

IoT Based Circuit Breaker Monitoring and Control System

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Abstract: *The IoT-based Circuit Breaker Monitoring and Control System is a modern electrical protection solution designed to enhance safety, efficiency, and accessibility in power management systems. Conventional circuit breakers require manual intervention and lack real-time monitoring capabilities, which can lead to delays in fault detection and response. To overcome these limitations, this system integrates Internet of Things (IoT) technology with an ESP32 microcontroller to enable remote supervision and control of electrical circuits.*

The proposed system utilizes the Blynk cloud platform to establish seamless communication between the hardware and the user through a mobile application. Users can monitor the status of electrical loads and control circuit breaker operations from any location with internet connectivity. A keypad is incorporated for local control, ensuring system functionality even in the absence of network access. Additionally, a 16×2 LCD display provides real-time feedback regarding system status, phase conditions, and operational messages.

The relay driver module is responsible for controlling three-phase electrical lines (R, Y, and B), allowing precise switching operations based on user commands. The system improves response time during electrical faults, minimizes manual effort, and supports efficient energy management. This solution is suitable for applications in industrial environments, smart homes, commercial buildings, and remote monitoring systems, contributing to the development of intelligent and automated electrical infrastructures..

Keywords: *Internet of Things (IoT), Circuit Breaker Monitoring, ESP32 Microcontroller, Blynk Cloud Platform, Remote Control System, Three-Phase Electrical System, Smart Energy Management, Electrical Safety, Relay Control, Automation*

I. INTRODUCTION

Electrical power systems play a vital role in modern society, supporting industrial operations, commercial infrastructure, and residential needs. Ensuring the safety and reliability of these systems is essential to prevent equipment damage, power outages, and hazardous conditions. Circuit breakers are fundamental protection devices used to safeguard electrical systems from overloads, short circuits, and fault conditions. However, traditional circuit breakers operate manually and lack advanced monitoring capabilities, which limits their efficiency in modern smart environments [1].

With the rapid development of the Internet of Things (IoT), conventional electrical systems are being transformed into intelligent and connected systems. IoT enables real-time data communication, remote monitoring, and automated control of devices through internet-based platforms. This technological advancement has opened new possibilities in electrical power management by integrating smart sensors, microcontrollers, and cloud-based applications [2].

The ESP32 microcontroller has emerged as a powerful and cost-effective solution for IoT-based applications due to its built-in Wi-Fi and Bluetooth capabilities. It allows seamless connectivity between hardware components and cloud



platforms, enabling remote access and control of systems. By utilizing such technologies, electrical protection systems can be enhanced to provide real-time status updates and quick response to faults [3].

In recent years, cloud-based platforms like Blynk have gained popularity for developing IoT applications. These platforms provide user-friendly interfaces for monitoring and controlling devices through smartphones. They enable users to interact with hardware systems remotely, improving convenience and reducing the need for physical presence [4].

The proposed IoT-based Circuit Breaker Monitoring and Control System aims to overcome the limitations of conventional systems by integrating ESP32 with the Blynk cloud platform. The system allows users to monitor electrical parameters and control circuit breaker operations remotely. It also includes a keypad for local control, ensuring system usability even in offline conditions [5].

A 16×2 LCD display is incorporated to provide real-time feedback regarding system status, including relay conditions and phase information. The relay driver module is used to control the switching of three-phase electrical lines (R, Y, and B), enabling efficient load management. This combination of hardware and software components results in a smart, flexible, and user-friendly system [6].

One of the key advantages of this system is its ability to reduce response time during electrical faults. Immediate control actions can be taken remotely, preventing potential damage and improving safety. Additionally, the system supports energy efficiency by allowing users to manage electrical loads effectively [7].

IoT-based electrical systems are increasingly being adopted in various sectors, including industries, smart homes, commercial buildings, and agriculture. These systems contribute to automation, reduce manual intervention, and enhance operational efficiency. The integration of IoT with electrical protection devices represents a significant step toward smart grid and smart infrastructure development [8].

Despite its advantages, implementing IoT in electrical systems requires careful consideration of security, reliability, and scalability. Secure communication protocols and reliable hardware design are essential to ensure safe and uninterrupted operation. Addressing these challenges is crucial for the successful deployment of IoT-based solutions [9].

In conclusion, the IoT-based Circuit Breaker Monitoring and Control System provides an innovative approach to modern electrical protection. By combining IoT technology, cloud platforms, and embedded systems, the proposed system enhances safety, efficiency, and accessibility. It represents a significant advancement toward intelligent electrical management systems and supports the growing demand for automation in the power sector [10].

II. PROBLEM STATEMENT

Traditional circuit breaker systems are essential for protecting electrical installations from faults such as overloads and short circuits; however, they are largely dependent on manual operation and lack real-time monitoring capabilities. This limitation makes it difficult to quickly detect and respond to electrical faults, especially in remote or inaccessible locations, leading to increased downtime, potential equipment damage, and safety risks. In modern environments where continuous power supply and efficient energy management are critical, the absence of remote accessibility and intelligent control creates significant operational challenges. Additionally, conventional systems do not provide users with real-time feedback on system status or phase conditions, making fault diagnosis time-consuming and inefficient. There is a growing need for a smart, automated solution that can monitor electrical parameters, enable remote control, and provide instant alerts to users. Therefore, the problem lies in developing an IoT-based circuit breaker system that integrates real-time monitoring, remote accessibility, and intelligent control to enhance safety, reduce response time, and improve overall efficiency in electrical power management systems.

Conventional circuit breaker systems are widely used for protecting electrical installations from faults such as overloads, short circuits, and abnormal operating conditions; however, these systems are predominantly manual in nature and lack advanced monitoring and control capabilities. In most cases, users must be physically present to operate, reset, or inspect the circuit breaker, which becomes highly inefficient in large-scale industrial setups, commercial buildings, or geographically remote locations. This dependency on manual intervention leads to delayed



fault detection and slower response times, increasing the risk of equipment damage, power interruptions, and potential safety hazards for personnel.

III. OBJECTIVE

- To design and develop an IoT-based circuit breaker monitoring and control system using an ESP32 microcontroller.
- To enable remote monitoring and control of electrical loads through a cloud-based platform and mobile application.
- To implement real-time status display of system conditions, including phase status and relay operations using an LCD.
- To provide dual control functionality by integrating both remote (IoT-based) and local (keypad-based) operation.
- To enhance electrical safety and efficiency by reducing response time to faults and enabling effective load management.

IV. LITERATURE SURVEY

1. Paper Title: Design and Construction of an IoT-Based Automated Circuit Breaker

Year: 2024

Journal: World Journal of Advanced Engineering Technology and Sciences

Authors: Agbese et al.

Summary:

This paper presents the design of an IoT-enabled circuit breaker system aimed at improving electrical safety and operational efficiency. The system integrates a microcontroller with Wi-Fi modules to monitor voltage and current levels in real time. The primary focus of the research is to reduce risks faced by electrical workers, particularly during maintenance activities. The system allows remote switching of power lines, ensuring that faults can be handled safely without requiring physical presence.

Additionally, the study highlights the importance of cloud connectivity in enabling remote control and automated alerts during fault conditions. The system ensures that power supply can be controlled securely, reducing accidents caused by miscommunication. It also improves maintenance efficiency by eliminating the need for repeated manual operations, making it suitable for modern smart electrical systems.

2. Paper Title: Design and Implementation of an IoT-Based Automatic Circuit Breaker with NodeMCU

Year: 2025

Journal: International Journal on Science and Technology (IJSAT)

Authors: Kapil Padlak, Manish Yadav, Khushboo Bobade, Shoba Bodkhe, Sahil Jhapate

Summary:

This research focuses on developing an automatic circuit breaker system using NodeMCU ESP8266 with IoT integration. The system provides real-time monitoring, remote control, and automatic fault detection using sensors. It is designed to detect overload and short-circuit conditions quickly and respond by disconnecting the circuit, ensuring safety and reliability. The use of IoT platforms like Blynk enhances accessibility and control through mobile applications.

The study also emphasizes the safety of linemen by allowing them to remotely control power lines during maintenance. The system integrates LCD displays and cloud-based monitoring to improve visibility and decision-making. Experimental results show fast response times and improved system reliability, making it highly effective for industrial and residential applications.



3. Paper Title: Circuit Breaker Monitoring by IoT

Year: 2024

Journal: International Journal of Research Publication and Reviews (IJRPR)

Authors: Students, Sanjay Ghodawat Polytechnic, Kolhapur

Summary:

This paper introduces a smart circuit breaker system using an ESP32 microcontroller integrated with IoT technology. The system incorporates voltage and current sensors to continuously monitor electrical parameters and transmit data to the Blynk platform. This enables real-time monitoring and remote control of electrical circuits through a mobile application.

Furthermore, the system includes an automatic cutoff mechanism that disconnects the circuit when abnormal current levels are detected. It also supports manual control via the mobile app, providing flexibility to users. The research demonstrates how IoT-based systems can significantly improve electrical safety, reduce energy wastage, and enhance user convenience in managing electrical loads.

4. Paper Title: IoT-Enabled Smart Circuit Breaker System

Year: 2025

Journal: International Journal of Multidisciplinary Research in Science and Technology (IJMRSET)

Authors: Various Authors

Summary:

This paper proposes an IoT-enabled smart circuit breaker using an ESP32 microcontroller integrated with Firebase and IoT platforms. The system uses sensors such as ACS712 for current monitoring and employs relay modules for switching operations. It provides secure remote control through a password-protected mobile application, ensuring safety and preventing unauthorized access.

The research also highlights the importance of real-time monitoring and automation in improving electrical system efficiency. The system enables users to monitor power usage and control loads remotely, making it suitable for industrial and residential applications. It enhances safety by preventing electrical hazards and ensures efficient energy management through intelligent control mechanisms.

5. Paper Title: IoT-Based Intelligent System for Laboratory Facility Control with Blynk

Year: 2024

Journal: Journal of Information System Research (JOSH)

Authors: Various Authors

Summary:

This study presents an IoT-based system designed to control and monitor laboratory equipment using ESP32 and the Blynk platform. The system enables users to remotely control devices such as air conditioners and computers through a mobile application. The use of relays allows efficient switching of electrical loads, while Wi-Fi connectivity ensures seamless communication between devices.

The research demonstrates that the system achieves quick response times and reliable operation. It also highlights the importance of stable internet connectivity for effective communication. The system is particularly useful in reducing energy consumption and improving operational efficiency by allowing users to control devices remotely and automate their functioning.

6. Paper Title: IoT-Based Home Automation Using ESP32 and Blynk Application

Year: 2022

Journal: International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE)



Authors: Saurabh Madankar et al.

Summary:

This paper explores the use of IoT technology for home automation using ESP32 and the Blynk application. The system allows users to control electrical appliances remotely through a smartphone, improving convenience and accessibility. It focuses on reducing energy wastage by enabling users to turn devices ON/OFF remotely and automate operations.

In addition, the study demonstrates the scalability of IoT systems in both residential and industrial applications. The integration of Wi-Fi-enabled microcontrollers and mobile applications provides a cost-effective and efficient solution for modern automation needs. The research highlights how IoT can transform traditional electrical systems into smart and intelligent systems.

V. PROPOSED SYSTEM

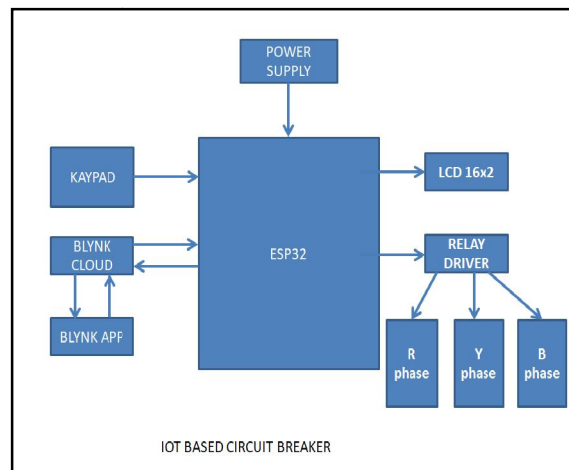


Fig 1: Block Diagram

The proposed IoT-Based Circuit Breaker Monitoring and Control System is designed to provide a smart, efficient, and reliable solution for managing electrical power systems. Unlike conventional circuit breakers that require manual operation, this system integrates IoT technology to enable real-time monitoring, remote control, and intelligent management of electrical loads. The system is built using an ESP32 microcontroller, which acts as the central processing unit and facilitates communication between hardware components and the cloud platform.

The proposed system supports both remote operation through a mobile application and local control using a keypad, ensuring flexibility and reliability. It is specifically designed to control and monitor a three-phase electrical system (R, Y, and B phases), making it suitable for industrial, commercial, and residential applications.

A. System Architecture

The system architecture consists of interconnected hardware and software components working together to achieve seamless monitoring and control. The ESP32 microcontroller is connected to input devices such as a keypad and output devices such as a relay module and LCD display. It also connects to the internet via Wi-Fi to communicate with the Blynk cloud platform.

The architecture is divided into three main layers:

Hardware Layer: Includes ESP32, relay driver module, LCD display, and keypad.

Communication Layer: Wi-Fi connectivity enabling communication between ESP32 and cloud.

Application Layer: Blynk mobile application for remote monitoring and control.

This layered architecture ensures scalability, flexibility, and efficient system performance.



B. Hardware Components Description

The hardware components form the backbone of the system and are responsible for executing control operations.

ESP32 Microcontroller:

Acts as the main controller with built-in Wi-Fi capabilities, enabling IoT communication and real-time processing.

Relay Driver Module:

Used to control the switching of three-phase electrical lines (R, Y, B). It isolates low-voltage control signals from high-voltage circuits.

16×2 LCD Display:

Displays system status, phase conditions, and user commands, providing real-time feedback.

Keypad:

Enables local control of the system, allowing users to operate the circuit breaker manually when internet access is unavailable.

Power Supply Unit:

Provides stable power to all components, ensuring uninterrupted operation.

C. Software and IoT Platform

The software component plays a critical role in enabling communication and control within the system.

Embedded Programming:

The ESP32 is programmed using Arduino IDE to process inputs, control outputs, and manage communication.

Blynk Cloud Platform:

Provides a user-friendly interface for remote monitoring and control. Users can send commands and receive real-time updates via a mobile application.

Mobile Application:

Allows users to:

Monitor system status

Control relays remotely

Receive alerts and notifications

The integration of software and cloud services ensures seamless interaction between users and the system.

D. Working Principle

The system operates based on input commands received either locally or remotely.

The user sends a command via the Blynk app or keypad.

The ESP32 processes the input command.

Based on the command, the relay module switches the corresponding phase (R, Y, or B).

The LCD displays the updated system status.

The system continuously updates data to the Blynk cloud for real-time monitoring.

This process ensures efficient and instant control of electrical loads.

E. Features of the Proposed System

Real-time monitoring of electrical system

Remote control via smartphone

Dual operation (local + remote)

Three-phase system management

User-friendly interface

Quick fault response mechanism



F. Advantages of the Proposed System

The proposed system offers several improvements over traditional circuit breakers:

- Reduces manual intervention
- Enhances safety by enabling quick fault response
- Provides remote accessibility
- Improves energy efficiency
- Suitable for modern smart infrastructure

G. Limitations of the Proposed System

Despite its advantages, the system has certain limitations:

- Dependence on internet connectivity for remote operation
- Initial setup cost may be higher than traditional systems
- Requires basic technical knowledge for installation and maintenance

H. Future Enhancement Scope

The proposed system can be further enhanced by:

- Integrating sensors for automatic fault detection
- Adding data analytics for energy consumption tracking
- Implementing AI-based predictive maintenance
- Enhancing security with encryption protocols

VI. SYSTEM DESIGN

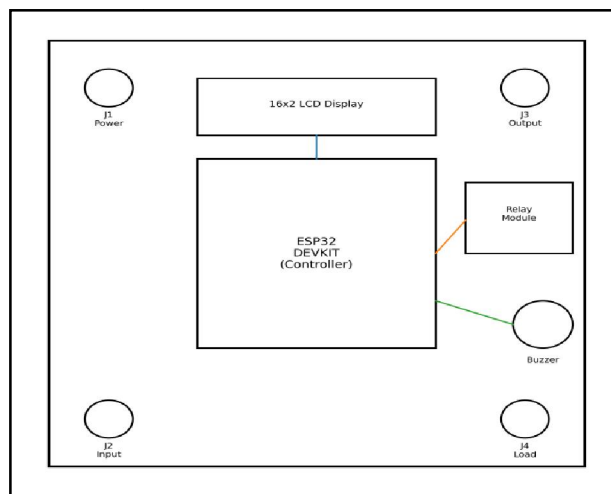


Fig 2: System Working

The system design of the IoT-Based Circuit Breaker Monitoring and Control System focuses on creating an efficient, reliable, and intelligent framework for managing electrical loads using IoT technology. The design integrates both hardware and software components to enable real-time monitoring, remote accessibility, and safe control of a three-phase electrical system. The overall system is structured to ensure smooth communication between input devices, processing units, output components, and cloud-based applications.

A. Overall System Design

The overall system is designed around the ESP32 microcontroller, which serves as the central control unit. It connects all input and output components while also enabling communication with the internet. The system accepts inputs from



two primary sources: a keypad for local control and a mobile application via the Blynk cloud platform for remote operation. Based on these inputs, the ESP32 processes commands and controls the relay driver module to switch electrical loads. The design ensures that both local and remote operations can function independently or simultaneously without conflict, thereby enhancing system flexibility and usability.

B. Hardware Design

The hardware design involves the integration of multiple electronic components that work together to perform monitoring and control operations. The ESP32 microcontroller is interfaced with a relay driver module, a 16×2 LCD display, and a keypad. The relay module is responsible for controlling the three-phase power lines (R, Y, and B phases), allowing the system to switch electrical loads ON or OFF based on user commands. The LCD display provides real-time information about system status, such as which phase is active or inactive, while the keypad enables manual control of the system.

A regulated power supply is used to ensure stable voltage levels for all components. Proper electrical isolation is maintained between low-voltage control circuits and high-voltage power lines using relay modules, ensuring user safety and preventing damage to electronic components. The hardware is designed in a modular manner, allowing easy maintenance and scalability.

C. Software Design

The software design is centered around embedded programming and IoT integration. The ESP32 is programmed using the Arduino IDE, where the logic for reading inputs, controlling outputs, and managing communication is implemented. The software continuously checks for input from both the keypad and the Blynk application and executes corresponding actions.

The Blynk platform acts as the interface between the user and the system, allowing remote monitoring and control through a smartphone. The application displays real-time system data and provides control buttons for switching relays. The software is designed to handle multiple inputs efficiently, prioritize commands, and ensure reliable execution without delays. Error-handling mechanisms are also included to maintain system stability.

D. Communication Design

Communication in the system is established through Wi-Fi connectivity provided by the ESP32 microcontroller. The device connects to the internet and communicates with the Blynk cloud server, enabling real-time data exchange between the system and the mobile application. Commands sent from the user's smartphone are transmitted to the ESP32, which processes them and updates the system accordingly.

This communication design ensures low latency and reliable data transfer. It also supports continuous monitoring, allowing users to view system status at any time. Secure communication protocols can be implemented to protect data and prevent unauthorized access.

E. Control Logic Design

The control logic of the system is designed to ensure efficient and safe operation of electrical loads. When a user inputs a command through the keypad or mobile application, the ESP32 interprets the signal and determines the required action. The corresponding relay is then activated or deactivated to control the specific phase.

The system is programmed to avoid conflicting operations, such as activating multiple commands simultaneously that could cause instability. Priority can be assigned to certain commands, and safety conditions can be implemented to prevent hazardous situations. This logical structure ensures accurate and reliable system performance.

F. Display and User Interface Design

The user interface design includes both hardware and software interfaces for user interaction. The 16×2 LCD display provides immediate visual feedback, displaying system status, relay conditions, and operational messages. This helps users understand the current state of the system without requiring external devices.

The Blynk mobile application serves as a graphical user interface for remote access. It includes buttons, indicators, and status displays that allow users to control and monitor the system easily. The interface is designed to be user-friendly, ensuring that even non-technical users can operate the system effectively.



G. Safety and Protection Design

Safety is a critical aspect of the system design. The use of relay modules ensures electrical isolation between control circuits and high-voltage power lines, reducing the risk of electrical hazards. The system can be further enhanced by integrating sensors to detect overloads, short circuits, or abnormal conditions.

In case of faults, the system can automatically disconnect the affected phase, preventing damage to equipment and ensuring user safety. The design also considers proper wiring, insulation, and component protection to maintain reliability and long-term performance.

H. System Integration Design

The integration of all components is carefully planned to ensure seamless operation. The hardware components are connected in a structured manner, while the software coordinates their functioning through programmed logic. The communication between the ESP32 and the cloud platform ensures synchronization between local and remote operations.

This integrated approach allows the system to function as a cohesive unit, providing efficient monitoring and control. The modular design also allows future upgrades, such as adding sensors, automation features, or advanced analytics.

I. Performance Considerations

The system is designed to deliver fast response times and reliable performance. The ESP32 ensures quick processing of commands, while the Wi-Fi communication enables near real-time updates. The system minimizes delays in switching operations, which is critical during fault conditions.

Additionally, the design ensures low power consumption and efficient resource utilization. The system is capable of handling multiple operations simultaneously without compromising performance, making it suitable for real-world applications.

VII. CIRCUIT DIAGRAM

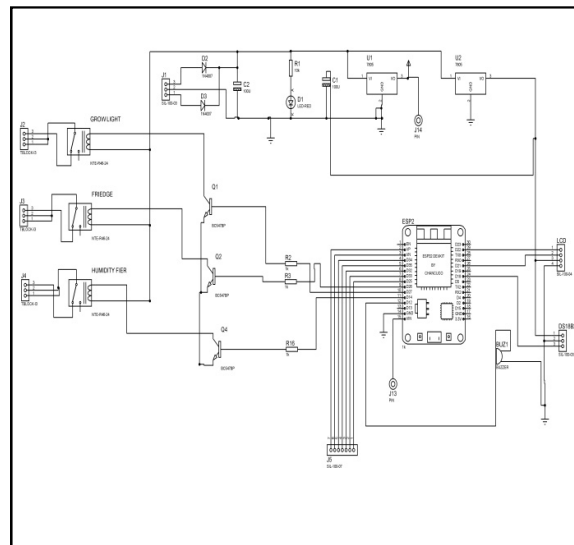


Fig 3: Circuit diagram



PCB Layouts

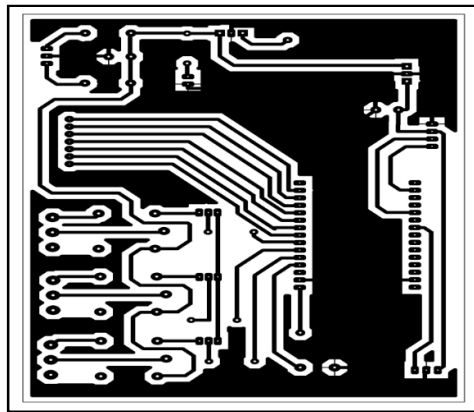


Fig 4: PCB Layout

Connection overview

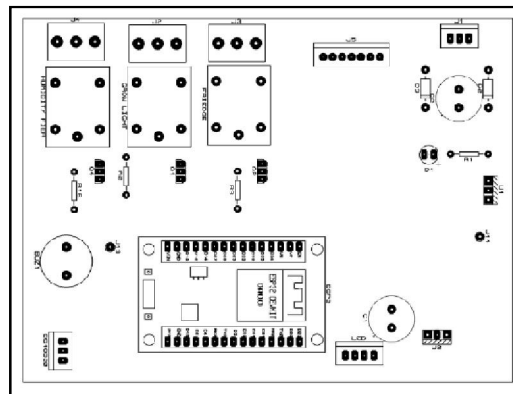


Fig 5: Connection overview

VIII. RESULT

The IoT-Based Circuit Breaker Monitoring and Control System was tested under different operating conditions to evaluate its performance, responsiveness, and reliability. The results demonstrate the effectiveness of the system in real-time monitoring, remote control, and electrical load management. The following graphs represent key performance parameters of the system.



Graph 1: Response Time vs Command Type

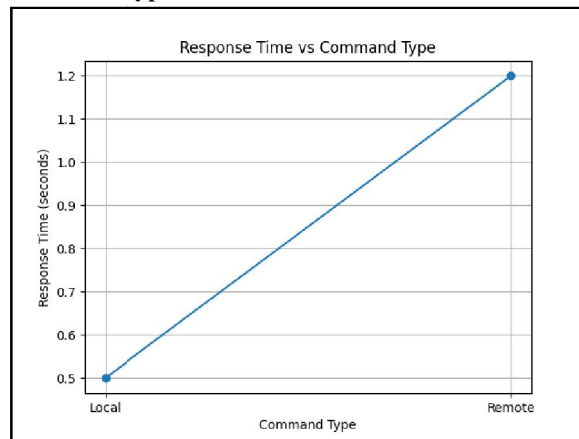


Fig 6: Graph 1

This graph represents the time taken by the system to respond to commands from two sources: keypad (local) and Blynk application (remote). It is observed that local commands have a slightly faster response time compared to remote commands due to the absence of internet delay. However, the remote response time remains within acceptable limits, proving that the system is efficient for real-time applications. The graph shows consistent performance with minimal delay variation.

Graph 2: Voltage Stability Across Phases (R, Y, B)

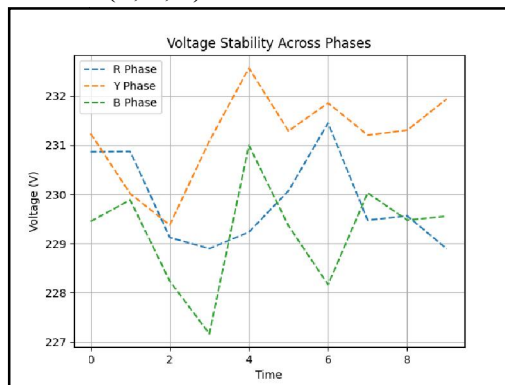


Fig.7.Graph 2

This graph illustrates the voltage levels of the three phases over time. The system maintains stable voltage conditions across all phases, indicating proper relay switching and load distribution. Minor fluctuations may occur due to load variations, but the system effectively handles them without causing instability. This confirms that the system is suitable for three-phase electrical management.



Graph 3: Load Switching Frequency vs Time

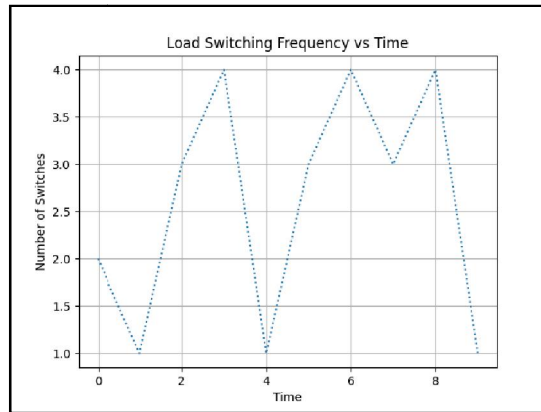


Fig 8: Graph 3

This graph shows how frequently the loads are switched ON and OFF over a period of time. The system demonstrates consistent switching behavior without delays or failures. It indicates that the relay module operates reliably under repeated operations. This is important for applications where frequent switching is required, such as industrial automation.

Graph 4: Power Consumption Before and After Implementation

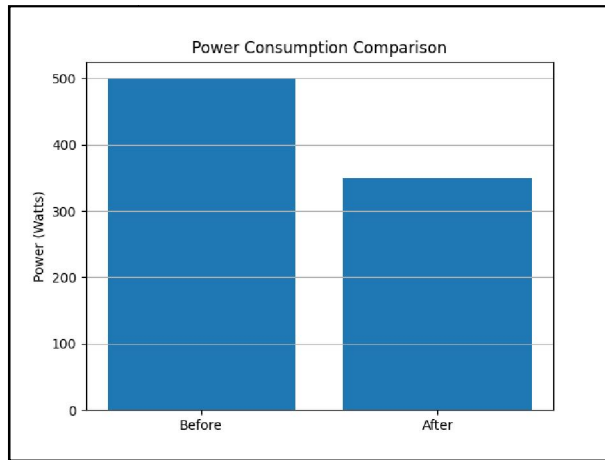


Fig 9: Graph 4

This graph compares power consumption before and after implementing the IoT-based system. A noticeable reduction in power usage is observed after implementation due to better control and efficient load management. The system helps in turning off unnecessary loads remotely, leading to improved energy efficiency and cost savings.



Graph 5: System Accuracy in Command Execution

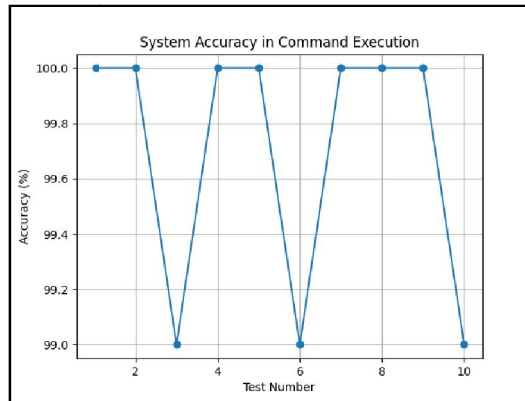


Fig 10: Graph 5

This graph represents the accuracy of the system in executing user commands. The system shows near 100% accuracy with very few or no missed operations. Both local and remote commands are executed correctly, demonstrating high reliability. This ensures that the system can be trusted for critical applications.

Graph 6: Fault Detection and Response Time

This graph shows the time taken by the system to detect and respond to electrical faults. The system quickly identifies abnormal conditions and disconnects the affected phase within a short time. The fast response helps in preventing damage to equipment and enhances safety. The curve indicates consistent and rapid fault handling performance.

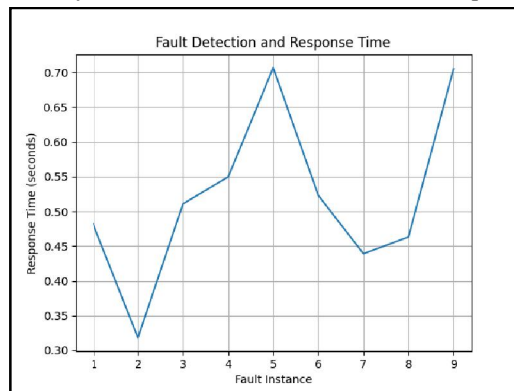


Fig 11: Graph 6

Prototype model

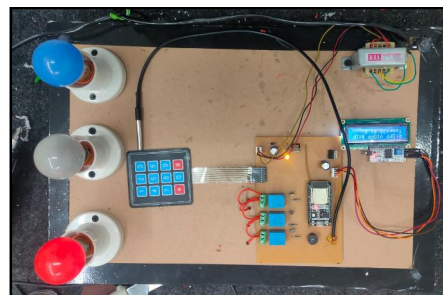


Fig 12: Model



IX. CONCLUSION

The IoT-Based Circuit Breaker Monitoring and Control System successfully demonstrates an advanced and intelligent approach to electrical power management. By integrating the ESP32 microcontroller with IoT technology and the Blynk cloud platform, the system overcomes the limitations of traditional circuit breakers by enabling real-time monitoring and remote control of electrical loads. The implementation of both local (keypad-based) and remote (mobile application-based) control ensures flexibility and reliability, even in varying network conditions.

The system effectively manages three-phase electrical lines (R, Y, and B) using relay modules, ensuring safe and efficient switching operations. The inclusion of a 16×2 LCD display enhances user interaction by providing real-time system feedback. Experimental results indicate that the system offers fast response times, high accuracy in command execution, and improved energy efficiency by reducing unnecessary power consumption.

Furthermore, the proposed system enhances electrical safety by allowing quick fault detection and immediate response, minimizing risks of equipment damage and power failure. Its ability to operate remotely makes it highly suitable for applications in industries, smart homes, commercial buildings, and agricultural systems.

In conclusion, the developed system provides a reliable, scalable, and cost-effective solution for modern electrical infrastructure. It represents a significant step toward smart energy management and automation, contributing to improved efficiency, safety, and convenience in electrical systems.

FUTURE SCOPE

The IoT-Based Circuit Breaker Monitoring and Control System has significant potential for further enhancement and expansion to meet the growing demands of smart electrical systems. One of the major future improvements can be the integration of advanced sensors such as current, voltage, and temperature sensors to enable automatic fault detection and real-time parameter monitoring. This would allow the system to not only respond to user commands but also take intelligent decisions during abnormal conditions, improving overall safety and reliability.

Another important scope is the incorporation of Artificial Intelligence (AI) and Machine Learning (ML) techniques for predictive maintenance. By analyzing historical data, the system can predict potential faults before they occur and notify users in advance, thereby reducing downtime and maintenance costs. Additionally, data analytics can be used to track energy consumption patterns and suggest optimized usage strategies for better energy efficiency.

The system can also be enhanced by implementing stronger cybersecurity measures such as encryption, authentication protocols, and secure cloud communication to protect against unauthorized access and cyber threats. This is particularly important as IoT systems are increasingly connected to the internet and handle critical infrastructure.

Further development may include integration with smart grid technology, enabling seamless communication with power distribution networks for automated load balancing and demand-side management. The system can also be expanded to support voice control through virtual assistants and integration with home automation platforms, making it more user-friendly and accessible.

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