iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: III Month of publication: March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67386

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

IoT-Enabled Energy Meter for Smart Home Monitoring and Control

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Abstract: This research introduces an IoT enabled energy meter that facilitates intelligent monitoring of household appliances, permitting users to observe and regulate their energy usage in real-time. The system employs an Arduino Uno microcontroller for data processing, alongside sensors such as the voltage sensor (ZMPT101B) and the current sensor (ACS712) to detect AC voltage and current flow, delivering precise and comprehensive power usage statistics for each device. The data is subsequently communicated through NodeMCU, a WiFi-enabled microcontroller, utilising IoT connectivity to a mobile or web application, thereby providing customers with convenient access to monitor household power use and remotely operate their appliances. This method conserves energy, diminishes power expenses, and facilitates automatic management of idle equipment, hence enhancing energy efficiency in smart homes.
Keywords: Arduino Uno NodeMCU, Voltage Sensor (ZMPT101B), Current Sensor (ACS712), Relays, Power Supply Unit

I. INTRODUCTION

With the growing demand for energy efficiency and smart home automation, the need for an intelligent energy monitoring system has become essential. Traditional energy meters provide cumulative energy consumption data but lack real-time monitoring and remote control capabilities. This limitation makes it challenging for users to track and manage their electricity usage effectively, often leading to unnecessary power wastage and higher electricity bills.

To address this issue, this project presents an IoT-based Smart Energy Meter that enables real-time monitoring and control of home appliances. The system is designed to provide users with accurate power usage insights, allowing them to optimize energy consumption and reduce electricity costs. By leveraging IoT technology, the system connects household appliances to a cloud-based platform, enabling remote access via a mobile or web application.

The proposed system utilizes an Arduino Uno microcontroller for data processing, along with voltage and current sensors (ZMPT101B and ACS712) to measure power consumption precisely. The NodeMCU (ESP8266) module facilitates Wi-Fi connectivity, ensuring seamless data transmission to the IoT platform. Users can monitor power usage in real-time and remotely control appliances, enabling automated power management and preventing energy wastage.

This smart energy meter aims to enhance energy efficiency in homes by providing users with greater control over their power consumption. By integrating IoT technology with smart monitoring and control features, the system promotes sustainable energy usage while offering convenience and cost savings to users.

II. EXISTING SYSTEM

The existing systems rely on manual monitoring of power consumption, which requires users to check their energy usage periodically and manage appliances accordingly. Recently, some studies have introduced IoT for monitoring power consumption in household appliances, offering enhanced real time tracking of energy usage.

III. PROPOSED SYSTEM

The proposed system integrates IoT technology for both real-time monitoring and remote control of household appliances. Using sensors like ZMPT101B for voltage measurement and ACS712 for current measurement, the system provides detailed energy consumption data. Additionally, the inclusion of a NodeMCU module enables users to control appliances remotely through a mobile or web app, allowing them to switch off power-hungry devices. This system not only helps in saving energy but also supports automated energy management, ensuring efficiency and cost-effectiveness in smart homes..

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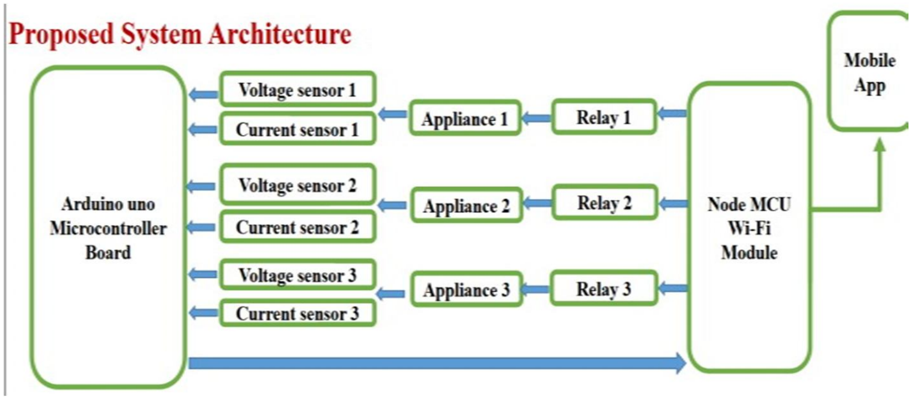

Fig.1. Architecture

IV. COMPONENTS USED AND DESCRIPTION

A. Arduino UNO

The ESP-12E module, which houses the ESP8266 chip with Tensilica Xtensa 32-bit LX106 RISC CPU, is included with the NodeMCU ESP8266 development board. This microprocessor runs at a configurable clock frequency of 80MHz to 160MHz and supports RTOS. To store information and applications, the NodeMCU features 4MB of Flash memory and 128 KB of RAM. It is perfect for Internet of Things applications because of its powerful processing capacity, built-in Wi-Fi and Bluetooth, and Deep Sleep Operating capabilities.

Fig.2. Arduino UNO

B. Power Supply

Either an external power source or a USB cable can be used to power the Arduino Uno. An AC to DC converter is the most common external power source; batteries are sometimes used. The adapter can be connected to the Arduino Uno by plugging into the power jack of the Arduino board. The Vin and GND pins of the POWER connector can also be used to connect the battery leads. Seven to twelve volts is the recommended voltage range.

C. Voltage Sensor (ZMPT101B)

The high-precision ZMPT101B voltage transformer makes the ADIY ZMPT101B AC Single Phase voltage sensor module ideal for DIY projects that require accurate

AC voltage readings. This sensor module's excellent galvanic isolation, wide range, and precision make it ideal for Arduino, ESP8266, Raspberry Pi, and other open-source platforms.

Fig.3. Voltage Sensor (ZMPT101B)

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D. Current Sensor (ACS712)

The 20A Range Current Sensor Module ACS712 has an accurate, low-offset linear Hall circuit with a copper conduction route near the die. Applied current through this copper conduction route creates a magnetic field that the Hall IC transforms into proportional voltage.

Current flow sensing and control are essential in over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, and more..

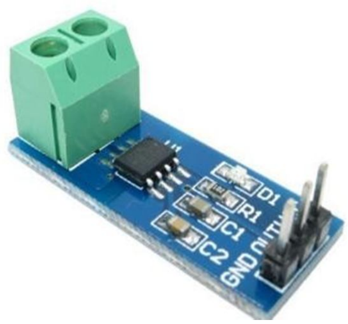

Fig.4. Current Sensor (ACS712)

E. LCD Display

In pipeline monitoring systems, LCDs (Liquid Crystal Displays) are frequently used to give visual feedback on system status. By showing data including sensor readings, alarms, and diagnostic messages, operators may quickly evaluate the pipeline network's condition.

Fig.6. LCD Display

F. BLYNK APP

Blynk is an IoT platform designed to make it easier to create web and mobile apps for the Internet of Things. In only five minutes, link more than 400 hardware models, including Arduino, ESP8266, ESP32, Raspberry Pi, and other comparable MCUs, and create drag-anddrop IOT mobile apps for iOS and Android.

Fig.7. Blynk App

V. WORKING

The proposed system operates based on the following step-by-step process:

A. Energy Measurement using Sensors

The system employs ZMPT101B voltage sensors and ACS712 current sensors to measure the voltage and current consumption of connected appliances.

These sensors provide real-time data, which is processed by the Arduino Uno microcontroller.

B. Data Processing by Arduino Uno

The Arduino Uno receives input signals from the voltage and current sensors.
It calculates power consumption using the formula: P=V×IP = V \times IP=V×I
The processed data is then sent to the

C. NodeMCU (ESP8266 Wi-Fi module) for

IoT connectivity.

D. IoT Connectivity with NodeMCU

The NodeMCU module acts as a bridge between the Arduino and a cloud-based platform or mobile application. It transmits the measured power consumption data to an IoT server via WiFi, making it accessible to users remotely.

E. Remote Monitoring and Control

Users can access real-time energy consumption data through a mobile app or web dashboard.
The app displays the power usage of each appliance, allowing users to analyze their energy consumption patterns.
The system also provides the option to remotely switch ON/OFF appliances using relays controlled via the mobile app.

F. Automated Energy Management

The system can be programmed to automatically turn off idle or highpower-consuming devices, preventing energy wastage.
Alerts and notifications can be sent to users when certain appliances exceed predefined power limits.

G. Energy Efficiency and Cost Reduction

By continuously monitoring power usage and controlling appliances remotely, the system helps reduce electricity bills.
It promotes energy-efficient smart homes by preventing unnecessary power consumption.
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VI. RESULTS

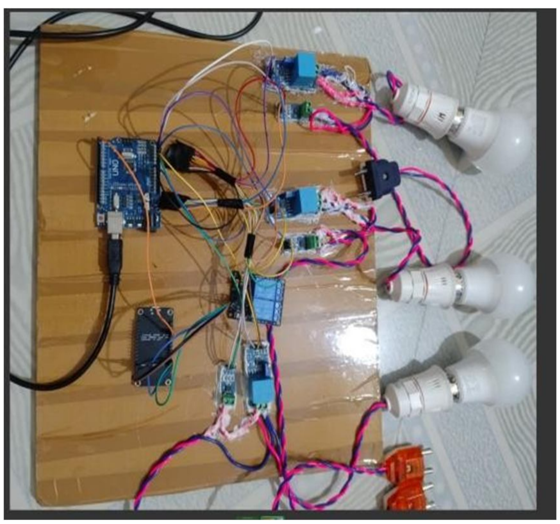

Fig 8: Developed system

The developed proposed system is shown in Figure 8, demonstrating its capability for real-time monitoring and remote control of household appliances. The system accurately measures voltage and current using ZMPT101B and ACS712 sensors, with data processed by the Arduino Uno and transmitted via NodeMCU (ESP8266) to a cloud-based platform. The Blynk mobile app successfully displays live energy consumption data, allowing users to remotely control appliances with minimal latency. The relay module responds efficiently to user commands, enabling seamless IoT integration. Automated power management features reduce unnecessary energy consumption by triggering alerts when power thresholds are exceeded.

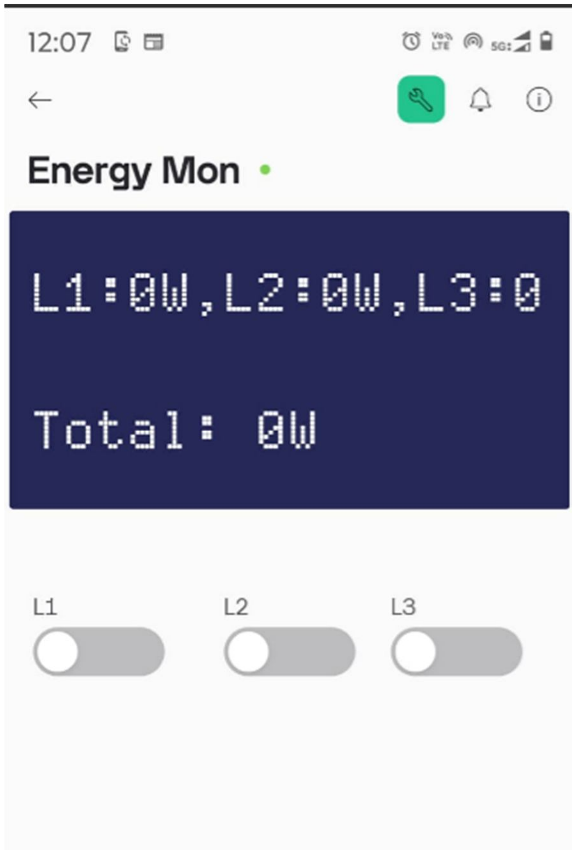

Fig 9: Remote control Appliance

This is the user interface integrated in Blynk IoT app. The User access the appliance from Remote location. We can control the appliance from remote location. In above fig the three appliance are in rest state with consuming 0W.

VII. CONCLUSION

The IoT-based Energy Meter with Smart Monitoring and Control of Home Appliances provides an efficient solution for real-time energy management. By integrating Arduino Uno, voltage and current sensors, NodeMCU (ESP8266), and IoT technology, the system enables users to monitor power consumption remotely and control appliances via a mobile application.

This system not only helps in reducing electricity costs by preventing unnecessary power usage but also contributes to energy efficiency and sustainability in smart homes. The ability to automate the control of appliances ensures optimized energy consumption, reducing environmental impact.

Overall, the proposed system offers a costeffective, user-friendly, and scalable approach to smart energy management, making it a valuable addition to modern smart homes and IoT-driven energy solutions.

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