LORA-ENABLED WIRELESS MONITORING OF OVERHEAD LINES IN IOT-BASED SMART GRIDS

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***Abstract*—** With the growing demand for efficient, reliable, and smart energy distribution, real-time monitoring of overhead transmission lines has become increasingly critical. This paper presents a LoRa-enabled wireless monitoring system designed for deployment in IoT-based smart grids. Leveraging the long-range, low-power capabilities of LoRa (Long Range) communication, the proposed system allows distributed sensor nodes to continuously monitor key electrical and environmental parameters such as line temperature, current flow, conductor sag, and fault occurrences. These nodes transmit data to a centralized server or cloud platform, enabling grid operators to detect abnormalities, predict maintenance needs, and prevent large-scale failures. The system architecture emphasizes energy efficiency, cost-effectiveness, and reliable long-range communication, making it a viable solution for rural and urban grid infrastructures. Simulation and prototype testing confirm the system's ability to enhance real-time decision-making and operational resilience in modern power networks.

I INTRODUCTION

The transformation of conventional power grids into smart grids involves the integration of advanced communication technologies, real-time analytics, and distributed sensing systems. One of the critical components of this transformation is the monitoring of overhead power transmission lines, which are prone to faults due to environmental exposure, aging infrastructure, and overload conditions. Accurate and timely detection of such issues can significantly reduce outages, maintenance costs, and safety risks.

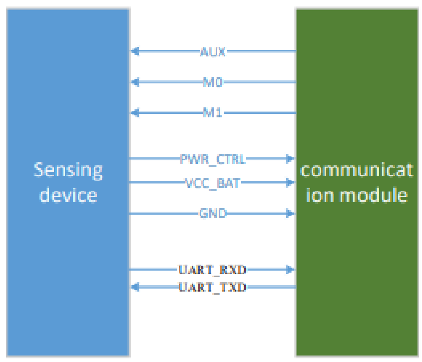
Traditional line monitoring techniques often rely on manual inspection or short-range wireless technologies, which can be expensive, labor-intensive, and inefficient. In contrast, IoT (Internet of Things) solutions offer scalable, autonomous, and real-time data acquisition capabilities. Among various IoT communication protocols, LoRa (Long Range Radio) stands out due to its low power consumption, long-distance transmission, and high scalability, making it ideal for wide-area monitoring applications.

This paper introduces a LoRa-enabled wireless monitoring system for overhead transmission lines in smart grid environments. The system deploys sensor nodes at key locations along power lines to capture real-time metrics such as voltage, current, conductor tilt, and environmental conditions. The data is transmitted via LoRa gateways to a centralized processing unit, where analytics and alerts are generated to support proactive maintenance and operational decision-making. The proposed solution aims to enhance grid visibility, fault detection speed, and overall reliability of the power infrastructure.

A. LoRa-based Overhead Line Low-power Wide Area Interconnection of Things Communication Network Architecture

Various sensors integrated with LoRa communication components are arranged on the transmission line. The sensors communicate with the LoRa-based station arranged on the tower through the LoRa components. LoRa-based stations can self-organize networks by multi-hop mode. Sensory data obtained from sensors can be sent back to power intranet through APN or power optical network, and processed and utilized by cloud platform. LoRa-based Overhead Line Low-power Wide Area Interconnection Communication Network Architecture consists of three layers of networks.

1) LoRa Access Network: The monitoring device is connected to the base station node by point-to-multipoint mode. Based on the standard LoRaWAN communication protocol, the protocol is tailored and optimized according to the characteristics of the power sensor. 2) Wireless multi-hop networking: Base station nodes can realize long-distance information transmission of wireless multi-hop. It has the ability of self-organizing network and adaptive routing, and optimizes data scheduling and transmission quality. 3) Existing network facilities: use mature APN technology, install APN terminal module in base station to realize the ability of base station to access power private network; or use power already laid power optical network, through wired access mode and encrypted and firewall, realize the access to power internal network.



Connection relationship between communication terminal module and sensor device

II OBJECTIVES:

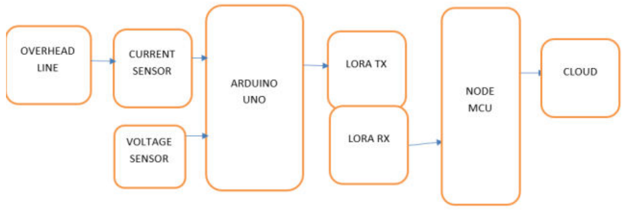
The objective of the project is to develop a reliable and efficient system for real-time fault detection and communication in an electrical grid. The system uses an electrical base station as a receiver, with each home near the base station containing a transmitter. The system is designed to detect faults such as over-consumption of voltage or fuse issues, and to enable easy communication between the homes and the base station. The system uses LoRaWAN technology for communication, which allows for low-power, long-range communication between the devices. The ultimate goal of the project is to improve the reliability and efficiency of the electrical grid by enabling real-time fault detection and communication, which can help to prevent outages and other issues.

III RELATED WORK

LPWANs play now a major role in the IoT, enabling applications in sectors such as smart cities, asset tracking, environmental monitoring, and intelligent transport systems [1]. To this end, telecommunication operators have embraced and deployed these new networks based on LoRa/LoRaWAN, NB-IoT (as part of 3GPP 5G specification) or Sigfox as the enabling technologies. The recent spur in space projects, and more notably in LEO satellites [2], is emerging as an appealing approach to extend the IoT service. In this paper we focus on LoRa/LoRaWAN-based DtS-IoT. At the physical layer, LoRa's chirp-based spread spectrum communication has been studied for satellite-based data collection systems [3]. Further studies have discussed adaptations to the satellite channel of the spread spectrum modulation. Later on, the reception of LoRa signals from satellites was successfully assessed for different spreading factors (SF). However, scalability issues of the integrated LoRa/LoRaWAN stack might hinder a sustainable throughput in wide-area coverage scenarios such as envisioned in DtS-IoT.

Recently, a new LoRa modulation, called LR-FHSS, has been proposed by Semtech and announced by Lacuna as the candidate for future LoRa-based LEO communications. LR-FHSS uses a fast Frequency Hopping Spread Spectrum technique that transmits replicas of the packet header and the packet itself, fragmented into 50 ms-duration per fragment. Several physical layer configurations are available in what are called Data Rates (DR).5 In Europe, DR8 and 9 operates over a bandwith of 137 kHz, while DR10 and 11 over 336 KHz. The details of coding rate, header repetitions, and physical bit rate of each DR are available. In general, a DR allows for sending the packet header multiple times, with only one repetition needed for a correct packet extraction at the receiver.

Recent studies provide general surveys of existing channel access schemes. In , using the position information of sensors and the satellite, the authors propose a joint power adaptation and access channel scheme that aims at improving the LoRaWAN performance over a satellite link. Wu et al.



IV BLOCK DIAGRAM EXPLANATION

Here in this project we create a small prototype in place of an overhead line , these will act same as overhead line . The current and voltage are measured using the sensors and later the data is given to Arduino to which LORA is interfaced which will transmit the information and on receiving end we have NODE MCU to which LORA is interfaced which will receive the data and the sent to the cloud platform through ESP8266 WIFI chip.

A. Module Description:

In Transmitter node ,The electricity comes from the overhead line , the current sensor and voltage sensor used to sense the amount of electricity comes from the Overhead line . sensor send the data to the Arduino and Arduino send that data to the Lora TX . In Receiver node , Lora RX Receives the data from the Lora TX . Lora RX send the data to the Node MCU . Node Mcu send the data to the cloud .

B. EXISTING SYSTEM

Currently there is no real time monitoring for the overhead lines , transformers and large electrical meters are used for measurement .

C. PROPOSED SYSTEM

This system does not require manual intervention because it is fully automated. Monitoring is done with current and voltage sensors, and there is real-time data monitoring. Internet-free data transmission is done via LORA Technology.

***V.* HARDWARE SPECIFICATION**

1. ARDUINO UNO
2. NODE MCU
3. LORA
4. VOLTAGE SENSOR
5. CURRENT SENSOR

A. ESP32

ESP32 is a low-powered, low-cost microcontroller (MCU) board, with both Wi-Fi and Bluetooth built in, and is based on a dual-core processor mechanism. The first one is a powerful processor, such as a Xtensa LX6 (~240 MHz) with

512 KiB memory and the second an ultra-low coprocessor (ULP) with only 8 KiB memory designed to run when ESP32 is in deep-sleep mode.

Other components include around 48 I/O pins (variable); an array of peripheral interfaces including temperature, hall effect, and capacitive touch sensors; and an 8-centimeter LCD panel, prominently visible here in an ESP32-WROVER board by Express if Systems.

B. BUCK CONVERTOR

A buck converter or step-down converter is a DC-to-DC converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current.[1] The efficiency of buck converters can be very high, often over 90%, making them useful for tasks such as converting a computer's main supply voltage, which is usually 12 V, down to lower voltages needed by USB, DRAM and the CPU, which are usually 5, 3.3 or 1.8 V.

C. LCD DISPLAY

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly[1] but instead use a backlight or reflector to produce images in color or monochrome.[2] LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden: preset words, digits, and seven-segment displays (as in a digital clock) are all examples of devices with these displays. They use the same basic technology, except that arbitrary images are made from a matrix of small pixels, while other displays have larger elements. LCDs can either be normally on (positive) or off (negative), depending on the polarizer arrangement.

D. BULB

An incandescent light bulb, incandescent lamp or incandescent light globe is an electric light with a wire filament that is heated until it glows. The filament is enclosed in a glass bulb that is filled with vacuum or inert gas to protect the filament from oxidation. Current is supplied to the filament by terminals or wires embedded in the glass. A bulb socket provides mechanical support and electrical connections.

E.NODE MCU

NodeMCU is an open source firmware for which open source prototyping board designs are available. The name "NodeMCU" combines "node" and "MCU" (micro-controller unit).[8] Strictly speaking, the term "NodeMCU" refers to the firmware rather than the associated development kits.

Both the firmware and prototyping board designs are open source.

The firmware uses the Lua scripting language. The firmware is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson and SPIFFS. Due to resource constraints, users need to select the modules relevant for their project and build a firmware tailored to their needs. Support for the 32-bit ESP32 has also been implemented.

F.DC MOTOR

A DC motor is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy. The most common types rely on the forces produced by induced magnetic fields due to flowing current in the coil. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

DC motors were the first form of motors widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor, a lightweight brushed motor used for portable power tools and appliances can operate on direct current and alternating current. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

i) EMBEDDED C:

Embedded c is a set of language extension for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. Historically embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations.

Embedded C uses most of the syntax and semantics of standard C, e.g., main () function, variable definition, data type declaration, conditional statements (if, switch, case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, etc. During infancy years of microprocessor-based systems, programs were developed using assemblers and fused into the EPROMs. There used to be no mechanism to find what the program was doing. LEDs, switches, etc. were used to check for correct execution of the program. But they were too costly and were not quite reliable as well. As time progressed, use of microprocessor-specific assembly-only as the programming language reduced and embedded systems moved onto C as the embedded programming language of choice. C is the most widely used programming language for embedded processors/controllers.

V. CONCLUSION

The implementation of a LoRa-enabled IoT system for overhead line monitoring marks a significant step forward in modernizing power grid operations. By harnessing the benefits of long-range, low-power communication and intelligent sensing, the proposed solution provides continuous, real-time surveillance of critical line parameters, enabling rapid response to emerging faults and operational anomalies.

The system proves to be cost-effective, energy-efficient, and highly scalable, suitable for both urban and remote locations. Prototype testing and simulations validate its potential to reduce outage durations, optimize maintenance schedules, and improve the resilience of the electric grid.

In conclusion, the presented architecture supports the broader goals of smart grid innovation by introducing a reliable and flexible monitoring framework that aligns with next-generation energy distribution demands. Future work may focus on integrating AI-based predictive analytics and cybersecurity enhancements to further strengthen its role in intelligent energy management.

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