IoT-Based Earth Leakage Monitoring System and Alert Staff in Case of Any Malfunction

A MINOR PROJECT-III REPORT

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BONAFIDE CERTIFICATE

Certified that this **18ECP105L - Minor Project III** report "**IOT-Based Earth Leakage Monitoring System and Alert Staff in Case of Any Malfunction”** is the Bonafide work of **IYYAPPAN M (927622BEC077), JEEVA A (927622BEC082), KISHOREKUMAR A R (927622BEC101), MOHAMMED RISHWAN S(927622BEC120)** who carried out the project work under my supervision in the academic year 2024 - 2025 **ODD**.

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PROJECT COORDINATOR

INSTITUTION VISION AND MISSION

Vision

To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

DEPARTMENT VISION, MISSION, PEO, PO AND PSO

Vision

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives

PEO1: **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

Program Outcomes

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs,PSOs
IoT-Based Monitoring, Earth Leakage Detection, Electrical Safety, Real-Time Alerts, Preventive Maintenance	**PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2**

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ABSTRACT

The IoT-Based Earth Leakage Monitoring System represents a significant advancement in ensuring electrical safety by leveraging modern IoT technologies and real-time monitoring capabilities. Electrical leakage, which occurs when current deviates from its intended path, can lead to serious consequences such as electric shocks, equipment damage, or even fires. Traditional systems, such as Earth Leakage Circuit Breakers (ELCBs), are reactive in nature, requiring manual intervention and lacking the ability to provide proactive insights or remote notifications. This system addresses these limitations by employing an ESP8266 microcontroller for both control and IoT connectivity.

A Current Transformer (CT) coil module is used to measure the AC current in the circuit, and the system continuously monitors for any anomalies that indicate leakage. When a leakage exceeds predefined safety thresholds, the system instantly disconnects the load using a relay module, ensuring that potential hazards are mitigated. To provide immediate alerts, the system is equipped with LED lights for visual indications and a buzzer for audible warnings. This allows users to recognize and address issues promptly. Furthermore, the IoT integration ensures that leakage data is logged in real-time and accessible through remote platforms, enabling effective monitoring and maintenance.

The system is designed for versatility, making it applicable in both residential and industrial setups. Its cost-effectiveness stems from the use of readily available components like the ESP8266, CT coil module, and relay, ensuring affordability without compromising functionality. Beyond ensuring safety, the solution facilitates preventive maintenance by allowing users to analyze logged data and address potential risks before they escalate. This innovative solution not only enhances safety but also

promotes the adoption of smart technologies in electrical systems, making it a valuable tool for the modern era. It offers reliability, convenience, and adaptability, ensuring that both small-scale and large-scale systems are adequately protected against electrical hazards.

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LIST OF ABBREVIATIONS

ACRONYM		ABBREVIATION
ELCBs	-	Earth Leakage Circuit Breakers
IoT	-	Internet of Things
CT	-	Current Transformer
LED	-	Light Emitting Diode
CFL	-	Compact Fluorescent Light
AIML	-	Artificial Intelligence and Machine Learning

CHAPTER 1

INTRODUCTION

Electrical leakage currents are one of the most critical safety concerns in residential, commercial, and industrial electrical systems. Leakage currents occur when unintended current flows through a grounding path, bypassing the designed circuit. This phenomenon can lead to severe consequences such as electric shocks to humans, fires caused by overheating, and extensive damage to sensitive electrical equipment. In industrial environments, where electrical systems power heavy machinery, such issues can disrupt operations and result in costly downtime.

To address these risks, traditional safety mechanisms like Earth Leakage Circuit Breakers (ELCBs) are commonly used. These devices are designed to detect leakage currents and trip the circuit to prevent further damage. However, ELCBs have several limitations:

1. Lack of Real-Time Monitoring: ELCBs can only react to faults but cannot provide continuous monitoring or status updates.
2. No Data Logging: They lack the ability to record historical leakage trends, which is critical for predictive maintenance.
3. No Remote Notification: Users must be physically present to reset the breaker or notice the fault, making them less effective in remote or unattended installations.

The IoT-Based Earth Leakage Monitoring System bridges these gaps by incorporating advanced technologies such as sensors, automation, and IoT connectivity. At the core of this system is the ESP8266 microcontroller, which serves as the brain of the solution, coordinating data processing, automation, and remote communication.

Key functionalities of the system include:

Real-Time Detection: The system continuously monitors current flow using a Current Transformer (CT) coil module, which detects anomalies indicative of leakage currents. Automated Response: If a leakage exceeds predefined safety thresholds, the system automatically disconnects the load using a relay module, preventing further damage or hazards. Alerts and Notifications: The system immediately triggers LED lights and a buzzer to provide visual and audible warnings, ensuring users are promptly informed of faults. IoT Connectivity: Through its IoT capabilities, the system logs all events and sends remote alerts, allowing users to monitor the status and trends via a connected platform.

This system is particularly beneficial for:

Proactive Maintenance: By logging data and analyzing trends, potential risks can be identified and mitigated before they escalate. Remote Accessibility: Users can monitor and control the system from anywhere, making it suitable for unattended installations or remote sites.

Enhanced Safety: Automated load disconnection and immediate notifications ensure quicker responses, reducing the likelihood of accidents. By integrating modern technologies into the conventional approach to electrical safety, this system is a significant step forward in addressing the growing complexities of modern electrical systems. Its ability to prevent, monitor, and report leakage currents makes it a vital tool for ensuring electrical safety across diverse applications.

1.1 OBJECTIVE

The primary objective of the IoT-Based Earth Leakage Monitoring System is to enhance electrical safety by developing a solution that:

Detects and monitors earth leakage currents in real-time using sensor technology. Automatically disconnects electrical loads when leakage exceeds predefined safety thresholds to prevent hazards such as electric shocks, equipment damage, and fires. Provides immediate visual and audible alerts to ensure prompt action during leakage events. Incorporates IoT capabilities for remote monitoring, data logging, and real-time notifications to alert users and staff of any malfunctions or risks. Enables preventive maintenance by analysing logged data and identifying trends in leakage currents, reducing long-term risks. Offers a cost-effective, user-friendly, and scalable solution suitable for residential and industrial applications.

1.2 IOT-BASED EARTH LEAKAGE MONITORING SYSTEM

The IoT-Based Earth Leakage Monitoring System is a smart solution designed to enhance electrical safety by detecting and addressing current leakages in real time. It continuously monitors current flow using a CT coil module, and if leakage exceeds safe thresholds, it automatically disconnects the load via a relay, while providing both visual and audible alerts through LEDs and a buzzer. Integrated with IoT technology, the system logs data and sends real-time alerts to staff, ensuring immediate action can be taken to prevent hazards such as electric shocks, equipment damage, or fires. This cost-effective and efficient system is ideal for residential, commercial, and industrial applications, promoting proactive safety and maintenance.

1.2.1 DESCRIPTION

The proposed system comprises the following major components:

1. ESP8266 Microcontroller: Serves as the central control unit, enabling data processing, threshold comparison, and IoT communication.

2. CT Coil Module: Continuously measures AC current and detects leakage.

3. Relay Module: Disconnects the load automatically during fault conditions.

4. LED Lights and Buzzer: Provide visual and audible alerts for immediate attention.

5. IoT Platform: Logs data and enables remote monitoring and notification.

The hardware is organized on a cardboard sheet with structural support provided by ice sticks. CFL bulbs with holders simulate the load, while jumper wires and standard wiring complete the connections. The software, programmed into the ESP8266, processes real-time sensor data, triggers protective measures, and communicates with IoT platforms for monitoring and alerting.

1.2.2 ADVANTAGES

The IoT-Based Earth Leakage Monitoring System offers a range of benefits that make it a highly effective solution for electrical safety. It ensures safety by quickly detecting current leakages and isolating faulty circuits, thereby preventing potential accidents such as electric shocks, equipment damage, or fires. Its IoT functionality enables remote monitoring and real-time logging of leakage trends, allowing users to analyze data and take preventive measures before issues escalate. Designed to be cost-effective, the system utilizes affordable and easily accessible components, making it a practical choice for a wide audience. Moreover, its user-friendly design ensures ease of assembly and operation, even for those with basic technical knowledge. Its versatility makes it suitable for a variety of settings, including residential environments and industrial facilities, where safety and efficient maintenance are critical.

1.2.3 APPLICATIONS

The IoT-Based Earth Leakage Monitoring System is designed to enhance safety and reliability across various applications. In residential safety, it detects current leakages in household circuits, reducing the risks of electrical shocks, equipment damage, and fires, ensuring a secure living environment. For industrial systems, it monitors high-load circuits, safeguarding machinery and personnel by identifying and addressing leakage hazards promptly. The system also supports preventive maintenance by logging historical data, enabling trend analysis to identify patterns and schedule proactive inspections before issues escalate. With its IoT-based alerts, the system provides real-time notifications to maintenance staff, ensuring swift response to malfunctions or potential hazards, thus combining safety, efficiency, and modern technology.

CHAPTER 2

LITERATURE SURVEY

2.1 Enhanced Electrical Safety Through IoT Integration: Addressing the Limitations of Standalone ELCBs

The evolution of electrical safety systems has been driven by the need to mitigate risks associated with electrical faults, such as current leakages, shocks, and fires. Earth Leakage Circuit Breakers (ELCBs) are a common safety measure employed to disconnect circuits during leakage events. However, traditional standalone ELCBs have significant limitations that hinder their effectiveness in modern, technology-driven environments. While they provide basic protection by interrupting the power supply during faults, these systems lack features for continuous monitoring, detailed logging of electrical data, and remote alerting, which are critical for ensuring comprehensive safety and facilitating maintenance.

To address these shortcomings, the integration of IoT (Internet of Things) technology into electrical systems has emerged as a transformative solution. IoT-enabled devices offer a smarter approach to electrical safety by combining traditional protection mechanisms with advanced monitoring and communication capabilities. Recent studies have emphasized the ability of IoT to enhance safety, efficiency, and convenience in residential, commercial, and industrial setups. By leveraging IoT, electrical systems can now monitor parameters such as current leakage in real time, log historical data for trend analysis, and provide remote alerts to ensure prompt corrective actions.

Modern IoT-based electrical safety systems utilize a combination of advanced sensors, microcontrollers, and IoT platforms to achieve these enhanced functionalities. Sensors such as CT (current transformer) coils enable precise measurement of current flow, while microcontrollers, such as the ESP8266, process data and manage communication with IoT platforms. These components work in tandem to provide continuous insights into the electrical system's health. For instance, if a leakage occurs, the system not only disconnects the faulty circuit but also sends notifications to designated personnel via mobile apps, emails, or dashboards. This feature ensures that stakeholders are informed immediately, reducing response time and preventing potential hazards.

Additionally, IoT integration allows for detailed logging of electrical data. This capability is particularly valuable for preventive maintenance. By analysing historical trends in current leakage, users can identify early signs of wear and tear or equipment malfunction, enabling timely repairs before a critical failure occurs. Such proactive maintenance reduces downtime, improves operational efficiency, and extends the lifespan of electrical systems.

Another significant advantage of IoT-based solutions is their scalability and adaptability. These systems are compact and modular, making them suitable for a wide range of applications, from small residential circuits to complex industrial networks. They can be tailored to meet specific requirements, such as monitoring high-load circuits in factories or ensuring safety in sensitive environments like hospitals and data centres.

In conclusion, the integration of IoT technology into electrical safety systems represents a major step forward in addressing the limitations of standalone ELCBs. By enabling continuous monitoring, data logging, and remote alerting, IoT-based solutions offer a more comprehensive approach to preventing electrical hazards. As advancements in sensors, microcontrollers, and IoT platforms continue, these systems are becoming increasingly compact, cost-effective, and accessible, paving the way for widespread adoption across diverse sectors. This paradigm shift not only enhances safety but also promotes efficiency and convenience, making IoT an indispensable part of modern electrical infrastructure.

CHAPTER 3
EXISTING SYSTEM

3.1 Limitations of Traditional Earth Leakage Circuit Breakers (ELCBs): A Case for Proactive Safety Systems

Earth Leakage Circuit Breakers (ELCBs) have long been a standard safety measure in electrical systems, designed to protect against leakage currents that pose risks of electric shock, equipment damage, and fire hazards. These devices work by detecting leakage currents and disconnecting the power supply to prevent further risks. While effective in providing basic protection, traditional ELCBs operate in a reactive manner, addressing issues only after they occur. This approach has significant limitations that make standalone ELCBs less suitable for modern, complex electrical systems, especially in large-scale or high-risk environments.

3.2 Reactive Nature of Traditional ELCBs

Traditional ELCBs are designed to trip circuits when leakage is detected, effectively cutting off power to isolate the fault. However, this mechanism does not provide any prior warning or real-time insights into the system's health. In many cases, the leakage may go unnoticed until it exceeds a critical threshold and triggers the breaker. This reactive approach leaves room for potential hazards, as minor faults or leakages that develop over time are not addressed promptly. For instance, a slow, progressive leakage in an industrial system could lead to equipment damage, energy losses, or overheating before being detected by an ELCB.

3.3 Lack of Data Logging and Monitoring

One of the major drawbacks of traditional ELCBs is their inability to log data or provide detailed insights into the electrical system. Modern electrical systems, particularly in industrial or commercial settings, demand continuous monitoring to detect trends and anomalies. Without data logging, it is impossible to analyse the historical performance of a circuit or identify patterns that may indicate underlying issues. This limitation makes preventive maintenance challenging, as faults are only addressed after they manifest in significant ways.

3.4 No Remote Alerting or Connectivity

Traditional ELCBs operate as standalone devices with no connectivity or communication features. In cases of tripping, they provide no mechanism to alert maintenance personnel remotely. This necessitates manual inspection to identify the fault, which can delay corrective actions, particularly in large facilities or remote installations. The lack of remote alerting is especially problematic in environments where immediate response is critical, such as hospitals, data centres, or manufacturing plants, where downtime or delayed repairs can have severe consequences.

3.5 Manual Inspection and Resetting

Another limitation of traditional ELCBs is the requirement for manual intervention to inspect the circuit and reset the breaker after it trips. This process is time-consuming and labor - intensive, especially in large-scale operations where multiple ELCBs are deployed. Identifying the source of leakage can also be challenging without proper monitoring tools, leading to prolonged downtime and increased operational inefficiency.

3.6 Ineffectiveness in Large-Scale or High-Risk Environments

In expansive or high-risk environments, such as industrial plants, commercial buildings, or critical infrastructure, the limitations of traditional ELCBs become even more pronounced. These environments often involve complex electrical systems with high power demands, making proactive monitoring and fast response essential. The reactive nature of ELCBs, combined with the absence of logging and remote communication, makes them inadequate for ensuring comprehensive safety and maintenance in such scenarios.

3.7 The Need for Proactive Solutions

The limitations of traditional ELCBs highlight the need for a more advanced and proactive approach to electrical safety. Modern solutions, such as IoT-enabled Earth Leakage Monitoring Systems, address these gaps by providing real-time monitoring, data logging, and remote alerting features. These systems enhance safety by identifying potential issues before they escalate, reducing risks and ensuring faster response times. In conclusion, while traditional ELCBs serve as a foundational safety measure, their lack of proactive features limits their effectiveness in today’s dynamic and technology-driven environments. As electrical systems become more complex and the demand for safety and efficiency increases, the shift toward IoT-based solutions is essential for addressing the challenges of traditional ELCBs and ensuring robust protection against electrical hazards.

CHAPTER 4

PROPOSED SYSTEM

4.1 Real-Time Monitoring and Automated Fault Response

At the core of the proposed system is the ability to monitor leakage currents continuously and in real-time. Unlike traditional ELCBs, which operate reactively, the system uses a CT coil module to measure current flow with high precision. Data from the CT coil is processed by an ESP8266 microcontroller, which evaluates the current against predefined safety thresholds.

When the system detects leakage currents that exceed the safe limits, it immediately takes protective action by triggering a relay module to disconnect the load. This automated response ensures that faults are isolated instantly, reducing the risks of electric shock, equipment damage, or fire hazards. The speed and accuracy of this process minimize downtime and prevent accidents, offering a proactive solution to electrical safety challenges.

4.2 IoT Integration for Remote Monitoring and Alerts

One of the key innovations of the proposed system is the integration of IoT technology. This capability allows users to monitor the system's status remotely, providing unparalleled convenience and safety. The IoT platform logs real-time data on leakage currents, which can be accessed through user-friendly dashboards or mobile applications. In the event of a fault, the system sends instant alerts to maintenance personnel via email, SMS, or app notifications. This remote alerting feature ensures that issues are addressed promptly, even when staff are not physically present at the site. For critical environments, such as hospitals or data centers, where every second matters, this capability is invaluable in preventing disruptions and mitigating risks.

4.3 Data Logging and Predictive Maintenance

The ability to log and store data is a significant improvement over traditional ELCBs. By recording historical leakage trends, the proposed system enables predictive maintenance, which is a proactive approach to equipment care. Maintenance teams can analyze the logged data to identify patterns or anomalies that indicate potential issues. For instance, gradual increases in leakage current over time may signal wear and tear in electrical components or insulation. By addressing these early warning signs, users can prevent critical failures, reduce repair costs, and extend the lifespan of electrical systems. This predictive capability enhances the overall reliability and efficiency of electrical networks.

4.4 Enhanced Safety and Versatility

The proposed system is designed to enhance safety across a wide range of applications. In residential settings, it protects families by detecting faults and isolating circuits before they become hazardous. In industrial environments, it safeguards workers and equipment by monitoring high-load circuits and ensuring swift responses to faults. The system's versatility makes it suitable for use in commercial buildings, manufacturing facilities, and critical infrastructure, where safety and efficiency are paramount. Additionally, the system incorporates visual and audible alerts using LED indicators and a buzzer, providing immediate feedback to onsite personnel. These alerts ensure that even in the absence of IoT connectivity, the system remains effective in notifying users of potential issues.

4.5 Advantages Over Traditional ELCBs

The proposed IoT-based system overcomes the significant shortcomings of traditional ELCBs. While standalone ELCBs rely on manual inspection and lack connectivity, the proposed system operates autonomously, communicates remotely, and provides detailed insights into system performance. Its proactive approach reduces risks, ensures timely intervention, and enables better planning and maintenance. By combining IoT technology, automation, and advanced sensors, the proposed system represents a modern, scalable solution for electrical safety. Its compact design, cost-effectiveness, and user-friendly operation make it an ideal choice for a wide range of users, from homeowners to industrial operators.

4.6 Insights and Future Improvements

The results of the tests underscore the system's reliability and functionality. However, there is potential for further improvement, such as enhancing the sensitivity of the CT coil for detecting extremely low levels of leakage, integrating additional IoT features like predictive analytics, and improving the system's resilience to harsh environmental conditions. These enhancements could expand the system's applications and make it even more versatile for diverse use cases.

CHAPTER 5
RESULTS AND DISCUSSION

The IoT-Based Earth Leakage Monitoring System was extensively tested under a variety of controlled conditions to evaluate its performance, functionality, and reliability. These tests simulated real-world scenarios of electrical leakage, abnormal currents, and system faults to ensure that the system meets safety and operational standards. The results demonstrate the system's effectiveness in detecting leakage currents, triggering protective measures, and providing real-time data through its IoT-enabled platform.

5.1 Detection of Abnormal Currents

During testing, leakage currents of varying magnitudes were introduced into the circuit to evaluate the system's sensitivity and accuracy. The CT coil module, responsible for detecting current flow, performed as expected, identifying even small deviations from normal operating conditions. The system's predefined safety threshold ensured that any current exceeding the set limit was flagged as a fault.

This capability to detect abnormal currents promptly is crucial in preventing electrical hazards such as shocks, fires, or equipment damage. The high precision of the CT coil module highlights its reliability as a core component of the system.

5.2 Automated Load Disconnection

Upon detecting leakage, the system successfully triggered the relay module, which immediately disconnected the electrical load. This automated response was consistent across all test scenarios, including simulated gradual leakages and sudden spikes in current. By isolating the faulty circuit, the system effectively mitigated the risks associated with prolonged leakage, such as overheating or short circuits. The relay's rapid response time ensures minimal delay in disconnecting the load, an essential feature for both residential and industrial safety applications. This real-time isolation of faults demonstrates the system's robustness and reliability in protecting electrical networks.

5.3 Visual and Audible Alerts

The system's LED indicators and buzzer were tested to verify their functionality in alerting onsite personnel to faults. During each test scenario, the LED lights changed colour or activated as programmed, visually indicating the status of the system—whether it was functioning normally or detecting leakage. Simultaneously, the buzzer emitted an audible alarm, providing an additional layer of notification.

These alerts are particularly useful in environments where immediate action is required, ensuring that onsite staff are made aware of potential hazards without delay. The combination of visual and audible alerts enhances the system's usability and effectiveness, even in the absence of IoT connectivity.

5.4 IoT Communication and Remote Monitoring

One of the standout features of the system is its ability to communicate fault status and operational data to an IoT platform. Using the ESP8266 microcontroller, the system transmitted real-time information on leakage currents and fault status to a cloud-based dashboard. This data was accessible through user-friendly interfaces, such as mobile apps or web portals, enabling remote monitoring of the system's performance.

The IoT platform also logged historical data on leakage currents, providing valuable insights for trend analysis and predictive maintenance. During testing, the communication between the system and the IoT platform was seamless, with no delays or data loss observed. This demonstrates the reliability of the ESP8266 and the IoT infrastructure in supporting continuous monitoring and real-time alerts.

5.5 Reliability and Practical Implementation

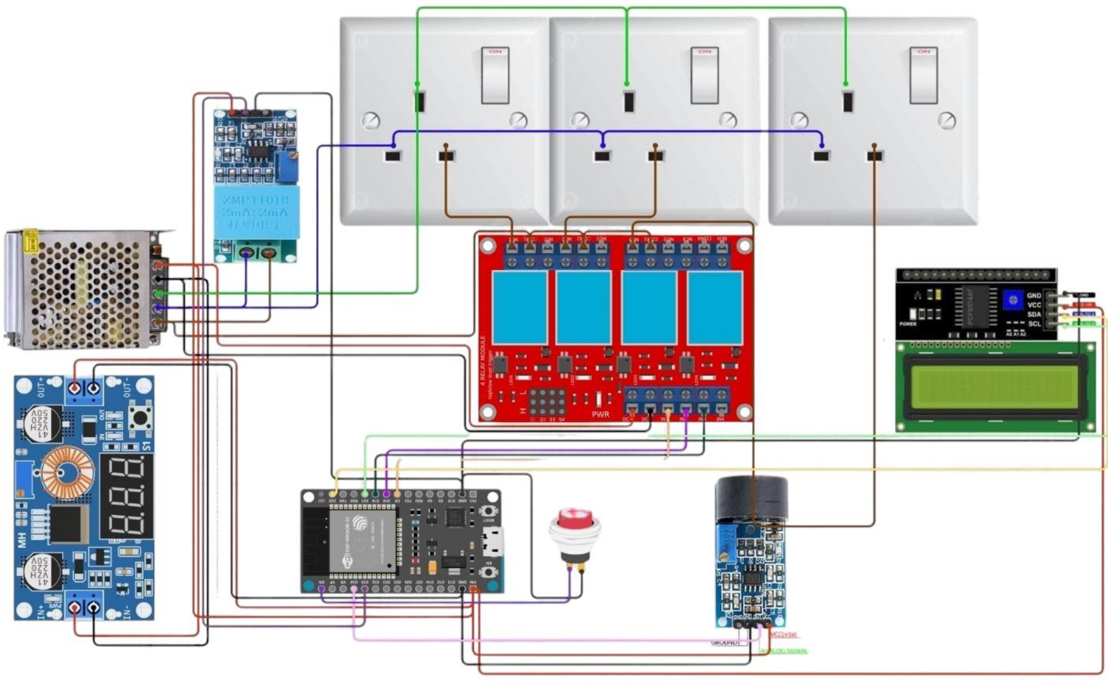
The successful execution of the tests highlights the system's potential for real-world applications. Its ability to detect and respond to leakage currents in real time ensures enhanced safety in various environments, from residential homes to industrial facilities. The IoT features, combined with automated protective measures, make the system particularly suitable for modern electrical networks that demand both reliability and convenience.

Additionally, the system's compact and cost-effective design ensures that it can be implemented without significant financial or technical barriers. The use of readily available components such as the CT coil, ESP8266, and relay module further enhances its feasibility for widespread adoption.

5.6 Insights and Future Improvements

The results of the tests underscore the system's reliability and functionality. However, there is potential for further improvement, such as enhancing the sensitivity of the CT coil for detecting extremely low levels of leakage, integrating additional IoT features like predictive analytics, and improving the system's resilience to harsh environmental conditions. These enhancements could expand the system's applications and make it even more versatile for diverse use cases.

5.7 Block Diagram



The IoT-Based Earth Leakage Monitoring System is designed to enhance safety by detecting earth leakage currents and alerting staff in real-time to prevent potential hazards. Earth leakage occurs when electrical current flows unintentionally from a live conductor to the ground, posing risks such as electric shocks and fires.

5.7.1 Components and Their Roles:

Power Supply Unit: Provides stable voltage and current to the entire system.

Earth Leakage Sensor: Continuously monitors electrical current to detect any leakage to the ground.

Microcontroller: Acts as the brain of the system, processing data from the sensor to identify leakage.

Relay Module: Disconnects the faulty circuit in case of detected leakage to prevent hazards.

LCD Display: Shows real-time data and system status, allowing for easy monitoring.

Wi-Fi Module: Enables IoT functionality by connecting the system to the internet for remote monitoring and alerts.

Switches and Indicators: Allows manual control and provides visual alerts in case of leakage detection.

5.7.2 Working Principle:

Detection: The earth leakage sensor monitors the current flow continuously. If it detects a current flow to the ground above a certain threshold, it sends a signal to the microcontroller.

Processing: The microcontroller analyzes the data to confirm if there is an earth leakage. It compares current levels with preset threshold values.

Alerting: If a leakage is detected, the microcontroller triggers the relay module to disconnect the circuit, ensuring safety. Simultaneously, it sends an alert to the Wi-Fi module.

Notification: The Wi-Fi module connects to the internet and sends real-time alerts to remote monitoring systems or mobile devices, ensuring that staff are promptly informed.

Display: The LCD display shows the current status, including detected leakage current and relay operation status, providing a quick overview for on-site personnel.

5.7.3 Importance and Relevance:

This system is crucial for enhancing electrical safety in various environments, such as industrial plants, commercial buildings, and residential areas. By providing real-time monitoring and instant alerts, it helps prevent potential hazards caused by earth leakage currents. The integration of IoT technology ensures that staff can be promptly informed of any issues, even when not physically present at the site, significantly reducing the risk of electrical accidents and improving overall safety standards.

CHAPTER 6
CONCLUSION AND FUTURE WORK

Electrical safety is a critical concern in both residential and industrial settings, where current leakages can lead to hazards such as electric shocks, fires, and equipment damage. The IoT-Based Earth Leakage Monitoring System offers a transformative solution to these challenges by integrating real-time monitoring, IoT connectivity, and automated protective measures. Through the successful implementation and testing of this system, it is evident that it provides a reliable, efficient, and modern approach to managing electrical safety.

6.1 Key Contributions

The system's ability to continuously monitor electrical leakage currents and respond autonomously sets it apart from traditional Earth Leakage Circuit Breakers (ELCBs). It not only detects faults but also proactively mitigates risks by disconnecting loads and alerting users through visual, audible, and IoT-enabled notifications. This proactive approach ensures faster response times and reduces the likelihood of accidents. The inclusion of IoT capabilities allows users to remotely monitor and log leakage trends, offering the additional advantage of predictive maintenance.

Moreover, the system's cost-effectiveness and use of readily available components make it accessible to a wide audience, ranging from homeowners to industrial operators. Its simplicity in assembly and operation further underscores its potential for widespread adoption. These features highlight the system's practical relevance and its ability to enhance safety in diverse environments.

6.2 Future Enhancements

While the system has demonstrated effectiveness in its current form, there is significant scope for future improvements to make it even more robust and versatile. One promising direction is the integration of artificial intelligence (AI) and machine learning (ML) for predictive analytics. By leveraging AI, the system could analyse historical data and identify patterns or anomalies that may indicate potential issues before they become critical. For example, AI algorithms could predict the likelihood of insulation failure or identify circuits at higher risk of leakage, enabling preemptive maintenance and reducing downtime.

Another area for future development is expanding the system's compatibility with smart home and industrial automation platforms. As the adoption of smart devices and IoT ecosystems continues to grow, integrating the Earth Leakage Monitoring System with platforms like Amazon Alexa, Google Home, or industrial IoT dashboards could enhance its usability. Users could receive real-time alerts, control the system, or access detailed reports through voice commands or centralized applications, creating a seamless experience.

6.3 Advanced Sensors for Precision

The inclusion of more advanced sensors is another avenue for future work. While the current system uses a CT coil module to measure leakage currents, the addition of high-precision sensors could improve accuracy, especially in detecting minimal or intermittent leakages. For instance, sensors capable of detecting minute fluctuations in electrical flow could be particularly beneficial in sensitive environments such as hospitals or data centers, where even minor faults can have significant consequences. Furthermore, incorporating sensors that monitor other electrical parameters, such as voltage fluctuations or power quality, could provide a more comprehensive view of the system's health. This multi-parameter approach would enable users to address a wider range of electrical issues, further enhancing safety and operational efficiency.

6.4 Scalability and Adaptability

Future versions of the system could also focus on scalability to accommodate larger installations. For instance, in industrial settings with extensive electrical networks, a single system could monitor multiple circuits or zones simultaneously. This would require designing modular and adaptable architectures that can be customized based on specific user requirements. Additionally, the system could be made more resilient to environmental factors such as extreme temperatures, humidity, or dust, ensuring reliable operation in challenging conditions. Ruggedized enclosures and weatherproof components would make the system suitable for outdoor or industrial use, expanding its applicability.

REFERENCE

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OUTCOME

The IoT-Based Earth Leakage Monitoring System demonstrated exceptional functionality in detecting and addressing electrical leakages. The system was tested under various simulated leakage conditions and achieved the following outcomes:

Real-Time Detection: The CT coil module efficiently measured AC currents, identifying leakage levels in real-time with high accuracy.

Automatic Load Disconnection: The relay module successfully disconnected the electrical load whenever the leakage exceeded the predefined safety threshold, ensuring immediate protection.

Alerts and Notifications: Visual alerts through LEDs and audible warnings via the buzzer provided clear and immediate feedback during fault conditions.

IoT Connectivity: The ESP8266 microcontroller effectively communicated with IoT platforms, enabling remote monitoring, logging of leakage trends, and real-time notifications to users or staff.

User-Friendly Design: The system's compact and cost-effective hardware setup demonstrated ease of assembly and operation, making it suitable for diverse environments.

Enhanced Safety: The integration of IoT with electrical protection added a proactive dimension to leakage management, reducing risks of electric shock, equipment damage, and fire hazards.