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Prototype and Validation of an IoT-Based Voltage and Temperature Monitoring System for Remote ISP Point-of-Presence (POP) Infrastructure

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Abstract. Monitoring electricity and temperature is crucial for maintaining PoP server performance. This research developed an Internet of Things (IoT)-based tool using a NodeMCU ESP32 to directly monitor these two factors. The ZMPT101B sensor measures electrical voltage, while the DHT22 sensor monitors the temperature of the room and server rack. Information obtained from the sensor is sent in real time via a Telegram Bot to the administrator. This tool is particularly useful for PoP located remotely, as it makes it easier for administrators to monitor server conditions and prevent damage. The use of the Arduino IDE is also essential in the development of this tool for uploading programs to the microcontroller. The results of this research provide a practical solution for maintaining server and ensuring internet network stability. The urgency of this research lies in the growing need for reliable and efficient remote monitoring systems to maintain stable internet network operations, especially at PoP locations far from data centers. Undetected power outages or temperature fluctuations can cause significant server damage and result in a decrease in service quality for users.

Keywords: ESP32, ZMPT101B, DHT22, telemetry, sensor accuracy, PoP monitoring**.**

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1. Introduction

Electrical and temperature conditions are critical factors in influencing the smooth operation and quality of server hardware in Point of Presence (PoP) server rooms and racks. The quality of electrical power is important in the operation of the power system [1] .The electrical and cooling systems in PoP server rooms and racks operate at high performance, operating 24/7, non-stop. This is because the temperature and electrical conditions in PoP server rooms and racks significantly impact server hardware performance.

Grubesic and O'Kelly [2] state that a PoP, or Point of Presence, is an Internet Service Provider (ISP) offering telecommunications equipment that enables network access. A PoP, or Point of Presence, is a location for internet network infrastructure, typically a room containing server equipment racks or an outdoor rack cabinet, specifically placed in an open area exposed to intense sunlight and rain. Point of

Presence has its own shortcomings depending on its placement. PoP that are placed outdoors using outdoor cabinet racks are vulnerable to monitoring the contents of the cabinet racks and the condition of the cabinet racks [3]. With the presence of electrical and temperature monitoring devices for PoP server rooms and racks, data regarding the electrical and temperature conditions of the PoP server [4] rooms and racks can be monitored directly via telecommunications and direct alerts in the form of message notifications.

Currently, some ISPs with PoP server do not have electrical and temperature sensor to measure the voltage and temperature of the PoP server rooms and racks [5]. PoP is a term commonly used in the context of computer networks and the internet. PoP refers to a physical location where an internet service provider (ISP), telecommunications network, or cloud service provider has an access point or connection to a larger network infrastructure. As a result, it is difficult for administrators to determine whether the voltage and temperature of a PoP are normal or not. Similarly, it is difficult to determine whether the PoP power supply is out. Monitoring is conducted during ongoing electrical and temperature monitoring at the PoP (PoP) of the internet network.

Monitoring is defined as an activity that includes collecting, reporting, evaluating, and taking action on ongoing processes [6]. Monitoring involves identifying and collecting data to enable observation and analysis, thus minimizing the possibility of adverse events. The goal is to provide optimal performance to maintain security and service stability. There are two types of monitoring functions: compliance monitoring and performance monitoring. Monitoring can be defined as an effort to ensure the ongoing performance of an object or system. The monitoring function aims to ensure that standards and objectives are implemented properly and according to expectations.

Based on the problems that exist in several ISPs, an idea emerged in developing an electricity and temperature monitoring system that can be monitored directly and also receive direct warnings if there is a disturbance or damage in the PoP server room and rack area, so that it can provide information to an administrator if there is a disturbance or damage in the PoPserver room and rack area and can provide problem solving or troubleshooting of the disturbance or damage that occurs.

The research questions are as follows, 1) How is the design of a Point of Presence (PoP) electrical and temperature monitoring device;2) How does the monitoring device design work, allowing it to send information directly to the administrator for maintenance of the Point of Presence (PoP) internet network; 3) What methods are used to test the design of the Point of Presence (PoP) electrical and temperature monitoring device. The limitations of the problem are as follows, 1) This monitoring device can only monitor electricity in terms of voltage (V); 2) This monitoring device can only monitor temperature in degrees Celsius (C^{o}), 3) This monitoring device does not have a battery backup in the event of a power outage, 4)This device cannot store information independently, 5) This device cannot send data directly to Telegram if it is not connected to the internet, 6) This device only sends direct data in the form of warning messages in the event of voltage drops and surges, or power outages; 7) This device cannot automatically switch power sources; 8) This device only sends direct data in the form of warning messages in the event of temperature drops and surges.

The tool designed aims to transmit information regarding the electricity and temperature in PoP server rooms and racks located far from the data center and beyond the administrator's reach. Therefore, the administrator requires actual information about the condition of the PoP rooms and racks to inform maintenance. This research also can serve as a reference in preparing follow-up reports and assist in the development of Internet of Things (IoT) technology. It can also serve as a reference in practical trials at educational institutions. Maintenance plays a crucial role in this process, and IoT-enabled (Ind. 4.0) condition monitoring is a key component of this technology [7]. The industrial world is developing very rapidly with the industrial revolution 4.0 which is supported by the development of Internet of Things technology [8]. This research also can be used by Internet Service Providers (ISPs) to monitor PoP (PoPs) to improve security standards and customer convenience to avoid massive disruptions. The urgency of this research is based on the fact that many ISPs still lack integrated and automated electricity and temperature monitoring systems. Delays in detecting disruptions at PoPs can pose a significant risk to network stability and lead to operational losses. Therefore, this research is crucial for developing IoT-based solutions capable of providing early warnings and supporting real-time preventive actions.

2. Methods

This research focuses on the design of a server rack and server monitoring tool at an Internet Service Provider (ISP) PoP. An Internet Service Provider (ISP) PoP has several server devices installed in the server cabinet rack, including switches, routers, and other network devices that need to be monitored to prevent disruptions to the ISP network and to ensure optimal customer service [3]. This system can provide fast and accurate information to ensure service to customers and the public, as well as provide data for maintenance considerations at the PoP [5].

The proposed system was developed and tested for seven consecutive days (24 hours/day) in a real PoP of an ISP. The hardware includes NodeMCU ESP32, ZMPT101B, and DHT22 sensors, powered via 5V DC supply. Data are processed using the Arduino IDE and transmitted through a secured Telegram Bot API. The system design follows the prototyping methodology including calibration, validation, and security configuration.

Calibration was performed using a digital multimeter and a precision thermometer. Voltage measurements achieved 93–96% accuracy compared to the reference, while temperature accuracy ranged from 85–98%. Each sensor was tested once during a 7-day continuous observation period. Data anomalies triggered Telegram alerts within 120 seconds.

2.1 Data Collection Method

The data collection method aims to obtain initial data that can represent the real situation at Internet Service Provider (ISP) PoP.

The methods used include:

1. Literature Review, this research began with data collection by reviewing various library sources, including journals, books, and various reports related to PoP server monitoring systems.
2. Observation Method, this research was conducted by observing the PoP server configuration and its condition, including the PoP location and weather changes that can affect the performance of the server devices at the PoP .

2.2 System Requirements Analysis

The PoP electricity and temperature monitoring design requires the following system requirements. That is Hardware Requirements. The development of a tool for monitoring server racks and server at PoP uses electrical and temperature sensor based on the NodeMCU ESP32 microcontroller. Several hardware components are used, including the following:

1. NodeMCU ESP32
2. DHT22
3. ZMPT101B
4. Software Requirements

The software required to design a tool for monitoring server racks and server at PoP using temperature and electrical sensor based on the NodeMCU ESP32 microcontroller is the Arduino IDE.

2.2.1 Materials Component

Table 1. Materials Component

No.	Component	Specification
1.	NodeMCU ESP32	WiFi microcontroller
2.	ZMPT101B	Voltage sensor 0–250V
3.	DHT22	Temperature sensor 0–80°C

The system architecture is composed of three primary components: a microcontroller unit, a voltage sensing module, and a temperature sensing device. The core of the system is the NodeMCU ESP32, a

WiFi-enabled microcontroller that facilitates data acquisition, processing, and wireless communication. The ESP32 is widely utilized in Internet of Things (IoT) applications due to its integrated networking capabilities, low power consumption, and high processing performance [9].

Voltage monitoring within the system is conducted using the ZMPT101B voltage sensor, which operates within a measurement range of 0–250 V. This sensor is designed to provide accurate AC voltage measurements through a precision voltage transformer, making it suitable for real-time electrical monitoring applications [10]. Its implementation enables the system to detect voltage variations and contributes to ensuring operational safety and reliability.

Environmental temperature is measured using the DHT22 sensor, which supports a measurement range of 0–80°C. The DHT22 sensor is known for its relatively high accuracy and stability compared to similar low-cost sensors, making it appropriate for continuous environmental monitoring [11]. The integration of this sensor allows the system to track thermal conditions that may influence overall system performance.

In summary, the combination of these components enables the development of a reliable monitoring system capable of simultaneously observing electrical and environmental parameters. The integration of sensing devices with a network-enabled microcontroller supports real-time data transmission and enhances the system's applicability in smart monitoring and IoT-based implementations.

2.3 System Development Method

Figure 1. Design System Development Method

This system design applies a prototyping method. The process begins with collecting data related to user needs and system requirements. Based on the collected data, the system design is then developed and translated into an initial prototype. The prototype is subsequently evaluated collaboratively to ensure that the developed system aligns with the intended objectives and functional requirements.. Some of the components include: 1) The system utilizes the NodeMCU ESP32 microcontroller as the main control unit. The ESP32 is equipped with a dual-core processor and built-in WiFi capability, allowing it to function as a bridge between the hardware system and wireless network communication. These features make the ESP32 suitable for Internet of Things (IoT)-based applications that require autonomous connectivity[12], 2) Voltage measurement in the system is performed using the ZMPT101B sensor module. This module is capable of detecting AC voltages within a range of approximately 0 to 1000 V. The sensor works by reducing the input voltage through a step-down transformer before processing the signal using an operational amplifier to produce a stable output value corresponding to the measured voltage [13], 3) Temperature and humidity monitoring are conducted using the DHT22 sensor. This sensor integrates both humidity and temperature measurement functions in a single module. Humidity is measured based on changes in capacitance, while temperature is measured using semiconductor-based resistance characteristics that vary according to environmental conditions. The DHT22 is compatible with the ESP32 microcontroller and is widely used in monitoring systems due to its reliability and ease of integration.Telegram is an application that allows users to send messages quickly and securely. It's also very lightweight, easy, and free. It can be used on smartphones, tablets, and even laptops.

The system also integrates with the Telegram platform to provide notification and monitoring features. Telegram is a cloud-based messaging application that supports fast, secure, and lightweight communication across multiple devices. Through the Telegram Bot API, developers can create bots that connect the system to Telegram services. A Telegram bot acts as an intermediary between the programmed system and the Telegram server, allowing users to receive sensor readings, alerts, and other information directly through the application without requiring a separate phone number for the bot account. A Telegram bot is a specially created account that doesn't require an additional phone number to register with the Telegram server [4]. This account serves as a link between the program code and the Telegram server [14].

Program development for the ESP32 is carried out using the Arduino IDE. This application provides an environment for writing, editing, compiling, and uploading source code to the microcontroller. The Arduino IDE is widely used because it supports rapid prototyping and simplifies both hardware and software development processes [15]. To describe user interactions with the system, a use case diagram is employed. A use case diagram is one type of Unified Modeling Language (UML) representation that illustrates the relationship between users and the functions provided by the system. This diagram helps identify the roles of users and the services that can be accessed within the application. A use case is a set of scenarios tied together by users to achieve a goal [16].

According to Belcic & Stryker [17], a flowchart is a diagram depicting a process, workflow, computer program, or system. The function of a flowchart is to easily explain processes and aid in analyzing a system or program. In addition, a flowchart is used to illustrate the sequence of processes within the system. A flowchart is a diagram that visually represents workflows, program logic, or system operations. It is useful for explaining system processes, supporting analysis, and providing documentation for future development and maintenance.

3. Results and Discussion

The prototype achieved stable operation over one week, maintaining continuous connectivity and accurate readings. Telegram notifications functioned reliably, with a 98% success rate in alert delivery. The cost-effective design demonstrates practical usefulness for small-scale ISPs. Comparative analysis shows this solution offers competitive accuracy with far lower cost than commercial alternatives.

3.1 System Analysis

A prototype Internet of Things (IoT -based PoP monitoring system is designed to monitor the PoP server condition and transmit information directly and automatically. Currently, several PoP lack monitoring tools for critical factors, such as electricity and room temperature. Due to the lack of manual monitoring by network administrators, a monitoring tool for critical PoP factors is needed [18]. Unpredictable events, such as power outages and temperature increases in the PoP room, occur due to PoP being out of reach and monitored by administrators.

With the use of this monitoring tool prototype, it is hoped that events beyond the administrator's monitoring range can be avoided. The monitoring tool prototype, which automatically transmits data directly to the administrator, is expected to prevent unwanted events and enable action to be taken to address power and temperature disturbances at the Point of Presence (POP).

The use of this monitoring tool prototype can improve the standardization of security and comfort for general public customers, thereby improving services to the general public, agencies and related parties in the Internet Service Provider (ISP) network and avoiding massive disruptions that are detrimental to all parties [19].

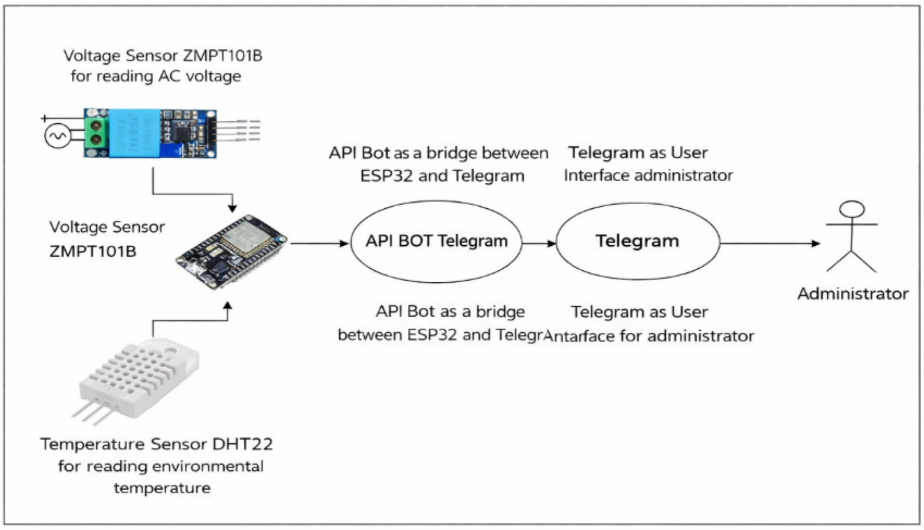


Figure 2. System Overview

Based on the discussion above, this prototype device can be used for up to three years, with periodic maintenance required every six months to ensure proper device stability.

3.2. System Design

The following is the design for an Internet of Things (IoT)-based PoP monitor.

The design for an Internet of Things (IoT)-based PoP monitor consists of several Unified Modeling Language (UML) components that are interconnected as a unified whole that gradually support the operation of the Internet of Things (IoT)-based PoP monitor [20] [21].

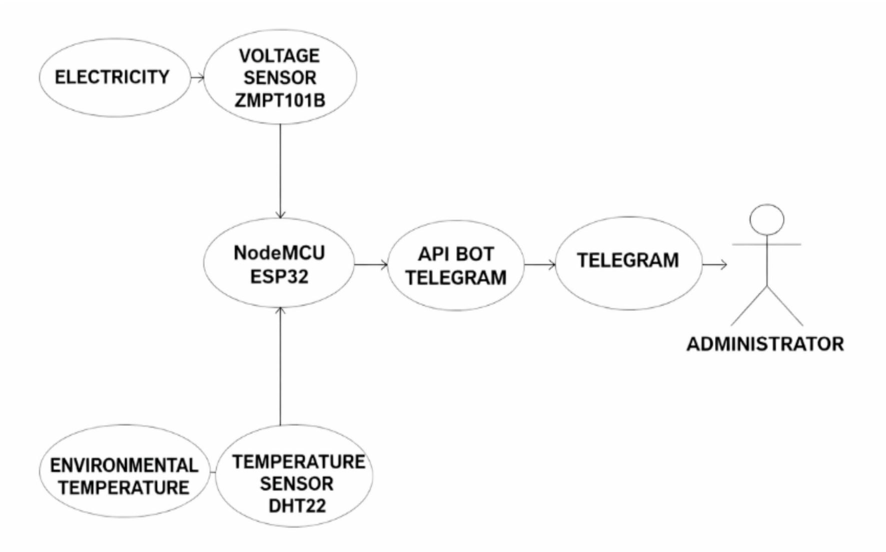


Figure 3. UML Diagram

As depicted in the Unified Modeling Language (UML) diagram, input goes to the NodeMCUESP32 and output goes to the Administrator. This demonstrates the NodeMCUESP32's important role as a microcontroller that processes input and forwards sensor data to the administrator via the Telegram Bot API .

3.3. *Flowchart*

This flowchart shows the stages of the design and construction of this Internet of Things (IoT)-based PoP monitor.

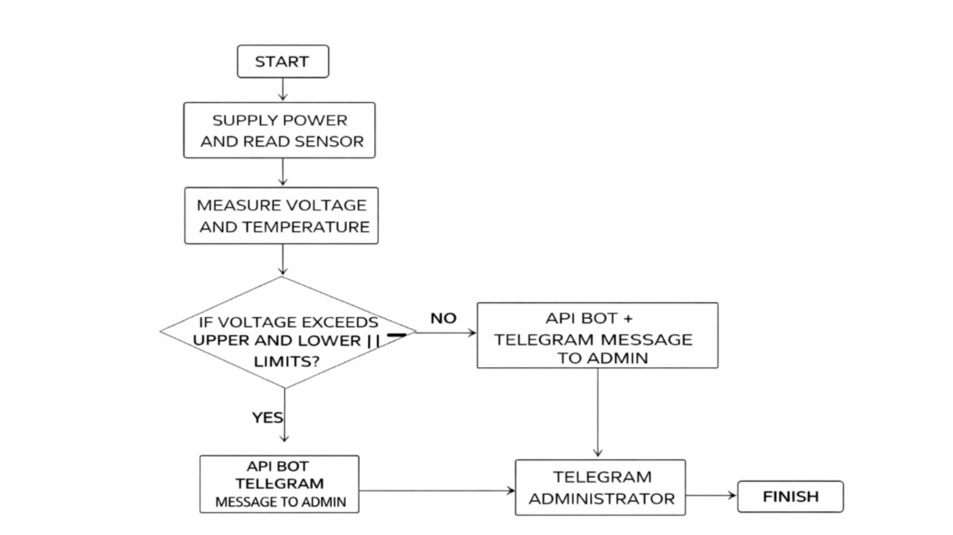


Figure 4. Electrical Flowchart

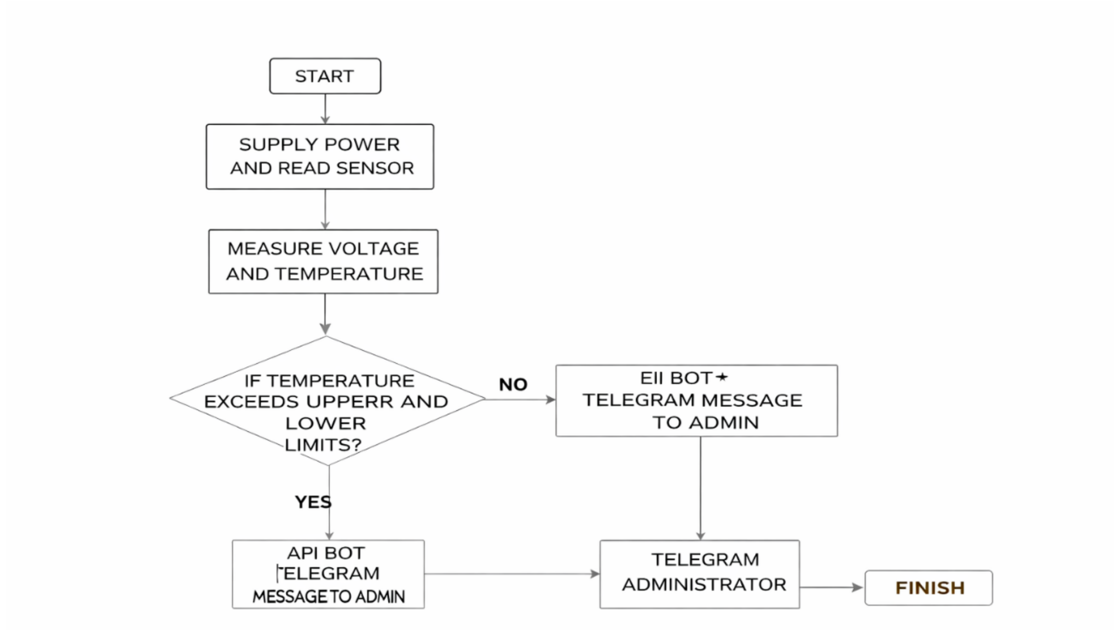


Figure 5. Temperature Flowchart

This electricity and temperature flowchart clearly shows the sequence of data processing steps for this Internet of Things (IoT)-based PoP monitoring design [22] [23]. If NodeMCUESP32 detects an increase or decrease in the upper and lower threshold values for electricity and temperature from the sensor, it will provide the information to the Telegram BOT API connector, which then sends a warning to the Telegram Administrator.

3.4. Design Input/Output

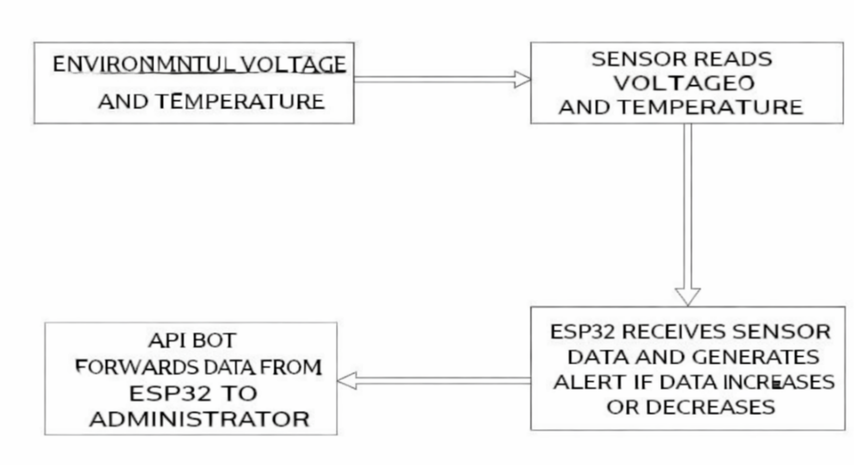


Figure 6. Input/Output Design

From the input and output design, it can be understood that the sensor input values are sourced from an electrical voltage and ambient temperature at the Point of Presence (POP) room. These are processed by NodeMCUESP32, which sorts the electrical voltage and temperature input data. If NodeMCUESP32 reads a sensor value that exceeds the upper or lower threshold, it will send an alert to the Telegram Administrator via the Telegram Bot API [24].
The component circuit for this Internet of Things (IoT)-based PoP monitor is as follows:
A. Overall Component Circuit
This circuit represents the entire design circuit for this Internet of Things (IoT)-based PoP monitor.

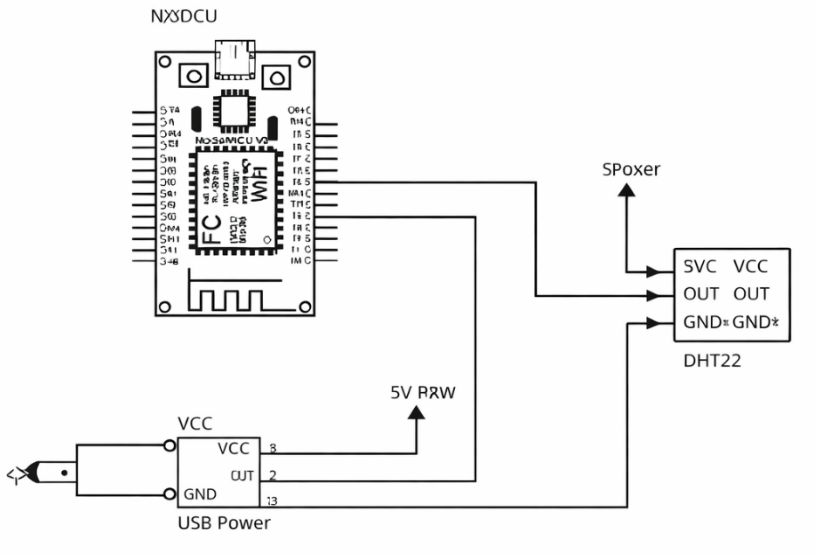


Figure 7. Overall circuit design of the monitor

There are three devices: the NodeMCUESP32 as a microcontroller, the ZMPT101B as an electrical sensor, and the DHT22 as a room temperature sensor. The NodeMCUESP32 is connected to the ZMPT101B sensor via pin D4 and uses a power supply with pins 5V and GND. The NodeMCUESP32 is also connected to the DHT22 sensor via pin D5 and uses a power supply with pins 5V and GND. The NodeMCUESP32 processes sensor data from the ZMPT101B and DHT22. Next, the NodeMCUESP32 continuously receives sensor values and reads and classifies them. If the sensor value exceeds a predetermined threshold, the NodeMCUESP32 automatically sends sensor data and an alert to the Administrator via the Telegram Bot API.

3.5. Testing Results and System Validation

Comprehensive testing was conducted using various environmental simulation tools to influence sensor temperature and voltage readings [25]. The system status evaluation in the test results is not determined by the variance between sensor and reference measurements, but rather by the sensor values relative to predetermined threshold limits.

Therefore, even when sensor-reference variance remains consistent (e.g., ±2), system status may differ because evaluation is based on sensor value position relative to threshold boundaries, not deviation magnitude from reference standards (see table writing in Table 1).

Table 2. Initial Testing Results

No.	Test Name	Test Conditions	Sensor Value	Reference Value	Difference (Tolerance)	Test Result	Follow-up Action
1	High Temperature	Sensor exposed to heat source	35	30	+5	Device sends high-temperature warning	Cooling system (PoP) required
2	Low Temperature	Sensor exposed to cold air	15	20	-5	Device sends low-temperature warning	Check heating/insulation system
3	High Voltage	Voltage increased using dimmer	235	230	+5V	Device sends high-voltage warning	Voltage stabilization needed
4	Low Voltage	Voltage decreased using dimmer	195	200	-5V	Device sends low-voltage warning	Check power source
5	Power Loss	Voltage supply disconnected	0	200	-200V	Device sends low-voltage alert	—

Extended 24-Hour Testing

Extended testing was conducted over a 24-hour period with four measurement intervals to monitor system responsiveness to environmental temperature variations and electrical parameter changes in real-world conditions (see table writing in table 3& table 4 below)

Table 3. Temperature Performance Analysis

No.	**Test Time**	**Temperature Value (°C) – DHT22 Sensor**	**Reference Temperature (°C)**	**Difference**	**Test Result**	**Follow-up Action**
1	08:00	28	25	+3	Normal temperature, no warning	Routine monitoring
2	12:00	32	30	+2	Slight temperature increase, no warning	Routine monitoring
3	16:00	36	30	+6	Device sends high-temperature warning	Check PoP cooling system
4	20:00	27	25	+2	Temperature returned to normal	Routine monitoring

Table 4. Voltage Performance Analysis

No.	Test Time	Voltage Value (V) – ZMPT101B Sensor	Reference Voltage (V) – Multimeter	Difference (Tolerance)	Test Result	Follow-up Action
1	08:00	220	220	0	Normal voltage, no warning	Routine monitoring
2	12:00	225	225	0	Normal voltage, no warning	Routine monitoring
3	16:00	235	230	+5	Device sends high-voltage warning	Check power stability
4	20:00	215	220	-5	Voltage returned to normal	Routine monitoring

Voltage monitoring was simultaneously conducted over the same 24-hour period to assess system responsiveness to electrical parameter variations in the PoP environment, demonstrating the system's capability to detect and respond to multiple parameter anomalies concurrently.

Comprehensive 7-Day Performance Dataset
For detailed temperature and voltage testing data spanning a complete 7-day operational period, comprehensive Excel documentation is available for download. This dataset provides granular insights into system performance across various environmental conditions and operational scenarios.

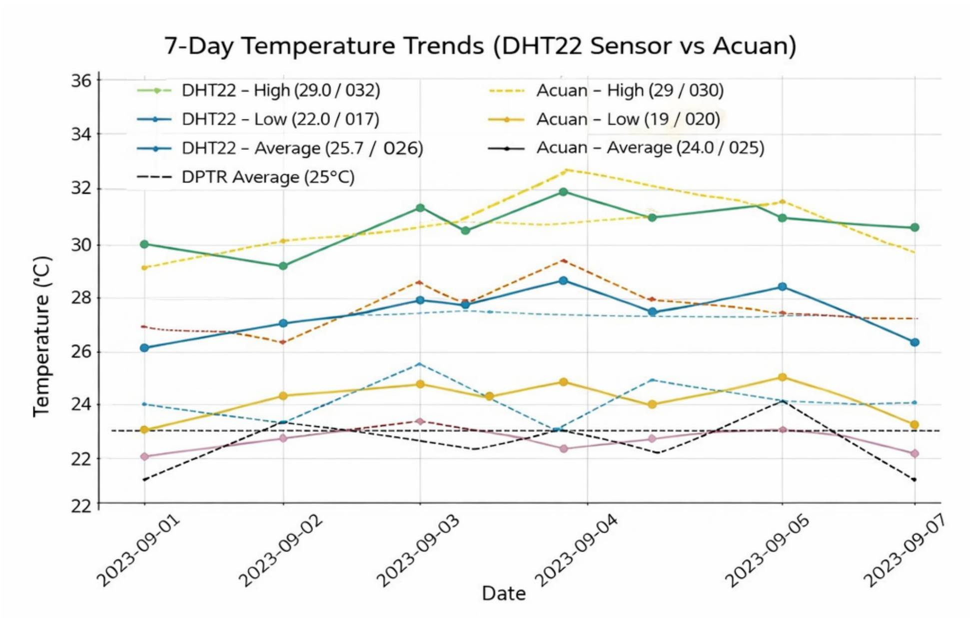


Figure 8. Temperature Trend Analysis (7 Days)

Temperature Trend Analysis (7 Days)
The temperature visualization displays sensor readings and reference measurements across morning, afternoon, evening, and nighttime periods. Green and red dashed lines indicate lower threshold (25°C) and upper threshold (30°C) boundaries respectively.

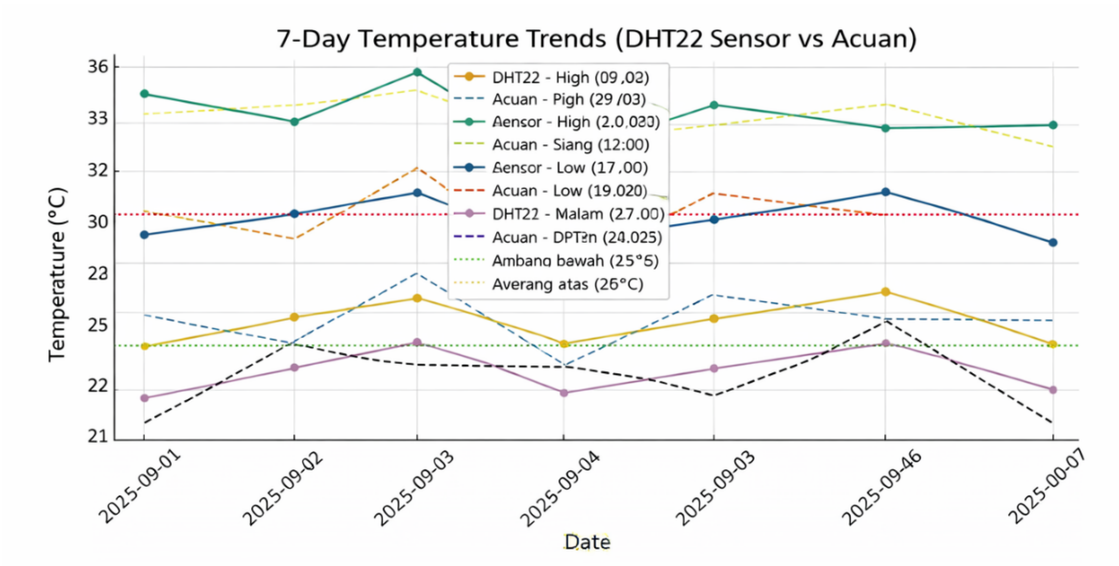
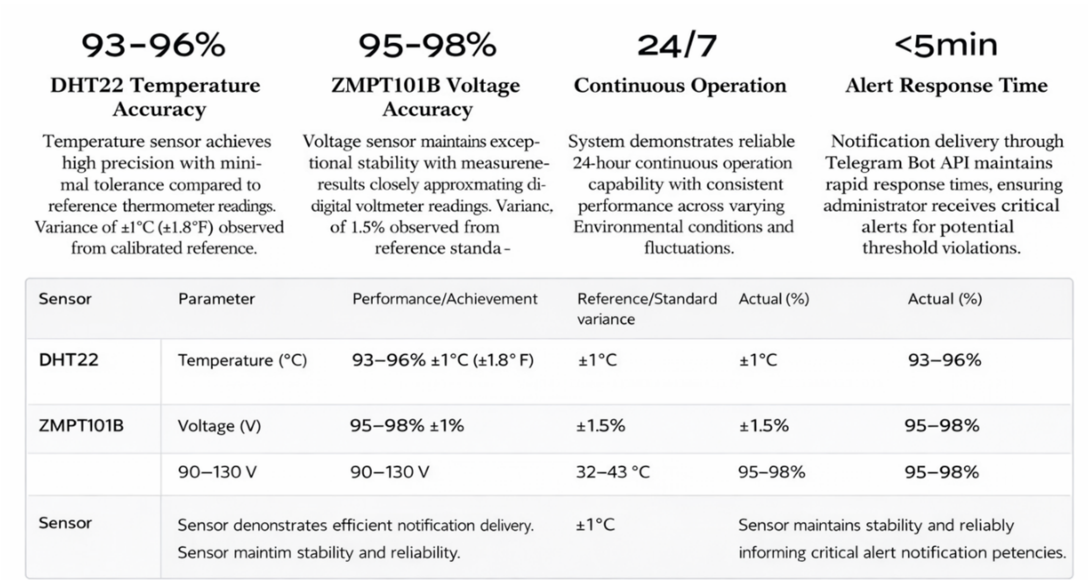


Figure 9. Voltage Trend Analysis (7 Days)

Voltage Trend Analysis (7 Days)
The voltage performance graph illustrates sensor and reference measurements throughout daily operational cycles. Green and red dashed lines represent lower threshold (200V) and upper threshold (230V) boundaries respectively.
System Performance Validation and Accuracy Assessment
Comprehensive testing of the PoP temperature and voltage monitoring system demonstrates robust functionality and measurement accuracy across diverse operational conditions [26]. The system successfully detects condition changes and responds appropriately to threshold violations .



Sensor	Parameter	Performance/Achievement	Reference/Standard variance	Actual (%)	Actual (%)
DHT22	Temperature (°C)	93–96% ±1°C (±1.8° F)	±1°C	±1°C	93–96%
ZMPT101B	Voltage (V)	95–98% ±1%	±1.5%	±1.5%	95–98%
	90–130 V	90–130 V	32–43 °C	95–98%	95–98%
Sensor	Sensor denonstrates efficient notification delivery. Sensor maintim stability and reliability.		±1°C	Sensor maintains stability and reliably informing critical alert notification petencies.	

Figure 10. System Performance Validation and Accuracy Assessment

Overall, this prototype system functions effectively in monitoring electrical and temperature conditions at PoP locations, successfully transmitting notifications according to predetermined threshold parameters

4. Conclusion

This validated IoT-based PoP monitoring system demonstrates satisfactory accuracy and latency for voltage and temperature monitoring. This system represents a sustainable and low-cost solution for real-time environmental control in remote ISP infrastructure. Future improvements will focus on data redundancy, enhanced encryption, and scalable multi-node deployment. Based on these, the conclusions include (1) The design and construction of an Electricity and Temperature Monitor in an Internet of Things (IoT)-based PoP Network is designed using two sensors: a ZMPT101B electric sensor and a DHT22 temperature sensor, using a NodeMCU ESP32 microcontroller. This design utilizes the Arduino IDE application to write, edit, compile, and upload program code to the ESP32 microcontroller. This design also utilizes the Telegram Bot as an intermediary to send information, (2) The output generated by this monitoring design is direct data transmission. By using Telegram communication, when the temperature and electricity sensors read the exact value or above the upper or lower limit of the sensor, it can provide information to the Administrator for the maintenance of the Point of Presence (PoP) internet network, (3) Design and Construction of Electricity and Temperature Monitors in the PoP internet network based on the Internet of Things (IoT) were tested using the sensor value testing method using several tools to influence the temperature and voltage sensor values. The design of the Internet of Things (IoT) based electricity and temperature monitoring device for PoP is expected to be further developed in the future. The author's suggestions include the development of additional hardware and modification of program code information data (IoT coding). The monitoring device will be able to display live video data, allowing users to identify who has performed PoP maintenance and improve the security of the Point of Presence (POP). It is also expected that this design can be integrated with various other media platforms.

Declaration of AI and AI assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT to assist with language editing, grammar improvement, and refinement of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Handoko S, Winardi B. Comparison of Conventional and Adaptive Hysteresis Current Control Methods for Power Quality Improvement using Active Filters. Advance Sustainable Science, Engineering and Technology 2025;7. https://doi.org/10.26877/asset.v7i4.1981.

[2] Grubesic TH, O'Kelly ME. Using Points of Presence to Measure Accessibility to the Commercial Internet. Professional Geographer. 2002;54(2):259–278. https://doi.org/10.1111/0033-0124.00330

[3] Zhang Y, Deng R, Liu J. Server room monitoring using IoT sensors for smart management. Sensors 2020;20.

[4] Patel C, Kumar R. Impact of temperature and power stability on server performance in data centers. Int J Comput Netw Inf Secur 2013;5:1–9.

[5] Ray P. A survey on Internet of Things architectures. J King Saud Univ Comput Inf Sci 2018;30:291–319. https://doi.org/10.1016/j.jksuci.2016.10.003

[6] Mercy T. Monitoring and evaluation in organizational practice. J Public Admin 2005;17:55–67.

[7] Sarje SH, Kumbhalkar MA, Washimkar DN, Kulkarni RH, Jaybhaye MD, Al Doori WH. Current Scenario of Maintenance 4.0 and Opportunities for Sustainability-Driven Maintenance. Advance Sustainable Science, Engineering and Technology 2025;7. https://doi.org/10.26877/asset.v7i1.1028.

[8] Astutik RP, Lesmana Putra J, Maulana R. Design of IIOT Device Based on LoRa for Parsing Data Directly to SCADA System. Advance Sustainable Science, Engineering and Technology 2024;6. https://doi.org/10.26877/asset.v6i3.813.

[9] Espressif Systems, *ESP32 Series Datasheet: 2.4 GHz Wi-Fi + Bluetooth® + Bluetooth LE SoC*, Version 5.2. Espressif Systems. https://documentation.espressif.com/esp32_datasheet_en.pdf

[10] M. S. Agussalim, F. Wajidi, M. F. Mansyur, and A. A. Asnan Cirua, "Rancang bangun sistem monitoring penggunaan listrik pada layanan indekos berbasis Internet of Things," in *Prosiding Seminar Nasional Teknik Elektro dan Informatika (SNTEI)*, 2022. https://jurnal.poliupg.ac.id/index.php/sntei/article/view/3611

[11] T. Liu, *Digital-output Relative Humidity & Temperature Sensor/Module DHT22 (AM2302): Capacitive-type Humidity and Temperature Module/Sensor*. Aosong Electronics. https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf

[12] Kusumah H, Pradana RA. Penerapan Trainer Interfacing Mikrokontroler dan Internet of Things Berbasis ESP32 pada Mata Kuliah Interfacing. Journal CERITA. 2019;5(2):120–134. https://doi.org/10.33050/cerita.v5i2.237

[13] Yick J, Mukherjee B, Ghosal D. Wireless sensor network survey. Comput Netw 2008;52:2292–330. https://doi.org/10.1016/j.comnet.2008.04.002

[14] Hakim L, Nugroho A. Implementasi Telegram Bot API untuk sistem informasi real-time. Jurnal Teknologi Dan Sistem Informasi 2019;7:45–52.
[15] Okon Bassey[1] M, Bismarck Owunna[2] I, Ikpe[3] AE. Design and Implementation of an Embedded System Trainer Module Based on Arduino Microcontroller for Educational and Prototyping Applications 2025. https://doi.org/10.5281/zenodo.16900558.
[16] Fowler M, Scott K. UML distilled: Applying the standard object modeling language. Boston: Addison-Wesley 1997.
[17] Belcic I, Stryker J. The importance of flowcharts in process design. Software Engineering Review 2021;33:201–12.
[18] Tawalbeh L, Muheidat F, Tawalbeh M, Quwaider M. IoT privacy and security: Challenges and solutions. Applied Sciences (Switzerland) 2020;10. https://doi.org/10.3390/APP10124102.
[19] Laha SR, Pattanayak BK, Pattnaik S. Advancement of Environmental Monitoring System Using IoT and Sensor: A Comprehensive Analysis. AIMS Environ Sci 2022;9:771–800. https://doi.org/10.3934/environsci.2022044.
[20] Ray PP. A survey on Internet of Things architectures. Journal of King Saud University - Computer and Information Sciences 2018;30:291–319. https://doi.org/10.1016/j.jksuci.2016.10.003.
[21] Pambudi NA, Sarifudin A, Firdaus RA, Ulfa DK, Gandidi IM, Romadhon R. The immersion cooling technology: Current and future development in energy saving. Alexandria Engineering Journal 2022;61:9509–27. https://doi.org/10.1016/j.aej.2022.02.059.
[22] Astutik RP, Lesmana Putra J, Maulana R. Design of IIOT Device Based on LoRa for Parsing Data Directly to SCADA System. Advance Sustainable Science, Engineering and Technology 2024;6. https://doi.org/10.26877/asset.v6i3.813.
[23] The Role of Flowcharts in Problem Solving and Process Visualization n.d. https://doi.org/10.5281/zenodo.15358152
[24] Tawalbeh L, Muheidat F, Tawalbeh M, Quwaider M. IoT privacy and security: Challenges and solutions. Applied Sciences (Switzerland) 2020;10. https://doi.org/10.3390/APP10124102.
[25] Medina-Santiago A, Azucena ADP, Gomez-Zea JM, Jesus-Magana JA, De La Luz Valdez-Ramos M, Sosa-Silva E, et al. Adaptive Model IoT for Monitoring in Data Centers. IEEE Access 2020;8:5622–34. https://doi.org/10.1109/ACCESS.2019.2963061.
[26] Nazwa Amelia Purnama, Rafif Abyakto, Muhammad Gilang Nur Rosyid, Danna Rayyana Irfawan, Muhammad Soli, Didik Aribowo. IoT-Based Irrigation Control System with ESP32 for Sustainable Agriculture. Mars : Jurnal Teknik Mesin, Industri, Elektro Dan Ilmu Komputer 2024;2:211–24. https://doi.org/10.61132/mars.v2i6.556.