A Project Report

On

"Smart Energy Monitoring System – Hybrid IoT + Software Visualisation"

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Abstract
The project aims to design and implement a smart energy monitoring system leveraging IoT devices integrated with a software dashboard. The system provides real-time monitoring of energy consumption, historical data analysis, alerts for abnormal usage, and cost estimation. Utilising ESP32 microcontrollers with current and voltage sensors, data is transmitted to a cloud platform. The interactive dashboard allows users to visualise energy trends, helping reduce wastage and enhance efficiency.

Acknowledgements
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Introduction
With increasing energy demands and costs, monitoring and optimising energy consumption have become vital. Smart energy monitoring systems provide real-time insights into power usage, enabling informed decisions and promoting sustainable practices. IoT technology plays a crucial role by facilitating automated, remote monitoring and analysis of energy data.

Literature Review
Energy monitoring has seen significant advancement with IoT integration. Previous studies have implemented smart meters, cloud-based monitoring solutions, and mobile applications for tracking energy usage. IoT-enabled devices provide accurate, real-time data, facilitating efficient energy management in residential and commercial settings.

Problem Statement
Manual energy tracking is inefficient and error-prone, leading to wastage and higher costs. The absence of real-time monitoring prevents timely interventions, making it challenging to optimise energy consumption effectively.

Objectives
- Monitor energy consumption in real-time
- Visualise energy data using an interactive dashboard
- Generate alerts for abnormal consumption

- Recommend energy-saving measures

Methodology

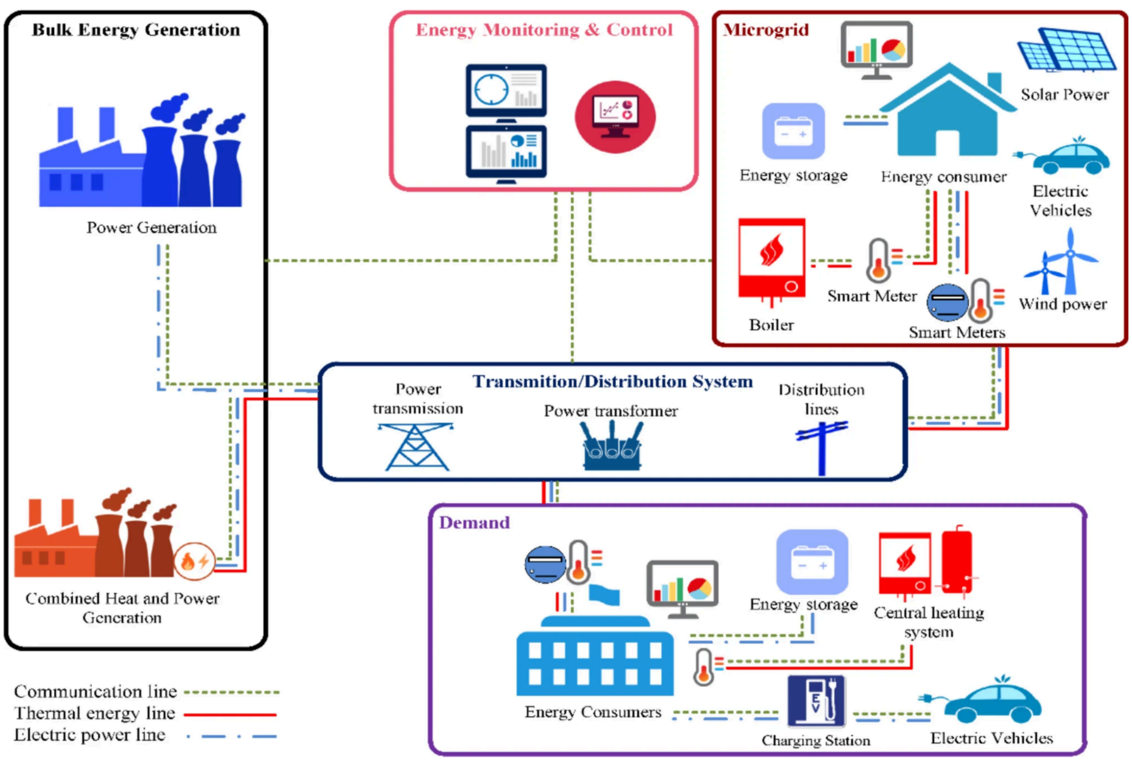
Hardware Setup:

ESP32 microcontroller connected to ACS712 current sensors and voltage sensors. Data is transmitted over WiFi to a cloud database.

Software Architecture:

Data collection via MQTT/HTTP, storage in Firebase/MySQL, and visualisation through a web dashboard built with React and Chart.js.

Block Diagram:



Implementation

Hardware Components:

- ESP32 microcontroller
- ACS712 current sensor
- Voltage sensor
- Power supply module

Software Components:

- Protocols: MQTT/HTTP
- Database: Firebase/MySQL
- Dashboard: React + Chart.js

Sample Code Snippet Placeholder: [Insert concise, functional code snippet]

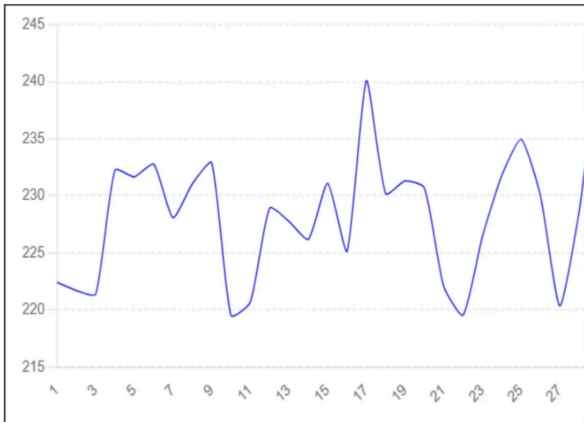
```
#include <WiFi.h>
#include <HTTPClient.h>

const char* ssid = "YOUR_SSID";
const char* password = "YOUR_PASSWORD";
const char* firebaseURL = "https://your-project.firebaseio.com/energy.json";

const int currentPin = 34; // ACS712 sensor analog pin
const int voltagePin = 35; // Voltage sensor analog pin

void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("\nWiFi connected");
}

float readCurrent() {
  int sensorValue = analogRead(currentPin);
  float current = (sensorValue - 2048) * 5.0 / 1024.0; // Adjust based on calibration
  return current;
}

float readVoltage() {
  int sensorValue = analogRead(voltagePin);
  float voltage = sensorValue * (230.0 / 4095.0); // Adjust based on voltage divider
  return voltage;
}
```

```
void loop() {
  if(WiFi.status() == WL_CONNECTED) {
    float current = readCurrent();
    float voltage = readVoltage();
    float power = voltage * current;

    String payload = "{\"current\":" + String(current) +
                     ",\"voltage\":" + String(voltage) +
                     ",\"power\":" + String(power) + "}";

    HTTPClient http;
    http.begin(firebaseURL);
    http.addHeader("Content-Type", "application/json");
    int httpResponseCode = http.POST(payload);

    Serial.println("Data sent to Firebase, response code: " + String(httpResponseCode));

    http.end();
  }

  delay(5000); // send data every 5 seconds
}
```

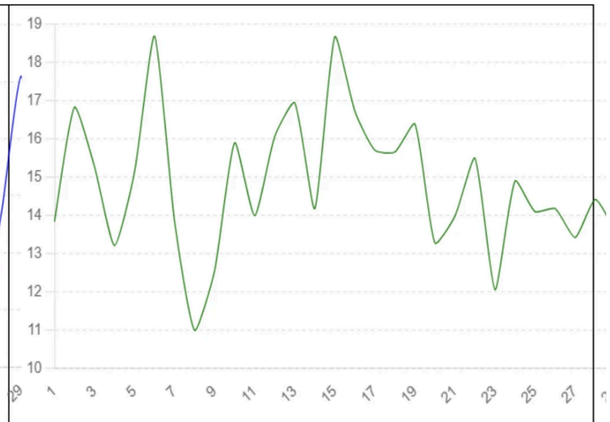
Results & Analysis

- **Energy consumption patterns**
- **Peak usage days**
- **Cost estimation and analysis**

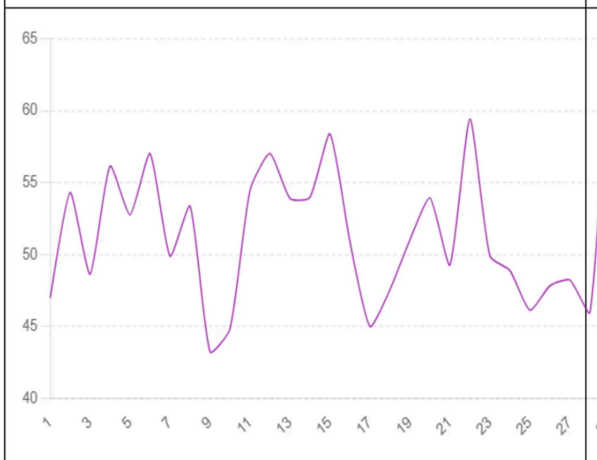
From: A secure smart monitoring network for hybrid energy systems using IoT, AI



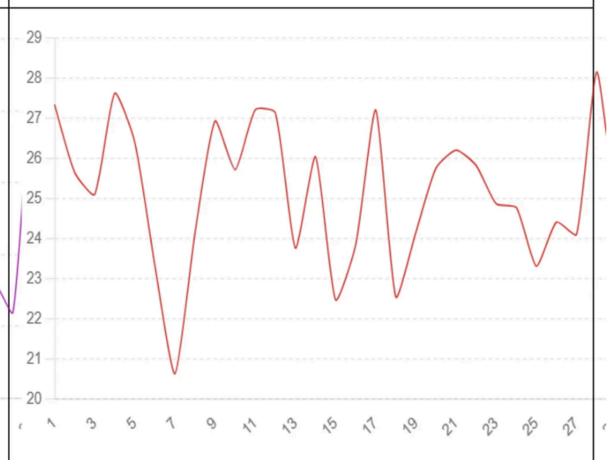
(a). Voltage over 30 Days



(b). Current over 30 Days



(c). Energy Output over 30 Days



(d). Temperature over 30 Days

Applications & Advantages

- Residential and commercial energy monitoring
- Integration with smart homes
- Provides actionable insights for reducing energy wastage
- Real-time alerts and historical data analysis

Limitations & Future Scope

- A limited number of sensors restricts coverage
- Dependent on stable internet connectivity
- Future enhancements: AI-based energy prediction and automation

Conclusion

The project demonstrates a feasible and practical hybrid IoT-based energy monitoring system. Real-time tracking, data visualisation, and actionable insights enable energy efficiency, cost savings, and better energy management.

References

- IEEE Journals on IoT and Energy Management

- Google Scholar articles on Smart Energy Monitoring Systems

- Textbooks and online resources on IoT applications

Industrial IoT-Based Energy Monitoring System: Using Data Processing at the Edge

- Reference: Asemani, M., Abdollahei, F., & Jabbari, F. (2024). Industrial IoT-based energy monitoring system: Using data processing at the edge. *MDPI IoT*, 5(4), 27. https://doi.org/10.3390/iot5040027

- Summary: This paper discusses an industrial energy monitoring system that utilises edge computing for data processing. It highlights the integration of wired and wireless energy meters with edge instances, offering insights into software implementation and user interfaces for energy monitoring.

A Low-Cost Energy Monitoring System with Universal Compatibility and Real-Time Visualisation

- Reference: Ngo, G.C., Floriza, J.K.I., Creayla, C.M.C., Garcia, F.C.C., & Macabebe, E.Q.B. (2015). A low-cost energy monitoring system with universal compatibility and real-time visualisation. In *Proceedings of the TENCON 2015—2015 IEEE Region 10 Conference*, Macao, China, 1–4 November 2015; pp. 1–4. https://doi.org/10.1109/TENCON.2015.7372813

- Summary: The authors present a low-cost energy monitoring system that ensures universal compatibility and provides real-time visualisation. The paper outlines the system's architecture and its application in grid-tied photovoltaic installations.

IoT Energy Management & Monitoring with ThingsBoard

- Reference: ThingsBoard. (n.d.). IoT energy management & monitoring with ThingsBoard. Retrieved from https://thingsboard.io/use-cases/smart-energy/

- Summary: This resource from ThingsBoard outlines an IoT-based energy monitoring solution that leverages the ThingsBoard platform. It discusses the integration of smart meters, data collection protocols, and real-time dashboard visualisations for energy management.

Optimising IoT Energy Efficiency: Real-Time Adaptive Algorithms for Smart Meters with LoRaWAN and NB-IoT

- Reference: Author(s). (2025). Optimising IoT energy efficiency: Real-time adaptive algorithms for smart meters with LoRaWAN and NB-IoT. *MDPI Energies*, 18(4), 987. https://doi.org/10.3390/en18040987

- Summary: This paper proposes algorithms for optimising energy consumption in smart meters using IoT technologies like LoRaWAN and NB-IoT. It emphasises real-time data processing and adaptive transmission to enhance energy efficiency.

Design and Development of an IoT Smart Meter with Load Control for Home Energy Management Systems

- **Reference**: Author(s). (2022). Design and development of an IoT smart meter with load control for home energy management systems. *MDPI Sensors*, 22(19), 7536. https://doi.org/10.3390/s22197536

- **Summary**: The paper details the design and development of an IoT-based smart meter equipped with load control features for home energy management. It includes discussions on the system's architecture and user interface for monitoring energy consumption.

Design and Implementation of a Cloud-IoT-Based Home Energy Management System

- **Reference**: Author(s). (2023). Design and implementation of a cloud-IoT-based home energy management system. *MDPI Sensors*, 23(1), 176. https://doi.org/10.3390/s23010176

- **Summary**: This research focuses on the design and implementation of a cloud-IoT-based home energy management system. It explores the integration of cloud computing with

IoT devices for efficient energy management in residential settings.

Smart Energy Management System: Design of a Monitoring and Peak Load Forecasting System for an Experimental Open-Pit Mine

- **Reference**: Author(s). (2022). Smart energy management system: Design of a monitoring and peak load forecasting system for an experimental open-pit mine. *MDPI Applied Systems Innovation*, 5(1), 18. https://doi.org/10.3390/asi5010018

- **Summary**: The paper presents a smart energy management system designed for an experimental open-pit mine. It includes the design of monitoring systems and peak load forecasting to optimise energy consumption in mining operations.

Energy Management System in Smart Buildings Based on Coalition Game Theory with Fog Platform and Smart Meter Infrastructure

- **Reference**: Author(s). (2023). Energy management system in smart buildings based on coalition game theory with fog platform and smart meter infrastructure. *Scientific Reports*, 13, 29209. https://doi.org/10.1038/s41598-023-29209-4

- **Summary**: This study explores an energy management system for smart buildings that utilises coalition game theory, fog computing, and smart meter infrastructure. It aims to optimise energy distribution and consumption within smart building environments.