IOT -BASED ENERGY CONSUMPTION ANALYZER FOR SMART ENERGY MONITORING AND MANAGEMENT

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Abstract : The IoT-Based Energy Consumption Analyzer is a tool that helps people see how much electricity they are using in real time. It measures things like voltage, current, power and energy consumption using sensors. The information it collects is sent to a computer and then to a cloud platform using Wi-Fi. People can check how energy they are using from anywhere using a website or a phone app. This system gives people updates all the time. It helps people find out where they are wasting energy and how they can use less. The system we are talking about is not expensive it works well. It is easy to set up. It helps people and Companies use energy in a way. It also helps the earth by saving energy.

Keywords: IoT, Energy Consumption Analyzer, Energy Monitoring, Smart Energy, Power Management.

INTRODUCTION

People are using more electricity, so there is a need to find better ways to use it wisely. Monitoring energy consumption is important to reduce energy wastage and save money. Traditional electricity meters only show the total amount of energy consumed, making it difficult to identify which devices or activities consume the most energy.

The Internet of Things (IoT) has changed the way energy consumption is monitored. It allows data to be collected in real time, accessed from anywhere, and analyzed efficiently. IoT-Based Energy Consumption Analyzers allow users to track their energy usage remotely. They can monitor voltage, current, power, and energy consumption. This makes it easier for users to understand their energy usage and make better decisions.

This project presents an IoT-Based Energy Consumption Analyzer that continuously monitors energy usage. It uses sensors and a small computer with Wi-Fi connectivity to send collected data to a cloud platform. Users can view the data through a website or mobile application and monitor their energy consumption in real time. The system helps users identify high energy consumption, observe usage patterns, and reduce overall energy wastage.

The system also helps users understand their energy consumption patterns. By analyzing energy usage data, users can identify devices that consume more energy, use electricity wisely, and reduce unnecessary wastage. In the future, the system can be enhanced to predict energy consumption, integrate with smart devices, and provide energy-saving recommendations. These features can make the system useful for homes and smart grids.The proposed system is cost-effective, efficient, and suitable for homes, commercial buildings, and industries. It helps users manage energy efficiently, reduce electricity wastage, and contribute to environmental sustainability.

II. RESEARCH WORK

One study, “A Method for Detecting High-Risk Electricity Theft,” developed an IoT-based system to detect electricity theft. It uses real-time data and algorithms to identify anomalies in electricity consumption. However, the system requires high-quality data and may face difficulties in detecting new consumption patterns.

Another study, “A Machine Learning-Powered Energy Consumption Prediction System with API,” developed a system to predict energy consumption using machine learning. The system uses historical data and provides effective predictions. However, it is not directly connected to IoT devices and requires a large amount of data.

The study “Implementation of Real-Time Optimal Load Scheduling for IoT-Based Smart Energy Management System” developed an energy management system using sensors and smart plugs to schedule energy usage. However, the system has certain limitations and depends on user requirements.

The study “Development of Intelligent Smart Energy Monitoring Systems for Renewable Energy Source Using Proteus-8” developed an energy monitoring system using Arduino and Raspberry Pi. The system monitors energy consumption but may face challenges related to communication and scalability.

These studies show that existing systems can monitor and manage energy consumption. However, they have limitations such as high cost, limited efficiency, and difficulties in real-time monitoring. The proposed IoT-Based Energy Consumption Analyzer is simple, cost-effective, and cloud-connected. It enables users to monitor energy consumption in real time and manage energy efficiently.

III. PROPOSED METHODOLOGY

The proposed IoT-Based Energy Consumption Analyzer is designed to monitor the electrical parameters of connected appliances in real time. The system uses a ZMPT101B voltage sensor to measure the supply voltage and an ACS712 current sensor to measure the current flowing through the connected load. The sensor readings are sent to the ESP32 microcontroller for processing.

The ESP32 processes the sensor data and calculates electrical parameters such as voltage, current, power, and energy consumption. The ESP32 has built-in Wi-Fi connectivity, which enables the system to connect to the Blynk Cloud and transmit the monitored data through the Internet.

The calculated values are displayed on a 16×2 LCD for local monitoring. The same data can also be viewed through the Blynk mobile application, allowing users to monitor energy consumption remotely from anywhere. A 5 V DC power supply is used to provide stable power to the system components.

When a load is connected to the system, the voltage and current sensors continuously measure the electrical parameters. The collected sensor data is processed by the ESP32 and transmitted to the Blynk Cloud using its built-in Wi-Fi connectivity. This enables real-time and convenient monitoring of electricity usage through a mobile device.

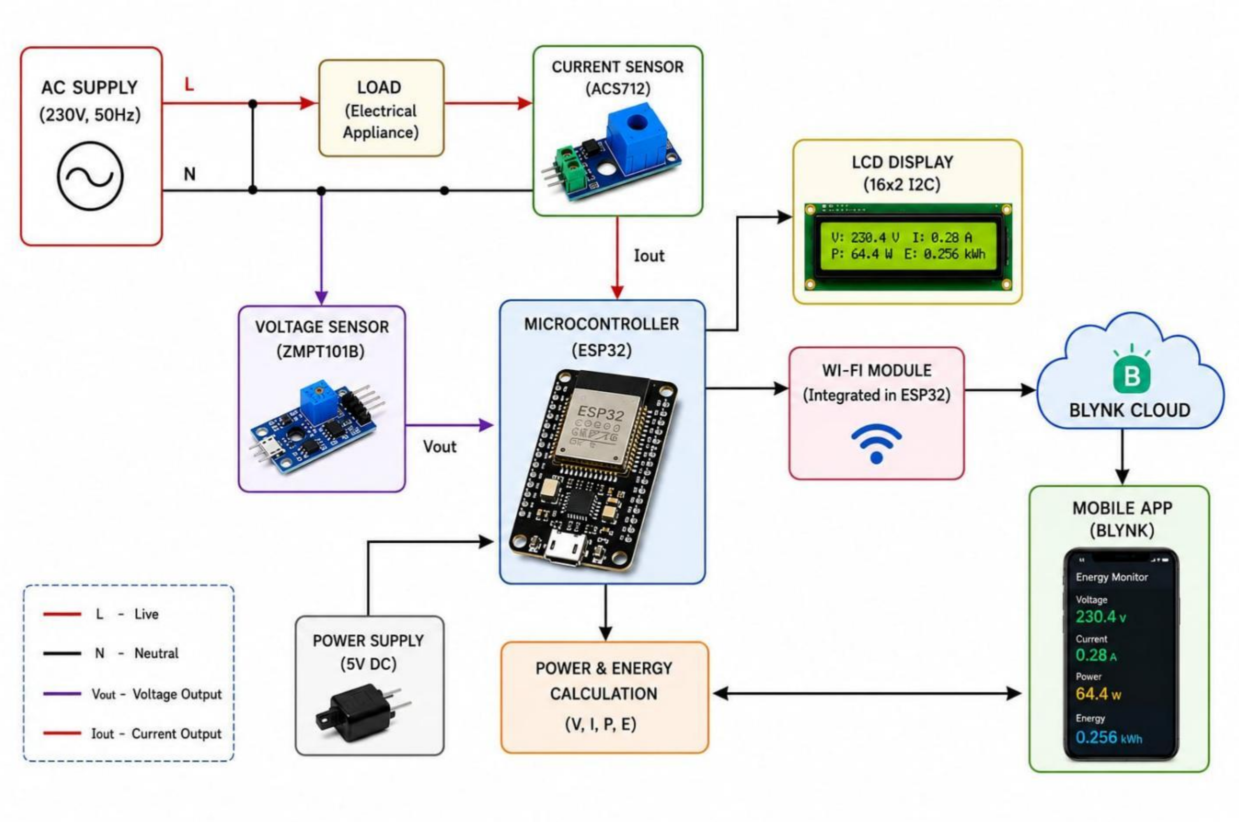

Fig -1: System Architecture of the Proposed IoT Based Smart Energy Consumption Analyzer.

3.1 Hardware Components

ESP32 Microcontroller: The ESP32 acts as the main processing unit of the system. It collects sensor data, processes the readings, calculates electrical parameters, and transmits the data to the Blynk IoT platform using its built-in Wi-Fi connectivity.
ZMPT101B Voltage Sensor: The ZMPT101B voltage sensor is used to measure the AC supply voltage. The measured voltage signal is provided to the ESP32 for further processing.
ACS712 Current Sensor: The ACS712 current sensor measures the current flowing through the connected electrical load and sends the measured data to the ESP32.
16×2 LCD Display (I2C): The LCD displays the real-time values of voltage, current, power, and energy consumption for local monitoring.
5 V DC Power Supply: The 5 V DC power supply provides the required power to the system components and ensures stable operation.
Electrical Load (Appliance): The electrical load is the appliance whose energy consumption is monitored, such as a bulb, fan, or charger.
230 V AC Power Supply: The 230 V AC supply acts as the main electrical source for the connected load.
Connecting Wires and Breadboard/PCB: Connecting wires and a breadboard or PCB are used to establish the required electrical connections between the hardware components.

3.2 Software Platform

Arduino IDE: Arduino IDE is used to write, edit, compile, and upload the program to the ESP32 microcontroller. It provides a simple development environment for programming and testing the system.
Blynk IoT Platform: The Blynk IoT platform is used to transmit and manage sensor data through the Internet. It enables communication between the ESP32 and the Blynk mobile application.
Blynk Mobile Application: The Blynk mobile application displays real-time values of voltage, current, power, and energy consumption on a smartphone. It allows users to monitor the system remotely through an Internet connection.

ESP32 Board Package: The ESP32 board package is installed in the Arduino IDE to support programming, compiling, and uploading code to the ESP32 development board.
Arduino Libraries: Libraries such as Blynk, Wire, LiquidCrystal_I2C, and WiFi are used for LCD communication, Wi-Fi connectivity, and data transmission to the Blynk IoT platform.

3.3 Working Principle

The IoT-Based Energy Consumption Analyzer continuously measures the voltage and current of a connected electrical appliance. The ZMPT101B voltage sensor measures the AC supply voltage, while the ACS712 current sensor measures the current drawn by the load. The measured values are sent to the ESP32 microcontroller for processing.
The ESP32 processes the sensor readings and calculates power and energy consumption. The calculated values are displayed on the 16×2 LCD for local monitoring. Simultaneously, the ESP32 transmits the monitored data to the Blynk Cloud using its built-in Wi-Fi connectivity.
Users can view the real-time readings through the Blynk mobile application from any location with Internet access. This enables continuous monitoring of electricity usage and helps users understand the energy consumption of connected appliances.

3.4 Algorithm

- Start the system and initialize the ESP32, ZMPT101B voltage sensor, ACS712 current sensor, 16×2 LCD display, Wi-Fi connection, and Blynk IoT platform.
- Check whether the Wi-Fi connection is established. If connected, proceed to the next step. Otherwise, attempt to reconnect.
- Read the voltage value from the ZMPT101B voltage sensor.
- Read the current value from the ACS712 current sensor.
- Validate the sensor readings. If the readings are invalid, discard them and read the sensors again.
- Calculate electrical power using: **Power = Voltage × Current**.
- Calculate energy consumption using the measured power and operating time: **Energy = Power × Time**.
- Display voltage, current, power, and energy consumption on the 16×2 LCD.
- Send the measured data to the Blynk Cloud through the ESP32 Wi-Fi connection.
- Check whether the data is uploaded successfully. If successful, display the live readings on the Blynk mobile application.
- Check whether the system power supply is ON. If ON, repeat the sensing and monitoring process continuously.
- If the power supply is OFF, stop the system.

IV. IMPLEMENTATION

After finalizing the system architecture, the hardware components were connected and tested individually before integrating them into a complete system. The ESP32 was programmed using the Arduino IDE, and all sensor readings were verified through the LCD display and the Blynk mobile application.

4.1 Voltage Measurement Module

The ZMPT101B voltage sensor is connected across the AC supply to measure the input voltage. The ESP32 reads the sensor output, converts it into the actual voltage value, and displays it on the LCD while also sending it to the Blynk application.

4.2 Current Measurement Module

The ACS712 current sensor is connected in series with the electrical load to measure the current flowing through the appliance. The ESP32 processes the sensor output and continuously updates the current value on both the LCD and the Blynk dashboard.

4.3 Power and Energy Calculation Module

The ESP32 calculates power using the measured voltage and current values and continuously computes the total energy consumed over time. These calculated values are updated in real time for monitoring.

4.4 LCD Display Module

A 16×2 I2C LCD is used to display the real-time voltage, current, power, and energy values. This allows users to monitor the system locally without requiring a mobile device.

4.5 IoT Monitoring Module

The ESP32 uses its built-in Wi-Fi to transmit the measured data to the Blynk Cloud. The Blynk mobile application displays live readings, allowing users to monitor energy consumption remotely from anywhere with an internet connection.

4.6 System Integration and Prototype

All hardware modules were integrated into a single prototype and tested under different electrical loads. The system successfully measured voltage, current, power, and energy consumption while displaying the readings on the LCD and the Blynk mobile application in real time.

RESULTS AND DISCUSSION

The voltage sensor and current sensor responded correctly, and the ESP32 successfully processed the collected data. Different electrical loads, such as a mobile charger and an LED bulb, were connected to observe changes in voltage, current, power, and energy consumption. The values displayed on the LCD matched the readings shown in the Blynk mobile application, with only a slight delay caused by internet communication .The results show that the proposed Energy Consumption Analyzer is capable of monitoring electricity usage accurately in real time and can help users manage energy consumption more effectively.

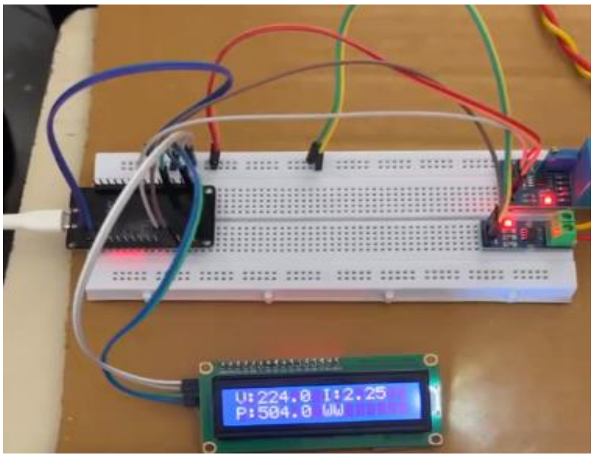

Fig-2: Hardware Prototype.

Fig-3: Energy Consumption Progress Report

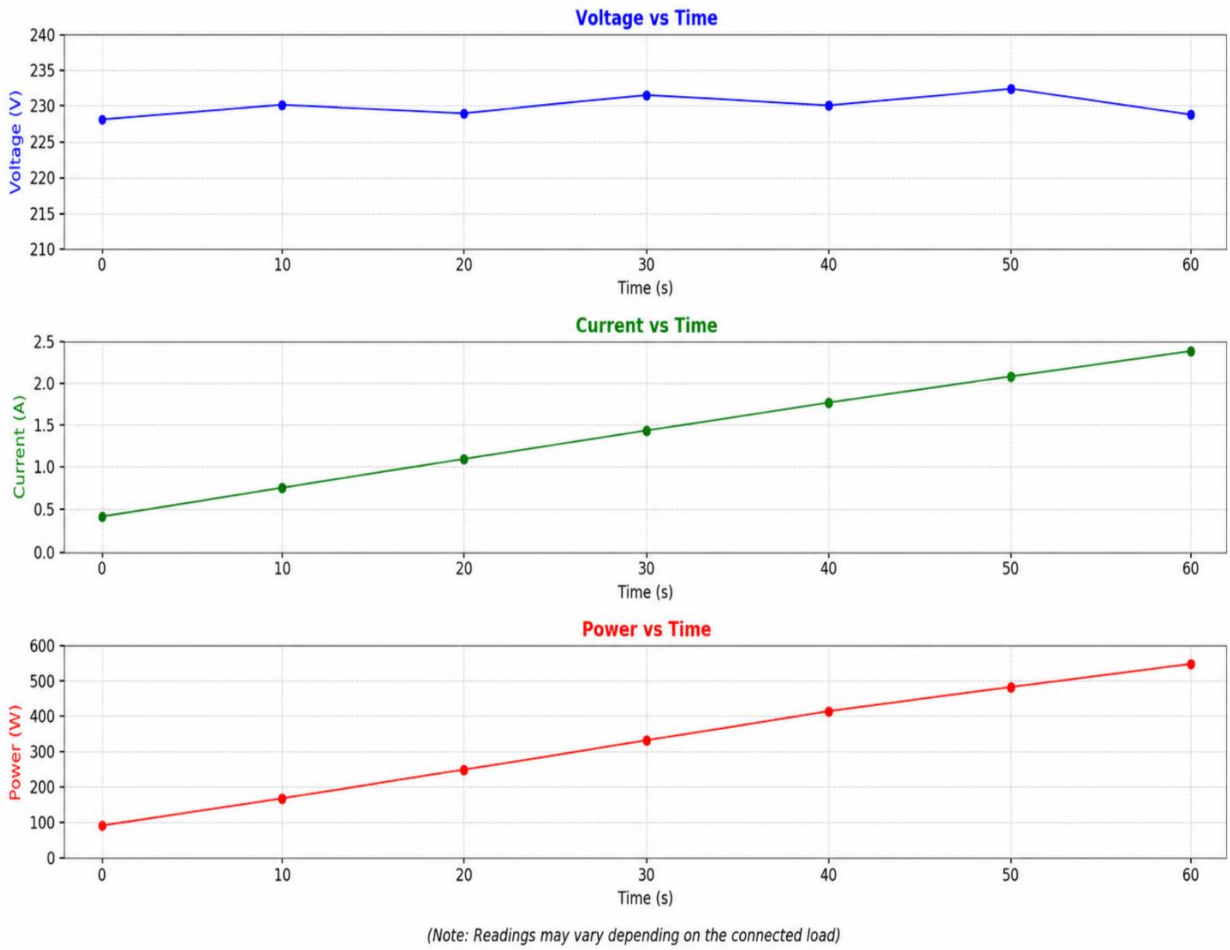

Fig-4: Real-Time Voltage, Current, and Power Measurements

Table -1: Functional Testing Summary

Module	Test Condition	Observed Behaviour	Result
Voltage Sensor	AC supply connected	Voltage measured and displayed correctly	Pass

Current Sensor	Electrical load connected	Current changed according to connected load	Pass
ESP32 Controller	Sensor data received	Power and enerrgy calculated successfully	Pass
LCD Display	System operating	Live reading displayed correctly	Pass
Wi-Fi Communication	Internet connecteed	Data uploaded to Blynk cloud	Pass
Blynk Dashboard	Mobile app opened	Real-time values updated	Pass
Compleet System	Different loads tested	Accurate energy monitoring achieved	Pass

CONCLUSION

The proposed Energy Consumption Analyzer provides a simple and effective way to monitor electrical parameters in real time. By using the ESP32 along with the ZMPT101B voltage sensor and ACS712 current sensor, the system accurately measures voltage, current, power, and energy consumption. The measured values are displayed on the LCD and are also available through the Blynk mobile application for remote monitoring. The system is affordable, easy to use, and suitable for a wide range of applications, including homes, offices, laboratories, and small industries. It encourages efficient energy usage and offers a strong foundation for future smart energy management solutions.

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