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IOT BASED ENERGY MANAGEMENT SYSTEM USING MICROCONTROLLER

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ABSTRACT- Effective monitoring and control systems are desperately needed due to the sharp increase in energy use. This project offers a microcontroller-based Internet of Things (IoT) energy management system that allows for real-time monitoring, analysis, and control of electrical energy consumption. Power metrics including voltage, current, and power consumption are measured by the system using smart sensors, processed by a microcontroller, and sent to the cloud via an Internet of Things platform. Users can monitor energy data remotely via a web or mobile application, allowing intelligent decision-making and load management. Automated control mechanisms can switch off unused appliances, thereby reducing wastage and improving overall energy efficiency. This approach promotes sustainable energy usage, cost savings, and supports the development of smart homes and smart grids for the future.
Keywords: IoT, Energy Management System, Microcontroller, Smart Energy Monitoring, Energy Efficiency, Automation

I. INTRODUCTION

The IoT-Based Energy Management System using a Microcontroller is designed to provide a smart and automated approach for managing electrical power usage. This system utilizes a microcontroller (such as Arduino Uno or ESP32) as the main control unit to collect

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data from sensors that measure voltage, current, and power consumption in real time. The gathered data is transmitted via the internet to a cloud platform, allowing users to remotely monitor and control their electrical appliances through a mobile app or a web interface Global energy demand has significantly increased as a result of ongoing industrialization, urbanization, and technological advancement. As a result, both the home and industrial sectors now face significant problems in the efficient use and conservation of electrical energy.

Traditional energy monitoring techniques are predominantly manual, time-consuming, and often ineffective in optimizing power usage. To overcome these limitations, modern research and development have focused on integrating intelligent control and communication technologies into energy systems. The Internet of Things (IoT) has emerged as a transformative technology capable of enabling real-time monitoring, analysis, and control of electrical systems through interconnected smart devices. IoT-based systems facilitate the automation of energy management by allowing continuous data acquisition from distributed sensors and controlling electrical loads through cloud-based or mobile interfaces. Such systems contribute to enhanced operational efficiency, reduced energy wastage, and lower electricity costs.

The primary objective of this system is to achieve real-time energy monitoring and automated load management. The system is designed to detect excessive energy usage, generate alerts, and automatically disconnect high-consumption appliances when necessary. Furthermore, the IoT integration enables the analysis of long-term energy consumption patterns, load forecasting, and scheduling operations to improve energy efficiency. The proposed system can also be extended to include renewable energy sources such as solar panels, promoting sustainable and eco-friendly power management practices. The implementation of the proposed IoT-based energy management system demonstrates the potential for smart energy utilization in domestic and industrial applications. By adopting such intelligent systems, users can contribute to reducing overall energy demand and support global initiatives toward sustainability and environmental conservation.

II. LITERATURE REVIEW

1. The system employs an ACS712 current sensor and an ESP8266 Wi-Fi module to measure and transmit real-time current and power data to a Firebase cloud database. A web-based graphical user interface (GUI) provides remote control of electrical lines in various rooms, promoting efficient energy utilization and reducing operational costs. The study achieved a current sensing accuracy of ±1.5%, demonstrating reliable system performance. However, voltage sensing was not included, which limits the precision of total power measurement. The authors suggest that integrating voltage measurement in future versions could enhance accuracy and scalability. From the literature, it is evident that this study successfully demonstrates real-time cloud-based monitoring, though its application scope remains confined to controlled institutional settings.

2. For data collection, transmission, and real-time monitoring, the suggested system makes use of a Node MCU microcontroller coupled with a Wi-Fi module. Home appliances can be controlled remotely by users, and a distant server receives periodic updates on energy consumption data and associated expenses.The study further introduces the concept of sub-metering for high-power appliances to achieve detailed consumption tracking. The system enhances data transparency and enables efficient load management, encouraging energy conservation. Compared to conventional metering systems, which lacked real-time data communication and user interactivity, this IoT-based design demonstrates greater flexibility, scalability, and automation potential for residential applications.

3. The system allows users to monitor and control household electrical loads through SMS-based communication. By employing a microcontroller interfaced with GSM modules and relays, the design enables automated load scheduling based on user-defined time intervals. This approach reduces power wastage by turning off appliances during idle periods and redistributing loads during peak hours. Although this system is an improvement over the manually run GSM models put out by previous researchers like Patil et al. and Rani et al., it still has limited scalability and is not capable of automated optimization or real-time cloud connectivity. These drawbacks highlight the necessity of incorporating IoT technologies to improve automation, adaptive control, and communication.

4. Presents a GSM-based remote energy management model suitable for domestic and small industrial setups. The system utilizes an ATmega8 microcontroller, SIM900 GSM modem, and relay-based switching to control appliances through SMS or missed calls. It also introduces a user-programmable contact registration feature to ensure authorized access to control functions. Although the system provides low-cost and secure remote operation, it is primarily limited to manual communication without real-time data acquisition, automation, or cloud integration. Therefore, while effective for small-scale use, it lacks the intelligence and adaptability required for modern large-scale energy management applications.

III. PROBLEM STATEMENT

In today's world, increasing electricity consumption and wastage of energy have become major concerns in homes and industries. Most users are unaware of how much power their appliances consume, leading to higher electricity bills and inefficient energy use. Traditional energy meters only provide total consumption data but do not offer real-time monitoring or remote control of devices. A smart system that can continually track, evaluate, and regulate energy consumption from any location is required. By utilizing Internet of Things (IOT) technology to provide real-time monitoring, data analysis, and remote management of electrical loads, the IOT-Based Energy Management System seeks to address this issue. Users may maximize power consumption, avoid energy waste, and encourage effective energy management with the aid of this system.

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IV. OBJECTIVE

1. To monitor real-time power consumption of electrical appliances.
2. To reduce energy wastage through smart control and monitoring.
3. To provide remote access for turning appliances ON or OFF using a mobile app.
4. To calculate and display voltage, current, and total energy usage accurately.
5. To store and analyze energy data for efficient management.

V. METHODOLOGY

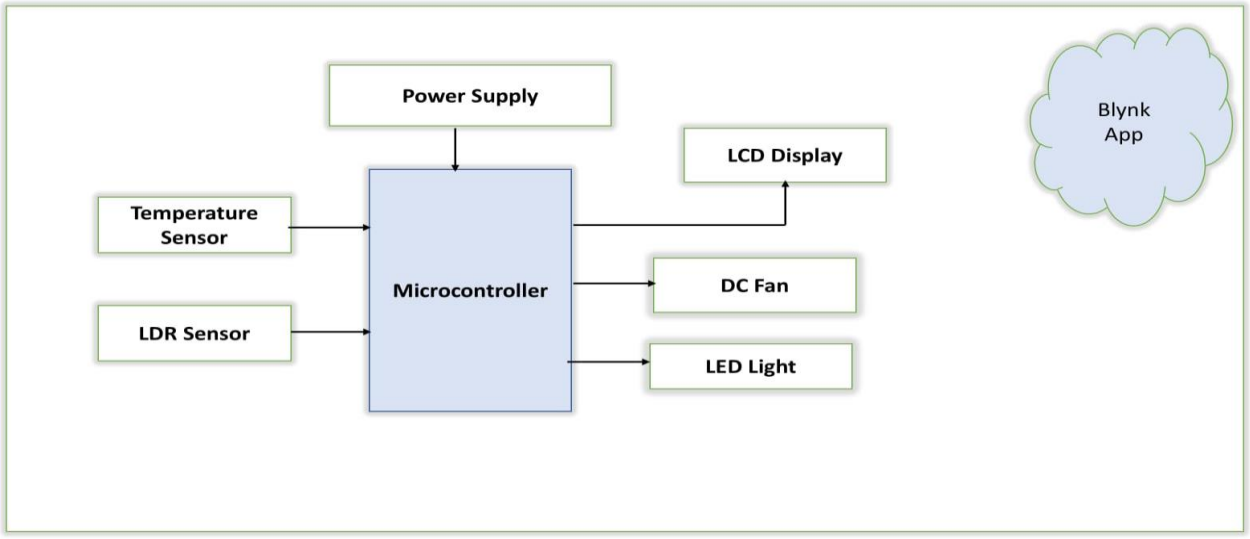


Fig1- Block Diagram

1. Power Supply

Provides the necessary voltage and current to the entire system. Converts AC mains voltage (230V/110V) to low DC voltage (usually 5V or 12V) suitable for the microcontroller, sensors, and actuators. Ensures stable operation of all components, preventing damage from voltage fluctuations.

2. Temperature Sensor (e.g., LM35, DHT11, DHT22)

Measures the ambient temperature in the environment or near a device. Sends temperature data to the microcontroller for processing. In energy management, it can help:

Turn ON/OFF fans, air conditioners, or heaters automatically. Monitor device overheating and prevent energy wastage. Send alerts to the user via the IOT app if temperature exceeds limits.

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3. **LDR Sensor (Light Dependent Resistor)**

Detects the intensity of ambient light. Outputs an analog signal to the microcontroller proportional to the light level. In energy management, it is used to:
Automatically switch LED lights ON/OFF based on natural light availability.
Reduce electricity usage during daylight. Implement smart lighting in homes or offices.

4. **LCD Display (16x2 or 20x4)**

Provides a local visual display of system data such as: Voltage, current, and power consumption of devices. Temperature readings from the sensor. Status of appliances (ON/OFF). Helps users monitor energy usage without using the mobile app. Can display real-time alerts for abnormal conditions.

5. **DC Fan**

Acts as a controllable load in the system for testing energy consumption. Can be turned ON/OFF automatically based on temperature readings or user commands from the IOT app. Demonstrates load control and automation features of the system.

6. **LED Light**

Serves as another controllable load. Can be switched automatically based on LDR sensor readings (ambient light) or manually via the app. Helps reduce electricity consumption by turning lights OFF when not needed.

7. **Microcontroller (Node MCU)**

Acts as the brain of the system. Collects data from sensors (temperature sensor, LDR, voltage/current sensors). Processes the data to calculate power consumption, detect thresholds, and control loads. Sends real-time data to the IOT platform (Blynk app) using built-in Wi-Fi. Receives commands from the app to switch devices ON/OFF remotely.

8. **Blynk App (IOT Platform)**

Cloud-based application for monitoring and controlling devices. Receives data from the microcontroller and displays it on smartphones. Allows users to: Monitor voltage, current, power, temperature, and light levels. Turn appliances like fans or lights ON/OFF remotely.

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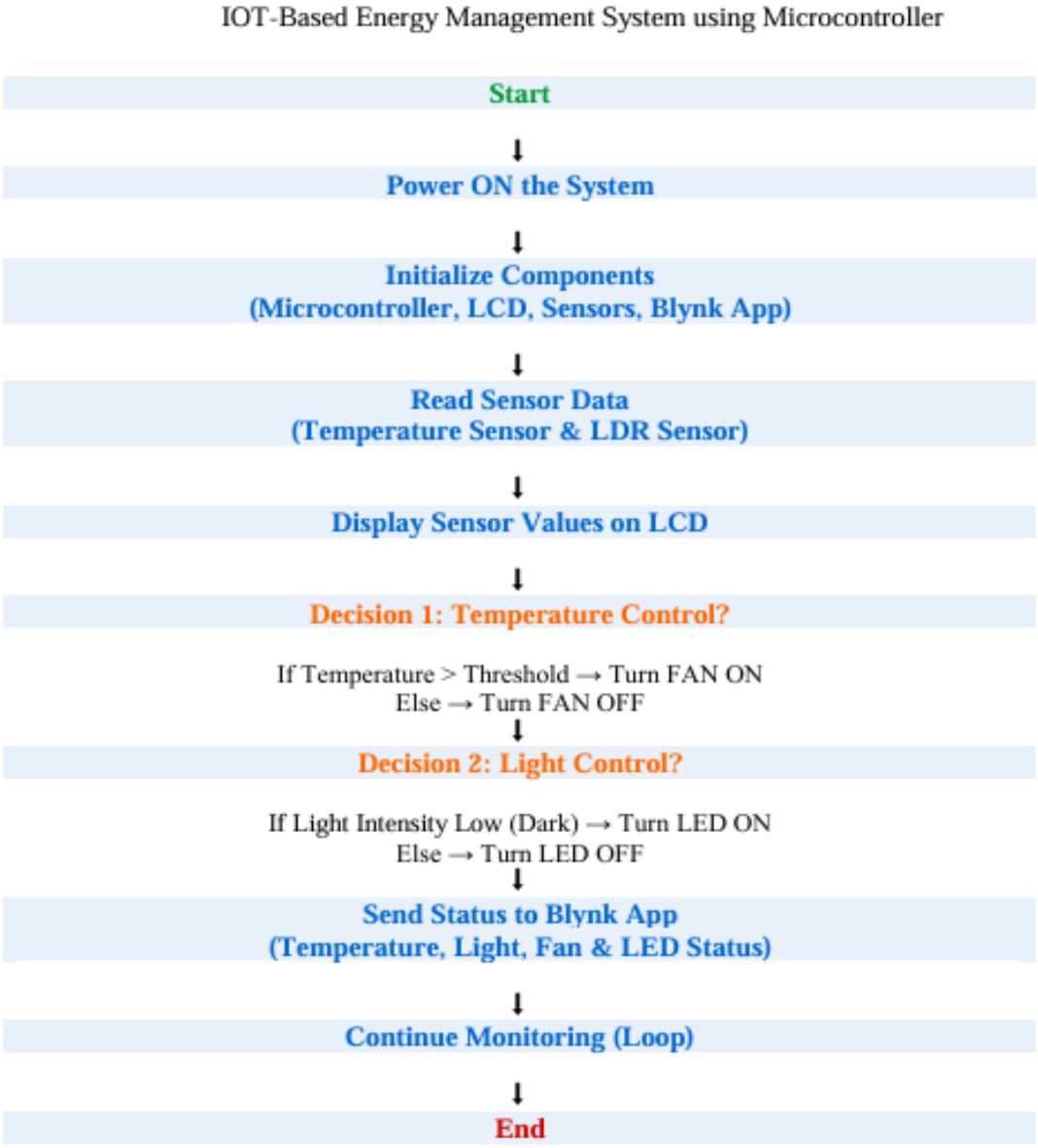


Fig.2- Flow Chart of Methodology

By incorporating AI-based analytics and machine learning algorithms to forecast energy consumption trends and automatically optimize power distribution, the suggested system can be further improved. For sustainable energy management, the system can be extended to incorporate renewable energy sources like solar panels. Future versions can feature mobile app integration with voice control or smart assistant compatibility (like Alexa or Google Home) for easier user interaction. Additionally, the use of advanced sensors and high-performance microcontrollers can improve accuracy, speed, and scalability, enabling the system to be implemented in smart homes, large buildings, and industrial environment.

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VI. CONCLUSION

This project successfully demonstrates the design and implementation of a Battery Management System (BMS) for Electric Vehicles with integrated charge monitoring and fire protection features. The system, based on the ESP32 microcontroller, continuously monitors key battery parameters including state of charge (SoC), current, and temperature. Accurate SoC estimation using the Coulomb Counting approach is made possible by real-time data capture, guaranteeing dependable energy tracking. Under constant load circumstances, simulated discharge curves demonstrate a continuous decline in SoC while current readings are within allowable operating bounds.