An IoT-Based Voice-Controlled System for Efficient Energy Monitoring

Dr. Parimala V[1], Arjun V[2], Giriprasath V[3], Dharshan S[4]
[1]AP III, Department of EEE, KPR Institute of Engineering and Technology Coimbatore, India
[2,3] Department of EEE, KPR Institute of Engineering and Technology Coimbatore, India
[4]Department of ECE, KPR Institute of Engineering and Technology Coimbatore, India

***Abstract*—The proposed system describes the voice assistanted Energy Monitoring and Control the devices using Sinric Pro platform and ESP32. This project improves user accessibility and convenience by controlling appliances like fans and lights with both voice commands and manual touch switches. For device switching, it uses relay-based actuation. It also uses the Sinric Pro cloud service to provide remote operation and status synchronization. To monitor in real time, the system uses the ZMPT101B sensor to detect voltage and the ACS712 sensor to measure current. On the Blynk mobile application, these figures are utilized to calculate energy and power consumption in kWh, which are updated continuously. EEPROM memory is used to store the energy data, guaranteeing consistency even after power resets and providing accurate tracking of electricity consumption. Both intelligent appliance control and effective energy management are benefits of this technology. Using cloud-based services and the ESP32 microcontroller, the system guarantees scalability and smooth connectivity. The design is extremely advantageous for home automation and energy optimization in residential settings since it incorporates power analytics through sensor interfaces and Blynk-based visualization.**

***Index Terms*—Voice-Controlled Automation, IoT Energy Management, ESP32 Microcontroller, Sinric Pro Integration**

I.INTRODUCTION

The Internet of Things' (IoT) quick development has revolutionized a number of industries, including energy management, by making it possible to create more intelligent and effective systems for managing and tracking energy use. The goal of this project is to create and deploy a voice-activated automation system that offers an easy-to-use and intuitive method of controlling electrical applications. Users can remotely operate equipment using voice commands and mobile interfaces thanks to the system's integration of the ESP32 microcontroller, relay modules, and cloud-based platforms like Sinric Pro and Blynk. Energy efficiency and conservation are encouraged by the use of sensors to monitor energy use and the real-time visualization of data. Targeting residential, commercial, and industrial settings, the project provides a scalable and adaptable solution for contemporary energy management requirements. In the end, the system demonstrates how IoT technology may revolutionize energy management procedures by streamlining the device control process and promoting sustainable energy use.

The use of voice recognition technology to operate a variety of systems or devices without requiring human involvement is known as voice-controlled automation. Voice-controlled automation in this project enables customers to operate electrical equipment by merely using voice requests on Google Assistant-like platforms. The system can receive speech inputs, connect to devices, and initiate actions like turning fans or lights on or off by using cloud services like Sinric Pro. By removing the need for physical switches or smartphone apps to control devices, this type of automation improves user convenience by offering a simple and hands-free method of interacting with smart gadgets. Voice-controlled automation is a crucial component of contemporary smart homes and companies since it not only increases accessibility but also encourages energy efficiency by providing real-time management and monitoring of electrical appliances in a variety of contexts.

II.RELATED WORK

This paper outlines the design and implementation of an energy [1] monitoring and control system based on the Internet of Things. It emphasizes on tracking and managing energy consumption in real time utilizing low-cost Internet of Things devices, such as sensors, microcontrollers, and communication modules. The technique aims to reduce energy waste and increase efficiency by providing consumers with remote control over their energy usage. Because it prioritizes affordability, ease of use, and accessibility, the recommended solution is a logical choice for households and small businesses searching for energy-saving solutions.

This article [2] looks at the several applications of control and monitoring systems based on the Internet of Things. It looks at their structures, highlighting crucial components such sensors, communication protocols, and data storage systems. Among the topics discussed in the study are interoperability with existing infrastructure, scalability, and data security. The writers talk about the evolution of IoT technologies and how they may impact industries like agriculture, healthcare, transportation, and energy management.

This evaluation emphasizes on Internet of Things-based technologies for monitoring and controlling electrical appliance energy consumption in order to reduce waste and [3] boost energy efficiency. It discusses the key components of these systems, including sensors, communication protocols, and data analytics platforms, and shows how they work in smart homes and buildings. The paper examines load balancing, automated control, and energy-saving strategies in addition to the benefits of real-time data analysis.

This academic review explains how [4] IoT devices could enhance energy management systems. It talks about the use of IoT technology for energy monitoring and control and provides details on its benefits, which include increased energy efficiency, reduced costs, and sustainability. Important topics covered in the study include interoperability, data security, and the need for dependable communication networks. It emphasizes the need for continuous advancements in IoT hardware and software, with a focus on automated control and real-time data monitoring, in order to improve the effectiveness of energy management systems.

In order to measure critical parameters like voltage and current, this study proposes a real-time energy monitoring and control system based on LoRa (Long Range) [5]. Delivering accurate and timely data for energy management in residential and commercial settings is the system's aim. The system provides reliable data transfer over long distances by utilizing LoRa's long-range, low-power communication features. The system might reduce operational expenses, increase energy efficiency, and provide consumers remote control over their energy consumption, according to the research.

This paper investigates the application of IoT-based analysis for intelligent energy management, with an emphasis on the role of algorithms for [6] energy disaggregation. The study looks at several approaches to analyzing energy consumption trends in order to decrease energy waste and boost efficiency in smart homes and buildings. It looks into how IoT networks could automate control, manage demand, and optimise energy distribution using real-time data.

Using machine learning and cognitive analysis to optimise energy use, this research examines IoT-based energy management frameworks for smart cities [7]. In order to support real-time energy decisions, it examines how sensors and Internet of Things devices may collect data on building performance, environmental factors, and energy consumption. Predictive models and advanced analytics that reduce energy use and promote sustainability are the study's main focus.

In this system, Maryam Sangharama [8] et al. have suggested In order to address location-aware, latency-sensitive, and security-critical applications (such as real-time manufacturing, patient health monitoring, and emergency fire events), smart city development today mainly depends on more complex computing paradigms. Due to its close closeness to the endpoints, fog computing—a powerful addition to cloud computing—is essential in this regard.

According to Chong-Wen Chen [9] et al., this system Smart city development now requires the successful integration of social landscapes, human well-being, and the built environment in addition to intelligent technological applications to provide sustainable living. Though happiness may be the key to sustainability, few studies have considered it as a measure of residents' quality of life in smart city development.

In this framework, smart city development has emerged as the current urban planning trend, according to N.S. Jayasena [10] et al. The concept of a "smart city" steers urban development in a deliberate direction towards sustainability. A review like this would help any region better understand the concept of smart cities. Similarly, in order to guarantee the success of smart city development initiatives, it is essential to identify the various stakeholders who will influence and contribute to them. The success of any project depends on timely and effective stakeholder consultation, as previous research has demonstrated.

III.PROPOSED SYSTEM

The suggested solution integrates voice control, cloud connectivity, and real-time data analytics to provide a full IoT-based smart automation and energy monitoring framework as shown in Figure 1. The ESP32 microcontroller, which is at the heart of the system, communicates with relay modules to regulate electrical appliances like fans and lights. The Sinric Pro platform is connected with the system, allowing hands-free operation through voice commands through Google Assistant. Touchscreen switches also allow manual control, providing a flexible way to engage with the device. Utilizing the ACS712 current sensor and the ZMPT101B voltage sensor, which continuously measure electrical characteristics such as voltage, current, power, and energy consumption, the system keeps an eye on energy use. By processing and visualizing these statistics in real-time, the Blynk mobile application raises user awareness of power consumption. To guarantee persistence across reboots, the cumulative energy data is kept in EEPROM. This suggested system offers a workable solution that encourages energy efficiency, usability, and sustainability through the integration of IoT technologies. It is scalable, user-friendly, and adaptable for residential, commercial, and industrial environments.

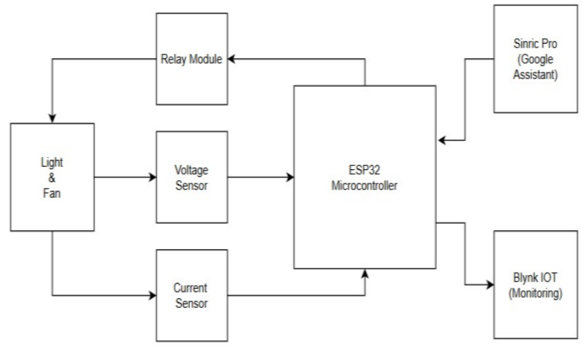

Figure 1. Block Diagram of the proposed system

Lighting Load

Controlling lights and fans in a smart automation system is the main application of Internet of Things-based home management. These appliances are great candidates for automation because of their extensive use in both home and commercial settings. Because the ESP32 microcontroller and relay module integrate light and fan control as shown in Figure 2, users may easily operate these devices using voice commands or smartphone apps. This enhances accessibility and user convenience by eliminating physical switches, especially for elderly or disabled individuals. Real-time control over lighting and fan speed or operation not only improves comfort but also encourages energy conservation by ensuring that devices are only used when needed. With systems like Sinric Pro and Blynk, users can automate tasks, track consumption, and schedule fans and lights to create a more intelligent and efficient living space.

Figure 2. Light and fan

Relay module

The relay module plays a crucial role in the implementation of Internet of Things-based automation systems by acting as a link between low-power microcontrollers and high-power electrical appliances. To handle the switching of equipment like fans and lights, this project uses a relay module as shown in Figure 3. This enables the system to control

these appliances with voice commands or mobile applications. The relay responds to a control signal from the ESP32 microcontroller by turning on or off the connected devices without the need for human intervention. This ensures the safe and effective functioning of AC equipment while maintaining electrical isolation between the devices and the control unit. Through the independent and efficient control of multiple devices inside the Internet of Things architecture, relay modules increase the system's scalability and flexibility.

Figure 3. Relay module

Voltage Sensor

Monitoring the voltage levels of connected electrical equipment is the responsibility of the voltage sensor as shown in Figure 4, a crucial part of the Internet of Things-based energy management system. In order to evaluate energy consumption, identify irregularities, and make sure that equipment are functioning within safe voltage limits, the sensor continuously measures the voltage and delivers real-time data. The microcontroller receives this data, processes it, and then sends it to cloud platforms for analysis and visualization. By enabling proactive energy monitoring and promoting educated decision-making for energy saving, the addition of a voltage sensor improves the system's dependability and safety. Its integration greatly increases the smart automation setup's efficiency and advances the larger objective of electricity consumption optimization.

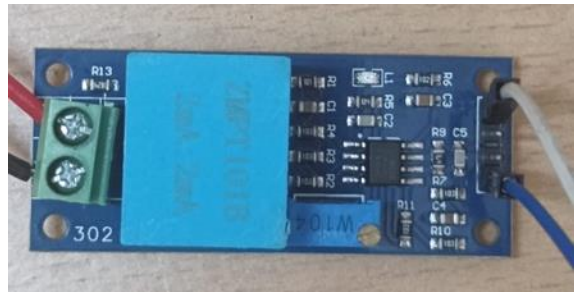

Figure 4. Voltage Sensor

Current Sensor

Because it measures the current passing through electrical appliances in real time, the current sensor as shown in Figure 5 is an essential component of the Internet of Things-based energy management system. This sensor aids in monitoring power usage trends and identifying overloads or anomalies that can point to broken equipment or wasteful energy use. The sensor gives the microcontroller precise current readings, which allow it to determine power consumption and send the data to cloud platforms for tracking and visualization. This helps with energy optimization and improves system safety by averting possible risks. By integrating a current sensor, users may make data-driven decisions for more effective device management, which helps to conserve energy and promote sustainable operation.

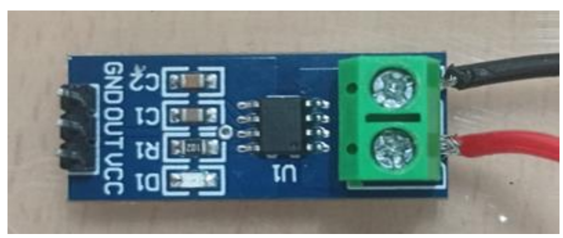

Figure 5. Current Sensor

Esp32 Micro Controller

A strong and adaptable mainstay of the voice-activated Internet of Things energy management system is the ESP32 microcontroller as shown in Figure 6. With built-in Wi-Fi and Bluetooth, this low-cost, low-power system-on-chip (SoC) is perfect for smart automation applications. The ESP32 manages device control, voice command processing, and communication with cloud platforms such as Sinric Pro. In order to carry out real-time monitoring and control duties, it also easily interacts with a variety of sensors, relay modules, and other peripherals. The ESP32 serves as the foundation of intelligent and responsive home and industrial automation systems because of its dual-core CPU, strong GPIO support, and vast library ecosystem, which provide effective data handling and wireless networking.

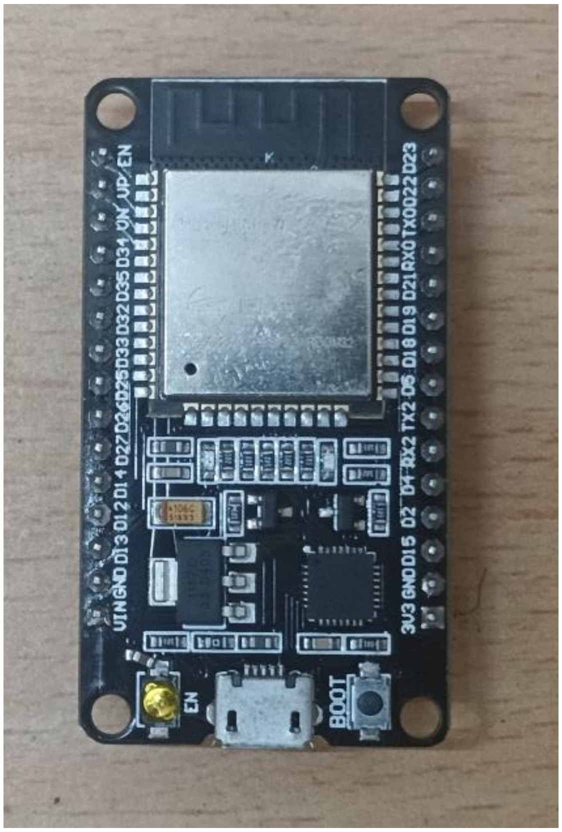

Figure 6. Esp32 Micro Controller

Sinric Pro

A cloud-based platform called Sinric Pro makes it possible for voice assistants like Google Assistant and Amazon Alexa to be seamlessly integrated with smart devices. In this project, Sinric Pro serves as a conduit between the user's voice commands and the ESP32 microcontroller, enabling remote, real-time control of electrical appliances using basic speech inputs. By registering gadgets on the Sinric Pro dashboard and associating it with Google Assistant, users can switch appliances like lights and fans on or off with ease. Additionally, it facilitates webhook support for sophisticated automation, device state synchronization, and secure two-way communication. Sinric Pro's integration promotes a smart and connected living environment by greatly increasing user convenience and lowering the need for in-person interaction.

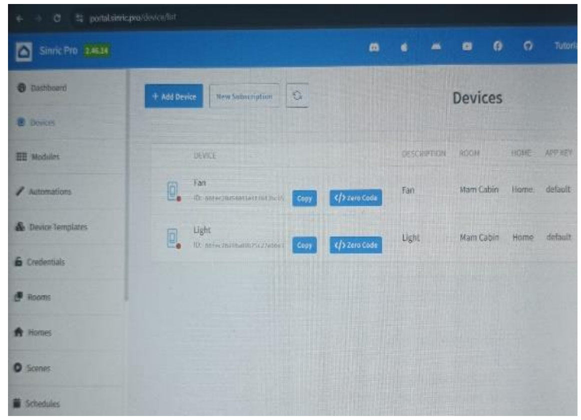

Figure 7. Sinric Pro

Blynk IoT

Blynk IoT is a robust platform that makes it possible to monitor and manage smart devices in real time via an intuitive web dashboard and mobile application. In order to provide visual insights into energy consumption and device operation, this project uses Blynk IoT to monitor a variety of electrical data, including voltage, current, power and unit as shown in Figure 8. Users can view and interact with real-time data remotely thanks to the ESP32 microcontroller's ability to gather sensor data and send it over Wi-Fi to the Blynk platform. Blynk improves system usability and engagement with customizable widgets and graphical interfaces, which makes it simpler to monitor performance, spot irregularities, and guarantee effective energy use in a smart home setting.

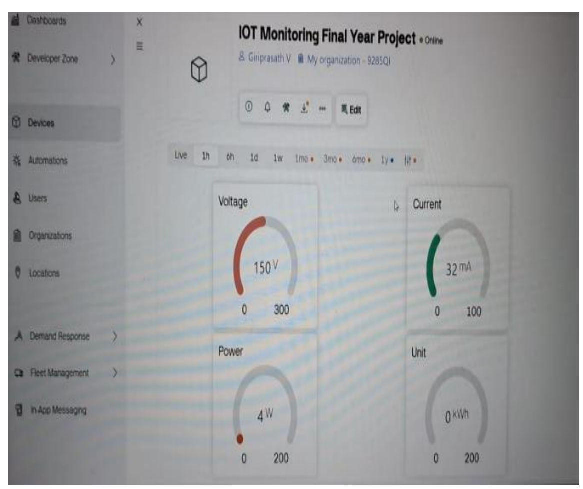

Figure 8. Blynk IoT

IV. EXPERIMENTAL SETUP

The deployment of the voice-activated Internet of Things-based energy automation system as shown in Figure 9 yielded encouraging and favorable results in terms of performance, reliability, and user experience. Voice control and mobile-based control of electrical devices are now available thanks to the system's successful integration of the ESP32 microcontroller with the Sinric Pro and Blynk platforms. The devices responded rapidly to voice commands delivered through Google Assistant, showing low latency and good execution accuracy. Additionally, the Blynk dashboard's real-time monitoring of voltage, current, and power consumption through connected sensors allowed users to easily see their energy usage patterns. EEPROM storage ensured that cumulative energy data was maintained even in the case of a power failure, enabling consistent energy tracking. Flip switch debouncing allowed for error-free manual operation while maintaining synchronization between the digital and physical controls. The Wi-Fi module remained stable during testing in a range of network scenarios, enabling seamless cloud connectivity.

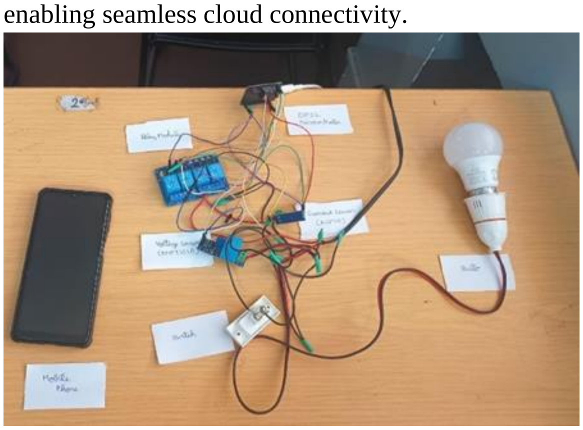

Figure 9. Experimental Setup

Overall, the results show that the system is versatile and scalable, supporting energy management in both homes and enterprises. This real-world example shows how, when combined with automation and intuitive user interfaces, IoT can greatly improve energy efficiency and convenience in smart settings.

V. RESULT AND DISCUSSION

The IoT-based voice-controlled automation system's outcomes show how effective it is in controlling energy use while offering real-time monitoring and control. The data gathered indicates that the voltage supply stayed constant at 220V, but that connected appliances' operations caused changes in current and power usage. As the current flow grew from 36 mA to 42 mA, the power usage progressively increased from 5 Wh to 8 Wh, demonstrating the system's capacity to manage a variety of loads. As anticipated considering the brief usage period during testing, the energy consumption in kWh remained low. Furthermore, the connectivity with platforms such as Sinric Pro and Blynk allowed for smooth remote control and real-time device state monitoring, complementing the automation and energy management goals of the system. These results show that the suggested solution is scalable and functional for real-world settings, guaranteeing minimal manual intervention, power optimization, and user convenience.

Voltage (V)	Current (mA)	Power (Wh)	Unit (kWh)
220	36	5	0
220	38	6	0
220	42	8	0

Comparison Table

This table shows the electrical measurements taken when the voice-activated automation system based on the Internet of Things was operating. Voltage, current, power, and energy consumption in units are among the parameters it contains. The voltage stays at 220V across all three measurements, suggesting a steady power source. The current exhibits gradual variations depending on the connected load, varying slightly between 36 mA, 38 mA, and 42 mA. As a result, the power consumption rises from 5 Wh to 8 Wh, demonstrating the connection between power consumption and current. The short length and low power consumption of the tests result in a minimal energy usage in kWh (reported as 0). This information aids in evaluating the system's trends of energy usage and efficiency.

VI. CONCLUSION

The voice-activated Internet of Things-based energy automation system effectively illustrates the possibilities of smart technology in contemporary energy management, to sum up. Utilizing the ESP32 microcontroller, Sinric Pro cloud platform, and Blynk interface, the system provides smooth electrical appliance control, monitoring, and real-time data visualization. While EEPROM allows for durable energy data storage, sensor integration guarantees precise tracking of voltage, current, and power usage. Users have a variety of control options thanks to voice commands through Google Assistant and physical switch inputs, which improve accessibility and convenience. The system is appropriate for a range of environments, including commercial, industrial, and residential ones, due to its dependable connectivity and strong performance. Overall, the project provides a sustainable and scalable solution for smart living spaces, supporting the larger goals of automation and energy conservation.

REFERENCES

[1] "Energy Monitoring and Control Using Internet of Things (IoT) System," International Journal of Electrical and Computer Engineering, 12(3), 135-144, Jain, R., & Sharma, P. (2018).

[2] "Evaluation of Internet of Things-Based Monitoring and Control Systems" Singh, A., and Kumar, S. (2020). Journal of Smart Technologies, 15(2), 95-108.

[3] "A Review of Energy Monitoring and Control Systems Based on the Internet of Things." Reports on Energy, 5, 143–153 (2019). Gupta, M. and R. Patel.

[4] Kumar, S. and Mehta, V. (2021). Monitoring and Controlling Energy Management Systems using Internet of Things (IoT) Devices—A

[5] 5.IoT and Smart Computing International Journal, 11(2), 78-86. 5. Joshi, D. and Verma, A. (2020). "Real-time Energy Monitoring and Control System Powered by IoT."

[6] "IoT-based Analysis for Smart Energy Management." Journal of Smart Energy Systems, 7(1), 51-63 (2019). Patel, N., & Sharma, S.

[7] Sharma and Yadav's article "Intelligent Energy Management with IoT Framework in Smart Cities Using Intelligent Analysis" (2022). Smart Cities and Energy Management, 6(2), 88-101.

[8] MoghadamFarid, A., Songhorabadi, M., Rahimi, M., & Kashani, M. H. (2023). IoT-enabled smart cities using fog computing techniques. 211, 103557, Journal of Network and Computer Applications.

[9] Chong-Wen Chen. "Is it possible for smart cities to foster happiness and support sustainable development? Urban liveability and subjective well-being contexts and indicators. Built Environment Developments 13 (2023): 100108

[10] Carlos Llopis-Albert, Yingjie Hu, Zeng, and Shouzhen. "Multi-criteria, stakeholder-inclusive creation of smart cities." Business Research Journal 154 (2023): 113281