IOT SMART ELECTRICITY ENERGY METER WITH LOAD CONTROLLING USING ESP32

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Abstract--**Advancements in technology have reshaped our world, enabling humans to seamlessly integrate the physical realm with the digital domain. The Internet of Things (IoT) offers a dynamic platform to interconnect devices, paving the way for a more automated and efficient environment. This paper introduces a Smart Energy Meter Design equipped with a Monitoring and Control System, harnessing the power of IoT. The system aims to streamline energy monitoring and billing processes, eliminating the need for manual intervention and reducing the likelihood of errors that contribute to energy-related corruption. Recognizing the growing demand for transparency in energy estimation, the proposed system addresses this by leveraging IoT capabilities. Utilizing the NODE MCU based on ESP-32 as the central control unit, coupled with sensors such as the ZMPT101B for voltage and SCT-013-030 for current, the system accurately measures key parameters like voltage, current, power consumption, units consumed, and corresponding costs. These metrics are conveniently displayed on a 20x4 LCD display module and accessible via a mobile application, ensuring users have real-time insights into their energy usage.**

Keywords-- Smart Energy Meter, Internet of Things (IoT), Monitoring and Control System, NODE MCU.

I. INTRODUCTION

With the increasing demand for energy and the growing emphasis on sustainability, the need for effective energy management solutions has become paramount. Traditional energy meters, while serving their purpose, lack the capabilities to provide real-time insights and control over energy consumption. In response to this challenge, smart energy meters have emerged as innovative tools that revolutionize the way we monitor and manage energy usage.

This paper presents a project aimed at developing a smart energy meter utilizing the ESP32 microcontroller platform and integrating it with the Blynk application for enhanced functionality. The project's primary objective is to create a cost-effective and user-friendly solution that empowers consumers to monitor their energy usage in real-time and take proactive steps towards energy conservation.

By incorporating sensor technologies such as the ZMPT101B AC voltage sensor module and the SCT-013-030 non-invasive AC current sensor, the smart energy meter accurately measures voltage, current, and power consumption. These measurements, combined with the ESP32's processing capabilities, enable the device to provide users with valuable insights into their energy consumption patterns.

Integration with the Blynk application further enhances the smart energy meter's capabilities by enabling remote monitoring and control via smartphones or other mobile devices. Through the Blynk platform, users can visualize their energy usage data in intuitive dashboards, set alerts for abnormal consumption levels, and even remotely control connected devices, such as appliances or lighting fixtures.

In summary, this project seeks to address the pressing need for efficient energy management solutions by developing a smart energy meter that combines hardware and software technologies to deliver actionable insights and control capabilities to consumers. By empowering users to monitor and manage their energy usage in real-time, the smart energy meter contributes to the ongoing efforts towards sustainability and energy efficiency.

[2]Smart energy meters are not a novel idea, but the incorporation of loT technology has completely changed how we monitor and control energy usage in homes and businesses. The original generation of smart meters, which were created in the 1980s, tracked energy use using analogue technology. The first digital smart meters were released in the early 2000s, allowing for more precise readings and remote monitoring. In the early 2010s, loT technology was first incorporated into smart meters. Sensors and communication networks are used by loT-based smart energy meters to collect data on energy use. This data may then be analyzed to optimize energy use and lower costs. The Dutch utility started one of the first loT-based smart energy meter experiments in 2010, More than 50,000 smart meters were installed as part of the project in Groningen, allowing customers to track their energy usage in real-time and receive individualized energy-saving guidance. The Indian government started the Smart Grid initiative in 2015 with the goal of implementing smart energy meters all over the nation.

[4]Considering all the above mentioned aspects it is possible to design an energy meter that is tamper proof, supports automatic metering and billing system, and at the same time helps in finding the fault location of transmission lines. This meter can be used to take the readings of industrialist which sends these readings to a secured data location and automatically reset it after recording it. Keeping in mind all these features we have implemented a single energy meter referred to as Smart Energy Meter.

[5]At present, Electricity is the essential commodity in the world for human life today. Every home, offices, companies, industries requires electricity connection for their functioning Due to rapid increase in human population and the human's dependency towards electrical energy, the demand for electricity has increased many folds, causing deficit of electrical energy during peak hours. In order to cope up with the energy challenges, it is necessary to modernize the electrical system. Internet of Things (loT) technology can be employed to energy consumption and distribution in different scenarios. Latest development in loT and digital technology, the concept of smart city is becoming smarter compared to earlier years. Therefore it is necessary to switch over to innovative and better altematives such as smart grid, smart metering and zero energy building that will assist to minimize reliance on these assets by minimizing energy consumption and improving usage of renewable energies. This will in turn increase the efficiency of power and energy manages system Accurate metering, detection of theft and implementation of proper tariff and billing system would manage the consumption of electrical energy

II. EXISTING SYSTEMS

For this project, we conducted a thorough analysis of existing meter reading techniques in India and conducted an extensive study on different energy measuring instruments available today. Currently, the prevailing system in use involves either an electronic energy meter or an electro-mechanical meter installed at the premises to measure energy usage. However, these meters are limited to recording kWh units only.

In the existing system, kWh units consumed still require manual recording by meter readers on a monthly basis, typically conducted on foot. Subsequently, the recorded data needs to be processed by a meter reading company. This processing involves linking each recorded power usage datum to an individual account holder and then determining the amount owed based on the specific tariff structure in place.

[1] Both the SCT-013 Current Transformer and the ZMPT101B Voltage Sensor VCC are connected to the ESP32's 5V supply, Vin. The ESP32's GND is connected to the GND pins of both modules. The ESP32's GPIO35 is connected to the analog output pin of the ZMPT101B Voltage Sensor. The analog output pin of the SCT-013 Current Sensor is connected to ESP32's GPIO 34 in a similar manner. The voltage divider and filter circuit consist of a 10uF capacitor, two 10K resistors, one 100-ohm resistor, and two 10K resistors. The input AC terminal of the voltage sensor is wired with the AC wires that need to be measured for current and voltage.

[2]Hardware Design: The smart energy meter's hardware design entails picking the right sensors, microcontroller, and communication module. The current and voltage sensors are used to measure the current and voltage levels of the electricity flowing through the meter, respectively. The LDR sensor is used to find any unauthorized individuals tampering with the meter. The ESP32 is in charge of processing the sensor data and operating the communication module to send the data to the cloud server. Installation of sensors; The primary power supply line would be equipped with voltage and current sensors to track how much energy is being used. For the purpose of detecting any efforts to tamper with the meter by covering it with a cloth or a black bag, an LDR (Light Dependent Resistor) sensor would be positioned close to the meter. Processing and data collection: A microcontroller such as the ESP32 would be used to collect and process the sensor data. The microcontroller would be designed to read the sensor data and send it over Wi□Fi or cellular networks to a cloud-based platform.

[3]The Web of things (IoT) idea empowers us to append the customary everyday gadgets with each other over the web. The web (Internet) connects hardware devices to one another of units and the comparing cost are determined. For energy meter, the ZMPT101B voltage sensor and current sensor are interacted with a microcontroller. A SMART ENERGY METER is the name given to a device that can perform all of these functions with a single energy meter. An Arduino Uno serves as the system's central controlling unit. the voltage, current, and power consumption readings, no. Because this small module lets the microcontroller connect to the Wi-Fi network, the Wi-Fi unit plays the most important role in sending controller data over the internet. The system is built on an ESP-8266.

[4]The microcontroller takes this reading and sends it to IOT Platform using a Wifi module. The Wifi module used in the project is ESP8266. It provides internet connectivity for microcontroller. Arduino UNO is used as a microcontroller in this project. ESP8266 transmits the data serially to the IOT platform for display where the energy meter readings are globally accessible. The IOT Platform used in this project is ThingSpeak. The Arduino is provided with a 3.3V supply and ESP8266 is powered using a 7.5V adapter. Arduino is programmed using Arduino IDE and the wifi module is programmed using AT commands in the same Arduino IDE. The consumed power reading is displayed in both, the digital and analog format, on the website page of ThingSpeak platform. The reports of the energy consumption are generated daily and can be monitored 24/7,365 days. The Arduino UNO is being used for processing all the gadgets

and modules used in this project. As shown in Figure 4.1 The liquid crystal display is used for displaying the status of the units. Data pins of LCD namely RS,EN,D4,D5,D6,D7 are connected to Arduino digital pin number 7,6,5,4,3,2. And RX and TX pin of arduino is directly connected to the wifi module ESP8266. Relay is used for switching electricity connection which is connected at pin 12 of arduino through ULN2003 relay driver.

[5]In the prototype system the power utility maintains a server and each consumer are provided an energy meter. The server, power sim meters and Wi-Fi module are used to communicate with each other using Wi-Fi network. Fig shows prototype power sim energy management system. The energy meter consists of a microcontroller (ATmega328), energy measuring chip (AAE7751), Current transformer, potential transformer, LCD display and a relay

III. PROPOSED SYSTEM

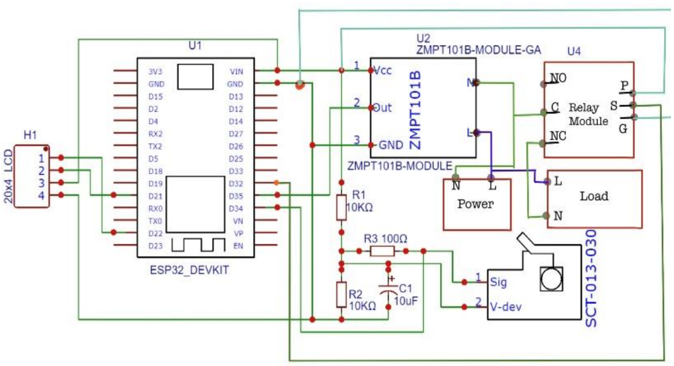

Fig. 1 represents the circuit diagram

Certainly! The proposed system aims to develop a smart energy meter utilizing the ESP32 microcontroller platform and integrating it with the Blynk application for enhanced monitoring and control capabilities. This system builds upon the existing infrastructure of traditional energy meters by introducing advanced features for real-time data acquisition, analysis, and remote management.

Hardware Components:

1. ESP32 Microcontroller:

The ESP32 microcontroller serves as the core of the smart energy meter system, providing processing power, memory, and connectivity options.

Known for its versatility and IoT capabilities, the ESP32 enables seamless integration with various sensors and communication protocols.

2. Sensors:

The system incorporates the ZMPT101B AC voltage sensor module and the SCT-013-030 non-invasive AC current sensor to measure voltage and current, respectively.

These sensors ensure accurate and reliable data acquisition, essential for precise energy consumption analysis.

3. Relay Module:

A relay module is integrated into the system to enable remote control of power-consuming devices.

By interfacing the relay module with the ESP32, users can remotely switch on/off connected devices based on predefined thresholds or user-defined preferences.

4. LCD Display:

An LCD display module, configured with the ESP32 microcontroller, provides users with real-time visual feedback on energy consumption metrics, including voltage, current, and power.

Software Implementation:

1. ESP32 Firmware:

The firmware running on the ESP32 microcontroller is responsible for data acquisition from the sensors, processing of sensor readings, and communication with the Blynk application.

It includes functions to read voltage and current values from the sensors, calculate power consumption, and control the relay based on predefined conditions.

2. Blynk Application Integration:

The Blynk application serves as the user interface for the smart energy meter, allowing users to monitor energy consumption data and control connected devices remotely.

Integration with Blynk involves configuring virtual pins to send and receive data between the ESP32 and the Blynk cloud server, enabling real-time data visualization and control functionalities.

System Workflow:

1. Data Acquisition:

The ESP32 microcontroller continuously reads voltage and current values from the sensors connected to the energy meter.

Sensor readings are processed in real-time to calculate power consumption, which is then displayed on the LCD display and sent to the Blynk application for remote monitoring.

2. Remote Monitoring and Control:

Users can access the Blynk application on their smartphones or other mobile devices to view real-time energy consumption metrics, such as voltage, current, and power.

Through the Blynk interface, users can also remotely control power-consuming devices connected to the relay module, providing flexibility and convenience in managing energy usage.

3. Alerts and Notifications:

The system can be configured to send alerts or notifications to users via the Blynk application in case of abnormal energy consumption levels or system malfunctions, enabling proactive intervention and troubleshooting.

Advantages of the Proposed System:

1. Real-Time Monitoring: Users can monitor energy consumption data in real-time, enabling proactive energy management and optimization.
2. Remote Control: Integration with the Blynk application allows users to remotely control connected devices, enhancing convenience and flexibility.
3. Data Visualization: The system provides visual feedback on energy consumption metrics, facilitating better understanding and decision-making.
4. Scalability: The modular design of the system allows for scalability and customization to meet specific user requirements and applications.

In summary, the proposed system offers a comprehensive solution for smart energy monitoring and management, leveraging the capabilities of the ESP32 microcontroller and integration with the Blynk application. By combining hardware and software technologies, the system provides users with actionable insights into energy usage patterns and empowers them to make informed decisions to optimize energy efficiency.

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A. Problem Statement

Despite the increasing global focus on energy conservation and sustainability, traditional energy monitoring systems often lack the capability to provide real-time insights and remote control functionalities. Conventional energy meters are limited in their ability to facilitate proactive energy management, leading to inefficiencies in energy consumption and higher costs for consumers. Furthermore, the lack of accessibility and user-friendly interfaces hinders consumers' ability to monitor and control their energy usage effectively.

The aim of this project is to address these limitations by developing a smart energy meter system that leverages advanced hardware and software technologies to enable real-time monitoring, analysis, and control of energy consumption. The project seeks to integrate the ESP32 microcontroller platform with sensors for voltage and current measurement, as well as the Blynk application for remote monitoring and control functionalities.

B. Block Diagram of Smart Energy Meter

The ZMPT101B voltage sensor and SCT-013-030 current sensor are connected to analog input pins of the ESP32 microcontroller for reading voltage and current data.
The relay module is connected to a digital output pin of the ESP32 for controlling the power to the connected load.
The load is connected to the relay, which acts as a switch to control its power supply.
The LCD display is interfaced with the ESP32 microcontroller using the I2C protocol for displaying real-time energy consumption metrics.
The ESP32 microcontroller communicates with the Blynk application over Wi-Fi, enabling remote monitoring and control functionalities.

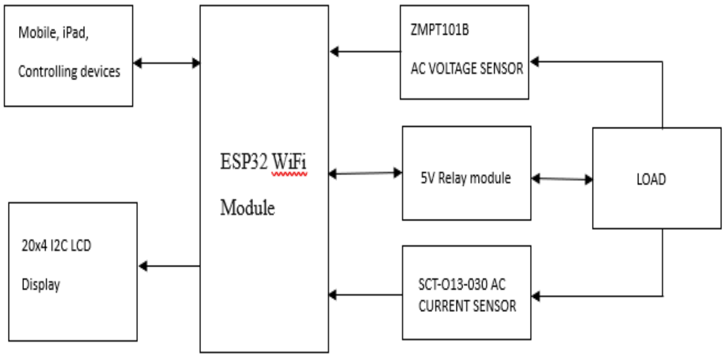

Fig. 2 Block Diagram of Smart Energy Meter

C. Working of Smart Energy Meter

1. Data Acquisition:

The smart energy meter collects data on voltage and current levels from the electrical system using sensors.
These sensors provide analog signals representing the voltage and current values.

2. Data Processing:

The microcontroller reads the analog signals from the sensors and processes them to calculate energy parameters.
Using mathematical formulas, the microcontroller computes parameters such as power consumption based on the voltage and current readings.

3. Displaying Data:

The calculated energy parameters, including voltage, current, and power, are displayed on an LCD screen.
The LCD screen provides real-time feedback on energy consumption metrics in an easy-to-read format.

4. Integration with Blynk Application:

The smart energy meter is integrated with the Blynk application for remote monitoring and control.
Through Wi-Fi connectivity, the microcontroller communicates with the Blynk cloud server.

5. Remote Monitoring and Control:

Users can access the Blynk application to view real-time energy consumption data and remotely control the meter.
This allows users to monitor energy usage and manage connected devices from anywhere using a smartphone or other mobile device.

The smart energy meter project utilizes sensors to measure voltage and current levels in an electrical system. These sensor readings are processed by a microcontroller, specifically an ESP32, to calculate energy parameters such as power consumption. The calculated data, including voltage, current, and power, is then displayed on an LCD screen in real-time. Additionally, the smart energy meter integrates with the Blynk application, allowing users to remotely monitor their energy consumption and control connected devices from anywhere using a smartphone or other mobile device. This comprehensive solution empowers users to make informed decisions about their energy usage, optimize efficiency, and reduce costs effectively.

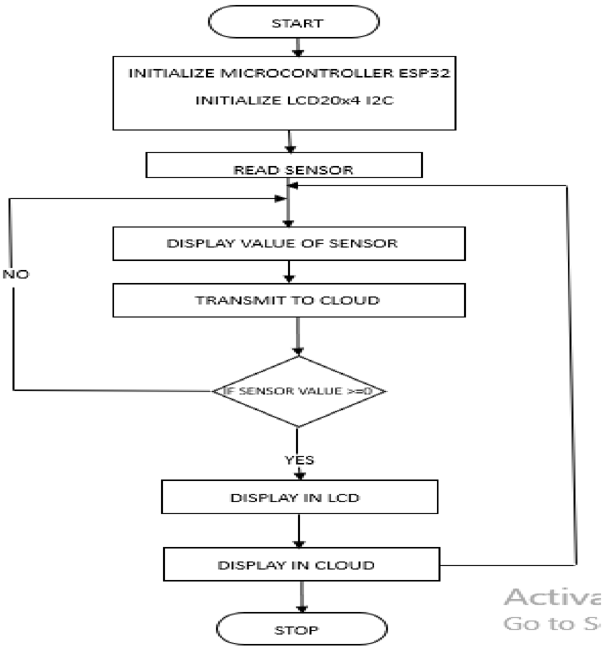

Fig. 3 represents the flowchart of system

The flowchart (Figure 2) illustrates the workflow of the project as described in the paper. Initially, the ESP32S microcontroller is initialized, which in turn initializes the built-in Wi-Fi module. Subsequently, the 16x2 LCD display is initialized. Once the sensors are prepared to read the values, the obtained data is printed using various outputs, including the serial monitor. The collected values are then transmitted to the Blynk cloud. If continuous values are detected, they are displayed on the LCD and Blynk output portals, such as the web and mobile dashboards.

IV. TOOLS AND TECHNOLOGY USED

ESP32 Microcontroller: The ESP32 microcontroller serves as the central processing unit for the smart energy meter. It provides processing power, memory, and Wi-Fi connectivity for data acquisition, processing, and communication with external devices and cloud services.

Sensors:

ZMPT101B AC Voltage Sensor Module: Measures AC voltage levels in the electrical system.

SCT-013-030 Non-invasive AC Current Sensor: Measures AC current levels without requiring direct electrical contact.

Relay Module: Enables remote control of power-consuming devices by switching the power supply based on user commands or predefined thresholds.

20x4 I2C LCD Display: Provides a visual interface for displaying real-time energy consumption metrics, including voltage, current, and power.

Blynk Application: A mobile application used for remote monitoring and control of the smart energy meter. It allows users to visualize energy consumption data and control connected devices remotely via smartphones or other mobile devices.

Arduino IDE: The Arduino Integrated Development Environment (IDE) is used for programming the ESP32 microcontroller and developing the firmware for the smart energy meter.

Blynk Cloud Server: Blynk provides a cloud-based platform for integrating IoT devices with mobile applications. The Blynk cloud server facilitates communication between the smart energy meter and the Blynk application for remote monitoring and control.

Wi-Fi Connectivity: The smart energy meter utilizes Wi-Fi connectivity provided by the ESP32 microcontroller to communicate with external devices and cloud services, such as the Blynk cloud server.

Overall, these tools and technologies work together to enable real-time monitoring, analysis, and control of energy consumption in the smart energy meter project. They provide users with actionable insights into their energy usage and empower them to optimize efficiency and reduce costs effectively.

D. Experimental Results of Smart Energy Meter

The output of the smart energy meter project encompasses a comprehensive set of features designed to empower users in managing their energy consumption effectively. Through real-time monitoring, users gain access to immediate insights into voltage, current, and power consumption displayed on both the LCD screen and the Blynk application. This facilitates informed decision-making, allowing users to adjust their energy usage patterns for optimal efficiency. Moreover, the integration with the Blynk application extends the meter's functionality by enabling remote monitoring and control from any location via smartphones or other mobile devices. The intuitive data visualization offered by the meter enhances user understanding of energy usage trends, further facilitating proactive energy management. Additionally, the alerting system provides timely notifications to users in case of abnormal consumption levels or system issues, enabling prompt intervention to prevent energy wastage. Collectively, these outputs contribute to a user-centric energy management solution, fostering energy savings, cost reduction, and environmental sustainability.

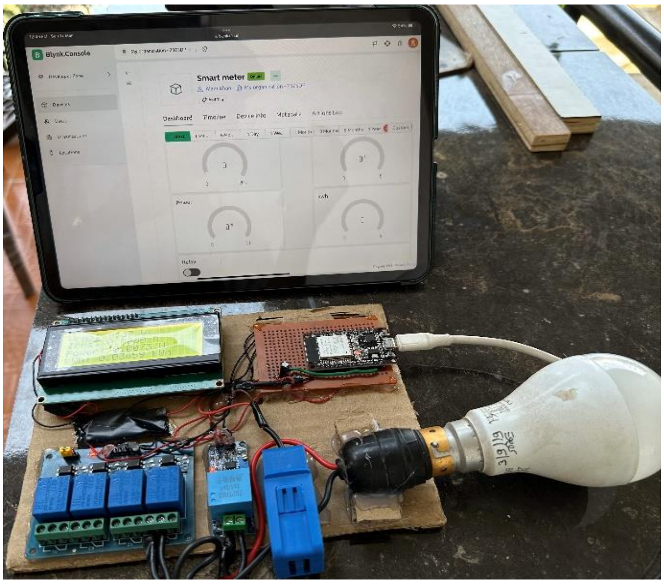

Fig. 4 represents the output of the smart energy meter

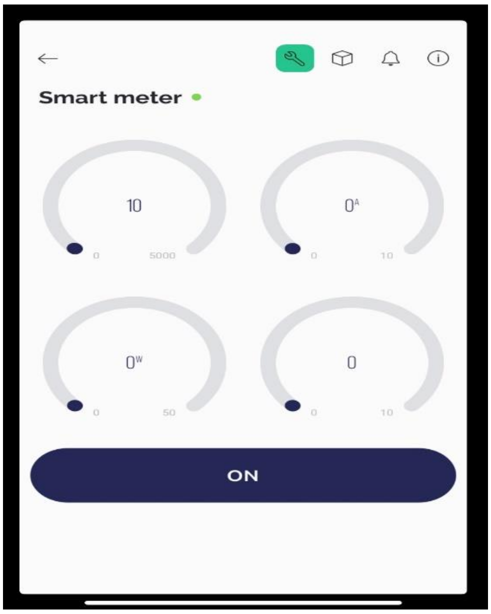

Fig. 7 shows result on BLYNK mobile application

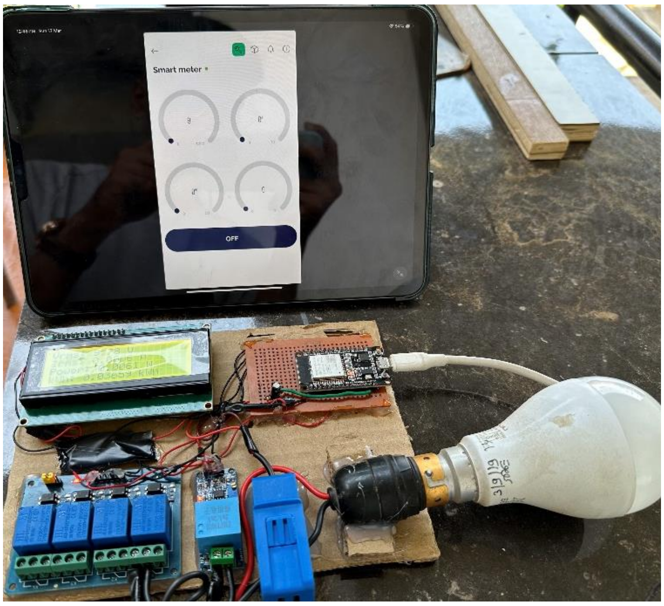

Fig. 5 represents the output of the smart energy meter on mobile application.

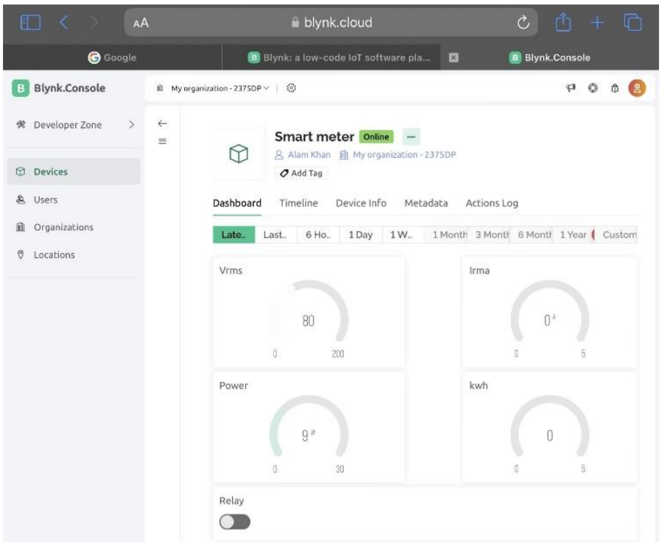

Fig. 8 shows result on BLYNK DASHBOARD

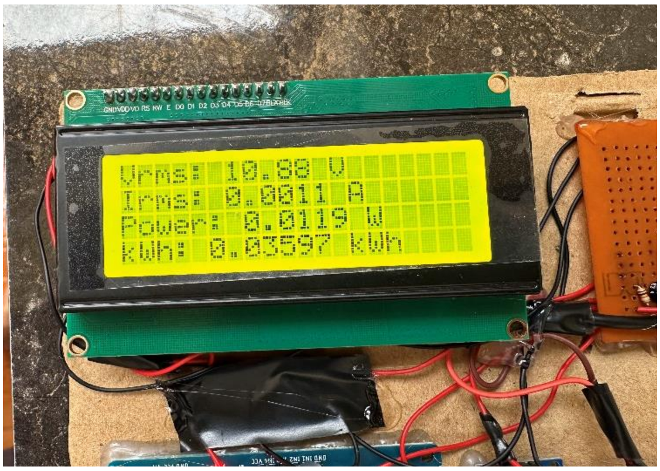

Fig. 6 represents the LCD module Output.

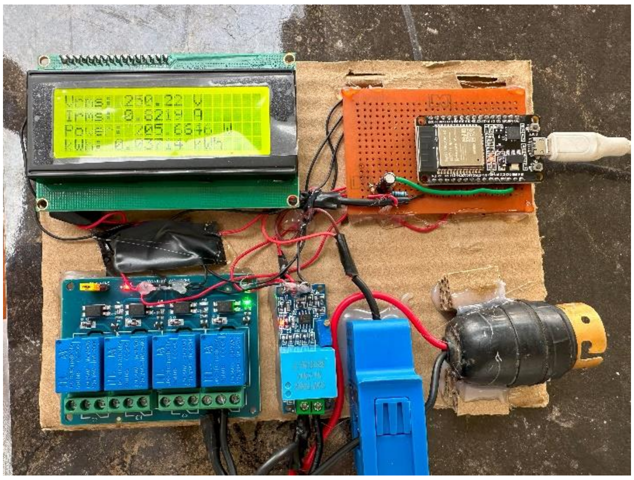

Fig. 9 Represent Proposed Prototype

V. CONCLUSION

The current electricity billing system requires EB workers to visit each consumer's home to record consumption readings, but this project aims to replace this manual process with automated systems, allowing bills to be generated remotely. By leveraging the Internet of Things (IoT), consumers will have the ability to monitor their daily energy usage, facilitating greater awareness and encouraging them to reduce consumption while gaining a clearer understanding of their energy expenditure.

VI. REFERENCES

[1] Paul stone Macheso and Doreen Thotho " ESP32 Based Electric Energy Consumption Meter" , Published 09-05-2022.

[2] Ruchitha P , SA Rajesh , Rakshitha B , Varsha Shetty L , DR.TP Surekha " IMPLEMENTATION OF IOT BASED SMART ENERGY METER" , Published 05-05-2023 .

[3] AMohamed Sheik Buhari S , Mani Bharathi K and Mohamed Jakeer M "IOT BASED SMART ENERGY METER IN THREE PHASE" ,Published 05-05-2023.

[4] Pranav Singhal, Sakshi Upadhyay ,Sheenam, Annurudh Pratap Upadhyay "IOT BASED SMART ENERGY METER" , Published 03-03-2019..

[5] Shubham Hadap, Deepti Ighe, Dhanashri Kadam, Rahul Niakm "Iot Based Smart Energy Meter" , Published 06-05-2022.

[6] Niloy Mondal, Mahdi Mohammed, Hashem Shake, Husam Ali Mahdi, Ch.Ravisankar " DESIGN OF A SMART ENERGY METER" ,Published 02-05-2022.

[7] Feras Alkowaiter, Majed Aldohailan, Abdullah Aldagani, Abdullah Alqarni "Smart Meter", Published 2020.