IoT based Smart Electricity Monitoring and Control Using ESP-Mesh Networking

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Abstract: The "IoT-Based Smart Electricity Monitoring and Control System Using ESP-MESH Networking" is a state-of-the-art project that aims to transform the way we manage and consume electricity in our homes. In today's world, our homes are equipped with a wide range of electrical appliances, each with varying levels of power consumption. Without an effective system to monitor and control these appliances, they can lead to excessive electricity usage. This not only results in high energy bills but also contributes to a significant carbon footprint, which is harmful to our environment. The Power consumption by the overall house can be monitored using this device and control the other electronic devices, able to monitor the power consumption in different rooms and able to monitor the current power by specific devices. User can check their Power usage from anywhere and at any time interval. The information can be monitored from mobile applications and also be monitored even on a web page. The Main can be turned on/off using a relay from anywhere. The Home application can also be controlled from anywhere through the mobile application.

Keywords— ESP-MESH Networking, Power Consumption, Energy efficiency, Carbon footprint, Relay control, Energy management

I INTRODUCTION

Our project provides a comprehensive approach to monitoring and controlling electricity consumption to address these problems. Users can monitor the total amount of electricity used in their homes as well as the amount used by each device in each room. Furthermore, the system offers remote data viewing using a mobile application and web interface. Because they can check their power usage at any time and from any location, users have more flexibility and control over how much energy they use. Overall, the IoT-based Smart Electricity Monitoring and Control Using ESP-MESH Networking project has greatly increased household energy management. It improves productivity, reduces expenses, and has less of an adverse effect on the environment by empowering consumers to make informed decisions about how much energy they use.

II PROBLEM STATEMENT

The "IoT Based Smart Electricity Monitoring and Control Using ESP-MESH Networking" project focuses on the shortcomings and inefficiencies of controlling home electricity with traditional methods. Because existing technology cannot provide real-time data on electricity consumption, it is difficult for clients to accurately track their usage habits. Without precise monitoring and control systems, homes may inadvertently waste a lot of electricity, leading to higher costs and negative environmental effects. Many homes lack the flexibility and ease of remote monitoring and control of their electricity consumption, which limits the users' options. Because of their complexity and implementation costs, modern monitoring and control systems could not be accessible to many users.

III NEED FOR THE SYSTEM

When giving customers access to real-time energy usage statistics and empowering them to optimize their electricity consumption habits, the initiative seeks to meet this requirement. As the need for sustainability and energy conservation grows, clever solutions that make effective monitoring and control of electricity consumption are required. Many customers need to be able to keep an eye on how much electricity is being used remotely, particularly when handling several properties or keeping an eye on energy usage in industrial environments. Through IoT-enabled devices connected to the ESP-Mesh network, the project enables remote monitoring of electricity usage, giving customers access to consumption data from any location with an internet connection. The project assists customers in optimizing their energy consumption and lowering their electricity bills by offering comprehensive insights into patterns of electricity usage and empowering them to pinpoint inefficient regions. Both home and commercial users may experience significant cost reductions as a result of this. The project is made to be flexible and scalable to fit in with a range of settings and applications. The ESP-Mesh networking technology enables the smooth integration of several devices and sensors to construct an all-encompassing monitoring and control system, regardless of whether it's tracking power usage in a single family, a commercial building, or an entire industrial site.

IV OBJECTIVE

To create three separate boards: one to monitor overall current, one to monitor device current consumption, and further subboards monitoring current usage in particular rooms. to connect the main circuit boards and subboards via a local network. to create a user-friendly mobile/web application that makes it simple for users to access the device's data. Provide customers with up-to-date, precise information about their energy consumption using a system that can continuously monitor power usage in real time. Provide a user-friendly interface that makes it simple for customers to comprehend and evaluate their consumption habits by presenting information regarding electricity usage in an easy-to-understand manner. Give customers the option to view information about how much electricity they use remotely from any location with an internet connection. This would facilitate the monitoring and management of energy usage even while the users are not on the premises under observation. Install components that can recognize and alert people to possible safety concerns, such as overloaded circuits or malfunctioning equipment, to enhance safety and security measures in residences and businesses.

V SYSTEM DESIGN

Blynk IOT: A complete software suite called Blynk makes it possible to prototype, install, and remotely manage any size of networked electronic device. Blynk enables users to connect hardware to the cloud and create iOS, Android, and web applications. It also allows users to analyze real-time and historical data from devices, remotely control them from anywhere, receive important notifications, and much more—whether they are personal IoT projects or commercial connected products with millions of users.

Arduino Integrated Develop Environment: The Arduino Software (IDE), also known as the Arduino Integrated Development Environment, has a text editor for writing code, a message box, a text console, a toolbar with buttons for frequently used tasks, and several menus. To upload and interact with programs, it establishes a connection with the Arduino hardware. Sketches are programs created with the Arduino Software (IDE). These drawings are saved as files with the. ino extension and are created using a text editor. The editor offers tools for searching through and replacing text as well as cutting and pasting. In addition to displaying faults, the message box provides feedback during exporting and saving. Complete error warnings and other text output from the Arduino Software (IDE) are displayed in the console. The configured board and serial port are shown in the window's lower right corner. You can create, open, save, and verify programs with the toolbar buttons. You can also open the serial monitor and create, open, and validate drawings.

ESP32: The ESP32 chip is designed to enable embedded devices, or Internet of Things devices, to connect via Wi-Fi and Bluetooth (in some variants). Though the chip itself is all that is known as ESP32, the manufacturer also frequently refers to the development boards and modules that house this chip as "ESP32." Tensilica Xtensa LX6 single core CPU was used in the initial ESP32 chip. The processor processed data at a comparatively high speed because of its clock rate, which was more than 240 MHz

ESP8266: You may enable WiFi network access for any microcontroller with the ESP-01 ESP8266 Serial WIFI Wireless Transceiver Module, which is a self-contained SOC with integrated TCP/IP protocol stack. A separate application processor can be used to handle all Wi-Fi networking functions, or the ESP8266 can host an application.
A pre-programmed AT command set firmware is included with every ESP8266 module, so all you have to do is connect it to your Arduino device and enjoy nearly the same level of WiFi functionality as a WiFi shield right out of the box! Having a large and continuously expanding community, the ESP8266 module is a very affordable board.

4-Channel Relay: The energization status indication light and release status led are off on this 4-channel, 5-volt relay module, which is a low pull, high release relay module. By default, this module is a 5V relay that operates on jd-vcc relay power and complies with international safety requirements, load area isolation trenches, and control. Controlling high voltage and high current loads, such as motors, solenoid valves, lights, and AC loads, is made easy with the help of the 4 Channel Relay Module. It is made to interface with PIC, Arduino, and other microcontrollers, among others. With a screw terminal, the relays' COM, NO, and NC terminals are brought out. It also includes an LED to show the relay's status. Large current equipment such as appliances and other devices can be managed by the 4-

channel relay module. The relay module's maximum output is DC5V 10A and AC250V 10A.

SCT-013-000 Current Sensor: The Non-invasive AC Current Sensor Clamp Sensor 30A is known as SCT-013-030. The SCT-013-000 is a current transformer that can measure AC up to 100 amperes and is classified as a non-invasive AC sensor. With the help of this non-invasive AC sensor that is clamped around the supply line, you can determine how much current is passing through a load of up to 30 amps. It can be helpful to construct an over-current protection device for an AC load or your energy monitor. Up to 30A of current can be detected using this current clamp. All you have to do is wrap it around the source of current you want to measure, and it will generate a very tiny AC voltage in direct proportion to the current. One end of the wire is terminated with a normal 3.5mm jack, similar to a headphone jack. Use this to construct an over-current protection device for an AC load, or use it to build your energy monitor and reduce your power consumption. Below is a link to an example project. To find out the 3.5mm jack pinout, consult the datasheet.

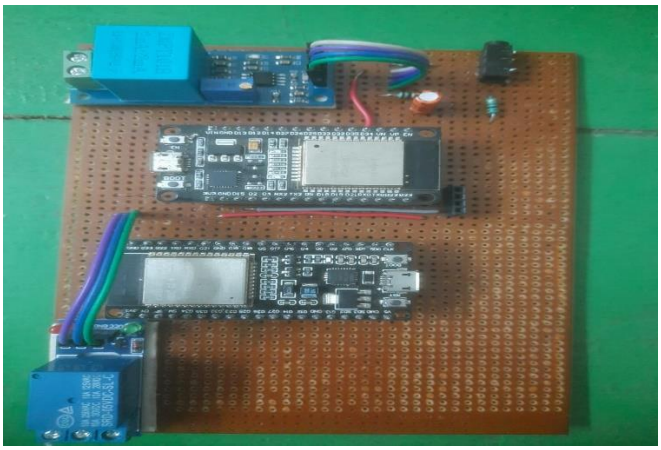
Single Channel Relay: Controlling high voltage and high current loads, such as motors, solenoid valves, lights, and AC loads, is made easy with the Single Channel Relay Module. It is made to communicate with different types of microcontrollers, including Arduino and NodeMCU. Relay terminals (COM, NO, and NC) are pulled out using screw terminals. It also includes an LED to show the relay's status. Relays are the equipment that opens or closes connections to turn on and off high-voltage appliances. In safety circuits, it is also employed to identify unwanted conditions in a designated area and instruct the circuit breaker to disconnect the impacted area by turning it ON or OFF.

OLED Panels: Organic materials used to make OLED screens emit light when power is passed through them. OLEDs are more effective, easier to manufacture, and considerably thinner than LCDs as they don't need filters or a backlight. They may be made flexible or even rollable. OLEDs produce images with excellent color , contrast, reaction time, and viewing angle clarity. OLED lighting is another application for OLEDs; it is efficient, thin, and free of harmful metals. The OLED emitter, which is an organic substance based on carbon and emits light when power is applied, is the primary part of an OLED display. An emissive layer is positioned between a cathode and an anode in the fundamental construction of an OLED.

ZMPT101B Voltage Sensor: Ultra Micro Voltage Transformer ZMPT101B. It is a small, accurate, and consistently reliable voltage and power monitoring device. We offer several kinds of force, flex, pressure, and load cell types. View our entire selection of load cells and weigh sensors.

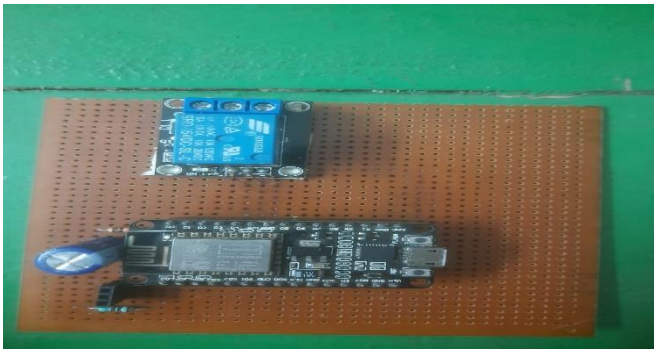
VI METHODOLOGY

Main Board:



This main board is connected near the meter box. It consists of two ESP32 microcontroller modules. Both ESP32 modules play distinct roles in the system. The bottom ESP32 module is connected to the internet. This indicates that it has internet access. There are two sensor boxes CURRENT SENSOR and VOLTAGE SENSOR. These sensors feed data to the ESP32, enabling it to monitor electrical parameters such as current and voltage

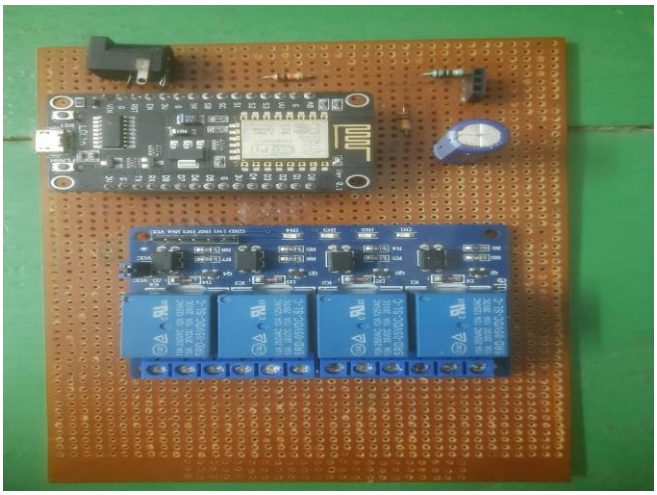
Sub Board:



This Sub board 1 is connected to high-current consuming appliances such as a TV, Refrigerator, Air conditioner, etc., and A relay module capable of

switching a single channel (e.g., turning a device on or off). this system involves an ESP32 module, sensor, internet connectivity, and output devices. The interplay between these components enables various functionalities, such as monitoring electrical parameters and controlling devices.

Sub Board:



The sub-board 2 is connected to the switchboards, which will detect the overall current consumed in that particular room. It consists of an ESP 8266 module, which is connected to the 4 CH-Relay. This channel relay is the replica of the electric switch.

Esp- Mesh Networking:

By using esp-mesh network , main board and sub board are connected and they can transfer data seamlessly. Large-scale IoT networks with hundreds or thousands of devices can be built with ESP-Mesh. In a mesh network, every device can function as a node, creating a decentralized design that is easily expandable to accommodate more devices.

4- Channel Relay:

Remotely operate electrical equipment, like fans, air conditioners, and lights, through a web interface or mobile application. You may individually control several items or zones in your house with the 4-channel relay. Connect the relay to security sensors, like door/window sensors or motion detectors. Relays can be used to turn on lights, alarms, or other security features when a sensor is triggered. Reduce electricity usage by putting energy-saving measures into practice by remotely shutting off non-essential appliances or equipment while it's not in use.

Single Channel Relay:

Utilize a smartphone app or web interface to remotely control a single electrical appliance or equipment. Use your smartphone, for instance, to turn on or off a fan, lamp, or coffee maker remotely. Connect the relay to security equipment including video cameras, door/window sensors, and motion sensors. The relay can be used to turn on lights, alarms, or other security features. In a smart home configuration, use the relay to regulate the locking system for gates or doors. This enables integration with access control systems and remote locking and unlocking.

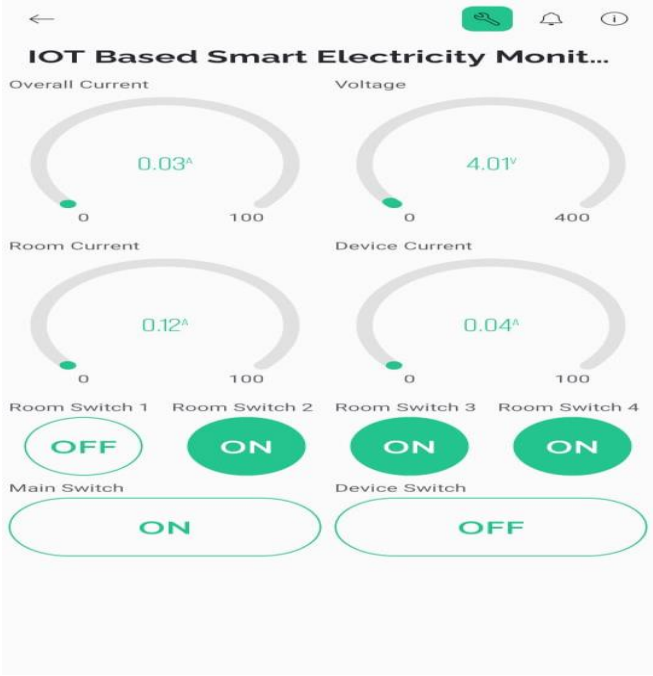
SCT-013-000 Current Sensor:

Alternating current (AC) up to 100A can be measured using the non-invasive SCT-013-000 current sensor. The current-carrying wire is fed via a split-core ferrite core, which produces a proportional voltage or current signal that reflects the measured current. Evaluate and track in real time the power usage of electrical systems or devices. You can gather data on energy usage and analyze it to spot patterns, trends, and inefficiencies by mounting the sensor to the power connections of appliances, lighting fixtures, or machinery.

Website Interface with Current Readings:

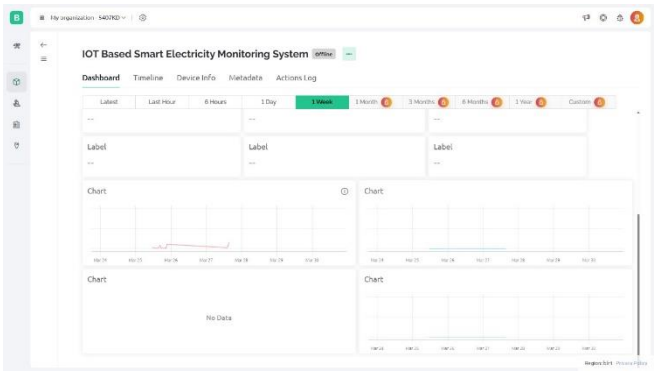
To read the output of the SCT-013-000 current sensor, use a microcontroller with an analog input, such as an Arduino or an ESP32. A voltage or current signal proportionate to the measured current will be emitted by the sensor. Transform this analog signal into a digital value that the microcontroller can understand Classification. To connect to the internet, use the Ethernet or Wi-Fi capabilities of the microcontroller. Libraries like ESP8266WiFi or Arduino WiFi can be used to connect to your Wi-Fi network and interact with web services. To safeguard access to the web interface, put user authentication and permission processes into place. To avoid manipulation and eavesdropping, make sure that sensitive data is delivered via HTTPS.To provide a smooth user experience across platforms, optimize the web interface for various screen sizes and devices (desktops, tablets, and smartphones).To guarantee operation, usability, and performance, extensively test the website's interface. Install the web application on a dedicated server or web hosting provider that is reachable via the internet.

VII. RESULT



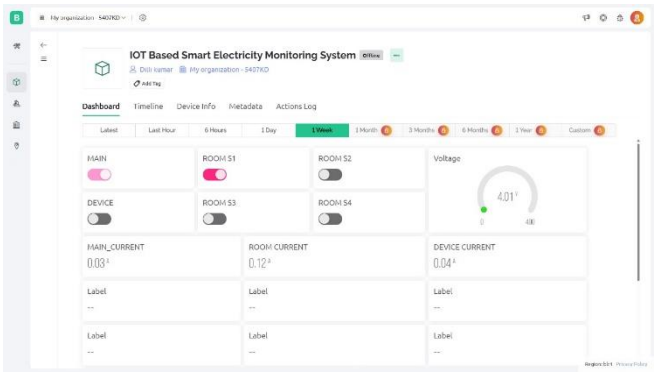
Mobile Interface

This mobile application shows the overall current consumed and the voltage. This application shows whether the room switches are switched on or off . Using the application the main switch and the device switch can be controlled. This smart electricity monitoring system . Users can remotely control IoT devices through their mobile interface. Users can monitor the status of their IoT devices in real-time. This could include checking the meter box in a room, viewing security camera feeds, or monitoring energy usage. Presenting data collected from IoT sensors in a user-friendly way, such as charts or graphs, to help users understand trends or anomalies.



Website Interface

This website will give the information in more detailed manner. Using this website the electricity consumed in graphically represented. It consist of dashboard, timeline, device info , metadata, and the action log . In detail the current consumed can be customized for a year , months, weeks, or even hours.



Website Interface with Current Readings

VIII. CONCLUSION

In conclusion, there has been major progress in the field of home energy management with the "IoT Based Smart Electricity Monitoring and Control Using ESP-MESH Networking" project. The system provides a comprehensive solution for monitoring and managing residential electricity usage by utilizing ESP-MESH networking and Internet of Things technology. We have addressed the shortcomings of conventional electricity management techniques throughout the project, such as ineffective energy management, a lack of real-time monitoring, and a restricted range of control options. With the system's real-time monitoring of electricity consumption, customers can correctly analyze usage trends and quickly pinpoint inefficient areas. By enabling dependable communication between IoT devices through ESP-MESH networking, a strong infrastructure for smart electricity monitoring and control is created. Future developments are also expected to improve the system's sustainability and functionality, including predictive analytics, energy harvesting technology, and integration with smart grids.

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