Internet of Things (IOT) based energy monitoring with ESP 32 and using Thingspeak

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***Abstract*— The project aims to develop an IoT-based smart energy meter for efficient monitoring of energy consumption. The system utilizes advanced components including I2C communication protocol, LCD display, ZMPT101B voltage sensor, Hall effect sensor, all integrated around the ESP32 processor. The primary objective is to provide users with real-time insights into their energy consumption patterns, enabling informed decisions for energy efficiency and conservation. The proposed system employs the ESP32 processor as the central controller, facilitating seamless integration of data from multiple sensors and peripherals. Through the I2C communication protocol, the system establishes efficient communication between various components, ensuring accurate data acquisition and transmission. The inclusion of the ZMPT101B voltage sensor and Hall effect sensor enables precise measurement of voltage and current parameters, allowing for accurate energy consumption calculations. The data collected from these sensors is processed and displayed in real-time on the LCD display, providing users with comprehensive insights into their energy usage. Furthermore, the IoT capabilities of the system enable remote monitoring and control of energy consumption via internet connectivity. Users can access the energy consumption data through a web interface or a dedicated mobile application, facilitating convenient monitoring and management of energy usage from anywhere, at any time.**

Overall, the IoT smart energy meter project presents a cost-effective and efficient solution for monitoring energy consumption, empowering users to make informed decisions towards energy conservation and sustainability.

Keywords—ESP32, LCD display I2C, ZMPT101B, Hall effect sensor and ThingSpeak

I. Introduction

The demand for sustainable solutions has increased recently In today's rapidly evolving urban landscapes, the quest for sustainable solutions has gained paramount importance, particularly as cities grapple with surging energy demands [1]. With urbanization on the rise, there's a pressing need to manage energy more efficiently. The advent of technologies like the Internet of Things (IoT) has ushered in a new era of possibilities, offering avenues for the creation of smarter cities equipped with cutting-edge software and hardware. However, as cities become smarter with the deployment of IoT devices, the demand for effective energy management solutions has become increasingly urgent [1].

Energy management is becoming more challenging as energy consumption continues to soar [1]. In response to this challenge, smart energy meters have emerged as crucial tools for empowering users to monitor their power consumption in real-time and make informed decisions about energy usage [10]. Despite the availability of smart meters, billing complexities and unexpected fluctuations in energy consumption still result in frequent surprises on electricity bills.

Researchers have explored a wide array of strategies and technologies aimed at enhancing energy management and consumption monitoring [2]-[5]. From smart metering systems to smart grids and wireless sensor networks, these innovations offer promising solutions. However, challenges persist, particularly with RFID-based smart meters, which rely on manual data gathering procedures that limit accuracy and efficiency [6].

Unlike conventional energy meters, smart meters equipped with advanced electronic components and communication capabilities enable real-time communication between utility providers and consumers [7]. Our project advocates for the adoption of smart metering systems characterized by low power consumption, self-healing networks, and efficient communication capabilities [7].

To address these challenges, our project leverages the ESP32 microcontroller, Hall effect sensor, voltage sensor, and ThingSpeak software to develop a smart energy meter [10]. This meter aims to provide users with a reliable means to track their energy usage in real-time, offering clear and precise insights into energy consumption trends [10]. By promoting the adoption of effective and sustainable energy management systems in smart cities, we aim to foster resilience and environmental stewardship in urban areas [1].

In conclusion, the development and implementation of smart energy metering systems represent a significant step forward in the realm of urban sustainability [1].

Through innovative technologies and collaborative research efforts, we endeavor to create a more energy-efficient and environmentally conscious urban landscape, one smart meter at a time. Our project uses the ESP32 microcontroller, Hall effect sensor, voltage sensor, and ThingSpeak software to construct a smart energy meter that will give users a dependable way to track their energy usage in real time. We hope to contribute to the creation of effective and sustainable energy management systems in smart cities, encouraging resilience and environmental stewardship in urban areas, by providing customers with practical information into their energy usage.

II. THEORY AND METHODOLOGY

The evolution of smart technologies has brought a revolution in the management and utilization of energy, rendering traditional energy meters nearly obsolete. The widespread adoption of smart meters, driven by government initiatives, legislation, and the need to modernize electricity distribution infrastructure, marks a transformative development in the industry.

This exploration delves into the complex landscape of smart meters, examining the various types available and their diverse applications. In India, the momentum behind the adoption of smart electric meters is increasing in both residential and commercial places. The discussion also highlights how smart energy meters can play a crucial role in reducing electricity bills and enhancing overall energy efficiency.

While conventional and smart meters share a basic operational similarity, the significant differences lie in the real-time data provisions by smart meters to suppliers, enabling automatic measurement and monitoring of energy consumption. This feature empowers both utilities and consumers, providing greater control over regulation, power distribution, and a deeper understanding of energy consumption patterns. The post further outlines specific applications of smart meters, starting with their role in managing charges. In cases of non-payment, smart meters streamline the reconnection process, eliminating the need for a prolonged procedure, additional fees, and paperwork.

The integration of pre-paid smart meters simplifies the recharging process, swiftly restoring energy supply to homes. Another notable application is resource conservation. Smart power meters provide detailed usage pattern data, enabling businesses and individuals to informed decisions about their energy consumption. This informed approach not only results in a significant reduction in overall energy usage but also translates into substantial cost savings. Additionally, smart metering assists utilities in resource management, mitigating the environmental impact of energy generation and negating the need for expensive infrastructure modifications. In this implementation, ThingSpeak is utilized for data access, enabling users to access information virtually anywhere with a WiFi/Network-enabled smartphone.

A) Hardware description

The hardware configuration of an IoT smart meter incorporates various essential components working together to efficiently monitor and control energy consumption. Our project utilizes an ESP32 microcontroller, which serves as the central processing unit for data collection and transmission. A 16x2 LCD display managed through I2C communication protocol provides a user-friendly interface for real-time data visualization. To measure line current, an SCT103 Hall effect sensor is employed, while a ZMPT101B sensor captures line voltage readings.

Data collected from these sensors undergoes preprocessing to ensure compatibility with the Arduino's input range. Following preprocessing, the data is processed to compute various parameters such as power, energy, voltage and current. These computed values are then displayed on the LCD display and are periodically updated to reflect real-time changes.

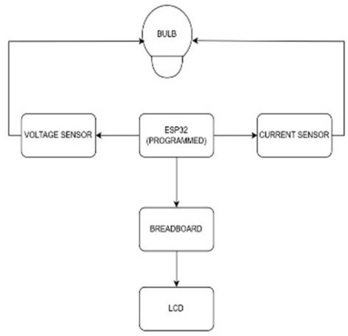

Fig. 1. Functional Block diagram

For data transmission and storage we utilize ThingSpeak software platform, which enables seamless integration with ESP32 microcontroller. Once the ESP32 establishes a secure internet connection via Wi-Fi, the relevant energy consumption data is transmitted to the ThingSpeak platform for further analysis and visualization.

B) Software Description

The software functionality of the IoT smart meter system seamlessly integrates with ThingSpeak, offering a centralized platform for visualizing and managing various facets of energy consumption. Within the ThingSpeak interface, users have convenient access to real-time data encompassing current, voltage, power usage, and the corresponding pricing for the consumed power.

The user-friendly application presents crucial energy parameters in an easily understandable format, allowing users to gain insights into their energy consumption patterns through showcased current and voltage readings, facilitating an understanding of instantaneous power usage.

Moreover, the ThingSpeak platform incorporates a feature that calculates the cost based on the consumed power. This functionality keeps users well-informed about the financial aspects of their energy consumption.

A unique and impactful capability within the ThingSpeak platform is its provision to adjust the price per unit of electricity. This feature empowers users to dynamically modify the cost-associated with the consumed power by utilizing controls to increase or decrease the price. By adjusting the price per unit, individuals can simulate various pricing scenarios, comprehending how fluctuating rates impact the overall electricity expenses.

ThingSpeak stands out as an intuitive and interactive platform, not only providing comprehensive energy data but also enabling users to actively control and manage their electricity expenses by adjusting the price per unit based on personal preferences or varying utility rates. In ThingSpeak application, we represent voltage, current, and power consumption in graphical form.

The comprehensive system architecture enables efficient monitoring and management of energy consumption providing users with valuable insights into their power usage patterns.

III. Working

The project aims to create an IoT-based smart energy meter for efficient monitoring of energy consumption. Utilizing advanced components, including the I2C communication protocol, LCD display, ZMPT101B voltage sensor, Hall effect sensor, all integrated around the ESP32 processor, the primary goal is to offer real-time insights into energy consumption patterns. This will enable users to make informed decisions for energy efficiency and conservation. The proposed system uses the ESP32 processor as the central controller, ensuring seamless integration of data from multiple sensors and peripherals. Through the I2C communication protocol, the system establishes effective communication between various components, ensuring accurate data acquisition and transmission.

Incorporating the ZMPT101B voltage sensor and Hall effect sensor allows precise measurement of voltage and current parameters, facilitating accurate energy consumption calculations. The data collected from these sensors undergoes real-time processing and is displayed on the LCD screen, providing users with comprehensive insights into their energy usage.

$$\text{Power (kilowatts)} = (\text{Voltage}*\text{Current})/1000$$
$$\text{Units}= \text{Power}*(3/3600)$$
$$\text{Rupees}= \text{Units}*6.77$$

Following the processing of data by the smart energy meter, the outcomes are displayed on the LCD module, offering users immediate insights into their energy consumption patterns. Simultaneously, the processed data is transmitted through the Wi-Fi module to ThingSpeak cloud storage. Within the ThingSpeak cloud, the data undergoes observation, analysis, and representation in graphical form. Observation encompasses the continuous monitoring of incoming data streams to ensure accurate capture of all relevant information. Analysis involves the execution of various calculations, such as discerning energy consumption trends, identifying peak usage times, or comparing the data with historical records. This analytical process aids in recognizing patterns and anomalies within energy usage.

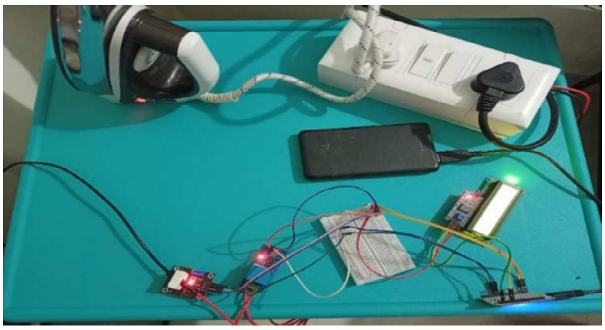

Fig. 2. Assembled view Smart Energy meter

IV. Result

The IoT smart energy system utilizes the ThingSpeak application as its interface and integrates an ESP32 microcontroller, various sensors(including current and voltage sensors), and an LCD display to establish an advanced framework for comprehensive power consumption management. Acting as the central processor, the ESP32 continuously gathers real-time data from the current and voltage sensors, performing calculations to determine power consumption, current usage, and voltage levels. This information is showcased on the connected LCD screen and transmitted to the ThingSpeak application, enabling remote access and monitoring. Fig 2 shows the assembled smart energy meter.

Within the ThingSpeak interface, users can conveniently visualize and monitor parameters such as consumed voltage, utilized power, drawn current, and estimate the total cost based on predefined pricing per unit of energy. Moreover, the system enhances user experience by providing a graphical representation of voltage, current, and power on the ThingSpeak platform. This dual presentation allows users to quickly grasp real-time values on the LCD display while gaining insights into long-term trends through graphical representation on ThingSpeak. Fig 4 shows the graphical representation of voltage and current. Fig 5 shows the data acquired from thingspeak. Fig 3 we can see the LCD display we can see all the parameters.

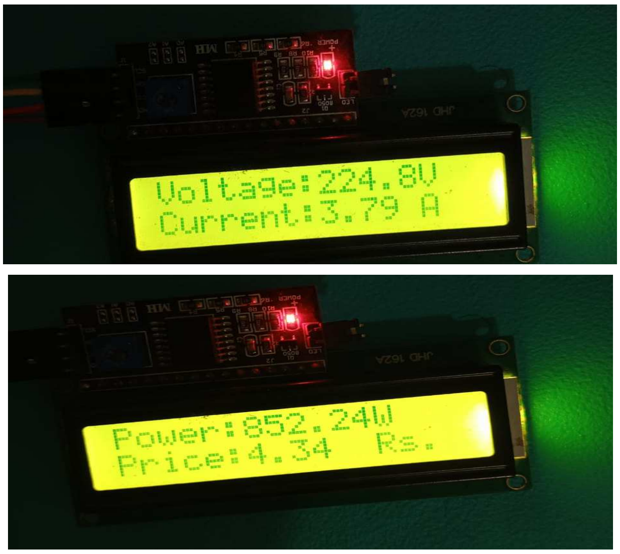

Fig. 3. LCD display

The collaborative integration of components facilitates real-time monitoring and data visualization, offering users valuable insights into their energy utilization patterns. This capability empowers users to take actionable measures for optimization or regulation. Successful implementation involves programming the ESP32 for data collection and processing, seamlessly integrating diverse sensors, and configuring the ThingSpeak platform for remote accessibility and visualization. Additionally, skillful circuit design and careful assembly of hardware are essential for the system's effective operation.

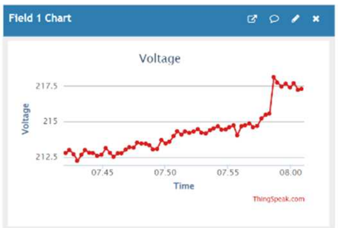

Fig. 4. Result of graphical form of voltage and current

created_at	entry_id	Voltage	current	power	cost	latitude	longitude	elevation	status
2024-02-14T05:52:18+00:00	3934	214.897	0.19158	41.17	6.45				
2024-02-14T05:52:36+00:00	3935	210.183	0.18655	39.21	6.45				
2024-02-14T05:52:55+00:00	3936	209.576	0.1901	39.84	6.45				
2024-02-14T05:53:14+00:00	3937	209.987	0.1872	39.31	6.45				
2024-02-14T05:53:33+00:00	3938	210.037	0.19687	41.35	6.45				
2024-02-14T05:53:53+00:00	3939	210.212	0.19604	41.21	6.45				
2024-02-14T05:54:12+00:00	3940	209.494	0.18148	38.02	6.45				
2024-02-14T05:54:31+00:00	3941	210.405	0.19881	41.83	6.45				
2024-02-14T05:54:51+00:00	3942	210.08	0.19078	40.08	6.45				
2024-02-14T05:55:10+00:00	3943	209.886	0.18238	38.28	6.45				
2024-02-14T05:55:29+00:00	3944	209.391	0.18955	39.69	6.45				
2024-02-14T05:55:50+00:00	3945	210.123	0.18213	38.27	6.45				
2024-02-14T05:56:08+00:00	3946	209.853	0.1958	41.09	6.45				
2024-02-14T05:56:27+00:00	3947	209.571	0.19306	40.46	6.45				
2024-02-14T05:56:48+00:00	3948	210.027	0.1914	40.2	6.45				
2024-02-14T05:57:06+00:00	3949	209.795	0.19152	40.18	6.45				
2024-02-14T05:57:27+00:00	3950	209.78	0.19435	40.77	6.45				
2024-02-14T05:57:46+00:00	3951	209.913	0.19718	41.39	6.45				
2024-02-14T05:58:08+00:00	3952	211.246	0.18415	38.9	6.45				
2024-02-14T05:58:34+00:00	3953	211.246	0.18495	39.07	6.45				
2024-02-14T05:59:01+00:00	3954	211.246	0.1911	40.37	6.45				
2024-02-14T05:59:28+00:00	3955	211.246	0.19328	40.83	6.45				
2024-02-14T05:59:55+00:00	3956	211.246	0.18642	39.38	6.45				
2024-02-14T06:00:22+00:00	3957	211.246	0.1983	41.89	6.45				
2024-02-14T06:00:49+00:00	3958	211.246	0.19016	40.17	6.45				
2024-02-14T06:01:16+00:00	3959	211.246	0.19849	41.93	6.45				
2024-02-14T06:01:43+00:00	3960	211.246	0.19044	40.23	6.45				
2024-02-14T06:02:09+00:00	3961	211.246	0.19574	41.35	6.45				
2024-02-14T06:02:36+00:00	3962	211.246	0.18476	39.03	6.45				
2024-02-14T06:03:02+00:00	3963	211.246	0.18325	38.71	6.45				

Fig. 5. Data acquired from sensors through thingspeak

V. CONCLUSION AND FUTURE SCOPE

In conclusion, the integration of a smart energy meter—which incorporates state-of-the-art features like an LCD display, an ESP32 microprocessor, and smooth ThingSpeak integration—represents a significant development in contemporary energy management. Users may make more informed decisions and develop a deeper awareness of their power usage dynamics with the help of the real-time display on the LCD, which gives them instant insights into their energy consumption habits. Additionally, the customizable consumption limitations give energy management a more individualized touch and motivate users to adopt sustainable and effective resource utilization techniques based on their individual requirements and preferences. Looking forward, the future scope of this smart energy meter system holds immense promise for further innovation and enhancement. One compelling avenue for advancement involves the implementation of an intelligent alert system capable of notifying users in real-time when power consumption surpasses predetermined thresholds. By delivering timely notifications, users can promptly identify and address instances of excessive power usage, thereby promoting proactive energy conservation behaviors and minimizing wastage.

An important step towards enhancing user response and promoting a culture of sustainable energy consumption is the integration of an alert messaging system. By having access to instantaneous warnings, users can optimize energy usage patterns, take rapid action to address potential overconsumption issues, and make a positive impact on overall energy efficiency and conservation efforts.

the integration of a smart energy meter not only transforms the field of energy management but also opens the door for revolutionary breakthroughs in sustainability. Future versions of smart energy meters might have improved user interfaces for easy interaction and accessibility, smooth integration with renewable energy sources for complete energy optimization, and sophisticated predictive analytics capabilities to forecast energy usage trends as technology advances.

These cutting-edge discoveries have the power to upend the current paradigm of energy management and pave the way for a more ecologically friendly and sustainable future. Through the utilization of technology and the promotion of a cooperative dedication to sustainability, smart energy meters act as agents of positive transformation, enabling both individuals and communities to adopt environmentally conscious behaviors and develop a more robust and balanced connection with the environment.

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