Journal of Industrial Automation and Electrical Engineering
Vol. 02, No. 01, June 2025, pp. 22~31
ISSN: 3089-1159

Monitoring of Multi Purpose Rack (MPR) interlocking system of Railway Stations based on Internet of Things

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Article Info

Article history:

Received *January* 30, 2025
Revised *February* 3, 2025
Accepted *February* 5, 2025

Keywords:

Interlocking of system
ESP32
Railway
Blynk
Internet of Things

ABSTRACT

Signaling devices such as signal lights and point machines are very important in railway signaling interlocking systems, where voltage and current affect their performance. Fluctuations in these parameters can cause malfunctions and endanger safety. Current manual monitoring is considered inefficient, error-prone, and slow to respond to problems. For this reason, an automatic monitoring system based on the Internet of Things (IoT) is needed to monitor parameters in real-time. The prototype uses two ESP32 microcontroller modules as data senders and receivers. Data is displayed via a TFT LCD screen and the Blynk application. The system is also equipped with a buzzer alarm to detect abnormal conditions. The test results show that the prototype monitoring device that was made can work well and in accordance with the design, where the PZEM-004T sensor is able to read current and voltage accurately and the buzzer alarm is able to detect when an abnormal condition occurs in the signaling device.

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1. INTRODUCTION

Currently, development is growing rapidly, especially in the transportation sector, one of which is railways [1],[2]. In every journey, the train is controlled by the PPKA (Train Travel Controller) who is on duty at the station and always coordinates with the Railway Operational Control Center (PUSDALOPKA) [3]. The railway signaling system is a series of facilities that function to provide signs in the form of shapes, colors, or lights that are placed at certain points, have a special meaning to regulate and control train operations [4]-[6]. When passengers hear an announcement about a signal failure, it usually indicates a problem in the signaling system as a whole, meaning the system does not have the complete information it needs. Such failures can be caused by various factors, such as equipment failure, electrical interference, or errors in data transmission [7]-[9]. Signaling devices, such as signal lights and point machines, are vital in a railway signaling system. Signal lights serve as guides in the railway interlocking system, helping the driver operate the train safely [10][11]. Meanwhile, the point machine (electric switch driver) functions to move the switch tongue according to the desired route direction for the train's journey [12][13].

Indonesia is the first and only country in Southeast Asia to design and produce railway traffic systems independently, and PT Len Railway Systems, a subsidiary of PT LEN Industri (Persero), is the only company that produces this system. According to information from the Engineering team at PT Len Railway Systems, which designs and produces railway traffic systems independently, voltage and current are critical parameters that affect the performance of devices such as point machines and signal lights. Fluctuations or instability in these two parameters can cause malfunctions, potentially disrupting train operations and endangering passenger safety. Interlocking System (SIL) is a PLC-based train traffic control system, replacing the old system that still uses mechanical technology. The interlocking system currently implemented is SIL02 [6]. The Len interlocking system (SIL-02 NextG) is an electronic interlocking system using a PLC based on dual processors that are mutually comparable and use the failsafe principle [14].

One of the sectors that is affected and benefits greatly from the Internet of Things (IoT) is transportation, which has grown rapidly in terms of research and application [15]. The Internet of Things or IoT is a concept where all objects in the real world can communicate with each other as part of an integrated system connected via the internet network [16]. The Internet of Things (IoT) allows users to manage and optimize electronic equipment connected to the internet [17],[18]. Through the internet media, all data will be sent in real-time or directly and also on time and monitored remotely.

Currently, PT. Len Railway Systems (LRS) still relies on manual methods for monitoring voltage and current in the railway signaling system. Based on this, in this study the author plans to design a monitoring prototype that can be monitored automatically from a distance. Therefore, a monitoring system for output voltage and current from the Multi Purpose Rack (MPR) on the Internet of Things (IoT) Based Railway Station Interlocking System is proposed.

2. METHOD

This paper proposes an interlocking system in a railway station. The current scheme of the interlocking system in a railway station is shown in Figure 1.

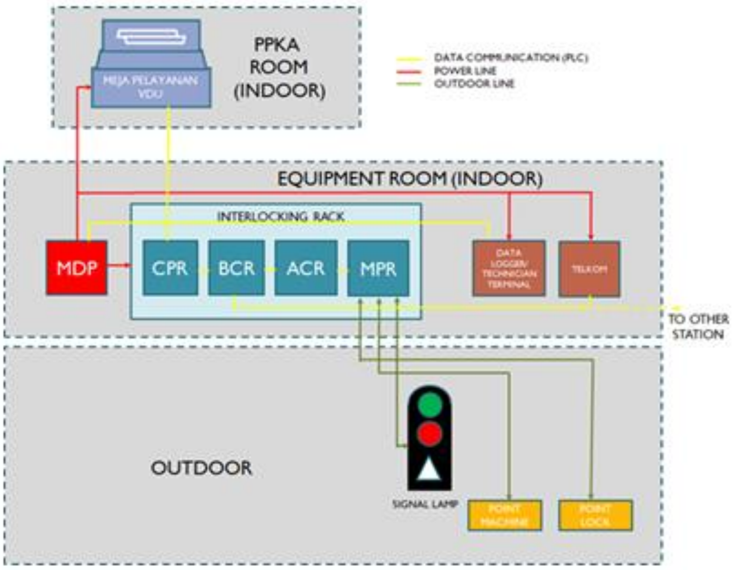

Figure 1. Interlocking System at Railway Station

This paper proposes a prototype of an IoT-based Interlocking System in Railway Stations. The prototype includes hardware and software design and implementation. In hardware design, components are needed to run the device, including: ESP32, PZEM-004T Sensor, Smartphone, Switch, Buzzer, and TFT LCD. When the device is connected to a power source, this device will read the results of voltage and current monitoring from the signal lights and AC motors (Point Machine) by capturing WiFi signals from the device. The monitoring results will be displayed on the TFT LCD and the Blynk application connected to the Smartphone. The device will stop operating when the OFF switch is pressed.

Figure 2 shows the block diagram of the proposed interlocking system. The explanation of the block diagram consist of: 1) ESP32 (2 units) functions as the main controller connected to the PZEM-004T sensor to measure the voltage and current of the signal lamp and AC motor (Point Machine). This ESP32 collects data from the sensor and sends this data wirelessly to the ESP32 in the PPKA via a WiFi network. The ESP32 (in the PPKA room) functions as a receiver of data sent by the ESP32 in the ER. This ESP32 receives voltage and current data, displays it on the TFT LCD, and controls the buzzer if there is an anomaly in the voltage or current. 2) The PZEM-004T sensor (2 units) functions to measure the voltage and current at the output of the signal lamp and AC motor (Point Machine). 3) The switch functions to control the operation of the signal lamp and AC motor (Point Machine). 4) The buzzer is installed in the PPKA room and functions as a warning alarm if there is an abnormal condition in the signal lamp and AC motor (Point Machine). 5) TFT LCD is connected to ESP32 in PPKA room and functions to display voltage and current data sent by ESP32 in ER. 6) Blynk functions as an interface to display output on the device.

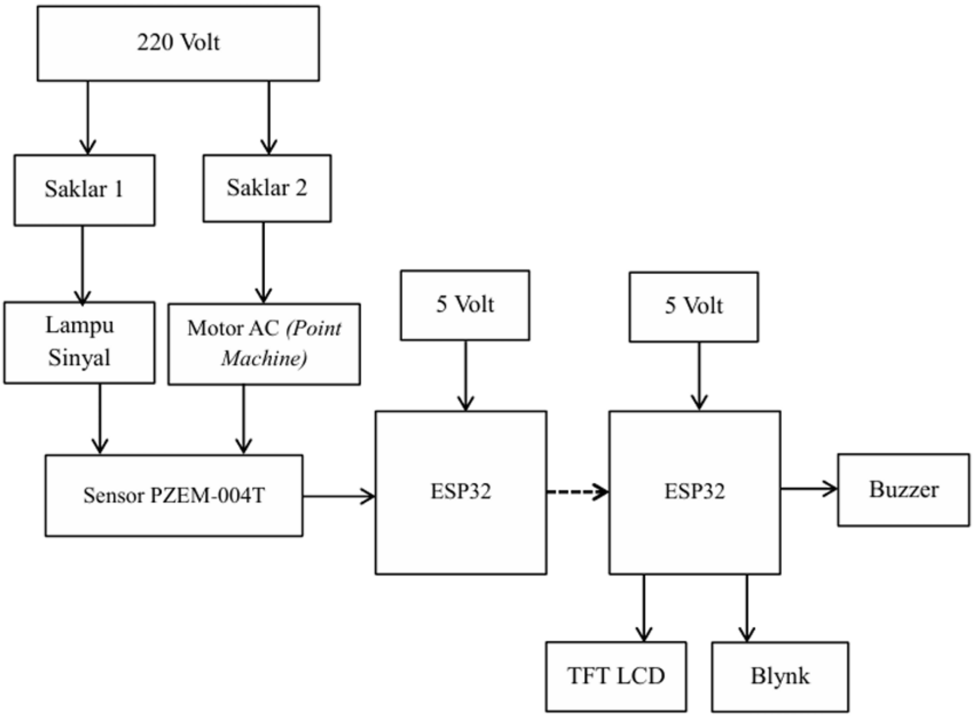

Figure 2. Block diagram of the proposed interlocking system.

Figure 3 shows the hardware design process, which is an important stage in making a tool. The goal is to simplify the manufacturing process while minimizing errors, so that optimal results are obtained.

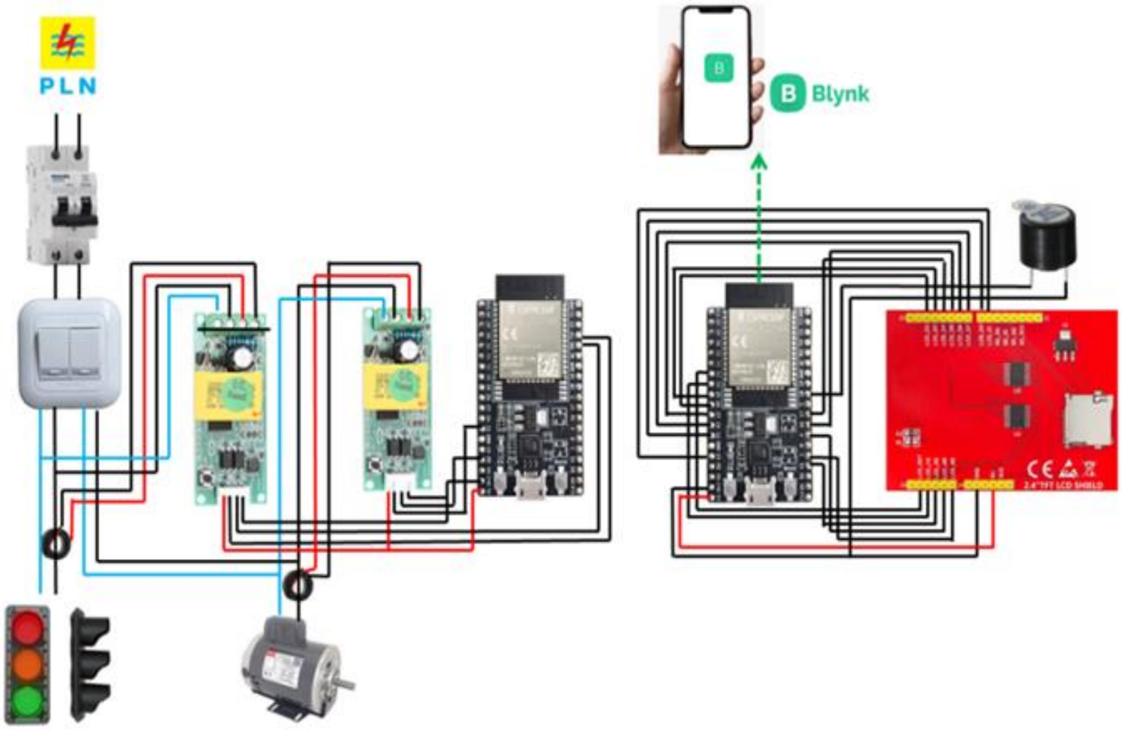

Figure 3. Circuit schematic of proposed interlocking system

Figure 4 is a mechanical design that aims to provide a clear picture of the tool shape and reduce the potential for errors during manufacture, so that the resulting tool meets expectations.

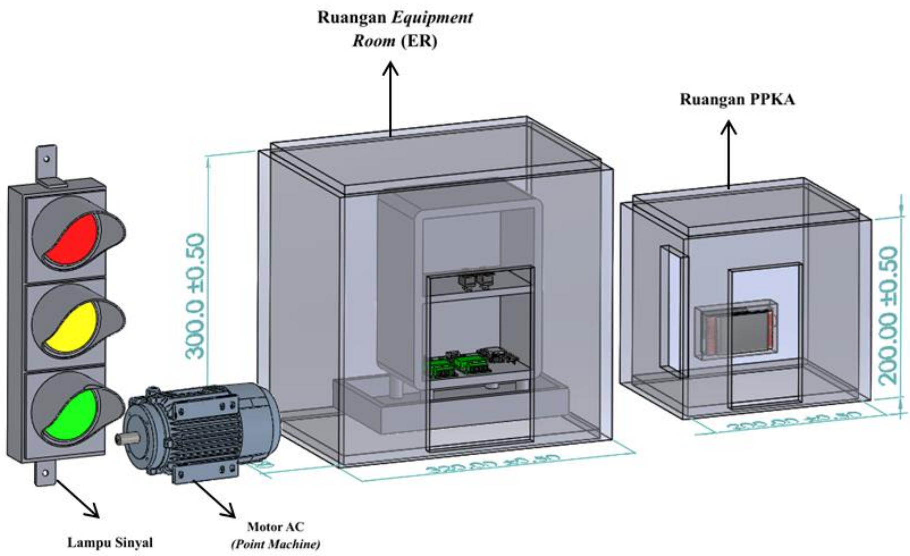

Figure 4. Overall Mechanics

Figure 5 is the design of an electronic circuit that plays an important role in supporting the smooth operation of hardware. The main components of this tool are PZEM-004T sensor, ESP32, buzzer, TFT LCD, and Smartphone. Smartphone is used as a medium to display the results of monitoring the voltage and current of signal lights and AC motors (point machines).

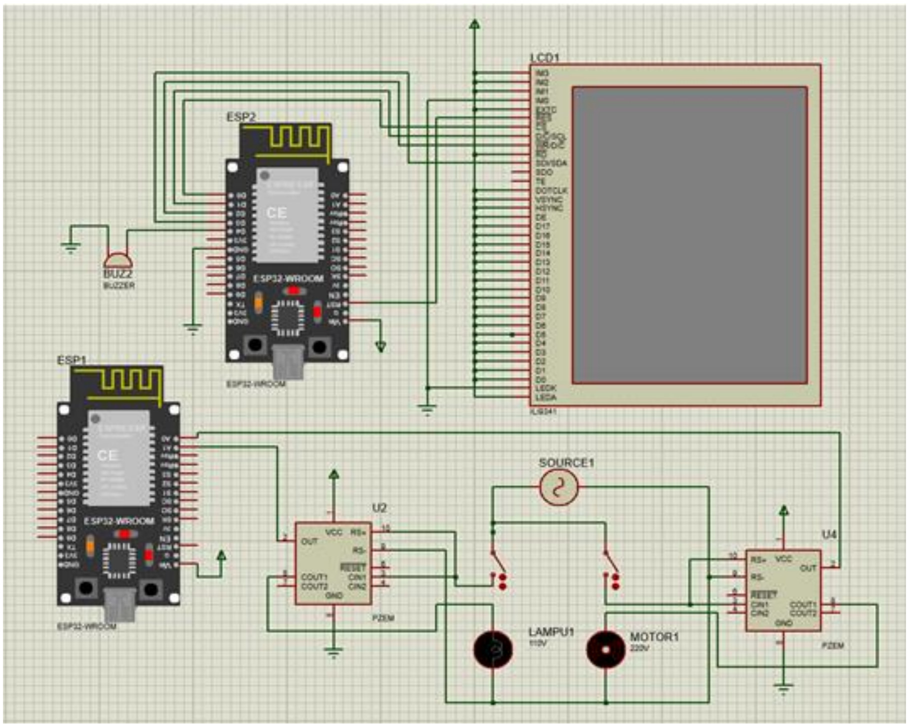

Figure 5. Electronic circuit

Software design includes creating a program for the tool according to its function, as well as using the Blynk application which will be used to display data on the results of the tool's performance. The tool program is created using the Arduino IDE application using ESP32, and the program is then uploaded to become the core of the design of this tool. The Blynk application functions to display data obtained from the monitoring process. The appearance of the Arduino IDE and Blynk applications can be seen in figure 6 below.

Figure 6. Arduino IDE and Blynk Application Display

The design of this tool involves a flowchart and program design (system work). The program flowchart describes the logic or sequence of instructions in the form of a diagram, while the system work flowchart displays the sequence of how the tool works in detail, showing the direction of the design work. The flowchart of this final project can be seen in Figure 7.

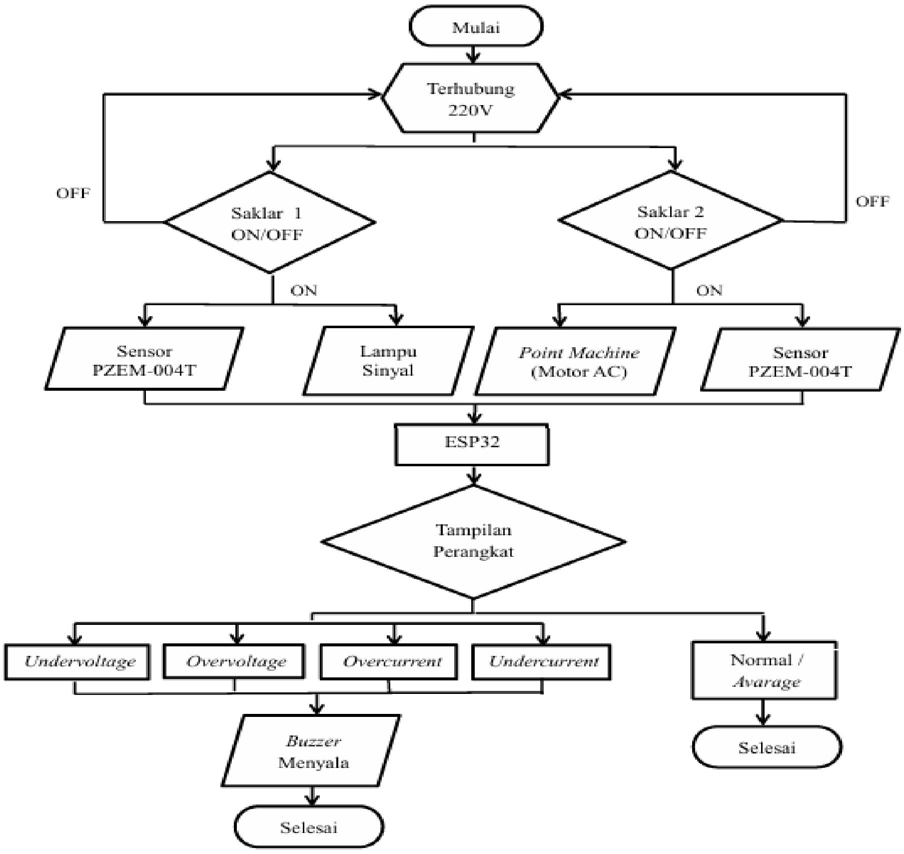

Figure 7. Flowchart

3. RESULTS AND DISCUSSION

After going through various stages of design that include hardware, mechanical, and software design. Then a prototype tool for monitoring Voltage and Current Output Multi Purpose Rack (MPR) on the Interlocking System of Train Stations Based on the Internet of Things (IoT) was formed. The following is the form of the design results of the tool that can be seen in Figures 8 and 9.

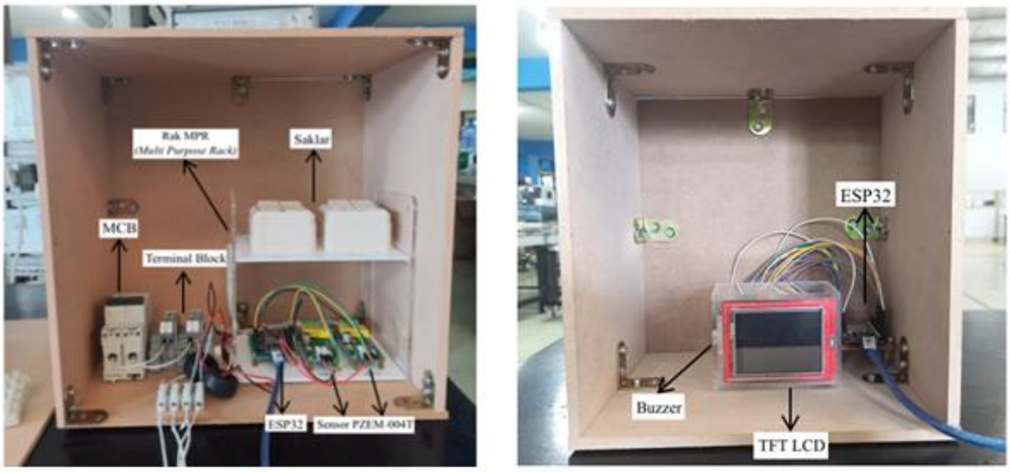

Figure 8. Tools in the equipment room and PPKA room

Figure 9. Results of making a prototype of an interlocking system

3.1. Testing the Voltage and Current Condition of Signal Lamps

Testing is carried out directly on signal lights at PT Len Railway Systems. During testing, the PZEM-004T sensor will measure voltage and current in real-time. If the voltage value exceeds 115.5V (overvoltage) or is less than 104.5 V (undervoltage), and the current value exceeds 0.21 A (overcurrent) or is less than 0.19 A (undercurrent), the system will identify an abnormal condition. In this condition, the buzzer will sound as a warning, and the data will be displayed on the TFT LCD and the Blynk platform to provide clear information. The test results are shown in Table 1 and Figure 10.

Table 1. Signal Lamp Voltage Testing

Measurement Time	Lamp Voltage (V)	Condition Voltage	Alarm Active (Yes/No)	Description
10.00	113	Avarage	No	Stable Voltage
10.30	118	Overvoltage	Yes	Voltage exceeds threshold and red LED in Blynk ON
11.00	103.8	Undervoltage	Yes	Voltage below threshold and yellow LED is Blynk ON

Figure 10. Lamp voltage testing, a) Testing process, b) first test, c) second test, d) third test

Testing the signal lights is done by measuring the voltage and current when the switch is ON, as in Table 1, the voltage value when the switch is ON is in average condition 113V, when in overvoltage condition 118V with the red LED lit in the blink, and when in undervoltage condition it is 103.8V which is indicated by the yellow LED lit in the blink as a warning sign.

Table 2. Signal Lamp Current Testing

Measurement Time	Lamp Current (A)	Condition Current	Alarm Active (Yes/No)	Description
10.00	0.203	Avarage	No	Stable Current
10.30	0.230	Overcurrent	Yes	Current exceeds threshold and Red LED in Blynk ON
11.00	0.088	Undercurrent	Yes	Current below threshold and yellow LED is Blynk ON

As in Table 2, the current value when the switch is ON is in average condition 0.203A, when in overcurrent condition 0.23A with the red LED lit in the blink, and when in undercurrent condition it is 0.088A which is indicated by the yellow LED lit in the blink as a warning sign. The display monitoring the lamp current test is shown in Figure 11.

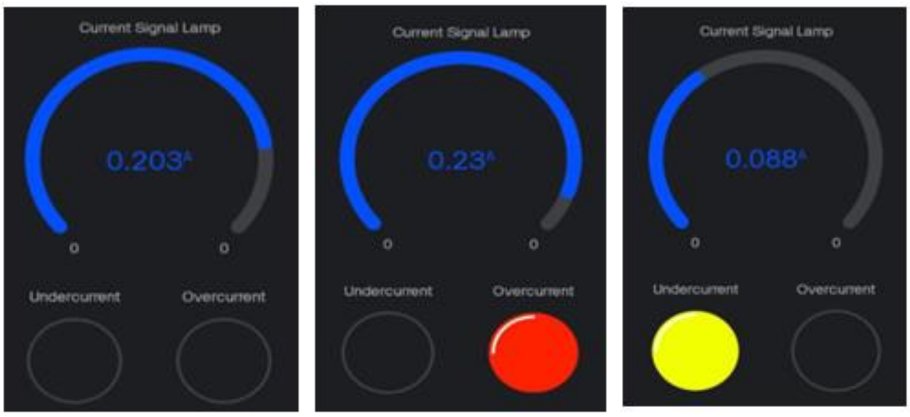

Figure 11. Display monitoring lamp current testing

3.2. Testing the Condition of Voltage and Current of AC Motor (Point Machine)

In testing AC motors, what is measured is also the same as for lamps, namely the voltage and current when active and inactive when the switch is pressed and given a 220 Volt source from PLN. Figure 12 shows the process of testing the motor voltage and current.

Figure 12. Testing of AC Motor Voltage and Current Conditions (Point Machine) at PT Len Railway Systems

AC motor testing (point machine) is done by measuring the voltage and current when the switch is ON, as in Table 3, the voltage value when the switch is ON is in average condition 224.4V, when overvoltage condition is 240.5V with the red LED lit in the blink, and when undervoltage condition is 205.6V which is indicated by the yellow LED lit in the blink as a warning sign. Then next, as in Table 4, the current value when the switch is ON is in average condition 0.486A, when in overcurrent condition 0.581A with the red LED lit in the blink, and when in undercurrent condition it is 0.411A which is indicated by the yellow LED lit in the blink as a warning sign. Figure 13 shows the AC motor current and voltage monitoring display.

Table 3. AC motor voltage testing (point machine)

Measurement Time	Lamp Voltage (V)	Condition Voltage	Alarm Active (Yes/No)	Description
10.00	224.4	Avarage	No	Stable Voltage
10.30	240.5	Overvoltage	Yes	Voltage exceeds threshold and red LED in Blynk ON
11.00	205.6	Undervoltage	Yes	Voltage below threshold and yellow LED is Blynk ON

Table 4. AC motors current testing

Measurement Time	Lamp Current (A)	Condition Current	Alarm Active (Yes/No)	Description
10.00	0.486	Avarage	No	Stable Current
10.30	0.581	Overcurrent	Yes	Current exceeds threshold and Red LED in Blynk ON
11.00	0.411	Undercurrent	Yes	Current below threshold and yellow LED is Blynk ON

Figure 13. Monitoring display of AC motor current and voltage

4. CONCLUSION

The Multi Purpose Rack (MPR) output voltage and current monitoring prototype on the Internet of Things (IoT)-based train station interlocking system has been successfully designed and tested. This system uses two ESP32s, with the sending ESP32 in the Equipment Room (ER) to send data from the PZEM-004T sensor to the receiving ESP32 in the Train Travel Control (PPKA) room via Arduino IDE programming. The test results show that the device is able to monitor the voltage and current parameters of the signal lamp load and AC motor (point machine) in real-time with good accuracy and is able to provide an indication in the form of an active buzzer when an anomaly occurs in the voltage and current. The measurement data is displayed on the TFT LCD screen and the Blynk application, allowing remote monitoring via the IoT protocol.

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