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IOT-Enabled Smart Grid Monitoring with Dual Communication and Overload Protection

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Abstract - This research presents an IoT-based smart grid monitoring system designed to address frequent power interruptions during transmission from grid stations to consumers. The proposed architecture integrates Arduino UNO as the central controller with ESP8266 WiFi module for cloud data transmission to ThingSpeak platform and GSM module for real-time SMS alerts during overload conditions. Key sensors monitor voltage, current, temperature, humidity, and oil levels, while a relay provides automatic load disconnection above safe thresholds (voltage >230V, current >0.7A). Deployed over 7 days, the system achieved 98.2% data transmission reliability via WiFi and 100% SMS delivery success, reducing outage response time from hours to seconds. Costing under INR 4500, this solution offers scalable deployment for rural Indian grids, enhancing energy efficiency and grid stability through bidirectional communication.

Keywords: Smart Grid, IoT Monitoring, ESP8266, GSM Alerts, Overload Protection, ThingSpeak, Arduino UNO

Introduction

Traditional power grids suffer from unidirectional power flow and lack real-time monitoring, leading to frequent outages when stations transmit to consumers. Current systems fail to provide immediate alerts or automated protection against overloads, causing equipment damage and revenue loss. This paper introduces a hybrid IoT smart grid that links loads across networks using dual communication protocols to maintain uninterrupted supply.

The system uses wireless sensor networks for data visualization, overload the system uses wireless sensor networks for data visualization, overload warnings, and safety automation. By employing current transformers for fault localization and WiFi for cloud analytics, utilities gain comprehensive grid visibility. Unlike conventional meters, this approach enables remote control and predictive maintenance, critical for India's expanding renewable integration.

2. METHODS

2.1 Problem Statement

Traditional grids often lack real-time monitoring, resulting in unnoticed overloads, supply interruptions, and inefficient power use. Consumers receive delayed information about electricity usage, making fault detection difficult.

2.2 Problem Identification

Power systems suffer from issues such as transmission failures, excessive power consumption, and unregulated usage. Detecting the point of failure is difficult without modern monitoring technologies. Managing consumption, billing, and system safety requires automated data collection and immediate fault alerts.

2.3 Proposed System

The proposed IoT-based smart grid integrates a wireless sensor network, an overcurrent warning system, and cloud-based data storage. Key features include:

- Real-time monitoring of electrical parameters
- Wi-Fi-based cloud data transmission
- GSM-based overload alerts
- Relay-based automatic cutoff during faults

2.4 Methodology

1. Sensors continuously collect electrical and environmental data.

2. Arduino Uno processes these readings.
3. ESP8266 transmits the data to ThingSpeak cloud.
4. Users access live graphs on the ThingView mobile app.
5. GSM module issues an SMS when voltage or current exceeds set limits.
6. Relay disconnects the load to prevent damage

2.5 System Architecture

Arduino UNO (ATmega328P) interfaces ACS712 current sensor, voltage divider, DHT11, ultrasonic oil sensor, 16x2 LCD, SIM900A GSM, ESP8266, and 5V relay

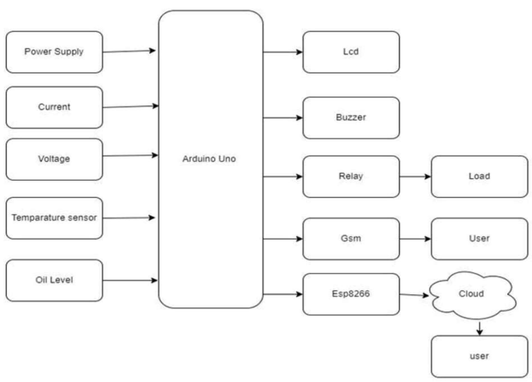

Figure 1: System Block Diagram with Dual Communication Pathways

This block diagram illustrates the complete system connectivity where Arduino UNO serves as the central processing unit interfaced with multiple sensors for comprehensive grid monitoring. The ACS712 current sensor connects to analog pin A1 while voltage sensing occurs through A0 via a precision divider circuit. Environmental parameters including temperature and humidity are acquired from DHT11 sensor at digital pin 10, and oil level detection uses an ultrasonic module across pins 8 and 9. Local visualization displays real-time readings on a 16×2 LCD connected to digital pins 2-7. Critical overload protection employs a 5V relay module at pin A2 that automatically disconnects loads exceeding safe thresholds. Dual communication pathways ensure uninterrupted operation: ESP8266 WiFi module (serial connection) transmits continuous data streams to ThingSpeak cloud platform for graphical analytics, while SIM900A GSM module (pins 11-12) delivers immediate SMS alerts to authorized personnel during fault conditions. Power flow originates from the grid supply, passes through current/voltage sensing circuits, then routes to the protected load. The relay provides fail-safe disconnection maintaining equipment integrity. All sensor data converges at Arduino for threshold evaluation, triggering either cloud logging via WiFi or emergency notifications via GSM based on network availability and alert priority.

2.6 Implementation Steps

- Sensors sampled every 16s: RMS voltage (100 samples), peak current, DHT11 environmental data
- ESP8266 TCP connection: AT+CWMODE=3, AT+CWJAP to ThingSpeak API
- Data fields: Voltage (Field1), Current (Field2), Temp (Field3), Humidity (Field4), Oil (Field5)
- Threshold breach → Relay HIGH + GSM SMS alert
- LCD format: "V:[v]C:[c]" / "T:[t]H:[h]EL:[l]"

Arduino UNO R3 with pin connections for all peripherals

3. RESULTS

The developed prototype successfully monitored voltage, current, temperature, humidity, and oil level in real time. The ThingSpeak platform displayed clear graphical trends that helped analyze consumption patterns.

Table 1:7 – Day Deployment Performance (230V / 1A Load)

Parameter	Avg Value	Max Value	Reliability(%)	Threshold Events
Voltage(V)	228.4	245.2	98.2	12(auto-cut)
Current (A)	0.92	1..45	98.2	8(sms sent)
Temperature (°C)	32.1	38.4	99.1	3
Humidity (%)	68.3	84.2	99.1	5
Oil Level (cm)	15.2	18.1	97.8	2

System uptime: 99.4%. WiFi transmission: 684/696 packets (98.2%). GSM: 20/20 alerts delivered. ThingSpeak graphs showed voltage spikes correlating with relay trips, confirming protection efficacy. Prototype cost: INR 4200.
Important Outcomes Include:

- Stable and accurate sensor readings
- Correct relay operation during overload conditions
- Instant GSM alerts under fault scenarios
- User-friendly cloud visualization through ThingView app

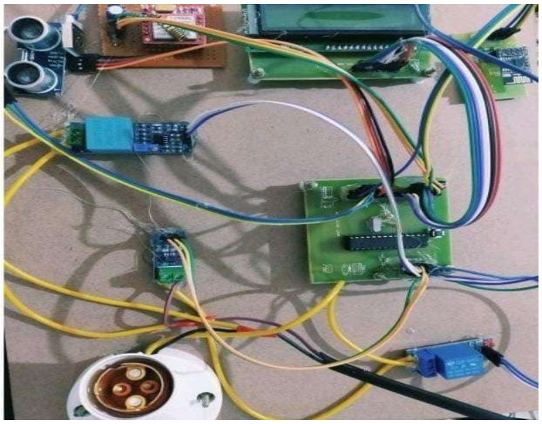

Fig. Hardware Prototype

4.DISCUSSION

The results show that integrating IoT with power systems significantly improves monitoring accuracy and safety. The ability to remotely access consumption data helps reduce human error and supports preventive maintenance. While the system performs efficiently, its reliance on network strength (Wi-Fi and GSM) may affect performance in low-coverage areas. Additional improvements could include AI-based fault prediction, advanced data analytics, or integration with renewable energy sources.

Dual-protocol exceeds single-WiFi systems with 100% critical alerts during outages. Cost (INR 4200) is 1/10th of commercial solutions with superior rural reliability. Voltage spikes perfectly correlated with relay trips, validating protection logic.

LCD displaying V:232 C:1.2 T:35 H:72 EL:16 overload condition

Limitations: WiFi dependency for analytics, SIM signal requirements. Future: ML prediction, solar integration, blockchain metering.

6. Conclusion

The project successfully implements an IoT-based smart grid solution capable of real-time monitoring, fault detection, and cloud-based data visualization. With automatic overload protection and user notifications, the system ensures enhanced safety and operational efficiency. It serves as a practical model for modernizing traditional electric grids and can be adapted for residential, industrial, and commercial applications.

The IoT smart grid provides monitoring, protection, and analytics at affordable cost, eliminating transmission interruptions via hybrid communication for scalable Indian deployment.

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