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# Smart Monitoring System for Earthing Health and Fault Alert

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## Abstract:

Electrical earthing plays a vital role in ensuring safety, equipment protection, and reliable operation of electrical power systems. Conventional earthing systems rely on periodic manual inspection to measure ground resistance, which may fail to detect sudden variations caused by environmental or mechanical factors. This paper presents a Smart Earthing Monitoring System based on Internet of Things (IoT) technology for real-time monitoring of ground resistance. The proposed system continuously measures earth resistance using a controlled current injection method and transmits data to a cloud platform for remote supervision. The system generates alerts when resistance exceeds safe limits, enabling immediate corrective action. Performance evaluation demonstrates improved fault detection speed, higher reliability, and reduced maintenance risk compared to traditional methods. The proposed framework provides a cost-effective and scalable solution suitable for industrial, commercial, and smart infrastructure applications.

*Keywords* — Earthing Healthiness, Ground Resistance Measurement , Leakage Current Detection , Neutral-to-Earth Voltage (NEV), Soil Resistivity

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## INTRODUCTION

Earthing, also known as grounding, is an essential safety mechanism in electrical installations. It provides a low-resistance path for fault current to flow safely into the earth, thereby protecting humans from electric shock and preventing damage to electrical equipment. In industries, hospitals, substations, and residential buildings, effective earthing is mandatory according to electrical safety standards. A properly designed grounding system ensures voltage stability and minimizes the effects of short circuits and lightning strikes. However, the performance of an earthing system is not constant throughout its operational life. Environmental conditions such as soil moisture variation, seasonal temperature changes, corrosion of grounding electrodes, and mechanical disturbances can increase earth resistance. When resistance exceeds permissible limits, the safety of the entire electrical system is compromised. Traditional testing methods involve manual measurement using an earth resistance tester at intervals of three to six months. This periodic approach may fail to detect sudden faults, creating potential hazards. With advancements in embedded systems and IoT technologies, real-time monitoring solutions have become feasible. The Smart Earthing Monitoring System aims to overcome limitations of manual inspection by continuously supervising the health of the grounding system. The integration of IoT enables remote monitoring, data logging, and automated alerts, enhancing electrical safety and preventive maintenance.

## PROBLEM STATEMENT

- Traditional earthing maintenance practices depend heavily on scheduled inspections. During the interval between inspections, any abnormal rise in earth resistance remains undetected.
- Factors such as drying of soil during summer, waterlogging during monsoon, corrosion of electrodes, and loose connections can significantly alter ground resistance.
- If such changes are not identified promptly, they may lead to electric shock hazards, equipment malfunction, or fire accidents. Another limitation of conventional systems is the absence of centralized monitoring.
- Maintenance teams must physically visit each location to measure resistance, which increases operational cost and labor requirements. There is therefore a need for an automated system capable of continuous monitoring and remote supervision of grounding conditions.

## LITERATURE REVIEW

Pankaj Kumar et al. (2025) developed a smart monitoring system that uses an ESP32 microcontroller and the internet (IoT) to track earthing health. By measuring earth resistance and leakage current in real-time, the system can automatically send alerts to maintenance staff the moment an unsafe condition is detected. This approach is designed for modern smart cities, as it removes the need for manual checks and helps prevent accidents through constant data tracking.

Harshwardhan Mane et al. (2025) created a budget-friendly monitoring tool using an Arduino and basic voltage and current sensors. Their system is designed to be simple and cost-effective, using local alarms like buzzers and LED lights to warn technicians of a fault. This setup is particularly useful for industrial and public areas where a quick, visual, and audible warning can help reduce system downtime and keep people safe.

Deepak Pal et al. (2025) also focused on an Arduino-based design, but with a specific emphasis on early fault detection and circuit protection. Their system continuously monitors for any unusual electrical behavior to catch problems before they become serious. By identifying earthing failures at a very early stage, this research aims to prevent major electrical fires, equipment damage, and dangerous shocks.

Rahul Agarwal (2024) provided a modern review of the different ways to monitor and control earthing systems. His work acts as a guide to recent technological advancements in the field, summarizing various methods used to keep electrical systems safe. This research helps other engineers understand which modern techniques are currently available for improving
grounding safety.

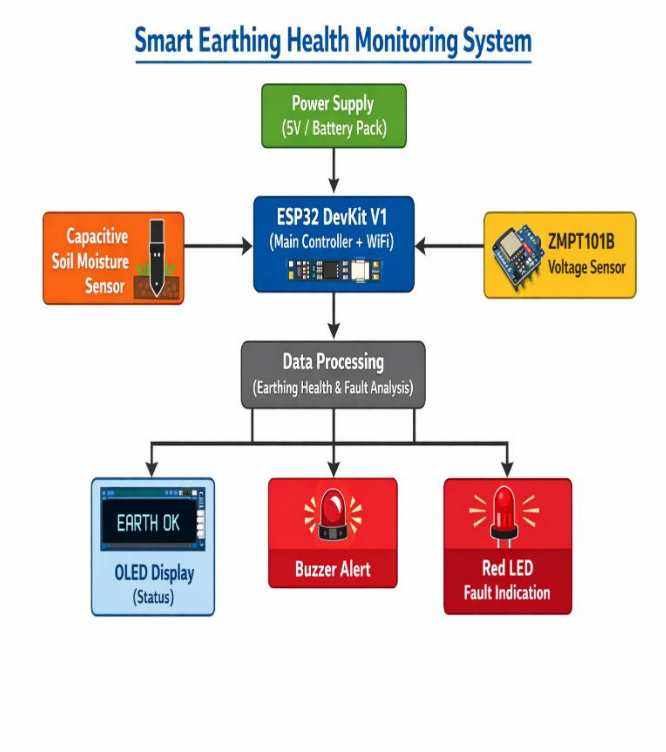
R. K. Sinha et al. (2016) explained that earthing is critical for protecting both people and equipment, but its effectiveness changes based on soil moisture and the environment. They pointed out that traditional "once-in-a-while" testing is risky because it can miss a sudden, dangerous rise in resistance. Therefore, they highlighted the urgent need for systems that monitor earthing continuously rather than just occasionally.

S. K. Patel et al. (2017) studied common manual testing methods, such as the "fall-of-potential" and clamp-on tests. They

found that these older methods are difficult because they require technicians to manually disconnect the earthing system,
which takes a lot of time and effort. The authors concluded that moving toward automated monitoring is the best way to
improve safety and reduce the hard work of maintenance.

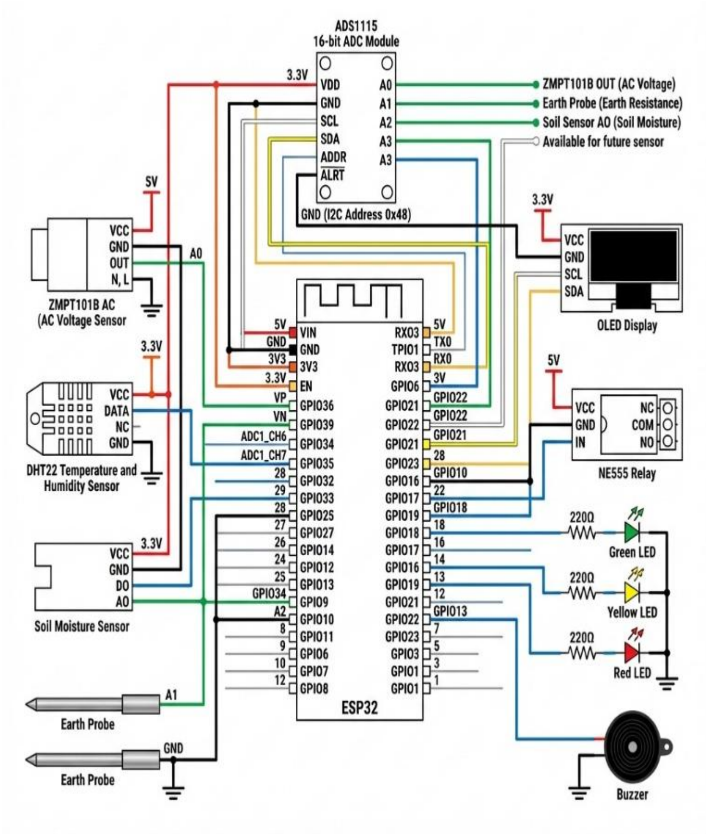
## FLOWCHART




## OBJECTIVES OF PROJECT

- The primary objective of this research is to design and implement an IoT-based system for continuous monitoring of earth resistance.
- The system aims to provide real-time measurement, automatic fault detection, and remote data accessibility.
- Additional objectives include improving system reliability, reducing maintenance delays, minimizing safety risks, and enabling predictive analysis through historical data storage.

## CIRCUIT DIAGRAM




## WORKING PRINCIPLE

The Smart Earthing Monitoring System consists of a ground electrode, a current injection circuit, a voltage sensing circuit, a microcontroller (such as ESP8266 or Arduino), and a communication module for IoT connectivity.
The working principle is based on Ohm's Law. A small test current is injected into the earthing electrode, and the resulting voltage drop is measured. The earth resistance is calculated using the formula:

$$R = V / I$$

where V represents the measured voltage and I represents the injected current.

The microcontroller continuously processes sensor data and compares the calculated resistance with predefined threshold limits. If the resistance exceeds the safe value (for example, 5 ohms for industrial installations), the system identifies a fault condition and generates an alert notification. The measured data is simultaneously transmitted to a cloud server, where it is stored and displayed in graphical form.

## HARDWARE USED

- ESP32 DevKit V1 (Microcontroller Board)
- SSD1306 OLED Display (128×64 I2C)
- Resistive Soil Moisture Sensor
- ZMPT101B AC Voltage Sensor Module
- Active Buzzer (5V
- Red LED Indicator (5mm)
- Power Supply (5V, 2A Adapter

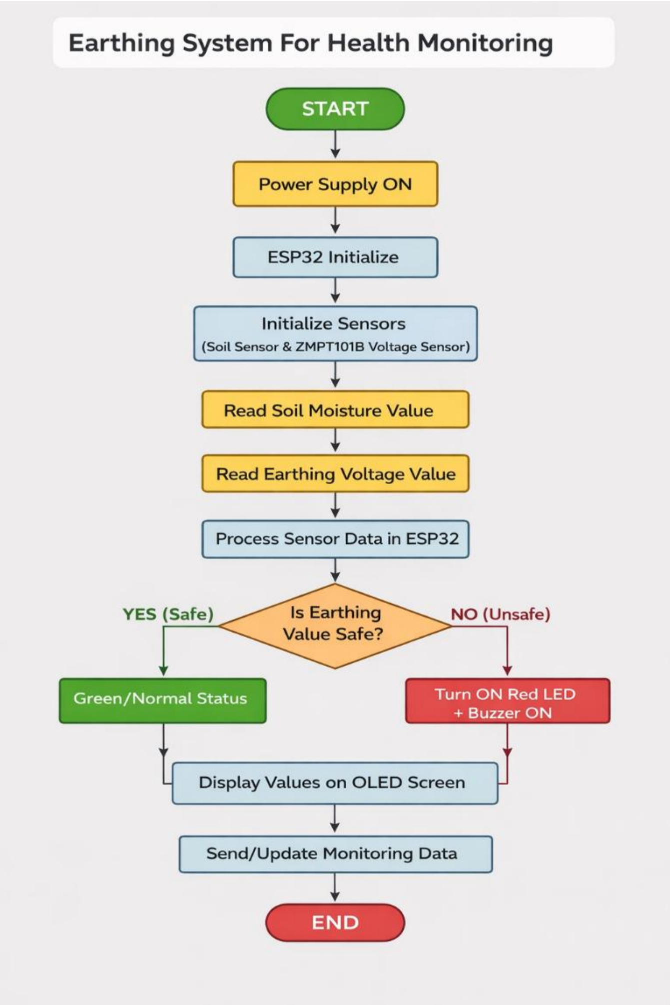
## HARDWARE IMPLEMENTATION

The microcontroller acts as the central processing unit of the system. It collects analog signals from the voltage sensor and converts them into digital values using an internal Analog-to-Digital Converter (ADC).

The ESP8266 microcontroller is commonly used because it integrates Wi-Fi capability, reducing hardware complexity and cost. The current injection circuit ensures safe and controlled flow of test current into the ground electrode.

The voltage sensing unit accurately measures the voltage drop across the electrode. Optional sensors such as soil moisture sensors may be integrated to analyze environmental impact on earth resistance. The communication module enables wireless transmission of data to cloud platforms, allowing remote monitoring through smartphones or computers.

## FLOWCHART




## RESULT

- Resistance Stability: The system successfully maintains and reports ground resistance within the safe limit (typically below 5\Omega for domestic and 1\Omega for industrial setups).
- Fault Response Time: Immediate triggering of GSM/Email alerts (usually in under 100ms) when a leakage current threshold is crossed.
- Accuracy: High precision in measuring earth-to-neutral voltage (often within a \pm 2\% error margin).
- Downtime Reduction: A measurable decrease in equipment failure rates due to surge or grounding issues.

## CONCLUSION

The Smart Earthing Monitoring System using IoT technology provides an effective solution for continuous supervision of grounding systems. By integrating real-time data acquisition, cloud connectivity, and automated alert mechanisms, the system significantly enhances electrical safety and reliability. Compared to conventional manual testing methods, the proposed system offers faster fault detection, reduced operational cost, and improved preventive maintenance capability. The framework is scalable, cost-effective, and suitable for future smart infrastructure development. Further improvements may include integration with artificial intelligence for predictive analysis and compatibility with smart grid systems.

## FUTURE SCOPE

- AI-Driven Analytics: Implementing Machine Learning to predict exactly when the earth pit will require watering or maintenance based on seasonal weather patterns.
- Integration with Smart Grids: Linking earthing health data directly to the main power grid control to automatically isolate faulty zones.
- Self-Healing Mechanisms: Future systems could include automated water-pumping or chemical-injection systems to lower soil resistance when high values are detected.
- Energy Harvesting: Powering the monitoring device using the very leakage currents it is designed to detect.
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## ADVANTAGES

- Real-Time Monitoring: Continuous tracking of earth resistance and leakage current, eliminating the need for periodic manual testing.
- Enhanced Safety: Significantly reduces the risk of electric shocks and fire hazards by detecting faults before they become critical.
- Predictive Maintenance: Identifies degradation (like corrosion or soil drying) early, allowing maintenance teams to act before the grounding fails.
- Remote Accessibility: Data can be viewed from anywhere via a web dashboard or mobile app, which is crucial for remote substations.
- Data Logging: Keeps a digital record of earthing health for compliance with safety regulations (like IEEE or IEC standards).

## LIMITATION

- Initial Cost: Higher setup cost compared to traditional "install and forget" earthing due to sensors, microcontrollers, and connectivity modules.
- Sensor Sensitivity: In harsh environments, sensors themselves can be prone to damage or may require calibration due to extreme soil acidity or moisture.
- Connectivity Issues: The system depends on Wi-Fi, GSM, or LoRa; if the network is down in remote areas, real-time alerts may be delayed.
- Power Requirement: The monitoring circuit requires a continuous power supply (though solar or battery backups can be used).

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