram

Data received by the Arduino Nano were processed and compared against predetermined threshold values [7]. If the temperature, current, or operating hours exceeded allowable limits, the system activated an alarm comprising a buzzer and a dashboard indicator to alert the operator. In general, the operational workflow of the system begins with the sensors continuously reading the real-time operating conditions of the compressor. The acquired sensor data are then transmitted to the Arduino Nano for processing and subsequently compared against predefined threshold values. Concurrently, the monitoring results are displayed on the panel for real-time observation. If an abnormal condition is detected such as any parameter exceeding its allowable limit the system automatically triggers the alarm, prompting the operator to carry out immediate inspection or appropriate maintenance actions based on the generated notification.

System Implementation

During the software design for hour-meter evaluation, the countdown parameter within the Arduino firmware was configured with a 1-minute test interval to effectively simulate runtime threshold alerts prior to resetting it to standard component service life values during actual deployment [8].



Fig. 4. Monitoring System Panel

System implementation was carried out by assembling all hardware components in accordance with the system design. The temperature sensor was installed at the measurement point of the compressor oil

temperature, while the current sensor was positioned along the power supply line of the compressor motor. The Arduino Nano was programmed using the Arduino IDE software to perform sensor reading, data processing, and alarm control. The system was subsequently integrated with the monitoring panel, enabling real-time visualization of temperature, electric current, and operating hour data.

III. RESULT AND DISCUSSION

The Arduino Nano-based compressor monitoring system was successfully implemented and evaluated for real-time monitoring of temperature, electric current, and operating hours. Testing was conducted to determine the measurement accuracy of the sensors relative to calibrated reference instruments and to evaluate the system's capability in delivering early warnings during abnormal compressor operating conditions.

Current Sensor Testing

The current sensor was evaluated by comparing its readings against a reference clamp meter across several electrical load variations. The experimental test results are presented in Table 1.

Table 1. Current Sensor Test Result

Load	Clamp Meter (A)	Sensor (A)	Error (%)
Angle Grinder	2,04	2,00	1,96
Electric Iron	1,85	2,00	8,11
Water Pump	3,10	3,00	3,23
Blower	0,90	1,00	11,11
Jigsaw	2,04	2,00	1,96

The average measurement error of the current sensor was 5.27%, yielding an overall system accuracy of 94.73%.

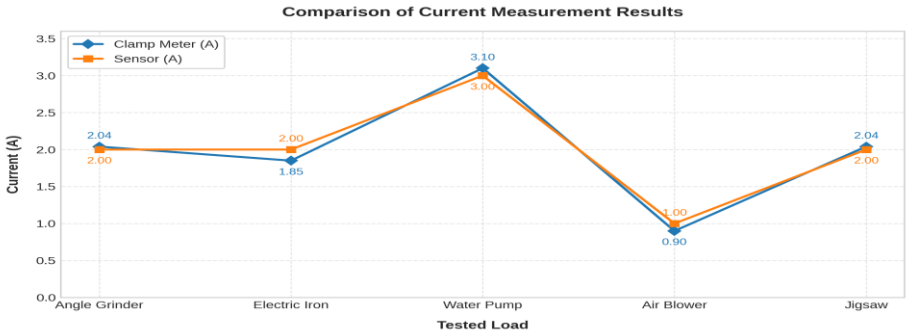


Fig. 4. Comparison of Current Measurement Results

Based on Table 1, it is evident that the current sensor reading pattern closely tracks the clamp meter measurements across all load variations. The highest value was recorded during the water pump test, with 3.10 A on the reference instrument and 3.00 A on the sensor. Meanwhile, the largest discrepancy occurred during the air blower test, with an error of 11.11%. Overall, the measurement results exhibit close agreement, demonstrating that the sensor is reliable and viable for use as a compressor motor load monitoring device.

Temperature Sensor Testing

The temperature sensor was evaluated by comparing its readings against a ThermoGun as the reference measuring instrument under two distinct test conditions, namely ambient temperature and a direct heat source.

Table 2. Temperature Sensor Test Results

Test Medium	ThermoGun (°C)	Sensor (°C)	Error (%)
Room Ambient	24	23	4,17
Lighter Flame	45	42	6,67

The average temperature measurement error was 5.42%, corresponding to an accuracy level of 94.58%

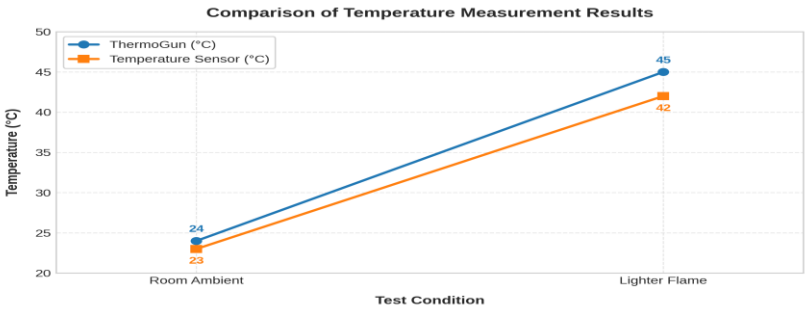


Fig. 5. Comparison of Temperature Measurement Results

Based on Table 2, it is observed that the temperature sensor readings exhibit a trend consistent with the ThermoGun reference instrument. The measurement discrepancy ranges from 1 to 3 °C. This difference is primarily attributed to the sensor response time and positioning variations relative to the heat source. Nevertheless, the resulting accuracy is adequate for real-time compressor temperature monitoring requirements.

Alarm System Testing

The alarm system testing was conducted to verify that the system is capable of delivering timely notifications whenever compressor operating parameters exceed predetermined threshold limits.

Table 3. Alarm System Test Result

Parameter	Condition	Alarm Status
Temperature < 80°C	Normal	OFF
Temperature > 80°C	Abnormal	ON
Current < 15 A	Normal	OFF
Current > 15 A	Abnormal	ON
Hour Meter < 6000 Hour	Normal	OFF
Hour Meter ≥ 6000 Hour	Maintenance	ON

The test results demonstrate that the alarm system functions strictly according to the designed programming logic. Whenever the temperature, current, or running-hour values exceed their respective threshold limits, the buzzer and alarm indicator activate automatically, enabling the operator to promptly initiate the necessary maintenance procedures.

Analysis of System Performance

Based on the evaluation results of the current and temperature sensors, the system demonstrates reliable performance for deployment in industrial environments. An accuracy rate of 94.73% for the current sensor and 94.58% for the temperature sensor confirms that the system is capable of providing real-time compressor health data with a relatively low error margin. Furthermore, the integration of the alarm system and the hour meter enables the practical implementation of predictive maintenance, allowing spare part replacements to be scheduled according to the machine's actual operating conditions and accumulated runtime. This approach has the potential to minimize the risk of sudden equipment failure, enhance compressor reliability, and reduce unscheduled maintenance costs.

IV. CONCLUSION

Based on the design, implementation, and testing carried out in this study, the Arduino Nano-based monitoring system for operating temperature, hour meter, and electric current protection was successfully developed and functioned in accordance with the research objectives. The experimental results demonstrated that the current sensor achieved an average measurement error of 5.27% with an accuracy of 94.73%, while the temperature sensor exhibited an average error of 5.42% with an accuracy of 94.58%.

The system is capable of displaying real-time data for temperature, motor current, and operating hours, while delivering automatic buzzer alerts whenever operating parameters fall outside predetermined limits. The implementation of this system effectively reinforces both preventive and predictive maintenance strategies, thereby minimizing potential compressor damage caused by delayed spare part replacements.

Due to its relatively low implementation cost compared to conventional SCADA and DCS architectures, this Arduino Nano-based monitoring system serves as an effective and economical alternative to improve the operational reliability of compressors in the manufacturing industry.

V. ACKNOWLEDGMENTS

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