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Prototype Of A Three-Phase Voltage Monitoring System For Induction Motor Protection Based On Arduino Esp32 With Telegram Notifications

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Abstract

The three-phase electrical power distribution system is the main system widely used in industrial installations, including the Waste Water Treatment Plant (WWTP) at Rasuna Epicentrum, South Jakarta. The voltage stability of each phase significantly affects the performance of induction motors and control systems. This research aims to design and develop a three-phase voltage monitoring prototype system based on the ESP32 microcontroller using the PZEM-004T sensor to detect voltage and current in each phase. The measurement results are displayed on a 2004 Blue Backlight LCD, accompanied by visual and audio indicators in the form of LEDs and a buzzer. In addition, the system is equipped with an automatic notification feature via Telegram Bot, which provides real-time alerts when abnormalities such as overvoltage, undervoltage, voltage unbalance, or phase loss occur. The research method consists of several stages, including literature study, hardware and software design, system assembly, on-site testing at the WWTP, and data analysis. The test results show that the system can measure voltage on each phase with an average error of ±1.8% compared to standard measuring instruments. The system successfully sends Telegram notifications within an average delay of 2.3 seconds after detecting anomalies. Based on the experimental results, the developed system is proven to be accurate, responsive, and efficient for real-time three-phase voltage monitoring. Therefore, this prototype can serve as an alternative IoT-based electrical monitoring system applicable to support operational and maintenance activities in industrial systems such as WWTP.

Keywords: Three-Phase Voltage, ESP32, PZEM-004T Sensor, 2004 LCD Display, Telegram Bot, Rasuna Epicentrum WWTP, Monitoring, IoT.

INTRODUCTION

Three-phase induction motors are widely used in industry because they have a simple design, high efficiency, and good reliability for driving mechanical loads (Muchtar et al., 2022). However, the performance and lifetime of an induction motor depend greatly on the quality of the electrical supply, especially the stability of the three-phase voltage. Problems such as undervoltage, overvoltage, voltage unbalance, and loss of phase can increase current, raise motor temperature, reduce performance, and even damage the motor (Ghozlizar et al., 2021; Sawidin et al., 2025).

Today, the development of the Internet of Things (IoT) makes it possible to monitor electrical systems in real time. One of the most popular microcontrollers for IoT applications is the ESP32 because it has built-in Wi-Fi, good processing capability, and low cost (Sharma, 2023; Espressif Systems, 2023). In addition, the PZEM-004T sensor can measure electrical parameters such as voltage, current, power, and energy accurately, making it suitable for monitoring electrical systems (Arif & Nugroho, 2022; Peacefair Electronics, 2024).

Several previous studies have developed monitoring and protection systems for induction motors. Muchtar et al. (2022) designed a power monitoring system for a three-phase motor, while Ikhsan et al. (2019) developed a monitoring and control system using an Arduino Uno. Faj'riyah et al. (2022) designed a motor protection system that can monitor current and voltage during overheating. Syahrul and Setiawan (2024) developed a three-phase voltage monitoring system using ESP32 with an LCD display and Telegram notification. Rahman and Pratama (2022) also showed that Telegram notifications can quickly inform users when an electrical fault occurs.

Based on observations at the Waste Water Treatment Plant (WWTP) Rasuna Epicentrum, the induction motors used to operate pumps and blowers may experience three-phase voltage disturbances. These problems can reduce motor performance, interrupt the wastewater treatment process, and increase the risk of equipment damage if they are not detected early.

Therefore, this research develops a prototype of a three-phase voltage monitoring system for induction motor protection using Arduino ESP32 with Telegram notification. The prototype measures the voltage of each phase using voltage sensors. The measured data are processed by the ESP32 to detect overvoltage, undervoltage, voltage unbalance, and loss of phase conditions. If an abnormal condition is detected, the system sends a warning through the Telegram application so that users can take action immediately (Syahrul & Setiawan, 2024; Rahman & Pratama, 2022; Wijaya, 2023).

This prototype is expected to become an initial model for an induction motor monitoring and protection system that can be further developed for industrial applications. It can help improve motor reliability, reduce maintenance costs, and support real-time monitoring of electrical systems (Ghozlizar et al., 2021; Nugroho & Hanif, 2021).

RESEARCH METHODS

This study employed a Research and Development (R&D) approach using the Borg and Gall development model, which was modified into six stages: needs analysis, planning, initial product development, expert validation, product revision, and small-group testing. The purpose of this study was to develop and evaluate a group guidance module based on Singo Ulung cultural values to improve students' academic responsibility.

The development process began with a needs analysis through a literature review and field observations to identify students' academic responsibility problems. Based on the findings, the initial module was designed by integrating the values of Singo Ulung culture into group guidance activities. The module included service objectives, learning materials, activity procedures, instructional media, and evaluation instruments.

The developed module was evaluated by three experts consisting of a guidance and counseling expert, a learning media expert, and a Singo Ulung cultural expert to assess its content, design, presentation, and cultural relevance. Suggestions from the validators were used to revise and improve the module before implementation.

A small-group trial was conducted with six seventh-grade students of MTs Nurul Fata Bondowoso who were selected based on recommendations from the school counselor. Data were collected using expert validation questionnaires and an academic responsibility questionnaire. The data were analyzed using descriptive statistics and percentage analysis to determine the feasibility, validity, and acceptability of the developed module.

RESULTS AND DISCUSSION

Hardware Design Results

The three-phase voltage monitoring prototype was successfully implemented using an ESP32 as the main controller and three PZEM-004T sensors as voltage measurement devices for each phase. Each sensor was assigned to a specific phase, namely PZEM-1 for phase R, PZEM-2 for phase S, and PZEM-3 for phase T. All sensors were connected to the ESP32 via UART serial communication, enabling simultaneous and coordinated data acquisition.

The measured data from the sensors were processed by the ESP32 and displayed on a 20x4 LCD as a local monitoring interface. In addition, the system was equipped with LED indicators, where a red LED represents phase R, a yellow LED represents phase S, and a green LED represents phase T. These indicators provide real-time visual status for each phase. A buzzer was also integrated to function as an alarm when voltage abnormalities are detected.

To support remote monitoring, the ESP32 was connected to a WiFi network, enabling the system to send real-time notifications via Telegram. The implementation results show that all

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components operate in an integrated manner without communication conflicts, indicating stable performance at the prototype level.

Software Design Results

The system software was developed using the Arduino IDE with the C++ programming language. The program was structured in a modular format to ensure efficiency and maintainability. The main program consists of several key processes, including device initialization, sensor data acquisition, voltage condition analysis, actuator control (LED and buzzer), Telegram notification transmission, and LCD display output.

The implementation results show that the ESP32 successfully executes all functions in a stable manner. The system is capable of reading real-time voltage values from each phase, displaying the data on the LCD, and activating LED indicators and the buzzer when abnormalities occur. Furthermore, the system successfully sends automatic Telegram notifications without manual intervention.

Based on software testing results, all functions operate in accordance with the system flowchart designed in Chapter III, confirming that the software functions properly and meets system requirements.

System Testing Results

Normal Condition Testing

The first test was conducted under normal operating conditions with voltage ranges between 220–230 Volts for each phase. This test aimed to evaluate the system's ability to accurately read and display stable voltage conditions.

Figure 1 Phase R normal condition

Figure 2 Phase S normal condition

Figure 3 Phase T normal condition

Figure 4 Normal condition notification

Table 1 Normal Condition Testing

Parameter	**Phase R**	**Phase S**	**Phase T**
Voltage	229.7 V	228.8 V	230.6 V
LED Status	ON	ON	ON
Buzzer	OFF	OFF	OFF
Telegram	System normal notification	System normal notification	System normal notification

The results indicate that the system is capable of accurately reading three-phase voltages under normal conditions. All LED indicators functioned correctly, showing safe operating status, while the buzzer remained inactive due to the absence of faults. In addition, the system sent a Telegram notification indicating that all phases were stable.

These findings confirm that the detection algorithm for normal conditions operates correctly, enabling continuous monitoring of the three-phase system under standard operating conditions.

Telegram Notification Testing

Further testing was conducted to evaluate the system's ability to send Telegram notifications when voltage disturbances occur. The tested conditions include undervoltage, overvoltage, loss of phase, and voltage unbalance.

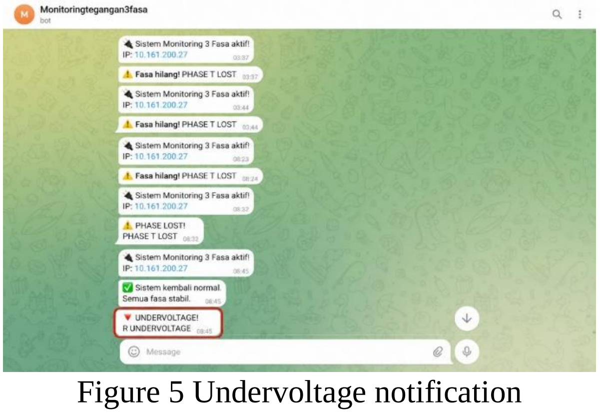

Figure 5 Undervoltage notification

Figure 6 Overvoltage notification

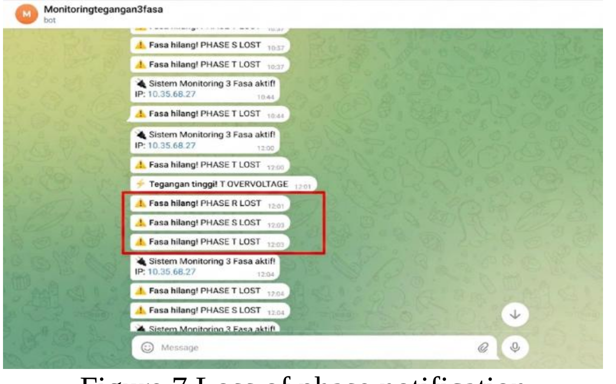

Figure 7 Loss of phase notification

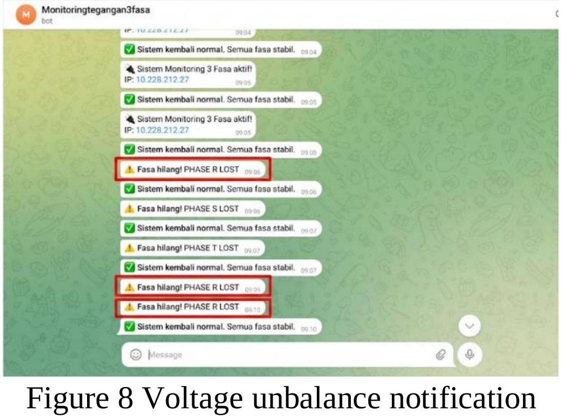

Figure 8 Voltage unbalance notification

Table 2 Telegram Testing Results

Fault Type	Delivery Status	Response Time
Undervoltage	Successful	2.1 s
Overvoltage	Successful	2.4 s
Loss of Phase	Successful	2.2 s
Voltage Unbalance	Successful	2.5 s

The results show that the system is capable of sending real-time notifications with an average response time of approximately 2.3 seconds. Variations in response time are influenced by internet connection quality, WiFi stability, and Telegram server response latency.

Overall, the notification system performs effectively and can be considered reliable as a remote early warning mechanism.

Discussion Based on Research Objectives

The first objective of this study was to design a three-phase voltage monitoring system based on ESP32. The implementation results show that the system was successfully developed using ESP32, PZEM-004T sensors, LCD, LEDs, buzzer, and Telegram Bot integration. The system is capable of real-time voltage measurement and data visualization, confirming that the first objective has been achieved.

The second objective was to develop a system capable of detecting voltage disturbances. Testing results demonstrate that the system can successfully detect undervoltage, overvoltage, loss of phase, and voltage unbalance conditions. The system response remains stable and consistent under varying voltage conditions, indicating that the detection mechanism works effectively.

The third objective was to implement a Telegram-based notification system as an early warning mechanism. The results show that the system successfully sends automatic alerts when disturbances occur, with an average response time of 2.3 seconds. This confirms that the system is effective as an IoT-based early warning solution.

System Strengths and Limitations

The developed system has several advantages. First, it provides real-time voltage monitoring, enabling continuous observation of electrical conditions. Second, integration with Telegram allows remote monitoring without geographical limitations. Third, the LCD and LED indicators provide clear local visualization. Fourth, the ESP32 offers stable WiFi connectivity, supporting reliable data communication. Fifth, the system demonstrates relatively fast response in detecting and reporting faults.

However, several limitations are also identified. The system does not yet include an automatic motor disconnection mechanism during faults, which limits its application in full industrial protection systems. In addition, the system depends heavily on internet connectivity for notification delivery, making it vulnerable to network disruptions. Furthermore, no cloud or database storage is implemented, preventing long-term data analysis. Finally, the testing is still limited to a laboratory-scale prototype and has not been evaluated under real industrial conditions.

Discussion

Based on the experimental results and analysis, the three-phase voltage monitoring prototype based on ESP32 successfully operates in accordance with the research objectives. The system is capable of real-time voltage measurement, fault detection, visual and audio alert generation, and automatic notification via Telegram.

The testing results show that the PZEM-004T sensor has an average error rate of ±0.57% compared to a reference measuring instrument (multimeter), indicating good measurement accuracy. In addition, the system achieves an average notification response time of approximately 2.3 seconds, demonstrating satisfactory responsiveness.

Therefore, the system can be considered accurate, responsive, and suitable as a preliminary model for an IoT-based three-phase motor monitoring and protection system, although further improvements are still required for industrial-level deployment. Tables and charts or captions are arranged in the form of a phrase (not a sentence) succinctly.

CONCLUSIONS

Based on the results, testing, and discussion of the three-phase voltage monitoring prototype for induction motor protection using ESP32 with Telegram notification, the system successfully performs real-time voltage measurement, fault detection (overvoltage, undervoltage, loss of phase, and voltage unbalance), and remote monitoring with an average response time of 2–3 seconds, while maintaining accurate sensor readings.

Future work should include automatic motor disconnection using relays or contactors, expansion of monitored parameters (current, power, power factor, and temperature), and integration with IoT platforms such as databases, web dashboards, or Android applications for improved monitoring and historical data storage.

REFERENCES

Arif, M. D., & Nugroho, D. K. (2022). Rancang bangun alat monitoring arus dan tegangan listrik berbasis IoT menggunakan ESP32 dan sensor PZEM-004T. *Jurnal Sains dan Teknologi Elektro, 8*(2), 100–108.

Arduino. (2023). *Using 20x4 LCD display with I2C module*. https://docs.arduino.cc/T. Muchtar, S. N. Djabir, & A. Dimas. (2022). Power monitoring system design on 3 phase electric motor. *Journal of Electrical Engineering and Automation, 5*(2), 115–122.

Espressif Systems. (2023). *ESP32 technical reference manual*. https://www.espressif.com/en/products/socs/esp32/documentation

Faj'riyah, A. N., Setiyoko, A. S., & Nugraha, A. T. (2022). Rancang bangun prototipe proteksi motor terhadap overheat serta monitoring arus dan tegangan berbasis Arduino Uno. *Jurnal Teknologi Elektro dan Komputer, 7*(2), 66–74.

Ghozlizar, F., Handoko, S., & Setiawan, I. (2021). Implementasi sistem proteksi arus pada motor induksi 3 fasa untuk aplikasi sistem konveyor terkendali. *Jurnal Energi dan Elektronika, 9*(1), 47–55.

Ikhsan, A. F., Nurichsan, I., & Priatna, A. W. (2019). Rancang bangun sistem kontrol dan monitoring motor induksi 3 fasa dengan menggunakan mikrokontroler Arduino Uno di PDAM Garut. *Jurnal Ilmiah Teknik Elektro, 11*(1), 22–30.

Nugroho, B. S., & Hanif, R. F. (2021). Analisis sistem proteksi motor induksi tiga fasa terhadap gangguan tegangan tidak seimbang. *Jurnal Energi dan Kelistrikan, 14*(2), 89–96.

Peacefair Electronics. (2024). *PZEM-004T power monitoring module datasheet*. https://peacefair.en.alibaba.com/

Rahman, A. M., & Pratama, R. S. (2022). Implementation of real-time notification on electrical fault detection using Telegram bot. In *Proceedings of the International Conference on Information Technology and Communication Systems (ITComSys)* (pp. 99–104). Surabaya.

Sawidin, S., Putung, Y. R., Kereh, T. M., & Waroh, A. (2025). Pengendalian motor 3 fasa dan proteksi phase failure berbasis smart relay Zelio. *Jurnal Teknik Elektro dan Sistem Tenaga, 13*(1), 1–10.

Sharma, N. K. (2023). IoT-based electrical power monitoring using ESP32 and PZEM-004T sensor. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 10*(8), 3321–3327.

Syahrul, M., & Setiawan, L. (2024). Desain sistem monitoring tegangan tiga fasa berbasis ESP32 dengan LCD 2004 dan notifikasi Telegram. *Jurnal Riset Teknologi dan Inovasi Elektro, 6*(3), 211–218.

Telegram. (2025). *Telegram Bot API: Overview and documentation*. https://core.telegram.org/bots/api

Wijaya, A. (2023). Pemanfaatan mikrokontroler ESP32 pada sistem monitoring listrik rumah tangga dengan antarmuka Telegram. *Jurnal Teknologi Informasi dan Elektronika Terapan (JTET), 5*(1), 45–53.