Realtime Monitoring and Analysis of Energy Consumption of Domestic Appliances Using Web Application

K Shankar, V Kamaleshwar, R Kavin and N Kishan Raaj

November 26, 2023

Real Time Monitoring of energy consumption of domestic appliances :A Literature Review

Mr.K.Shankar[1] ,Kamaleshwar V[2] , Kavin R[3] , Kishan Raaj N[4]

Department of Computer Science and Engineering,
Easwari Engineering College,
Chennai
shankar.k@eec.srmrmp.edu.in [1] , kamaleshwarvcse@gmail.com [2], kavinnn142@gmail.com [3] , kishanraaj12@gmail.com [4]

Abstract Interest in smart cities and infrastructure is growing, and with it, so is the need for energy saving. One of the most difficult problems in the world today is energy conservation, particularly since the majority of the electrical energy produced today comes from nonrenewable resources. However, in order to identify consumption patterns at a granular level, an accurate and comprehensive monitoring infrastructure is needed to ensure optimal energy conservation. Given the possibility of electrical energy loss at any level of detail, a precise, affordable, and easily installable power monitoring system is needed.

In today's energy-conscious world, understanding domestic appliance usage is crucial. This research presents a web-based application designed to monitor and analyze real-time energy consumption patterns of household appliances. The application offers users an intuitive interface to track individual appliance usage, energy consumption trends, and costs incurred. By employing IoT sensors and data analytics, the system provides instant insights into energy usage, enabling users to make informed decisions about their electricity consumption. The study emphasizes the importance of real-time monitoring in promoting energy efficiency and environmental sustainability. Through this innovative web application, consumers can actively manage their energy consumption, reduce wastage, and contribute to a greener future. The findings underscore the significance of technology-driven solutions in fostering energy awareness and empowering users to create more sustainable living environments.

Key Words : Energy monitoring; Interpretable insights;IoT-based edge devices; IoT sensors,Web servers; Energy consumption; Energy costs; Residential settings;

I. INTRODUCTION

In an era marked by burgeoning energy demands and growing environmental concerns, the prudent management of energy resources has become a paramount global priority. Within the realm of residential energy consumption, domestic appliances play a pivotal role, serving as the silent sentinels of our daily lives. With their unmatched ease, these appliances—which range from air conditioners and televisions to refrigerators and washing machines—have assiduously merged into our homes. Nevertheless, they also account for a sizeable portion of the overall energy usage in homes, which makes a major contribution to both power costs and greenhouse gas emissions.

The ever-expanding array of domestic appliances available in the market, coupled with changing lifestyles and technological advancements, has led to an exponential growth in the number of these energy-consuming devices within our homes. As a result, it is now crucial for governments, utilities, environmental organizations, and individual homes to comprehend and monitor their energy consumption. In addition to enabling customers to make knowledgeable decisions about their energy use, efficient monitoring is the cornerstone of programs designed to cut energy use, save utility costs, and lessen environmental effects.

This literature review seeks to explore the extensive body of research dedicated to monitoring the energy consumption of domestic appliances. It endeavors to provide a comprehensive overview of the methodologies, technologies, and approaches employed in this field, shedding light on the challenges, advancements, and opportunities that researchers and practitioners face. By delving into the existing literature, we aim to extract valuable insights into the current state of knowledge regarding energy monitoring in residential environments.

II. METHODOLIGIES

The primary methodologies for energy monitoring in domestic appliances involves:

1.Smart Plugs and Smart Meters: Smart plugs[12] are placed between individual appliances and power outlets, enabling real-time measurement of energy consumption. Smart meters, on the other hand, are typically installed by utility companies at the household level and provide comprehensive energy consumption data. These devices are equipped with communication interfaces, such as Wi-Fi, Zigbee[10], or cellular networks, to transmit collected data.

2.IoT Sensors and Devices: By incorporating sensors and connectivity into appliances and household infrastructure, the Internet of Things (IoT) has transformed energy monitoring. Granular data on energy usage is collected by IoT-enabled devices and sensors, allowing for real-time monitoring and transmission of consumption data to web-based platforms[7].

3.Home Energy Management Systems (HEMS): HEMS serve as centralized hubs for energy monitoring[12]. They integrate various monitoring technologies, including smart meters and IoT devices, to provide a holistic view of energy usage within a household. HEMS[12] often include user-friendly interfaces that allow residents to monitor and manage their energy consumption effectively.

DATA MONITORING METHODOLOGIES

1.IoT Sensors: To gather information on energy consumption, Internet of Things (IoT) sensors[7] can be incorporated into home infrastructure and appliances. These sensors give users real-time consumption insights by wirelessly connecting to a cloud-based platform or central hub.

2.Mobile Applications: Users frequently utilize mobile apps on their smartphones and tablets to get information about how much energy they use. These applications have the ability to show usage statistics in real time, historical patterns, and warnings and notifications.[14]

3.Web-Based Portals: Web-based portals[9] offer users access to their energy consumption data from any internet-connected device. These portals provide detailed information, charts, and historical data for deeper analysis.

4.Energy Monitors and Displays Dedicated energy monitors and displays can be installed in homes to show real-time energy consumption data in a prominent location. Some displays also provide cost estimates.[12]

5.Energy Management Software: Software applications installed on computers or accessed through web browsers offer advanced analysis of energy consumption data. They can provide insights into energy-saving opportunities and cost projections[15].

III. WEB BASED DEVELOPMENT

1.Custom Web Development: Custom web development involves designing and building web-based interfaces tailored to specific sensor data needs. These portals offer flexibility in data presentation, visualization, and user interaction.

2.Visualization Libraries: Data visualization libraries like D3.js, Plotly, and Highcharts facilitate the creation of interactive and visually appealing charts and graphs. These libraries can be integrated into web portals to present sensor data effectively.

3.D3.js: D3.js is a versatile library that empowers developers and data scientists to create custom, data-driven visualizations tailored to their specific needs. While it has a learning curve, the flexibility and capabilities it offers make it a valuable tool for crafting engaging and informative data visualizations on the web.

4.Plotly: Plotly can be leveraged to build interactive web-based dashboards and reports that combine multiple charts and widgets to convey insights effectively.Plotly boasts compatibility with multiple programming languages, including Python (plotly.py), R (plotly R), and JavaScript (plotly.js). Its seamless integration into Jupyter Notebooks and web applications extends its versatility.

IV. RELATED WORKS

[6] *Puthireddy Umapathi Reddy and Kelothu Naresh," Monitoring and control of single-phase electrical systems using IoT based microcontrollers".* The Internet of Things (IoT) provides an innovative method for building a Smart Voltage and Current Monitoring System (SVCMS) by utilizing an Arduino Uno microcontroller and a Wi-Fi module[6]. In massive power systems, this technique enhances the efficiency and quality of electricity. The integrated SVCMS design measures the readings from the voltage and current sensors, interprets the information, and sends it to an Android phone[6]. The system also uses a Global Systems for Mobile Communication (GSM) module for communication.

[7] *Xiaohong Lu,Yahong Lu,Lihua Luo,Wenyu Lin and Jiming Zhang," Remote Data Acquisition and Management Technology of Power Equipment Based on Internet of Things",*The monitoring platform gets information in real-time on the state of the environment and the functioning of the equipment by gathering data from the Internet of Things network. The wireless access network that makes up the Internet of Things is based on LPWAN technology[7], which provides wide coverage, a large number of connections, cheap cost, and low power consumption. This network enables data transfer and sensor monitoring, making it perfect for power grid applications.

[8] *Darwin Alulema,Mireya Zapata and Miroslava Aracely Zapata,"An IoT-based Remote Monitoring System for Electrical Power Consumption via Web-Application*", provides an internet of things-based remote power usage monitoring solution. With wireless sensor networks and communication modules like XBee, the system tracks and manages a household's electricity consumption. Enabling remote monitoring of a household's electricity consumption, it consists of hardware and software. The system is expandable and versatile, with four measurement modules (MMods) placed around the house. Monitoring the supply voltage and the quantity of current that appliances consume is the responsibility of these modules.

[9] *Yuhei Nozaki, Yasunori Mitani, Qudaih Yaser and Masayuki Watanabe," Simple Measurement System for Indoor Power flow Distributions using Voltmeters at Electrical Outlet",* shows how to monitor the power flow distributions inside of buildings using voltmeters at electrical outlets in a simple system. Installing voltmeters at various outlets around a house or place of business is the necessary step in the system deployment. We call this dispersed installation because the voltmeters are placed at different outlets throughout the space. With no disruption to the functioning of electric appliances, this allows one to verify the amount of power being supplied to every outlet.

[10] *Sanket Thakare , Akshay Shriyan, Vikas Thale, Prakash Yasarp and Keerthi Unni ,"Implementation of an Energy Monitoring and Control Device based on IoT",* The current sensor measures the power consumption of individual electrical appliances, and the Arduino microcontroller processes the data before transmitting it over the Wi-Fi module to the server. The system also includes a Real Time Clock (RTC) module and a Nokia 5110 display module for user display and time tracking. The power consumption data is shown on a website designed for home energy monitoring.

[11] *Mark Apperley and Jishaal Kalyan,"A Mobile Personal Residential Electricity Dashboard",* explains how creating a client-server setup was necessary for the mobile home electricity dashboard's deployment.Real-time data regarding the mix of generation and electricity usage was shown on the dashboard. It gave a summary of the amount of electricity used currently as well as the relative amounts of various energy sources. Users have the option to delve deeper into specific details, including weekly consumption totals, breakdowns of

household use by functional area, and comprehensive details on specific equipment.

[12] *Maytham S. Ahmed, a, Azah Mohamed, Raad Z.Homod,"Smart Plug Prototype for Monitoring Electrical Appliances in Home Energy Management System",* forming and size similar to a standard plug, it is intended to use two primary sensors for voltage and current. Along with bidirectional communication with a home's central meter, it offers remote monitoring and the ability to turn appliances on and off. Starting with the setting of the Zigbee nodes, the implementation steps show the maximum and lowest values of the measured signal as well as initialize the system parameters.It's connected to the HEMS controller through the electrical appliances, allowing for remote monitoring and appliance on/off management. The setup of Zigbee nodes to establish system parameters and display the maximum and lowest values of the measured signal is the first phase in the smart plug installation process.

[13] *Anupama S and Dr. U. B Mahadevaswamy, "Design and Development of a Smart Device for Energy Monitoring and Control of Domestic Appliances: An Android Application*", An instrumentation module was created and built to measure power, voltage, current, power factor, and frequency. Embedded C code for computing many parameters was created by integrating a microcontroller with the hardware module. To test a Bluetooth module, connectivity between the app and the module was established. An Android application was developed for device monitoring and control.

[14] *Rajeev Piyare," Internet of Things: Ubiquitous Home Control and Monitoring System using Android based Smart Phone",* utilizes an Android based smartphone app and an integrated micro-web server to display a monitoring system.The home portal's foundation is an Ethernet mini web server for Arduino and is accountable for overseeing, directing, and observing the parts of the system. The graphical user interface for smartphone apps interface for gaining access to and managing the equipment at home. The hardware configuration incorporates Ethernet and Arduino Uno use shield, switches that are relayed,current sensors and temperature sensors for power tracking. One can access the system. and managed with any Wi-Fi or 3G/4G device. able smartphone that works with Java.

[15] *Shishir Muralidhara , Niharika Hegde and Rekha PM* "*An internet of things-based smart energy meter for monitoring device-level consumption of energy",* indicates that the components of the system design are the ESP8266 WiFi module, the OLED screen, the ACS712 current sensor, and the Arduino Uno microcontroller.It tracks the device's energy usage continually and utilizes the WiFi module to communicate the data to a ThingSpeak channel. Customers can access the consumption data through the ThingSpeak channel, which provides analytics and visualizations of the energy use pattern.

The Literature Survey is in a comparative format below

Ref.	Title	Authors	Hardware	Communication module	User Interface	Parameter Monitoring
[6]	Monitoring and control of single-phase electrical systems using IoT based microcontrollers	Puthireddy Umapathi Reddy and Kelothu Naresh	Arduino UNO microcontroller, Wi-Fi module, GSM module	GSM for sending data to Android phone	Simple messaging service	Voltage, current, temperature, frequency
[8]	An IoT-based Remote Monitoring System for Electrical Power Consumption via Web-Application	Darwin Alulema,Mireya Zapata And Miroslava Aracely Zapata	Measurement Modules, XBee Modules, Coordinator, XBee Explorer USB	XBee wireless communication for data transmission	Web application for remote data access	Voltage and current
[12]	Smart Plug Prototype for Monitoring Electrical Appliances in Home Energy Management System	Maytham S. Ahmed, a, Azah Mohamed, Raad Z.Homod	Zigbee module, current sensor, voltage sensor, microcontroller	Zigbee for wireless communication	LCD Display	Voltage and Current
[13]	Design and Development of a Smart Device for Energy Monitoring and Control of Domestic Appliances: An Android Application	Anupama S And Dr. U. B Mahadevaswamy	PCB,voltage regulator, microcontroller, Bluetooth module, LCD display	Bluetooth Low Energy (BLE) for wireless communication	Android app for data retrieval and load control	Voltage and current
[7]	Remote Data Acquisition and Management Technology of Power Equipment Based on Internet of Things	Xiaohong Lu,Yahong Lu,Lihua Luo,Wenyu Lin and Jiming Zhang	Four wireless modules (using XBee), cloud-based database	XBee for communication	Web application for data display and accessibility	Voltage and Current
[10]	Implementation of an Energy Monitoring and Control Device based on IoT	Sanket Thakare , Akshay Shriyan, Vikas Thale, Prakash Yasarp and Keerthi Unni	Zigbee wireless sensor, microcontroller, power measurement circuit	Zigbee for wireless sensing and data transmission	Not Available	Voltage and current
[14]	Internet of Things: Ubiquitous Home Control and Monitoring System using Android based Smart Phone	Rajeev Piyare	Arduino UNO, Ethernet shield, relays, temperature sensors, current sensors	Wifi for data transmission	Android application	Volatage and current
[15]	An internet of things-based smart energy meter for monitoring device-level consumption of energy	Shishir Muralidhara , Niharika Hegde and Rekha PM	Arduino UNO, Current sensor (ACS712), WiFi module (ESP8266), OLED screen	WiFi (ESP8266)	ThingSpeak channel for visualizations and analytics	Voltage and current

V. EXISTING SYSTEM

Existing system like Smart meters, which use cutting-edge technologies to completely change how electricity use is tracked and managed, are essential parts of the energy industry's modernization. From a technological standpoint, these gadgets make use of digital measuring methods, which use specialized sensors to accurately record and transform analog electrical impulses into digital data. Smooth connection between the utility providers and smart meters is made possible by the integration of two-way communication modules, like radio frequency or cellular technology. Along with the possibility of remote real-time consumption data collecting, this feature also gives providers the option to remotely communicate updates or commands to the meters.

The incorporation into an Advanced Metering Infrastructure (AMI), which creates a complex network of data management systems, software, and communication technologies, is one important component. Larger-scale data gathering, analysis, and management of electricity consumption are made possible by this system. Smart meters also perform exceptionally well in interval data logging, giving readings on usage at predetermined intervals. This level of detail improves comprehension of consumption trends and facilitates the application of creative payment schemes, such time-of-use pricing.

Smart meters have a number of drawbacks that should be taken into account despite these technical improvements. The precise data obtained raises privacy issues because it may reveal sensitive information about the actions of the residents. Large-scale smart meter deployment can come with high upfront expenses, which include staff training, communication network deployments, and infrastructure modifications. Because the two-way communication capability opens up channels for cybersecurity concerns including unauthorized access and data breaches, security issues present a serious challenge. Furthermore, low user participation limits the usefulness of smart meters; although these gadgets offer comprehensive consumption data, consumers might not completely understand or actively use this information to manage their energy usage. Concerns about electromagnetic fields (EMFs) and other interoperability problems add to the complexity of the smart meter environment.

VI. PROPOSED SYSTEM

The goal of the proposed project is to create a sophisticated system for monitoring electricity consumption that will provide customers with control over their energy use and real-time information. The project consists of a number of important modules, the first of which is the Sensor Interface Module, which gathers data from voltage and current sensors. The Analog Signal Processing Module processes the received analog signals before the Analog-to-Digital Conversion Module converts them to digital representation. The digital data processing is then handled by the Arduino Processing Module, and the ESP8266 module is used by the Wireless Transmission Module to send the processed data, guaranteeing effective wireless connection.

By creating a strong web application with an intuitive user interface, the user-centric component is taken care of and users are able to engage with the system and see patterns in their electricity consumption. Users can adjust parameters like transmission frequency and calibration for individualized monitoring with the use of this interface.

In order to protect the privacy and confidentiality of user data, the project incorporates strong user authentication and permission procedures. Security is given top priority. In order to provide safe data transfer and storage, the system also connects to a server or cloud platform. The backend data processing system is designed to manage incoming data, putting real-time analysis algorithms into practice and employing a database to store past data.

By including sophisticated capabilities like the integration of data visualization tools and libraries, the project goes beyond basic data collection. This makes it possible to dynamically display data on electricity consumption in real-time graphs and charts, improving user comprehension and promoting well-informed decision-making.

Offering a comprehensive solution that smoothly incorporates data collection, processing, user interaction, security protocols, and sophisticated visualization, this project stands out from the competition. By taking a forward-looking stance, the project establishes the groundwork for an intelligent and user-friendly monitoring system for power usage that not only satisfies users' present needs but also can grow to suit future advancements in the field of energy management.

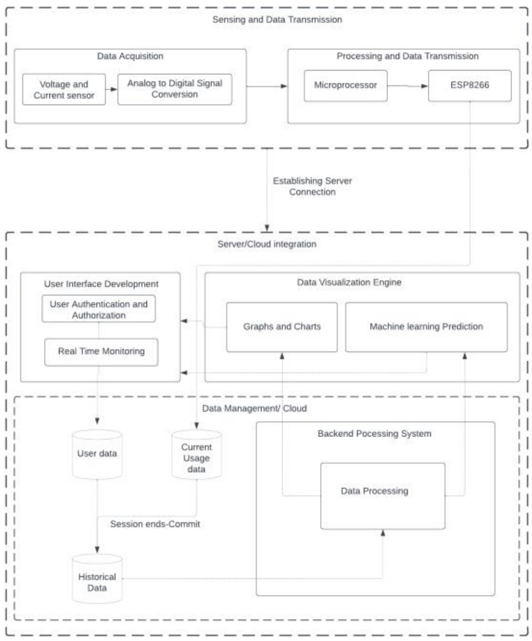

Fig 1 : Architecture diagram of the proposed system

VII. CONCLUSION

The way end users interact with and control their energy usage is revolutionized by the power consumption monitoring system. People are enabled to make educated decisions, optimizing electricity consumption and cutting expenses, using real-time insights and a user-centric interface. A focus on security guarantees the protection of user data, which promotes confidence and trust. By enabling management and monitoring from any location, remote accessibility improves user control even further and encourages convenience and flexibility to current lifestyles. The project encourages users to actively participate in lowering their carbon footprint because of its commitment to environmental consciousness, which is in line with global sustainability goals. While real-time analysis and dynamic visuals help users better understand energy patterns, historical insights present opportunity for strategic planning.Essentially, this project benefits end users and the community at large by improving the immediate user experience while simultaneously laying the groundwork for a more sustainable, economical, and mindful approach to energy consumption.

VIII. FUTURE WORKS

Future developments for the electricity consumption monitoring project present exciting opportunities for increased impact and innovation. Initially, the use of machine learning algorithms may improve the system's capacity to anticipate and adjust to customers' consumption patterns, offering customized suggestions for energy efficiency. Furthermore, investigating the integration of smart appliances and Internet of Things (IoT) devices will broaden the scope of the system, permitting more precise regulation and automation of energy-hungry devices. Users may be able to make more economical selections by working with utility providers to integrate real-time price data, which could encourage dynamic energy management techniques. Along with supporting sophisticated grid interactions, demand response initiatives, and grid stability, the project may possibly develop in the future. Another interesting direction is to embrace emerging technologies like blockchain for safe and transparent transactional procedures in energy trading or sharing scenarios. Last but not least, encouraging community involvement with gamification and social aspects may lead to a more cooperative attitude to energy saving, which might make the initiative a catalyst for larger social change. In general, the upcoming projects have the ability to improve the system's functionality, integrate it with cutting-edge technology, and promote a more integrated and sustainable energy environment.

IX. REFERENCES

[5] A. R. Jadhav, S. Kiran M. P. R. and R. Pachamuthu, "Development of a Novel IoT-Enabled Power- Monitoring Architecture With Real-Time Data Visualization for Use in Domestic and Industrial Scenarios," in IEEE Transactions on Instrumentation and Measurement, vol. 70, pp. 1-14, 2021, Art no. 1002314, doi: 10.1109/TIM.2020.3028437.

[6] Reddy, Puthireddy & Naresh, Kelothu. (2022). Monitoring and control of single-phase electrical systems using IoT based microcontrollers. International Journal of Reconfigurable and Embedded Systems (IJRES). 11. 275. 10.11591/ijres.v11.i3.pp275-283.

[7] Lu, Xiaohong & Lu, Yahong & Luo, Lihua & Lin, Wenyu & Zhang, Jiming. (2022). Remote Data Acquisition and Management Technology of Power Equipment Based on Internet of Things. Mobile Information Systems. 2022. 1-9. 10.1155/2022/3902541.

[8] D. Alulema, M. Zapata and M. A. Zapata, "An IoT-Based Remote Monitoring System for Electrical Power Consumption via Web-Application," 2018 International Conference on Information Systems and Computer Science (INCISCOS), Quito, Ecuador, 2018, pp. 193-197, doi: 10.1109/INCISCOS.2018.00035.

[9] Nozaki, Yuhei & Mitani, Yasunori & Qudaih, Yaser & Watanabe, Masayuki. (2013). Simple Measurement System for Indoor Power flow Distributions using Voltmeters at Electrical Outlet. Journal of International Council on Electrical Engineering.3.10.5370/JICEE.2013.3.4.323.

[10] S. Thakare, A. Shriyan, V. Thale, P. Yasarp and K. Unni, "Implementation of an energy monitoring and control device based on IoT," 2016 IEEE Annual India Conference (INDICON), Bangalore, India, 2016, pp. 1-6, doi: 10.1109/INDICON.2016.7839066.

[11] M. Apperley and J. Kalyan, "A Mobile Personal Residential Electricity Dashboard," 2015 19th International Conference on Information Visualisation, Barcelona, Spain, 2015, pp. 195-199, doi: 10.1109/iV.2015.43.

[12] M. S. Ahmed, A. Mohamed, R. Z. Homod, H. Shareef, A. H. Sabry and K. Bin Khalid, "Smart plug prototype for monitoring electrical appliances in Home Energy Management System," 2015 IEEE Student Conference on Research and Development (SCOReD), Kuala Lumpur, Malaysia, 2015, pp 32-36, doi: 10.1109/SCORED.2015.7449348.

[13] S, Anupama & U B, Mahadevaswamy. (2018). Design and Development of a Smart Device for Energy Monitoring and Control of Domestic Appliances: An Android Application. International Journal of Image, Graphics and SignalProcessing.10.3646.10.5815/ijigsp.2018.01.05.

[14] Piyare, Rajeev. (2013). Internet of Things: Ubiquitous Home Control and Monitoring System using Android based Smart Phone. International Journal of Internet of Things. 2. 5-11. 10.5923/j.ijit.20130201.02.

[15] Muralidhara, Shishir & Hegde, Niharika & P M, Rekha. (2020). An internet of things-based smart energy meter for monitoring device-level consumption of energy. Computers & Electrical Engineering. 87. 106772. 10.1016/j.compeleceng.2020.106772.