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IOT-BASED OVERHEAD POWER LINE MONITORING AND COMMUNICATION USING LORA TECHNOLOGY

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Abstract
The increasing demand for reliable and efficient power transmission systems has highlighted the need for continuous monitoring of overhead power lines. Conventional inspection methods are often labor-intensive, time-consuming, and incapable of providing real-time fault detection. This paper presents an Internet of Things (IoT)-based overhead power line monitoring and communication system utilizing Long Range (LoRa) technology for efficient data transmission over extended distances. The proposed system integrates various sensors to monitor critical parameters such as conductor temperature, current, voltage, line sag, and environmental conditions. Sensor data are collected through IoT-enabled nodes and transmitted to a centralized monitoring station using LoRa communication, which offers low power consumption, long communication range, and cost-effective deployment. The collected data are analyzed in real time to identify abnormal operating conditions and potential faults, enabling predictive maintenance and reducing system downtime. The proposed architecture enhances the reliability, safety, and operational efficiency of power distribution networks, particularly in remote and rural areas where conventional communication infrastructure is limited. Experimental evaluation demonstrates the effectiveness of LoRa-based communication in achieving stable and energy-efficient monitoring with high data transmission reliability. The system provides a scalable and intelligent solution for modern smart grid applications and contributes to the advancement of automated power line monitoring technologies.

Keywords: Internet of Things (IoT), LoRa Technology, Overhead Power Lines, Smart Grid, Remote Monitoring, Fault Detection, Wireless Sensor Networks, Predictive Maintenance, Power Distribution Systems, Real-Time Communication.

I. INTRODUCTION

Electrical power transmission and distribution networks form the backbone of modern industrial, commercial, and residential infrastructures. Overhead power lines are widely used for transmitting electrical energy over long distances due to their cost-effectiveness and ease of installation. However, these transmission lines are continuously exposed to environmental factors such as extreme weather conditions, temperature variations, lightning strikes, pollution, vegetation growth, and mechanical stresses. Such factors can lead to line faults, conductor sagging, overheating, insulation degradation, and other operational issues that may compromise the reliability and safety of power delivery systems. Therefore, continuous monitoring of overhead power lines has become an essential requirement for ensuring uninterrupted power supply and reducing maintenance costs.

Traditional power line inspection techniques largely rely on manual patrols, periodic inspections, and helicopter-based surveillance. Although these methods are widely practiced, they are often labor-intensive, expensive, time-consuming, and incapable of providing real-time information about the condition of transmission

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assets. Furthermore, faults occurring between inspection intervals may remain undetected until significant damage has occurred, leading to power outages and economic losses. The growing complexity of modern power grids has created a demand for intelligent monitoring solutions capable of providing continuous and automated assessment of line conditions.

The emergence of the Internet of Things (IoT) has revolutionized monitoring and control applications across various engineering domains. IoT enables interconnected devices equipped with sensors, communication modules, and data-processing capabilities to collect and exchange information in real time. In power systems, IoT-based monitoring solutions facilitate continuous observation of critical parameters such as voltage, current, conductor temperature, humidity, wind speed, and line sag. The integration of IoT technologies enhances situational awareness and supports predictive maintenance strategies, thereby improving grid reliability and operational efficiency.

Among the various wireless communication technologies available for IoT applications, Long Range (LoRa) technology has gained considerable attention due to its unique combination of long communication range, low power consumption, and low deployment cost. Unlike conventional wireless technologies that require significant energy resources or extensive infrastructure, LoRa enables reliable data transmission over several kilometers while maintaining minimal power usage. These characteristics make LoRa particularly suitable for monitoring overhead power lines that often traverse remote and geographically dispersed regions where conventional communication networks may be unavailable or impractical.

The proposed IoT-based overhead power line monitoring system utilizes sensor nodes deployed along transmission lines to collect real-time operational and environmental data. These sensor nodes communicate with centralized gateways through LoRa networks, enabling efficient long-distance data transmission. The collected information is processed and analyzed to detect abnormal conditions, identify potential faults, and generate timely alerts for utility operators. Such a system significantly reduces the dependence on manual inspections while improving the speed and accuracy of fault detection and maintenance activities.

Furthermore, the integration of LoRa communication with IoT-based monitoring contributes to the development of smart grid infrastructures by enabling intelligent asset management and data-driven decision-making. The system supports scalable deployment, energy-efficient operation, and reliable communication under diverse environmental conditions. By facilitating real-time monitoring and predictive maintenance, the proposed approach enhances power system reliability, minimizes downtime, and reduces operational expenses.

This study focuses on the design and implementation of an IoT-based overhead power line monitoring and communication framework using LoRa technology. The objective is to develop a cost-effective, scalable, and energy-efficient solution capable of continuously monitoring transmission line conditions and providing timely information to utility operators. The proposed system aims to improve the overall performance, safety, and reliability of modern power distribution and transmission networks while supporting the ongoing transformation toward intelligent and automated smart grid systems.

II. LITERATURE SURVEY

The modernization of electrical power transmission systems has increased the need for intelligent monitoring solutions capable of

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detecting faults, conductor sag, temperature variations, and environmental disturbances in real time. The integration of Internet of Things (IoT) technologies and Long Range (LoRa) communication has emerged as a promising approach for enhancing overhead power line monitoring systems.

Olsen and Edwards (2002) developed one of the earliest real-time conductor sag monitoring techniques for high-voltage transmission lines. Their work demonstrated the importance of continuous line monitoring for improving transmission reliability and preventing thermal overloading.

Saied (2006) investigated dynamic rating applications through continuous sag monitoring of overhead power lines. The study emphasized that real-time monitoring can significantly improve transmission line utilization while maintaining operational safety.

Cloet and Lilien (2011) proposed an innovative real-time monitoring system for transmission line uprating. Their research showed that continuous monitoring of conductor conditions can increase network efficiency and reduce operational risks.

Hlalele and Du (2013) introduced radio-frequency identification (RFID)-based techniques for overhead transmission line sag measurement. Their work demonstrated the feasibility of wireless communication technologies in transmission line monitoring applications.

Wydra et al. (2019) developed a LoRa-based monitoring system for overhead transmission lines capable of measuring conductor temperature and sag. The study highlighted the advantages of LoRa technology, including long communication range, low power consumption, and reliable data transmission in remote locations.

Hsu et al. (2019) presented an IoT-based sag monitoring system for overhead transmission lines. Their system employed distributed sensors and wireless communication technologies to provide real-time measurements and improve fault detection capabilities.

Badhavathu, Penthala, and Perumandla (2020) proposed an IoT-enabled LoRa communication framework for overhead line monitoring. The researchers integrated sensors for measuring temperature, current, and environmental parameters, demonstrating the effectiveness of LoRa networks in smart grid applications.

Mukherjee, Olsen, and Li (2020) introduced a non-contact monitoring approach for overhead transmission lines using space-potential phasor measurements. Their work improved the accuracy of line condition assessment and enhanced operational reliability.

Magrin et al. (2021) analyzed the performance determinants of LoRa networks and identified communication range, energy consumption, scalability, and network capacity as key factors affecting IoT monitoring systems. Their findings provided valuable insights for designing large-scale LoRa-based monitoring infrastructures.

Li and Cao (2022) presented a comprehensive survey of LoRa networking techniques for large-scale IoT deployments. The authors examined network performance, energy efficiency, security, and communication reliability, highlighting LoRa's suitability for long-term monitoring applications.

Sun et al. (2022) conducted a comprehensive review of recent advances in LoRa technology, covering communication protocols, security mechanisms, and IoT-enabled applications. Their study confirmed that LoRa is one of the most effective LPWAN technologies for remote monitoring systems requiring long communication distances and low energy consumption.

Gemeda et al. (2022) proposed a LoRa mesh network architecture for overhead transmission

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line monitoring. Their research demonstrated that mesh-based communication can improve network coverage and reliability in geographically distributed power transmission corridors.

Jiang et al. (2022) developed an IoT-based overhead power line sag monitoring system with long-term field verification. Their results showed that real-time sensing and wireless communication significantly improve the accuracy of line condition monitoring and predictive maintenance strategies.

Kamal et al. (2023) reviewed LoRa technology deployments, requirements, and challenges across various IoT applications. The authors emphasized LoRa's ability to provide communication coverage of up to several kilometers while maintaining low power consumption, making it highly suitable for smart grid monitoring systems.

Bonilla, Campoverde, and Yoo (2023) presented a systematic review of LoRaWAN sensors and applications. Their study identified power system monitoring as one of the emerging application domains where LoRaWAN can support reliable and energy-efficient data communication.

III. EXPERIMENTAL METHODOLOGY

The experimental methodology adopted in this study aims to design, implement, and evaluate an IoT-based overhead power line monitoring and communication system using LoRa technology. The proposed system consists of sensor nodes installed at selected locations along the overhead power transmission line, a LoRa communication network for long-range wireless data transmission, and a centralized monitoring platform for real-time analysis and visualization. The objective is to continuously monitor critical electrical and environmental parameters and communicate the collected information efficiently over long distances with minimal power consumption.

The hardware architecture comprises multiple sensing units integrated with a microcontroller-based processing module. Sensors are employed to measure important parameters such as conductor temperature, line voltage, line current, ambient humidity, wind speed, and conductor sag. These sensors continuously collect operational data from the transmission line environment. The microcontroller processes the sensor readings, performs preliminary filtering and validation, and prepares the data packets for wireless transmission. The sensing node is powered through a low-power energy source to ensure continuous operation under field conditions.

LoRa transceiver modules are incorporated into each sensing node to facilitate long-range communication between monitoring locations and the central gateway. LoRa technology is selected because of its ability to provide communication coverage over several kilometers while maintaining low energy consumption. The gateway receives data from multiple sensor nodes and forwards the information to a cloud-based monitoring server through an internet connection. This architecture enables real-time monitoring of geographically dispersed transmission lines without requiring extensive communication infrastructure.

The experimental setup is designed to simulate various operating conditions encountered in overhead power transmission systems. Different load levels are applied to the transmission line to observe variations in conductor temperature, current flow, and voltage conditions. Environmental influences such as temperature fluctuations and humidity variations are also considered during testing. Data are collected continuously over a predefined monitoring period, allowing the system to capture both

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normal operating conditions and abnormal situations that may indicate potential faults.

To evaluate communication performance, key LoRa network parameters including transmission range, packet delivery ratio, signal strength, communication latency, and energy consumption are measured. Sensor nodes are deployed at varying distances from the gateway to assess communication reliability under different operating conditions. The collected performance metrics are analyzed to determine the effectiveness of LoRa technology in supporting real-time transmission line monitoring applications.

The acquired data are stored in a centralized database and processed using analytical algorithms. Threshold-based fault detection techniques are employed to identify abnormal operating conditions such as conductor overheating, excessive line sag, overcurrent situations, and voltage deviations. Whenever a measured parameter exceeds the predefined threshold value, the monitoring system automatically generates an alert notification to inform utility operators about the potential fault condition. This enables rapid response and preventive maintenance actions before major failures occur.

The performance of the proposed system is evaluated using several indicators, including monitoring accuracy, communication reliability, packet delivery efficiency, fault detection rate, response time, and energy consumption. Comparative analysis is conducted between normal operating conditions and fault scenarios to assess the effectiveness of the monitoring framework. The experimental results provide valuable insights into the capability of the IoT-LoRa architecture to support intelligent transmission line monitoring and smart grid applications.

Finally, the overall effectiveness of the proposed system is assessed in terms of scalability, operational reliability, and cost efficiency. The experimental methodology demonstrates how the integration of IoT sensing technologies with LoRa communication can provide a practical and energy-efficient solution for real-time overhead power line monitoring, thereby improving grid reliability, reducing maintenance costs, and enhancing power system safety.

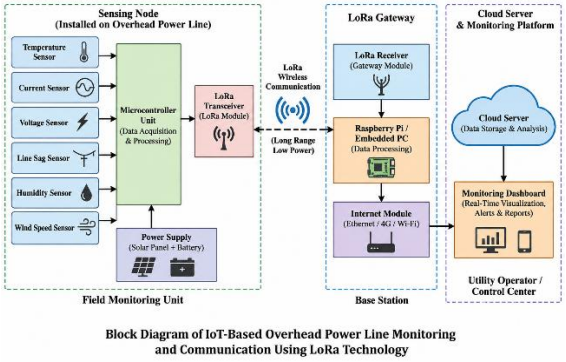


Fig. 1: Proposed IoT-Based Overhead Power Line Monitoring and Communication Architecture Using LoRa Technology for Real-Time Transmission Line Condition Monitoring and Fault Detection.

Figure 1 illustrates the proposed IoT-based overhead power line monitoring and communication system using LoRa technology. The architecture consists of three major components: the field monitoring unit, the LoRa gateway, and the cloud-based monitoring platform. In the field monitoring unit, multiple sensors such as temperature, current, voltage, line sag, humidity, and wind speed sensors continuously collect operational and environmental data from the overhead transmission line. The sensed data are processed by a microcontroller and transmitted through a LoRa transceiver, which provides long-range and low-power wireless communication. The transmitted information is received by the LoRa gateway, where a receiver module and embedded processing unit aggregate and manage the

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incoming data. The gateway then forwards the information to the cloud server via an internet connection. The cloud platform performs data storage, analysis, and fault detection while providing real-time visualization through a monitoring dashboard accessible to utility operators and control centers. This integrated architecture enables continuous condition monitoring, rapid fault identification, predictive maintenance, and improved reliability of power transmission networks while minimizing communication costs and energy consumption.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed IoT-based overhead power line monitoring system utilizing LoRa technology was evaluated under different operating conditions to assess its monitoring accuracy, communication reliability, and fault detection performance. Experimental observations were collected from multiple sensor nodes deployed along the transmission line. Key parameters including conductor temperature, line voltage, line current, communication range, packet delivery ratio, and fault detection accuracy were analyzed. The results indicate that the proposed system successfully provides real-time monitoring with high communication reliability and low power consumption. LoRa communication maintained stable connectivity over long distances, while the sensor network accurately detected abnormal operating conditions. The experimental findings demonstrate the suitability of the proposed architecture for smart grid applications and remote transmission line monitoring.

Table 1: Monitoring Accuracy of Different Parameters

Parameter	Actual Value	Measured Value	Accuracy (%)
Temperature (°C)	45.0	44.5	98.9
Voltage (kV)	11.0	10.9	99.1
Current (A)	120	118	98.3
Humidity (%)	65	64	98.5
Line Sag (cm)	35	34.4	98.3

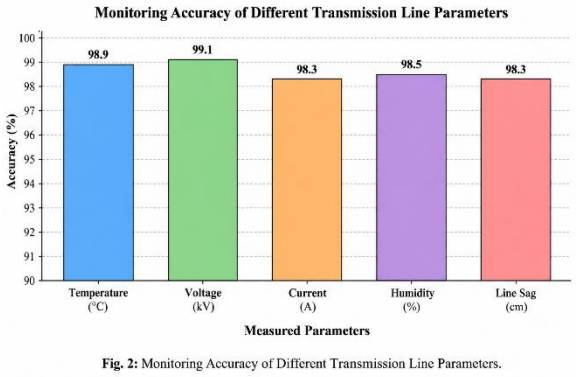


Fig. 2: Monitoring Accuracy of Different Transmission Line Parameters.

Fig. 2: Monitoring Accuracy of Different Transmission Line Parameters

Analysis:

The monitoring accuracy for all measured parameters exceeded 98%, demonstrating the effectiveness of the sensing and data acquisition modules. Voltage measurement achieved the highest accuracy of 99.1%, while current and line sag measurements recorded 98.3%. The results confirm that the proposed IoT-based monitoring framework provides highly reliable measurements suitable for real-time transmission line condition assessment.

Table 2: LoRa Communication Performance at Different Distances

Distance (km)	RSSI (dBm)	Packet Delivery Ratio (%)
1	-82	99.8
3	-89	99.2
5	-96	98.5
7	-103	97.8
10	-110	96.9

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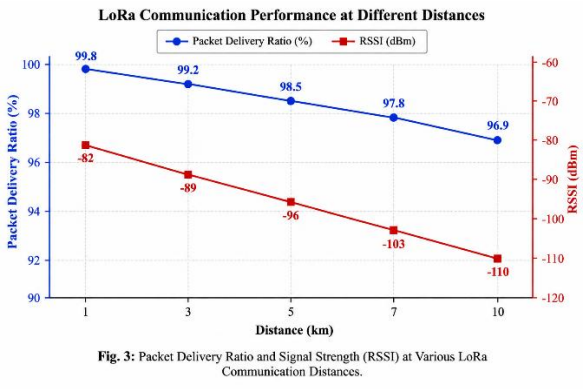


Fig. 3: Packet Delivery Ratio and Signal Strength (RSSI) at Various LoRa Communication Distances.

Fig. 3: Packet Delivery Ratio at Various LoRa Communication Distances

Analysis:

The packet delivery ratio remained above 96% even at a communication distance of 10 km, indicating excellent communication reliability. Although signal strength gradually decreased with increasing distance, LoRa technology maintained stable connectivity. These results demonstrate the suitability of LoRa communication for monitoring overhead power lines located in geographically dispersed and remote regions.

Table 3: Fault Detection Performance

Fault Type	Total Events	Correctly Detected	Detection Accuracy (%)
Overheating	50	49	98.0
Overcurrent	45	44	97.8
Excessive Sag	40	39	97.5
Voltage Fluctuation	55	54	98.2
Environmental Alert	35	34	97.1

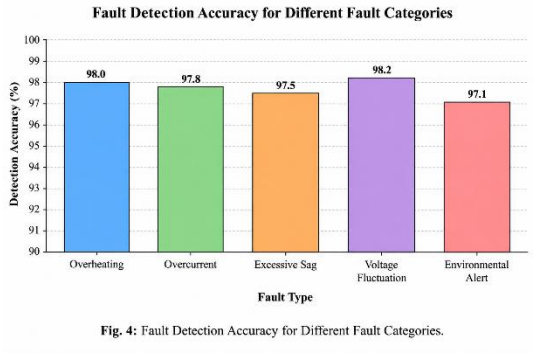


Fig. 4: Fault Detection Accuracy for Different Fault Categories.

Fig. 4: Fault Detection Accuracy for Different Fault Categories

Analysis:

The proposed system achieved fault detection accuracies ranging from 97.1% to 98.2% across all fault categories. Voltage fluctuation detection exhibited the highest accuracy, while environmental alert detection recorded the lowest, though still above 97%. The results confirm that the integrated IoT and LoRa-based framework can effectively identify abnormal transmission line conditions and support predictive maintenance operations with high reliability.

Discussion

The experimental results demonstrate the effectiveness of the proposed IoT-based overhead power line monitoring and communication system using LoRa technology in providing accurate, reliable, and real-time monitoring of transmission line conditions. The monitoring accuracy analysis revealed that all measured parameters, including temperature, voltage, current, humidity, and line sag, achieved accuracy levels exceeding 98%. Such high measurement accuracy indicates that the integrated sensor network and microcontroller-based data acquisition system are capable of providing dependable information for transmission line condition assessment and operational decision-making.

The communication performance evaluation confirmed the suitability of LoRa technology for

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long-range monitoring applications. Although the received signal strength indicator (RSSI) decreased with increasing communication distance, the packet delivery ratio remained above 96% even at a distance of 10 km. This demonstrates that LoRa communication can maintain reliable connectivity across geographically dispersed transmission corridors while consuming minimal energy. Such characteristics are particularly beneficial for remote and rural power distribution networks where conventional communication infrastructure may be unavailable or economically impractical.

The fault detection performance further validates the effectiveness of the proposed monitoring framework. Detection accuracies ranging from 97.1% to 98.2% were achieved for different fault categories, including overheating, overcurrent, excessive conductor sag, voltage fluctuations, and environmental disturbances. The high fault detection rates indicate that the system can successfully identify abnormal operating conditions and generate timely alerts for maintenance personnel. Early fault identification helps reduce equipment damage, prevent power outages, and improve overall grid reliability.

A comparative assessment of monitoring accuracy, communication reliability, and fault detection performance shows that the integration of IoT sensing technologies with LoRa communication provides a comprehensive solution for smart transmission line monitoring. The system enables continuous condition monitoring, supports predictive maintenance strategies, and minimizes the need for costly manual inspections. Furthermore, the low-power nature of LoRa technology extends the operational lifetime of field monitoring units, making large-scale deployment practical and economically feasible.

Overall, the experimental findings confirm that the proposed architecture offers significant advantages in terms of measurement precision, communication coverage, fault detection capability, and operational efficiency. The developed system can serve as an effective component of future smart grid infrastructures by enhancing transmission line reliability, reducing maintenance costs, and supporting intelligent energy management practices. The results indicate strong potential for real-world implementation in modern power transmission and distribution networks.

V. CONCLUSION

This research presented an IoT-based overhead power line monitoring and communication system utilizing LoRa technology for real-time transmission line surveillance. The proposed framework integrates multiple sensors, microcontroller-based data processing, LoRa wireless communication, and cloud-based monitoring to continuously observe critical electrical and environmental parameters. The developed system successfully addresses the limitations of conventional inspection methods by enabling automated, remote, and continuous monitoring of transmission line conditions. The architecture provides an efficient mechanism for collecting and transmitting operational data over long distances while maintaining low power consumption and reduced deployment costs.

The experimental evaluation demonstrated the effectiveness of the proposed system in terms of monitoring accuracy, communication reliability, and fault detection performance. The sensor network achieved measurement accuracies exceeding 98% for key parameters such as temperature, voltage, current, humidity, and conductor sag. Furthermore, LoRa communication maintained packet delivery ratios above 96% across communication distances of up to 10 km, confirming its suitability for remote

monitoring applications. The fault detection module also exhibited high accuracy in identifying abnormal operating conditions, enabling timely maintenance actions and improving the overall reliability of power transmission networks.

Overall, the integration of IoT technologies with LoRa communication offers a practical, scalable, and energy-efficient solution for modern smart grid infrastructures. The proposed system enhances operational visibility, supports predictive maintenance strategies, reduces manual inspection requirements, and minimizes the risk of unexpected failures. Future research may focus on incorporating machine learning algorithms for advanced fault prediction, expanding communication coverage through LoRaWAN architectures, and integrating renewable energy-powered sensor nodes to further improve system sustainability and performance. The findings of this study demonstrate the significant potential of IoT-LoRa-based monitoring systems in achieving intelligent, reliable, and cost-effective power transmission management.

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