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Automatic Energy Monitoring and Management System Using IoT

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***Abstract*—Efficient energy use is essential for the growth of the smart grid in power systems. So the smart grid's top priority is to properly monitor and control energy consumption. One of the main issues with the current energy metering system is that full duplex transmission is not available. An automated energy monitoring and management system based on the Internet of Things (IoT) is suggested as a solution to this issue. An autonomous energy monitoring and management system can track energy consumption in real-time. Thanks to the ESP8266 microcontroller and HLW1208 IC, both of which are Internet of Things (IoT) components. The system is designed to analyze and assess power usage, spot energy waste, and identify patterns. After the data is wirelessly uploaded to the cloud platform ThingSpeak for visualization and analysis. Users can monitor their energy usage, set energy-saving goals, and get alerts about energy waste. The proposed system provides a cost-efficient and practical method for monitoring energy use and reducing energy waste, and it can be applied in residential, commercial, and industrial environments.**

Keywords—HLW8012 IC, IoT, ESP8266 Microcontroller

I INTRODUCTION

The Internet of Things (IoT) offers a wide range of cutting-edge solutions across many application areas, including critical infrastructures, and is a technology field that is just beginning to gain popularity. Urban development that is booming at an exponential rate has made it difficult to monitor energy consumption in the power industry. Devices like air conditioners require a significant amount of power, which makes it particularly difficult for the power industry to control customer demand in countries with high temperatures [1], [2]. With the aid of the IoT, the conventional power system network can be transformed into a smarter and more efficient energy grid. Smart energy grid-related IoT technologies, including sensing, communication, computing, and their standards. The tremendous increase in energy use and the rapid growth of renewable energy sources like solar and wind power provide enormous problems for energy security and the environment. These difficulties are pushing the development of energy networks towards a more intelligent state in the interim.Smart meters are the essential components of Intelligent Energy Networks (IENs). In addition to measuring energy flows, smart energy meters may share data on energy usage, the state of energy networks, and consumers with utilities and other users. Other devices, like home appliances, can be monitored and controlled by smart energy meters in line with the preferences of each user. Appliance load monitoring in smart homes has become more important due to its significant advantages in developing an energy-efficient smart grid.In order to provide insights into energy usage trends, the system gathers data on energy use from sensors and devices installed throughout the building. This method decreases expenses while improving energy management by identifying energy wasters[3]–[6]. This system makes use of Internet of Things (IoT) technology, which uses sensors, cloud computing, and data analytics to relay real-time data on energy usage. In order to find patterns in energy use and potential areas for improvement, the data is then analyzed utilizing tools.Building owners and managers may receive alerts and warnings from the technology advising them of any anomalies in energy usage and potential trouble spots for improvement. Cost savings, energy efficiency, and sustainability are all benefits of an automated internet of things-based energy monitoring and management system. Building owners can decrease energy waste, lower utility costs, and lower their carbon footprint by identifying areas for improvement. Additionally, technology can free up staff members' time for other work by reducing the need for human energy usage monitoring and management [7]-[10].The usage of energy in homes and buildings might be fundamentally altered by an IoT-based automated energy monitoring and management system, paving the way for a more efficient and sustainable future. We have demonstrated the deployment and validation of an IoT-based energy management system (EMS) in this study. The monitoring and calculation portion of the framework is focused on IoT-enabled meters.

The remainder of this paper is organized as follows: in section two, background information of the proposed system is discussed. In section three proposed methodology for Automated Energy Monitoring and Management System (AEMMS) is provided. Simulation studies and results are presented in section four. Finally a discussion of the future scope and conclusion are provided in section five. To understand these terminologies, a brief overview of each is provided below.

II BACKGROUND INFORMATION

A. Smart Meters

A smart meter is a cutting-edge digital tool used to track and measure the water, gas and electricity use in residential and commercial facilities. Smart meters automatically monitor and report consumption data to utility companies in almost real-time, unlike conventional meters, which require manual reading. Here are some key features and benefits of smart meters:

1) Accurate and timely data: Smart meters offer more precise and in-depth data about energy or water usage. Both consumers and utility providers have access to this data, which is recorded throughout the day at regular intervals.
2) Real-time monitoring: Smart meters let users keep an eye on how much electricity or water they use. They can use this information to better understand their behavior patterns and make resource- and money-saving decisions.
3) Remote reading: Smart meters may be read remotely by utility companies, doing away with the requirement for physical meter reading visits. This cuts down on costs, saves time, and lessens human mistakes in manual readings.
4) Automatic billing: By enabling automated billing systems based on actual consumption, smart meters do away with predicted costs. This reduces the need for meter reading disputes and results in more accurate billing.

B. The Internet of Things (IoT)

It refers to the system of actual physical objects, including machinery, automobiles, appliances, and other things, that are connected to the internet and equipped with sensors, software, and connectivity capabilities. The idea behind IoT is to build a network where common things can talk to one another and with people, increasing automation, efficiency, and convenience in many areas of life. Here are some key features and benefits of IoT:

1) Connectivity: Connectivity features like Wi-Fi, Bluetooth, cellular networks, or low-power wireless protocols like Zigbee or LoRaWAN are included in IoT devices. They can communicate and exchange data with other systems or devices thanks to their connectivity.
2)Sensors and Actuators: IoT devices frequently
include sensors to collect information from the outside world. Sensors are capable of measuring a variety of things, including temperature, humidity, light, pressure, motion, and more. Actuators, on the other hand, allow IoT devices to carry out physical tasks based on the data they receive, such as switching a switch on or off or modifying a parameter.
3)Data Collection and Analysis: IoT devices gather data from sensors or other outside sources and send it to remote servers or cloud platforms for archiving and analysis. This information can then be analyzed, visualized, and utilized to help choose wisely, spot patterns, or start automated processes.
4)Automation and Control: Automation and remote control of equipment are made possible by IoT. Users can monitor and control IoT equipment from anywhere using IoT platforms or applications, which improves efficiency and convenience.

C. Energy Management

Monitoring, regulating, and optimizing energy consumption across a range of industries, including residential, commercial, and industrial contexts, is referred to as energy management. Enhancing energy efficiency, reducing energy waste, and minimizing environmental effect while preserving comfort and productivity are the objectives of energy management. Here are some key aspects and strategies involved in energy management:

1) Energy Monitoring: Monitoring and measuring energy use are the first steps in energy management. This includes tracking energy usage in real-time, spotting patterns, and locating high consumption regions using smart meters, submeters, or energy management systems.
2) Energy Audits: Energy audits are conducted to find possibilities for improvement and chances for energy savings. Energy audits examine building systems, machinery, and operational procedures to evaluate energy performance, spot inefficiencies, and suggest energy-saving strategies.
3) Energy Efficiency Measures: Central to energy management is the implementation of energy-saving measures. This can entail switching to energy-efficient lighting, enhancing insulation, improving HVAC systems, implementing efficient appliances and equipment, and implementing energy-friendly building design techniques.
4)Load Management and Peak Demand Reduction: Controlling and adjusting energy use to avoid periods of high demand, when energy bills are often greater, is known as load management. To lessen dependency on the grid during peak hours, this can be accomplished by load shedding, demand response initiatives, or the use of energy storage technologies.

III PROPOSED SYSTEM

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Fig. 1 shows the basic block diagram of the proposed Automated Energy Monitoring and Management System (AEMMS) **.**Many buildings and facilities consume large amounts of energy, which can result in high energy costs and environmental impact. To address this problem, an IoT-enabled energy monitoring system is needed to provide real-time data on energy usage,

identify energy inefficiencies, and optimize energy consumption. This system must be cost-effective, easy to install and use, and able to integrate with existing building management systems. The goal is to promote sustainable energy management practices, reduce energy costs, and minimize environmental impact.

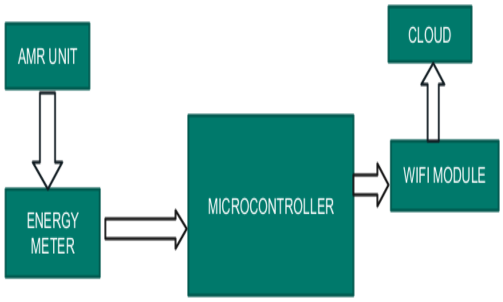

Fig. 1: Block diagram of (AEMMS)

The overall block diagram comprises the following components:

A. *AMR Unit:*Automation Metre Reading is referred to as AMR. It alludes to a method of automatically gathering usage information from utility meters in the electricity, gas and water industries. The physical visits to each meter required by traditional meter reading techniques to capture the consumption data can be time-consuming and prone to human mistake. By employing technological tools to remotely gather and transmit meter data, AMR systems automate this operation.Here are some common features found in AMR units:

1) Automated Data Collection: An AMR unit's main job is to automatically gather consumption information from utility meters. By doing away with manual meter reading visits, this lowers the risk of human mistake while also saving time and resources.

2)Remote Data Transmission: The data acquired by AMR units can be remotely transmitted thanks to their communication capabilities. They can convey the data safely and effectively to a central database or a distant server using a variety of communication techniques, including powerline communication, radio frequency, or cellular networks.

*3)Data Accuracy and Integrity:*AMR equipment is made to guarantee precise and dependable data collecting. They use cutting-edge technology and algorithms to collect accurate meter readings and reduce the likelihood of mistakes or tampering.

4)Real-time Monitoring: Real-time monitoring features are offered by some AMR systems, giving energy companies access to the most recent consumption statistics. This makes it possible for them to react swiftly to problems like leaks, unusual consumption patterns, or power outages.

B . IC (HLW8012): A non-intrusive single-phase energy metering IC (integrated circuit) called the HLW8012 is used in commercial and residential settings to measure AC power. Multiple electrical characteristics, including voltage, current, active power, apparent power, and power factor, are measured in real-time. Fig. 2 shows the details of the IC (HLW8012)

Here are some key features of the HLW8012:

1)Non-invasive: Instead of using a direct connection or cutting the wire, the HLW8012 employs a non-intrusive current sensor that clamps around the live wire.

2)Energy measurement: Its measurement capabilities include active power, perceived power, and power factor, enabling users to keep an eye on and control their energy use.

3)High accuracy: Reliable power measurements are made possible by the IC's high accuracy level, which normally has an error margin of 0.5% or less.

4)SPI communication: The Serial Peripheral Interface (SPI) protocol is used by the HLW8012 to communicate with a microcontroller or other devices, making it simple to integrate into a variety of systems.

5)Low power consumption: Low-power applications can benefit from the IC's extremely low power consumption.

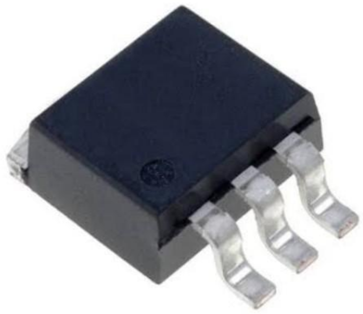

Fig. 2: IC (HLW8012)

C . Microcontroller(ESP8266) : The ESP8266 is a well-known and commonly used microcontroller module with Wi-Fi functionality created by Espressif Systems. It is a versatile platform for Internet of Things (IoT) projects and numerous embedded applications thanks to the combination of a potent microcontroller and built-in Wi-Fi capabilities. Fig. 3 shows the details of the ESP8266. Here are some key features of the ESP8266.

1)Microcontroller: The Tensilica Xtensa LX106 microcontroller found inside the ESP8266 module runs at 80 MHz (but some models can be upgraded to 160 MHz). It features a variety of I/O interfaces and peripherals and has a 32-bit RISC architecture.

2)Wi-Fi Connectivity: By integrating Wi-Fi capabilities, the ESP8266 module enables devices to connect to Wi-Fi networks and communicate with one another via the internet. It is useful for setting up Wi-Fi networks or establishing connections to existing networks because it supports both client and access point modes.

3)Low Power Consumption: The ESP8266 module is designed to operate efficiently with low power consumption. It includes various power-saving modes and features, making it suitable for battery-powered IoT applications.

4)GPIO Pins: Numerous General Purpose Input/Output (GPIO) pins are available on the ESP8266 module and can be used to connect to sensors, actuators, and other external devices. GPIO pin counts can change based on the module's particular variation.

5)Programming: The Arduino IDE, MicroPython, and the Espressif IoT Development Framework (ESP-IDF) are just a few of the programming languages and frameworks that may be used to programme the ESP8266. Developers may easily get started and create applications on the platform because of its versatility.

Fig. 3: ESP82666

D. ThingSpeak: MathWorks created the Internet of Things (IoT) analytics platform known as ThingSpeak. It enables real-time data collection, analysis, and visualization from IoT devices or sensors. Fig. 4 shows the details of the ThingSpeak model.

Here are some key points about ThingSpeak:

1)Data Collection: You can submit information from your IoT devices or sensors to the platform using the APIs and libraries that ThingSpeak offers. To transport data, you can utilize HTTP, MQTT, or other protocols.

2)Channels and Fields: Data is arranged into channels in ThingSpeak. Each channel is a particular gadget or sensor. You can define fields within a channel to hold many types of data, including temperature, humidity, pressure, etc.

3)Time Series Data: With each data entry having a timestamp attached, ThingSpeak is built to handle time series data. This enables you to examine and view historical data trends.

4)MATLAB Integration: MATLAB, a well-known environment for programming and data analysis, is tightly linked with ThingSpeak. On the gathered data, you may utilize MATLAB to run sophisticated analytics, implement algorithms, and produce visualizations.

5)Visualization: Charts, graphs, and gauges can be made to order using the visualization tools that are already included in ThingSpeak. To share information and insights with others, you can establish public or private dashboards.

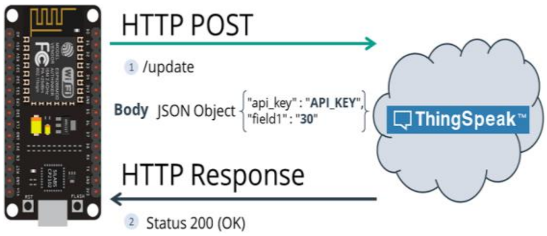

Fig. 4 : ThingSpeak block diagram

E. Device Description: The IC HLW8012, the ESP8266 Wi-Fi module, the Current Transformer (CT), and the Potential Transformer (PT) are the key parts that went into this project. Power monitoring applications frequently employ the non-intrusive split-phase current transformer sensor IC known as the HLW8012. To gather and process data, it can be connected to an ESP8266 microcontroller. To connect the HLW8012 to the ESP8266, following steps need to be followed:

1) Power Supply: Give the ESP8266 and HLW8012 a reliable power source. ESP8266 can function at 3.3V or 5V depending on the individual board or module you are using, but the HLW8012 normally runs at 3.3V.

2) Current and Voltage Connections: Connect the ESP8266's corresponding pins to the current and voltage lines coming from the HLW8012. The output pins of the HLW8012 typically have three values: voltage, current, and ground. The voltage pin measures voltage, the current pin measures current, and the ground pin serves as a common ground reference. To measure voltage and current, connect the HLW8012's voltage pin to an analogue input pin on the ESP8266 and the current pin to a digital input pin.

3)Communication: The GPIO pins on the ESP8266 can be used to communicate with the HLW8012. To determine power usage, you must programme the ESP8266 to read the voltage and current readings from the HLW8012 and carry out the relevant calculations. Common protocols like SPI or I2C can be used for communication between the two devices.

4)Data Processing: The ESP8266 can process the data and carry out additional actions as needed once it has read the voltage and current values from the HLW8012 and stored them. It may, for instance, present the data on a local display, send it to a cloud server for analysis and storage, or start specific processes based on power usage readings.

To connect a load (fluorescent lamp) to the HLW8012 power monitoring chip, you will need to make the following connections:

- HLW8012:

VCC pin: Connected to the 3.3V power supply of ESP8266.GND pin: Connected to the ground of the circuit.CF1, CF2, and SEL pins: Connected to the appropriate GPIO pins of the ESP8266.VOLT pin: Connected to the AC voltage line.CURR pin: Connected to the load's current line.

- ESP8266:

VCC pin: Connected to a 3.3V power supply.GND pin: Connected to the ground of the circuit.GPIO pins: Connected to the HLW8012's CF1, CF2, and SEL pins as per the connections described above.Wifi antenna: Ensure the ESP8266 module has a proper Wi-Fi antenna for communication.

- Load (Fluorescent Lamp):

Live wire: Connected to the HLW8012's CF1 pin.Neutral wire: Connected to the HLW8012's CF2 pin.

The HLW8012 measures the voltage and current of the load (fluorescent lamp) and communicates the data to the ESP8266 module. The ESP8266 module, with the help of appropriate firmware, can then process and transmit the energy consumption data to a server or display it locally. Fig. 5 shows assembled view of an energy meter with single load , Fig. 6 energy meter with multiple load.When connecting the HLW8012, load (such as a fluorescent lamp), and ESP8266, it is important to take the following precautions to ensure safety and proper functionality:

1)Power Off: Before making any connections, ensure that the power supply is turned off to avoid electric shock or short circuits.

2)Proper Insulation: Use insulated wires for all connections to prevent accidental contact with bare conductors.

3)Wiring Gauge: Choose an appropriate wire gauge based on the current requirements of your load. Ensure that the wires can handle the load's current without overheating or causing voltage drops.

4)Grounding: Properly ground the circuit by connecting the GND pins of the HLW8012, ESP8266, and load to a reliable earth ground connection.

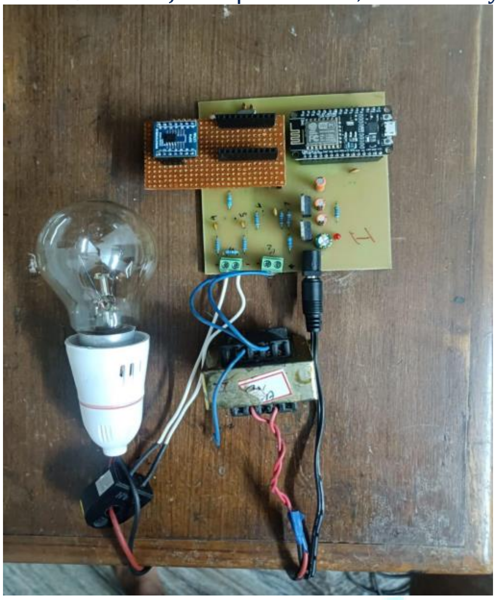

Fig. 5: Hardware of single load

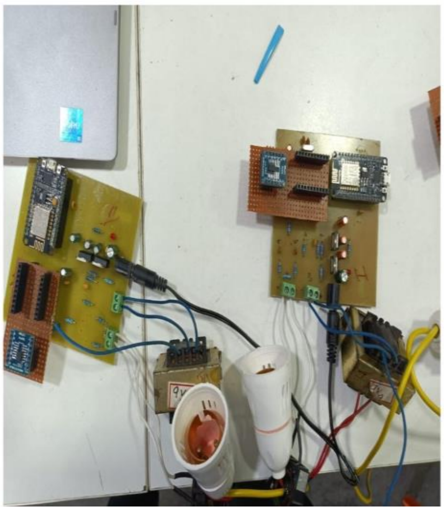

Fig. 6: Hardware of multiple load

IV SIMULATION STUDIES AND RESULTS

A. Simulation part of energy meter

Fig. 7 shows the simulation part of the proposed Automated Energy Monitoring and Management System (AEMMS). Understanding an energy meter's functionality, validating its design, and improving its performance are the goals of MATLAB simulations of energy meters. It enables you to research various scenarios, evaluate various parameters and methods, and learn how the energy meter responds to various situations. The HLW8012 chip can simulate an energy meter, and the simulation output frequently consists of numerous measurements and energy consumption-related parameters. These outputs offer insightful data regarding the operation and behavior of the energy meter. To simulate an energy meter using the HLW8012 energy monitor chip, you can follow these steps:

1) *Initialize the HLW8012:* Start by setting up the relevant settings, including calibration coefficients, voltage reference, current scaling factor, etc., and initializing the HLW8012 device by establishing its communication interface (for example, SPI or I2C).
2) *Generate Input Signals*: Make time-domain signals that correspond to the desired simulated voltage and current waveforms.
3) *Read Voltage and Current:* Read the voltage and current values from the simulated signals using the HLW8012 library functions.
4) *Calculate Instantaneous Power:* Calculate the instantaneous power using the voltage and current readings from the previous step.
5) *Accumulate Energy:* Calculate the energy consumption by integrating the instantaneous power levels across time.

Examining the simulated output of the energy meter using the HLW8012 chip allows one to gain greater insight into the effectiveness, accuracy, and behavior of the energy metering system. Users can use this to optimize the energy meter's design, calibration, and operation to guarantee accurate and reliable energy measurements. The specifics of the simulation utilizing HLW8012 are shown in Fig. 8.

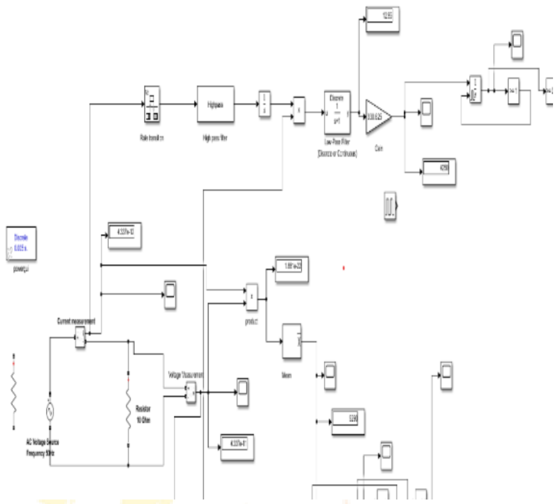

Fig. 7: Simulation of AEMMS

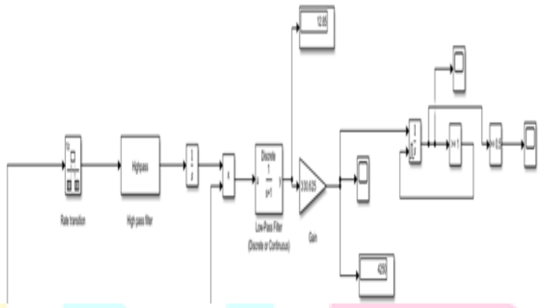

Fig. 8: Simulation using HLW8012

The simulation output of HLW8012 is displayed in Fig. 9. The output from the simulation can be used to analyze and improve the energy metering system's design. Key characteristics of simulation output include:

1)Pulse Count: The number of pulses produced is counted by the HLW8012 chip. The overall number of pulses generated throughout the simulation as well as the pulse count at each time step may be included in the simulation output

2)Pulse Width and Frequency: The simulation output for pulse-based energy meters might offer details on the pulse width and frequency. While the frequency shows how often the pulses happen, the pulse width measures the length of each pulse. For the energy consumption to be calculated correctly, these variables are necessary.

3)Define Pulse Parameters: The parameters of each pulse can be specified once the points at which they occur have been located. This contains the pulse length (pulse duration), pulse energy (each pulse's energy value), and the pause between each pulse.

Here we are taking 1 pulse equals 1000W using pulse generation method

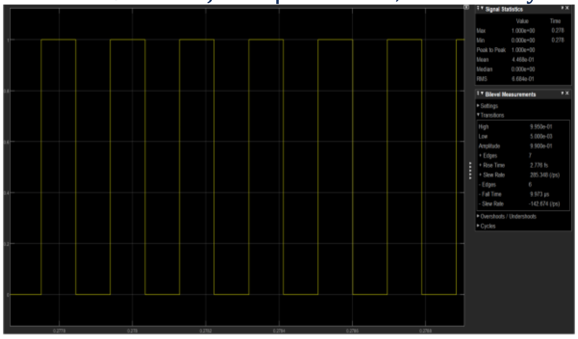

Fig. 9: simulation output of HLW8012

B. Automated Energy Monitoring and Management System (AEMMS) Results

When the device is prepared, the user must follow specific instructions as shown in the flowchart of Fig. 10 in order to display the records in an internet browser. To gather data, store it in the cloud, and create new IoT applications, use the IoT platform ThingSpeak.

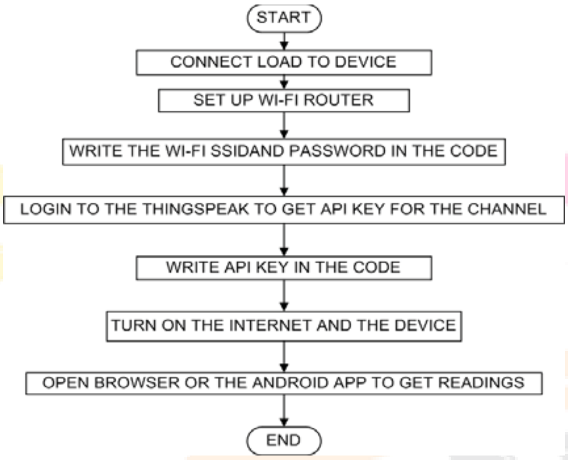

Fig. 10 :Step for activating and running en

The AEMMS was tested using a simulated energy monitoring and management scenario. The scenario was created by randomly selecting a fluorescent lamp of 100w and monitoring for different intervals of time. Fig. 11, 12 and 13 show the respective results for energy and power. Here are some key features and benefits of monitoring a 100-watt fluorescent lamp in ThingSpeak:

1) Real-time Monitoring: You can track the 100-watt fluorescent lamp's power usage and energy usage in real-time using ThingSpeak. You can watch the immediate power draw and monitor energy use in real time, giving you direct feedback on the lamp's performance.

2) Historical Data Analysis: You can examine the energy consumption and power usage patterns over time by using the historical data that ThingSpeak stores. You can spot trends, usage fluctuations, and performance changes, which will help you comprehend the lamp's behavior and make wise optimisation decisions.
3) Visualization Tools: In order to depict energy consumption and power usage statistics in graphs, charts, and other visual formats, ThingSpeak offers visualization tools. Data-driven decision-making is facilitated by these visualizations, which make it simpler to understand and evaluate the lamp's performance, usage patterns, and oscillations.
4) Energy Efficiency Assessment: You can evaluate the 100-watt fluorescent lamp's energy efficiency by listening to it in ThingSpeak. You can evaluate the lamp's efficiency in converting electrical energy into useful light by comparing the energy consumption to the light output or using efficiency calculations like lumens per watt. This assessment supports sustainability efforts and aids in locating energy-saving opportunities.
*5) Threshold Alerts:*You can configure threshold alerts and notifications using ThingSpeak depending on predetermined limitations. You can set up alerts to assist you solve possible problems or inefficiencies as soon as they arise if the lamp's energy consumption exceeds a certain threshold or if there are abrupt variations in power usage.

Using ThingSpeak, you may set threshold alerts and notifications based on predefined restrictions. If the lamp's energy consumption rises above a predetermined threshold or there are sudden changes in power usage, you may set up alerts to help you address potential issues or inefficiencies as soon as they occur.

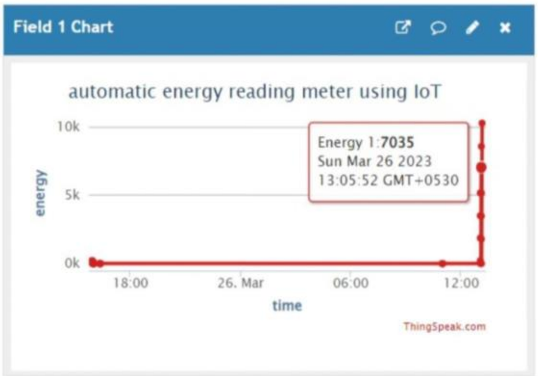

Fig. 11: Energy consumption of first load set

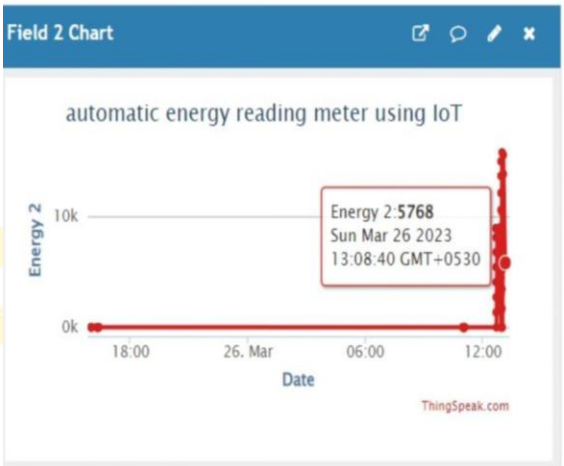

Fig. 12 : Energy consumption of second load set

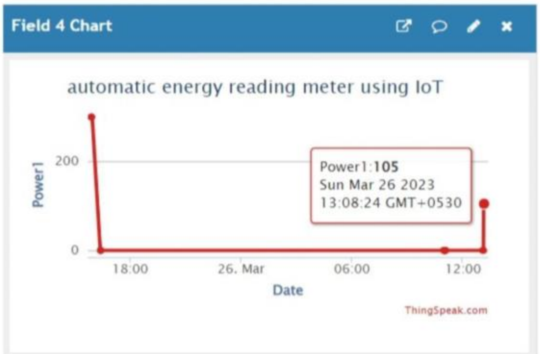

Fig. 13 : Power consumption of first load set

V FUTURE SCOPE AND CONCLUSION

The Internet of Things (IoT) holds great promise for an automated energy monitoring and management system in the future. IoT-based solutions for energy monitoring and management are becoming more crucial as technology develops and the demand for energy efficiency rises.Here are some potential future developments and opportunities in this field:

1) *Enhanced Data Analytics:*Energy monitoring IoT-based solutions generate a tonne of data. Future research will focus on extracting useful insights from this data using sophisticated analytics techniques like machine learning and artificial intelligence. To identify patterns in energy consumption, increase energy efficiency, and make informed energy management decisions, use these insights.
2) *Real-time Monitoring and Control:* As Internet of Things (IoT) devices become more sophisticated and connected, energy monitoring systems will offer real-time monitoring and control capabilities. In order to optimize energy use and reduce waste, users will be able to utilize this to remotely operate energy-consuming equipment in real-time, monitor energy usage, and identify anomalies.
3) *Integration with Smart Grids:* Integrating IoT-based energy monitoring devices with smart grid infrastructure will enable intelligent and more efficient energy management. Based on the supply and demand conditions at the time, the system may adjust energy use dynamically to improve energy distribution and reduce peak loads. Bidirectional communication between energy users and utility providers is used to achieve this.
4) *Energy Optimization Algorithms:* Future systems will employ complex algorithms that consider a number of factors, including energy cost, weather conditions, occupancy patterns, and user preferences, in order to optimize energy use. These algorithms will automate the process of adjusting how much energy is used, resulting in cheaper costs, greater efficiency, and less adverse environmental effects.

5) *Demand Response and Load Management:*IoT-based energy monitoring devices can help demand response programmes work better. By employing load-shifting strategies or automatically adjusting energy usage, these systems can help control peak loads. They accomplish this by keeping an eye on trends in energy use and communicating with utility providers. This will increase the stability and dependability of the electrical grid.

Overall, the future of automatic energy monitoring and management systems using IoT is bright, offering numerous opportunities to optimize energy usage, reduce costs, and contribute to a more sustainable and resilient energy infrastructure.

To sum up, the automatic energy monitoring and management system utilizing the Internet of Things has enormous potential to revolutionize how we track, manage, and optimize energy consumption. These systems can offer useful insights, improve energy efficiency, and contribute to a more sustainable future by making use of the capabilities of IoT devices, advanced analytics, and real-time connectivity.Energy monitoring systems can gather real-time data on energy usage patterns, pinpoint inefficiencies, and spot anomalies by integrating smart meters, sensors, and connected devices. Advanced algorithms and machine learning approaches can then be used to analyze this data in order to produce useful insights and suggestions for reducing energy consumption. Additionally, energy ecosystem components like smart grids and renewable energy sources can communicate with IoT-based energy management systems. Through this integration, dynamic load control, demand response, and improved use of renewable energy are made possible, leading to a more robust and effective energy infrastructure.Additionally, by providing real-time feedback, tailored recommendations, and gamification components, these systems have the ability to encourage energy-saving behaviors and support behavioral change. IoT-based solutions can promote increased awareness and deliberate decision-making towards sustainability by providing users with knowledge and control over their energy consumption. However, issues like data security, interoperability, and scalability must be solved if automatic energy monitoring and management systems are to reach their full potential. For widespread acceptance and success, reliable cybersecurity safeguards, standardized protocols, and seamless interaction across numerous devices and platforms will be essential. IoT-based automated energy monitoring and management systems have a promising future, providing enormous opportunity to optimize energy use, save costs, reduce environmental impact, and build a more robust and long-lasting energy ecosystem for future generations.

VI REFERENCE

[1] M. U. Saleem, M. R. Usman and M. Shakir, "Design, Implementation, and Deployment of an IoT Based Smart Energy Management System“, *IEEE Access*, vol. 9, pp. 59649-59664, 2021.

[2] J. Y. Kim, Y. M. Hwang, Y. G. Sun, I. Sim, D. I. Kim and X. Wang, "Detection for Non-Technical Loss by Smart Energy Theft With Intermediate Monitor Meter in Smart Grid“, *IEEE Access*, vol. 7, pp. 129043-129053, 2019.

[3] W. Li, T. Logenthiran, V. -T. Phan and W. L. Woo, "A Novel Smart Energy Theft System SETS)for IoT-Based Smart Home*“, IEEE Internet of Things* Journal, vol. 6, no. 3, pp. 5531-5539, June 2019.

[4] S. M. A. A. Abir, A. Anwar, J. Choi and A. S. M. Kayes, "IoT-Enabled Smart Energy Grid: Applications and Challenges" , IEEE Access, vol. 9, pp. 50961-50981, 2021.

[5] G. A. Raiker et al., "Energy Disaggregation Using Energy Demand Model and IoT-Based Control," *IEEE Transactions on Industry Applications*, vol. 57, no. 2, pp. 1746-1754, March-April 2021.

[6] W. Ali, I. U. Din, A. Almogren, M. Guizani and M. Zuair, "A Lightweight Privacy-Aware IoT-Based Metering Scheme for Smart Industrial Ecosystems," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 9, pp. 6134-6143, Sept. 2021.

[7] R. J. Tom, S. Sankaranarayanan and J. J. P. C. Rodrigues, "Smart Energy Management and Demand Reduction by Consumers and Utilities in an IoT-Fog-Based Power Distribution System“, *IEEE Internet of Things Journal*, vol. 6, no. 5, pp. 7386-7394, Oct. 2019.

[8] Q. Sun et al., "A Comprehensive Review of Smart Energy Meters in Intelligent Energy Networks“, *IEEE Internet of Things Journal*, vol. 3, no. 4, pp. 464-479, Aug. 2016.

[9] M. R. Chowdhury, S. Tripathi and S. De, "Adaptive Multivariate Data Compression in Smart Metering Internet of Things“, *IEEE Transactions on Industrial Informatics*, vol. 17, no. 2, pp. 1287-1297, Feb. 2021.

[10] P. Franco, J. M. Martínez, Y. -C. Kim and M. A. Ahmed, "IoT Based Approach for Load Monitoring and Activity Recognition in Smart Homes“, *IEEE Access*, vol. 9, pp. 45325-45339, 2021.