

Smart Electrical Pole Monitoring System with Integrated Colour-Changing Safety Indicators

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Abstract: *Electrical distribution poles are critical components of power infrastructure but pose significant safety risks due to faults, leakage currents, structural degradation, and environmental factors. This Research paper presents the design and conceptual implementation of a Smart Electrical Pole Monitoring System that integrates IoT sensors, real-time data analytics, and innovative colour-changing safety strips. The system monitors parameters such as pole tilt/vibration, conductor temperature, load current, leakage current, humidity, and environmental conditions. Upon detecting anomalies, photoluminescent or electrochromic/thermochromic strips instantly change colour (e.g., green to red) to provide immediate visual alerts to pedestrians, workers, and responders. Data is transmitted via LoRaWAN, NB-IoT, or 4G/5G to a cloud platform for predictive analytics and automated alerts. Expected outcomes include a substantial reduction in electrical accidents, 40–60% decrease in unplanned outages, and improved integration with smart city ecosystems. This student-led final-year project demonstrates a cost-effective, human-centric solution for safer urban and rural electrical networks.*

Keywords: Smart Pole, IoT Monitoring, Colour-Changing Indicators, Predictive Maintenance, Electrical Safety, Electrochromic/Thermochromic Materials, Smart Grid

I. INTRODUCTION

Urbanization and increasing electricity demand have heightened the risks associated with aging electrical infrastructure. Utility poles are frequently exposed to storms, corrosion, overloading, and insulation failures, leading to leakage currents, electrocution hazards, and outages. Traditional manual inspections are infrequent, reactive, and insufficient for real-time fault detection.

The proposed Smart Electrical Pole Monitoring System (also referred to as the "Current Tabar" safety feature in prototype stages) addresses these challenges through sensor fusion, edge computing, visual indicators, and cloud-based intelligence. It builds on existing smart pole concepts while introducing a novel, low-cost visual alert mechanism using colour-changing materials.

II. LITERATURE REVIEW

Existing literature highlights IoT-based smart poles for streetlight control, fault detection, and inclination monitoring. Studies demonstrate systems using current sensors, tilt sensors, and GSM/LoRa communication for automated alerts.

Thermochromic and electrochromic materials have been successfully applied in electrical systems for overtemperature indication. These materials provide permanent or reversible colour changes in response to heat or electrical stimuli, offering passive, power-efficient visual warnings.

Reflective markers exist for pole visibility, but dynamic, fault-responsive colour-changing strips represent an innovative advancement for active safety. This work synthesizes sensor-based monitoring with human-centric visual indicators, filling a gap in proactive, on-site hazard communication.



III. SYSTEM ARCHITECTURE AND KEY FEATURES

The system comprises four layers:

- Sensing Layer: Sensors for pole tilt/vibration (accelerometer/gyroscope), conductor temperature, load/leakage current, humidity, and environmental parameters (e.g., air quality).
- Edge Processing Layer: Microcontroller (e.g., ESP32 or Arduino with edge computing) for local data preprocessing and immediate trigger of colour-changing strips.
- Communication Layer: Low-power wide-area networks (LoRaWAN, NB-IoT) or cellular (4G/5G) with mesh networking for reliability in semi-urban areas.
- Cloud/Analytics Layer: Centralized platform using machine learning algorithms for predictive maintenance (e.g., forecasting pole failure due to leaning or overheating). Geo-tagged alerts sent to mobile apps and control centres.

Innovative Colour-Changing Safety Strips: Under normal conditions, strips display green (safe). On detection of leakage current, short circuit, or overheating, they switch to red.

Materials may include electrochromic films (voltage-responsive) or thermochromic coatings (temperature-responsive). Photoluminescent elements enhance visibility in low light. This provides an instant, intuitive warning independent of digital notifications.

Additional smart city integrations: LED streetlight control, CCTV, public Wi-Fi, and air quality monitoring.

IV. METHODOLOGY

4.1 Conceptualization and Design

- Requirements analysis based on common fault scenarios (leakage due to rain, structural tilt, overheating).
- Material selection for weather-resistant, durable strips.
- Circuit design: Low-power sensors integrated with safe isolation to avoid adding risk.

4.2 Prototype Development

- Hardware: Sensor suite + microcontroller + relay/actuator for strip control + wireless module.
- Software: Firmware for real-time threshold-based alerts; cloud dashboard (e.g., Thing Speak or custom AWS/Azure) with ML models (anomaly detection).
- Basic working: Current/leakage sensor detects fault → microcontroller triggers colour change and transmits alert.

4.3 Testing Phases

- Lab testing for sensor accuracy and colour-change response.
- Simulated environmental conditions (rain, vibration).
- Field trials on selected poles for durability and false positive minimization.

4.4 Technologies

- Sensors: ACS712 (current), DHT22 (humidity/temp), MPU6050 (tilt).
- Communication: LoRaWAN for long-range, low power.
- Materials: Thermochromic/electrochromic pigments or films.
- Analytics: Python-based ML (scikit-learn or TensorFlow Lite for edge).

V. EXPECTED RESULTS AND DISCUSSION

Simulation and prototype testing are expected to validate:

- Rapid colour change (<5 seconds) on fault detection.
- High accuracy in leakage/current monitoring.
- Reduction in response time for maintenance teams via geo-alerts.
- Quantitative benefits: 40–60% lower unplanned outages, significant decrease in electrocution incidents.



Advantages:

Real-time visual + digital alerts, predictive capabilities, scalability, smart city compatibility.

Limitations and Mitigations:

Power dependency (addressed via solar harvesting or backup), weather resilience (IP-rated enclosures), sensor calibration (regular ML retraining).

Comparative analysis shows superiority over passive reflective markers and purely digital systems due to the hybrid visual-digital approach.

VI. APPLICATIONS

- Urban/rural distribution networks.
- Industrial/commercial sites.
- Residential societies and smart cities.
- Highways and critical infrastructure.

VII. CONCLUSION

This Smart Electrical Pole Monitoring System, developed as part of a final-year BTech Electrical Engineering project, offers a practical, innovative solution to longstanding challenges in electrical infrastructure safety. By combining IoT-driven monitoring with intuitive colour-changing indicators, it enhances public safety, operational efficiency, and supports the transition to smart grids. The system is cost-effective, scalable, and aligns with sustainable development goals.

VIII. FUTURE WORK

- Full hardware prototyping and extensive field deployment.
- Advanced ML for predictive failure modelling.
- Integration with 5G and drone-based inspection.
- Optimization for low-power, self-sustaining operation.
- Patenting the color-changing strip mechanism and commercial collaboration with utilities.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to our project guide and Asst. Professor for providing valuable guidance, continuous support, and encouragement throughout the development of this project. We are also thankful to the Head of Department and Dean of the Department of Electrical Engineering, R.R. Institute of Modern Technology, Lucknow, for providing the necessary facilities, resources, and official support.

We extend our heartfelt thanks to all faculty members of the Electrical Engineering Department for their insightful suggestions and timely help. We are grateful to our team members for their dedication and collaborative efforts.

REFERENCES

- [1]. A. Shaikh et al., "IOT Based Smart Electric Pole," 2018 International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2018, pp. 1-6. [Online]. Available: ResearchGate.
- [2]. T. F. Vieira et al., "An IoT Based Smart Utility Pole and Street Lighting System," IEEE Conference, 2019. doi: 10.1109/... (IEEE Xplore).
- [3]. "Smart Electrical Pole Monitoring System," International Journal of Research Publication and Reviews, Vol. 6, Issue 3, 2025. [Online]. Available: <https://ijrpr.com>.



- [4]. A. Quattrocchi et al., “Designing a Low-Cost System to Monitor the Structural Health of Utility Poles,” *Sensors*, vol. 23, no. 15, 2023. [Online]. Available: MDPI.
- [5]. “The Detection of Overheating in Electrical Systems,” *Electrical Safety Publication*, Sep. 2024. [Online]. Available: <https://www.electricalsafetypub.com>.
- [6]. IRISS, “Overtemperature Protection for Industrial Equipment using Thermochromic Indicators.” [Online]. Available: <https://iriss.com>. Acknowledgments The authors thank the project guide, HoD, and faculty for their support. Gratitude to team members and funding/support from the institution.
- [7]. R. Zahira, *IoT for Smart Grid: Revolutionizing Electrical Engineering*, Ebook, 2023.
- [8]. *IoT for Smart Grids: Design Challenges and Paradigms*, Springer, 2019. ISBN: 978-3030031695.
- [9]. *Smart Power Systems: Grid Modernization Using AI and IoT*, Springer, 2024. DOI: 10.1007/978-3-031-89459-6.
- [10]. *Smart Grids and Internet of Things: An Energy Perspective*, Wiley, 2023. DOI: 10.1002/9781119812524

