Jurnal Studi Multidisipliner
Vol 10 No. 5 Mei 2026
eISSN: 2118-7453

AN IOT-INTEGRATED APPROACH FOR REAL-TIME MONITORING AND CONTROL OF AIR COMPRESSOR SYSTEMS

Jaka Aman Prakasa
jakaamanprakasa46@gmail.com
Universitas Tanjungpura

ABSTRACT

This research focuses on the design, implementation, and evaluation of an Internet of Things (IoT)-based air compressor monitoring and control system deployed in the automotive workshop of UPT PKPTK, West Kalimantan Province. The proposed system enables real-time monitoring of key compressor operational parameters, including air pressure, voltage, current, electrical power, and operating duration. Data are presented locally through an LCD interface and remotely via the Adafruit IO platform. Experimental findings reveal that the voltage, current, and pressure sensors produce minimal measurement deviations when compared with standard instruments. The low Mean Square Error (MSE) and Root Mean Square Error (RMSE) values confirm the stability and reliability of the sensors for operational monitoring purposes. During starting current testing, a substantial inrush current was recorded, ranging between 15.10 and 34.2 A per phase, whereas the steady-state operating current was observed between 7 and 8 A. Variations in current among phases R, S, and T at startup were attributed to imbalance in motor winding impedance. Performance tests using different pneumatic tools demonstrate that load variations significantly influence power consumption, with operating pressure maintained between 8 and 9.9 kg/cm² in compliance with the pressure switch specifications. The implemented protection mechanism effectively mitigates overpressure conditions by automatically disconnecting the compressor supply via a solid-state relay (SSR). Additionally, the system can detect air leakage through pressure drop analysis and respond with automatic alerts and power cutoff. Overall, the developed system contributes to enhanced energy efficiency and improved occupational safety in automotive workshop environments.

Keywords: *Air Compressor, Internet of Things, Monitoring, Automatic Control, Energy Efficiency.*

INTRODUCTION

The Technical Implementation Unit for Job Training and Labor Productivity (UPT PKPTK) of West Kalimantan Province, previously recognized as the Pontianak Job Training Center (BLK Pontianak), is a regional government institution tasked with enhancing workforce competence through competency-based training programs. The institution provides various vocational training fields, including automotive, welding, electrical, refrigeration, computer engineering, and business management. In the era of global competition and the Industrial Revolution 4.0, the role of job training centers has become increasingly strategic in producing skilled and industry-ready human resources capable of adapting to rapid technological developments. To support hands-on and application-oriented learning, the institution is equipped with industrial facilities and equipment, including air compressors [1].

Air compressors function to generate compressed air and are widely utilized in industrial applications such as welding, painting, pneumatic system operation, and cleaning processes. Within the training environment, particularly in the automotive engineering program, air compressors serve as essential supporting equipment for practical activities. Consequently, their availability and optimal performance are crucial to ensuring uninterrupted training operations.

However, job training centers in Indonesia continue to face challenges in managing practical equipment, including air compressors. Monitoring and maintenance activities are generally conducted manually and reactively, meaning maintenance is performed only after failures or performance degradation occur. This approach increases the likelihood of operational disruptions, more extensive component damage, and higher maintenance costs. Furthermore, inefficient compressor operation may lead to excessive electrical energy consumption, especially due to air leakage in pneumatic installations and failure to turn off compressors outside operational hours. Such inefficiencies contribute to energy waste and conflict with national energy efficiency and conservation policies.

Additionally, many compressors are still equipped with outdated protection systems, which may increase the risk of tank explosions and workplace accidents caused by overpressure conditions. Therefore, an additional microcontroller-based protection mechanism is required to enhance operational safety by automatically disconnecting the power supply when unsafe pressure thresholds are detected.

With the rapid advancement of digital technologies in the Industrial Revolution 4.0 era, opportunities for automation and digitalization of equipment monitoring have expanded through the implementation of Internet of Things (IoT) technology. IoT enables interconnected devices to share data, perform remote control functions, and process information from integrated sensors. By connecting air compressors to the internet, real-time operational data can be accessed remotely. Through the integration of sensors and microcontrollers, essential parameters such as air pressure, voltage, and electric current can be continuously monitored and transmitted to an IoT-based visualization dashboard [2].

The adoption of an IoT-based monitoring and control system for air compressors offers substantial advantages from both operational and educational standpoints. Operationally, the system enhances maintenance efficiency, facilitates early fault detection, and extends equipment lifespan through data-driven preventive maintenance strategies. From an educational perspective, the system provides trainees with practical exposure to IoT applications in industrial settings. Thus, trainees not only develop conventional technical competencies but also gain knowledge of digital technology integration, which is increasingly essential in modern industry.

Based on these considerations, the development of an IoT-based air compressor monitoring and control system for implementation in job training centers is necessary. The proposed system is expected to address technical challenges related to compressor monitoring, overpressure protection, and energy efficiency while simultaneously improving training quality by introducing technology aligned with current industrial demands.

Previous studies have explored related implementations. Ma'arif investigated air compressor motor performance monitoring using Modbus communication integrated with an Outseal PLC, focusing on improving on–off efficiency due to frequent automatic restarts triggered by air leakage in pneumatic lines, which caused current surges and increased motor temperature [3].

Supriyadi developed an IoT-based monitoring system for air compressors in a utility area, utilizing pressure and electrical sensors for real-time condition monitoring. The collected data were transmitted to the Blynk platform and visualized through an online dashboard [4].

Romansdani implemented an IoT-based system for monitoring electric current and compressed air temperature at PT Mekar Armada Jaya to support preventive maintenance. A Type-K thermocouple sensor measured exhaust temperature, while a PZEM-004T module monitored electrical parameters. Data were processed using an ESP8266 microcontroller and displayed via the Blynk application. A relay mechanism automatically disconnected power when temperatures exceeded 105 °C to prevent equipment damage [5].

Mohammd examined an IoT-based monitoring system for air compressors within an air distribution network, aiming to maintain optimal machine performance and enhance occupational safety in industrial environments [6].

Zakaria conducted research on an IoT-based monitoring system for small-scale industries, focusing on voltage, current, and compressor temperature measurements. The HMCT103C sensor achieved 97.94% accuracy with a relative error of 0.02052%, while the ZMPT101B sensor reached 99.44% accuracy with a relative error of 0.00225%. The GY-906 MLX90614 temperature sensor demonstrated 99.93% accuracy (relative error 0.00062%) in Celsius measurements and 99.91% accuracy (relative error 0.00082%) in Fahrenheit measurements. Testing of the NodeMCU ESP8266 Wi-Fi module indicated an average transmission delay of 34.7 seconds with zero packet loss [7].

METHODOLOGY

The system design model was developed to monitor electrical power consumption and control the air compressor by utilizing three PZEM-004T sensors, each assigned to the R, S, and T phases. Each phase is monitored using a PZEM-004T sensor, and the measured data are processed by an ESP32 microcontroller and subsequently displayed on an LCD. The result of methodology content figure in Figure 1.

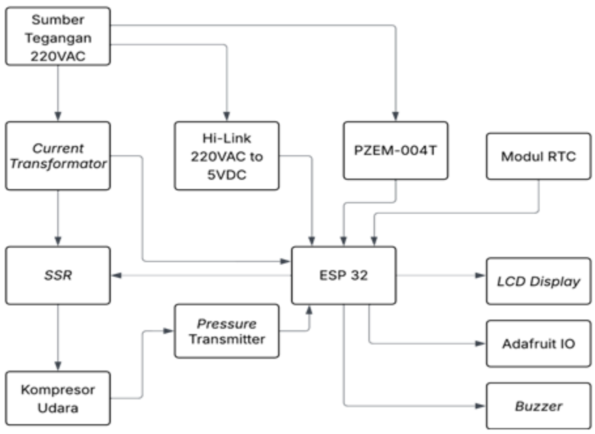

Figure 1. Methodology Content

A 220 VAC voltage source is used as the system power supply and is stepped down to 5 VDC using a Hi-Link power module. The same power source is also routed through a current transformer for current measurement, with the acquired data transmitted to the ESP32. Similarly, data from the PZEM-004T module, real-time clock (RTC) module, and pressure sensor are sent to the ESP32. All collected data are processed by the ESP32, which subsequently generates outputs to the IoT system, solid-state relay (SSR), and buzzer.

The ESP32 connects to the IoT platform via a Wi-Fi interface, which acts as a communication medium to the Adafruit IO server. Adafruit IO is responsible for displaying and storing data transmitted from the ESP32. The data visualization can be accessed through a personal computer and a smartphone. Compressor used in this research are Iwata with belt driven PSP-200A 1980, with pressure set 8-9,9 kg/cm2. The model used in this research as shown in Figure 2.

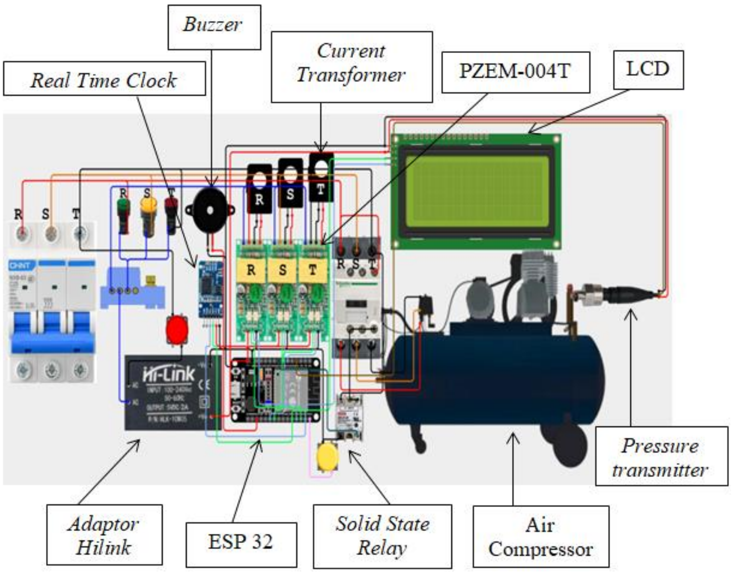

Figure 2. System Operation

The system operation process shown in Figure 2. begins with data acquisition from various sensors, including a pressure sensor for air pressure measurement, as well as a current transformer and PZEM-004T module for measuring electric current, voltage, and power consumption. The collected data are then transmitted to the ESP32 microcontroller, which serves as the central processing unit. The processed data are displayed on an LCD, with time information recorded using a real-time clock (RTC) module. When abnormal conditions are detected, the ESP32 activates an LED indicator and a buzzer as warning signals, while simultaneously controlling the operation of the air compressor through a solid-state relay (SSR). All system components are powered by a Hi-Link power adapter, enabling the system to automatically and continuously perform real-time monitoring and control of the air compressor and its electrical energy consumption.

The pressure sensor is installed at the second output valve of the air compressor, while the first output valve is used for the compressor hose connection. The current transformer and PZEM-004T module are placed inside the control panel box together with the ESP32, Hi-Link power adapter, SSR, LCD, push button, buzzer, and other supporting components.

RESULTS AND DISCUSSION

The proposed IoT-based air compressor monitoring and control system is developed to enable real-time measurement, data recording, and operational control of compressor parameters. The system integrates current sensors, voltage sensors, a real-time clock (RTC), and an air pressure sensor mounted on the compressor tank to acquire accurate operational data. All sensor outputs are processed by an ESP32 microcontroller and transmitted to an IoT platform for visualization and remote monitoring. This architecture provides comprehensive, real-time information to support data-driven operational decisions.

Beyond monitoring capabilities, the system incorporates automated control features that allow the compressor to shut down outside designated working hours, during voltage or current irregularities, and when air leakage is identified. The use of a solid-state relay (SSR) combined with automatic protection mechanisms improves operational safety and minimizes the risks associated with overpressure and excessive energy consumption. Overall, the system is designed to enhance energy efficiency and improve the reliability of compressor performance within an automotive workshop setting. The IoT system architecture is illustrated in Figure 4.

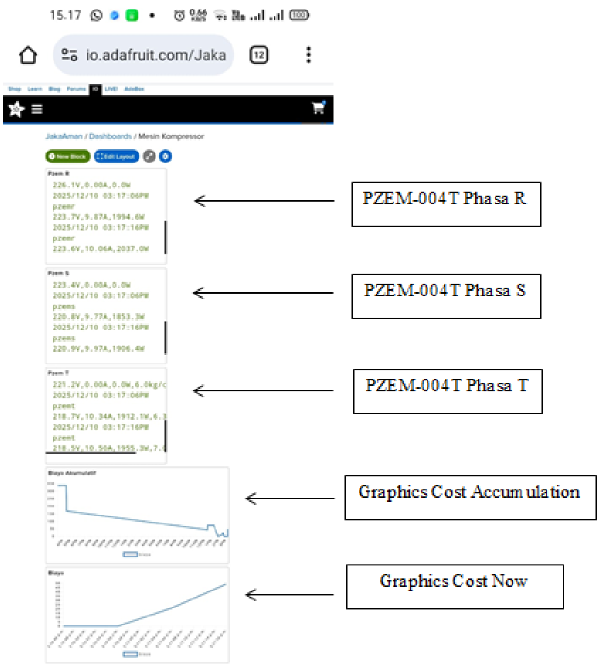

Figure 4. IoT System

Pressure sensor calibration was conducted to align the sensor output with actual pressure values measured using a standard pressure gauge. The calibration procedure involved testing the sensor at multiple reference points, including zero pressure, intermediate levels, and the compressor's maximum operating pressure. Sensor readings were compared with the gauge measurements, and the deviations were used to derive a correction factor or calibration equation implemented in the microcontroller program. This process ensures accurate, stable, and consistent pressure measurements, providing reliable data for system decision-making. The calibration and testing process is presented in Figure 5.

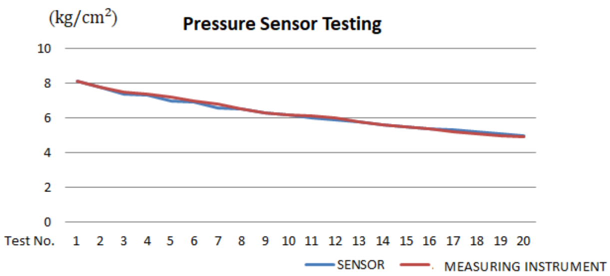

Figure 5. Pressure Sensor Testing

The PZEM-004T module was tested to verify the accuracy of voltage, current, and power measurements within the monitoring system. Measurements obtained from the PZEM-004T were compared against readings from a calibrated digital multimeter serving as a reference instrument. Testing was performed under various load conditions to assess measurement stability and consistency.

The analysis of measurement deviations determined whether the sensor operated within acceptable tolerance limits. Voltage measurement was performed by detecting the input voltage supplied to the module and converting it into digital values readable by the microcontroller. Current measurement utilized a current transformer (CT) to detect the current flowing through the conductor. The test results validate the reliability of the sensor for monitoring compressor power consumption. Initial power and initial cost measurements are presented in Figures 6 and 7, respectively.

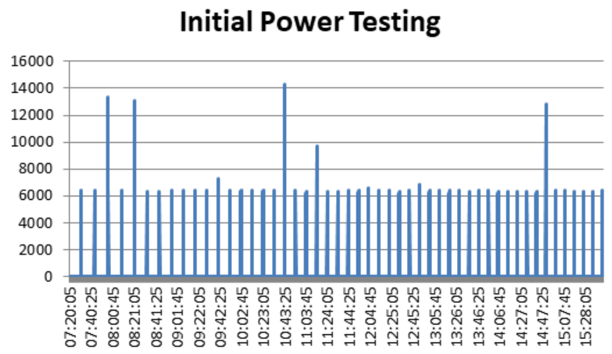

Figure 6. Initial Power Testing

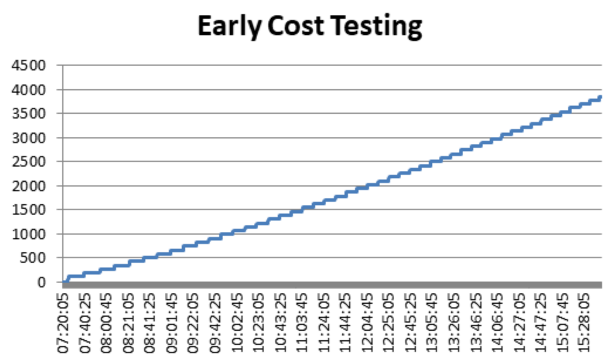

Figure 7. Early Cost Testing

System performance during non-working hours was evaluated between 15:00 and 16:12. The compressor was programmed to automatically shut down from 15:45 until 07:15 the following day as part of operational scheduling. The system response is indicated by a reduction in electrical power consumption, as shown in Figure 8.

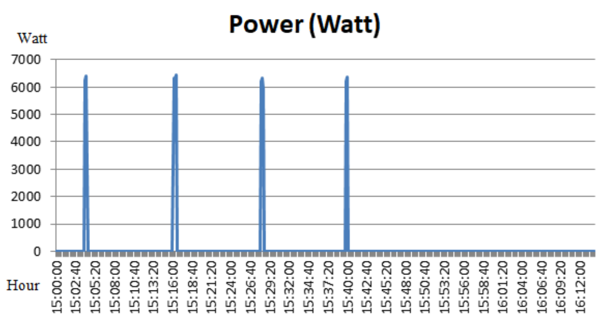

Figure 8. Operational Power Testing

Based on Figure 8, the compressor consumes approximately 6500 W during active operation. Once the system enters the predefined off-working period, the SSR immediately disconnects the compressor's power supply, preventing operation. Temporary reactivation is possible only through manual intervention via a push button on the control panel. These results confirm that the system operates according to the predefined schedule and effectively prevents unnecessary power consumption outside working hours.

Leakage testing was conducted during working hours for one hour using an air duster gun with a minor intentional leak installed on the compressor hose, resulting in gradual pressure reduction within the tank. The comparison between leakage conditions without the system and with the system is illustrated in Figures 9 and 10.

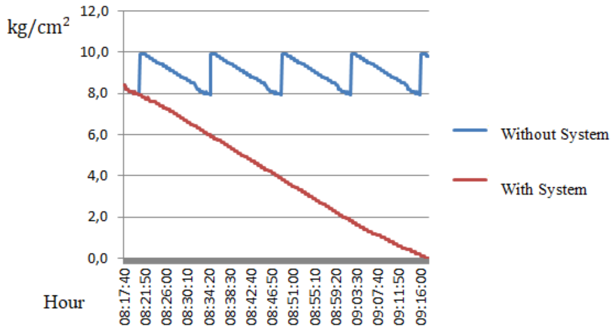

Figure 9. Pressure Leakage

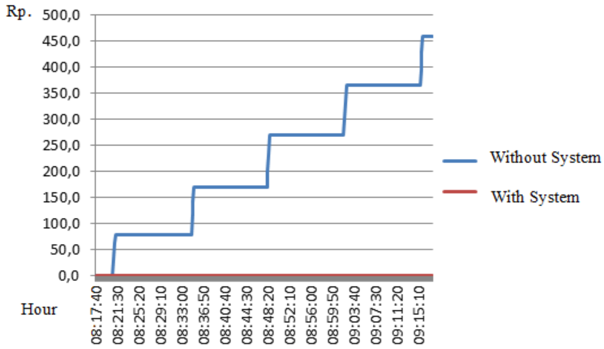

Figure 10. Cost for Leakage

The results demonstrate that tank pressure gradually decreases over the one-hour period, although the leakage is not easily detected visually or audibly. With the proposed system, leakage can be identified through pressure monitoring, enabling timely corrective action. This condition directly impacts operational cost efficiency. The pressure drop graph from a fully pressurized to an empty tank condition indicates a cost saving of IDR 459.1 within one hour of leakage detection. If such leakage persists during an entire 8-hour working day, the projected inefficiency could reach IDR 3,672.8. Detailed leakage test data are provided in the appendix.

CONCLUTION

Based on the design, implementation, and experimental evaluation of the IoT-based air compressor monitoring and control system at the automotive workshop of UPT PKPTK West Kalimantan Province, it can be inferred that compressor load has a direct impact on electrical power consumption, as evidenced by testing with different pneumatic tools. Throughout the experiments, the compressor operating pressure was maintained within the range of 8–9.9 kg/cm², consistent with the specifications of the installed pressure switch.

Moreover, the system effectively identified air leakage conditions, indicated by a faster decline in tank pressure and prolonged compressor operating time. When leakage was detected, the system generated an audible warning through a buzzer and automatically disconnected the power supply via a solid-state relay (SSR). This mechanism successfully minimized unnecessary energy consumption and enhanced operational efficiency.

REFERENCES

E. Team, “Jurnal Dedikasi Pendidikan,” Angew. Chemie Int. Ed. 6(11), 951–952., No. Mi, Pp. 5–24, 1967.

F. Adani And S. Salsabil, “Internet Of Things: Sejarah Teknologi Dan Penerapannya,” Isu Teknol. Stt Mandala, Vol. 14, No. 2, Pp. 92–99, 2019.

E. S. Ma’arif And S. Yudihastoro, “Monitoring Kinerja Motor Kompresor Angin Dengan Komunikasi Modbus Menggunakan Outseal Plc,” Resist. (Elektronika Kendali Telekomun. Tenaga List. Komputer), Vol. 6, No. 1, P. 11, 2023, Doi: 10.24853/Resistor.6.1.11-16.

J. Supriyadi And O. A. Rozak, “Rancang Bangun Sistem Monitoring Kompresor Udara Di Area Utility Berbasis Iot,” Vol. 3, No. 2, Pp. 135–144, 2025.

Damar Romansdani, A. Pudin, And W. Budi Mursanto, “Monitoring Arus Dan Temperature Discharge Kompresor Berbasis Iot (Internet Of Things) Untuk Kebutuhan Preventive Maintenance Di Pt. Mekar Armada Jaya,” J. Surya Tek., Vol. 11, No. 1, Pp. 449–454, 2024, Doi: 10.37859/ Jst.V11i1.7416.

M. S. Hidayat, D. S. A. Pambudi, And A. T. Nugraha, “Sistem Monitoring Air Compressor Pada Sistem Pendistribusian Udara Berbasis Iot,” Elektriese J. Sains Dan Teknol. Elektro, Vol. 12, No. 02, Pp. 126–140, 2022, Doi: 10.47709/Elektriese.V12i02.1944.

B. Fredo Zakaria, M. Ary Murti, And A. Surya Wibowo, “Sistem Pemantauan Kompresor Udara Berbasis Internet Of Things Monitoring System Air Compressor Based On Internet Of Things,” E-Proceeding Eng., Vol. 7, No. 1, Pp. 272–280, 2020.