Smart IoT System for Detecting Current Leakage in Electric Poles and Shock Prevention

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***Abstract*—Electric poles in public spaces pose significant safety hazards due to the risk of electric shock from current leakage, often unnoticed until an accident occurs. This paper proposes an IoT-driven approach for identifying current leakage in electric poles and delivering real-time alerts to mitigate the risk of electric shocks. The system integrates voltage and current sensors with an Arduino microcontroller and an ultrasonic proximity sensor to continuously monitor conditions around electric poles. When current leakage is detected, and individuals approach within a specified proximity, the system activates a buzzer and displays a warning message. This proactive approach improves safety by minimizing the risk of electrocution in both urban and rural regions. The implementation demonstrates how IoT can enhance public safety, offering potential for scalable applications across diverse infrastructures, including smart cities and industrial zones.**

***Index Terms*—IoT, Current Leakage Detection, Electric Poles, Public Safety, Shock Prevention**

I. Introduction

Electric poles serve as essential elements of power distribution networks but pose safety risks due to potential current leakage from damaged insulation, worn-out wiring, or environmental factors like rain. Conventional methods for detecting current leakage depends on manual inspection and lack real-time alerts, leading to preventable incidents.

This paper proposes a smart IoT-based system to detect current leakage in electric poles and prevent electric shocks. The system combines current and voltage sensors with an ultrasonic proximity sensor to dynamically detect hazardous situations and provide immediate alerts. By enhancing real-time responsiveness and incorporating proximity detection, this system offers a comprehensive solution to minimize the risk of electric shock around electric poles in both urban and rural areas.

Current solutions primarily focus on manual inspections or basic detection methods without immediate safety measures. While some IoT-based systems monitor electric infrastructure, most do not integrate real-time hazard alerts or proximity detection. Therefore, there is a significant gap in developing a robust, real-time safety solution that detects both current leakage and hazardous voltage levels and determines if someone is near a dangerous electric pole.

This report proposes a comprehensive solution to mitigate the risk of current shock due to current leakage in electric poles. Our system uses an IoT-based approach that combines current and voltage detection with proximity sensing to trigger alerts when hazardous conditions are present. Through the use of an Arduino microcontroller, ultrasonic sensors, and a voltage threshold-based alert mechanism, the system provides a reliable and efficient way to monitor electric poles. The integration of a fail-safe design ensures that only genuine hazards activate the alert system, reducing false alarms and increasing safety for nearby individuals. This work aims to improve the safety of electrical infrastructure, preventing shocks and potential fatalities caused by undetected current leakage.

II. Literature Review

A. Electrocution Prevention Using IoT

Jayanth Reddy et al. [1] propose an IoT-based system to enhance electrical safety by detecting and alerting users to potential electrical hazards in real-time. This system is valuable for both residential and industrial environments. It includes monitoring key electrical parameters with sensors, using a microcontroller for data processing, and establishing cloud connectivity and mobile notifications for immediate user alerts. The results demonstrate the system's effectiveness in anomaly detection, potentially reducing electrocution risks through real-time monitoring. However, challenges such as reliance on continuous power, cybersecurity risks, and setup costs are noted. The study highlights IoT's role in advancing electrical safety despite these limitations.

B. IoT-Based Electric Pole Safety System

Jadhav and More [2] address the urgent issue of electrocution accidents caused by faulty electric poles. They present an IoT solution that uses sensors and a microcontroller to monitor and detect faults, notifying authorities and disconnecting power automatically to prevent accidents. The system includes real-time fault detection and automated notifications via an LCD display and a voice module for local alerts. Hardware components such as the ATmega328 microcontroller, voltage and current sensors, and NodeMCU (ESP8266) enable fault detection and communication. While results show improved safety and rapid response, the system requires stable internet, skilled technicians for installation, and environmental adjustments for sensor accuracy. Future developments may incorporate biometric security and mobile applications for expanded functionality.

C. IoT-Grounded SLT (Smart Line Transmission) Pole with Electrical Lineman Safety

H. R. and K. N. [3] address the issue of electrical accidents from broken power lines by introducing an IoT-based system that detects line breaks and alerts authorities while also preventing unauthorized access. The system uses RF transceivers to monitor line integrity, providing automatic alerts through SMS notifications with GPS location when faults occur. Additionally, a password-protected circuit breaker allows only authorized personnel to manage power lines. Key components include an Arduino microcontroller, RF transceivers, GPS and GSM modules, a relay, and a keypad. This solution enhances public and lineman safety, though it requires reliable wireless connectivity and skilled technicians for installation. Future improvements may involve mobile applications and biometric security.

D. Integrated Leakage Current Detection and Alert System for Electric Meters

Cheng et al. [4] introduce a new power converter design tailored for renewable energy systems to improve efficiency and reliability. Traditional converters often lose energy due to fluctuating energy inputs, so the authors propose a system that uses advanced control techniques, such as model predictive control, for optimal real-time energy management. The system includes power semiconductors, microcontrollers, batteries, and sensors, tested through simulations and experiments. Results indicate a significant efficiency boost over conventional designs, making it suitable for renewable applications, though it adds complexity and cost. Overall, the study offers a promising approach to enhance energy conversion in renewable technologies.

E. Safety Measures and First Aid Protocols for Electric Vehicles

Hao and Yang [5] address the risk of electric shock in electric vehicles (EVs), which operate at high voltages between 200-600V, posing safety concerns. The authors propose a comprehensive safety framework that includes both direct and indirect protection strategies, emphasizing preventive measures and first aid protocols. Key techniques include remote monitoring platforms for safety tracking, insulation fault monitoring, and high-voltage training for maintenance personnel. Results highlight the need for these measures and proper training to minimize risks. While enhancing safety, these strategies may add complexity and costs. Overall, the paper underscores essential safety protocols to prevent electric shocks in EVs.

F. Introduction to Electric Shock Protection

Qiu and Lu [6] explore electric shock hazards in electrical installations and examine protection systems primarily based on UK regulations but adaptable worldwide. They identify electric shock as a serious safety concern, often occurring when the human body becomes part of an electrical circuit. Key protection mechanisms discussed include earthing, equipotential bonding, and Residual Current Devices (RCDs), which disconnect the power in fault conditions. The study provides a descriptive analysis of factors affecting electric shock severity, such as current and duration, and outlines various earthing systems (e.g., TN, TT). Although focused on UK standards, the paper emphasizes the global importance of timely disconnection (within 0.4 seconds) to reduce risks, with RCDs recommended when other measures may be insufficient.

G. Ultrasonic Distance Measurement for Automotive Use

Abubakar et al. [7] introduce a low-cost ultrasonic sensor designed to measure vehicle height from the ground, supporting automotive applications like parking assistance and headlight leveling. Using a 40 kHz piezoelectric transducer, it calculates distance via time-of-flight measurements, adjusting for noise and temperature variations to improve accuracy. The system features constrained optimization for precise echo detection, automatic gain control, and temperature compensation, achieving a 1 mm accuracy within speeds up to 30 m/s. Tests show it performs well under moderate noise and temperature ranges, though accuracy declines in high-speed or extreme temperature conditions. This sensor offers an affordable, adaptable solution for vehicle height measurement, with potential limitations in extreme settings.

H. Analysis of Ultrasonic Distance Measurement Techniques and Their Challenges

Qiu and Lu [8] analyze various ultrasonic ranging methods, highlighting their wide-ranging applications in fields such as automotive, industrial automation, and healthcare. While ultrasonic sensors are effective for accurate distance measurement, they face challenges like environmental noise, multipath interference, and temperature sensitivity. The authors review different sensing techniques, including time-of-flight, phase shift, and frequency modulation, as well as improvements like noise-canceling and adaptive filtering to enhance accuracy. Despite advancements, issues with long-range accuracy and robustness remain, prompting a call for further research in algorithm refinement and sensor fusion (e.g., with radar or LiDAR). The paper underscores the adaptability of ultrasonic sensors but notes limitations in noisy or extreme environments, suggesting that sensor fusion and advanced processing may boost future performance.

I. Enhancing ZMPT101B Voltage Sensor Accuracy with Polynomial Regression for Load Monitoring

Abubakar et al. [9] focus on improving the accuracy of the ZMPT101B voltage sensor, commonly used for AC voltage measurement in smart meters and load monitoring. The researchers employed polynomial regression, specifically using a third-order polynomial, to calibrate the sensor and reduce errors in voltage readings. By correlating the sensor's ADC output with the actual input voltage, the method significantly improved measurement accuracy, reducing errors to less than 1

This literature review provides a comprehensive overview of existing research and solutions related to electric shock prevention, IoT-based safety systems, and sensor technologies. It highlights the advancements, challenges, and future directions in these areas, setting the stage for the proposed IoT-based system for detecting current leakage in electric poles.

III. METHODOLOGY

The methodology outlines the design and operation of the IoT-based current leakage detection system, detailing how the components work together to identify and respond to hazardous conditions.

A. System Architecture

The system comprises three main modules:

1) **Sensing Module**: Voltage and current sensors detect electrical activity around the pole. If the measured voltage exceeds a set safety threshold, the system flags it as hazardous. For the prototype, a voltage sensor module is used, but in real applications, a device capable of handling large currents is required.
2) **Proximity Detection Module**: An ultrasonic sensor continuously monitors the distance of nearby individuals. When someone approaches within a critical range, it triggers the alert system.
3) **Alerting Module**: A buzzer and LCD display issue audible and visual alerts when both voltage and proximity thresholds are breached, warning nearby individuals of the hazard.

B. Operational Workflow

The workflow of the system is as follows:

1) **Voltage and Current Detection**: The sensors measure voltage and current levels around the pole, with data sent to the Arduino microcontroller for real-time analysis.
2) **Threshold Comparison**: The Arduino evaluates whether the detected voltage surpasses a predefined threshold, indicating potential leakage.

$$V_{\text{detected}} > V_{\text{threshold}}$$

3) **Distance Calculation**: The distance is calculated using the speed of sound and the time it takes for an ultrasonic pulse to travel to an object and return. The formula used is
$$d = \frac{v \cdot t}{2}$$
where d represents the distance,, v is the speed of sound in air (approximately 343 m/s), and t is the total time for the pulse to make the round trip to the object and back.
4) **Alert Activation**: The buzzer sounds and the LCD displays a warning only when both voltage and distance exceed safe limits, ensuring alerts are issued only under genuine risk conditions.

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C. Fail-Safe Mechanism

The system incorporates a fail-safe feature, where the alert is activated only if both the voltage threshold and proximity conditions are met. This design prevents false alarms and ensures that the system responds reliably to actual hazards.

D. Proposed System

The proposed system is designed to detect current leakage in electric poles (represented practically in our model by a conductor) and activate an alert system only when both current leakage and high voltage levels are detected. The system functions as follows:

1) **Current and Voltage Detection**:
   - A wire is wrapped around the circumference of the conductor (pole).
   - This wire is connected to a voltmeter, which detects the voltage across the conductor.
   - The sensed voltage values are transmitted to an Arduino for processing.
2) **Threshold-Based Safety Mechanism**:
   - The Arduino continuously monitors the voltage values detected from the conductor.

- If the current is detected and the detected voltage exceeds the predefined threshold, it indicates potential current leakage.
- Only when both conditions are met, the system activates the alert mechanism.

3) **Alert System**:
   - **Ultrasonic Sensor**: Detects if anyone is approaching the conductor, ensuring the alert system is relevant only when a person is nearby.
   - **Buzzer**: Activated to warn nearby individuals about the danger when current leakage is detected and voltage surpasses the threshold.
   - **LCD Display**: Shows a warning message indicating it is unsafe to approach the pole.
4) **Fail-Safe Design**:
   - If voltage does not exceed the threshold, the alert system remains inactive, preventing false alarms and ensuring alerts are only triggered under hazardous conditions.

E. Flowchart of Entire Process

The flowchart represents a step-by-step methodology for a system that monitors voltage and distance, triggers alerts, and activates a buzzer based on threshold conditions. Here's a detailed breakdown:

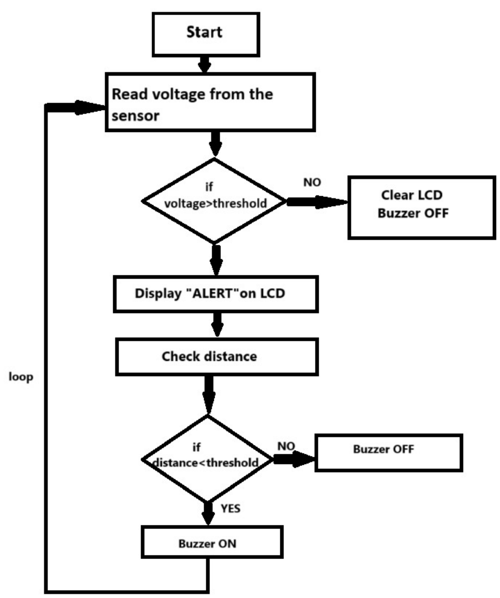

Fig. 1. Flowchart of the entire process

1) **Start**: The process begins.
2) **Measure voltage from the sensor**: The system measures the voltage value from a connected sensor..
3) **Check if voltage is greater than threshold**:
   - If the voltage is greater than a predefined threshold:
     - **YES**: Continue to the next step.
     - **NO**: Skip to ”Clear LCD, Buzzer OFF.”
4) **Display ”ALERT” on LCD**: If the voltage exceeds the threshold, the system displays an ”ALERT” message on an LCD screen.
5) **Measure distance**: The system then measures the distance value from another sensor (e.g., an ultrasonic sensor).
6) **Check if distance is lesser than threshold**:
   - If the distance falls below a certain threshold:
     - **YES**: The buzzer is turned ON, alerting about the proximity issue.
     - **NO**: The buzzer remains OFF.
7) **Loop**: The process goes back to the beginning to continuously monitor voltage and distance.
8) **Clear LCD, Buzzer OFF**: If the voltage is below the threshold, the system clears the LCD screen and turns off the buzzer.

This methodology is intended to provide real-time alerts based on specific voltage and distance conditions, ensuring a quick response when necessary.

F. Circuit Diagram

The circuit consists of an Arduino Uno connected to a voltage sensor, ultrasonic sensor, buzzer, and LCD display. The voltage sensor detects potential leakage, while the ultrasonic sensor ensures activation of the alert system only when a person is nearby. The Arduino processes the data and triggers the buzzer and LCD alert if both current leakage and high voltage are detected.

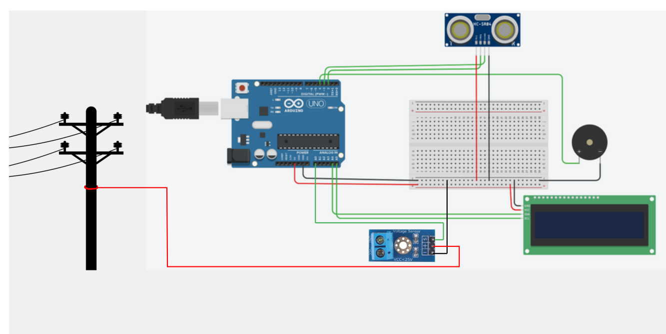

Fig. 2. Circuit diagram of the proposed IoT-based current leakage detection system.

G. Software and Hardware Requirements

Software Requirements

- **Arduino IDE**: An open-source software platform used for programming and uploading code to Arduino boards. It provides a user-friendly interface for writing, compiling, and debugging code, and supports code uploading via USB.
- **LiquidCrystal Library**: A library for controlling LCD displays with Arduino

Hardware Requirements

- **Arduino Uno**: A microcontroller board for reading inputs from sensors and controlling outputs like LEDs, motors, or displays.
- **Buzzer**: An audio signaling device used for providing alerts.
- **LCD I2C**: A Liquid Crystal Display module using I2C communication for displaying data with a two-wire interface.
- **Breadboard**: A tool for prototyping electronic circuits without soldering.
- **Ultrasonic Sensor**: Determines the distance to objects by emitting sound waves and timing how long it takes for the echo to return.
- **LED**: Light Emitting Diodes used to indicate status or display visual feedback.
- **Jumper Wires**: Flexible wires with pin connectors used to link components on a breadboard or connect them to an Arduino.
- **USB Cable**: Used for connecting the Arduino board to a computer for code uploading and power.
- **Voltage Sensor Module**: Measures the voltage of connected circuits, ideal for monitoring battery levels or external power supplies.

IV. Results and Discussion

A. Results

The Smart IoT System for Detecting Current Leakage in Electric Poles was implemented and tested successfully, showcasing its potential to enhance public safety. The results are summarized as follows:

1) **Real-Time Monitoring**: The system effectively monitored voltage and current leakage in electric poles, ensuring prompt identification of hazardous conditions.
2) **Threshold-Based Activation**: The alert mechanism was triggered only when both high voltage and current leakage were detected, reducing false positives and ensuring reliability.
3) **Proximity Detection**: The ultrasonic sensor successfully detected nearby individuals, ensuring the system activated alerts only when proximity posed an additional risk.
4) **Effective Alerts**: Clear audio-visual warnings (buzzer and LCD messages) were delivered promptly, effectively notifying individuals of potential hazards.
5) **Fail-Safe Operation**: The system's design ensured alerts remained inactive under safe conditions, optimizing its reliability.

B. Discussion

The system demonstrates a practical solution to addressing electrical hazards in urban and rural infrastructure. Its integration of real-time monitoring and automated alerts represents a significant step toward enhancing public safety in areas prone to current leakage.

The hardware components, including Arduino, voltage sensors, and ultrasonic sensors, were cost-effective and easy to deploy. However, environmental factors, such as moisture or temperature fluctuations, could potentially impact the accuracy of detection. Additionally, reliable power and connectivity remain critical for continuous operation, particularly in remote regions.

Future Enhancements:

- **Enhanced Voltage Sensor Module**: In real-world applications, the voltage sensor module should be designed to handle and detect large currents without damage, ensuring durability and reliability.
- **Automated Notifications**: Implementing a feature to directly send notifications to the electric department about current leakage or hazardous conditions around the pole, enabling quicker response times and improved safety.
- **Environmental Resilience**: Improving the system's resilience to environmental factors such as moisture and temperature fluctuations to maintain accuracy and reliability in various conditions.

V. Conclusion

The Smart IoT System for Detecting Current Leakage in Electric Poles has proven to be an effective solution for enhancing public safety by providing real-time monitoring and alerts for hazardous conditions. The integration of voltage and current sensors with proximity detection ensures that alerts are only triggered under genuine risk conditions, reducing false positives and improving reliability.

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