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Using IoT applications for detection of the overvoltage and undervoltage in electrical systems

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Abstract

A significant advancement in managing systems is the development and implementation of an IoT-based voltage monitoring system. The study aims to treat the issue of voltage fluctuations, including overvoltages and undervoltages, which pose risks to electrical devices and infrastructure. Utilizing the ZMPT101B voltage sensor on the Blynk platform and the ESP 32 microcontroller unit, this system offers a solution for real-time monitoring and alerting of voltage situations. The system's structure allows for data collection, processing, and transmission, enabling users to receive notifications on their mobile phones through a user-friendly interface. Extensive testing at voltage levels has confirmed the accuracy and reliability of the system in detecting voltage differences. The results showed a high level of reactivity and efficacy in warning users about possible hazards, which improved electricity efficiency and safety. Further developments in proactive electrical system management are anticipated as future work concentrates on enhancing the system's scalability, predictive capabilities, and integration with smart grid technology. This study demonstrates how IoT technologies have the power to completely transform electrical system monitoring and maintenance, with major advantages for sustainability, safety, and dependability.

Keywords: Overvoltage, Undervoltage, Blynk platform, Internet of Things

1. Introduction

At present, given the advancements in technology in the field of communications, and in particular the development of the Internet of Things and its use in several fields, including medical, industrial, and including the fields of electrical energy. The electrical devices in this work were designed to run between 180 and 230 volts and will last as long as possible at this voltage. The appliance may malfunction or the components may melt down if the voltage is too low, causing the current to rise [1, 2]. Appliances will operate too quickly and too hotly if the voltage is too high, which will reduce their service life. Since the voltage reaching the consumer is not properly stable, there may be a drop in voltage below the voltage at which electrical appliances operate normally, or a rise in voltage higher than the voltage at which electrical appliances operate normally [3, 4]. In order for this to be detected using modern methods and faster than traditional methods for detecting a drop or rise. In the voltages supplied to the consumer, the Internet of Things has been used to know this, through the use of a voltage sensor and an Arduino device, where the data is sent via Wi-Fi to a mobile device or any tablet, and through the Blunk application. Several research investigations and academic papers have investigated the use of technology to detect overvoltage and undervoltage in electrical systems. In 2022, a study team [5] devised a monitoring system that used technology. This revolutionary technology uses IoT to create a protection mechanism that analyzes and monitors high and low voltages to prevent damage to the electrical load. D. D.Tungand and N.M. Khoa [6] developed a system that monitors parameters and protects against both low-voltage scenarios in a single-phase power setup. The setup relies on an Arduino Uno microcontroller board. They delve into the components detailing the software and hardware for constructing the system. An Arduino Uno serves as a microcontroller for collecting voltage and current data from ACS712, ZMPT101B, and other sensors. Moreover, all readings are transmitted from the Arduino to a computer through a connection, for visual data analysis. The authors [7] presented a technique for tracking voltage disturbances that use wavelet transform and an adaptive linear network, they analyzed three types of voltage disruptions; voltage sag, voltage swell, and voltage interruption. After implementing this approach they referred to the IEEE Std. 1159-2009 was used to classify the voltage disturbances. An approach based on a deep belief network was suggested by [8] for the identification of online voltage sags. Analysis was done on the causes and waveform features of voltage sags. Ten voltage sag characteristic parameters were then provided and shown to be successful based on the characteristics of various sag waveforms. Lastly, a deep belief network model was constructed employing the parameters to fully automatically recognize the distinct sag event kinds. N. A. Hussien, et al. [9] used IoT to monitor electrical energy consumption at Wasit University.

2. Overvoltage, undervoltage, and their disadvantages

2.1. Overvoltage

An overvoltage is a voltage that exceeds the maximum value of operating voltage in an electric circuit. High voltages have the potential to damage equipment by disturbing it and producing electromagnetic radiation. When a fault occurs where a power line touches the ground directly in a line setup it can cause a surge in voltage that affects the other phases as well. When the load is suddenly disconnected from the system the current drops sharply leading to a rise in voltage due, to the line's inductance [10-14].

Electrical equipment can sustain serious harm from overvoltages, which pose significant risks to their functionality and longevity. Overvoltage can create stress on insulation systems, leading to equipment failure, short circuits, and insulation breakdown. This stress not only accelerates the aging and degradation of electrical equipment but also weakens insulation materials, ultimately shortening the equipment's lifespan and increasing the likelihood of early failure. Furthermore, excessive voltages can disrupt the normal operation of electrical networks and power systems. As a result, overvoltage-related equipment faults and system failures can lead to power outages, downtime, and inefficient operations, underscoring the importance of managing voltage levels to protect electrical infrastructure.

2.2. Undervoltage

When the voltage level drops below the designated range, under voltage, is a serious problem in electrical systems. The performance and dependability of connected electrical equipment may be impacted by these phenomena, which can cause a number of issues.

Sensitive electronic equipment, such as computers, laptops, and communication devices, may suffer damage due to undervoltage conditions. These devices are designed to operate within specific voltage ranges, and when the voltage drops below the required level, it can lead to malfunctions and potential data loss. Similarly, low voltage can negatively impact electric motors, resulting in inefficient operation, increased power consumption, and elevated temperatures. When motors do not receive adequate voltage, they may struggle to reach their rated speed, causing them to draw more current and operate less efficiently. This can ultimately lead to overheating and increased wear on the motor's components, further compromising their performance and lifespan.

3. Suggested system architecture

Figure 1 presents the suggested system block diagram, which highlights the sensor node, ESP32, and server as the three primary system components. The monitoring system functions overall through a series of steps: first, the sensing node collects information from the physical environment and sends it to the server. Next, the server gathers and processes this data, making it accessible on the web portal. Finally, the web portal provides a report on the gathered and processed data through visualization [7, 8].

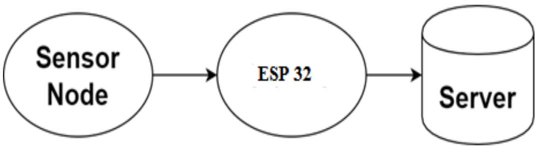

Figure 1. The proposed system design diagram

3.1. Sensing node

The sensor node comprises seven components; a microcontroller unit for processing data; a power source; a transmitter unit for sending data; a memory unit for storage; a sensing unit, for detecting the surrounding environment; a mobile phone; and an LCD screen to display information. These components are depicted in Figure 2. The sensor nodes' responsibility is to identify and transmit to the server any physically interesting settings.

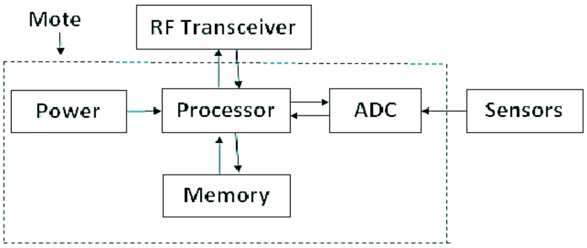

Figure 2. The general block diagram of the sensor node

The ESP32 microcontroller is utilized in the design of sensor nodes. It upports various serial communication protocols. The communication protocol employed in the system under discussion is UART TX/RX protocol which enables the transceiver module to interact with the microcontroller. The transmitter implemented in the design utilizes a Wi-Fi connection integrated within the ESP32 Microcontroller [15-20]. The sensor node is created to identify the AC voltage input and detect any instances of over or undervoltage using the sensor module.

3.2. ZMPT101B

One module for measuring AC voltages is the ZMPT101B AC voltage sensor module, as Figure 3 shows. When the input voltage varies, so does the analog output. The module generates an analog output by means of a DC voltage sensing device based on a resistive voltage divider circuit [21-25].

Figure 3. The wiring diagram of the ZMPT101B

It can measure the levels of AC voltage and is frequently used in do-it-yourself applications where accurate measurements are required. Open-source platforms like ESP8266, Raspberry Pi, and Arduino can be linked to this sensor.

3.3. ESP32

The ESP32 is a chip that combines 2.4 GHz Wi-Fi and Bluetooth in a single unit, utilizing advanced 40nm technology from Taiwan Semiconductor Manufacturing Corporation for optimal RF power efficiency and performance in a variety of power-related applications and situations while keeping durability and versatility in mind. The ESP32 was designed primarily for use in the Internet of Things (IoT), wearable electronics, and mobile phone applications. The overview covers characteristics of modern energy-efficient processors such as adaptive power adjustment, various power-saving modes, and sophisticated clock management mechanisms. For example, the ESP32 remains dormant until certain conditions are met, such as when the power of a device linked to a sensor hub application scenario diminishes. Using a low-duty cycle helps reduce the chip's energy consumption. There is also the option to change the power amplifier output. Figure 4 shows the balance between communication efficiency, data transmission speed, and energy consumption levels when displaying the microcontroller ESP32 [26, 27].

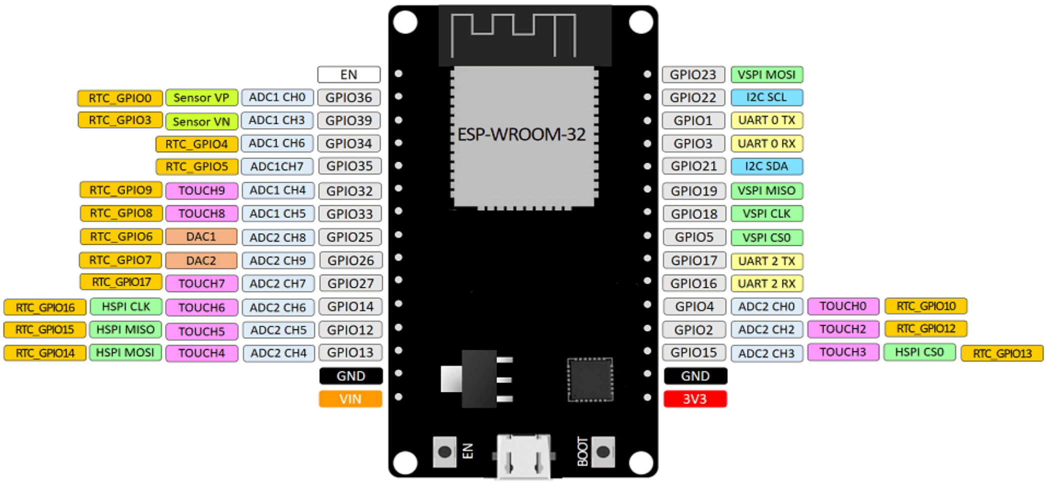

Figure 4. The ESP32 microcontroller

The ESP32 is an integrated solution for Wi-Fi and Bluetooth IoT applications with nearly 20 external components included in its design such as the antenna switch and power amplifier, among others as shown in Figure 6 of its block diagram.

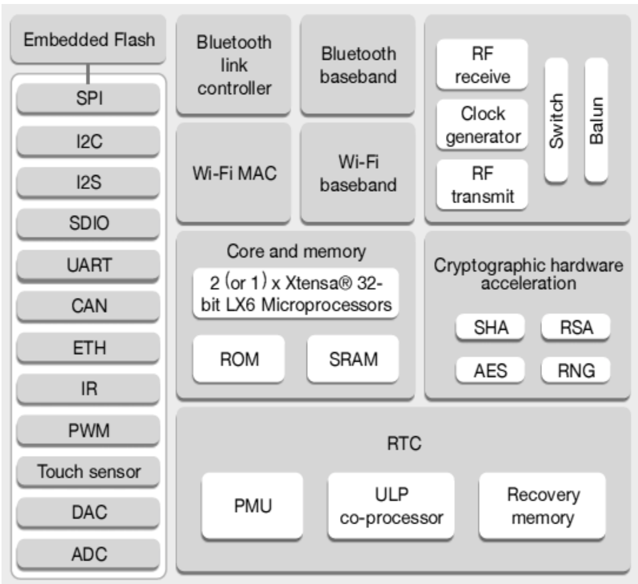

Figure 5. The ESP32's block diagram

3.4. Sensor node connection

Through development within this project, the Internet of Things application to the industrial Modbus communication protocol for overvoltage and undervoltage detection in an electrical system has been improved. Figure 6 depicts the creation and execution of the process flow and IoT detection of overvoltage and undervoltage, along with how this figure accomplishes it.

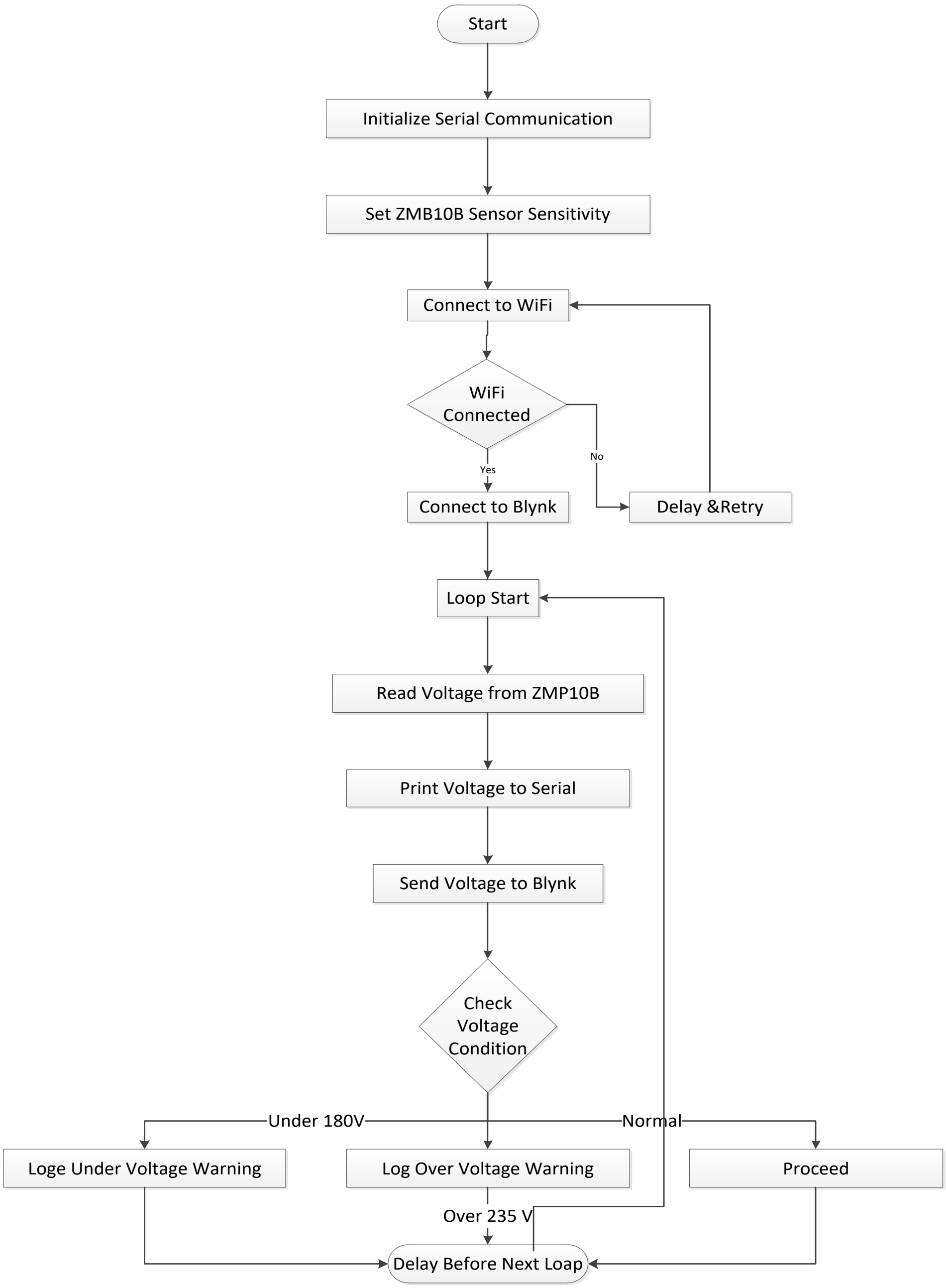

Figure 6. IoT-based Modbus flow chart

Figure 8 shows how the sensor node is linked, with the ZMPT101B connected to the ESP32 via the UART TX/Rχ protocol. The ESP32 receives voltage data from the ZMPT101B and converts it into JSON.

4. Designed work

A system was designed consisting of the components mentioned in the search terms and were connected according to the circuit shown in Figure 7.

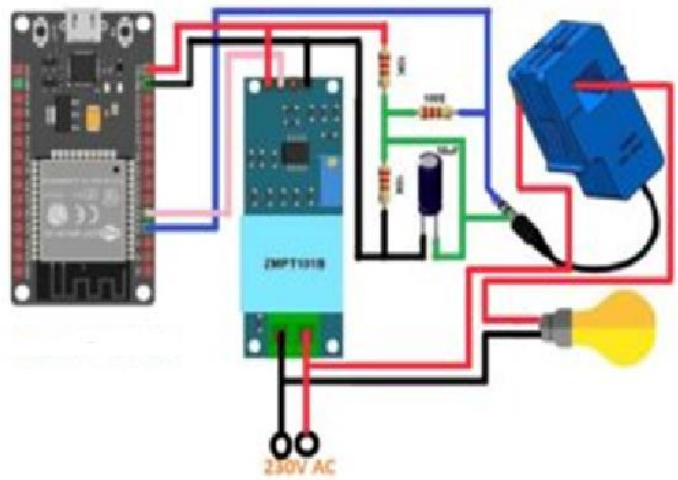

Figure 7. The block diagram of the proposed system

The system can be operated through the following steps:

1. Wi-Fi Connectivity: The firmware includes features that allow the ESP8266 to be linked to a nearby Wi-Fi network and send data online. This entails setting up the network's SSID and password as well as creating a reliable connection.
2. Reading Sensor Data: The primary role of the firmware involves reading the voltage levels detected by the ZMPT101B sensor. This includes setting up the ESP8266s ADC (Analog to Digital Converter) parameters to accurately capture the analog signals.
3. Data Transmission to Blynk: the firmware contains API commands for sending sensor data to the Blynk platform as well as real-time viewing and monitoring. The use of the Blynk library for ESP8266 is critical since it reduces the intricacies of networking and protocols, allowing this method to go smoothly.

5. Workflow in operations

The process begins with initialization, where the Wi-Fi module is activated upon powering the ESP8266 MCU. It connects to the specified local network while simultaneously configuring the ZMPT101B sensor to monitor voltage. Following this, data acquisition occurs as the system continuously monitors the voltage levels from the ZMPT101B sensor. This information is analyzed and converted into values that reflect the current-voltage status of the monitored system. Once the data is processed, it is transmitted through the Wi-Fi network to the Blynk server. This transmission includes real-time voltage levels along with timestamps, ensuring data integrity and facilitating analysis. Finally, an alert mechanism is in place; the system sends alerts through the Blynk app to notify the user if voltage readings fall outside established ranges, indicating potential overvoltage or undervoltage issues.

6. Testing and result

In order to replicate real-life scenarios, was tested the system under conditions, like operation, high voltage and low voltage. Thanks to the AC power supply, with settings we could closely examine how the system reacts to voltage levels by controlling the exact amount of voltage supplied.

Under voltage conditions, the system consistently showcased its monitoring capabilities by sending information to the Blynk platform in a continuous stream. The system promptly detected abnormalities when faced with high-voltage scenarios and informed the user via the Blynk application. The system's ability to monitor in time was evident, from the notification after detection. If voltage surpasses 235V it is classified as overvoltage triggering an alert on smartphones, through the Blynk app to notify users of the issue. The system effectively detected situations of voltage. Alerted the user, similar, to how it responds to high voltage scenarios. This feature is crucial for preventing harm caused by voltage levels to electrical systems and devices. When the voltage drops below 180 volts it is considered voltage prompting the Blynk app to send a notification, to the smartphone for alarm activation.

The results outcomes observed during the testing phase affirmed the reliability and efficiency of the system, in monitoring voltage levels and detecting fluctuations. By combining the ESP8266 MCU, ZMPT101B sensor, and Blynk platform a groundwork was laid for real-time voltage surveillance and alerting. Users received notifications in case of voltage spikes or drops enabling actions to mitigate potential risks. Moreover Table 1 below presents the conducted experiments, on the proposed system showcasing its functionality through voltage outputs using the aforementioned final prototype.

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Table 1. Overview of the experiments conducted on the proposed system demonstrating functionality through voltage outputs from the final prototype

Test No.	Voltage (V)	Voltage Condition	Send Notification to Phone
1	150	Under voltage	✓
2	180	Normal	✗
3	200	Normal	✗
4	220	Normal	✗
5	250	Overvoltage	✓
6	155	Undervoltage	✓
7	230	Normal	✗
8	240	Overvoltage	✓
9	165	Normal	✗
10	245	Overvoltage	✓
11	175	Normal	✗
12	225	Normal	✗
13	190	Normal	✗
14	210	Normal	✗
15	235	Overvoltage	✓
16	145	Undervoltage	✓

The voltage monitoring system based on the Internet of Things (IoT) demonstrated the potential of technologies to enhance safety and reliability through an effective real-time monitoring solution, for electrical systems. The study can be as future developments joint with the reported methodologies in [27-36] in dissimilar applications.

7. Conclusions

A significant advancement in managing systems involves creating and implementing an Internet of Things-powered system to monitor overvoltage and undervoltage incidents. By utilizing the ESP8266 microcontroller, ZMPT101B sensor, and Blynk platform, this initiative successfully demonstrated the practicality and effectiveness of establishing a real-time voltage monitoring system that alerts users about electrical safety risks. This innovative technology can prevent harm to devices and infrastructure, as evidenced by the results of the testing phase and valuable feedback from users.

In the future, they planned to enhance the system by improving its accuracy, predictive abilities, and scalability. By leveraging advancements, we can create more efficient solutions for managing electrical systems as technology progresses.

Finally, this study marks a move in leveraging IoT to enhance electrical safety and efficiency. The outlook for driven electrical monitoring and safeguarding setups appears promising and brimming with potential due to continuous advancements.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

Abbas Q. Mohammed: Conceptualization of the study, methodology design, and overall supervision of the research project. He contributed to the writing and editing of the manuscript. Zahraa H. Dawood ALBadri: Conducted the literature review, developed the IoT application framework, and performed data analysis. She also contributed to drafting sections of the manuscript. Ihsan Mousa Jawad: Implemented the experimental setup, collected data, and assisted in the validation of results. He contributed to the technical writing and revision of the manuscript. Ibtihal R. N. ALRubeei: Assisted in the design of the IoT system, contributed to troubleshooting and testing, and provided critical feedback on the manuscript's content.

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