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Integrated Smart Monitoring System for Electricity Theft Prevention

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ABSTRACT: Electricity theft remains a major challenge in power distribution systems, causing revenue loss, grid instability, and safety hazards. These issues can be overcome by adopting smart meters, real-time monitoring, and GIS/AI-based analytics to detect abnormal consumption patterns. Implementing strict regulations, automated alerts, and community awareness further strengthens theft prevention and ensures reliable power delivery. Therefore, this project proposes a Geo-Integrated Monitoring System for Electricity Theft Prevention that combines real-time sensing, location tracking, and wireless communication to detect and prevent unauthorized power usage in distribution networks. The system is built around an ESP32 controller, which collects critical electrical parameters using sensors such as the SCT013 current sensor, ZMPT101B voltage sensor, hall-effect sensor, and a vibration sensor to monitor abnormal tampering or bypassing attempts. A GPS module is integrated to provide accurate geo-location data, enabling theft detection at the exact point of occurrence. The sensed data is transmitted through a NodeMCU ESP8266 Wi-Fi module, which relays voltage levels, coordinates, and possible theft indicators to a cloud-based IoT platform in real time.

1. Introduction

Electricity is a critical resource that fuels modern society's infrastructure, industry, and daily life. However, one of the most persistent challenges faced by power utilities worldwide is electricity theft. It not only results in substantial economic losses but also affects the quality and reliability of the power supply. According to global estimates, billions of dollars are lost annually due to non-technical losses such as unauthorized connections, meter tampering, and bypassing of energy meters. These illegal practices not only put an undue burden on honest consumers but also degrade the overall efficiency and stability of power distribution networks. Traditional methods of detecting electricity theft, such as manual inspections and audits, are time-consuming, labour-intensive, and often inefficient.

2. Objectives

The primary objective of the proposed Integrated Smart Monitoring System for Electricity Theft Prevention is to design and develop an intelligent, reliable, and automated system capable of detecting and preventing unauthorized electricity usage in power distribution networks. The system aims to accurately monitor real-time energy consumption at both the feeder and consumer ends using smart metering technology and to compare these measurements in order to identify discrepancies beyond permissible technical losses. It further seeks to integrate IoT-based communication modules for secure and continuous data transmission to a centralized

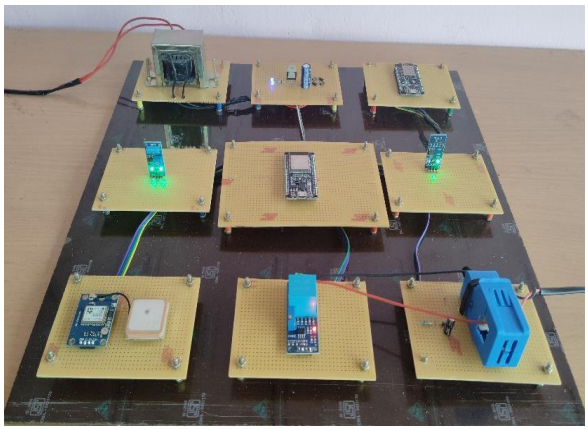
monitoring station, enabling remote supervision and control. Another key objective is to implement tamper detection mechanisms to identify illegal activities such as meter manipulation, line bypassing, and unauthorized tapping patterns are detected.

3. Literature Survey

Economic viability is necessary for the successful running of any system and network. All industries and infrastructure constructed for commercial purposes need to be economically viable, have a good economic model, and be adaptable and robust in design. These measures are necessary for a successful business. It should also have contingency plans in the case of rare but possible emergency events. Along with these, there is always a need to update, modernize, and push innovation. Most organizations that do not do this activity stagnate, face great market competition, and eventually default or declare bankruptcy. This is greatly problematic when this occurs within the State or Government. It becomes an economic weight, a load pulling the economy down as it cannot make profits, and leads to a loss in revenue. The above mention economic steps are necessary for essential services, such as electricity. Theft of resources has been an issue for as long as people have existed. It is the exploitation of the system for personal gain and through unfair means to profit or utilize resources that you have not paid for. The modern world has undergone many changes, especially regarding its power infrastructure. There has been consistent investment in the improvement and security of such facilities. With regards to the Third World economies, problems, such as a lack of investment, corruption, mismanagement, and innovation, have stagnated their electrical industry. This has halted progress or even reverted progress in some countries.

4. Proposed Methodology

In this project Integrated Smart Monitoring System for Electricity Theft Prevention is proposed. The proposed Integrated Smart Monitoring System for Electricity Theft Prevention operates by continuously sensing and analysing electrical parameters at the consumer end using an ESP32 controller. Current and voltage values are measured through the SCT013 current sensor and ZMPT101B voltage sensor to calculate real-time power consumption. A hall effect sensor and vibration sensor monitor physical disturbances and unauthorized meter tampering. The GPS module provides the exact location of the monitored point, enabling accurate identification of theft-prone areas.



All sensor data are processed by the ESP32 and transmitted to the Node MCU ESP8266 Wi-Fi module for wireless communication. The collected information, including voltage level, current usage, and location details, is uploaded to an IoT cloud platform for remote monitoring. If abnormal consumption patterns, sudden load changes, or tampering activities are detected, the system automatically generates alerts for utility authorities. This real-time, automated monitoring approach minimizes manual inspection, improves response time, and significantly reduces electricity theft and revenue loss.

5. Results and Discussion

The implemented Integrated Smart Monitoring System was tested under different operating conditions, including normal load operation, overload conditions, and simulated electricity theft scenarios (such as line tapping and meter tampering). The system successfully monitored

real-time energy consumption using smart meters and compared it with distribution-side readings..

The results confirm that integrating smart meters, IoT communication, and data analytics significantly enhances electricity theft detection compared to traditional manual inspection methods. The system reduces human dependency and enables faster identification of illegal activities. Early detection minimizes financial losses and prevents transformer overloading caused by unauthorized connections. The use of automated alerts and remote monitoring improves operational efficiency for utility providers. Furthermore, the ability to analyze historical consumption data enables predictive maintenance and proactive monitoring. This makes the system not only reactive but also preventive in nature. However, challenges such as initial installation cost, network reliability in rural areas, and cybersecurity risks must be considered. Ensuring data encryption and secure communication protocols is essential to prevent system misuse.

5.1 Preparation of Figures and Tables

Fig 1 in this project Integrated Smart Monitoring System for Electricity Theft Prevention is proposed. The proposed Integrated Smart Monitoring System for Electricity Theft Prevention operates by continuously sensing and analysing electrical parameters at the consumer end using an ESP32 controller. Current and voltage values are measured through the SCT013 current sensor and ZMPT101B voltage sensor to calculate real-time power consumption. A hall effect sensor and vibration sensor monitor physical disturbances and unauthorized meter tampering. The GPS module provides the exact location of the monitored point, enabling accurate identification of theft-prone areas.

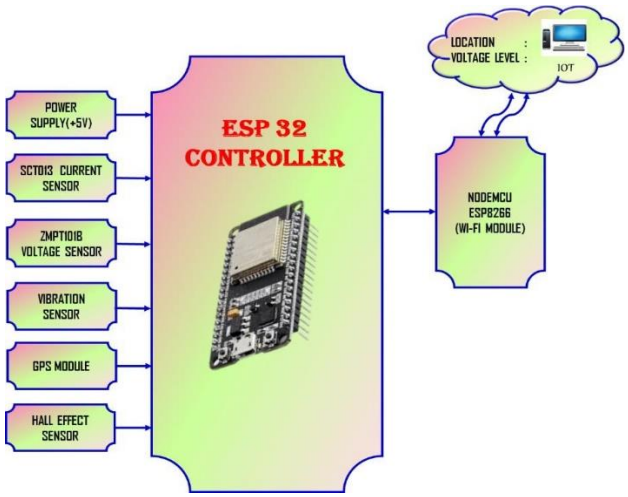


Figure 1: *Block diagram of proposed System*

5.1.1 Formatting Tables

Table 1 summarizes the hardware components used in the integrated smart monitoring system along with their specifications and functional roles. The table is properly numbered, provided with a descriptive title, and includes relevant measurement units in the column headings for clarity. It is placed appropriately within the manuscript and referenced in the corresponding section to support the explanation of the system design and implementation.

Table 1: *Hardware Components Used*

Component	Specification	Function
Vibration sensor	Typically 3.3 to 5V	Vibration detection
SCT013 Current Sensor	Measures Up to 100A	Measures current
ZMPT1018 Voltage Sensor	Measures Up to 250V AC	Measures AC mains voltage
GPS Module	±2.5m accuracy	Location tracking
ESP 32 Controller	Dual core Xtensa LX	Integrated wifi And Bluetooth

5. Conclusion

In conclusion, the proposed Integrated Smart Monitoring System for Electricity Theft Prevention offers a reliable and intelligent

approach to detect and prevent unauthorized electricity usage. By combining real-time electrical parameter monitoring, tamper detection, GPS-based location tracking, and IoT enabled communication, the system ensures accurate identification of theft incidents and rapid response. The automated monitoring process reduces dependency on manual inspections, minimizes revenue loss, and enhances the safety and reliability of power distribution networks. Overall, this system provides a cost-effective, scalable, and efficient solution for strengthening energy security and supporting the development of smart grid infrastructures.

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