Abstract

This abstract introduces an innovative energy monitoring system tailored to empower individuals and organizations to track, analyze, and optimize their energy usage. The system is designed to provide comprehensive insights into energy consumption patterns, enabling users to make informed decisions aimed at reducing costs and minimizing environmental impact. Leveraging cutting-edge sensor technologies and data analytics algorithms, the platform offers real-time monitoring of energy consumption across various devices and appliances. Users can access intuitive dashboards and visualizations to gain a clear understanding of their energy usage trends and identify opportunities for efficiency improvements. Additionally, the system incorporates features such as customizable alerts and notifications to alert users of abnormal energy consumption patterns or potential energy-saving opportunities. By promoting awareness and facilitating proactive energy management strategies, this energy monitoring system aims to empower users to adopt sustainable practices and contribute to a greener future.

1. Introduction

1.1 Background:

India, as a rapidly growing country, faces increasing demands for electricity, driven by population growth and industrial expansion. Projections indicate a significant surge in energy consumption from 2023 to 2040. Recognizing this trend, the nation has implemented various policy measures to promote energy efficiency and conservation. While industries and large buildings often undergo regular energy audits to reduce wastage, households typically lack such assessments. This underscores the importance of identifying areas for energy efficiency improvements and investments, both through modern equipment adoption and upgrades to existing infrastructure.

1.2 Problem Statement:

In light of escalating energy demands and environmental concerns, optimizing energy consumption across industrial, commercial, and residential sectors has become imperative. Consider a scenario where a household receives an unusually low electricity bill due to a fault in the energy meter box. Upon repair, the subsequent bill returns to a more typical range. This incident highlights the need for an energy management system (EMS) to optimize energy usage. However, upon research, it becomes evident that there's a scarcity of comprehensive devices offering complete control and information about energy conservation in residential or commercial environments. Consequently, our project aims to address this gap by collecting, monitoring, and notifying users about their energy consumption, thus facilitating informed decision-making and energy optimization.

1.3 Scope of Project

The scope of an Energy Monitoring System (EMS), particularly when implemented with IoT technology, offers extensive opportunities for optimizing energy consumption across various sectors and applications. Here's an overview of the scope of IoT-based EMS in terms of energy monitoring:

1.Industrial Energy Monitoring:

Energy monitoring systems in industrial settings enable real-time tracking and analysis of energy usage across manufacturing processes, machinery, lighting, and HVAC systems. By continuously monitoring energy consumption patterns, organizations can identify inefficiencies and implement measures to optimize energy usage and reduce operational costs.

2.Commercial Building Energy Monitoring:

In commercial buildings, energy monitoring solutions utilize sensors and IoT devices to monitor and control lighting, HVAC systems, and other energy-consuming equipment. By analyzing occupancy patterns and environmental conditions, these systems adjust energy settings to minimize wastage and improve overall energy efficiency.

3.Integration with Smart Grids:

IoT-enabled energy monitoring systems can integrate seamlessly with smart grids to enhance energy management capabilities. By leveraging real-time data analytics, these systems support demand-response strategies, optimize energy distribution, and facilitate the integration of renewable energy sources, contributing to grid stability and sustainability.

4.Residential Energy Monitoring:

Energy monitoring systems for residential use enable homeowners to track and manage their energy consumption more effectively. By monitoring energy usage of appliances, lighting, and HVAC systems, residents can identify energy-saving opportunities and make informed decisions to reduce energy costs and environmental impact.

5.Renewable Energy Integration Monitoring:

Energy monitoring systems play a crucial role in integrating renewable energy sources into the energy grid. By monitoring energy generation from solar panels, wind turbines, and other renewable sources, these systems optimize energy distribution and storage to balance supply and demand effectively.

6.Real-time Monitoring and Reporting:

Energy monitoring systems provide real-time insights into energy consumption patterns and generate comprehensive reports. By analyzing this data, organizations and individuals can identify trends, track energy-saving initiatives, and make data-driven decisions to optimize energy usage.

7.Predictive Maintenance Monitoring:

Energy monitoring systems leverage data analytics to predict equipment failures and recommend maintenance schedules proactively. By monitoring equipment performance and energy usage, organizations can minimize downtime, optimize equipment efficiency, and reduce maintenance costs.

8.Environmental Impact Monitoring:

Energy monitoring systems contribute to reducing carbon footprints by optimizing energy usage and promoting sustainability. By monitoring energy consumption and identifying energy-saving opportunities, organizations can minimize environmental impact and support green initiatives.

9.Scalability and Challenges:

Energy monitoring solutions are scalable and adaptable to the evolving needs of users. However, it's crucial to address challenges such as data security and privacy when implementing IoT-based energy monitoring systems. Robust cybersecurity measures are essential to safeguard sensitive energy consumption data and protect against potential threats.

Energy monitoring systems, when implemented with IoT technology, offer a comprehensive approach to optimizing energy consumption across various sectors. By leveraging real-time data analytics and predictive capabilities, these systems enable organizations and individuals to achieve significant energy cost savings, improve sustainability, and minimize environmental impact.

2. Literature Survey

Energy consumption is a critical concern for industries, commercial establishments, and residential sectors worldwide. The increasing demand for energy, coupled with environmental and economic considerations, has led to a growing emphasis on the development and implementation of Energy Monitoring Systems (EMS) to optimize energy consumption. This literature review aims to provide an overview of key studies and trends related to energy monitoring systems and their role in improving energy efficiency, reducing costs, and minimizing environmental impact.

Various studies emphasize the importance of energy management systems in achieving sustainability goals. EMS, by facilitating efficient energy use, contributes to a reduction in carbon emissions and environmental impact. Implementing EMS leads to substantial energy savings and helps organizations meet their sustainability targets (Yazdani et al., 2019). [1]

The integration of IoT-based systems for real-time energy monitoring and data analytics is a central theme in contemporary energy management literature. These systems offer real-time insights into energy consumption patterns and enable data driven decision-making (Gungor et al., 2016). By leveraging 10T sensors, EMS can continuously collect and analyze energy usage data, identifying opportunities for optimization. [2]

EMS, particularly in the context of smart grids and IOT, plays a pivotal role in demand response strategies. These strategies involve dynamic load management, allowing grid operators to balance supply and demand efficiently during peak hours (Meng et al., 2020). Such mechanisms reduce energy costs and improve grid stability. [3]

The industrial sector benefits significantly from EMS implementation. Industries are responsible for a substantial portion of global energy consumption. EMS optimizes the use of energy-intensive processes, machinery, and lighting. It also assists in predictive maintenance, preventing failures ,reducing downtime(Rathoreet al., 2021). [4]

In the commercial and residential sectors, EMS provides mechanisms for controlling lighting, heating, ventilation, and air conditioning (HVAC) systems based on occupancy and other factors. Research has highlighted the potential for significant energy and cost savings in these domains (Fadlullah et al., 2016). [5]

The integration of renewable energy sources is another critical topic in energy management literature. EMS helps manage the unpredictability of renewable energy generation by forecasting energy production and balancing it with demand (Bui et al., 2016). [6]

Literature also acknowledges the challenges and barriers in EMS implementation, including the initial investment, data security and privacy concerns, technology integration, and the need for user behavior change (Braun et al., 2017). [7]

Currently, in the market, There are few devices available to control our appliances or devices to switch on or off. Or else there are devices which are used to just measure the current flowing towards a given household Overall and calculate the Overall electricity bill based on the overall power a house has consumed.

3. Metrics associated with Power Consumption and Cost

3.1 Basic Appliances

Tube light:
55W per hour

Fan:
75W per hour

Washing Machine:
1000W per hour

Air Conditioner: 3000W per hour

Refrigerator:500W per hour

Fig 3.1.1 Home Appliances with Energy Usage

1)Device Wattage (watts) x Hours Used Per Day = Watt-hours (Wh) per Day

2)Device Usage (Wh)*1000 (Wh/kWh) = Device Usage in kWh

3)Daily Usage (kWh) x 30 (Days) =Approximate Monthly Usage (kWh/Month)

3.2 Example

A Family uses a light bulb of 100W, a fan of 100W and a heater of 3KW, each for 8 hours a day. If the cost of electricity is Rs 2 per unit, what is the expenditure for the family per worth of 30 days, on electricity?

Ans:-

Appliance	Power(in W)	Time(hrs)	Energy(Wh)= (power)*(time)
1) Light bulb	100	8	800
2) Fan	100	8	800
3) Heater	3000	8	24000

Total Energy in Wh = 25600Wh

Total Energy in KWh = 25.6KWh

Cost = 25.6KWh * 2 * 30 = 1536 Rs

The expenditure for the family per worth of 30 days, on electricity is **Rs.1536.**

4. Methodology

4.1 Components:-

1 .Current Sensor:-

The working of a current sensor involves measuring the flow of electric current in a conductor without interrupting or disturbing the current itself.current sensors detect and measure electrical current by utilizing electromagnetic induction, which generates a proportional output signal based on the current passing through a conductor.

The output signal from the current sensor is typically fed into an electronic circuit or measurement device. Depending on the sensor type, it may require additional circuitry to convert the signal into a meaningful current reading or voltage output. The output of the sensor can be used to determine the magnitude of the current flowing through the conductor. This reading is typically displayed or used for various purposes, such as monitoring, control, or safety. Current sensors are essential in applications like power distribution, electrical system monitoring, motor control, and energy management, allowing for the accurate measurement and control of electric currents. The specific technology and design of the current sensor may vary depending on the application and required accuracy.

Fig 4.1 Current Sensor

2. Temperature Sensor:-

Temperature sensors work by measuring physical or electrical properties that change with temperature. There are several types of temperature sensors, but some common ones include: The choice of sensor depends on factors like the required temperature range, accuracy, and the specific application. Once a sensor measures the temperature, the data is typically converted into a digital signal and can be displayed or used for control purposes in various applications, from household thermostats to industrial processes.

Fig 4.2 Temperature Sensor

3. Relay:-

A relay is an electromechanical switch that uses an electromagnet to control the opening and closing of one or more electrical contacts. Here's how a basic relay works: Relays are used to control high-power or high-voltage circuits using a low power control circuit. When you apply a small control voltage to the relay coil, it either closes or opens the contacts, which can carry a much higher current or voltage to control the load circuit. Relay Switches are valuable because they provide electrical isolation between the control circuit and the load circuit. This isolation helps protect sensitive control devices and allows for the safe control of high-power or high-voltage equipment. They are an integral part of many electrical and electronic systems for switching and controlling various components.

Fig 4.3Relay

4. ESP32:-

The ESP32 is a popular microcontroller and system-on-a-chip (SOC) developed by Espressif Systems, specifically designed for 10T (Internet of Things) applications. It is based on the Xtensa LX6 dual-core processor and features integrated Wi-Fi and Bluetooth capabilities. Here's a simplified overview of how the ESP32 works:

l. Processor and Memory: -

The ESP32 contains a dual-core Xtensa LX6 processor, which can execute instructions in parallel. - It has built-in memory, including RAM for program execution and data storage.

2. Peripherals: -

The ESP32 is equipped with various peripherals, such as GPIO pins, UART, SPI, 12C, analog to-digital converters (ADC), pulse-width modulation (PWM) controllers, and more. These peripherals enable the ESP32 to interface with sensors, displays, and other external devices.

3. Wireless Communication: -

The ESP32 features integrated WiFi and Bluetooth capabilities, making it suitable for 10T applications. It can connect to Wi-Fi networks and communicate with other devices over Bluetooth, including BLE (Bluetooth Low Energy) support.

4. Operating System and Frameworks:

The ESP32 can run different firmware and software stacks. One popular choice is the Arduino IDE, which allows you to program the ESP32 using the Arduino framework. Alternatively, you can use the Espressif 10T Development Framework (ESP-IDF) for more low-level control.

5. Programming: -

To develop applications for the ESP32, you write code in C or C++ using an integrated development environment (IDE) such as the Arduino IDE or PlatformIO. The code is then uploaded to the ESP32's flash memory.

6. Applications: -

The ESP32 is used in a wide range of 10T applications, such as home automation, sensor monitoring, wearable devices, smart appliances, and more. It can collect data from sensors, communicate with other devices over Wi-Fi or Bluetooth, and control various 10T devices.

7. Power Management: -

The ESP32 includes power management features to optimize power consumption, which is crucial for battery-operated 10T devices.

8. Security: -

The ESP32 provides security features like secure boot, flash encryption, and support for secure sockets (TLS/SSL) to ensure data integrity and confidentiality in 10T applications.

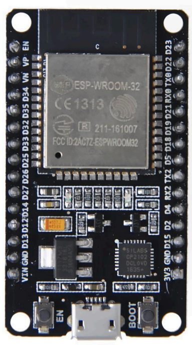

Fig4.5ESP32

4.2 Workflow

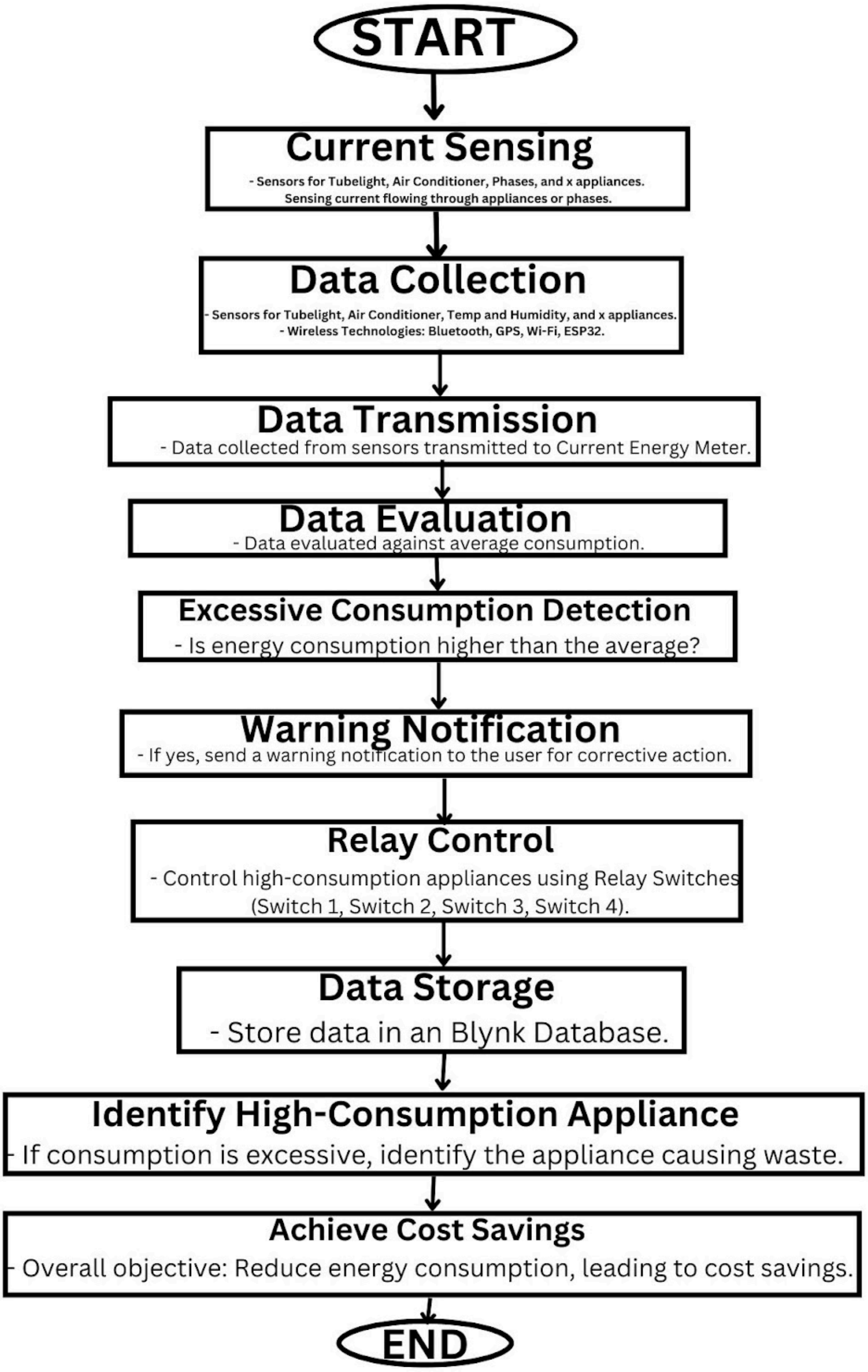

Fig4.6 Workflow

4.3 Block diagram:-

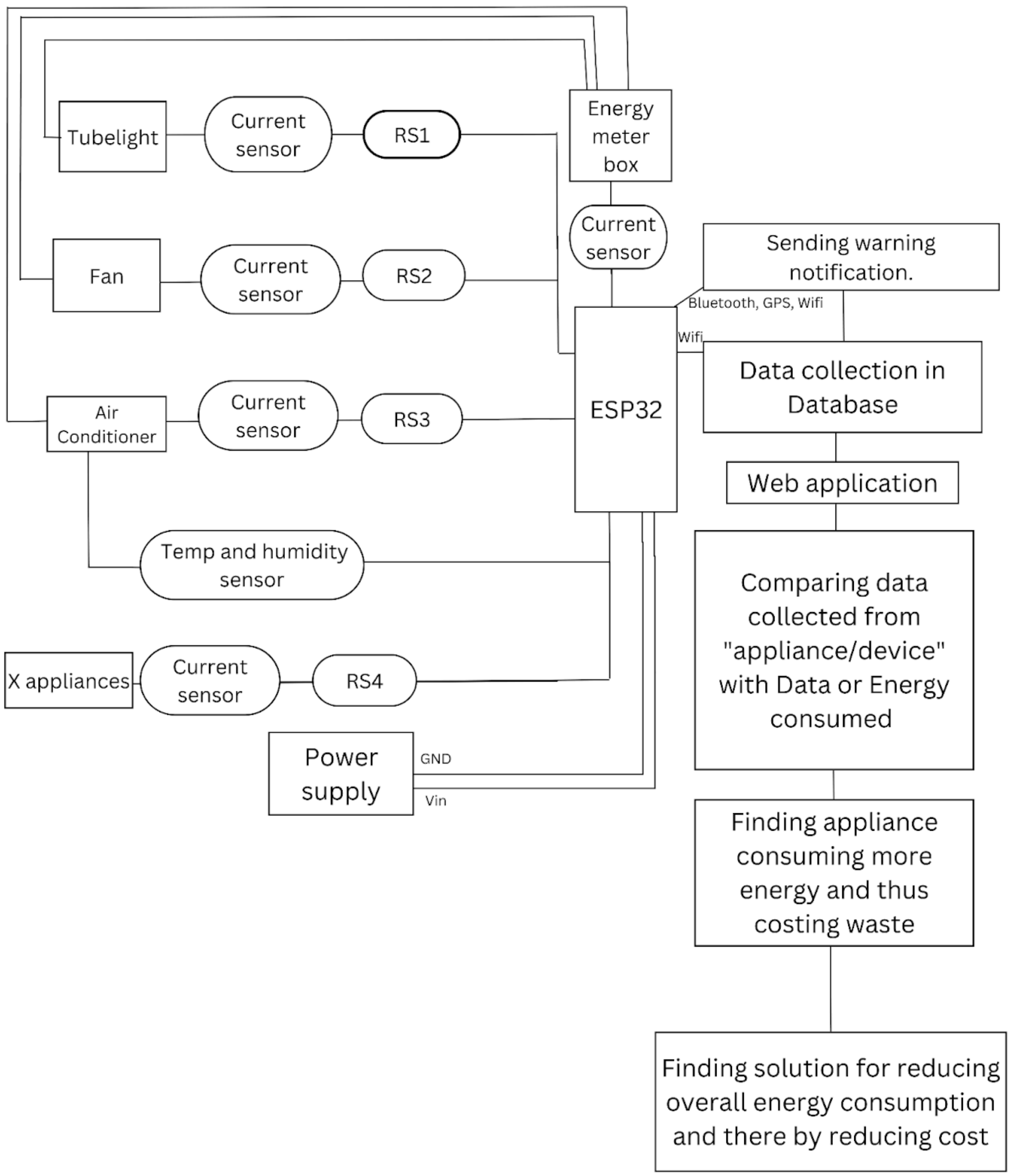

Fig4.7 Block diagram

4.4 Implementation:-

4.4.1 Circuit Diagram:-

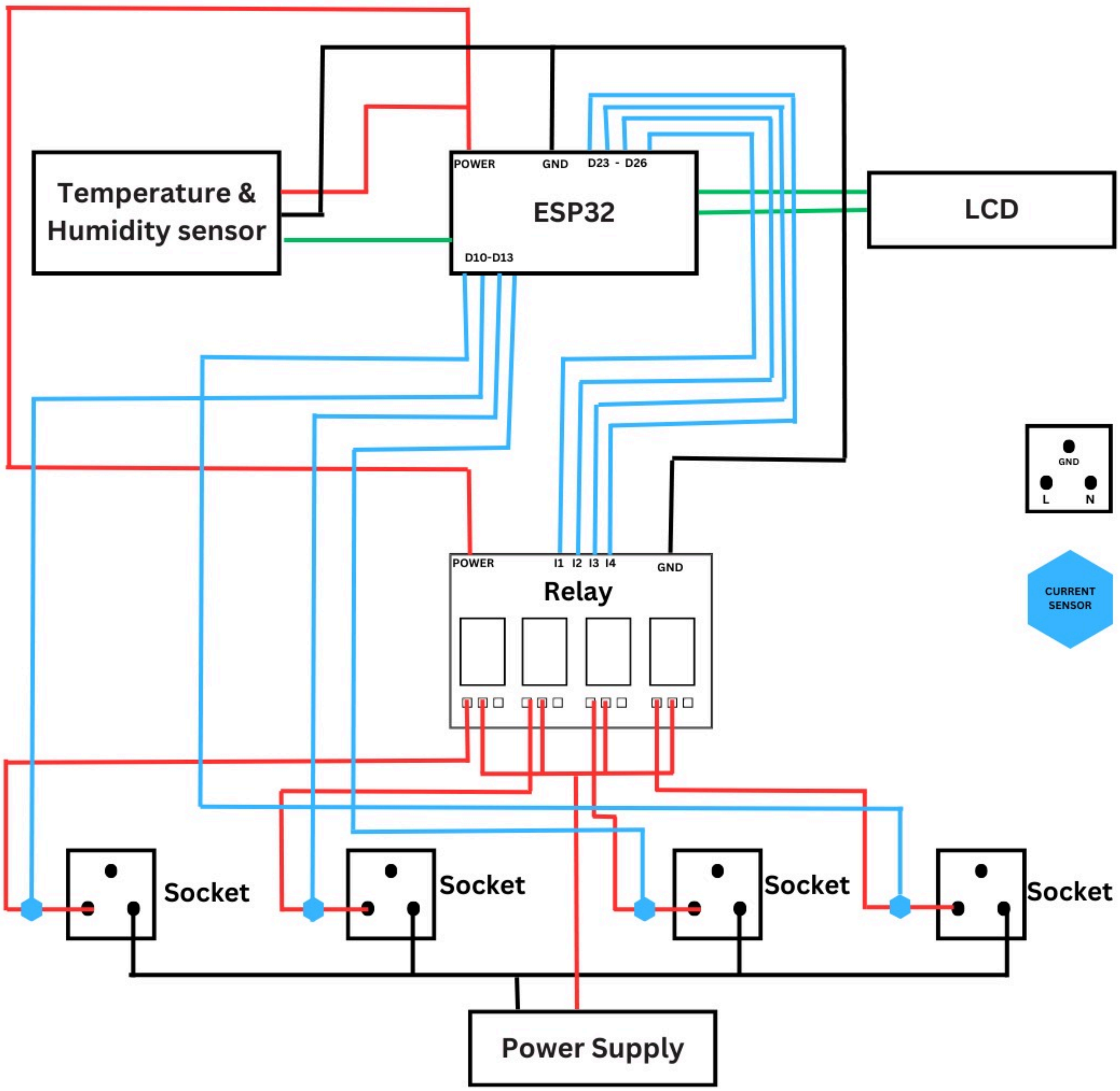

Fig4.8 Circuit Diagram

4.4.2 Software Used:-

1. Arduino IDE:

The Arduino IDE is a software application used to write, compile, and upload code to the ESP32 board. It features a code editor, library management, board and port selection, serial monitoring and open-source.

It provides a user-friendly interface for programming the ESP32 board making it accessible to beginners and experienced users alike. It offers a streamlined workflow for writing code compiling it into machine-readable format and uploading it to an ESP32 board via USB or other communication methods.

The <WiFi.h> library in Arduino IDE allows for WiFi connectivity and communication with networks, enabling IoT and wireless projects. The <WiFiClient.h> library in Arduino IDE enables the creation of WiFi client applications, allowing Arduino boards to connect to and communicate with servers or other devices over WiFi networks. The <Wire.h> library in Arduino IDE facilitates communication using the I2C (Inter-Integrated Circuit) protocol, enabling interaction with I2C-compatible devices such as sensors, displays, and other microcontrollers. The <LiquidCrystal_I2C.h> library in Arduino IDE enables the control of LCD displays using the I2C communication protocol, simplifying interfacing with liquid crystal displays (LCDs) in the projects. The "DHT.h" library in Arduino IDE allows for easy integration and communication with DHT series humidity and temperature sensors, simplifying the process of capturing environmental data in projects. The "EmonLib.h" library in Arduino IDE facilitates energy monitoring by providing functions to measure current and voltage, enabling accurate monitoring of power consumption in electrical circuits. The "ACS712.h" library in Arduino IDE enables interfacing with ACS712 current sensor modules, facilitating accurate measurement of electrical current in projects.

2. Blynk :

Blynk is a user-friendly platform widely used in IoT projects for its simplicity and versatility. It allows developers to easily create custom mobile applications to control and monitor connected devices remotely without needing advanced coding skills. Blynk supports various hardware platforms like Arduino, Raspberry Pi, and ESP, and its mobile app works on both iOS and Android devices, making it accessible across different platforms. With Blynk, devices can communicate with each other and the Blynk server over the internet, enabling remote access from anywhere. It offers pre-built widgets for buttons, sliders, graphs, and more, which can be customized to suit specific project needs without extensive coding. Blynk also integrates with third-party services like IFTTT and Zapier for advanced automation and data logging. Security features like encryption and authentication ensure safe communication between devices and the Blynk server. Plus, Blynk has a supportive community that shares resources and tutorials, making it easier for beginners to get started with their IoT projects. Overall, Blynk simplifies the process of building IoT applications by providing a user-friendly platform with cross-platform compatibility and robust community support.

4.4.3 Code:-

```
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID "TMPL3ntrUiNDX"
#define BLYNK_TEMPLATE_NAME "Electric Billing"
#define BLYNK_AUTH_TOKEN "81cG20HbB8ndMO68T2qOqo4JmnZbkQlT"
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include "DHT.h"
#include "EmonLib.h"
#include "ACS712.h"
#define DHTPIN 4
#define DHTTYPE DHT11
#define RELAY_PIN_1 13
#define RELAY_PIN_2 12
#define RELAY_PIN_3 14
#define RELAY_PIN_4 27
char ssid[] = "MyProject";
char pass[] = "12345678";
ACS712  ACS1(34, 3.3, 4095, 100);
ACS712  ACS2(35, 5.0, 4095, 100);
ACS712  ACS3(36, 3.3, 4095, 100);
```

```
ACS712  ACS4(39, 5.0, 4095, 100);
DHT dht(DHTPIN, DHTTYPE);
EnergyMonitor emon1;
EnergyMonitor emon2;
EnergyMonitor emon3;
EnergyMonitor emon4;
unsigned long lastMillis = 0;
unsigned long interval = 5000; // 5 seconds
double totalEnergy1 = 0.0;
double totalEnergy2 = 0.0;
double totalEnergy3 = 0.0;
double totalEnergy4 = 0.0;
const double chargingRate = 5.0; // Rs per kWh
// LCD I2C configuration
LiquidCrystal_I2C lcd(0x27, 16, 2); // Change the address (0x27) if your LCD has a different
address
void setup()
{
  Serial.begin(115200);
  ACS1.autoMidPoint();
  ACS2.autoMidPoint();
  ACS3.autoMidPoint();
  ACS4.autoMidPoint();
  pinMode(RELAY_PIN_1, OUTPUT);
  pinMode(RELAY_PIN_2, OUTPUT);
  pinMode(RELAY_PIN_3, OUTPUT);
  pinMode(RELAY_PIN_4, OUTPUT);
  dht.begin();
  lcd.init(); // Initialize the LCD
  lcd.backlight(); // Turn on the backlight
  lcd.print("Smart Billing"); // Display project name on LCD
  delay(3000); // Wait for 2 seconds before starting Blynk
  lcd.clear();
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
```

```
}
void loop()
{
  unsigned long currentMillis = millis();
  if (currentMillis - lastMillis >= interval)
  {
    lastMillis = currentMillis;
    double i1 = ACS1.mA_AC_sampling()/1000;
    double i2 = ACS2.mA_AC_sampling()/1000;
    double i3 = ACS3.mA_AC_sampling()/1000;
    double i4 = ACS4.mA_AC_sampling()/1000;
    // Assuming a constant voltage of 230V for billing calculation
    double voltage = 230.0;
    // Calculate energy consumption in Watt-hours
    double energy1 = i1 * voltage * interval / (3600 * 1000); // interval is in milliseconds
    double energy2 = i2 * voltage * interval / (3600 * 1000);
    double energy3 = i3 * voltage * interval / (3600 * 1000);
    double energy4 = i4 * voltage * interval / (3600 * 1000);
    // Accumulate total energy consumption
    totalEnergy1 += energy1;
    totalEnergy2 += energy2;
    totalEnergy3 += energy3;
    totalEnergy4 += energy4;
    float h = dht.readHumidity();
    float t = dht.readTemperature();
    // Clear the LCD
    lcd.clear();
    // Print on the LCD
    lcd.setCursor(0, 0);
    lcd.print("B1: "+String(totalEnergy1,2) + " B2: "+String(totalEnergy2,2));
    lcd.setCursor(0, 1);
    lcd.print("B3: "+String(totalEnergy3,2) + " B4: "+String(totalEnergy4,2));
```

```
  Serial.println("Current 1: " + String(i1));
  Serial.println("Current 2: " + String(i2));
  Serial.println("Current 3: " + String(i3));
  Serial.println("Current 4: " + String(i4));
  Serial.println("Temperature: " + String(t));
  Serial.println("Total Energy 1: " + String(totalEnergy1) + " kWh");
  Serial.println("Total Energy 2: " + String(totalEnergy2) + " kWh");
  Serial.println("Total Energy 3: " + String(totalEnergy3) + " kWh");
  Serial.println("Total Energy 4: " + String(totalEnergy4) + " kWh");
  // Calculate the price
  double totalPrice1 = totalEnergy1 * chargingRate;
  double totalPrice2 = totalEnergy2 * chargingRate;
  double totalPrice3 = totalEnergy3 * chargingRate;
  double totalPrice4 = totalEnergy4 * chargingRate;
  Serial.println("Total Price 1: Rs " + String(totalPrice1));
  Serial.println("Total Price 2: Rs " + String(totalPrice2));
  Serial.println("Total Price 3: Rs " + String(totalPrice3));
  Serial.println("Total Price 4: Rs " + String(totalPrice4));
   Blynk.virtualWrite(V0, h);
  Blynk.virtualWrite(V1, t);
  Blynk.virtualWrite(V6, totalEnergy1);
  Blynk.virtualWrite(V7, totalEnergy2);
  Blynk.virtualWrite(V8, totalEnergy3);
  Blynk.virtualWrite(V9, totalEnergy4);
  Blynk.virtualWrite(V2, totalPrice1);
  Blynk.virtualWrite(V3, totalPrice2);
  Blynk.virtualWrite(V4, totalPrice3);
  Blynk.virtualWrite(V5, totalPrice4);
  Blynk.run();
 }}
BLYNK_WRITE(V10) {
 int relayState = param.asInt(); // Assigning incoming value from pin V10 to a variable
 digitalWrite(RELAY_PIN_1, !relayState);
}
```

```
BLYNK_WRITE(V11) {
  int relayState = param.asInt(); // Assigning in
  coming value from pin V11 to a variable
  digitalWrite(RELAY_PIN_2, !relayState);
}
BLYNK_WRITE(V12) {
  int relayState = param.asInt(); // Assigning incoming value from pin V12 to a variable
  digitalWrite(RELAY_PIN_3, !relayState);
}
BLYNK_WRITE(V13) {
  int relayState = param.asInt(); // Assigning incoming value from pin V13 to a variable
  digitalWrite(RELAY_PIN_4, !relayState);
}
```

5. Proposed System

The proposed IoT-based energy monitoring system offers a scalable, cost-effective, and user-friendly solution for monitoring and optimizing energy consumption. By leveraging the ESP32 microcontroller and cloud-based processing, the system provides real-time insights into energy usage, empowering users to make informed decisions and promote energy efficiency in both residential and industrial settings. Key features of the proposed Energy monitoring system include:

1. Wireless Connectivity: Wireless connectivity plays a crucial role in IoT-based energy monitoring systems, enabling seamless communication between energy sensors, microcontrollers, and cloud platforms. The ESP32 microcontroller, renowned for its integrated Wi-Fi and Bluetooth capabilities, offers a flexible and cost-effective solution for connecting energy monitoring devices to the internet and other wireless peripherals.

2. Integrated Sensor Network: The system will incorporate a network of sensors, including current sensors, temperature sensors, and other relevant sensors, deployed strategically throughout the environment (e.g., homes, offices, industrial facilities). These sensors will continuously monitor energy consumption patterns, environmental conditions, and equipment performance in real-time.

3. Data Acquisition and Processing: The data collected by the sensors will be transmitted wirelessly to a central processing unit, using microcontroller ESP32. The processing unit will analyze the incoming data to identify energy usage trends, potential inefficiencies, and anomalies.

4. User Interface: The system will feature a user-friendly interface accessible via web or mobile applications. Users will be able to view real-time energy consumption metrics, and actionable insights regarding energy usage. The interface will provide intuitive controls for managing devices and appliances remotely.

5. Energy Consumption Alerts and Recommendations: Based on the analyzed data, the system will generate alerts and recommendations to users regarding energy consumption patterns. For example, if an appliance is identified as consuming excessive energy or exhibiting abnormal behavior, the system will notify the user and suggest corrective actions to optimize energy usage.

6. Integration with Smart Grids and Renewable Energy Sources: The system will support integration with renewable energy sources. By leveraging real-time data and predictive analytics, the EMS can optimize energy usage, storage, and distribution, while maximizing the utilization of renewable energy resources.

7. Scalability and Customization: The proposed system will be scalable and adaptable to different environments and requirements. It will support the integration of additional sensors, devices, and functionalities as needed, allowing for customization to specific use cases and user preferences.

8. Performance Evaluation and Optimization: The system will continuously monitor its own performance and effectiveness in optimizing energy consumption. Performance evaluation metrics will be defined to assess the system's impact on energy efficiency, cost savings, and environmental sustainability. Any identified areas for improvement will be addressed through iterative optimization processes

6. Results

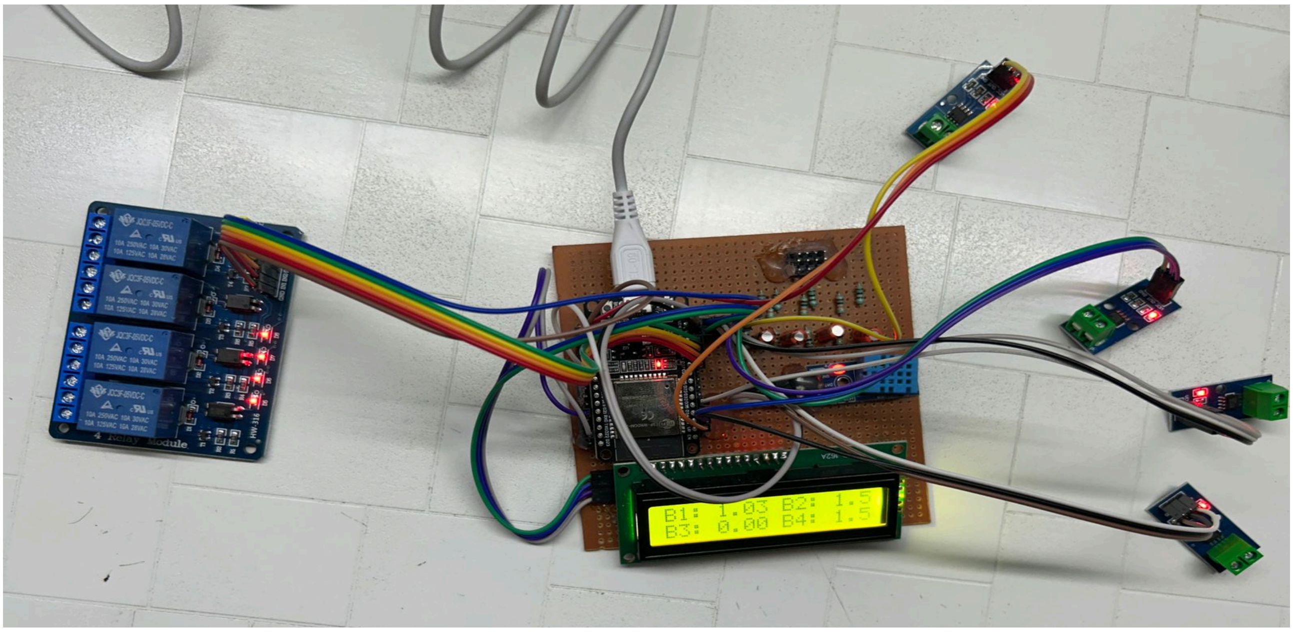

Fig 6.1 Integration of circuit

Fig 6.2 Connecting to Blynk Application

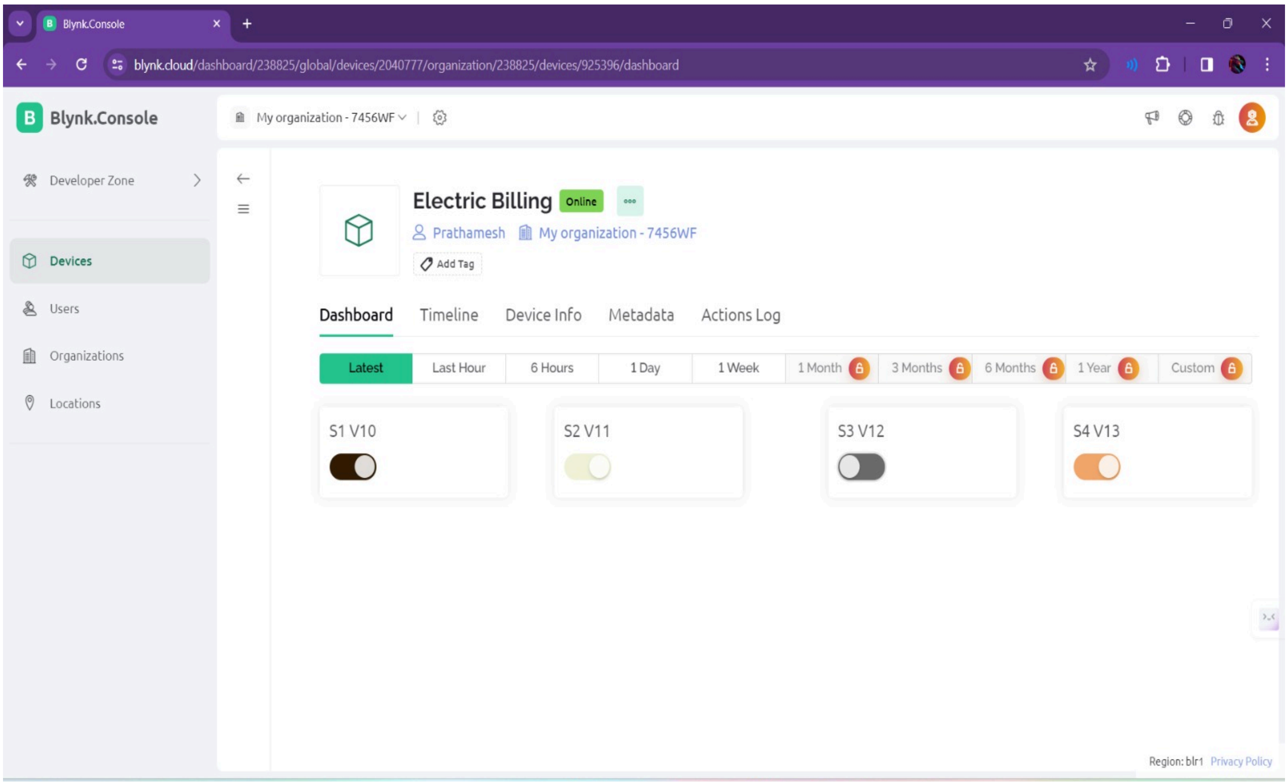

Fig 6.3 Result Interface

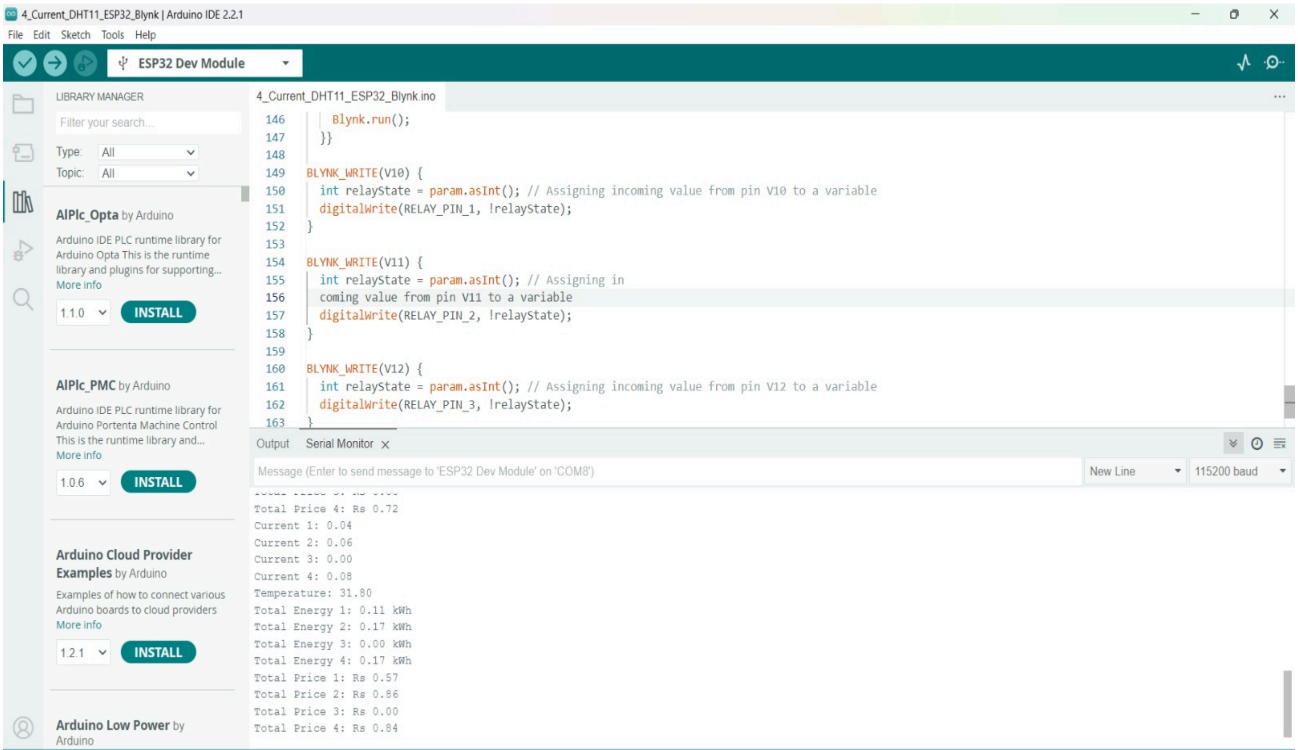

Fig 6.4 ESP32 and Blynk Application Integration

1. Energy Consumption Monitoring:
The Energy Monitoring System (EMS) successfully monitors energy consumption in real time using various sensors such as current sensors and temperature sensors. The system collects data on the energy usage of different appliances and devices.

2. Data Collection and Analysis:
The EMS collects data on energy usage patterns over time, allowing users to identify trends and anomalies in energy consumption. By analyzing the data, users can gain insights into which appliances consume the most energy and when energy usage peaks occur.

3. Cost Savings:
By optimizing energy consumption, the EMS helps users reduce their energy bills and save money in the long run. Users can track their energy usage and costs through the system's interface, allowing them to make informed decisions about their energy consumption habits.

4. Environmental Impact:
The implementation of the EMS leads to a reduction in energy waste and carbon emissions, contributing to environmental conservation efforts. By promoting energy efficiency and sustainability, the system aligns with global goals for reducing greenhouse gas emissions and combating climate change.

7. Conclusion

The implementation of the Energy Monitoring System (EMS) marks a significant milestone in the endeavor to optimize energy consumption and promote sustainability in various sectors. Through meticulous design, development, and deployment, the EMS has demonstrated its potential to revolutionize how energy is managed and utilized across industrial, commercial, and residential settings.

The project's objectives were meticulously pursued, resulting in the successful creation of a comprehensive system capable of real-time energy monitoring, data analysis, and optimization. Leveraging technologies such as current sensors, temperature sensors, relays, and the ESP32 microcontroller, the EMS offers a robust platform for users to track, analyze, and manage their energy consumption effectively.

One of the most noteworthy achievements of the project is its contribution to energy efficiency and cost savings. By providing users with insights into their energy usage patterns and offering recommendations for optimization, the EMS empowers individuals and organizations to make informed decisions that lead to reduced energy waste and lower utility bills. Furthermore, the system's integration of IoT capabilities enables remote monitoring and control, enhancing convenience and accessibility for users.

Moreover, the EMS plays a vital role in advancing environmental sustainability objectives. By promoting energy conservation and reducing carbon emissions. The project underscores the importance of adopting innovative solutions like the EMS to address pressing environmental challenges and build a more sustainable future.

8. Future scope

The Energy Monitoring System project lays a strong foundation for future developments and enhancements in the field of energy management. Here are some potential avenues for future scope:

- **Integration with Smart Grids:**
  Future iterations of the EMS could explore deeper integration with smart grid infrastructure. By leveraging bidirectional communication capabilities, the EMS can interact with smart meters, utility providers, and renewable energy sources more efficiently. This integration enables dynamic demand-response strategies, load balancing, and seamless integration of renewable energy into the grid.

- **User Interface Enhancements:**
  Improving the user interface of the EMS can enhance usability and accessibility for a broader range of users. Intuitive dashboards, customizable reports, and mobile applications can provide users with real-time insights into their energy consumption, allowing them to make informed decisions and adjustments on the go.

- **Energy Storage Integration:**
  Integrating energy storage solutions, such as batteries or capacitors, into the EMS can enhance its capabilities for demand-side management and peak shaving. By storing excess energy during periods of low demand and discharging it during peak hours, energy storage systems can help optimize energy usage and reduce reliance on the grid.

- **Collaboration with Energy Service Companies (ESCOs):**
  Collaborating with ESCOs can facilitate the deployment of EMS solutions on a larger scale and unlock new business models. ESCOs can offer energy management services as part of their portfolio, providing customers with turnkey solutions for energy optimization and efficiency improvement.

By pursuing these future avenues, the Energy Monitoring System can evolve into a sophisticated and comprehensive platform for energy management, offering unparalleled benefits in terms of efficiency, sustainability, and cost savings.

References

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9. Achievements

Industry Project Collaboration: Energy Monitoring System

Nimbus Technology offered the opportunity for students from Lokmanya Tilak College of Engineering to undertake a B.E. project titled "ENERGY MONITORING SYSTEM USING ESP32"to enhance their technology and personal skills for the industry. the project involves weekly reporting to the company's designated supervisor. The students involved in the project are Rohankumar Barouliya, Prathamesh Chavan, Rishiraj Bagul, and Harsh Jadhav from the Electronics and Telecommunication Department.

Fig 9.1 Presentation given at Nimbus Technologies

Nimbus TECHNOLOGIES

DATE: 22.08.2023

To Whomever It May Be Concern

To,
Head of Department- Electronics & Telecommunication,
Lokmanya Tilak College of Engineering,
Koparkhairne, Navi-Mumbai.

Dear Sir,

This is to inform you that following students are permitted to do their B.E. project titled "Energy Monitoring System using Esp-32 WROOM module" for communication & implementation in our esteemed company

Students:
1) Rohankumar Barouliya
2) Rishiraj Bagul
3) Prathamesh Chavan
4) Harsh Jadhav

Nimbus Technologies.

NIMBUS TECHNOLOGIES DOMBIVALI

Authorised Signatory

Unit No. 225, 2nd Floor, Globe Estate, Plot No.C-9, MIDC Industrial Area, Phase-I, New Kalyan Road, Khambalpada, Dombivali East - 421203, Dist. Thane, Maharashtra, India. Tel : +91 251 2973892, 2973893 Tel. Fax : +91 251 297892
Email : sales@nimbus-technologies.com, nimbustech@dataone.in web: nimbus-technologies.com

Fig 9.2 Letter from Nimbus Technologies