REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

A Cloud-Connected Smart Energy Monitoring and Control System Using ESP8266 and Blynk

Dr. G. Jeevagan Navukarasu Lenin[1], Dr.P.Ramesh[2]

[1]Assistant Professor (Sr.Gr), Department of Electronics and Communication Engineering, Anna University Regional Campus Coimbatore, Tamilnadu, India
[2]Assistant Professor (Sr.Gr), Department of Electrical and Electronics Engineering, Anna University, University college of Engineering Ramanathapuram Campus, Tamilnadu, India

Abstract— This paper presents a cloud-connected smart energy monitoring solution that enables real-time tracking of electrical parameters such as voltage, current, power, and energy consumption for individual electrical loads in household and small-scale commercial applications. By integrating the ESP8266 Node MCU microcontroller with a PZEM-004T sensor and relay modules, the system supports both monitoring and automated control functionalities. A key feature is its integration with the Blynk cloud platform, which offers a user-friendly interface for data visualization and remote device interaction. The system also includes automated billing based on usage slabs and carbon footprint estimation to raise awareness of environmental impact. Implementation results show that the system is cost-effective, accurate, and accessible, making it well-suited for promoting energy efficiency and smarter consumption behaviors. The prototype demonstrates a 15% reduction in energy usage (~45 kWh/month), equating to a carbon savings of ~38.25 kg CO_2 per household.

Keywords: IoT, Smart Energy Meter, ESP8266, PZEM-004T, Blynk, Energy Monitoring, Carbon Footprint

I.INTRODUCTION

The growing global demand for energy, combined with increasing concerns over sustainability and efficiency, has led to a surge in the development of intelligent energy monitoring and management systems. Traditional energy meters offer limited insight into consumption patterns and often fail to promote conscious energy usage. In contrast, recent advancements in the Internet of Things (IoT) have enabled real-time, device-level monitoring and control of electrical systems, making energy management more accessible and efficient for both residential and commercial users.

The convergence of Internet of Things (IoT) technologies with smart metering has catalyzed a transformation in energy management. Advanced smart meters now enable remote monitoring, bi-directional control, and granular feedback to both consumers and grid operators, facilitated by integrated communications within Advanced Metering Infrastructure (AMI).Smart energy meters integrated with IoT platforms provide a transformative solution for modern power systems. These systems can monitor electrical parameters such as voltage, current, power, and energy consumption in real time, often at the individual appliance level, enabling precise load analysis and optimized usage behavior. Studies have demonstrated the effectiveness of such systems using ESP8266 and ESP32 microcontrollers, in combination with energy sensing modules and cloud interfaces, for delivering reliable data acquisition and remote accessibility via mobile and web applications [1]–[2].

Academic and industrial research from the past decade has produced a growing body of evidence supporting IoT-enabled smart energy systems. [3] Introduced an ESP8266 based system enabling remote monitoring and control via Wi Fi, highlighting improved transparency in household energy use. Moreover, the integration of cloud platforms such as Blynk enhances user interaction by offering intuitive dashboards for visualization, device control, and data logging [4], [5]. Researchers have explored additional functionalities such as fault detection, theft prevention, and automated billing [6],[7], pushing the capabilities of smart meters beyond basic monitoring. Some systems have even incorporated environmental awareness through carbon footprint estimation and load automation for energy-saving interventions [8], [9]

Firmansyah, R., et al. [10] demonstrated the development of an IoT-based temperature control system utilizing the NodeMCU ESP8266, emphasizing efficient sensor data acquisition, wireless communication, and actuator control. Desnanjaya et al. [11] designed an integrated room monitoring and HVAC optimization system using ESP-12E microcontrollers and a suite of environmental sensors. Their approach implemented PID control algorithms to achieve significant energy savings by adjusting cooling efficiency while maintaining comfort, and featured cloud connectivity for data visualization and logging. The system in [12] used microcontrollers and wireless networks to aggregate data from distributed solar units, enabling remote supervision and efficiency analysis. The paper also stressed the importance of real-time telemetry and data integrity in achieving effective energy management in distributed renewable systems. smart

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

load monitoring and control system [13] designed for integration with solar power systems employed the ESP32 microcontroller for data acquisition and control, interfacing with sensors to measure voltage, current, and energy consumption. A variety of low-cost, Wi-Fi–based systems have demonstrated the feasibility and practical value of such technologies. For instance, [14] developed a remote energy monitoring setup using ESP8266 NodeMCU and ADC modules to track picowatt-scale solar yields over six months. At the building and community level, Pan et al. [15] introduced an IoT framework for smart buildings that delivers automated, location-based energy control through cloud and smartphone integration, achieving measurable reductions in energy use. Meanwhile, MDPI studies [16] present four-layer HEMS architectures combining cloud-based storage, smart meter and plug-level monitoring, and mobile control—with practical deployments and long-term datasets. Furthermore, research on edge intelligence and energy-aware IoT systems [17] has shown how privacy-sensitive, locally processed analytics and recommendation engines can encourage behavioral changes and enhance system efficiency. Meanwhile, load disaggregation approaches such as Non-Intrusive Load Monitoring (NILM), pioneered in the 1980s, remain relevant for household energy profiling without appliance-level sensors. Unlike prior systems that focus on monitoring alone, the proposed system offers end-to-end integration of real-time monitoring, automated load control, user-defined billing thresholds, and environmental impact estimation through an intuitive cloud interface

This paper presents the design and implementation of a cost-effective, cloud-connected smart energy monitoring solution that builds on these innovations. Using ESP8266 Node MCU, PZEM-004T energy monitoring sensors, and relay modules, the proposed system supports device-level tracking, automated control, slab-based billing, and carbon impact assessment. It is particularly suited for household and small-scale commercial applications, where efficient energy use and remote operability are critical. The system aims to bridge the gap between conventional energy meters and intelligent energy infrastructure by promoting data-driven decision-making and energy conservation behaviors.

II.EXISTING SYSTEM

Traditional energy monitoring systems, such as electromechanical or basic digital meters, primarily offer cumulative readings of total energy consumed over a billing period. These systems do not support real-time monitoring, lack granularity at the appliance or load level, and provide no actionable insights for users to adjust consumption behavior. Furthermore, they do not include remote access, automation capabilities, or environmental metrics such as carbon footprint estimation. Even many existing smart meters deployed by utilities focus on centralized data collection for billing rather than offering consumer-friendly interfaces or individualized load monitoring. Additionally, conventional systems are often expensive, non-modular, and require proprietary infrastructure, which limits their adaptability for small-scale or domestic uses. Recent IoT-based solutions have started addressing some of these limitations by incorporating microcontrollers like the ESP8266 or ESP32, along with sensor modules and cloud platforms. However, many of these are either limited to monitoring alone or lack features such as slab-based automated billing, mobile-based control, or environmental feedback integration. These gaps create the opportunity for a more holistic, scalable, and cost-effective solution tailored for households and small businesses.

III.PROPOSED SYSTEM

The proposed system enables automated monitoring and control of household appliances, machineries, for finding power theft, for controlling the voltages etc., using smart meter, sensors, microcontrollers, along with Internet of Things (IoT). Here the loads can be controlled in accordance to the monthly tariff chosen with the help of sensors and relay. Users can choose their own tariff in accordance with their monthly budget. If they need any extra power, then the user itself can edit their tariff. In such a way energy gets consumed by controlling unnecessary loads automatically and save money. Simply, the idea is to create a user friendly system in order to monitor energy usage in real time. Data is collected by electronic devices and is transmitted to the server using Node MCU. The Cloud Connected Energy Monitoring Solution represents a transformative leap in the field of smart energy management, bringing together the power of IoT, cloud computing, and real-time analytics. Designed with the user in mind, this innovative system empowers individuals to track, control, and optimize electricity usage with just a few taps on their smartphone. Using the ESP8266 microcontroller and the PZEM-004T sensor, our model not only monitors voltage, current, and power consumption but also calculates carbon footprint and billing in real-time via a user-friendly Blynk dashboard. The seamless integration of relay-based automation ensures that power supply is intelligently cut off when consumption exceeds pre-set limits, fostering sustainability and reducing electricity bills. This work doesn’t just provide data—it offers actionable insights that drive energy efficiency, safety, and eco-conscious living in both residential and industrial settings.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

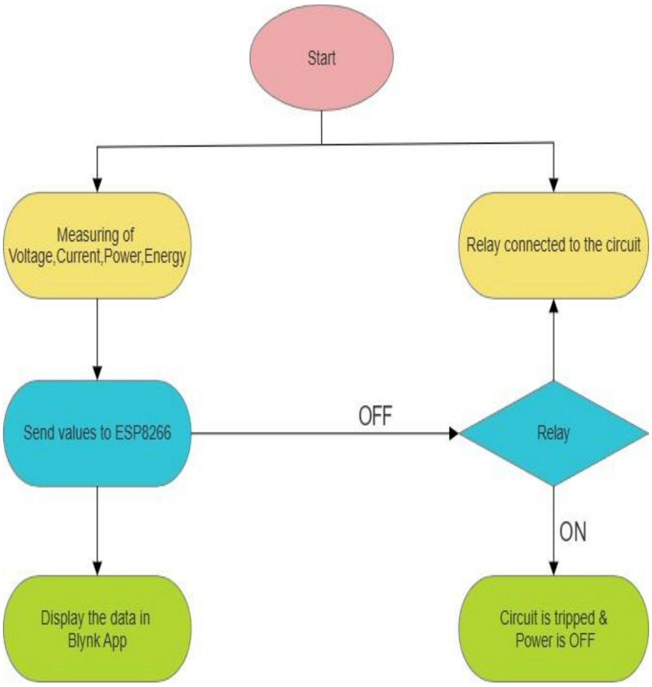

Fig.1 Work flow of Cloud Connected Energy Monitoring System

Figure 1 reveals the flow diagram where the controller receiving the values of the attributes from sensors, calculates the power consumed, which in turn sent them to the cloud for analysis and visualization. Once the set values for the tariff reached, controller enables the relay to cut off the power.

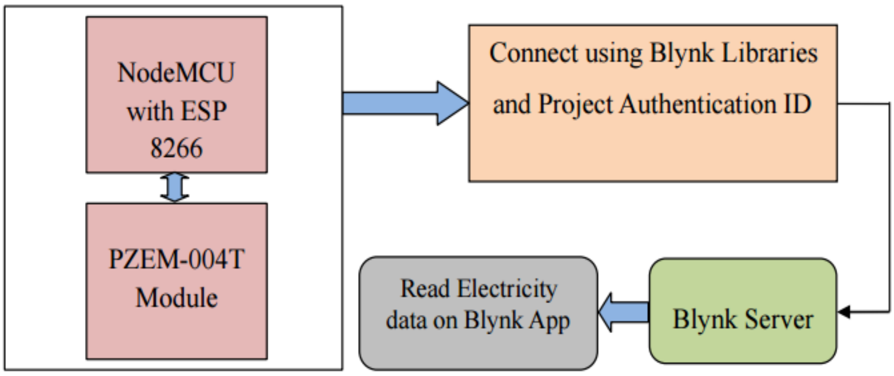

Fig.2. System architecture showing sensor-controller-cloud interface

PZEM-004T module senses and gives power data to Node MCU. Power consumption data is transmitted to the Blynk cloud and displayed via the web interface after authentication through the Blynk app

IV.HARDWARE MODELLING

The Cloud Connected Energy Monitoring System showcases the fully developed product and demonstrates its functionality in a real-world context. The primary objective of this system is to accurately measure the power consumption of any connected electrical appliance. For demonstration purposes, a standard household bulb is connected as the load to visually represent energy usage. A notable component of this system is the CT19 current transformer sensor, which is placed externally around the live wire to detect current flow without direct contact, ensuring safety and reliability. Internally, the setup is enclosed in a protective casing— referred to here as the "sun box"—which houses the essential electronics, including a current-voltage multimeter (PZEM- 004T) and the Node MCU ESP8266 microcontroller. The Node MCU serves as the system's core, handling data collection from the sensor and communication with the cloud platform.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

The system operates using an external power supply, with the neutral line providing continuous voltage reference. Power to the bulb is delivered through the load terminal, enabling real-time monitoring of energy consumption. All measured data is transmitted wirelessly to the cloud and visualized through the Blynk application. This live feedback allows users to observe voltage, current, power, and energy usage metrics, helping them make informed decisions about their electricity consumption. By assembling the hardware correctly and powering the system, users can expect accurate and immediate output as per the designed functionalities

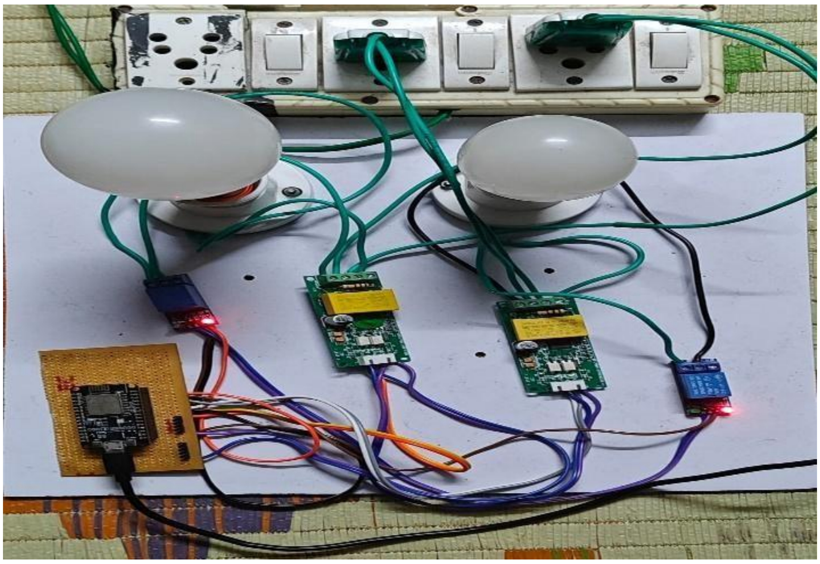

Fig.3. System setup hardware

The CT sensor is used outside the system. The internal system inside the sun box consists of a current-voltage multimeter and a Node MCU. The system is powered by a neutral. Electricity for the bulb is also received through the load. The entire system must be supplied with an external power supply for this purpose.

Software part:
The Arduino Integrated Development Environment (IDE) is a crucial tool used here for developing and uploading the embedded C code required to operate the ESP8266- to read energy consumption data from the PZEM-004T sensor module, process the information, control relays, and transmit real-time data to the Blynk cloud platform for remote monitoring. Several libraries were integrated into the development environment, including ESP8266WiFi.h, BlynkSimpleEsp8266.h, and PZEM004Tv30.h, which facilitated seamless WiFi connectivity, cloud communication, and sensor integration.

IV.RESULTS AND DISCUSSION

Cloud Connected Energy Monitoring Solutions is to conserve energy thereby reducing the bill amount by proper load management and by determining our own tariff. This is cost efficient than the existing models available in the market and is user friendly. Hence using this technology we can analyze the usage of power in our work place or at home and plan accordingly to save power. Similar projects like this usually use internet connection for transmission of data. The main advantage of this work is that the data can be visualized from the sensor without the use of internet connection in budgetary manner. The usage of Node-MCU allows us to operate the Power meter even without the use of internet. Node-MCU connects through the local network which includes a Wi-Fi modem, mobile phone.

A. System Behavior

The implementation of IoT-based smart energy meters for monitoring systems is a significant advance in the field of energy management. This revolutionary solution gives real- time insights into energy consumption, enhances productivity, and promotes sustainability by combining the Internet of Things (IoT) and energy monitoring. The main objective of an IoT-based smart energy meter is to monitor and gauge electricity use in real-time. In contrast to conventional energy meters, which require human readings and offer limited information, smart meters give a thorough picture of energy consumption. Due to their sensor and communication capabilities, these meters may transmit data to a centralized server or cloud platform.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

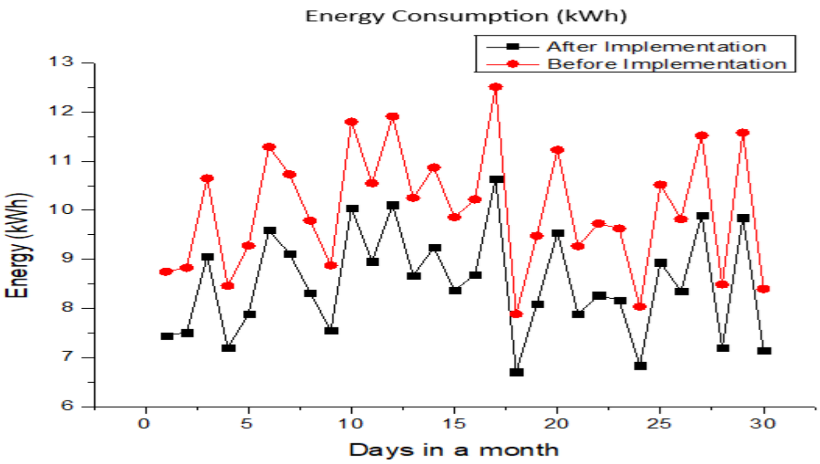

Fig.4. Energy Consumption on daily basis

Figure 4 illustrates the day-to-day energy consumption recorded by the IoT-enabled smart energy monitoring system. The graph reflects the dynamic usage behavior across different days, showcasing fluctuations based on appliance usage patterns and operational hours. Peaks in the graph represent days with higher appliance load or extended usage time, while troughs indicate low-demand days. This visualization helps users identify trends and optimize usage by reducing load during peak times, ultimately promoting more efficient energy management.

The capacity to deliver real-time data is one of the main benefits of IoT based smart energy meters. This indicates that both consumers and utility suppliers have access to the most recent data regarding energy use. This gives people the power to choose their energy usage patterns. They can pinpoint periods of peak usage, maximize tasks that consume a lot of energy, and eventually cut their electricity costs.

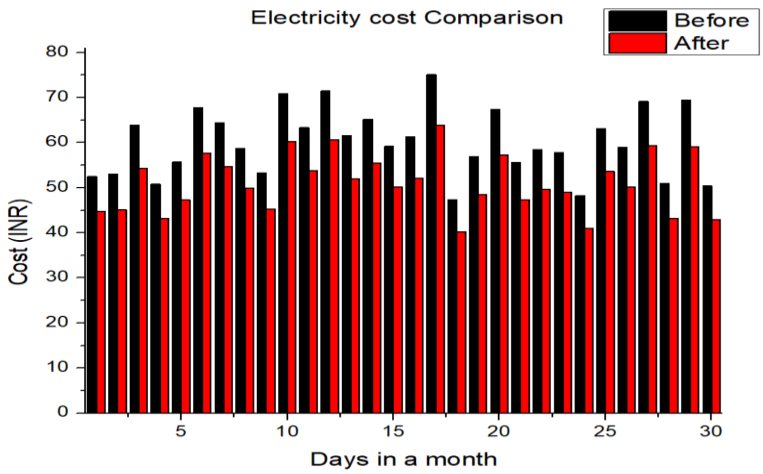

Fig.5. Electricity Cost on daily basis

Figure 5 presents the corresponding daily cost of electricity consumption derived from the energy usage data shown in Figure 4. The system automatically calculates the cost based on predefined tariff slabs, providing users with a clear understanding of how daily usage impacts their monthly bill. The alignment between energy consumption and cost highlights the direct financial implications of usage habits, encouraging users to make energy-conscious decisions. This feature enhances transparency and facilitates better budgeting for households and small businesses. Smart energy meters also help to improve energy efficiency. These meters can identify anomalies or inefficient behavior by tracking usage patterns. For instance, they might spot electrical system leaks or very energy-hungry gadgets. Consumers can be informed of this information and encouraged to take appropriate action. Sometimes the meters themselves can start automated processes, including turning off unnecessary gadgets during times of high demand.

Carbon Footprint Calculation:

The carbon footprint is calculated based on usage, giving users insight into the environmental impact of their energy habits. This helps promote energy-efficient behavior and raises awareness of sustainable living.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

Table.1 Energy to carbon foot print equivalent

Electricity Consumption (kWh)	Estimated Carbon Footprint (kg Co2)
1 kWh	0.85 kg Co2
5 kWh	4.25 kg Co2
10 kWh	8.50 kg Co2
20 kWh	17.00 kg Co2

Carbon emission factor is assumed as 0.85 kg CO_2 per kWh. Table.1 illustrates the estimated carbon footprint as measured in kgCO2 for the consumption units.

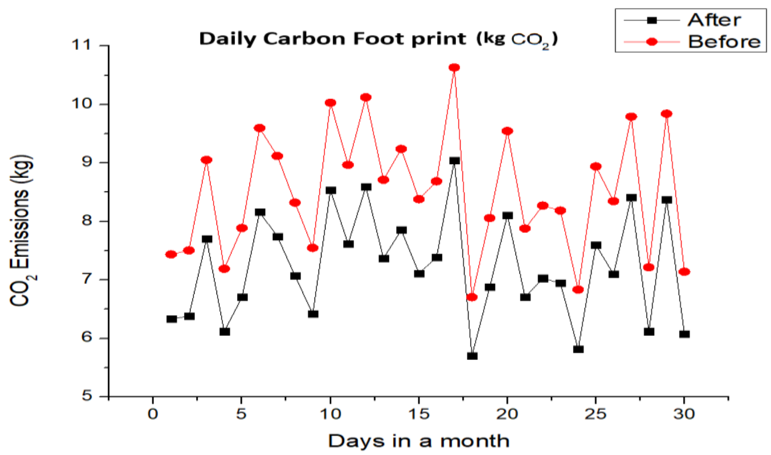

Fig 6. Carbon Footprint for daily consumption

Figure 6 showcases the daily carbon footprint generated by electricity usage, calculated using an emission factor of 0.85 kg CO_2 per kWh. This graph enables users to track their environmental impact in real time, correlating directly with their energy usage patterns. Days with higher electricity consumption lead to proportionately higher carbon emissions, making the environmental cost of energy more tangible. This insight promotes sustainability by encouraging users to reduce energy waste and shift toward greener practices.
B. Serial Monitor Output

Implementation procedure start with the uploading of written code to ESP8266 via Arduino IDE; Power the circuit and check serial monitor for Wi-Fi connection status; Open Blynk App and verify real-time data; Test Relay control via Blynk button. Blynk dashboard displays Voltage Current, power and energy I their respective units. Relay Control (if enabled) allows switching appliances remotely. Node MCU microcontroller results, upon receiving data from sensor, responses in the Arduino IDE's Serial Monitor, through the COM port connection to the ESP8266 Node MCU as shown in figure 7. It reveals in detail about the statuses of Wifi and Blynk interface and discloses the consumption of every meter in use along with total bill details for easy monitoring of the electrical devices.

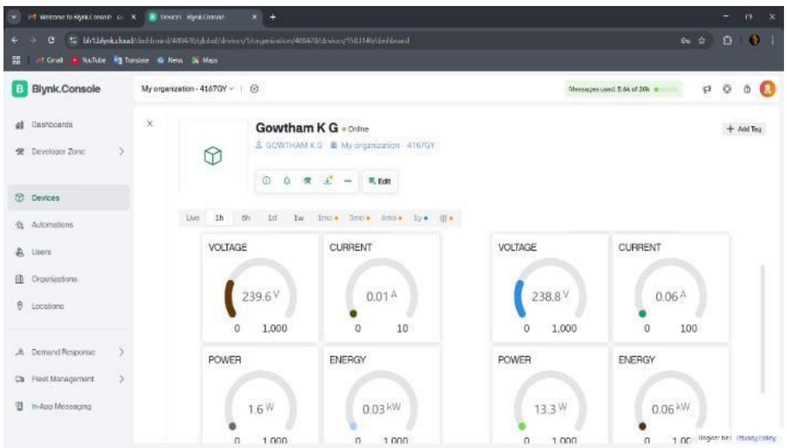

Fig.7. Implementation Output In Serial Monitor

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

C. Web and Mobile App Interface

The Blynk console of the Blynk IoT platform which is a cloud based interface lets the users to visualize real time data in terms of voltage, current, power etc as shown in figure 8.

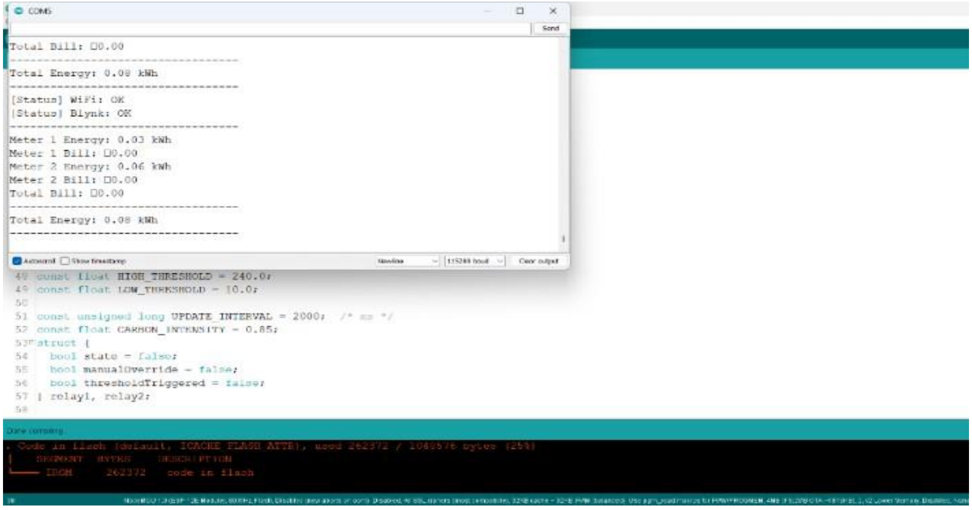

Fig.8. Implementation Output in Web Dashboard

The ESP8266 send those data to the Blynk cloud. User name is registered for the reference. The data can be seen in varying time basis. This interface eases user by providing remote controlling of devices by turning ON/OFF relays and viewing device statuses in addition to the access usage history or graphs. This dashboard can be accessible either via web browser or by mobile app.

Fig. 9 Mobile Output Of the System

Figure 9 illustrates the mobile Blynk interface optimized for smartphone showing similar output parameters for every metered connection revealing all the details including carbon footprint and bill features. mobile app shows this data through interactive widgets. Watching, controlling and viewing features are available similar to the web counterpart.

Table 2 provides a detailed comparison between traditional energy monitoring systems and the proposed cloud-connected smart energy solution. Traditional systems typically lack real-time data access and rely on manual readings, offering limited user engagement and no automation capabilities. In contrast, the proposed system leverages IoT technologies to enable real-time monitoring through cloud and mobile interfaces, allowing users to track energy usage instantly and make informed decisions. Another key advantage of the proposed system is automation — integrated relay controls can automatically disconnect loads when consumption exceeds user-defined thresholds, promoting energy efficiency and safety. While traditional systems often involve high implementation costs due to proprietary hardware, the proposed system is built using low-cost, open-source components, making it more affordable and scalable. Notably, the proposed system can function on local Wi-Fi without requiring continuous internet access, adding to its reliability and cost-effectiveness. Furthermore, by including carbon footprint estimation based on daily consumption, the system introduces an environmental dimension that is absent in conventional models, encouraging more sustainable usage behaviors. This comprehensive functionality makes the proposed system more adaptable for modern smart homes and commercial settings.

Table.2. Comparison of Traditional vs. Proposed Energy Monitoring Systems

Feature	Traditional System	Proposed System
Real-time Monitoring	Not Supported	Fully Supported via Cloud & App
Automation	Manual Reading & Control	Automated Relay Control Based on Usage
Cost	Relatively High (Proprietary)	Low-cost Open Source Components
Internet Independence	Depends on Manual Processes	Can Operate via Local Wi-Fi Network
Environmental Benefit	No Tracking or Feedback	Carbon Footprint Estimation & Reduction

IoT based smart meters provide businesses and industries with granular insights into energy usage, enabling them to optimize operations. For instance, large industrial facilities can identify operations that use a lot of energy and deploy energy-efficient technology to reduce waste.

IV CONCLUSION

The Cloud-Connected Smart Energy Monitoring Solution plays a vital role in controlling and monitoring the power consumption of energy-intensive devices such as heaters, fans, and cooling systems. It is particularly useful in industrial applications like refrigeration systems, where energy management can lead to significant cost savings. By enabling real-time monitoring and historical data analysis, the system simplifies the task of tracking electricity usage, especially in large residential setups like apartment complexes. This solution eliminates the need for manual meter readings, reducing human error and administrative overhead. Integration with the Blynk cloud platform allows intuitive remote monitoring and control, while the system's automated billing feature simplifies usage tracking and cost estimation for consumers. It provides users with the ability to calculate energy consumption at any given time and track monthly average usage. Importantly, it also empowers users to identify and eliminate unnecessary power usage, contributing to smarter and more efficient energy practices. On average, the system helps reduce electricity usage by approximately 15%, which equates to a saving of about 45 kWh per month. This translates to a monthly reduction of approximately 38.25 kg CO_2 emissions per household.

REFERENCES

[1] S. Muralidhara and N. Hegde, "An internet of things-based smart energy meter for monitoring device-level consumption of energy," *Computers & Electrical Engineering*, vol. 87, p. 106772, 2020.
[2] A.-W. Muhammed, V. Oisamoje, H. Amhenrior, E. Evbogbai, V. Abanihi, L. Bello, and C. Obasi, "Design and implementation of an IoT-based home energy monitoring system," 2022.
[3] P. S. Macheso and D. Thotho, "ESP32 based electric energy consumption meter," *International Journal of Computer Communication and Informatics*, vol. 4, no. 1, pp. 23–35, 2022
[4] A. Shukla and R. Diwan, "IoT based load automation with remote access surveillance using ESP32 Cam and ESP8266 module," *Annals of the Romanian Society for Cell Biology*, vol. 25, no. 3, pp. 690–870, 2021
[5] O. O. Akintade, T. K. Yesufu, and L. O. Kehinde, "Development of power consumption models for ESP8266-enabled low-cost IoT monitoring nodes," *Advances in Internet of Things*, vol. 9, no. 1, pp. 1–20, 2019
[6] P. K. Sebastian and K. Deepa, "Internet of Things based smart energy meter with fault detection feature and theft detection," in *Proc. 2022 Int. Conf. on Electronics and Renewable Systems (ICEARS)*, pp. 494–500, IEEE, 2022.
[7] A. S. Salunkhe, Y. K. Kanse, and S. S. Patil, "Internet of things based smart energy meter with ESP32 real-time data monitoring," in *Proc. 2022 Int. Conf. on Electronics and Renewable Systems (ICEARS)*, pp. 446–451, IEEE, 2022..
[8] N. A. Hussien, A. A. D. Al-Magsoosi, H. T. S. Alrikabi, and F. T. Abed, "Monitoring the consumption of electrical energy based on the Internet of Things applications," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 7, pp. 4–17, 2021
[9] P. Srivastava, M. Bajaj, and A. S. Rana, "IoT based controlling of hybrid energy system using ESP8266," in *Proc. 2018 IEEMA Engineer Infinite Conf. (eTechNxT)*, pp. 1–5, IEEE, 2018.
[10] R. Firmansyah, M. Yusuf, P. P. S. Saputra, M. E. Prasetyo, F. M. Mochtar, and F. A. Kurniawan, "IoT based temperature control system using NodeMCU ESP8266," in *Int. Joint Conf. on Science and Engineering (IJCSE)*, pp. 401–407, Atlantis Press, 2020.
[11] I. G. M. N. Desnanjaya, A. A. S. Pradhana, I. N. T. A. Putra, S. Widiastutik, and I. M. A. Nugraha, "Integrated room monitoring and air conditioning efficiency optimization using ESP-12E based sensors and PID control automation: A comprehensive approach," *Journal of Robotics and Control (JRC)*, vol. 4, no. 6, pp. 832–839, 2023.
[12] R. I. Pereira, S. C. Jucá, and P. C. Carvalho, "IoT embedded systems network and sensors signal conditioning applied

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 03/11/2023 Article Revised: 22/11/2023
Article Accepted: 29/12/2023 Article Published-07/01/2024

to decentralized photovoltaic plants," *Measurement*, vol. 142, pp. 195–212, 2019.

[13] C. Z. I. Arnob, N. S. Mitra, A. B. H. Saad, M. T. Alam, M. Islam, and A. N. Huda, "Smart load monitoring and controlling approach connected to solar system using ESP32 and Blynk," in *Proc. 2022 Int. Conf. on Energy and Power Engineering (ICEPE)*, pp. 1–5, IEEE, 2022.

[14] A. Swart, "Cost-effective remote energy monitoring using the ESP8266 NodeMCU," *International Journal of Recent Technology and Engineering*, vol. 7, pp. 974–979, 2019

[15] J. Pan, R. Jain, S. Paul, T. Vu, A. Saifullah, and M. Sha, "An Internet of Things framework for smart energy in buildings: Designs, prototype, and experiments," *IEEE Internet of Things Journal*, vol. 2, no. 6, pp. 527–537, Dec. 2015.

[16] F. Condon, J. M. Martínez, A. M. Eltamaly, Y.-C. Kim, and M. A. Ahmed, "Design and implementation of a Cloud-IoT-based home energy management system," *Sensors*, vol. 23, no. 1, p. 176, 2023.

[17] Q. Yang and H. Wang, "Privacy-preserving transactive energy management for IoT-aided smart homes via blockchain," *IEEE Internet of Things Journal*, vol. 8, no. 14, pp. 11463–11475, Jul. 2021.