Single Phase AC Multifunction Electric Energy Metering Power Monitor

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***Abstract*—This project presents a Single-Phase AC Multifunction Electric Energy Metering Power Monitor designed to measure and display multiple electrical parameters such as voltage, current, power, energy consumption, frequency, and power factor. The system uses a micro controller and energy metering IC to calculate and record energy usage. The data can be displayed on an LCD or transmitted to a remote monitoring system through RS485 or Wi-Fi communication. This project helps in monitoring real time power usage efficiently and ensures better load management.**

Key word: Energy Monitoring, IOT, ESP32, PZEM-004T, Smart Meter

I. INTRODUCTION

Electrical energy monitoring is essential for efficient power management and reducing energy wastage. Traditional energy meters only display cumulative energy consumption and require manual reading, which limits real-time analysis. With the advancement of IoT technology, smart energy monitoring systems can provide real-time data, remote access, and cloud storage. This project implements a smart energy monitoring system using ESP32 and PZEM-004T module. The system measures electrical parameters and transmits data wirelessly to cloud platforms, enabling efficient monitoring and analysis of energy consumption.

II. MATERIAL AND METHODS

2.1 Study Design

This project is an experimental IoT-based energy monitoring system designed to measure and analyze electrical parameters in real time.

2.2 Components Used

PZEM-004T Energy Meter Module

ESP32 Microcontroller

Current Transformer (CT)

AC Load

Power Supply Module

Wi-Fi Network

Google Sheets (Cloud Storage)

2.3 Experimental Setup

The experimental setup of the project consists of a real-time single-phase AC energy monitoring system implemented using the PZEM-004T Energy Meter Module and ESP32 Development Board. The system is connected to the college laboratory main switchboard, which acts as the AC supply source (230V AC). Unlike small test loads, using the main switchboard ensures that the readings reflect real-time practical electrical conditions.

2.3.1 Setup Description:

The phase wire (live wire) from the switchboard is passed through the Current Transformer (CT) of the PZEM module. The neutral wire is directly connected to the module. The PZEM module measures electrical parameters such as:

Voltage, Current, Power, Energy, Frequency, Power factor.

The PZEM module communicates with the ESP32 using UART serial communication (TX, RX pins). The ESP32 is powered via USB and connects to Wi-Fi.

2.3.2 Data collected is:

Sent to Google Sheets. Displayed on a web dashboard. Optionally used for alerts (mail/notifications).

2.3.3 Important Setup Considerations:

Proper insulation is maintained to avoid electric shock. CT is clamped correctly to ensure accurate current measurement. Secure wiring is done to avoid loose connections. The system is placed in a protective enclosure for safety.

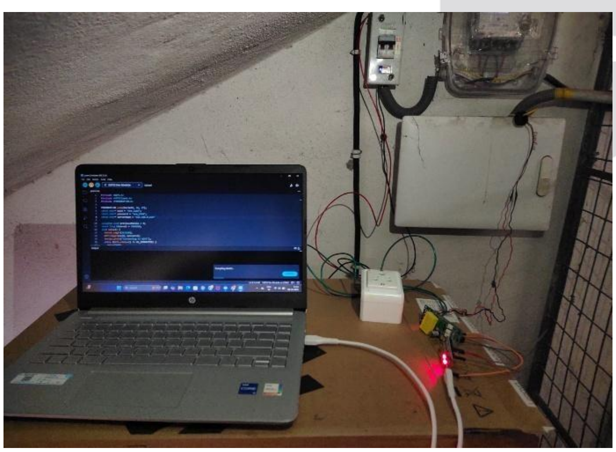

Fig 1: Experimental setup

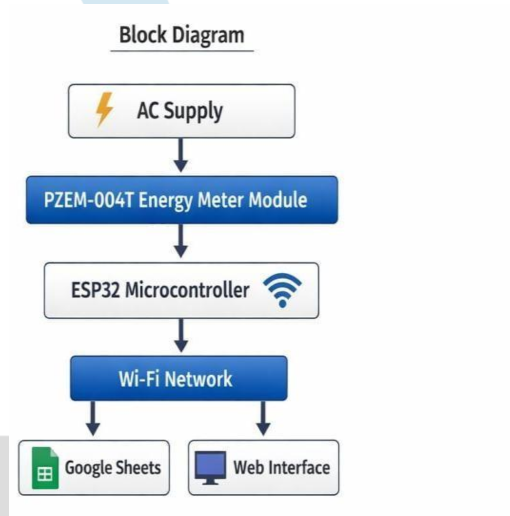

Fig.2 Block Diagram

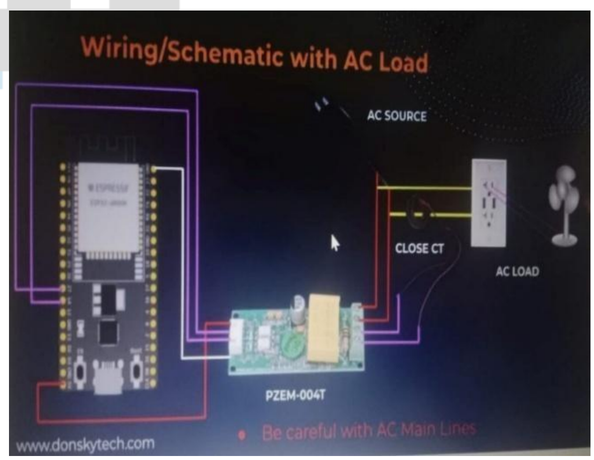

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Fig.3 Circuit Diagram

2.4 Working Principle

Step 1: AC supply is given to the load.

Step 2: PZEM measures voltage and current.

Step 3: Power is calculated using P = V × I ×PF.

Step 4: Energy is calculated using E = P × t.

Step 5: Data is sent to ESP32 through UART communication.

Step 6: ESP32 connects to Wi-Fi network.

Step 7: Data is displayed on webpage and stored in Google Sheet.

III. RESULT

The system successfully measures and displays real-time electrical parameters. Voltage observed around 230V Frequency around 50Hz.Power varies with load. Power factor close to unity for resistive loads. The data is displayed on: Serial Monitor, Web Interface, Google Sheets.

3.1 Advantages

- Real-time monitoring
- Remote access
- Cloud data storage
- Low cost
- Easy installation

3.2 Disadvantages

- Depends on Wi-Fi
- Supports only single-phase
- No automatic load cutoff

284	10/18/2025 11:42:46	247.7	6.82	1416	38.77	49.9	
285	10/18/2025 11:44:00	247.4	6.81	1413.6	38.8	49.9	0.84
286	10/18/2025 11:45:00	248.4	6.85	1425.2	38.83	49.8	0.84
287	10/18/2025 11:46:00	249.7	6.9	1438.9	38.85	49.9	0.83
288	10/18/2025 11:47:00	248.7	6.87	1428.3	38.88	49.8	0.84
289	10/18/2025 11:48:00	248	6.83	1420.1	38.9	49.9	0.84
290	10/18/2025 11:49:02	248.5	6.86	1427.2	38.92	49.9	0.84
291	10/18/2025 11:50:00	250.2	6.92	1445.4	38.95	49.9	0.83
292	10/18/2025 11:51:00	248.9	7.57	1587.6	38.97	49.9	0.84
293	10/18/2025 11:52:02	249.8	7.61	1599.1	39	49.9	0.84
294	10/18/2025 11:53:00	250.6	7.66	1611.5	39.03	49.9	0.84
295	10/18/2025 11:54:00	250.8	7.67	1613.8	39.05	49.9	0.84
296	10/18/2025 11:55:00	250.7	7.66	1611.5	39.08	49.9	0.84
297	10/18/2025 11:56:00	248	7.52	1575.8	39.11	49.9	0.84
298	10/18/2025 11:57:00	249.5	7.6	1597	39.13	49.9	0.84
299	10/18/2025 11:58:00	248.5	7.54	1582.9	39.16	50	0.84
300	10/18/2025 11:59:59	249.4	6.59	1396	39.21	50	0.85
301	10/18/2025 12:03:00	249.8	6.59	1398.2	39.28	49.9	0.85

Fig.4 Google Sheets output

3.3 Applications

- Residential energy monitoring
- Hostels and apartments
- Laboratories
- Small industries
- Energy auditing

IV. Discussion

The developed system successfully demonstrates real-time monitoring of electrical parameters using IoT. The Google Sheets data shows voltage values between 247 V and 250 V in the G Pulla Reddy Engineering College laboratory. Although the normal supply in India is 230 V, a variation of ±10% is allowed, so the acceptable range is 207–253 V. Therefore, these readings are normal. The higher voltage indicates that the laboratory was receiving a stable supply, possibly because it is close to the transformer or because the electrical load was low at that time. The frequency remained near 50 Hz and the voltage changed very little even when current increased, showing that the laboratory power supply was stable. When the current increased, the power also increased accordingly, confirming that the PZEM-004T accurately measured the actual electrical conditions of the laboratory. P=VIcos⁡ϕP = V I \cos\phiP=VIcosϕ . For example, at 250.6 V, 7.71 A, and power factor 0.83, the calculated power is about 1600 W, which matches the value stored in Google Sheets.

4.1 Observations:

The system provides continuous live data from the main supply. Readings vary based on load conditions in the lab (fans, lights, equipment). The Wi-Fi-based monitoring ensures remote accessibility. Data logging in Google Sheets helps in long-term analysis.

4.2 Performance Analysis:

The PZEM module shows good accuracy for voltage and current. Minor fluctuations are observed due to: Supply variations, Load switching in the lab. Communication between ESP32 and PZEM is stable. Internet dependency may cause slight delays in data updates.

V. Conclusion

The project successfully demonstrates an IoT-based smart energy monitoring system using ESP32 and PZEM-004T. The system accurately measured electrical parameters such as voltage (around 230–250V), frequency (50 Hz), and power based on varying load conditions. The results confirm stable and reliable performance under real-time laboratory conditions. The integration with Wi-Fi enables remote monitoring, cloud data storage, and web-based visualization. Overall, the system is cost-effective, efficient, and suitable for modern energy management and monitoring applications.

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