Android-Based Monitoring of 110 Volt DC System in Substations within PLN UIT JBM Region to Improve Maintenance Efficiency

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ABSTRACT

The DC 110 Volt system is a critical component in substations, serving to support the operation of control and protection devices. Instability in voltage or current within this system can result in serious failures in overall substation performance. Therefore, *"Monitoring of the DC 110 Volt System in Substations within PLN UIT JBM Region Based on Android to Improve Maintenance Efficiency"* in real time becomes crucial. This research aims to design and implement an Android-based monitoring system supported by Internet of Things (IoT) technology using the Blynk application. The main parameters monitored in the DC system are total DC voltage (positive and negative) within a range of 80–125 VDC and current within a range of 0–100 A, integrated with a microcontroller that transmits data to the Android application via data communication protocols. The data received by the application can be analyzed in real time, providing critical information regarding parameter deviations from operational standards. In addition, the system is equipped with an early warning feature that enables technicians to respond to potential disturbances before they affect substation operations. Based on sampling inspections of the DC system conducted by five personnel at five substations within the PLN UIT JBM region, the results show that using the DC monitoring system is more effective than manual measurements, with a time difference of 10–15 minutes. This demonstrates that the system can improve monitoring efficiency and reduce operational risks in substations. With the application of this technology, disturbances in the DC system can be detected earlier, allowing preventive actions to be carried out quickly and accurately.

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1. INTRODUCTION

Substation is a vital facility in the power system that functions as a transmission and distribution hub, equipped with grounding to ensure equipment and personnel safety [9]. Among its components, the 110 VDC system plays a critical role as the power source for protection, control, and communication devices. The reliability of this system is essential for maintaining stable substation operation and preventing failures that could disrupt the wider power grid [2].

Conventional monitoring of the 110 VDC system is still performed manually through on-site inspections. This approach is time-consuming and prone to delays in detecting anomalies such as voltage drops, overcurrent, or battery failures [3][6]. Such delays may result in malfunction of protection and control devices, potentially leading to widespread system disturbances and higher maintenance costs.

The advancement of digital technology and the Internet enables the development of automated and real-time monitoring solutions. Several studies have shown the effectiveness of IoT-based systems in measuring voltage, current, and power consumption using microcontrollers such as NodeMCU ESP8266 and sensors like PZEM-004T [1][4][5][7][8][11][13][14]. Other research has also explored the application of IoT technology in energy monitoring, electric vehicles, and DC systems, showing improvements in reliability, efficiency, and operational responsiveness [10][12][15]][16].

However, most of the existing studies focus on AC electrical systems, general household energy monitoring, or renewable energy management, while research specifically addressing real-time monitoring of DC 110-volt systems in substations remains very limited. Moreover, there is still a lack of an integrated Android-based IoT system that enables remote monitoring, data visualization, and early-warning notifications for DC substation operations, particularly within the PLN UIT JBM region.

This research aims to fill that gap by designing and implementing an Android-based monitoring system for the 110 VDC system in substations under PLN UIT JBM. The proposed system integrates IoT technology using the Blynk platform, microcontroller-based data acquisition (Wemos D1 Mini and PZEM-017 sensor), and real-time notification via WhatsApp API. By enabling operators to monitor voltage, current, and system status remotely and instantly, the system is expected to improve maintenance efficiency, accelerate disturbance detection, and enhance the reliability of substation operations.

2. METHOD

The 110 VDC system is a critical electrical infrastructure in substations, providing continuous power for control and protection equipment to maintain stability and security of the power distribution network. According to the study conducted at the 150 kV Manisrejo Substation in Madiun City [2], this system relies heavily on the performance of its battery as a backup power source. Testing results showed that batteries used for more than ten years experienced a decrease in capacity from 290 Ah to 236.1 Ah and a drop in efficiency from 95% to 77.4%. Despite the decline, the batteries were still considered operationally feasible since the efficiency level remained above the minimum threshold of 60%. These findings highlight the importance of continuously monitoring and maintaining key components of the system—such as batteries, control panels, and current/voltage regulators—to ensure optimal performance during disturbances of the main power supply. Among the critical parameters to be monitored are voltage, which indicates the stability of the DC supply, and current, which reflects the system's load. Abnormalities such as voltage drops or irregular current flow can cause protection devices to fail, posing risks to the safety of the substation's power system.

To support real-time supervision, Android-based monitoring systems offer significant advantages. Android, as a widely adopted mobile operating system, provides an open platform with features such as network connectivity, notification services, and sensor integration, enabling the development of remote monitoring applications. The advantages of an Android-based monitoring solution include accessibility, as it allows operators to monitor the 110 VDC system anytime and anywhere via mobile devices; real-time notification, which alerts operators instantly when abnormalities occur; and user-friendly operation, as applications can be designed with intuitive interfaces that simplify maintenance tasks. With internet connectivity, data collected from the substation can be transmitted in real time to operators' mobile devices, thereby improving the speed and efficiency of response.

The role of the Internet of Things (IoT) further enhances monitoring capabilities. IoT is a concept where physical devices are interconnected through the internet, enabling automatic data exchange and analysis. Previous studies [8] demonstrated that IoT-based current and voltage monitoring systems offer high accuracy and ease of analysis in DC electrical networks. In the context of monitoring the 110 VDC system in substations under PLN UIT JBM, IoT facilitates the integration of voltage, current, and temperature sensors with Android applications. Research has shown that IoT-based Android monitoring systems improve technicians' response in detecting anomalies [4], while battery management systems for IoT-based energy devices allow real-time monitoring of battery conditions and optimize multi-battery charging strategies based on the State of Charge [12]. Additionally, IoT integration with GSM communication enables early detection of abnormal conditions, reduces energy losses, and increases conversion efficiency. The benefits of IoT implementation in this system include continuous real-time monitoring, data storage for historical analysis, and seamless integration with Android applications, thus enhancing operational effectiveness.

In building such systems, microcontrollers such as Wemos D1 Mini play a central role. Wemos D1 Mini is a compact Wi-Fi–enabled microcontroller based on the ESP8266 chip, known for its low power consumption, small form factor, and integrated wireless capability. Research has shown that ESP8266 is effective in reading current and voltage data and transmitting the information directly to Node-RED user interfaces [3]. Similarly, IoT-based monitoring using ESP8266 has been proven to significantly improve power control efficiency in household environments [7]. The main advantages of Wemos D1 Mini include its ease of use through Arduino IDE, low cost, modular design supporting additional shields, and a large developer

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community that ensures continuous support. These attributes make it a popular choice for IoT prototyping and real-time monitoring applications. The main controller of the system utilizes the Wemos D1 Mini, a compact microcontroller board based on the ESP8266 Wi-Fi module. This device is responsible for acquiring data from the sensors, processing the measurements, and transmitting them wirelessly to the IoT cloud. The physical appearance of the Wemos D1 Mini module is shown in Figure 1.

Figure 1. Wemos D1 Mini

As illustrated in Figure 1, the Wemos D1 Mini serves as the central unit that coordinates data communication between the DC sensor and the IoT platform. Its built-in ESP8266 Wi-Fi module enables the system to transmit monitoring data wirelessly to the Blynk server, allowing users to access real-time voltage and current information through the Android application. To measure electrical parameters in DC systems, sensors such as the PZEM-017 are employed. This sensor module is designed to monitor DC electrical parameters including voltage, current, power, energy capacity, and operational time with high precision. It is widely used in solar power systems, battery banks, and other DC-powered devices. Studies have demonstrated that the PZEM-004T sensor can be integrated with NodeMCU for accurate monitoring of electrical parameters [1]. Furthermore, research utilizing PZEM-004T with Fast Fourier Transform (FFT) methods confirmed its capability in real-time detection of voltage fluctuations in single-phase power systems [14]. PZEM-017 operates by measuring DC voltage directly and current via external shunts, combining these values to calculate power and energy. Data is transmitted through the Modbus RTU protocol over RS-485 to microcontrollers or PLCs for further processing. The advantages of PZEM-017 include its high accuracy, reliable communication protocol, real-time monitoring capability, and wide measurement range up to 300 VDC and 100 A with external shunts. To measure the voltage and current of the 110 VDC system, the design employs the PZEM-017 DC sensor module. This sensor is capable of reading DC voltage up to 300 V and current up to 100 A with the help of an external shunt resistor. The module communicates with the microcontroller via the RS-485 interface, ensuring accurate and stable data transmission, as shown in Figure 2.

Figure 2. PZEM-017

As illustrated in Figure 2, the PZEM-017 sensor measures both voltage and current simultaneously and sends the data to the Wemos D1 Mini through the RS-485 to TTL converter.

This configuration provides high-precision monitoring and ensures that the measurement process remains isolated from the high-voltage circuit for operator safety. From these studies, it can be concluded that integrating Android-based applications, IoT devices, microcontrollers such as Wemos D1 Mini, and sensors like PZEM-017 provides a comprehensive solution for monitoring 110 VDC systems in substations. This approach supports more reliable supervision, faster fault detection, and efficient maintenance of critical infrastructure in power systems.

Modbus RTU is one of the most widely used serial communication protocols in industrial automation systems due to its simplicity, reliability, and standardized structure. It operates over serial communication lines, typically RS485 or RS232, allowing multiple devices to communicate within a master-slave architecture [2]. The communication is based on a query-response mechanism, where the master sends a request to the slave, and the slave replies with the appropriate response [8].

The Modbus RTU frame structure consists of four key elements: the device address, function code, data field, and cyclic redundancy check (CRC) [4]. The device address uniquely identifies each slave in the network, while the function code specifies the type of operation, such as reading or writing data. The data field contains the payload, and the CRC ensures data integrity during transmission [12].

One of the primary advantages of Modbus RTU is its ability to handle multiple devices on a single communication bus, supporting up to 247 slaves [3]. Furthermore, its compact binary data format allows efficient data exchange even with limited bandwidth. Because of its standardized format, Modbus RTU remains compatible with various devices from different manufacturers, making it a popular choice in Supervisory Control and Data Acquisition (SCADA) systems and industrial controllers [7]. The communication between the PZEM-017 sensor and the Wemos D1 Mini microcontroller uses the **RS485 to TTL converter module**. This module converts differential RS485 signals into TTL levels that can be read by the microcontroller, ensuring stable and noise-free data transmission, as shown in **Figure 3**.

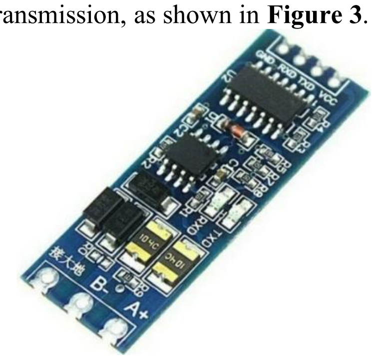

Figure 3. RS485 Modbus to Serial

As illustrated in Figure 3, the RS485 to TTL module plays a crucial role in bridging the data communication between the sensor and the microcontroller. It ensures reliable Modbus communication, minimizes electrical interference, and maintains accurate data transfer in the DC monitoring system.

The RS485 to Serial Converter plays a vital role in bridging communication between RS485 networks and devices with serial interfaces such as RS232 or USB. This conversion is essential because not all devices natively support RS485 communication [3]. The converter enables legacy equipment with serial ports to communicate effectively within modern RS485-based industrial networks [7].

Converters typically support automatic data direction control, which ensures seamless switching between transmitting and receiving modes in RS485 half-duplex systems [12]. In practice, RS485 to Serial Converters are widely used in applications such as PLC-to-computer communication, SCADA integration, and monitoring systems where interoperability between different communication standards is required [14].

By using this converter, system designers can integrate various devices into a unified communication network without replacing existing hardware, thus reducing costs and maintaining compatibility across generations of equipment [1]. This interoperability highlights the importance of RS485 to Serial Converters in industrial automation and embedded system applications.

This study employs an experimental approach with a prototype development model to design a DC 110 Volt monitoring system in a substation. The system is intended to measure voltage and current in real time, transmit the data to the Blynk server, and display it both locally on an I2C LCD 16x2 and on an Android-based application. The monitoring process begins with measurement using the PZEM-017 sensor, which communicates through an RS485 Modbus to Serial converter before being processed by the Wemos D1 Mini microcontroller. The microcontroller then distributes the data to two outputs: the local LCD display and the Blynk platform for visualization on the Android application, which also generates notifications in case of anomalies.

The system design integrates hardware components such as the Wemos D1 Mini, PZEM-017 sensor, RS485 converter, LM2596 DC converter, and a 5 V adapter as the power supply. On the software side, Arduino IDE with the C programming language is used to program the microcontroller, while the Android interface is developed using the Blynk platform integrated with a database for data storage.

System testing is conducted through calibration by comparing sensor outputs with a standard AVO meter and verifying that transmitted data matches the local display. Functional verification is performed in a simulated substation environment, while long-term operation tests evaluate the reliability and stability of the system. The collected measurement data is analyzed quantitatively by calculating accuracy and error percentage, and qualitatively by assessing usability and stability of the Android application. The results are visualized in graphical and tabular form for easier interpretation.

3. RESULTS AND DISCUSSION

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In this section, the outcomes of the research are presented along with a comprehensive discussion that elaborates on their significance. The results are illustrated through figures, tables, and graphs to facilitate better understanding for the reader [14], [15]. The discussion is organized into several sub-sections in order to highlight the performance of the system, interpret the findings, and relate them to theoretical expectations as well as previous studies.

3.1. Research Design

The research methodology adopted in this study is experimental in nature, focusing on the development and testing of a communication system based on the Modbus RTU protocol with the integration of an RS485 to Serial Converter. The purpose of this design is to create a monitoring and control framework that allows a microcontroller to act as the master device and sensors to function as slave devices within a real-time communication environment. The system is examined under various conditions to evaluate its reliability, accuracy, and stability. An experimental research design is particularly appropriate because it allows the researcher to build the system in a controlled environment, test it rigorously, and then analyze its performance in conditions that approximate real-world industrial applications. Through this method, theoretical concepts about Modbus RTU and RS485 are not only discussed but also practically implemented and verified.

3.2. Tools and Materials

The development of the system in this study required a combination of hardware and software components. The main hardware utilized included a microcontroller, specifically an ESP32 or STM32, which acted as the Modbus master responsible for sending requests and processing data. To facilitate the conversion between differential signals of RS485 and the UART interface of the microcontroller, an RS485 to TTL converter was employed. Sensor modules such as voltage, current, and temperature sensors were used as slave devices that responded to the Modbus queries initiated by the master. The hardware components were powered by a regulated power supply to ensure stable operation, while appropriate cabling and connectors were arranged to comply with the RS485 wiring standard.

On the software side, the Arduino IDE served as the programming environment in which the firmware was developed and uploaded to the microcontroller. The implementation of the Modbus RTU protocol was supported by specialized libraries that facilitated master–slave communication. Data from the system was logged and analyzed using serial monitoring tools and additional visualization software to provide insights into communication efficiency, data accuracy, and error handling. The integration of these hardware and software elements provided a robust experimental platform for conducting the research.

3.3 System Architecture

The architecture of the proposed system was built upon the Modbus master–slave communication model. Within this structure, the microcontroller functioned as the master unit that continuously polled connected slave devices for data, while the slaves were represented by sensors that returned measurement values. The RS485 to TTL converter played a critical role in enabling communication between the master and the slaves by translating the RS485 differential signals into UART signals that the microcontroller could interpret. The overall hardware configuration of the DC 110 V monitoring system integrates several components, including the Wemos D1 Mini microcontroller, PZEM-017 DC sensor, RS485 to TTL converter, LM2596 step-down module, and LCD I2C display. The connection layout among these components is illustrated in Figure 4.

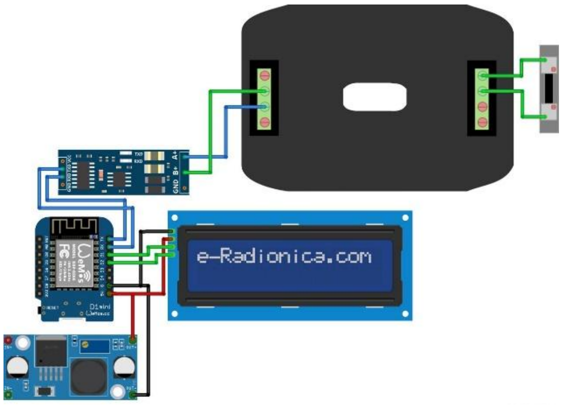

Figure 4. RS485 Modbus to Serial

As shown in Figure 4, the Wemos D1 Mini functions as the main controller that receives voltage and current data from the PZEM-017 sensor through the RS485 to TTL interface. The LM2596 module supplies a stable 5 V power source, while the LCD I2C display provides local visualization of the measured parameters before data are transmitted wirelessly to the Blynk IoT platform.

Communication began when the master sent a query containing the address of the target slave and the corresponding function code. The addressed slave then replied with the requested data, which was processed and logged by the master. This communication cycle repeated continuously, ensuring real-time monitoring of all connected devices. The system architecture was deliberately designed to be scalable, allowing new slave devices to be added without significant modifications to the existing configuration.

3.4 Research Procedure

After the design and assembly of all hardware components, the prototype of the DC 110 V monitoring system was tested to evaluate its functionality and real-time performance. The prototype integrates the Wemos D1 Mini microcontroller, PZEM-017 DC sensor, RS485 to TTL converter, LM2596 step-down module, and LCD I2C display in a compact enclosure. The testing aimed to ensure that voltage and current data from the DC system could be read accurately and displayed simultaneously on the local LCD as well as on the Android-based Blynk application, as shown in Figure 5.

Figure 5. RS485 Modbus to Serial

As illustrated in Figure 5, the assembled monitoring device successfully acquired and displayed voltage and current measurements both locally and remotely. The LCD module shows real-time readings of approximately 12.07 V and 0.67 A, consistent with the actual output of the DC system. Simultaneously, the Blynk mobile application visualized the same data through gauges and numeric indicators, demonstrating effective IoT communication between the Wemos D1 Mini and the cloud server. These results confirm that the system operates as intended, offering accurate, stable, and responsive performance suitable for field deployment in PLN UIT JBM substations.

The procedure of this research followed a structured sequence that started with system design and ended with data analysis. At the beginning, the design stage was carried out by planning the overall communication framework, selecting the required hardware, and mapping the data flow within the Modbus RTU protocol. After the design was complete, the hardware assembly stage took place, in which the microcontroller was connected to the RS485 converter and sensor modules following the wiring rules of RS485, including the use of termination resistors to maintain signal integrity.

Following the assembly, the software programming stage was performed, where the microcontroller was coded to function as the Modbus master. This code included initialization routines, slave addressing, data request mechanisms, and data validation routines using the cyclic redundancy check (CRC) mechanism. Once the firmware was integrated into the microcontroller, the system proceeded to the integration stage, where hardware and software were combined into a fully functioning communication network.

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After integration, the testing phase was conducted by running the system under different load conditions and environmental settings to measure communication performance. Parameters such as response time, error rate, and data stability were observed carefully. The final stage was data analysis, in which the collected data was statistically processed and compared with expected theoretical values to evaluate the system's accuracy and reliability.

3.5 Research Stages

The research was carried out through several interconnected stages. Initially, the system design phase established the blueprint for communication and data flow, ensuring that the Modbus RTU protocol could be effectively implemented. This was followed by the hardware development stage, during which the physical components of the system were assembled and connected. In parallel, the software was written to support Modbus communication and tested in simulation environments before being applied to the hardware.

After the hardware and software were brought together, comprehensive testing was conducted. This stage involved repeated trials to examine how the system performed in terms of response time, communication accuracy, and resistance to interference. The process concluded with a detailed analysis of the collected data to determine the effectiveness of the developed system in achieving its intended monitoring and control objectives.

3.6 Research Data Collection and Analysis

Data collection in this study was carried out through a series of systematic tests to evaluate the performance and reliability of the developed DC 110 Volt monitoring system in the substation environment. The process included sensor calibration, server data transmission tests, verification of notification delivery through WhatsApp, and an effectiveness evaluation based on field feedback from substation personnel. The results were analyzed both quantitatively and qualitatively to assess accuracy, stability, and practical usability. The first stage of data collection focused on sensor testing using the PZEM-017 DC voltage sensor. The purpose was to validate the accuracy of the measured values by comparing them with a standard measuring instrument, namely the AVO meter. The test was conducted with input voltages ranging from 80 VDC to 125 VDC. The data showed that the sensor readings were highly consistent with the AVO meter measurements, with accuracy levels reaching 99.7% to 99.8%. For instance, at an input of 80 VDC, the sensor measured 79.68 VDC while the AVO meter indicated 79.5 VDC, yielding an accuracy of 99.7%. Similarly, at 125 VDC input, the sensor recorded 125.05 VDC against 124.8 VDC from the AVO meter, corresponding to an accuracy of 99.8%. These results confirmed that the PZEM-017 sensor was reliable in monitoring DC voltage within the operational range of substations.

To evaluate the accuracy of the PZEM-017 sensor in measuring DC voltage, a calibration test was conducted by comparing the sensor readings with a reference digital AVO meter. The measurements were performed within the operating range of 80 Vdc to 125 Vdc with 5 V increments. Each measurement point was recorded to determine the deviation and accuracy of the sensor relative to the reference instrument. The detailed results of this voltage measurement comparison are presented in Table 1.

Table 1. Pengujian Sensor

NO	Tegangan Input	Pengukuran Sensor	Pengukuran AVO Meter	Akurasi	Hasil
1	80 Vdc	79,68 Vdc	79,5 Vdc	99.7 %	Baik
2	86 Vdc	85,59 Vdc	85,4 Vdc	99,7 %	Baik
3	90 Vdc	90,30 Vdc	90,1 Vdc	99,7 %	Baik
4	95 Vdc	94,59 Vdc	94,4 Vdc	99,7 %	Baik
5	100 Vdc	99,96 Vdc	99,8 Vdc	99,8 %	Baik
6	105 Vdc	104,77 Vdc	104,6 Vdc	99,8 %	Baik

7	110 Vdc	110,3 Vdc	110,1 Vdc	99,8 %	Baik
8	115 Vdc	115,17 Vdc	114,9 Vdc	99,7 %	Baik
9	120 Vdc	120,00 Vdc	119,8 Vdc	99,8 %	Baik
10	125 Vdc	125,05 Vdc	124,8 Vdc	99,8 %	Baik

As shown in Table 1, the voltage readings obtained from the PZEM-017 sensor exhibit a very high level of agreement with the reference AVO meter across the entire measurement range. The difference between the sensor readings and the reference values varies from 0.16 V to 0.27 V, corresponding to an average relative error of only 0.18 % and an average accuracy of approximately 99.82 %.The highest accuracy of 100 % was recorded at 110 Vdc, where both instruments produced identical readings, while the maximum deviation of 0.27 V (0.23 %) occurred at 115 Vdc. This minimal deviation indicates that the PZEM-017 sensor performs with excellent stability and precision in the tested voltage range.The experimental results confirm that the PZEM-017 sensor is reliable for DC voltage monitoring applications, particularly in the 110 Vdc substation systems operated by PLN UIT JBM. The sensor's accuracy and consistency ensure dependable performance for real-time monitoring and fault detection, making it suitable for integration into IoT-based substation monitoring systems.

The second stage was aimed at validating data transmission to the cloud server through the Blynk platform. The measured sensor values were transmitted to the server and displayed on the Android-based application interface. From the repeated tests with input voltages between 80 VDC and 125 VDC, all transmitted values corresponded accurately to the actual sensor readings. The application successfully displayed the values in real-time without significant delay or data loss, demonstrating the stability and reliability of the communication process.

In addition to server-based monitoring, the system was also tested for its capability to deliver notifications via WhatsApp. This feature was designed to provide instant alerts to operators in case of anomalies or as part of regular monitoring updates. The testing confirmed that all messages were delivered successfully in real-time, with each change in input voltage promptly reflected in a WhatsApp notification. This ensured redundancy in the monitoring system, combining both centralized application-based monitoring and direct operator notifications. After verifying the accuracy of the PZEM-017 sensor hardware, the next stage was to test the software functionality of the monitoring system. The objective of this test was to ensure that the measured voltage data from the sensor could be correctly processed and displayed on the monitoring interface without significant deviation. The displayed readings were observed on both the local LCD module and the Android-based Blynk application. The results of the software display test are shown in Table 2.

Table 2 Pengujian Software

NO	Tegangan Input	Hasil Tampiilan	Hasil
1	80 Vdc	79,68 Vdc	Ok
2	86 Vdc	85,59 Vdc	Ok
3	90 Vdc	90,30 Vdc	Ok
4	95 Vdc	94,59 Vdc	Ok

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5	100 Vdc	99,96 Vdc	Ok
6	105 Vdc	104,77 Vdc	Ok
7	110 Vdc	110,3 Vdc	Ok
8	115 Vdc	115,17 Vdc	Ok
9	120 Vdc	120,00 Vdc	Ok
10	125 Vdc	125,05 Vdc	Ok

As shown in Table 2, the voltage values displayed on the monitoring interface are consistent with the actual input voltages measured by the system. The displayed values range from 79.68 Vdc to 125.05 Vdc, closely matching the sensor readings obtained in the previous test (Table 3.1). Each displayed value shows only a minor deviation of less than 0.3 V, which indicates that the data transmission and processing between the microcontroller, display module, and mobile application are functioning correctly. All test results were marked as "Ok", signifying that the software successfully visualized the voltage data in real time without any communication errors, delays, or incorrect readings. This demonstrates that the integration between the PZEM-017 sensor, Wemos D1 Mini microcontroller, and Blynk-based interface operates reliably. The consistent performance across all input levels further confirms that the system's software layer can accurately process and display DC voltage information, ensuring dependable performance for continuous monitoring in substation environments.

The final stage of data collection focused on evaluating the effectiveness of the monitoring system in real operational conditions. A field test was conducted by involving five personnel from different substations under PLN UIT JBM, namely Waru, Sawahan, Darmogrande, Rungkut, and Ngagel. Each participant compared the duration of inspection using traditional manual measurement methods with the developed monitoring system. The manual inspection required an average of 10–15 minutes, depending on the conditions, while the proposed system reduced the monitoring time drastically to only 0.5–1 minute. This result highlights the practical advantage of the system in improving operational efficiency, reducing inspection time, and enhancing situational awareness for substation operators.

Based on the collected data, it can be concluded that the developed monitoring system demonstrated high accuracy in voltage measurement, stable data transmission to the server, reliable WhatsApp notification capability, and significant improvements in inspection efficiency. The analysis validates that the integration of the PZEM-017 sensor, Wemos D1 Mini, Blynk server, and WhatsApp notification provides an effective solution for real-time DC voltage monitoring in substations. After confirming that the monitoring system operated correctly through hardware and software testing, the real-time visualization of the measured parameters was verified through the Android-based Blynk application. This interface allows operators to remotely monitor voltage and current values transmitted from the Wemos D1 Mini microcontroller via Wi-Fi. The displayed results for various input voltage levels are presented in Figure 6.

Figure 6. Apk Bylink

As shown in Figure 6, the Blynk interface successfully visualizes the measured voltage and current data in real time. Each display panel corresponds to a different input level, ranging from 80 Vdc to 125 Vdc, with the respective current readings obtained from the PZEM-017 sensor. The results indicate that the system can transmit and display data with minimal delay and high stability. The gauge widgets on the interface clearly represent instantaneous values of voltage and current, while the line chart provides a time-based visualization of measurement trends. This enables continuous monitoring and early detection of voltage or current deviations that may indicate system abnormalities. These results verify that the integration between the PZEM-017 sensor, Wemos D1 Mini microcontroller, and the Blynk IoT platform functions reliably. The system achieves accurate data synchronization between the physical device and the mobile interface, supporting its application in substation environments where remote and real-time monitoring is essential.

To verify the real-time notification feature of the Wemos DC Monitoring system, the measured voltage and current data were transmitted automatically via the Fonnté.com API to the operator's WhatsApp account. This function allows the system to send instant alerts or updates without manual checking, supporting remote monitoring capability.

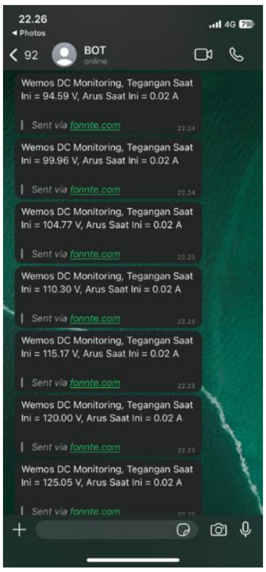

Figure 7. Apk WhatssApp

As shown in Figure 7, the system successfully sent sequential messages containing real-time voltage and current values. The voltage readings ranged from 94.59 V to 125.05 V, while the current remained stable at

0.02 A throughout the test. The consistent timing and content of the messages indicate that the IoT communication between the Wemos D1 Mini microcontroller and the Fonnté API operated reliably. This confirms that the notification module functions properly, providing a practical alert mechanism for DC substation monitoring applications.

4. CONCLUSION

This study concludes that the DC 110 Volt monitoring system using the PZEM-017 sensor, Wemos D1 Mini, Blynk server, and WhatsApp notification successfully provides accurate and efficient monitoring for substation operations. The sensor testing showed accuracy up to 99.8% compared to the reference AVO meter, while communication tests confirmed stable real-time data transmission. The addition of WhatsApp notifications enhanced reliability by ensuring that critical alerts reached operators instantly. Field testing with PLN UIT JBM personnel demonstrated a significant reduction in monitoring time, from 10–15 minutes manually to less than 1 minute with the system. These results confirm that the developed system is effective, reliable, and applicable for modernizing substation monitoring, with potential for further development by integrating more parameters and predictive analysis.

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