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Remote monitoring of three-phase motor performance through Internet of Things integration with PZEM004T

Ulil Amri[1], Muldi Yuhendri[1]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

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ABSTRACT

Three-phase induction motors are critical components in various industrial applications, driving essential machinery and production processes. Ensuring optimal motor performance requires accurate monitoring of electrical parameters such as current and voltage. Conventional monitoring systems are often costly, inflexible, and lack real-time accessibility. This research proposes the design and implementation of a real-time current and voltage monitoring system for three-phase induction motors using the PZEM004T sensor integrated with the ESP8266 microcontroller and the Blynk IoT platform. The system employs three PZEM004T modules, each dedicated to one phase (R, S, T), to collect electrical data. These values are transmitted wirelessly via Wi-Fi and visualized on both a TFT LCD and the Blynk mobile application. Experimental results demonstrate that the system effectively captures and displays voltage and current values with high accuracy. The measurements for each phase showed consistent readings compared to standard instruments, with total power consumption measured at 1381.66 W and total current at 5.88 A. The system provides real-time data visualization and remote accessibility, enabling users to monitor motor status conveniently and take proactive measures against potential electrical faults. Furthermore, the integration of low-cost components and an open-source platform makes this system a practical solution for industrial environments seeking to enhance operational efficiency and reliability. This research highlights the potential of IoT-based monitoring systems in industrial motor applications and suggests that real-time visibility into motor performance can significantly improve energy management and preventive maintenance strategies.

Corresponding Author:

Ulil Amri
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: ramadhanulil1999@gmail.com

1. INTRODUCTION

Three-phase induction motors are widely used in industrial applications due to their reliability, efficiency, and ability to handle high-power operations [1]-[3]. These motors are commonly found in manufacturing lines, conveyor systems, and large-scale mechanical equipment [4], [5]. The operational reliability of such motors is critical to the overall productivity of industrial systems. Therefore, maintaining their performance through continuous monitoring of electrical parameters such as voltage and current is essential to prevent unexpected failures and reduce downtime [6].

Traditional methods for monitoring motor performance often involve complex instrumentation, high costs, and limited accessibility. These systems typically require manual observation and on-site equipment, which reduces efficiency and increases maintenance costs [7]-[9]. Moreover, in many industrial setups, there is a growing need for real-time data acquisition and remote control capabilities to enhance operational responsiveness [10]. As the demand for smarter and more connected industrial systems increases, the integration of Internet of Things (IoT) technology offers a promising solution [11].

This research introduces the design and implementation of an IoT-based monitoring system utilizing PZEM004T sensors and the ESP8266 microcontroller. The system is capable of measuring voltage, current, and power in real-time for each motor phase and transmitting the data wirelessly to the Blynk platform [11]-[14]. The simplicity and low cost of the components make the system suitable for small to medium-scale industrial environments [15]-[17]. Additionally, the use of a mobile-based interface through Blynk provides an intuitive and flexible user experience for operators [18].

The proposed system aims to enhance the reliability and efficiency of three-phase motor operations by enabling real-time monitoring and data visualization. With the capability to detect abnormalities and irregularities in motor performance promptly, the system supports proactive maintenance and energy optimization efforts. This study demonstrates the practical value of integrating low-cost IoT solutions in industrial motor monitoring and contributes to the advancement of smart industrial automation.

2. METHOD

This study implements a real-time monitoring system for current and voltage in three-phase induction motors using the PZEM004T sensor, ESP8266 microcontroller, and Blynk IoT platform. The system design consists of both hardware and software components that operate interactively to enable accurate measurement and remote monitoring of motor parameters. The measurement circuit integrates three PZEM004T modules—each assigned to one of the three motor phases (R, S, T)—to capture voltage and current values. These measurements are transmitted wirelessly to a mobile device through Wi-Fi using the ESP8266, which also processes the data locally and displays it on a 20x4 TFT LCD.

The overall structure of the system can be described through the block diagram shown in Figure 1. It illustrates the interaction between the current and voltage sensors (PZEM004T), microcontroller (ESP8266), local display module (TFT LCD), motor load, power supply, and cloud-based mobile interface (Blynk). Each PZEM004T module is connected to its corresponding motor phase and communicates serially with the ESP8266 using TTL-based UART. The ESP8266 is programmed to periodically retrieve, compute, and transmit the electrical parameter data.

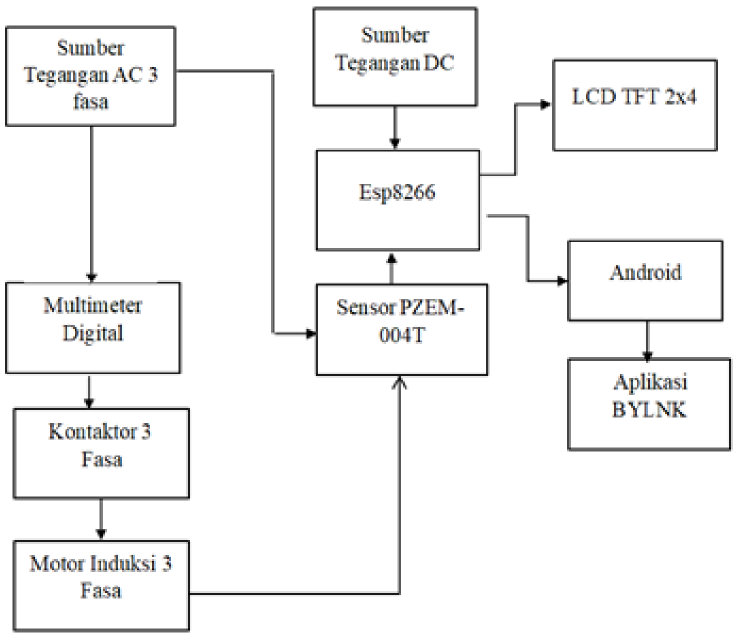

Figure 1. System Block Diagram

The hardware implementation is further detailed in Figure 2, which presents the physical circuit layout used in the system. This figure shows the configuration of the current transformers, power supply connections, microcontroller module, and the relay-based contactor system that enables controlled switching of the motor. The ESP8266 is powered via a 5V DC source, while the motor and sensor modules operate on AC three-phase input. When the system is activated, the sensors begin real-time data acquisition, and the results are concurrently sent to the Blynk cloud server and displayed on the local TFT LCD.

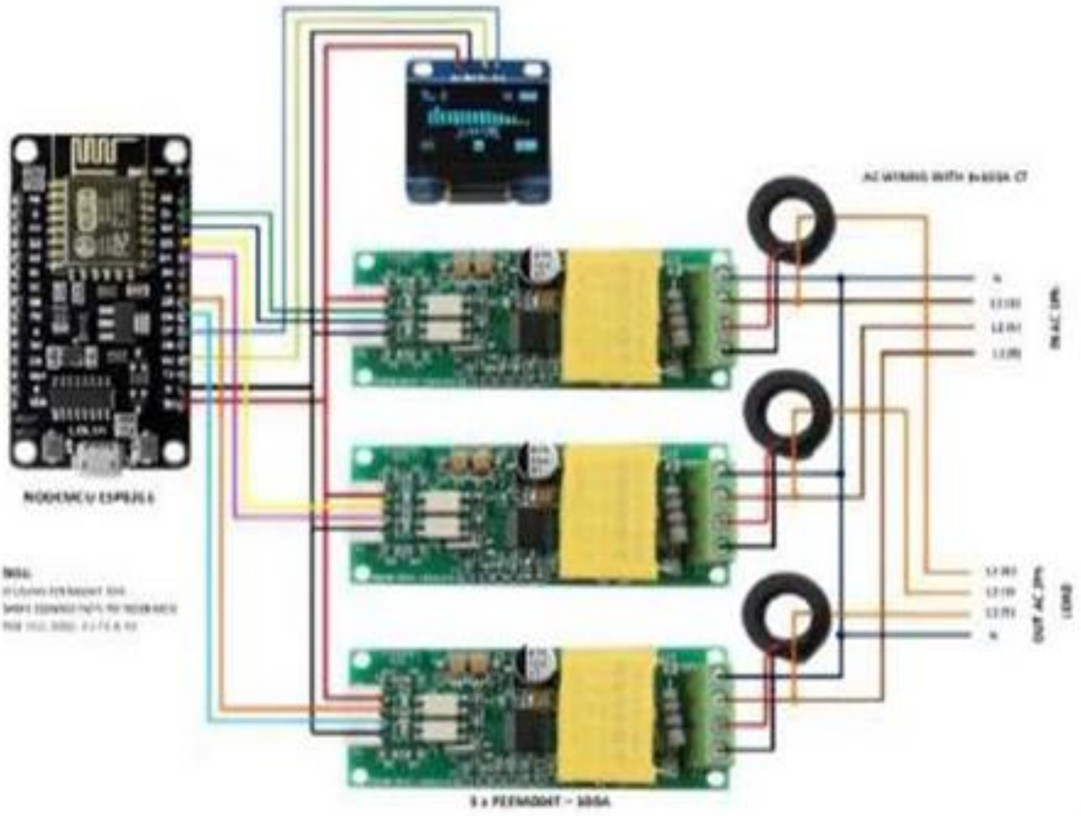

Figure 2. System Hardware Design Layout

All software development was carried out using the Arduino IDE, with custom logic programmed to read serial data from the sensors, process electrical parameters (voltage, current, power), and distribute the information to the virtual dashboard via Blynk APIs. Data transmission is performed every 3 seconds to ensure real-time responsiveness. This method ensures the system’s capability for real-time monitoring, fault detection, and flexible integration in industrial electrical systems.

3. RESULTS AND DISCUSSION

The design and implementation of the proposed system successfully resulted in a three-phase current and voltage monitoring device based on the Internet of Things (IoT) using the PZEM004T sensor. The system is controlled by a NodeMCU ESP8266 microcontroller that transmits data directly to a smartphone via the Blynk application, enabling real-time monitoring and display. The system is capable of detecting whether a load is connected to each phase and identifying the absence of voltage in any of the phases, which is critical for diagnosing faults in three-phase induction motors. Structurally, the system consists of two main components: the hardware, which handles the acquisition and display of electrical data, and the software, which governs data processing and wireless communication. These components are designed to work cohesively to form an integrated monitoring system suitable for industrial applications.

The hardware setup includes a 20x4 character LCD that serves as the local visual output for current and voltage measurements. The system features input/output terminals connected to the motor, with PZEM004T sensors placed on each phase line to capture accurate readings. The ESP8266 microcontroller acts as the core processing unit that links the sensor network to both the LCD and the cloud-based monitoring platform. The software component, programmed via Arduino IDE, enables continuous data acquisition, processing, and transmission. Custom logic is embedded to read and compute the values of current and voltage in each phase and forward the data to the Blynk dashboard and local LCD. The system was then subjected to component-level and system-level testing to validate its functionality and ensure the reliability of both hardware and software integration.

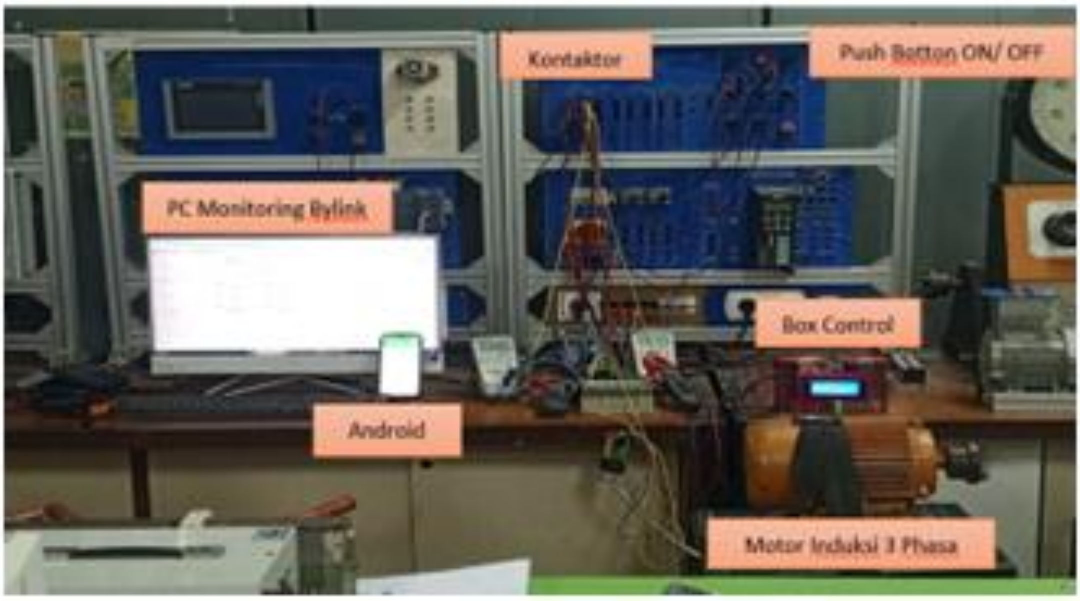

Figure 3. Current and Voltage Monitoring Device Using PZEM004T

The device was tested by applying it directly to a three-phase induction motor to check whether current and voltage were flowing through the motor. The following shows the results of the monitoring device system test, in the form of parameters from the LCD display and Android device, to see how accurate the device is from two different perspectives.

Sensor testing is used to determine the accuracy of the sensor's readings. For the PZEM004T sensor, we will take the values from the current and voltage readings. The current and voltage flowing through the motor are read by the sensor installed on the power cable leading from the motor contactor. For sensor testing, we compare the readings on the sensor (via the BLYNK dashboard app) with those from a measuring instrument. During sensor testing, we connect the device directly to the motor without connecting the motor to the generator. Figure 4 shows the results of monitoring tests using Android devices, while table 1 shows the results of the LCD Display Per Phase.

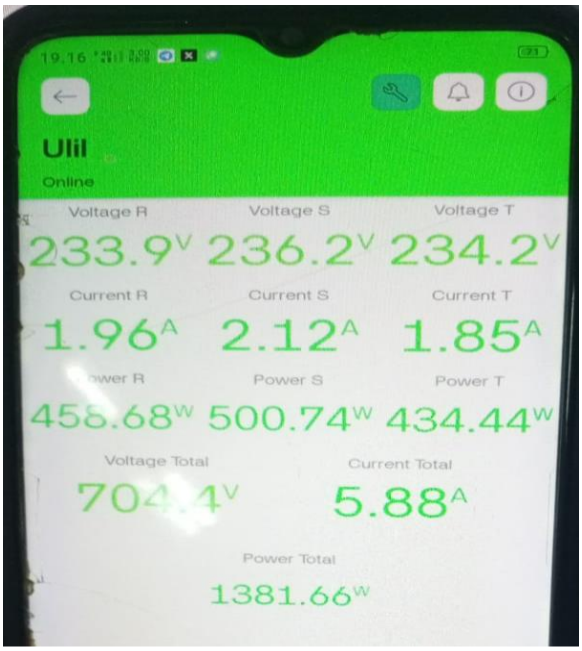

Figure 4. The results of monitoring tests using Android devices

Table 1. LCD Display Per Phase

Phase	Results
R-N	 V = 233,9 V ,A = 1,96 A, P = 458,86 W
S-N	 V = 236,1 V, A = 2,12 A, P = 500,53 W
T-N	 V = 234,2 V, A = 1,85 A, P = 434,44 W
TOTAL	 V = 702,4 V, A = 5,88 A, P = 1381,66 W

Based on Table 1, before the reading value is read and displayed by the LCD, the value will be received by the PZEM004T sensor, which then forwards the value to the nodeMCU ESP8266. After being processed by the nodeMCU ESP8266, the data will be displayed by the LCD. When the LCD is operational, the measured values are displayed one by one. The values displayed are: phase R-N 233.9 V, phase S-N 236.1 V, phase T-N 234.2 V, and the total voltage is 702.4 V. During current measurement on the motor, the current read on phase R-N is 1.96 A, phase S-N is 2.12 A, phase T-N is 1.85 A, and the total current is 5.88 A. The measured power of the motor during operation was 458.86 W on phase R-N, 500.53 W on phase S-N, and 434.44 W on phase T-N, with a total power of 1381.66 W.

Based on the test results of the device, it was found that the device operates properly. When the motor is started, the voltage flowing through the motor is 233.9 V for phase R-N, 236.1 V for phase S-N, and 234.2 V for phase T-N, with a total voltage of 702.4 V. During current measurement on the motor, the current readings were 1.96 A for phase R-N, 2.12 A for phase S-N, and 1.85 A for phase T-N, with a total current of 5.88 A. The measured power on the motor during operation was 458.86 W for phase R-N, phase S-N 500.53 W, and phase T-N 434.44 W. The total power is 1381.66 W. Meanwhile, this data is also displayed on the LCD monitor screen of the device and on the BLYNK application platform used for monitoring the device's operation.

The discussion of the results in this study is in line with the findings of a previous study by Musyafiq, which also used PZEM004T and NodeMCU ESP8266 to monitor three-phase motor current and voltage parameters through the Blynk application. In that study, the system demonstrated high measurement accuracy (voltage error of only 0.1–0.5%) and the ability to detect faults such as phase failure and overcurrent [18]. This reinforces the validity that the combination of PZEM004T and ESP8266 can provide reliable real-time monitoring in an industrial context. Research by Ichpas & Núñez also demonstrated the successful implementation of an IoT-based monitoring system using the PZEM004T sensor, albeit with an ESP32 microcontroller and the Ubidots platform [15]. They highlighted the importance of automatically alerting users when parameters exceed thresholds, a feature aligned with the system's objectives in this study, though with a different dashboard approach.

Meanwhile, the study by Chaihang takes a different focus, namely phase shift disturbance detection using ESP8266 and the Blynk application [19]. Although it does not emphasize power readings or parameter visualization like this study, the study confirms the effectiveness of the ESP8266 in real-time data transmission, although they note significant delays depending on internet speed (0.99–2.51 seconds). Another study by Busaeri developed a more complex three-phase motor monitoring system with additional temperature, vibration, and rotational speed sensors [20]. Compared to the simple and low-cost approach in this study, Busaeri's system is more comprehensive but also requires additional hardware and higher costs.

From the comparison results, it can be concluded that the approach taken in this study successfully adopted IoT technology effectively for real-time monitoring of three-phase induction motors with high accuracy and low cost. This system aligns with previous research trends emphasizing remote monitoring, system simplicity, and ease of use, while also demonstrating potential for further development in integrating automatic protection and additional parameters such as temperature and vibration.

4. CONCLUSION

Based on the design and testing of the developed system, it can be concluded that the implementation of a current and voltage monitoring system for three-phase motors using the PZEM004T sensor and NodeMCU ESP8266 has been successfully achieved. The system effectively integrates hardware and software components to measure electrical parameters with high accuracy and reliability. The Android-based application developed using the Blynk platform provides a user-friendly interface, allowing real-time remote monitoring and control via mobile devices. The system demonstrates reliable performance, delivering measurement results that align with industrial standards. Furthermore, the availability of accurate electrical data contributes to improved energy efficiency by enabling users to optimize motor operation and perform preventive maintenance actions. Overall, this system offers a practical, scalable, and low-cost solution for industrial motor monitoring based on Internet of Things (IoT) technology.

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