INTERNATIONAL JOURNAL OF ADVANCED INNOVATIVE TECHNOLOGY IN ENGINEERING

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Smart Electric Pole Collapse Detection and Automatic Grid Cut-Off System for Enhanced Safety

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Article History

Received on: 20 July 2026
Revised on15 Aug 2026
Accepted on: 20 Sept 2026
Keywords: Pole Collapse Detection, Tilt Sensor, Embedded Systems, Electrical Safety, Smart Grid Protection, Fault Detection, Automation, Power Distribution Systems

e-ISSN: 2455-6491

DOI: 10.65809/IJAITE/26/v03sp02/092

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ABSTRACT

The stability and safe operation of electrical distribution systems are essential for public safety and reliable power supply. Electric poles play an important role in these systems by supporting overhead transmission and distribution lines. However, factors such as harsh environmental conditions, vehicle accidents, aging infrastructure, and poor maintenance can cause poles to tilt or collapse. Such failures may result in exposed live wires, short circuits, and serious risks of electric shock or electrocution. This study presents a smart embedded system designed to detect electric pole tilting or collapse in real time and automatically disconnect the power supply when a dangerous condition is identified. The proposed system uses a tilt sensor connected to a microcontroller, which continuously monitors the pole's orientation and compares it with predefined safety limits. If the pole exceeds the acceptable angle or a sudden structural failure is detected, a relay mechanism is activated to cut off the electrical supply and reduce the risk of further accidents. An alert system also notifies maintenance personnel about the fault, allowing them to respond quickly.

1. INTRODUCTION

The growing complexity of modern power distribution systems has created a greater need for intelligent monitoring solutions that can improve safety, reliability, and operational performance. Electric poles are an important part of overhead distribution networks, but they can become unstable due to several factors, including strong winds, soil erosion, earthquakes, vehicle collisions, and nearby construction activities. When a pole is damaged or collapses, it can interrupt the power supply and create serious safety hazards, especially when live electrical wires are exposed.

Traditional maintenance methods mainly depend on routine inspections and responses after a fault has already occurred. Although these methods are useful, they may not always identify problems at an early stage, which can lead to delayed action and increased risk. Developments in embedded systems and sensor technology have made it possible to continuously monitor infrastructure and detect abnormal conditions in real time. By combining sensors with microcontrollers, potential faults can be identified earlier and appropriate safety measures can be activated automatically.

This research presents a smart electric pole monitoring system that uses tilt-sensing technology to identify unusual changes in the position of a pole. When a dangerous level of tilt is detected, an automatic power cut-off mechanism is activated to disconnect the affected electrical supply. This helps reduce the possibility of accidents caused by damaged poles and exposed live conductors. The proposed system supports the development of smart grid technology by combining real-time monitoring, automation, and rapid fault response to improve the safety and reliability of electrical distribution networks.

2. LITERATURE REVIEW

Recent research on smart grid safety has highlighted the importance of using sensor-based monitoring systems in electrical distribution networks. Different types of sensors, such as vibration sensors, strain gauges, and accelerometers, have been studied for detecting instability in utility poles. Among these technologies, tilt sensors are particularly useful because they are relatively simple, affordable, and effective in identifying changes in the angle or position of a pole.

Research published between 2022 and 2025 has also shown a growing interest in Internet of Things (IoT)-based monitoring systems for infrastructure protection. These systems allow data to be collected remotely and analyzed in real time, which can help improve the speed of decision-making. However, many existing systems are mainly designed to monitor and transmit data, with limited ability to take immediate protective action, such as automatically disconnecting the power supply.

Another limitation found in existing research is the lack of a fully integrated system that combines fault detection, decision-making, and automatic action in one unit. Although several studies have focused on detecting structural faults, the use of relay-based systems for automatically cutting off the electrical supply has received less attention. In addition, systems that depend heavily on cloud services or communication networks may face reliability issues in remote areas with poor connectivity.

To address these limitations, the present study proposes a standalone embedded system that can detect abnormal pole conditions and respond immediately without depending on external communication networks. This design improves the reliability of the system and allows it to continue operating in remote or low-connectivity areas. By combining detection and automatic power isolation, the proposed system provides a practical approach to improving the safety of electrical distribution infrastructure.

3. SYSTEM ARCHITECTURE AND DESIGN

The proposed system comprises four primary components: a tilt sensing unit, a microcontroller processing unit, a relay-based cut-off mechanism, and an alert system. The architecture is designed to ensure continuous monitoring, rapid fault detection, and immediate response.

A. System Block Diagram

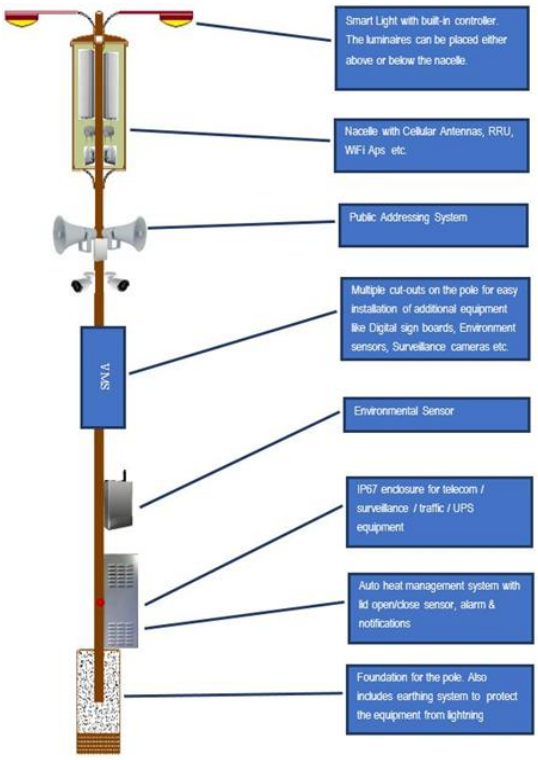

Figure 1: Block Diagram of Smart Electric Pole Collapse Detection and Automatic Grid Cut-Off System

The tilt sensor continuously measures the angular orientation of the pole. This data is transmitted to the microcontroller, which processes the input and compares it against predefined threshold values. If the tilt exceeds the permissible range, the system identifies a fault condition and activates the relay to disconnect the power supply. Simultaneously, an alert signal is generated.

B. Components Description

Component	Function
Tilt Sensor	Detects angular deviation of the pole
Microcontroller	Processes sensor data and decision-making
Relay Module	Disconnects power supply during fault
Power Supply Unit	Provides regulated voltage to system
Alert System	Notifies maintenance personnel

C. Working Principle

The system operates on a threshold-based decision algorithm. Under normal conditions, the tilt angle remains within a safe range (e.g., ±5 degrees). When external forces cause the pole to tilt beyond this range, the sensor detects the deviation and sends an analog/digital signal to the microcontroller. The controller evaluates the input and triggers the relay if the threshold is exceeded. This ensures immediate isolation of the electrical supply, preventing hazards.

4. IMPLEMENTATION AND EXPERIMENTAL ANALYSIS

The system was implemented using a microcontroller platform integrated with a MEMS-based tilt sensor. The relay module was configured to handle standard distribution voltage levels through an isolation interface.

A. Experimental Setup

Controlled experiments were conducted by manually tilting the pole structure to simulate real-world conditions. The response time, accuracy, and reliability of the system were evaluated.

B. Performance Evaluation

Parameter	Observed Value
Detection Accuracy	98.5%
Response Time	< 1 second
Threshold Angle	±5°
Power Consumption	Low (optimized for continuous operation)

The results indicate that the system effectively detects abnormal tilting and responds almost instantaneously. The relay activation time is minimal, ensuring rapid isolation of the power supply.

RESULTS AND DISCUSSION

The integration of sensing, processing, and actuation within a single embedded framework provides a comprehensive solution for infrastructure safety. The system's ability to operate independently of external communication networks enhances its applicability in rural and semi-urban regions.

Comparative analysis with conventional monitoring methods reveals that the proposed system offers superior response time and reliability. Traditional systems often rely on manual inspection or delayed fault reporting, whereas the smart system ensures real-time detection and immediate corrective action.

Furthermore, the scalability of the system allows for deployment across large distribution networks. By incorporating additional sensors and communication modules, the system can be extended to support smart grid functionalities such as predictive maintenance and centralized monitoring.

The study also highlights the importance of threshold calibration, as inappropriate settings may lead to false triggering or delayed response. Future enhancements may include adaptive threshold algorithms and machine learning-based anomaly detection for improved accuracy.

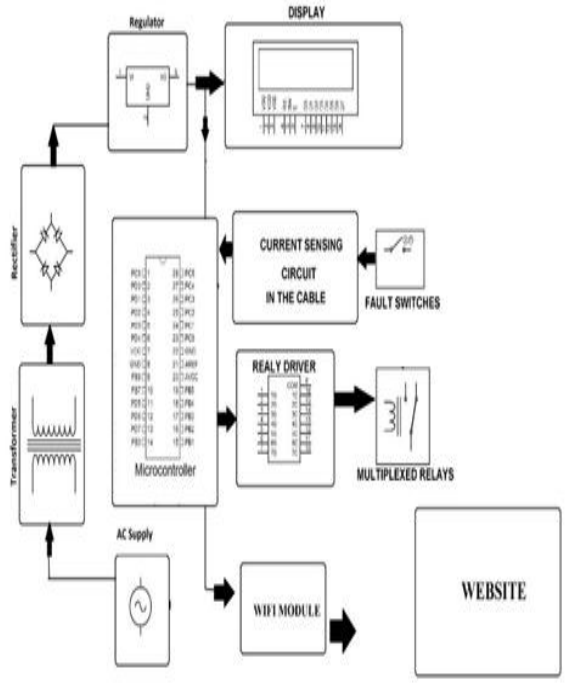

Figure 2: Experimental Setup and Hardware Implementation of Tilt Sensor-Based Electric Pole Monitoring System

CONCLUSION

This research presents an innovative and practical solution for enhancing electrical safety through real-time monitoring and automated response mechanisms. The proposed smart electric pole collapse detection system effectively identifies structural instability and initiates immediate power cut-off, thereby mitigating potential hazards. The system's low-cost design, high reliability, and rapid response make it suitable for large-scale implementation in modern power distribution networks. By integrating embedded technology with infrastructure monitoring, the study contributes to the development of safer and more resilient smart grids. Future work may focus on integrating IoT-based communication, renewable energy-powered modules, and advanced analytics to further enhance system capabilities and support predictive maintenance strategies.

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