RESEARCH ARTICLE OPEN ACCESS

IOT Based Smart Power Monitoring

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Abstract:

This project introduces an intelligent energy monitoring system based on Internet of Things (IoT) technology for measuring and tracking electricity usage in real time. The system uses an ESP32 microcontroller along with a PZEM-004T sensor module to capture key electrical parameters such as voltage, current, power, and total energy consumption.

The collected data is transmitted through a wireless network to a cloud-based platform using the MQTT communication protocol. This enables users to access and analyze their electricity usage remotely through a web dashboard. In addition to remote monitoring, an OLED display is incorporated to provide instant on-site readings.

The system is designed to reduce manual effort, improve energy efficiency, and provide continuous monitoring without interruption. It can also assist in identifying unusual power usage patterns, which may help in detecting faults or unauthorized consumption.

Overall, the proposed solution is economical, easy to implement, and suitable for both domestic and small-scale industrial environments, contributing to smarter energy management practices

Keywords — **ESP32 Microcontroller, PZEM-004T Power Module, OLED Display, Relay Driver Circuit, Wi-Fi Module, Adafruit IO Dashboard.**

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I. INTRODUCTION

The Internet of Things (IoT) enables the interconnection of everyday devices through the internet. Devices connected via IoT can be monitored and analyzed remotely. This concept provides the necessary infrastructure to establish a connection between the physical world and computer-based systems. It has gained significant importance due to the rapid increase in wireless devices in the market. In this system, hardware components are interconnected over the internet, and the ESP8266 Wi-Fi Module provides internet connectivity [1].

Nowadays, the demand for electricity is increasing at a constant rate due to its usage in various sectors such as agriculture, industries, households, and hospitals. This growing demand has made electricity management and maintenance more complex. Therefore, there is an urgent need to conserve electrical energy. As the population continues to grow and reliance on electricity increases, technological advancements must also keep pace.

The proposed system introduces a modern approach to conventional energy meters by integrating IoT technology. It also addresses issues such as power theft, which leads to economic losses for the nation.

Monitoring, optimized power usage, and reduction of energy wastage are the primary objectives for developing an efficient system [3].
The Smart Energy Meter using a Wi-Fi system is designed based on the following objectives:

1. To provide automated and real-time energy consumption readings.
2. To ensure optimal utilization of electricity.
3. To reduce power wastage.

The system can be broadly classified into two sections based on service ends:

1. Consumer End
2. Service Provider End

The data collected from the system is displayed on a web page, which can be accessed by the consumer for monitoring and analysis.
The system is designed using an Arduino micro-controller [2]. It can be structurally divided into three main parts: the controller, theft detection circuit, and Wi-Fi unit. The controller performs the necessary calculations and processes the data. The theft detection circuit identifies any unauthorized or excess energy consumption. The Wi-Fi unit plays a crucial role by transmitting the processed data from the controller to the internet.
The Arduino controller is programmed using the Arduino IDE (Integrated Development Environment), which is required to operate the Arduino board. The programming language used is based on the C language [4].

II. LITERATURE SURVEY

A. Introduction

A literature review provides a strong foundation for any engineering project by summarizing and analyzing previous developments in the field. This project integrates embedded electronics with IoT-based energy monitoring systems. Earlier research has explored GSM-based meters, wireless sensor networks, cloud-integrated home automation, and power analytics systems. This section reviews representative works and identifies the research gaps addressed by the proposed system.

B. GSM-Based Energy Monitoring Systems

Early remote energy monitoring systems used GSM (Global System for Mobile Communication) modules to transmit meter readings. For example, Sharma et al. (2017) developed a smart energy meter capable of sending consumption data via SMS. While this approach reduced manual meter reading, it had several limitations, including high communication costs, low data bandwidth, and one-way communication. Additionally, latency was high since each transmission required a complete SMS cycle.
In contrast, the proposed system uses Wi-Fi and MQTT over broadband networks, enabling near real-time communication with minimal cost and improved efficiency.

C. Zigbee and Bluetooth-Based Solutions

Technologies such as Zigbee and Bluetooth have been used for short-range wireless energy monitoring. Kumar and Sinha (2018) proposed a Zigbee-based smart metering system that enabled local data transmission within a network.
Although Zigbee is energy-efficient, it requires multiple repeaters and a central coordinator, increasing system complexity. Bluetooth, while easy to implement, has limited range and supports only one-to-one communication. Therefore, both technologies are more suitable for localized applications rather than scalable IoT systems.

D. Smart Grid and Industrial Monitoring Research

Recent studies focus on integrating IoT systems into Smart Grid environments. These systems include advanced features such as energy analytics, fault detection, and automated load management using AI techniques.
Although highly efficient, such systems require expensive infrastructure and high computational resources, making them less suitable for small-scale

or academic projects. The proposed system adopts a simplified and cost-effective version of these concepts.

D. Comparative Summary

Approach	Communication	Data Access	User Control	Cost	Complexity
GSM-Based	SMS (2G/3G)	Manual	No	High	Medium
Zigbee	Local Mesh	Limited	Partial	Medium	High
Bluetooth	Short Range	Single Device	Yes	Low	Low
Wi-Fi + IoT (Proposed)	Internet (MQTT)	Global Dashboard	Yes	Low	Low

From this comparison, it is evident that the Wi-Fi + MQTT architecture provides the best balance between cost, scalability, and functionality.

III. HARDWARE IMPLEMENTATIONS

A. ESP32 DevKitC

The ESP32 is a low-cost microcontroller that includes built-in Wi-Fi and Bluetooth. It is commonly used in IoT applications since it allows devices to connect to the internet and communicate wirelessly. The board contains a dual-core processor along with several GPIO pins, which makes it possible to interface with external components. It also supports communication methods like UART, SPI, and I2C, while maintaining efficient power usage for embedded system applications.

B. PZEM-004T Power Measurement Module

The PZEM-004T is a digital module designed for measuring electrical parameters in AC circuits. It provides readings such as voltage and current, while also calculating power, energy usage, frequency, and power factor. A current transformer sensor is used to detect the flow of current safely. The module connects to microcontrollers like Arduino or ESP32 through serial communication, which allows it to be integrated into energy monitoring systems and smart meter applications.

C. OLED Display (SSD1306 — 0.96″)

An OLED display based on the SSD1306 controller is a small screen used in embedded systems and electronics projects. The 0.96-inch version is widely used because it is compact, energy-efficient, and simple to connect with microcontrollers such as Arduino or Raspberry Pi.

D. Relay Module & Transistor Driver (PN2222A)

A relay module is an electromechanical switch that controls high-voltage or high-current devices using a low-power signal from a microcontroller. It provides electrical isolation between the control circuit and the load. The relay consists of a coil and switching contacts. When current passes through the coil, a magnetic field is generated, which changes the position of the contacts and either completes or interrupts the circuit.

The PN2222A is an NPN transistor used as a driver to operate the relay. A microcontroller cannot supply enough current to drive the relay coil directly. The transistor acts as an interface by using a small base current to control a larger current flowing through the collector and emitter, which activates the relay.

E. Power Supply (LM7805CV Linear Regulator)

The LM7805CV is a linear voltage regulator designed to provide a constant 5V DC output from a higher and varying input voltage. It is commonly used in electronic circuits to ensure a stable power supply for components such as microcontrollers and sensors.

The device operates by dissipating excess voltage as heat while maintaining a fixed output level. This regulation prevents fluctuations in the input from affecting the performance of connected components.

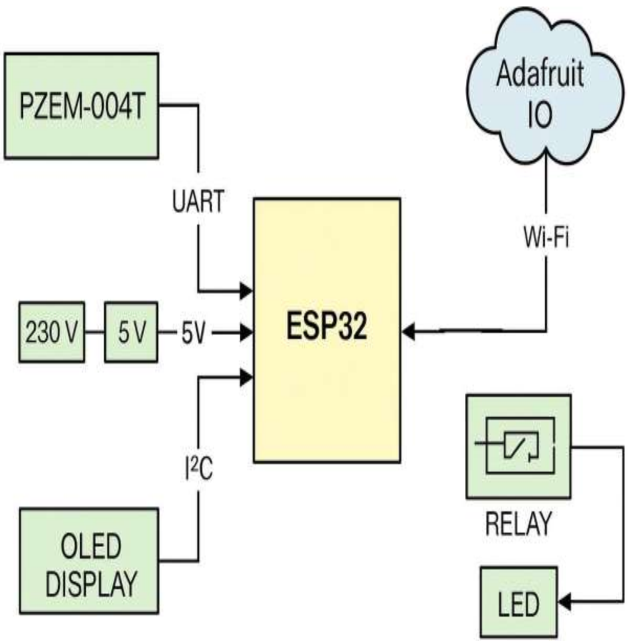
It typically requires input and output capacitors to improve stability and reduce noise.
The LM7805CV is reliable, easy to implement, and suitable for applications where a regulated 5V supply is necessary.

F. current transformer

A **Current Transformer (CT)** is a device used to measure alternating current (AC) safely.

It works by sensing the magnetic field produced by current flowing through a conductor and generating a proportional low-level current on its output side.
The CT converts high current into a small signal that can be measured by instruments or microcontrollers like Arduino and ESP32 without direct contact with the high-voltage line.
It is widely used in energy monitoring and power measurement systems because it provides safety and isolation while measuring electrical loads.

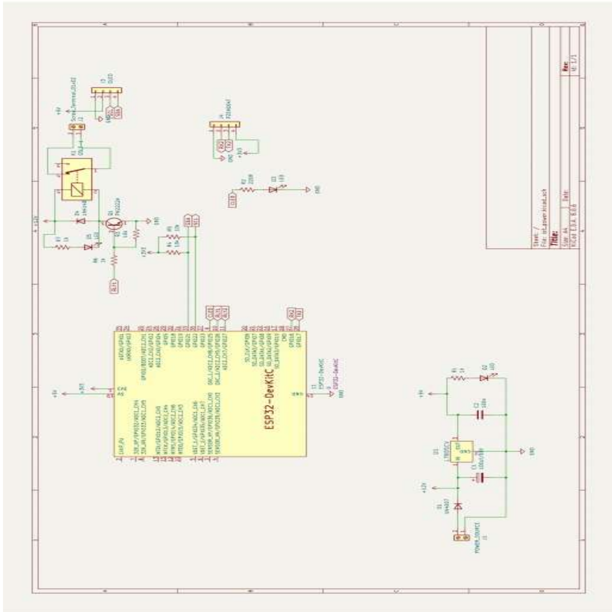
IV. Block Diagram



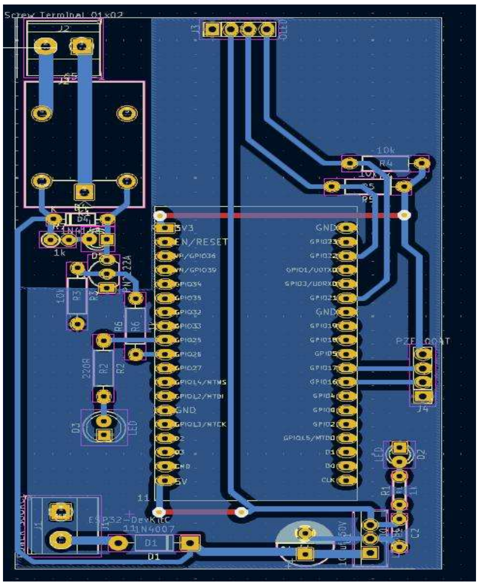
V CIRCUIT DIAGRAM

Two circuit diagrams have been used in the project. The
circuit diagrams are as follows:

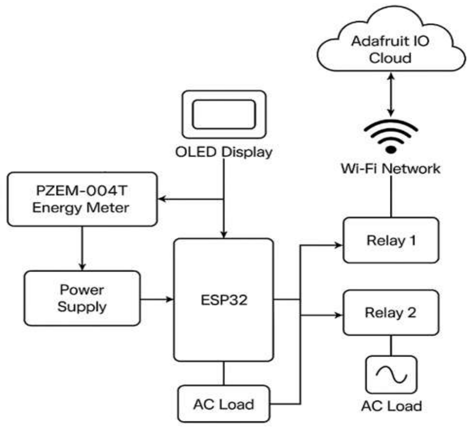
A. Power Supply Unit Circuit Diagram:



B. PCB LAYOUT



VI. FLOWCHART

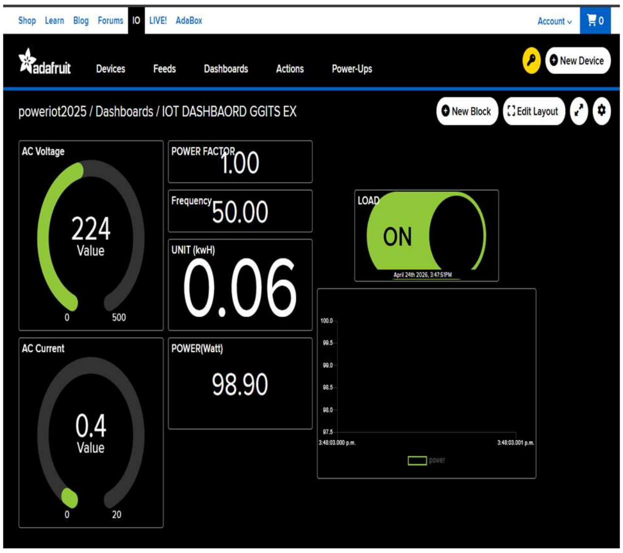


VII. WEB PAGE

The proposed system displays load energy usage in terms of watts. Users can access this information from any location using an internet connection.

ThingSpeak is a web platform that uses MATLAB analytics from MathWorks to analyze and present device data with detailed visualization. It allows users to create multiple channels under a single account, and each channel can store data in up to eight fields.

An account can represent a specific area or division, while multiple channels can be created for different energy meters within that location. The analytics can be accessed by both consumers and service providers.



VII. PROBLEM STATEMENT

The conventional methods such as SMS-based monitoring are relatively expensive. In comparison, IoT-based systems provide a more cost-effective solution for monitoring energy usage.

The system generates daily consumption reports that can be viewed through an Android application or a web portal. It collects accurate readings directly from energy-consuming devices and allows real-time monitoring through mobile and online platforms.

Human intervention is minimized as all data is automatically stored in a central server. This improves reliability and reduces manual errors. The communication process is secured, which helps in detecting issues such as meter tampering or electricity theft.

In case of a system error, incorrect values are not updated in the central database. Since all data is stored centrally, reports can be accessed from any location. The server remains active continuously, ensuring 24×7 availability.

CONCLUSION

The project "IoT-Based Power Monitoring and Control System using ESP32" successfully integrates embedded systems, IoT, and power measurement into a low-cost and efficient solution.

It provides real-time monitoring of voltage, current, power, power factor, and energy using the PZEM-004T sensor with good accuracy. Data is sent to the Adafruit IO cloud using MQTT, enabling remote access through internet-connected devices.

An OLED display shows live readings locally, while relay modules allow remote control of AC loads. The system works in both online and offline modes and was tested for stable operation over long periods. The PCB was designed using KiCad and fabricated at low cost, making the system easy to reproduce.

The project demonstrates practical skills in embedded programming, IoT communication, PCB design, and hardware testing, and shows how such systems can improve energy monitoring and control.

References

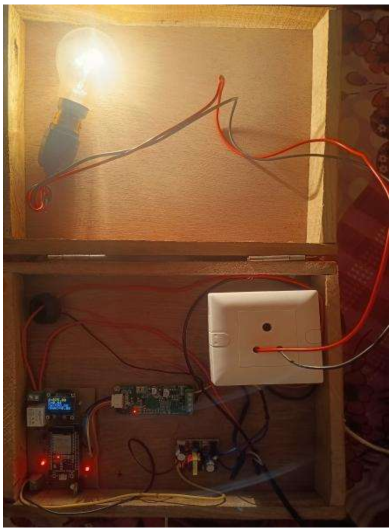
A. Software and Tools

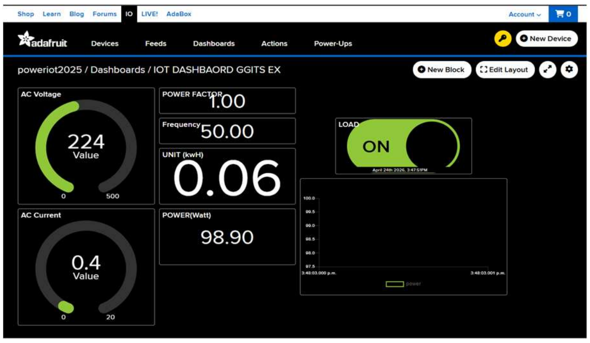
1. Espressif Systems, *ESP32 Technical Reference Manual*, Espressif, 2023.
2.ArduinoIDE– https://www.arduino.cc/en/software
3. KiCad EDA – https://www.kicad.org
4. Adafruit IO – https://io.adafruit.com
5. MQTT Protocol Specification, OASIS Standard, https://mqtt.org

B. Libraries and APIs

6. Adafruit MQTT Library for Arduino, GitHub Repository, https://github.com/adafruit/Adafruit_MQTT_Library
7. Adafruit SSD1306 OLED Library – https://github.com/adafruit/Adafruit_SSD1306
8. AdafruitGFXCoreLibrary- https://github.com/adafruit/Adafruit-GFX-Library
9. PZEM-004T Arduino Library, GitHub – https://github.com/mandulaj/PZEM-004T-v30

9. Final Remarks





The design and implementation of this IoT power monitoring and control system show how embedded microcontrollers can convert traditional electrical measurement into a connected and user-friendly system.The project meets academic requirements and provides a basis for smart energy management, IoT-based industrial control, and renewable energy applications. It combines electronics, computer networks, power systems, and software to deliver a practical solution for efficient energy usage.

