Real Time Electricity usage Monitoring Systems with Live Alerts

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IndiaAs electricity consumption in homes and little workplaces is increasing as fast as possible, there comes a necessity to have intelligent real-time monitoring systems, which most of us in the engineering laboratories are attempting to create. Conventional meters do not provide us with finely. Granular, appliance level data, and thus we are denied the opportunity to identify inefficiency and reduce wastage. In this work we suggest a real-time monitoring transfer system based on IoT technology, i. e. a non-invasive current sensor under ESP32 microcontroller, to collect data on per-appliance consumption without re-wiring it. This collected data is forwarded to a cloud service and displayed in a web and mobile dashboard which provides live notification when a threshold is met, as well as remote control of relays. According to our lab results, the system is good enough to monitor what is being consumed in real time, which does show that the system can be useful when it comes to energy conservation and electrical safety.

Index Terms — Internet of Things (IoT), Real-Time Monitoring, Smart Energy Management, ESP32 Microcontroller, Non-Invasive Current Sensor, Appliance-Level Energy Monitoring, Cloud Computing, Web Dashboard, Mobile Application, Threshold-Based Alerts, Remote Relay Control, Energy Conservation, Electrical Safety.

I. INTRODUCTION

The increased need of electricity in residential and small business environment has rendered it extremely essential to possess smart energy-monitoring devices. The traditional electricity meters just provide you with a total figure and do not indicate what is actually consuming power in the real time and at the appliance level. Due to this, individuals are unable to identify which devices are consuming the most amount of energy, which ones exhibit strange usage behaviors, or respond quickly to reduce wastage of electricity and reduce their bills.

The Internet of Things (IoT) technology allows real-time procurement, relay and interpretation of electrical parameters. A non-invasive electricity monitoring system that is an IoT based, implemented using ESP32 microcontroller and non-invasive current and voltage sensors enables continuous measurement of voltage, current, power and energy consumption.

The obtained data is sent to a cloud-based solution where it is stored and represented in a web-based dashboard, which offers users real-time monitoring and historical consumption data.

An alert system that is based on a threshold is a way of improving the system by letting the user set up how much consumption is admissible. In case of the real-time utilization, which surpasses the predetermined thresholds, the notification will be created to foster energy consciousness and guarantee electrical safety. Modular architecture guarantees scalability, low cost and ease of deployment, as well as offers a base on which predictive analytics and intelligent energy optimization methods will be integrated.

II. SYSTEM ARCHITECTURE

The system architecture includes IoT sensing, data processing, cloud communication, visualization and alert modules. Noninvasive current and voltage sensors are used to measure the electrical parameters. This data is processed by ESP32 microcontroller to compute voltage, current, energy and power. The data is sent to cloud platform for storage and real time access. Visualisation and analysis of the consumption is done using a web-based dashboard. A relay control module and a threshold based alert system is also proposed for effective energy usage and electrical safety.

A. Acquisition and Monitoring Interface

Real-time electrical parameters are measured by non-invasive current and voltage sensors connected to the ESP32 microcontroller. The ESP32 calculates the current, energy, power and voltage consumption from the measured signals and sends the data to the cloud. A web-based dashboard provides live consumption, trend analysis, and usage threshold configuration.

Modules: IoT Sensing, ESP32 Processing, Cloud Storage, Monitoring Dashboard

- Build System: Dashboards for real-time data visualization, alert-configuration.

The process of automated monitoring and decision-making is carried out in the Embedded Processing and Control module, which allows for real-time data acquisition, overload detection, warning generation, and intelligent energy management.

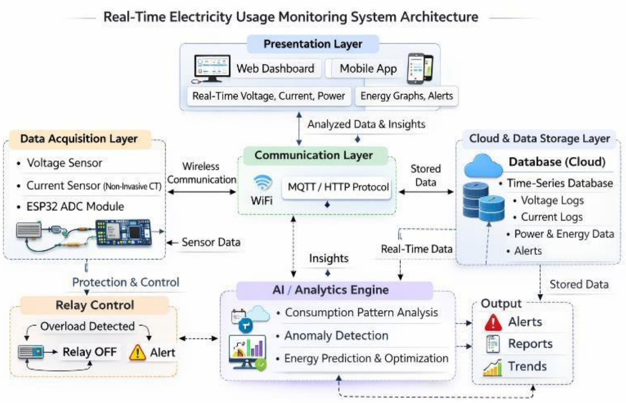


Fig. 1: Detailed System Architecture: Real-Time electricity usage Monitor with live alerts

B. Proposed methodology

The system is based on continuous sensing, real-time processing, and cloud transmission. The ESP32 sends the data to the cloud via Wi-Fi, and the dashboard visualizes the consumption and compares it with defined thresholds through the live data. The user is alerted when the threshold is crossed, and the relay control allows controlling the power remotely.

III. Methodology and Algorithms

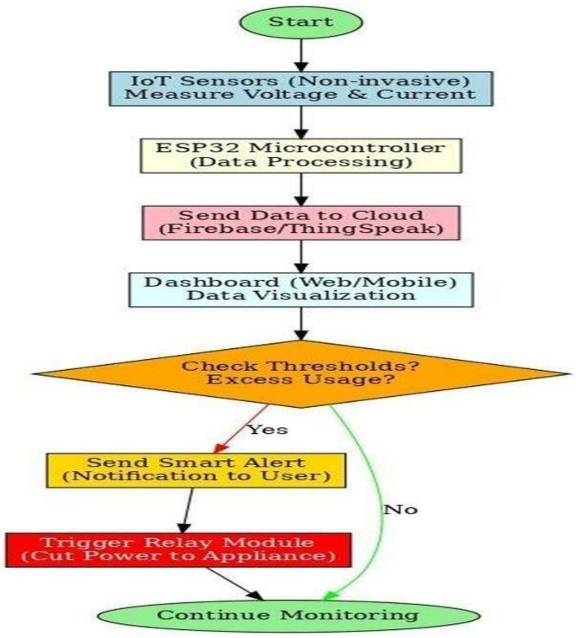
A. User Financial Logic

The Real-Time Electricity Usage Monitoring System uses IoT sensing and processing concepts for precise measurement and smart energy management. Non-invasive current and voltage sensors are used to read real-time electrical values, which are then converted to digital signals using the ESP32's analog-to-digital converter for further calculations. Mathematical equations are used to compute real-time power values using the formula ($P = V \times I$) and total energy values through time integration. A threshold-control algorithm is developed to continuously compare the measured current values with pre-defined safety thresholds for overload detection. Moreover, cloud-based data logging and time-series analysis is also integrated to support consumption pattern analysis, anomaly identification, and predictive energy optimization for intelligent power management.

1) If the current reading goes beyond the threshold limit → "Overload Protection Phase". The system recognizes irregular or excessive usage of power and instantly switches on the relay cutoff system along with buzzer notifications to avoid any electrical damage or risk of fire.

- If the current and voltage values are within the safe operating range → "Normal Monitoring Phase". The system continues to measure, calculate power and total energy consumption, and store the data in the cloud for analysis.
- **Data Acquisition Point:** We are taking real-time voltage and current values with non-invasive sensors and feeding it into the ADC of ESP32 to turn it into digital values to analyze.
- **Processing and Control Interaction:** This basically involves calibration of the data and crunching some power and energy statistics. Then a threshold-based algorithm monitors overloads, switch the relay, and send the readings to the cloud to be able to monitor and analyze all the things.

The workflow is illustrated in Fig. 2.

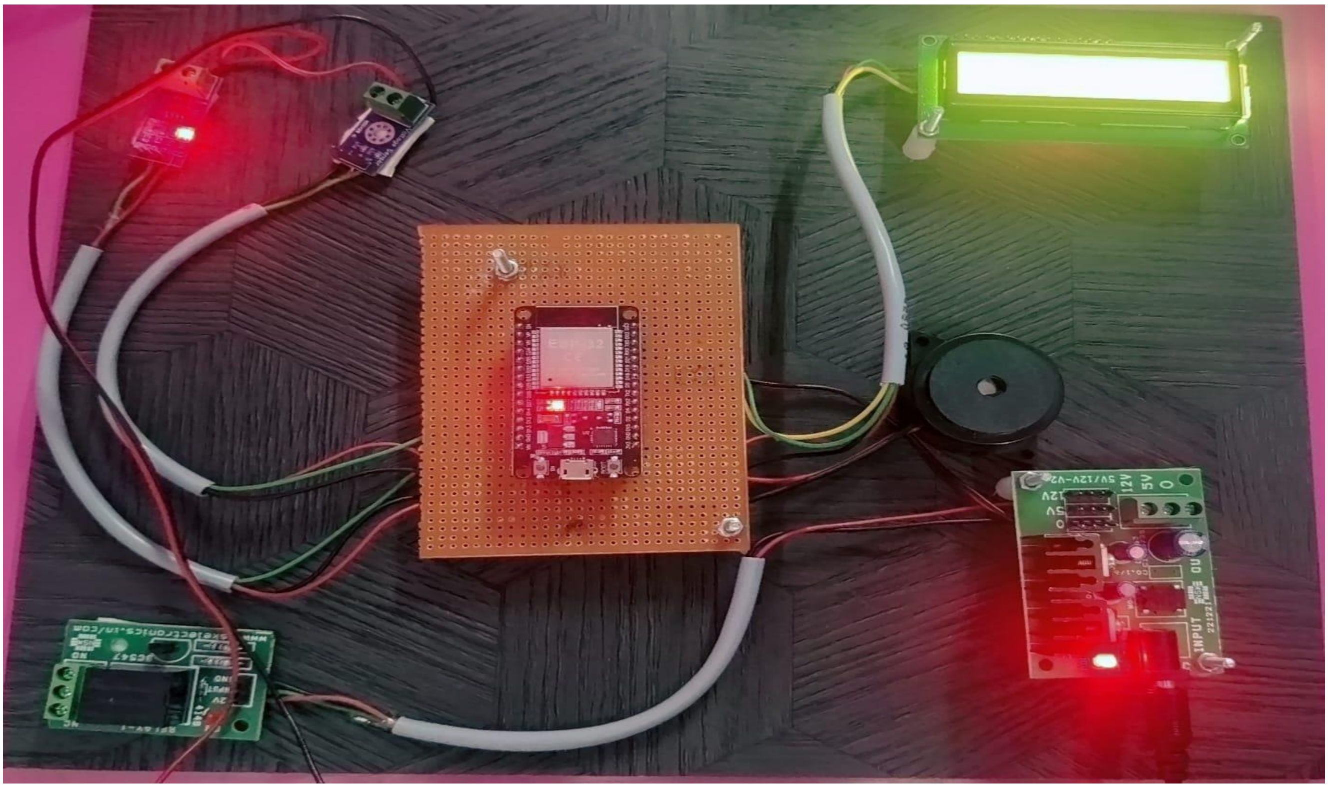


1. Thus, the IoT sensors are monitoring voltage and current live and the ESP32 is doing all the work and then sending it to the cloud allowing you to view it on a dashboard.

2. I record all measurements in the radar to note whether it exceeds the set threshold.

3. When I reached the high-usage alarm, I get a brilliant notification and the relay turns off; in the case of no problem, no event occurs and I continue with the monitoring.

IV. INTERFACE



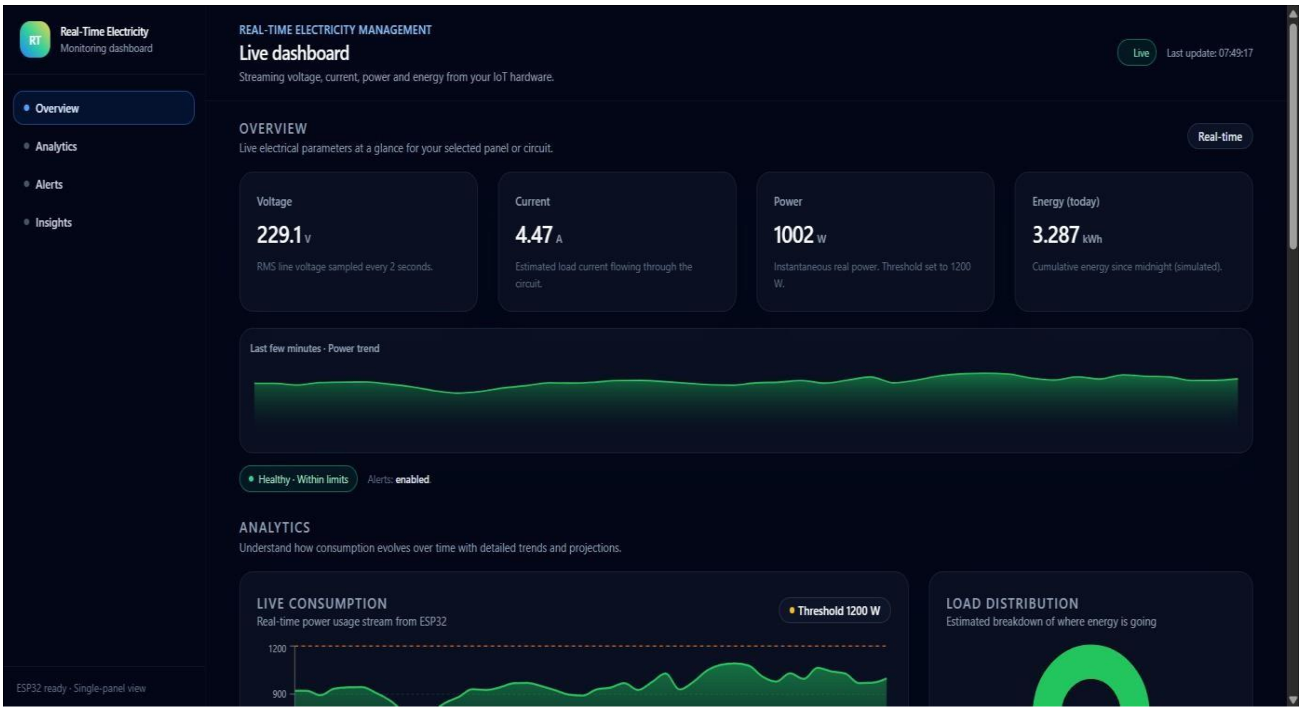


Fig. 3: Hardware Prototype of Electricity usage monitor

Fig. 4: Real Time Dashboard of the System

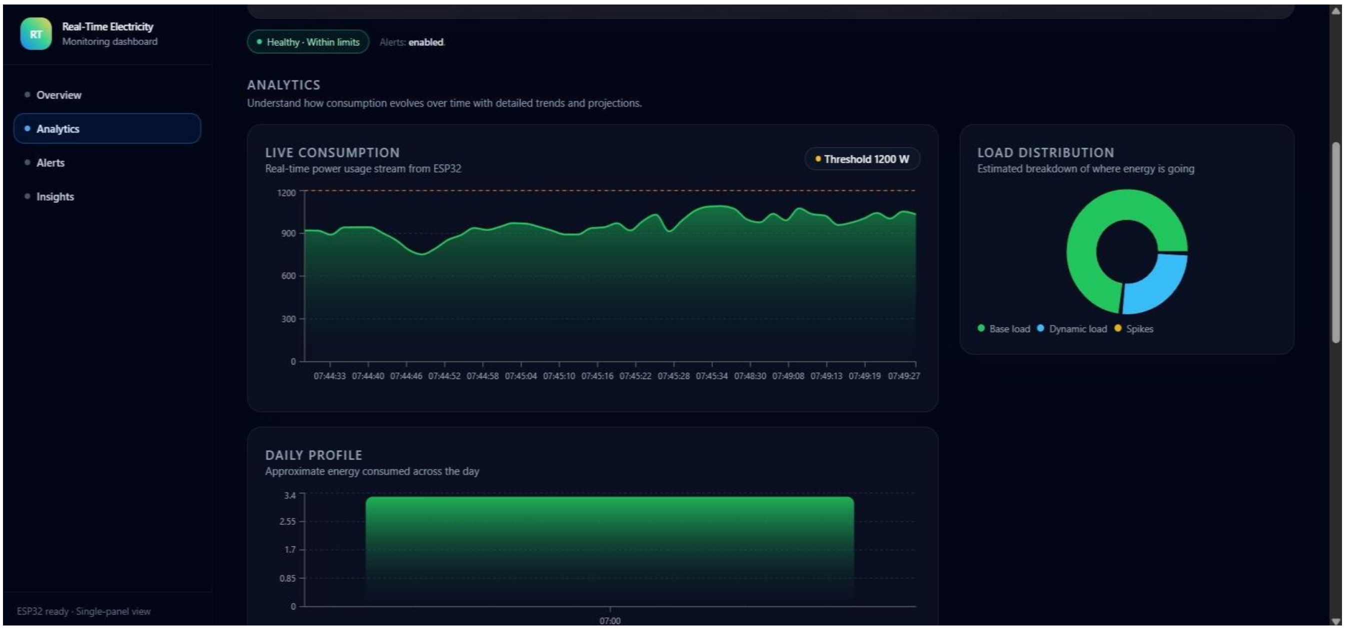


Fig. 4: Visualization of live consumption of electricity

V. RESULTS

In my course work, I have experimented with the Real -Time Electricity Usage Monitoring System to determine its accuracy at varying loads. It really performed a remarkably wonderful job at capturing runtime facts, fetching the figures directly off the ESP32 voltage and current sensors, correcting the signals, and processing the equations of power and energy - even warning of overloads. The limit control did not slack at all - it identified the odd spikes in consumption, fired the relay protection and sent me warning signals just as they occur. In general, the establishment of the system reduced the number of manual inspections and increased the electrical safety many times due to the automated tracking and cloud-logging. The dashboard proved to be a life-saver in identifying patterns of energy and trends, and it actually demonstrates that with this set, it is possible to keep the use of electricity at home or in small business within check.

VI. CONCLUSION

Through this paper, the Real-Time Electricity Usage Monitoring System using IoT technology and embedded sensing approaches has been shown to improve energy transparency and electrical safety. The system can automatically calculate the voltage, current, power, and accumulated energy consumption, and control the power supply according to the set threshold values. The experimental result has verified the correctness of the electrical parameter measurement and the reliability of the real-time cloud transmission of data, which can facilitate effective energy management and quick overload response. The proposed system is a scalable and cost-effective solution for home and small-scale industrial electricity usage monitoring, and provides a solid basis for future upgrades, such as AI-assisted consumption prediction and smart energy optimization.

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