International Journal of Innovative Research in Engineering
Volume 6, Issue 3 (May-June 2025), PP: 09-12.
www.theijire.com ***ISSN No: 2582-8746***

Power Theft Detection in Distribution Lines

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How to cite this paper:
Ande Venkata Vani[1], Vennapusa Yasaswini[2], BoppaJayaSumanthGoud[3], Sankati Ravi Prakash[4] "Power Theft Detection in Distribution Lines", IJIRE-V6I3-09-12.

Abstract: *The integration of Internet of Things (IoT) technology into the energy sector offers innovative solutions to longstanding challenges, such as electricity theft, which occurs when consumers tamper with or bypass energy meters to avoid payment. This illegal activity leads to significant financial losses for utility providers and poses safety risks to both consumers and the electrical infrastructure. In this project, we propose an IoT-based electricity theft detection system using the ESP32 microcontroller. The system employs smart meters installed at both the main line (upper meter) and user end (lower meter) to monitor electricity usage in real time. The ESP32 compares the readings from both meters, and if a significant discrepancy is found—indicating potential theft—an alert is triggered. Data is transmitted via Wi-Fi to a cloud server for analysis and visualization, and alerts are sent to a user-friendly mobile interface through the Blynk app, which users can access globally using their email login. This system reduces manual monitoring, enhances the accuracy of consumption tracking, and promotes safer, more efficient energy distribution. It provides real-time insights to both utilities and consumers, helping detect unauthorized usage, prevent losses, and improve customer service, all while supporting the broader goal of smart grid development and energy conservation.*

Key Words: *Internet of Things (IoT), Electricity theft detection, ESP32 microcontroller, Smart meter, Energy monitoring.*

I.INTRODUCTION

The global energy crisis is a pressing issue that can be addressed, in part, by monitoring and reducing energy wastage. One of the major contributors to this wastage is electricity theft, a common problem faced by power corporations that leads to significant financial losses and increased operational costs. This project presents an IoT-based electricity theft detection system that utilizes the ESP32 microcontroller, which comes with built-in Wi-Fi capabilities for seamless IoT connectivity. The system leverages the Internet of Things to enable remote communication, data monitoring, and alert generation. It connects to the Blynk server, allowing users and utility operators to monitor electricity usage in real time and receive instant notifications via the Blynk mobile app and email. The system includes current sensors (CTs) and voltage sensors (VTs) to measure real-time power consumption and inlet voltage levels. These readings are continuously pushed to the cloud, where they are analyzed for any discrepancies or anomalies that might indicate unauthorized usage. If a significant deviation in expected consumption is detected, the system flags it as potential theft and immediately alerts the operator. Additionally, the operator can remotely disconnect the load via the Blynk app, thereby preventing further loss and potential damage. A confirmation message is also sent to the end-user to notify them of the action taken. The Internet of Things plays a crucial role by enabling connected devices to communicate via unique IP addresses, thus facilitating automated monitoring and control without manual intervention. With the increasing adoption of IoT technologies, systems like this are transforming energy management and theft prevention, especially in developing countries where electricity theft remains a major obstacle to economic stability and industrial growth. Electricity is used extensively for residential, commercial, and industrial purposes, and theft at any level not only affects utility revenues but also disrupts fair distribution and stable supply. This smart system combines modern sensors, microcontrollers, and wireless communication to create an efficient energy monitoring solution. The objective is to reduce electricity theft, especially at the distribution level where most preventable losses occur due to illegal tapping and meter tampering. The project uses a combination of ARM Cortex Pico Wi-Fi modules and NodeMCU ESP32 boards, which work in tandem to gather and transmit sensor data. These modules are connected to CTs and VTs, which monitor current draw and voltage levels at different points in the supply chain. By continuously comparing expected and actual readings, the system identifies abnormal patterns and triggers theft alerts in real time. The data is transmitted to the Electricity Commission or relevant authorities through the Blynk IoT platform, enabling a quick response and minimizing loss. This project not only helps detect theft but also improves the overall efficiency of the electrical grid, reduces manual labor, and enhances the transparency of energy usage for both utilities and consumers. By integrating IoT technology with power system monitoring, the proposed solution presents a scalable and cost-effective approach to combat electricity theft and contribute to smarter, more secure energy distribution systems worldwide.

The system uses a voltage sensor and ACS712 current sensor with an Arduino to detect electricity theft in

distribution lines. It identifies unauthorized tapping, ensures power line protection, and sends real-time alerts to a central server, enabling efficient monitoring, quick response, and enhanced control by utility authorities [1]. The smart energy theft detector uses an Atmega328P-based Arduino Uno and a Bluetooth module to detect power theft on distribution lines. It displays alerts for detected theft on red, blue, or yellow phases through an LCD, enabling utility operators to monitor and respond to unauthorized usage effectively [2]. The theft detection in distribution lines is achieved through a BLE-based system that monitors signals from a line beacon. If the line is cut, the beacon signal disappears or weakens, indicating theft and enabling accurate tracking of the stolen wire [3]. The paper proposes a segmented Dynamic Time Warping (DTW) distance method to detect electricity theft in distribution lines by analyzing the correlation between individual users' electricity consumption and overall line loss. Suspicious users are identified based on similarities in their consumption patterns relative to expected usage behavior [4]. The system employs BLE-based IoT technology to monitor electricity distribution lines for theft by detecting sudden disappearance or significant weakening of beacon signals. This method ensures high accuracy and reliability in identifying unauthorized access or tampering, providing an effective solution for real-time electricity theft detection and grid protection [5]. The method detects power theft in distribution lines by estimating technical losses through resistance calculations and comparing these estimates with actual losses. When significant discrepancies are observed, it indicates non-technical losses, which are a sign of potential theft. This approach helps identify unauthorized usage in the power distribution system [6]. The system detects electrical power theft by identifying unauthorized tapping on distribution lines in real-time. It accurately pinpoints the affected zone and line, utilizing wireless data transmission for efficient monitoring. This approach helps reduce operational losses, improving the overall efficiency and security of the distribution network [7]. The proposed system detects theft in distribution lines by injecting a narrow-band power line carrier signal. It monitors amplitude changes along the line, where illegal consumption causes signal attenuation. This method enables precise detection of electricity theft, allowing for accurate identification of tampered sections in the distribution network [8]. The paper presents a method for detecting energy theft in low-voltage distribution lines by analyzing voltage differences at pole nodes. It utilizes a matrix of consumer branch resistances to identify irregularities, achieving a detection accuracy of 96% to 100% for thefts ranging from 10 W to 260 W, ensuring highly reliable theft detection [9]. The paper presents a controller-based system that detects power theft in distribution lines by analyzing voltage drops and current readings. The system identifies the exact theft locations and has the capability to automatically disconnect the power supply. It rechecks for theft before alerting the electricity provider if further action is required [10].

II.PROPOSED SYSTEM

Our proposed system is an electricity theft detection system designed to automatically identify theft when transmission lines or meters are bypassed. The system uses current transformers (CTs) and voltage transformers (VTs) to measure the total amount of current and voltage consumed by the connected load. These real-time measurements are monitored and visualized through the Blynk IoT app, which is connected via a Wi-Fi module. Additionally, an LCD screen displays the current and voltage values along with their respective units for local monitoring. If unauthorized taps are made on the line or extra loads are illegally introduced, the system detects a sudden increase in current and voltage. These anomalies are captured by the sensors and relayed to the Blynk app, where a theft alert is displayed. This real-time detection mechanism helps utility providers respond promptly and take preventive action. By continuously monitoring electrical parameters and alerting operators to irregularities, the system offers an efficient and automated solution to electricity theft. It not only enhances grid security but also helps reduce energy loss and improve operational efficiency. The proposed system addresses the growing challenges of electricity theft and energy wastage with a cost-effective and scalable IoT-based approach.

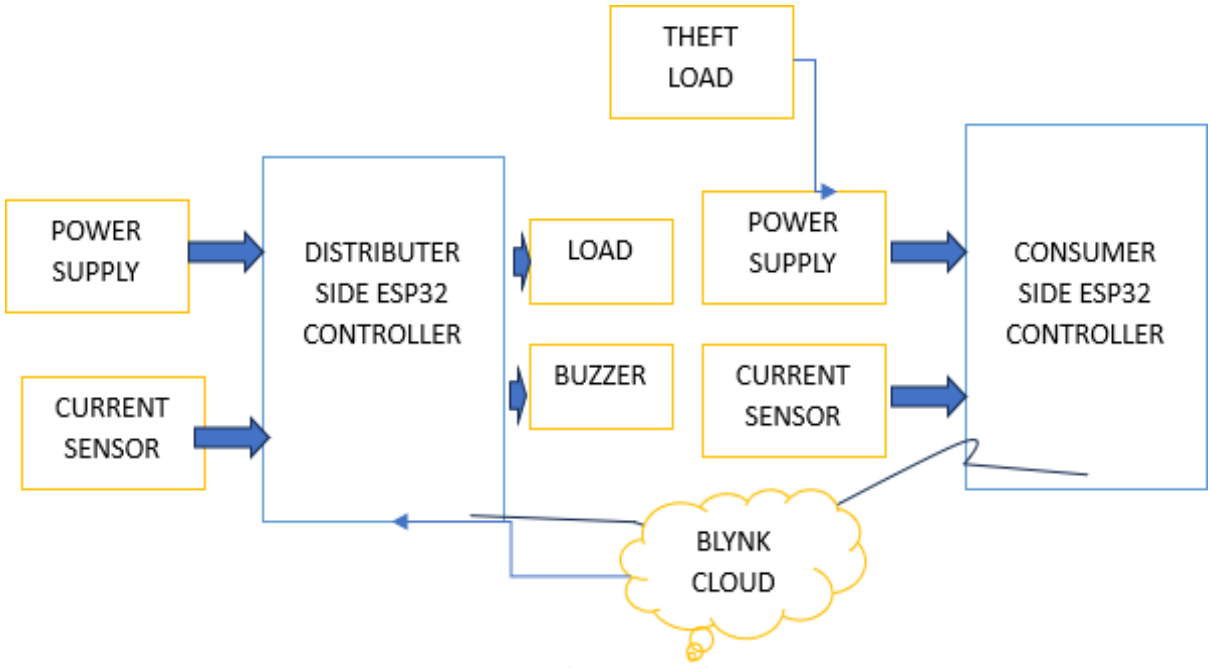

Fig.1 Block Diagram for power Theft detection

You can control your Arduino board using your smartphone and the Blynk app over the Internet. This project marks my first experience with the Blynk app to control an Arduino board. Although a Bluetooth connection can also be used to connect the Arduino to a smartphone, this method is not covered here. Blynk is available for download from the Google Play Store (for Android) and the App Store (for iOS). It provides a virtual dashboard for interfacing with the Arduino and managing connections. Programming with Blynk is simple—users can drag and drop widgets, configure their functions, and assign them to specific pins on the Arduino board. For this type of project, a standard Arduino board (without a dedicated internet screen) connected to a computer and a smartphone with internet access is sufficient. The computer is used to connect the Arduino to the Internet and to upload the necessary Arduino code. To get started, you must install the Blynk library on your computer and configure it accordingly. Blynk sketches follow the typical Arduino programming structure but include additional commands for communication with the mobile app. I used a basic example from the Internet and modified it slightly to suit my project, finding the process very similar to writing regular Arduino code.

III.RESULT

This paper presents an IoT-based electricity theft detection system designed to monitor energy usage and automatically identify unauthorized power consumption. The core of the system is built on the ESP32 DevKitC board, a powerful and low-power Wi-Fi and Bluetooth-enabled microcontroller. The Internet of Things (IoT) enables physical devices to communicate and exchange data over the internet. In this system, the energy meter is connected to the internet through the ESP32 module, allowing real-time monitoring and reporting. This approach significantly reduces the need for manual intervention in monitoring, disconnection, and reconnection processes. More importantly, it provides utility suppliers with instant alerts in case of electricity theft, making the system highly efficient and responsive.

The ESP32 DevKitC Board is a compact, dual-core microcontroller designed using TSMC's ultra-low-power 40 nm technology. It features integrated Wi-Fi and Bluetooth capabilities, which makes it highly suitable for IoT applications like energy monitoring. The ESP32 combines multiple functions, such as RF balun, power amplifier, low-noise receiver amplifier, antenna switch, and power management modules into a single chip, reducing the need for external components. This not only makes the device cost-effective but also ensures better reliability and performance. It supports multiple power modes and includes precise power measurement features, enabling it to operate efficiently in various environments. These characteristics make the ESP32 an ideal choice for mobile, wearable, and embedded IoT applications.

In this system, transmission modules are used to control the flow of electricity electronically. These modules act like switches that can be turned on or off remotely. The system uses a 2-channel relay module, powered by 5V, which is compatible with Arduino boards. However, versions powered by 3.3V are also available for direct compatibility with ESP32 or ESP8266 microcontrollers. These relays can disconnect the power supply when theft is detected, thereby preventing further energy loss.To measure electrical current, the system incorporates an ACS712 current sensor module. This sensor is based on the Hall Effect principle and can measure both AC and DC current. The module is available in different ranges, such as ±5A, ±20A, and ±30A, depending on the project's requirements. The ACS712 outputs an analog voltage (0–5V) that corresponds to the current flowing through the conductor. This output can be easily read by the ESP32's analog input pins. Accurate current sensing is crucial for detecting discrepancies in energy consumption, which could signal potential electricity theft.

Voltage measurements are also taken and monitored via the Blynk IoT app, which displays real-time data on the user's smartphone. An LCD screen is used locally to display voltage, current, and units of measurement. When irregularities, such as unexpected load increases or line tampering, are detected, the system sends alerts through the Blynk app. This immediate feedback allows for swift action to be taken, ensuring safety and minimizing loss.Overall, the system presents a reliable, low-cost, and automated solution for detecting electricity theft and monitoring energy usage using modern IoT technologies.

IV.CONCLUSION

This system plays a crucial role in controlling energy consumption and minimizing energy wastage. It is an ESP32-based design that implements a smart energy meter using the Internet of Things (IoT) concept. In the proposed system, a current sensor and voltage sensor are used to continuously monitor readings from both the mains and the load. These readings are transmitted to a remote server, allowing real-time data access from anywhere in the world. This enables remote energy monitoring, efficient management, and proactive detection of unauthorized usage. A key feature of this project is its ability to identify electricity theft. By analyzing the sensor data and detecting irregularities in power consumption, the system effectively identifies instances of theft. The Electricity Theft Detection System offers a reliable and straightforward method for combating power theft. Leveraging IoT-based wireless communication, this solution reduces significant energy and revenue losses caused by unauthorized usage. Upon detecting suspicious activity, the system can immediately alert the authorities, ensuring quick intervention. This approach is particularly beneficial for both urban and remote areas, where manual monitoring may not be feasible. Overall, the smart energy meter with IoT-based theft detection provides a scalable and effective solution for modern energy distribution networks.

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