**1. Project Overview**

* **Objective**: This project aims to design an energy monitoring system using IoT technology to help users track their household energy consumption for individual appliances via a mobile application. By setting thresholds, users receive alerts if usage exceeds preset levels, helping them manage and reduce unnecessary power consumption.
* **Key Components**:
  + **ESP32 Microcontroller**: Acts as the core controller, processing data from sensors and transmitting it to the mobile app.
  + **CT Sensor (SCT-013-020)**: Measures the current flowing through appliances.
  + **Voltage Sensor (ZMPT101B)**: Monitors voltage to calculate power consumption.
  + **Mobile Application (Blynk)**: Displays real-time energy data and allows users to control and manage their energy usage directly from their smartphones.

**2. Introduction and Background**

* **Context**: Increasing dependency on electronic devices has led to higher residential energy consumption. The paper highlights India’s position as the third-largest consumer of energy globally and emphasizes the need to mitigate energy wastage at the household level.
* **Problem Statement**: Current energy grids typically only allow one-way energy flow from the station to homes, making it difficult to track specific appliance usage. The emergence of IoT enables two-way communication and the ability to monitor energy on-demand, empowering consumers to optimize usage.
* **Proposed Solution**: Implementing an IoT-based smart energy monitoring system allows consumers to monitor and control energy usage for individual appliances, thereby supporting energy conservation at the household level.

**3. Literature Review**

* **Prior Work**:
  + Various studies demonstrate the effectiveness of IoT-based energy monitoring systems that integrate mobile applications to control and track appliance usage.
  + Examples include systems using Arduino controllers, XBee technology, big data analytics, and cloud integration to monitor or predict energy consumption.
  + **Highlighted Studies**:
    - Systems designed with machine learning predict future energy consumption, offering actionable insights.
    - Energy management systems with clustering techniques reduce the number of internet connections and bandwidth consumption.

**4. System Design**

* **Circuit Design and Components**:
  + **ESP32 Board**: Facilitates processing and communication between the sensors and the mobile application.
  + **CT Sensor (SCT-013-020)**: This current transformer sensor detects the magnetic field produced by electric current, measuring current flow accurately using electromagnetic induction.
  + **Voltage Sensor (ZMPT101B)**: Protects the circuit from voltage fluctuations, providing a maximum voltage withstand of up to 250V.
  + **LCD Display**: Shows real-time readings, including voltage, current, and power data.
  + **Other Components**: The circuit includes a Hi-Link 5V supply, resistors, capacitors, and other essential hardware for stable operation.

**5. Mobile Application Setup (Blynk App)**

* **Blynk Configuration**:
  + Users create an account and receive an authentication token for project setup.
  + The ESP32 board is selected as the hardware, and widgets are added through a drag-and-drop interface to customize monitoring and control features.
* **Features**:
  + The Blynk app sends an alert when energy consumption exceeds a set threshold.
  + Users can view energy consumption data, configure new threshold limits, and reset limits if needed.
* **User Interaction**: By leveraging the app, users can remotely monitor, schedule, or stop appliance usage based on energy data.

**6. Methodology**

* **Circuit Setup**:
  + The ESP32 microcontroller is programmed and connected to the CT and voltage sensors to gather data on current and voltage.
  + The sensors are calibrated using the Emon energy monitoring library to ensure accurate readings.
  + Power calculations are conducted in real time and displayed on the LCD and mobile application, with data uploaded to the Blynk app every 5 seconds.
* **Data Calculations**:
  + Using Emon functions, the system calculates real and apparent power, root mean square (RMS) voltage (Vrms), RMS current (Irms), and power factor.
  + **Power (kWh) Calculation**:
    - The accumulated power consumption is updated in kWh based on the equation: 
  + Results are sent to the GPIO pins on the ESP32, with LCD display showing voltage (Vrms) and current (Irms) values.

**7. Results and Observations**

* **Data Monitoring**:
  + Real-time data on energy usage is displayed on the Blynk app, Arduino serial monitor, and LCD display. Discrepancies between any of these displays indicate a need to troubleshoot circuit connections.
* **Appliance Power Consumption**:
  + Tests conducted on common appliances (fan, light, AC) reveal different power consumption rates based on usage and environmental factors:
    - **Fan**: Consumes moderate power, as it often runs for extended periods.
    - **Light**: Lower power usage, mainly used at night.
    - **AC**: Highest power consumption, indicating potential for significant savings with efficient usage.
* **Data Tabulation**: Power consumption data is organized in a table format, displaying date, timestamp, Vrms, Irms, and calculated power (W) for each appliance.
* **Graphical Analysis**:
  + A plot of power consumption against appliance type indicates a high energy demand for the AC, followed by moderate usage for fans and minimal use for lights. This highlights the AC as a primary target for energy conservation efforts.

**8. Conclusion and Future Scope**

* **Project Impact**:
  + This model provides a low-cost solution for energy monitoring and management, affordable for middle-class households. By monitoring individual appliances, users can make immediate adjustments to their energy usage, potentially lowering monthly electricity bills.
* **Future Enhancements**:
  + Expanding the system to support more appliances, including additional high-power devices.
  + Developing advanced analytics within the Blynk app to identify trends, anomalies, and provide energy-saving recommendations.
  + Integrating predictive analytics for energy consumption forecasting to help users budget for upcoming bills.
  + Leveraging machine learning to optimize appliance usage schedules based on peak and off-peak hours.