

## **Next-Generation Smart Metering and Load Management via IoT**

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### **Abstract**

This paper presents an IoT-based Smart Energy Meter and Controller designed to enable real-time monitoring, analysis, and intelligent control of electrical energy consumption. The system integrates the PZEM004T sensor for precise measurement of voltage, current, power, and energy, ensuring accurate data acquisition. An ESP32 microcontroller serves as the central unit, offering built-in Wi-Fi connectivity for seamless transmission of data to cloud platforms and mobile applications. An LCD interface provides real-time display of consumption metrics for improved user awareness. The inclusion of a relay allows automated control of electrical loads based on predefined conditions, schedules, or remote instructions. Enhanced with features such as tamper detection, alert notifications, and historical data logging, the system supports efficient energy usage, enhances transparency, and promotes smart grid compatibility for residential and industrial applications.

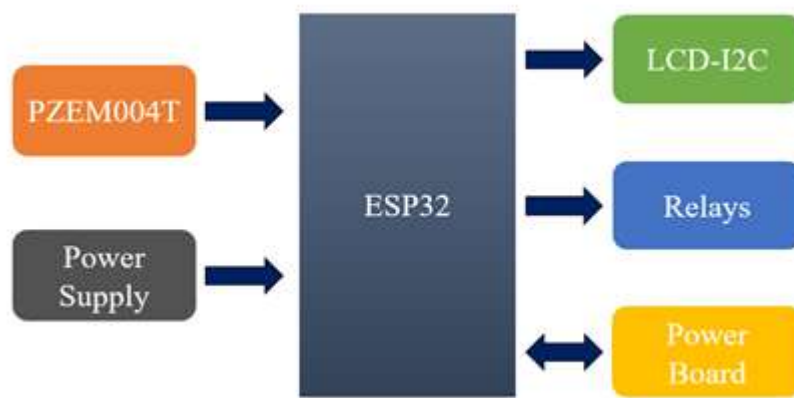
**Keywords:** IoT, Smart Energy meter, PZEM004T Sensor, ESP 32, LCD

### **1. Introduction**

Electric power systems play a crucial role in sustaining modern life by supplying energy to homes, industries, and public infrastructure. Conventional energy meters, however, are limited in scope, typically providing only cumulative energy usage data without offering insights into real-time consumption or control. With the rapid expansion of smart infrastructure and the growing need for efficient energy usage and remote supervision, advancements in embedded systems, sensor technologies, and wireless communication have become essential. The Internet of Things (IoT) has significantly enhanced power systems by enabling real-time monitoring, intelligent automation, and remote energy control. Smart energy meters now offer features like load monitoring, peak demand analysis, remote switching, and instant notifications.

At the heart of the system is the ESP32 microcontroller, which handles data processing, sensor interfacing, wireless communication, display control, and output actuation. Its dual-core processor, combined with built-in Wi-Fi and Bluetooth, allows for multitasking and stable performance. Real-time current sensing is achieved using the PZEM004T sensor based on the Hall-effect principle, ensuring safe and non-intrusive measurements. Voltage sensing is implemented through a voltage divider and conditioning circuit for accurate ADC input.

A 16x2 LCD connected via I2C provides live data display while reducing wiring complexity. A dual-channel relay module enables automated switching of loads based on sensor data, thresholds, and defined logic, supporting functions such as overload protection, scheduled operation, and remote shutdown.



**Figure 1:** Block diagram

## **2. Internet of Things**

The Internet of Things (IoT) refers to a network of smart physical devices embedded with sensors, software, and communication technologies that operate and exchange data without human intervention. These devices—ranging from home appliances and vehicles to industrial machines—can detect environmental changes and communicate in real time. Each device has a unique identity, enabling integration into broader systems. IoT supports automation, real-time monitoring, and data-driven decisions across sectors like healthcare, agriculture, industry, energy, and smart cities. Applications include remote diagnostics, precision farming, predictive maintenance, smart grids, and intelligent traffic systems. In homes, IoT enhances energy efficiency, security, and appliance control. Retailers benefit

from automated inventory and personalized marketing. Businesses use IoT data to improve operations and customer experience. Its scalable architecture allows easy device integration. Though challenges such as security and privacy persist, on-going advancements continue to expand IoT's role in building efficient, intelligent, and connected environments.

### **3. Smart Energy Meter & Controller**

The Internet of Things (IoT) refers to a network of physical devices embedded with sensors, software, and communication technologies, enabling them to collect, share, and process data without human involvement. These smart devices, including home appliances, vehicles, industrial equipment, and wearables, can respond to environmental inputs and communicate in real time. Each device has a unique identity, ensuring seamless integration into larger systems.

IoT plays a vital role in automation, real-time monitoring, and intelligent decision-making across various sectors such as healthcare, agriculture, manufacturing, transportation, and urban management. It enables remote health monitoring, smart farming, predictive maintenance, traffic control, and home automation. In retail, it supports inventory management and personalized customer service. IoT helps businesses enhance efficiency, cut costs, and deliver better services. Its scalable nature allows easy expansion with minimal changes to infrastructure. However, challenges like data security, privacy, and standardization must be addressed to ensure its reliable and secure adoption in the future.

### **4. Existing System**

Conventional energy monitoring systems depend largely on mechanical meters that require manual data collection. This approach limits real-time access to energy consumption information, leading to delayed recognition of usage patterns. Issues such as electricity theft, meter tampering, and equipment malfunctions often go unnoticed due to the lack of continuous monitoring. Manual billing methods are prone to human error, inconsistencies, and time lags. The absence of remote connectivity further restricts user control and real-time supervision.

Many existing smart meters lack features like mobile notifications, load management, and integration with cloud services. While some systems support wireless communication, they often do not include centralized analytics or automation capabilities. SCADA systems, though advanced, are generally too costly and complex for small-scale or rural deployment.

Older infrastructure struggles with scalability, compatibility, and affordability. Without demand-response features or intelligent scheduling, energy is frequently wasted. Traditional setups also hinder renewable energy integration and provide no real-time support for grid load balancing or outage response. Furthermore, local-only data storage limits the ability to perform predictive maintenance and long-term trend analysis.

## **5. Proposed Method**

The IoT-enabled smart energy meter with an integrated controller provides real-time monitoring and automated energy management. It transmits consumption data to the cloud via Wi-Fi or GSM for storage, analysis, and visualization. A microcontroller processes readings from voltage and current sensors, while data is displayed on mobile apps, web dashboards, and an LCD screen. Relays enable automatic load control based on preset thresholds or schedules. The system includes tamper detection, fault alerts, and theft identification through embedded algorithms. Cloud services offer advanced analytics, usage forecasting, and support for prepaid billing and remote recharge. It also integrates solar power and dual-source monitoring. Peak loads are managed by disconnecting non-essential appliances. Encrypted communication ensures data security, while over-the-air updates and remote diagnostics improve reliability. The controller works with smart devices for efficient energy use, providing detailed consumption reports for improved decision-making and energy optimization.

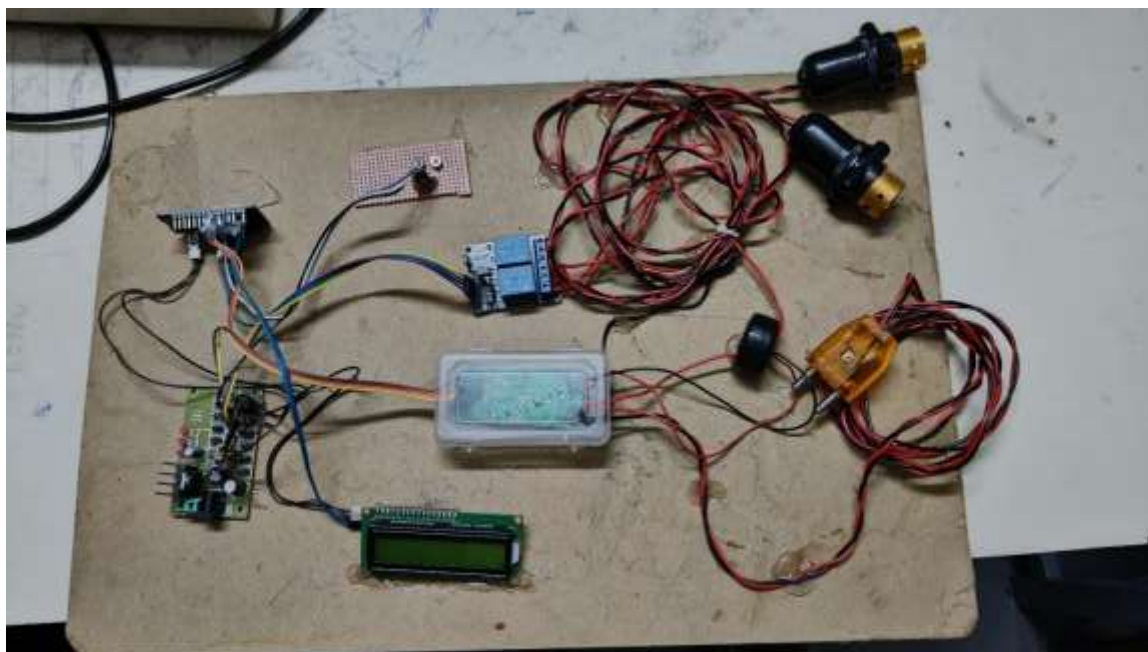
## **6. Software Employed**

The software for the IoT-enabled smart energy meter uses Arduino IDE as the main development platform. ESP32 libraries support Wi-Fi, I2C, UART, and GPIO functionalities. The PZEM004T library handles real-time voltage, current, and energy data, while the LCD I2C library manages efficient display updates. MQTT protocol ensures lightweight, real-time data transfer to platforms like Firebase or Blynk for cloud storage and mobile access. JSON is used for structured data exchange, and EEPROM stores thresholds and schedules. FreeRTOS manages multitasking, and OTA updates allow firmware upgrades without physical access. Real-time clock libraries enable time-based automation, with local data backups via SD card or SPIFFS. Load control and alert logic are built into the firmware. Web dashboards or Blynk apps offer user interfaces, while IFTTT or webhooks handle

notifications. Security is maintained using SSL/TLS and token-based access. Modular code structure supports sensor input, data processing, and system diagnostics.

## **7. Results and Discussions**

This section includes setup instructions such as installing the ESP32 board manager and circuit configuration. The system allows load control using relays and push buttons, while voltage, current, and power data are displayed on an LCD. Users can monitor and control the load remotely via the Blynk IoT platform. If consumption exceeds the set threshold, alerts are sent through the app. The ESP32 efficiently handles sensing, processing, and communication using its dual-core and Wi-Fi features. The PZEM004T sensor delivers accurate readings under changing load conditions. Real-time feedback is shown on the LCD, and the relay operates based on threshold logic. The system supports data logging, remote control, and stable performance during live tests. Cloud connectivity ensures continuous monitoring and quick response to overloads, with reduced power consumption through ESP32's deep-sleep mode.



**Figure 2:** Experimental Setup

## **7. Conclusion**

The IoT-Based Smart Energy Meter and Controller highlights modern advancements in energy management through the integration of intelligent technologies. Real-time energy

tracking is made possible by sensor-based data acquisition and wireless communication. Remote monitoring and control are enabled via cloud platforms and mobile applications. The system supports data analysis, usage forecasting, and trend visualization to guide informed decision-making. Automated load regulation is implemented using relay control and programmable scheduling. Alerts and fault detection mechanisms respond to irregular consumption or system issues.

It also supports renewable energy sources through dual-input tracking and smart switching capabilities. Demand-response strategies and optimized scheduling contribute to greater energy efficiency. User-friendly dashboards and analytical tools help identify consumption trends. The system is scalable and adaptable for residential, commercial, and industrial use. By promoting intelligent resource use and minimizing waste, the solution contributes to reduced environmental impact and supports sustainable energy practices.

## **References**

- [1] BibekKanti Barman, Shiv NathYadav, Shivam Kumar, SadhanGope. IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid, 2018 2nd International Conference on Power, Energy and Environment:Towards Smart Technology (ICEPE), 2018
- [2] Chaudhari S, Rathod.P, A. Shaikh, D. Vora and J. Ahir. Smart energy meter using Arduino and GSM, 2017 International Conference on Trends in Electronics and Informatics (ICEI), Tirunelveli, 2017, pp. 598-601.
- [3] Salman siddiq S , S. Reshma , K. Anuja , P. Priyanka , Ch. Karunapravaha Smart Electricity Meter using Wi-Fi, International Journal of Research in Advent Technology, Vol.5, No.3, March 2017 E-ISSN: 2321-9637.
- [4] Swamy M, Pravallika R.Design and implementation of smart energy meter, 2017 International Journal of Innovative Research in Computer and Communication Engineering, Vol. 5, Issue 8, August 2017,ISSN: 2320-9801.
- [5] R.Kappagantu , S. Senn , M.Mahesh , S.A.Daniel “Smart grid implementation in India – A case study of Puducherry pilot project”International Journal of Engineering, Science and Technology Vol. 7, No. 3, 2015, pp. 94-101