Internet of Things Fundamentals

Subject Project

BS AI 6th Smester SP-25 (AIE-3079)

Date:

Project Title: Smart Energy Monitoring System

Group Name/no.: IOTRIX

Team Members:

Members	Registration no	Name	Signature
Member-1 (Leader)	**22-NTU-CS-1361**	**M Hasham Ul Haq**	
Member-2	**22-NTU-CS-1337**	**Abdul Wahab**	
Member-3	**22-NTU-CS-1335**	**Abdul Qayoum**	
Member-4			

Contributions in % of each Team Members for each component					
		Member-1	Member-2	Member-3	Member-4
Distribution Components		Name	Name	Name	Name
Coding	ESP32-coding	40%	35%	25%	
	Python Coding				
UI Design		15%	15%	70%	
Database		35%	40%	25%	
Cloud Integration		33.33%	33.33%	33.33%	
IoT Gateway					
Edge Processing		33.33%	33.33%	33.33%	
Documentation		50%	25%	25%	
Presentation Design		5%	80%	15%	
Replace for other contribution					
Replace for other contribution					
Replace for other contribution					
Replace for other contribution					

To be filled by the evaluator

Team-Based Evaluation (60 Marks)

Criteria	Obtained Marks	Out of
System Design & Architecture		10
Hardware Integration & Circuit Setup		10
IoT Gateway and Cloud Communication		10
Working Prototype Demonstration		10
Performance & Reliability Testing		10
Presentation		10
Total (Team-Based)		60

Individual-Based Evaluation (40 Marks per Member)

	Member 1	Member 2	Member 3	Member 4
Criteria				
Understanding of the Project & Role	/10	/10	/10	/10
Code Contribution and Explanation	/10	/10	/10	/10
Q/A VIVA	/10	/10	/10	/10
Documentation/Reporting & Communication	/10	/10	/10	/10
Total (Individual-Based)	/40	/40	/40	/40
Total Overall (60+40)	/100	/100	/100	/100
Weightage Lab Grade (50)				

1. Abstract / Executive Summary

This IoT-based Smart Energy Monitoring System project is designed to monitor household electricity usage in real time using ESP32, voltage and current sensors, and an OLED display. It calculates power consumption (kWh), estimates the cost of energy usage based on Pakistani tariffs, logs data to an SD card, and visualises metrics using Blynk. Time synchronisation is handled via NTP servers. This system aims to promote energy efficiency and real-time monitoring without reliance on traditional utility meters.

2. Table of Contents

3. Introduction

Background & Motivation:

Electricity usage in homes often lacks visibility until monthly bills arrive. Real-time insights can help reduce consumption and optimise usage patterns.

Problem Statement:

There is a lack of accessible, real-time energy monitoring tools for domestic users in Pakistan.

Project Goals:

- Measure real-time voltage, current, power, and energy.
- Display results on OLED and mobile (via Blynk).
- Log data to SD card for offline analysis.
- Estimate bill in PKR.

- Ensure time accuracy using NTP(Network Time Protocol).

4. Literature Review

Relevant IoT/ESP32 Concepts:

ESP32 is a low-cost, Wi-Fi-enabled microcontroller ideal for IoT applications. EmonLib helps accurately measure power parameters. Blynk is a mobile dashboard for IoT.

Similar Projects/Research:

Numerous Arduino- and ESP32-based energy meters exist, but few offer a complete stack, including SD logging, mobile visualisation, and NTP syncing.

5. Methodology / System Design

5.1 Hardware Components

- ESP32-S3
- ZMPT101B (Voltage Sensor)
- SCT-013 (Current Sensor)
- OLED 128x64 (SSD1306)
- Micro SD Card Module
- Resistors, breadboard, jumper wires, USB cable

Circuit Diagram: (Include labeled diagram in submission)

5.2 Software Design

- Arduino IDE
- Libraries:
    - EmonLib
    - Adafruit_GFX
    - Adafruit_SSD1306
    - Blynk
    - WiFi, SD, SPI, Time, SNTP
- Blynk App
- NTP Time Sync

Pseudocode:

- Initialize hardware
- Connect WiFi and Blynk
- Sync time using NTP
- Loop:
    - Read sensors
    - Calculate kWh & cost
    - Update OLED
    - Send to Blynk
    - Log to SD

6. Implementation

Step-by-step Setup:

- Connect sensors to ESP32 GPIOs
- Connect OLED to I2C pins (GPIO8 SDA, GPIO9 SCL)
- Connect SD card module (CS = GPIO10)
- Power up via USB
- Upload Arduino sketch

Code Snippets: (included in main sketch with comments)

- display.print() used for OLED
- Blynk.virtualWrite() for app
- calculateCost() implements real tariff slabs
- SD.open() logs readings to microSD

Challenges & Solutions:

- **OLED not displaying**: Fixed by correct I2C address and display.display()
- **Low Vrms readings**: Handled with voltage threshold logic
- **NTP failure**: Added timeout and fallback logic

7. Results & Discussion

Screenshots/Output:

- OLED shows V, I, P, kWh, PKR
- Blynk app reflects same in real-time
- SD card logs in CSV format

Performance Analysis:

- **Accuracy:** Acceptable within sensor limits
- **Latency:** Minimal (updates every 5 sec)
- **Reliability:** Stable with good power supply

Comparison:

Matches expectations. Accurate kWh accumulation, clean OLED and Blynk UI.

8. Testing & Validation / Limitations

Test Cases:

- Disconnected sensors → fallback to 0
- Voltage spike → correctly handled
- SD not present → shows warning on OLED

Limitations:

- Not calibrated for industrial use
- Wi-Fi dropout disrupts Blynk
- SD card may fail if not initialized properly

9. Conclusion & Future Work

Key Takeaways:

- Real-time energy monitoring is feasible using ESP32
- Multi-channel output (OLED + Blynk + SD) enhances value

Future Work:

- Add AI to predict usage
- Cloud dashboard (e.g., Firebase, AWS IoT)
- Solar input monitoring
- Overload alert notifications

10. References

- EmonLib: https://openenergymonitor.org
- SSD1306 Docs: https://learn.adafruit.com/monochrome-oled-breakouts
- NTP: https://www.pool.ntp.org
- Blynk Docs: https://docs.blynk.io

11. Links

- GitHub Repo: *https://github.com/hashhaam/IOT_LABS.git*
- Video Demo: *[Add YouTube link or QR here]*