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Design of Real-Time Energy Monitoring and Slab Based Alert System for Domestic Application

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Abstract

The Power Consumption Monitoring System offers a comprehensive solution for residential energy management by measuring power usage and estimating costs in real-time. This paper introduces a user-friendly approach to empower individuals to control their energy consumption actively. With an integrated alert system, users receive notifications when nearing a higher cost slab, promoting more cautious energy use and potentially reducing expenses. Enhanced through IoT automation, the system allows control of home appliances and intruder detection when the consumer is away. With its IoT-driven insights and reminders, the system helps users reduce unnecessary energy usage. Key components, including a Telegram chatbot, ESP8266 microcontroller, and PZEM module, provide instant energy monitoring, while Google Sheets ensures accessible data storage. This system also delivers personalized recommendations and integrates seamlessly with smart home devices, balancing convenience with energy efficiency. Emphasizing data security and scalability, this approach aims to lower energy costs by avoiding unnecessary energy consumption, reducing environmental impact, and empowering users in sustainable energy consumption. The

proposed method also directly supports Sustainable Development Goals (SDGs), particularly in areas of affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), and climate action (SDG 13).

Keywords
Internet Of Thing, Slab-Based Alert System [Sbas], Pzem Module, Esp8266, User-Friendly Interface, Python Anywhere, Energy Consumption Monitoring.

1. Introduction
Electricity has become an indispensable element of modern civilization, permeating every aspect of our society. It serves as a crucial medium for signal transmission in technologies such as computers and cell phones. In the industrial sector, manufacturing heavily relies on electricity to power nearly all moving parts and can be transformed into various forms such as light, heat, and magnetism. Scientific advancements, exemplified by portable batteries and memory sticks, have significantly enhanced our quality of life. Additionally, electric treatment plays a role in curing diseases, and the electric printing press has given rise to newspapers, magazines, and books, illuminating both our homes and minds. Managing energy is pivotal in navigating this realm of thought (Saran et al. 2020). Energy management and theft detection are critical concerns for utility companies and consumers alike. Traditional energy meters lack real-time monitoring capabilities and effective theft detection mechanisms, often resulting in significant revenue losses and inefficient energy usage. Manual meter reading is prone to human error, time-consuming, and fails to provide immediate data on energy consumption patterns. (Jawale et al. 2021)

This paper integrates various systems to develop the idea further, employing concepts from the Internet of Things (IoT), Data Science, Telegram bot (referred to as Smart Workspace), ESP8266, and PZEM-004T.The Internet of Things, or IoT, is a concept that uses constant internet access for various uses, including remote control and data sharing (Hassan et al. 2020). Remotely controlling various electronic components in a workspace, such as lights, fans, drawer locks, plugs, and temperature sensors, is one useful application. For this research project, an ESP8266 device will be used to create a remote-control system that will provide local control via an AI-powered chatbot that can be accessed through the Telegram Messenger platform (Patel et al. 2021). The idea is to make it easier for workers to use their PCs or cell phones to manage electronic equipment in their workspace, doing away with the need for manual labour and encouraging energy efficiency by using less electricity. By putting in place a Smart Workspace, staff members may easily control their electronic devices without having to go back to the workplace to switch the lights on or off. (Muslih et al. 2018)

Telegram Messenger is a popular chat program that is growing in popularity. Telegram is being used by an increasing number of individuals; there are currently 62 million active users (DAU) with 15 million daily users, and 1 million new users join the platform each week. (Telegram Revenue and Usage Statistics 2018). Due to its ease of use and ability to be accessed with or without a smartphone—it can still be accessed through a web browser and is not limited to smartphones—Telegram Messenger has become a popular tool for families, friends, and business users alike. (Thomas et al. 2022)

It is anticipated that staff will find it simpler to use the electronic equipment on their desks with Smart Workspace since orders will only be placed from smartphones via Telegram messengers and the AI chatbot this study provides. Through notifications, chatbots are used to remind staff members whether to turn on or off their devices and to remind them to put on the fan when it gets too hot outside. In this instance, the chatbot functions as an unseen office assistant, providing secretarial-like support to the workplace in workplace management. (Muslih et al. 2018)

2. Components
2.1 PZEM Module
For electrical parameters like voltage, current, and active power measurement function Pzem-004t is utilized. Four-part display function: active power, current, and voltage are displayed. The TTL serial interface's serial communication function allows you to read and set parameters while interacting with the adapter plate through a variety of terminals (Table 1).

The primary functions of the PZEM-004T AC communication module are the measurement of AC voltage, current, active power, frequency, power factor, and active energy. The module lacks a display feature, and the TTL interface reads the data. Figure 1 illustrates the PZEM connection with ESP8266, Figure 2 illustrates the PZEM Block diagram (Figure 1).

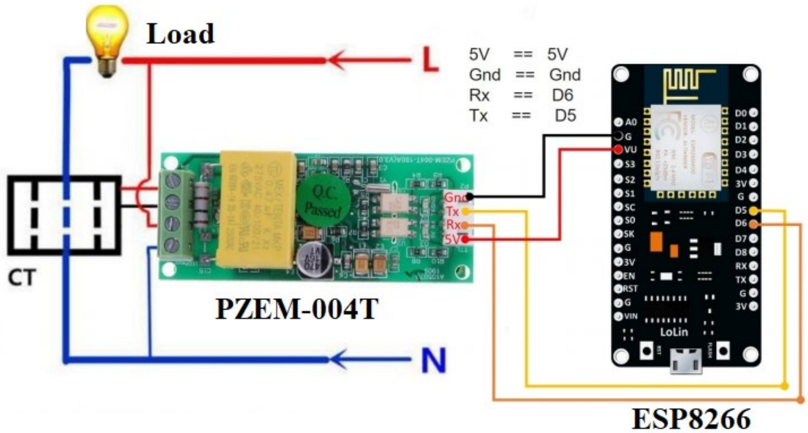


Figure 1. Schematic of Pzem-004t.

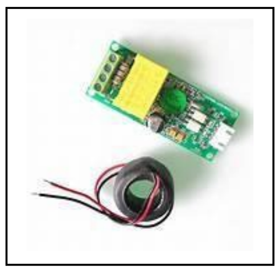


Figure 2. Pzem-004t

Table 1. Ratings of Pzem-004t.

Features	Details
Voltage Current Active power Active energy Frequency Power factor	R: 80-260V, Res: 0.1V, Ac: 0.5% R: 0-100A, Res: 0.001A, Ac: 0.5% R: 0-23KW, Res: 0.1W, Ac: 0.5% R: 0-9999.99kWh, Res: 1kWh, Ac: 0.5% R: 45-65Hz, Res: 0.1Hz, Ac: 0.5% R: 0-1, Res: 0.01, Ac: 0.5%
Measuring range 100A	External transformer
Phase	Single phase
Physical protocol	UART to TTL communication interface, band rate is 9600, 8 data bits, 1 stop bit, no parity.
Application protocol	Modbus-RTU
Operating temperature	-10 to 60℃

2.2 ESP8266

The ESP8266 boasts a small form factor and a wealth of functionality. Figure 1 displays the functional block diagram for the modules. Figure 1: Functional block diagram of the ESP8266 (Jain et al. 2019). The ESP8266 is especially appealing for Internet of Things applications due to its primary features, which are:
• Tensilica L106 32-bit RISC processor with 160MHz maximum clock speed.
• 36kB internal SRAM and 4MB external SPI flash.

• several native sleep modes.
• small form-factor (24x16 mm) making it embeddable in many devices.
• very low cost, especially when compared to other Wi-Fi modules.
• standard IEEE 802.11 b/g/n (Wi-Fi) compliance with on- board antenna.
• WPA/WPA2 security protocols.

The following functionalities can be operated with sufficient processing power by a 32-bit processor, greatly simplifying the creation of Internet of Things applications:

- An end-station, softAP, or combination of both; and a real-time operating system softAP, or both in combination (Chandra babu et al. 2020).
- The whole TCP/IP protocol stack. Numerous Internet of Things applications are being created on publisher-subscriber middleware's, which can be directly integrated with these capabilities and the module's processing capability, according to previous experiments (Babu et al. 2023).

However, we hypothesize that the functions that the ESP8266 module offers are hardly necessary to create Wi-Fi-enabled gadgets that are simple to program and connect to the Internet. (Mesquita et al. 2018) (Figure 3).

Figure 3. Esp8266 module.

2.3 Pushbullet Notification

The quickest and easiest method for retrieving notes, links, files, lists, and addresses from a desktop computer to a mobile device and vice versa is using Pushbullet. The pushbullet Android apps and the services website handle this. Use to send out alerts when the room temperature rises or to detect the presence of fire or harmful gases like smoke, LPG, and other substances.

To use the ESP8266NodeMCU and application pushbullet to send an alert message to the phone and PC, the setup First, access Pushbullet.com. A setup account is made. Next, connect your phone and download the pushbullet program. Chrome will further allow you to notify the machine if you use it as a Chrome user. Your prerequisite authorizes the access to utilize the API. then locate the API by logging into your account. Who links the ESP8266NodeMCU to the pushbullet is shown in Figure 4. (Abdelaziz et al. 2020)

Figure 4. Connect ESP8266Nodemcu to Pushbullet Application

3. Methodology

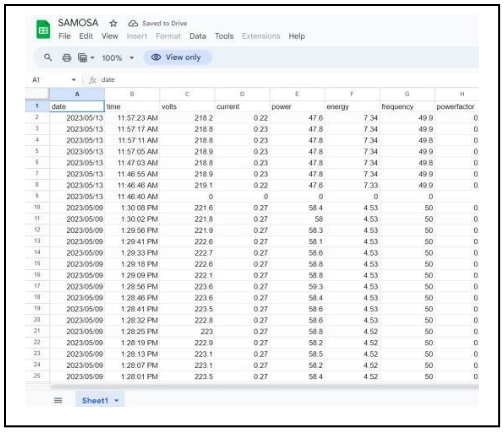
3.1 Architecture

As shown in Figure 6 the components are arranged as follows:

1. Telegram Chatbot: Crafted through the Telegram API, this chatbot delivers a seamless interface for users to access up-to-the-minute energy consumption data and receive alerts.

2. ESP8266 Microcontroller: Collaborating with the Pzem module, this element meticulously gathers precise energy consumption data while fostering seamless communication with the chatbot. (Figure 5).

3. Google Sheets: Operating as the designated repository, Google Sheets not only stores energy consumption data but also provides an accessible and adept platform for data management. (Chandra Babu et al. 2024)



	date	time	volts	current	power	energy	frequency	powerfactor
2	2023/05/13	11:57:23 AM	218.2	0.22	47.6	7.34	49.9	0.
3	2023/05/13	11:57:17 AM	218.8	0.23	47.8	7.34	49.9	0.
4	2023/05/13	11:57:11 AM	218.8	0.23	47.8	7.34	49.8	0.
5	2023/05/13	11:57:05 AM	218.9	0.23	47.8	7.34	49.9	0.
6	2023/05/13	11:47:03 AM	218.8	0.23	47.8	7.34	49.8	0.
7	2023/05/13	11:46:55 AM	218.9	0.23	47.8	7.34	49.9	0.
8	2023/05/13	11:46:46 AM	219.1	0.22	47.6	7.33	49.9	0.
9	2023/05/13	11:46:40 AM	0	0	0	0	0	
10	2023/05/09	1:30:08 PM	221.6	0.27	58.4	4.53	50	0.
11	2023/05/09	1:30:02 PM	221.8	0.27	58	4.53	50	0.
12	2023/05/09	1:29:56 PM	221.9	0.27	58.3	4.53	50	0.
13	2023/05/09	1:29:41 PM	222.6	0.27	58.1	4.53	50	0.
14	2023/05/09	1:29:33 PM	222.7	0.27	58.6	4.53	50	0.
15	2023/05/09	1:29:18 PM	222.6	0.27	58.8	4.53	50	0.
16	2023/05/09	1:29:09 PM	222.1	0.27	58.8	4.53	50	0.
17	2023/05/09	1:28:56 PM	223.6	0.27	59.3	4.53	50	0.
18	2023/05/09	1:28:46 PM	223.6	0.27	58.4	4.53	50	0.
19	2023/05/09	1:28:41 PM	223.5	0.27	58.6	4.53	50	0.
20	2023/05/09	1:28:32 PM	222.8	0.27	58.6	4.53	50	0.
21	2023/05/09	1:28:25 PM	223	0.27	58.8	4.52	50	0.
22	2023/05/09	1:28:19 PM	222.9	0.27	58.2	4.52	50	0.
23	2023/05/09	1:28:13 PM	223.1	0.27	58.5	4.52	50	0.
24	2023/05/09	1:28:07 PM	223.1	0.27	58.2	4.52	50	0.
25	2023/05/09	1:28:01 PM	223.5	0.27	58.4	4.52	50	0.

Figure 5. Data storage using Google Sheets

4. Real-time Alerts: The system boasts real-time monitoring capabilities, promptly issuing alerts when predefined thresholds signify anomalies in energy consumption.
5. Hosting and Deployment: The chatbot and server-side code find a reliable home on the PythonAnywhere platform, ensuring steadfast system availability and optimal performance. Leveraging the capabilities of PythonAnywhere enhances deployment efficiency and overall system reliability. (Chandra babu et al. 2023).

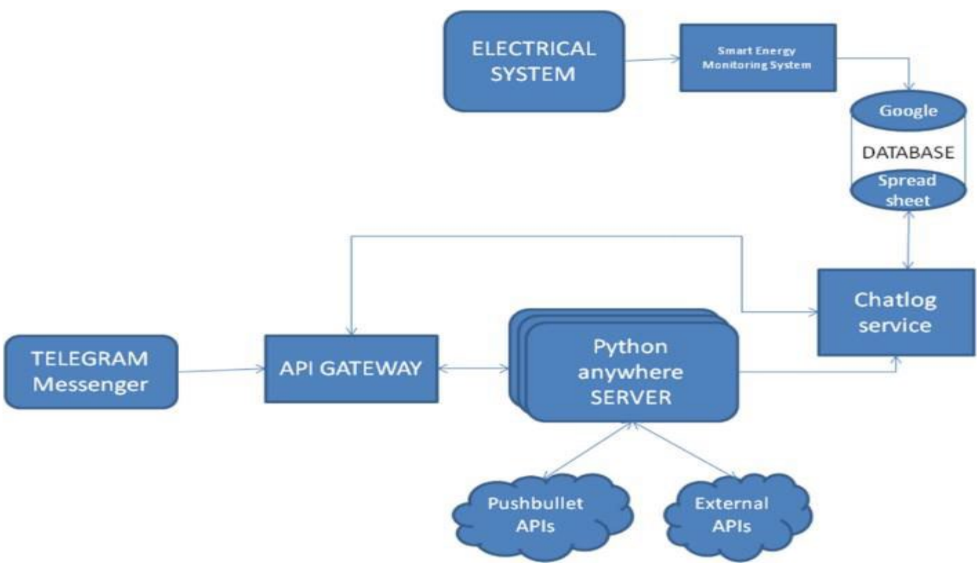


Figure 6. Block Diagram

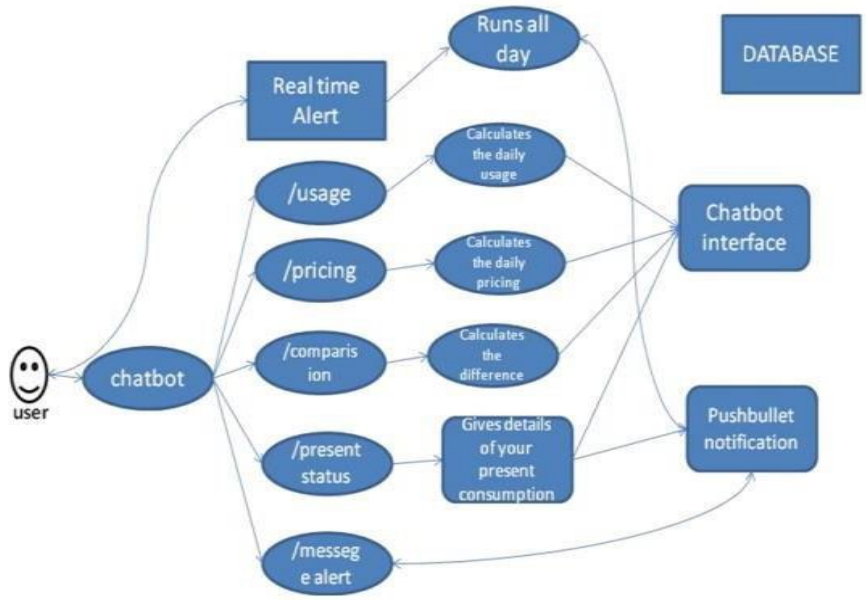


Figure 7. Workflow

The paper involves a Systematic approach illustrated in Figure 7 to design, implement, and evaluate the energy management system. The initial stages involved the careful selection of hardware components, such as PZEM modules and ESP8266, to ensure accurate and cost-effective real-time energy monitoring. The integration of Google Sheets as the database facilitated organized data storage. The development of a Telegram chatbot interface utilized API gateways for seamless communication with the central server, enabling users to query and visualize energy consumption data (Shafeeq et al. 2023). Real-time alerts and Pushbullet notifications were implemented for immediate user awareness of slab crossings or critical events. The system's command handling and data analysis capabilities were refined to generate graphical representations of energy patterns based on user queries. User testing and feedback sessions provided valuable insights for iterative improvements, and performance evaluation included scalability testing and benchmarking against industry standards. (Kumar et al. 2022)

Total Cost = Amount for Tier 1 + Amount for Tier 2 + … + Amount for Tier n ------------ [1]
Energy = [RMS power] x [number of samples] / [sample rate] ---------------------------------[2]
Cost=Energy Consumption × Real-Time Price ---[3]

4. Results and Discussion

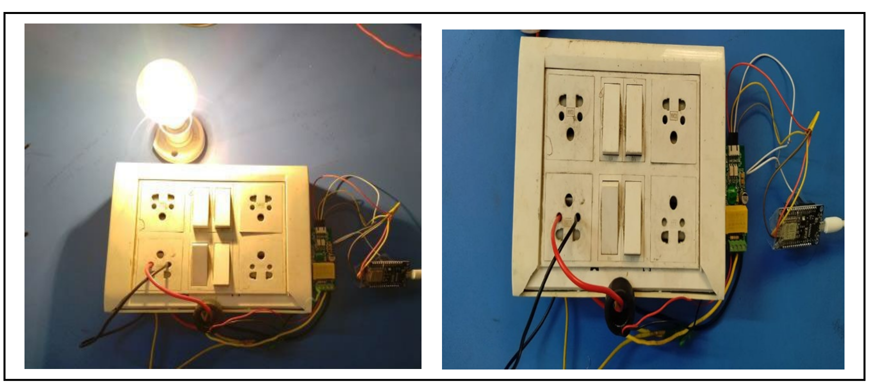


Figure 8. Prototype model, energy monitoring system connection with the load

Figure 8 illustrates the prototype model and demonstrates the successful integration of hardware and software components in realizing an efficient and user-centric energy management system. The circuit connection dynamically illustrates IoT device model's response to active energy consumption when the load is turned on. This configuration vividly showcases the real-time monitoring capabilities of our system, adeptly responding to fluctuating energy demands as appliances draw power. The figure encapsulates the essence of our technology, emphasizing its ability to adapt dynamically to varying load conditions. This real-time adaptability serves as a cornerstone of our system, empowering users with immediate insights into their energy usage during periods of increased load.

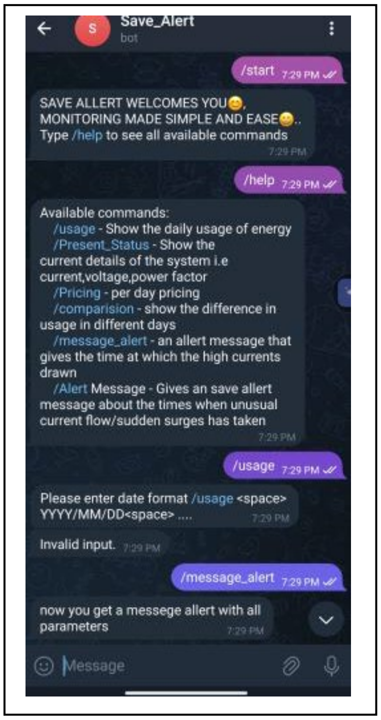


Figure 9. a. Chatbot Interface

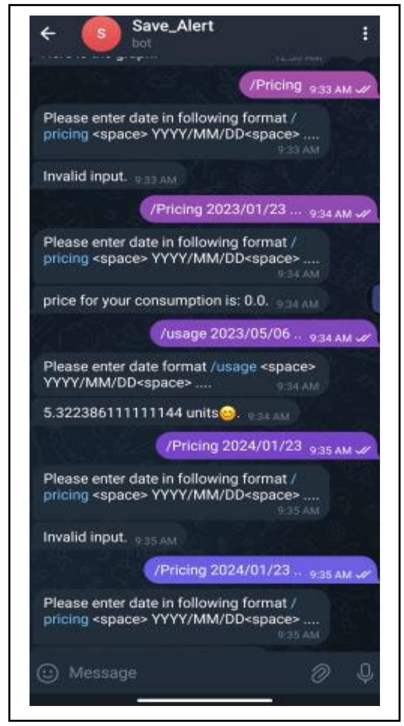


Figure 9. b. Chatbot Interface

Figure 9 offers a glimpse into the user interface of our chatbot, representing the seamless interaction between users and our energy management system. The interface is designed for accessibility and user-friendliness, enabling users to receive real-time alerts, insights into their energy consumption, and personalized recommendations. This visual representation underscores our commitment to providing a direct and intuitive platform for users to engage with the system. The chatbot interface serves as a pivotal bridge between advanced technology and the end user's experience in managing their energy consumption (Figure 10).

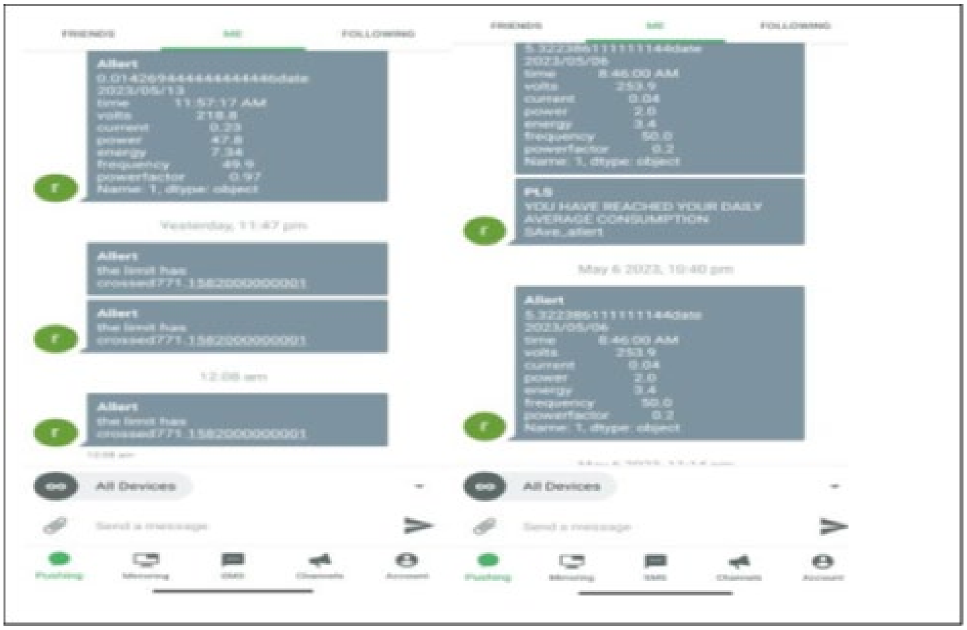


Figure 10. live notifications through push bullet

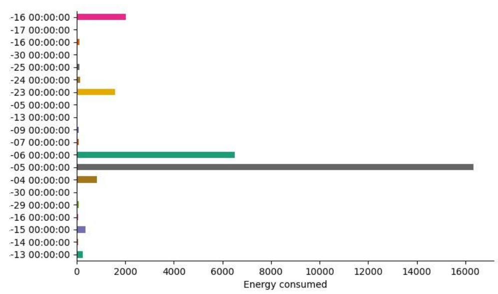


Figure 11. Visualized view of daily consumption

Figure 11 presents a visualized view of daily energy consumption, offering users a comprehensive overview of their energy usage patterns. Through intuitive graphical representations, users can discern trends, peaks, and troughs in their energy consumption over a day. This visualization enhances users understanding of their energy usage dynamics, enabling them to identify opportunities for optimization and efficiency. By providing a clear and insightful depiction of daily consumption, Figure 11 empowers users to make informed decisions to manage and regulate their energy usage effectively.

5. Future Scope

The paper's future scope lies in further enhancing the chatbotbased energy monitoring system to improve user accessibility and usability while embracing advancements in demand-based and real-time pricing models. This entails refining the user interface, integrating advanced data analytics for predictive insights, exploring smart home technology integration, scaling the system for industrial applications, and addressing policy implications and regulatory compliance. By focusing on these areas, the paper aims to contribute to the ongoing evolution of energy management technologies, ensuring they remain adaptable, user-friendly, and effective in optimizing energy usage and reducing costs for diverse user groups.

6. Conclusion

The developed energy management system, orchestrated through the Telegram chatbot, ESP8266 microcontroller, and Google Sheets database, represents a cohesive and user-centric solution for real-time energy monitoring. The

Telegram API facilitates an intuitive interface for users to seamlessly retrieve data and receive immediate alerts. Integration with the ESP8266 and Pzem module ensures precise data collection, which is crucial for accurate energy consumption insights. Google Sheets, as the chosen database, provides a flexible and scalable storage solution accessible via the Google Sheets API. The system's real-time alert mechanisms enhance user awareness, promoting timely actions for optimized energy usage. Rigorous testing has affirmed the system's reliability and functionality. Overall, this methodology underscores our commitment to empowering users to actively manage their energy consumption, foster sustainability, and embrace efficient energy practices through a technologically advanced and user-friendly solution. Future enhancements may include refining the system based on user feedback and advancements in energy management technologies, as well as integrating a voice assistant to make it accessible for illiterate users.

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Biographies

Rohan Raj Pasupunoori is a passionate engineer with a strong interest in innovation and technology. He is currently working as a Graduate Engineer Trainee at Schindler India Pvt. Ltd. Rohan completed his undergraduate studies in Electrical and Electronics Engineering at B V Raju Institute of Technology, in 2024. His research interests include power system protection, smart metering, power electronics and drives.

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Dr. K. Rayudu, was born in East Godavari District, Andhra Pradesh, on 10-11-1975. He completed his B.Tech. in Electrical and Electronics Engineering (EEE) from Jawaharlal Nehru Technological University (JNTU) College of Engineering, Kakinada, Andhra Pradesh in 1999, M.Tech, (Information Technology in Power Engineering) from Jawaharlal Nehru Technological University (JNTU) College of Engineering, Hyderabad, Andhra Pradesh in 2004 and completed Ph.D. in Optimal Reactive power Dispatch using GA, ACO, ABC and BAT Algorithms- under Power Systems area of specialization) from Jawaharlal Nehru Technological University Hyderabad (JNTUH) College of Engineering, Hyderabad in 2018. He has 20 years of teaching experience. He has worked as faculty (Teaching Assistant) at JNTU College of Engineering, Hyderabad and is presently working as Professor & Head, B V Raju Institute of Technology (BVRIT), Narsapur, Medak District. He has 9 International and National Journals to his credit. He has 21 International and National papers published in various conferences held in India. His research interests are Artificial Intelligence applications to Power Systems, Reactive Power Dispatch, Voltage Stability, Computer Applications to Power Systems, Smart Grids & Microgrids and Distributed Generation. He is a Life Member of ISTE, FIE,SESI and IEEE.

Dr. D. Gireesh Kumar is an Associate Professor in the Department of Electrical and Electronics Engineering at BVRIT Narsapur. He holds a PhD from Lovely Professional University, Punjab, and an M.Tech in Power Electronics and Drives from SRM University. Dr. Gireesh Kumar has delivered guest lectures at various engineering colleges on topics such as Power Systems Operation and Control, MATLAB Simulation of Electrical Circuits, and Hybrid Electric Vehicles.His research interests include power electronics and advanced electric drives, design of transformer-less inverters for solar PV applications, and optimization techniques. In 2022, he published a patent on an efficient asymmetric multilevel solar inverter. His research work has appeared in Q1 and Scopus-indexed journals, as well as in book chapters.

Mangli Mahesh is currently a UG student at the Department of Mechanical Engineering, BVRIT, Narsapur.
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