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# IOT BASED SMART ENERGY METER USING CLOUD COMPUTING

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**Abstract:** The growing global demand for electricity, driven by industrial development and the proliferation of energy-intensive electronic devices, has placed increasing stress on conventional power grids. This review explores the transformative role of Internet of Things (IoT)-based smart energy meters integrated with cloud computing in advancing modern energy management systems. These technologies enable real-time monitoring, automated billing, remote load control, and outage detection, facilitating efficient energy utilization and the integration of Distributed Energy Resources (DERs) such as solar and wind power. Studies report that IoT-based implementations can achieve energy savings of up to 49%, improve grid reliability, and enhance consumer engagement through mobile applications and wireless sensor networks. Despite their advantages, challenges related to data security, interoperability, and scalability persist, limiting large-scale deployment. The convergence of IoT, cloud platforms, and advanced analytics presents a sustainable and intelligent framework for future energy systems, promoting optimized power distribution, reduced operational costs, and greater energy resilience.

**Keywords: IoT-based Smart Energy Meter, Cloud Computing, Smart Grid, Distributed Energy Resources (DERs), Real-time Monitoring, Demand-side Management, Energy Optimization, Automated Billing.**

## I. INTRODUCTION

The global surge in electricity demand, fueled by the proliferation of energy-intensive household appliances and rapid industrial growth, has exposed the limitations of conventional power grids in maintaining energy balance, power quality, and cost-efficiency [1], [2]. Traditional energy systems, characterized by manual meter readings, two-way communication, and limited monitoring capabilities, are increasingly unable to cope with the dynamic and complex nature of modern electricity consumption patterns. These constraints have driven the evolution of Smart infrastructures, which leverage the Internet of Things (IoT) and cloud computing technologies to enable real-time monitoring, predictive analytics, and intelligent energy management [3].

Recent advancements in Intelligent Energy Management Systems (IEMS), Wireless Sensor Networks (WSNs), and IoT-enabled Smart Meters (SMs) have significantly enhanced the capabilities of modern power networks [4]. These technologies support bidirectional communication between utilities and consumers, continuous monitoring of energy quality, and seamless integration of Distributed Energy Resources (DERs) such as solar and wind energy. Studies report energy savings ranging from 15% to 49% when IoT-based energy management systems are deployed in diverse applications [5].

This review critically examines existing research on IoT-enabled, highlighting their effectiveness in optimizing energy use, enhancing operational efficiency, and reducing costs [6]. Conventional power systems often lack the automation, data analytics, and responsiveness required for real-time energy optimization, leading to frequent outages, energy losses, and increased operational expenses [7]. By contrast, IoT-based smart grids offer automated demand-side management, real-time data acquisition, and intelligent DER integration, improving energy efficiency, user engagement [8].

The convergence of IoT, cloud platforms, and advanced analytics is poised to transform energy management, providing predictive insights, actionable control, and scalable solutions for future power systems [9]. Nevertheless, challenges such as data security, interoperability, and system scalability remain, emphasizing the need for further research in AI-driven analytics, edge computing, and blockchain-based security frameworks to fully realize the potential of smart grid infrastructures [10].

## II. RESEARCH BACKGROUND

The rapid increase in global electricity consumption, driven by industrial expansion and the widespread adoption of energy-intensive devices, has created significant challenges for traditional power grids. Conventional energy systems rely on manual meter readings, limited monitoring capabilities, and one-way communication between consumers and utilities, resulting in inefficient energy distribution, higher operational costs, and reduced reliability [1], [2]. To address these limitations, researchers have increasingly focused on integrating Internet of Things (IoT) technologies with cloud computing platforms, giving rise to smart energy meters capable of real-time monitoring, automated control, and predictive energy management [3], [4].

IoT-based smart energy meters offer a transformative approach to energy management by enabling continuous data collection, remote access, and analytics-driven decision-making. These systems facilitate bidirectional communication between utilities and consumers, allowing for dynamic load control, outage notifications, and improved demand-side management [5], [6]. The integration of cloud computing further enhances the scalability, storage, and processing capabilities of these meters, enabling advanced features such as predictive analytics and long-term energy consumption forecasting [5], [7].

Several implementations have demonstrated tangible benefits. For instance, Mehmet Güçyetmez and Husham Sakeen Farhan [5] employed time-series prediction to improve energy forecasting accuracy, while D. Adinarayana Naik et al. [6] implemented cloud-based smart meters to enhance real-time monitoring and energy optimization in grid systems. Similarly, Saleem et al. [7] showed that IoT-cloud integration improves demand-side management, peak load reduction, and grid stability, emphasizing the potential of these systems for large-scale deployment.

Despite these advancements, challenges remain. Issues such as data security, interoperability, and scalability persist, particularly when integrating heterogeneous devices and Distributed Energy Resources (DERs) like solar and wind energy [8], [9], [10]. Moreover, most reported implementations are limited to residential or small-scale pilot projects, highlighting the need for robust architectures that can handle high data volumes, low latency requirements, and industrial-scale deployments.

## III. METHODOLOGY

The proposed method presents an IoT-based smart energy monitoring system that enables real-time tracking and management of electricity usage. A sub-meter is employed to measure power consumption, and its readings are interfaced with the NodeMCU (ESP8266) microcontroller. Users can access the real-time energy data through the Blynk mobile application, which displays parameters such as energy consumption, load status, and environmental conditions. Additionally, the system provides remote control features, allowing users to manage connected loads directly from the app.

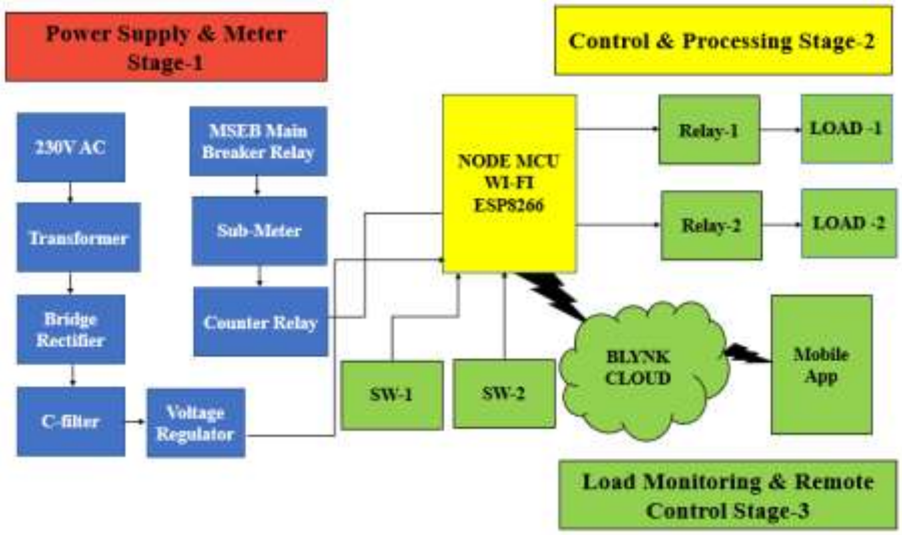


Fig.1: Block diagram

This stage handles the conversion of raw AC power and energy measurement. The 230V AC input is first stepped down using a transformer and converted to DC using a bridge rectifier and capacitor filter. A voltage regulator ensures stable voltage is supplied to the control circuitry. Meanwhile, an MSEB main breaker relay connects to a sub-meter, which records the power consumption. A counter relay is used to count the pulses representing energy units consumed. This stage is essential for safe and accurate energy data acquisition from the grid. The core of the system is the NodeMCU ESP8266 microcontroller, which receives signals from the sub-meter and counter relay. It processes this data and controls two relays (Relay-1 and Relay-2) that manage Load-1 and Load-2 respectively. Physical Switches (SW-1 and SW-2) are also connected for local manual control. The NodeMCU is responsible for sending and receiving data via Wi-Fi, making this the processing and decision-making hub of the system. This stage enables wireless monitoring and control using the Blynk Cloud platform and a mobile application. The processed data from the NodeMCU is uploaded to the cloud, allowing users to monitor real-time energy consumption and control loads remotely via the app. This enhances user convenience, allows load scheduling, and supports efficient energy management from any location.

**Flow chart**

This flowchart explains the working of an IoT-based smart sub-metering and load control system. The process begins with a 230V AC power supply, which is converted into a regulated 5V DC supply to power the NodeMCU (ESP8266) and associated components. The system is connected to the MSEB main breaker relay and a sub-meter, which continuously measures energy consumption. A counter relay connected to the sub-meter keeps track of the consumed units.

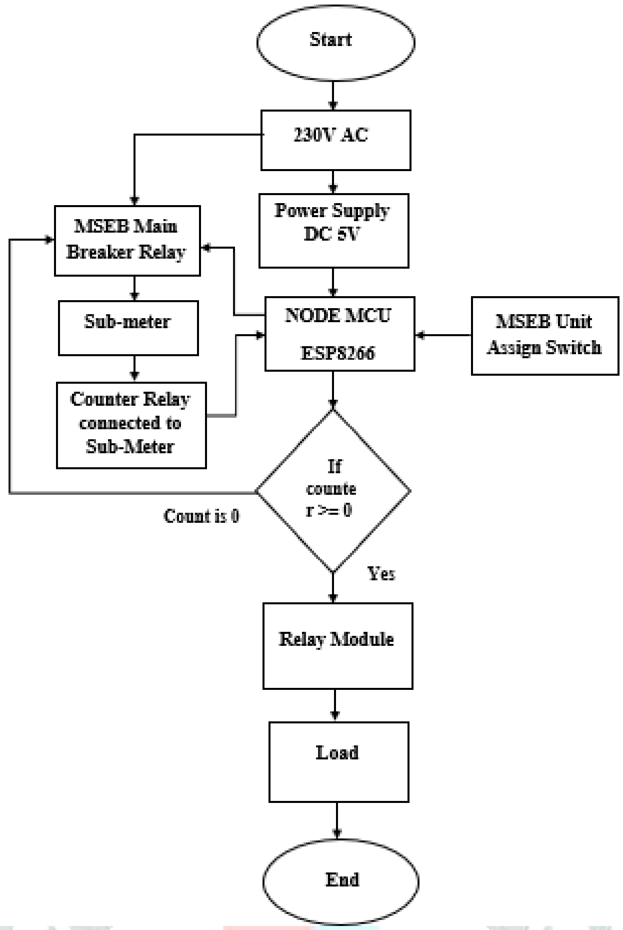


Fig.2: Flowchart of hardware

The NodeMCU receives input from the sub-meter and the MSEB unit assign switch**,** which defines the assigned energy quota. The controller then checks the counter value. If the counter is greater than or equal to zero, meaning sufficient units are available, the relay module is activated and the connected load operates normally. If the assigned units are exhausted (counter = 0), the system automatically cuts off the load by deactivating the relay, thereby preventing excess consumption. This ensures efficient monitoring and automated control of energy usage based on predefined unit allocations.

## Algorithm

- Start the system.
- Initialize components: Power supply, NodeMCU, sensors, relays, and Wi-Fi connection.
- Connect NodeMCU to the Wi-Fi network.
- Read pulses from the energy meter through Relay 1.
- Calculate energy consumption based on pulse count.
- Send consumption data to the Blynk cloud platform for real-time monitoring.
- Check if pulse count = 0 for a predefined time:
- If yes, activate Relay 2 to disconnect the energy meter supply.
- If no, continue monitoring.
- Check for user commands from the Blynk app:
- If received, control loads using Relay 3 (ON/OFF).
- Trigger send notification if abnormal conditions are detected.
- Repeat the cycle continuously for real-time operation.
- Stop if the system is manually shut down or reset.

## IV. RESULT & DISCUSSION

The system starts with a 230V AC power supply**,** which is the standard electrical voltage in household and industrial settings. This supply is essential for powering the loads (like bulbs or appliances) as well as the circuitry involved in monitoring and controlling the system. The 230V AC is passed through a step-down transformer to reduce the voltage to a safer level suitable for low-voltage electronics (like the ESP8266 and other modules). The reduced AC voltage is then sent to a bridge rectifier**,** which converts the alternating current (AC) to direct current (DC). This DC voltage is needed for operating the microcontroller and relay circuits. The rectified DC voltage is filtered using a capacitor to remove ripples and smooth the output. After that, a voltage regulator (e.g., LM7805) ensures a constant, regulated voltage 5V for powering the NodeMCU ESP8266 and other sensitive electronics. One relay module is used to control the connection of power from the main AC supply to the sub-meter**.** This allows the system to remotely enable or disable the energy supply going into the metering and monitoring unit. The sub-meter is used to measure the electrical parameters such as voltage and energy consumed. It acts as the core sensing device to track how much power the connected load is using. The sub-meter is connected to a counter relay which converts electrical pulses (representing energy units) into digital signals that the ESP8266 can count. Each pulse may represent a fixed energy unit (e.g., 1 unit per 1 pulses). This is the main controller that receives data from the counter relay, processes it, and sends it to the Blynk app over Wi-Fi. It also controls the relay module that switches the load ON or OFF. It plays the central role in cloud connectivity and automation. Another relay module is connected to the output side to control the load **(**e.g., lights, fans, etc.). This relay is triggered by the NodeMCU either automatically (based on load conditions) or manually via the Blynk app or physical switch. The load represents the appliances or devices powered by the smart meter system. The relay determines whether power is delivered to these devices or not. A physical switch is included to allow manual add reading of assigned meter. That two switches are indicate that MSEB when you recharge your device that accordingly meter reading assign. This switch is also connected to the NodeMCU, which can read its state and perform corresponding actions.

Fig.3: Unit not assign

In figure 3 shows that, we see the starting condition of the smart meter system using the Blynk app interface. The digital gauge at the top shows “0” units, which means no electricity units are currently available. When you assign unit, it will update on mobile application and then we can turn ON/OFF load accordingly. A submeter and a relay is counting submeter pulses and send to the microcontroller and read the pulses and update on cloud and it will show on mobile app. When you recharge device, it sends to the MSEB and MSEB press the switches and assign unit. And it will update on mobile app. we see the starting condition of the smart meter system using the Blynk app interface. The digital gauge at the top shows “0” units, which means no electricity units are currently available. that energy is being consumed the gauge has dropped to “2” units, meaning only 2 units are left. Still, both LOAD 1 and LOAD 2 remain ON. This shows that the system continues to supply power as long as units are available. Users can keep an eye on remaining units through the app and decide when to turn off any devices if needed.

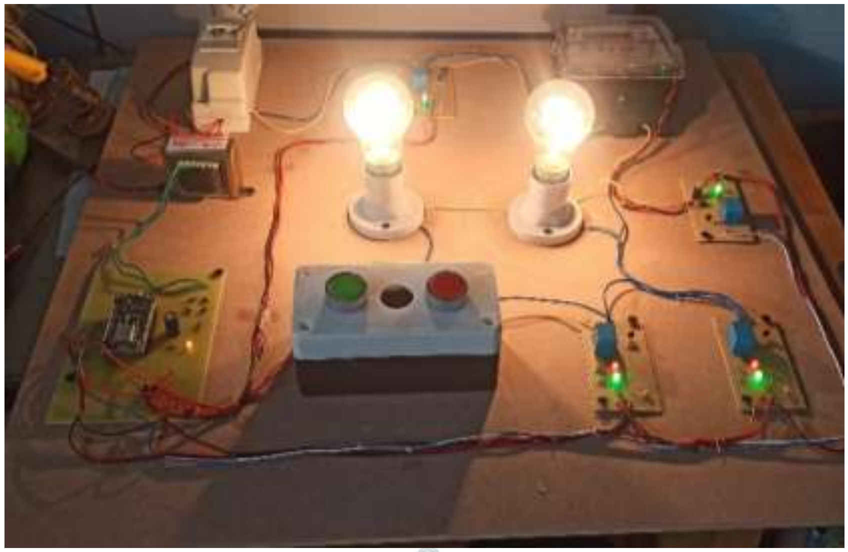

Fig.4: Final project

Finally, when the energy units run out completely, the main relay disconnects, and both loads are automatically turned OFF. The Blynk interface updates again to show "0" units, and both bulb icons disappear. The system won't allow any load to turn back on unless more units are added. Once the user recharges the system, new units are assigned, the main relay reconnects, and the loads can be turned ON again from the app.

This real-world a close-up of the hardware setup connected to the smart meter system. One bulb is glowing, indicating that either LOAD 1 or LOAD 2 has been activated. The relay modules, visible in the center of the setup, serve as electronic switches controlled via the ESP8266 (or similar microcontroller). The energy meter on the left measures the power being drawn, and the setup is powered using AC supply. This practical setup matches the first active-load scenario shown in the app. One of the bulbs is turned ON, which corresponds to a single load being active. The relay board is connected to switches and a controller, possibly an ESP8266 or NodeMCU, which receives commands from the Blynk cloud to control the relays. This setup represents how a remote digital signal can physically operate home appliances, making energy systems more efficient and controllable.

In below table we have given consumption of load combination with watt, time, unit and cost. As per MSEB bill calculator Electricity Unit Rate Breakdown (Residential):

- 0-100 units: ₹4.43 per unit
- 101-300 units: ₹9.64 per unit
- 301-500 units: ₹12.83 per unit

| Load Combination | Watt | Time | Unit / Day | Unit / Month | Cost / Month | Cost / Month System |
|---|---|---|---|---|---|---|
| Bulp | 200 W | 24 hr | 4.8 | 144 | 1388.16 | 1388.16 |
| Bulp + Fan | 350 W | 24 hr | 8.4 | 252 | 2429.28 | 2429.28 |
| Refrigerator + Bulp | 500 W | 24 hr | 12 | 360 | 3470.4 | 3470.4 |
| Fan + TV | 350 W | 24 hr | 8.4 | 252 | 2429.28 | 2429.28 |
| Refrigerator + Bulp + TV | 650 W | 24 hr | 15.6 | 468 | 4511.52 | 4511.52 |
| **Total** | | | **49.2** | **1476** | **14228.64** | **14228.64** |

Table No.1: Consumption of load combination

With the help of above load combination, we have concluded that per month consumption unit is 1476. In our house we required 84 unit per month is Rs.372.12.

We are taking 1 unit = 1 pulse in proposed system

So, Consider 1 pulse = 3200 Pulses

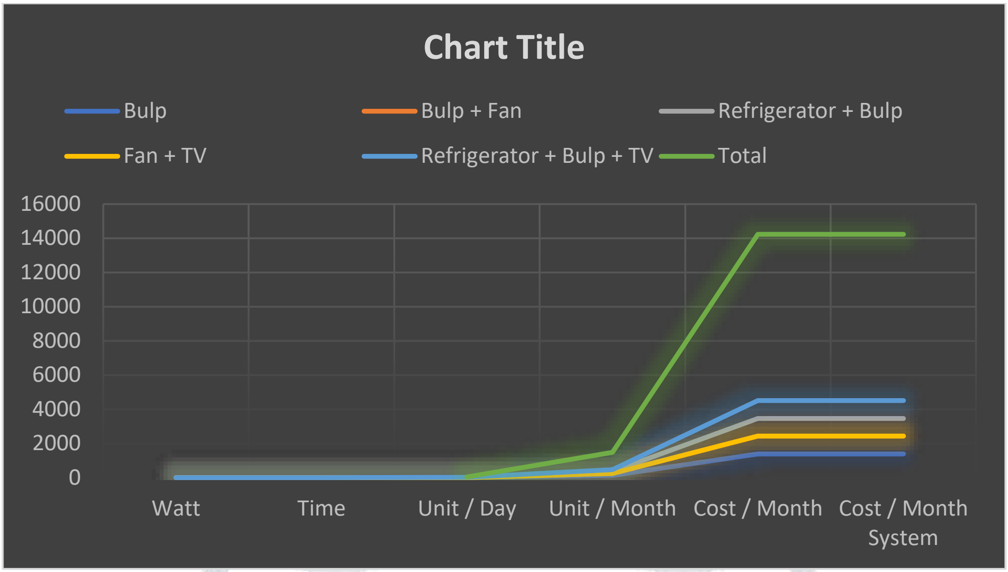


Fig.5: System cost & unit

## V. CONCLUSION

The developed smart energy metering system effectively combines hardware and IoT technologies to provide a reliable, user-friendly, and remotely accessible platform for energy monitoring and load management. The system operates on a 230V AC supply, which is safely converted and regulated through step-down transformation, rectification, filtering, and voltage regulation stages for microcontroller operation. At the core, the NodeMCU ESP8266 processes input from the energy meter, counts energy pulses via a counter relay, and communicates consumption data to the cloud through Wi-Fi connectivity. Through the Blynk application, users can visualize real-time energy consumption and control multiple loads (LOAD 1 and LOAD 2) remotely with a simple tap. The dual relay setup enables convenient switching of appliances, promoting both energy conservation and user convenience. The inclusion of a sub-meter ensures accurate monitoring, while manual switches and a digital interface enhance system functionality, usability, and safety. This project demonstrates the feasibility of transforming traditional energy meters into smart, cloud-connected systems. The successful hardware implementation and real-time synchronization with the Blynk interface validate the robustness and effectiveness of the design. In practical terms, for a household requiring 84 units per month with a bill of Rs. 372.12, the system can optimize energy consumption by allowing users to switch loads on or off via the mobile application as needed, saving both energy and operational effort. Moreover, the model can be extended in future developments to support prepaid metering, overload protection, fault alerts, and integration with renewable energy sources. Overall, this project provides a solid foundation for user-centric, data-driven smart grid innovations, highlighting the potential of IoT-enabled energy management for residential, commercial, and industrial applications.

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