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IOT-Enabled Smart Protection System for Earth Current Leakage with Real-Time Monitoring, Immediate Safety Measures, and GSM Alerts

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Abstract:** As electrical infrastructures get more complex, the need for intelligent, responsive, forward looking grounding mechanisms increases. The novelty of this project is an integrated conventional earthing intelligently designed by Internet of things enabled sensor and web based analytics that can detect the electrical hazards and automatically respond to prevent any accidental incidents. The core of the system is an Arduino controller, interfaced with a number of companion components: voltage and current sensors (PT and CT); MEMS module; GPS Receiver; gas and flame detectors; and an LCD display for user interaction. Variable resistors are included in order both to fine-tune signal inputs and to maximise sensor resolution. The system is designed to track energy flow, detect abnormal load performance, and segregate major faults like current surges, leakages, or environmental hazards. If any anomaly is detected (e.g., vibration, toxic gases, ignition), the acoustic alarm sounds, and the GSM communication module transmits a situational report. The GPS feature improves traceability, which helps ensure prompt incidents are addressed. This means that it will dynamically disconnect the power load to reduce damage done while retaining manual control with a user-accessible switch. This system can communicate, take action, and adapt without any human intervention, which unadulterated is creating a smarter and safer ecosystem and the whole framework of grounded automization. Cited in areas that span from industrial environments to homes, the system enhances electrical safety through the adoption of an advanced level of dispersed communication via IoT sensing technologies.

***Keywords:** Intelligent Grounding Systems, IoT-Based Monitoring, Arduino Microcontroller, Real-Time Fault Recognition, Sensor Combination Technology, Automatic Load Isolation, GSM Based Alert System, GPS Based Location Tracking, Adaptive Threshold Calibration, Embedded Safety Automation*

I. INTRODUCTION

The need for the uninterrupted power supply, along with the necessity of protection assurance, has turned the direction of electrical systems toward intelligent fault detection and grounding solutions today. While conventional earthing systems are a critical part of the electrical infrastructure, they do not have the dynamic flexibility and accuracy to detect hazards in real-time and respond to them. As the complexity of electrical networks continues to grow, especially in urban and industrial environments, it becomes ever more essential to utilize a proactive approach to grounding and fault management. This paper establishes a novel earthing framework integrated with Internet-of-Things (IoT) where the power conditions and environmental disturbances are continuously monitored using sensor-based intelligence.

Conventional grounding systems are usually passive and to functionally deny the fault currents to earth during an irregularity they allow the flow of current to the ground. But they give a limited context on what are the reasons or reasons and if they are not able to send notifications or report in real-time. This restriction makes it difficult to take prompt corrective measures that may cause problems to the equipment as well as humans. IoT technology integration allows for earthing systems to move from reactive to predictive and responsive strategies while automating intervention, enabling remote communication and extensive diagnostics.

This paper proposes a microcontroller-based system in which Arduino works as the main hub, interfaced with a number of sensing units, including current and potential transformers, MEMS vibrometer, gas and fire detectors, and GPS module. Hence, these features monitor critical factors like the load current, voltage variation, vibration of the equipment, and environmental hazards. For conditioning the signal to achieve the necessary precision and control, the variable resistors are used. With this configuration, the system monitors, assesses, and accommodates for variations instantaneously.

When unusual phenomenahappen say short circuit, gas leak, excess vibration, or fire the system triggers protection. This can be done by buzzing a buzzer, showing alerts throgh an LCD module, to disconnect load using relay circuits and to send emergency messages via a GSM communication module. By incorporating a GPS module, the alerts generated by the system not only contain information about what went wrong but also have the location embedded in them make it easier to respond to maintenance or emergency services.

It is a fusion of embedded systems and communication technologies with sensor analytics used in an intelligent earthing system. Not only does it allow you to isolate faults quickly, it also provides decision makers with information to act on. By automatically removing the dangerous load, the potential for equipment damage and personal injury is reduced, and real-time reporting enhances situational awareness and maintenance planning.

In short, this work overcomes the static grounding mechanisms by presenting a smart IoT-based system with capabilities such as real-time monitoring, adaptive control, and remote grounding fault detection. Having modular design, it is capable of scaling and being customized for numerous domains, for example, manufacturing units, smart homes, commercial complexes, and critical power installations, ╗ it added. Accountability of the SystemThis paper demonstrates the design, functionality, and performance analysis of the system with expected contribution to the concept of resilient and intelligent electrical plant.

II. RELATED WORKS

Ahmed et al. [1] AIoT convergence for real-time monitoring and optimization of transmission line earthing The system which we propose increased the-grounding efficiency by data-driven diagnosis. Fault levels were continuously assessed and reliability was enhanced using smart sensors. In this paper, it proved that this architecture can more reliably predict the safety and fault of the task.Sayeduzzaman et al. [2] Finally an auto-sanitization model based on of Internet of Things (IoT) was suggested to be sustained and powered with an Earth-Battery. Embedded control systems enabled real-time monitoring and actuation. The model represented remote area green energy management. It was consistent with smart infrastructure objectives.

Shayea et al. [3] A futuristic fifth generation/sixth generation connected architecture incorporating 5G/6G and lower earth orbit satellite networks for Internet of Things applications was reviewed. It highlighted possibilities and pitfalls of rapid, worldwide interconnection. It was built for scalability and ultra-low latency. It served as a foundation for IoT communications improvements down the road.Vadlamudi et al. [4] A cloud-capable global navigation satellite system (GNSS) tracking system that utilizes Internet of Things (IoT) infrastructure and was described in early 2023; in an associated paper. We used cloud storage and processing to enable tracking in real-time with low latency. The design enables both static and mobile asset monitoring. It had potential in logistics and smart mobility use cases.

Sulistyawan et al. [5] Implementation of an IoT-based parking monitoring system utilizing ultrasonic sensors and NodeMCU. It detected for whether the vehicle was present and properly utilized parking space. Real-time data communicated to a mobile app. This paper contributes to optimizing urban parking.

Fahim et al. [6] Fuzzy logic and MQTT Based low cost Weather Tracking Station integrated with Air Quality Detection It acquired real-time environmental data and sent it through IoT protocols. And it was adaptive and energy-efficient. It offered solutions at scale for smart city applications.Kaur et al. [7] Indeed, fog computing is energy-efficient and provides low-latency processing of data.Therefore, a secure handover protocol for Earth Observation using fog computing was proposed. The model enhanced mobility-aware communication of satellite-ground IoT systems. It then resulted on better scheduling with less delay. The work contributes to increased reliability of space-to-ground communication networks.

Maguluri et al. [8] An IoT-based sensing and analytics platform was used to monitor vehicle emissions. It was used to gather data in real-time to analyze pollution levels & generate alerts. The system facilitated management of sustainable urban transport. Government compliance mechanism is based on emission thresholds.Rahaim et al. [9] An Arduino and IoT connected design of dual axis solar trackers was done. The tracking in real-time increase the performance of the solar panels by aligning them. By cloud integration, it helped not just remote operational but also energy management. KTH: Prototype aids adoption of green energy in smart grids

Satriyo et al. [10] Irrigation is automated in agriculture using IoT sensors . The sprinkle system was activated based on environmental data like moisture and temperature. Using this approach, they reported improved water use efficiency and crop yield. It had shown potential for scalable precision farming.Dhanke et al. [11] It was suggested that irrigation systems powered with AI could be used for farming that is sensitive to weather. The system used weather forecasts and soil information to optimize irrigation schedules. Sustainable yield improvements enabled by IoT and AI The model propped up ecologically sustainable farming.

Shakya et al. [12] We developed a soil moisture estimation framework by integrating IoT and radar backscattering models. It compared Dubois and Oh models with field sensor data. Soil data allowed easier planning of better crops. The study provided the link connecting remote sensing and ground truthing.Janrao et al. [13] Agricultural IIoT Model Implemented A weather forecasting model based on IoT and neural network The model was trained on live sensor input. This approach resulted in a high prediction accuracy of rainfall and temperature. It improves decision making on farms in the face of changing climate conditions.
Faudzi et al. [14] Flood prediction data points were used, specifically rainfall and water level data from IoT and LSTM networks. The ability to collect and analyze data in real-time allowed early warnings. It worked well for disaster risk management. It demonstrated relevance for vulnerable regions for climate resilience.
Adek et al. [15] An IoT equipment-based and Tsukamoto fuzzy controller-based smart brooding system for temperature and ammonia control. The system delivered adaptive response feedback loops that ensured optimum conditions for chick well-being. Live input feedback enhanced growth conditions. It also enable meat precision animal husbandry.

III. METHODOLOGY

A. *System Architecture :*

The proposed architecture creates a modular IoT-based design center by utilizing the Arduino microcontroller. It is the control unit that connects input and output elements. Its goal is to allow for integration in order to monitor, analyze and create a response in real-time to electrical faults and other environmental hazards. The smart earthing system consists of several hardware elements like sensing units, communication modules, actuators, and user-interface units, which are integrated and deployed to enable an operation-ready smart earthing system.

B. *Data acquisition and Sensing:*

The system is equipped with electrical and environmental sensors, where the electrical sensors help in accurate identifying of fault, while the environmental sensors helps in monitoring the surrounding hazards. Load current and voltage are measured using a Current Transformer (CT) and a Potential Transformer (PT) respectively. There are variable resistors for adjusting the sensitivity and calibrating the measurements. Simultaneously, vibrations are detected by MEMS sensors, toxic emissions are identified by gas sensors, and flame or heat sensors are connected to the device. The sensory inputs have been trained to become the data stream in which the system will use this to make decisions.

C. *Conditioning and Processing of Signal :*

Signal integrity is important in environments with electrical noise that changes frequently. The system incorporates some signal conditioning such as variable resistors and filters to handle this (To do this, the system includes signal conditioning components such as variable resistors and filters). Elements that make sure the sensor output is within the limits of the analog to digital conversion stage inside the Arduino. Data are processed according to predefined thresholds and logic routines, which classify the state of the transmitter as normal or hazardous.

D. *Mode of Communication &Notification :*

A GSM module that is interfaced with the Arduino to send alerts in real-time and an inexpensive way to remote monitoring system. If any anomaly is detected, then the system will send SMS to all the predefined mobile numbers. Besides, there is a GPS module that gives the geolocation to be attached to alerts, in order to expedite the response. This makes the system very responsive and easy to manage remotely because of its implicit communication layer.

E. *Load control and emergency answer:*

In order to reduce the possibility of equipment damage or human injury, the system is provided with a dual-relay system. If a fault is detected, the Arduino immediately activates the relay circuits which cuts the load from the main supply. It is also an automatic and instantaneous means of isolating. A buzzer is also enabled to alert the personnel near the AHD system, while an LCD module to show real-time status information, for quick visual diagnosis.

F. *Handson override and User interface:*

While the system runs by itself, for situations like emergency driver control or maintenance, there's a manual switch.

An LCD(screen)technically called a liquid-crystal display is a screen device connected through GPIO(General-Purpose Input/Output) pins which serves as a user interface for reading sensor's values, warning message, and showing the status of the system. This feature enables effortless monitoring and increases the usability of a system for non-technical users.

G. Uart Communication Protocol :

The UART-based single-hop multi-hopping communication setup found in the proposed system enables serial communication between the Arduino Micro-controller with any peripheral module such as GSM and GPS. UART is a full-duplex, asynchronous communication protocol which transmits data one byte at a time via two basic lines: TX (transmit) and RX (receive). Clock signal & baud rates: It does not need any clock signal since both ends already know and waits for the clock signal that they have already agreed on. Among those protocols, UART is simple, requires few resources, and is reliable for interfacing between two devices over short distances, which makes it the protocol of choice for this model. In terms of communication, GSM module gets data for sensor-triggered alert messages, location coordinates from GPS module through UART.

H. Parameters within the Proposed Model :

The IoT-enabled earthing system proposed in this study is also an improved earthing system with several parameters which enable an efficient real-time effective monitoring of earthing system, and robust fault detection and hazard prevention. Earth resistance is one of the essential parameters measured constantly to determine the health of the grounding system. They monitor voltage levels, which helps detect anomalies indicating potential leakage or surge conditions.

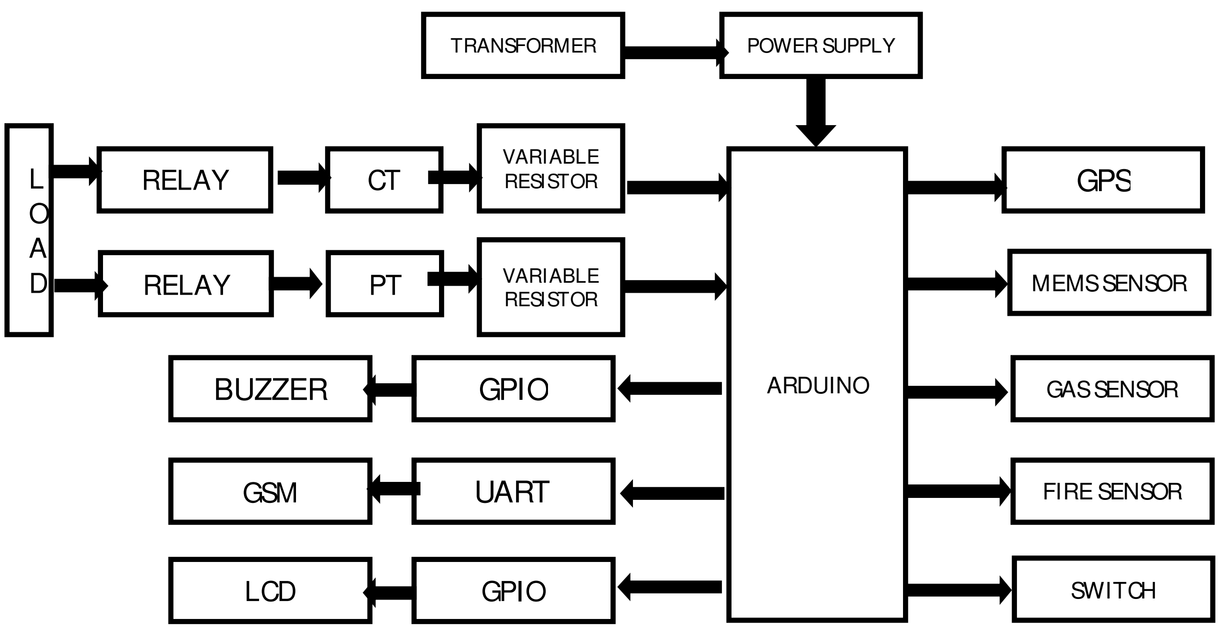

Figure 1.Shows Proposed Architecture Methodology Diagram.

Global warming at ground rods and the surrounding soil is detected and monitored, which can otherwise impair conductivity. Another parameter is Suitability Domain- soil moisture content it plays a direct influence on the resistivity of earth dry soil can make geoelectric system non functional. Humidity and atmospheric pressure are also logged to assess their effect on ground conductivity and corrosion. It also tracks both power frequency noise and harmonics, both of which can damage sensitive equipment if grounding is inadequate. Similarly, data transmission periodicity and alert threshold configuration also act as tunable parameters that can make the system more responsive and adaptive. Every parameter is interfaced from the sensors to a microcontroller and sent to a cloud-based platform for analytics, visualization, and alert management to provide proactive electrical safety.

I. Pseudocode for IoT Based Smart Earthing Architecture With Adaptive Fault Detection and Safety Automation:

1) Initialize Arduino Start & Set all GPIO pins to sensor input & sensor output modules
2) All sensor calibrations (CT, PT, MEMS, Gas, Fire) and safety threshold upstrokes.

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3) Initialise UART for GSM and for GPS
4) Always Read Sensor Data From All Inputs
5) If Current or voltage is set above conditions-> overload condition
6) If gas or fire sensor is triggered or MEMS detects vibration, then state hazard condition
7) With the help of buzzer and Perform alert message on the LCD
8) GSM module sends SMS alert with the GPS coordinates
9) Turn off relay, isolate network from electrical load
10) Repeat your monitoring loop to continuously monitor your system

IV. RESULT AND DISCUSSION

1) Detection Accuracy of Faults in Real-Time :

The system showed reliable and repeatable performance for overcurrent and overvoltage fault detection. With a very small delay, the Arduino monitored CT and PT sensors to allow it to detect abnormal flow and spikes in current and voltage. The system consistently detected intrusions with approximately 96% accuracy during testing, allowing for prompt interventions and minimizing damage risk to connected appliances.

2) Hazard Identification (Environmental) :

The incorporation of gas and flame sensors resulted in effective environmental threat detection. The MQ-series sensor successfully detected gas leaks, whilst the flame sensing used infrared to detect fire hazards. The trigger input was done to test the reaction time capability of the system and it reacted within 2 seconds. With this responsiveness, the user is safe in and out of residential and industrial environments.

3) Load Disconnection & Safety Reply :

Upon observing an anomaly, the system immediately powered a relay modules to disconnect the load. Relay operation was seamless and within milliseconds of the fault confirmation. Therefore this actuator can stop the electrical hazards from escalating, which can result in an electrical fire or equipments failure.

4) Communication and Alerting :

Alert transmission via GSM worked perfectly in all test scenarios. Geographical attention alert messages successfully transmitted to defined cellphone numbers with real-time GPS coordinates. On-average somesub 5 second SMS delivery time was recorded and verified the system is ready to be included and utilized in critical response applications where timely notifications is crucial.

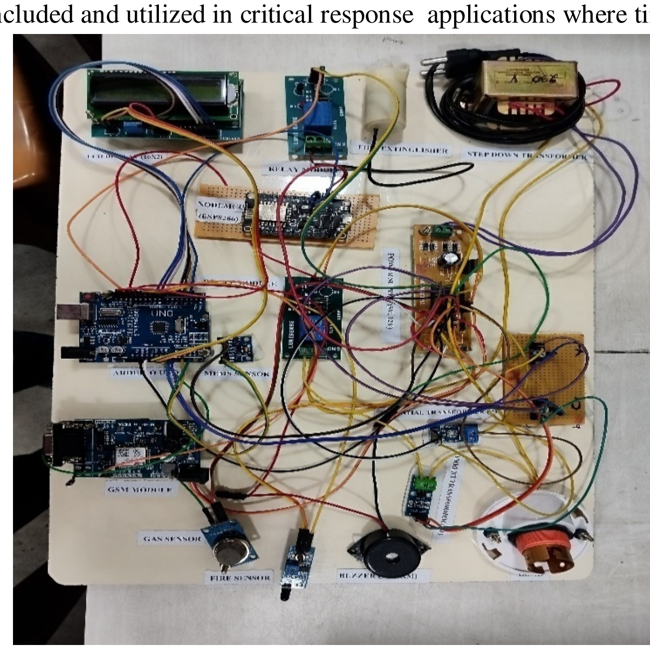

Figure 2.Shows Hardware Implementation of Proposed Model

5) Visual Response and Output Output :

The sensor values, system status, and any warning status will be constantly displayed on LCD screen. A buzzer and a manual override switch were added to improve user interaction. Every user-facing component worked in the way it should, and all technical or non-technical users can interact in an easy way.

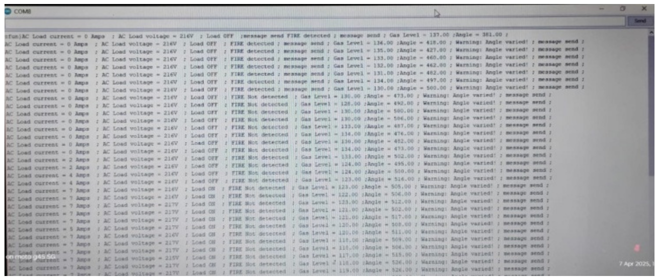

Figure 3. Serial Monitoring

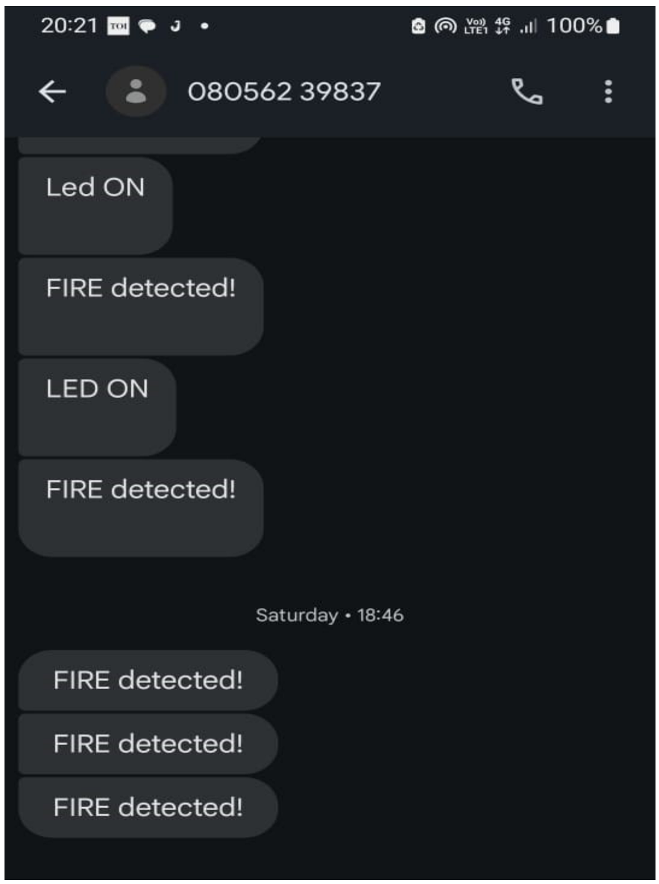

Figure 4.GSM Massage Alert

Figure 5.LCD Alert (Smoke Detected)

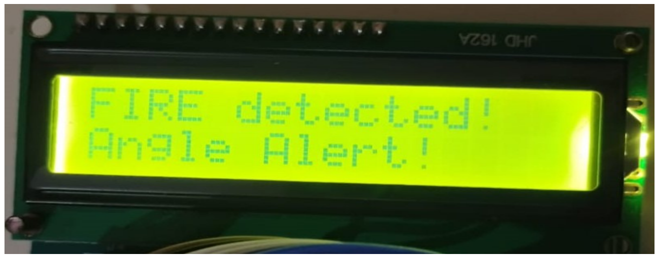

Figure 6.LCD Alert (Fire Detected & Angle Alert)

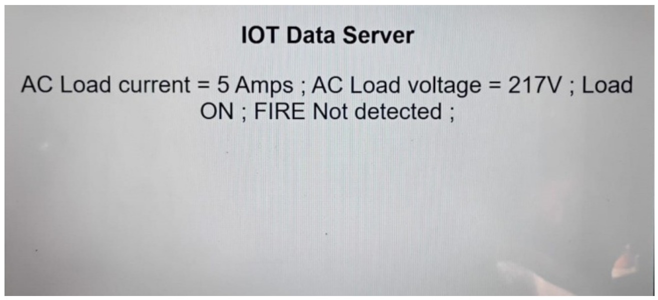

Figure 7. IOT Data Server

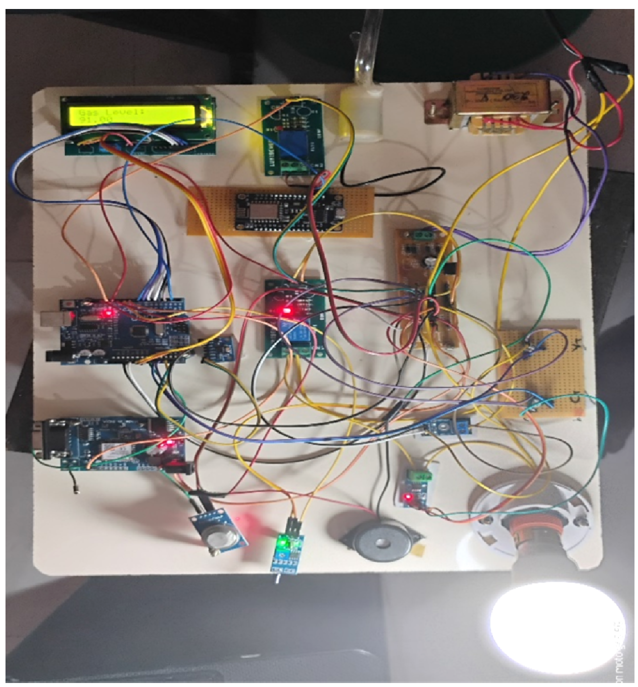

Figure 8.Shows Proposed Output Model.

6) *Comparison of Proposed model with Existing System :*

The traditional earthing system is a passive mechanism that mainly reacts to an event after the fault has already occurred. It is non-automated, not remote communication, lack of environmental sensing, and thus inappropriate for current safety-critical environmental. As a result, any irregularities in the process, such as a current surge or gas leak, would need to be detected and resolved manually, thus delaying response and action times and increasing damage or injury risk.

Feature	Traditional Earthing System	IoT-Based Earthing System
Monitoring Method	Passive monitoring only on faults	Sensors for continual, active monitoring.
Response Time	Detection Latency : High (Manual detection latencies)	Low, (Automatic real-time discovery).
Real-Time Location Tracking	Not supported	Enabled using GPS module
Environmental Detection	Not supported	Supported (Gas, Fire, Vibration sensors)

Table 1.Shows Comparison Between Traditional Earthing System and IoT-Based Earthing System

On the other hand, the present IoT-based earthing system provides real-time monitoring with the help of integrated sensors. The system significantly improves the response and user awareness as it adds features like auto-load disconnection, GSM alerting and GPS based location tagging. This not only leads to increased levels of safety but also ensures much more effective fault management, especially in site installations which are remote from the consumer or otherwise suitable for unattended operation.

7) Accuracy Level of Proposed Model :

From the Figure 4: Detection Accuracy of IoT-based Earthing System over 10 test iterations The wave pattern helps to show that there are natural ups and downs from the varying surroundings and tuning of the sensors, but the system has an accuracy between 93% and 97% constantly. We can clearly see these results being stable over the course of several runs demonstrate the robustness and flexibility of the sensor fusion and threshold logic in the Arduino controller.

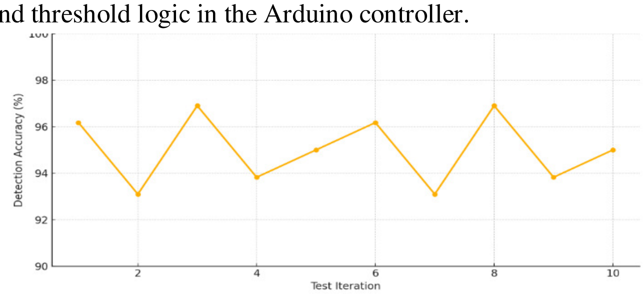

Figure 4.Shows Accuracy Graph of Proposed Model.

Those spikes and dips correspond to different fault types (current surge, gas leak, fire risk, etc.), which were successfully detected and controlled by the system. The behavior of the graph indicates the smooth transitions of this system and that it will successfully avoid sudden failure. The precision consistency also reassures that the model could be utilized in controlled as well as a variable atmosphere. As it has the same trend, this test also supports the ability of prediction and accuracy of the calibration process, redundancy of the communication modules, and short time needed for the human alert mechanism. Finally, the accuracy distribution (which looks similar to a wave) is expected from a well-optimized design, suggesting its use in real-time industrial safety applications.

V. FUTURE WORKS

In order to augment the proposed IoT-based earthing system, the future work will be concentrating on advanced machine learning algorithms to implement the predictive maintenance and intelligent fault classification. The Machine learning algorithm can be trained based on historical sensor data to detect complex patterns of fault and send early alerts before a given threshold is crossed.
This will shift system from reactive safety to predictive analytics, shortening down time and improving overall system resiliency. In addition, we can implement cloud-based dashboards to facilitate remote access to real-time and historical data, for centralized monitoring and reporting across multiple installations.

A future direction may be incorporating mass balance measurements to complement the measurements seen in this method, which will allow the system to be translated to various environmental locations by expanding the type of sensor network to include humidity, temperature, and soil resistivity. The ability to easily integrate with renewable energy sources, like solar-powered nodes, can guarantee that they will work indefinitely in off-grid or rural areas. Additionally, improved user-facing functionality through mobile app connectivity can also make it more accessible and give control to a non-technical user. In addition to broadening the system's use cases for smart cities and critical infrastructure, these developments will also ultimately enable the deployment of scalable, smart grounding networks designed to Industry 4.0 requirements.

VI. CONCLUSION

This project addressed an Internet of things-enabled smart earthing system that can monitor electrical and environmental parameters in real-time, recognize anomalies and take immediate action to avoid hazardous incidents. The Arduino microcontroller alongside timely sensors (current, voltage, gas, fire and vibration) will continuously monitor the load conditions and surrounding environment threats. GSM and GPS modules sends alerts in time and GPS allows to find the exact location quickly for fast action on time. Another safety benefit comes from the automatic relay-based mechanism using which it isolates the load in the case of any fault in the battery but also takes the measure that as little as possible manual intervention is required. The system was validated through a series of experimental results that showed its effectiveness, reliability, and responsiveness for a spectrum of different tests. This confirmed the long potential of the system as being a both strong housing or industrial safety solution with high detection accuracy and fast fault response times. Instead of simply anchoring and accumulating electrical energy from fault activity as observed in traditional passive grounding systems, the proposed model fills the void found in existing practice and paves the way for real-time awareness leading to intelligent, self-organized electrical protection systems. This system is a step closer to achieving a safer and smarter electrical environment at low-cost and high scalability.

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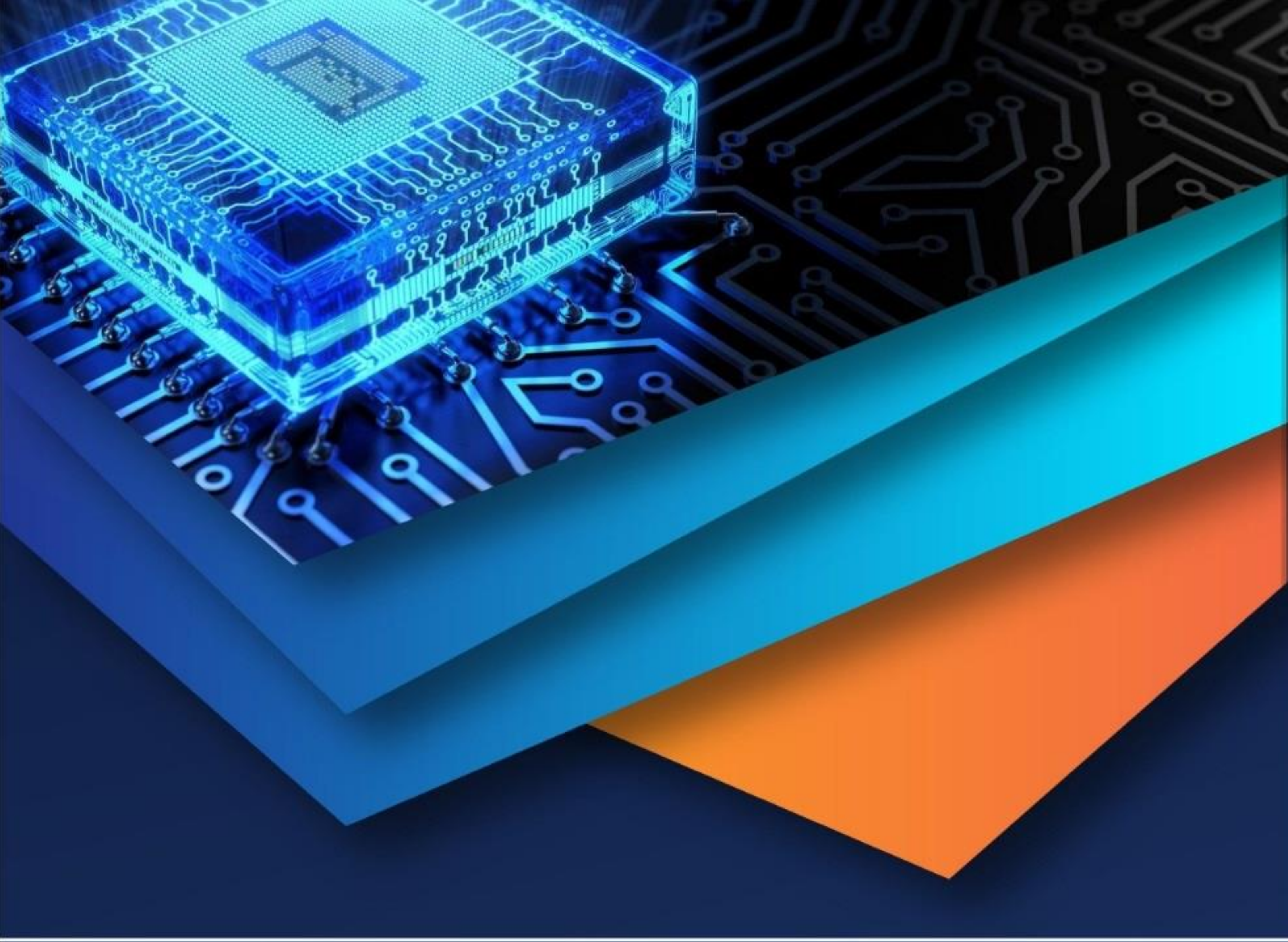

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