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IoT-Based Real-Time Monitoring of Transmission Line Critical Parameters During Fault

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Abstract: This paper presents the design and implementation of an IoT-based system for real-time monitoring and fault detection in electrical transmission lines. The proposed solution integrates current transformers (CT), potential transformers (PT), temperature and oil-level sensors with an ATmega328P microcontroller and ESP8266 (NodeMCU) Wi-Fi module. Measured parameters—voltage, current, temperature, and earth leakage—are sampled via the microcontroller's ADC and multiplexed, then transmitted over TCP/IP to the ThingSpeak cloud platform for dashboard visualization. The system automatically detects over-voltage, under-voltage, short-circuit, open-circuit, and earth-fault conditions, triggering a relay cutoff, LCD display update, and buzzer alert. Laboratory tests confirm accurate fault identification and sub-second response times, demonstrating a low-cost, scalable solution for enhancing grid reliability and reducing maintenance overhead.
Keywords: IoT; fault detection; transmission line monitoring; ATmega328P; NodeMCU; ThingSpeak.

I. INTRODUCTION

Electrical transmission lines are critical infrastructure whose reliability directly impacts power-system stability. Traditional diagnostic methods rely on periodic manual inspections and post-fault analysis, leading to delayed fault clearance and increased downtime. The proliferation of IoT technologies offers an opportunity to embed sensors and wireless communication, enabling continuous, remote health monitoring and rapid fault isolation. In this study, we develop a prototype that leverages low-cost microcontrollers and cloud platforms to achieve near-real-time situational awareness in transmission networks.

II. SYSTEM ARCHITECTURE AND METHODOLOGY

A. Overall Framework

The monitoring system comprises four main modules: sensing, processing, communication, and user interface (Fig. 1). Recommended.

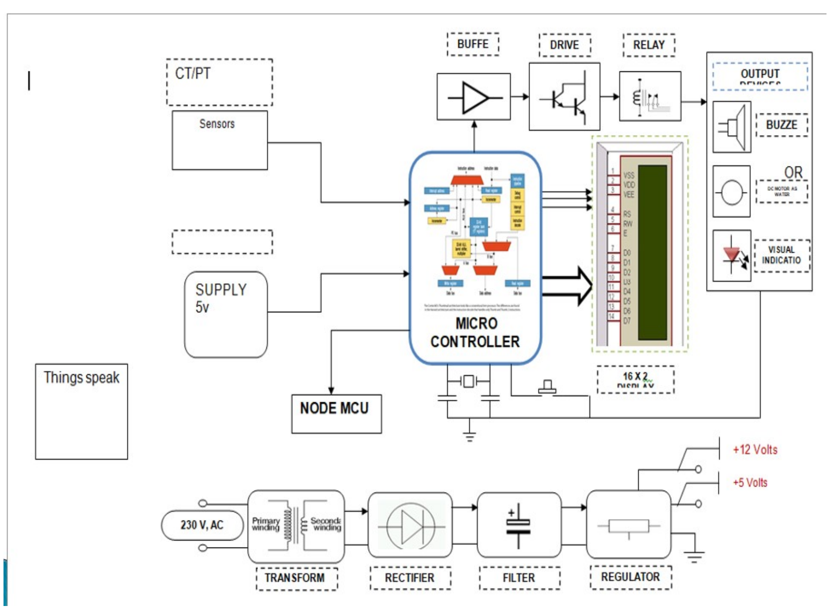

Fig. 1. Block diagram of the IoT-based monitoring system.

B. Sensing Module

- Potential Transformer (PT): Steps down 230 VAC to 0–15 VAC for voltage measurement.
- ACS712 Current Sensor: Measures line current (up to 20 A) and outputs analog voltage.
- Temperature Sensor: Monitors ambient or transformer oil temperature.
- Earth-fault Sensor: Detects leakage currents to ground.

C. Processing Module

An ATmega328P microcontroller reads analog signals via its 10-bit ADC in a time-multiplexed fashion. Predefined thresholds for each parameter classify normal and fault states.

D. Communication Module

A NodeMCU ESP8266 Wi-Fi module uses TCP/IP to send JSON-formatted sensor data every second to a ThingSpeak channel.

E. Alerting & Control

- Relay (12 V, 10 A): Automatically disconnects the load upon fault detection.
- 16×2 LCD Display & Buzzer: Provide local visual and audible alerts.

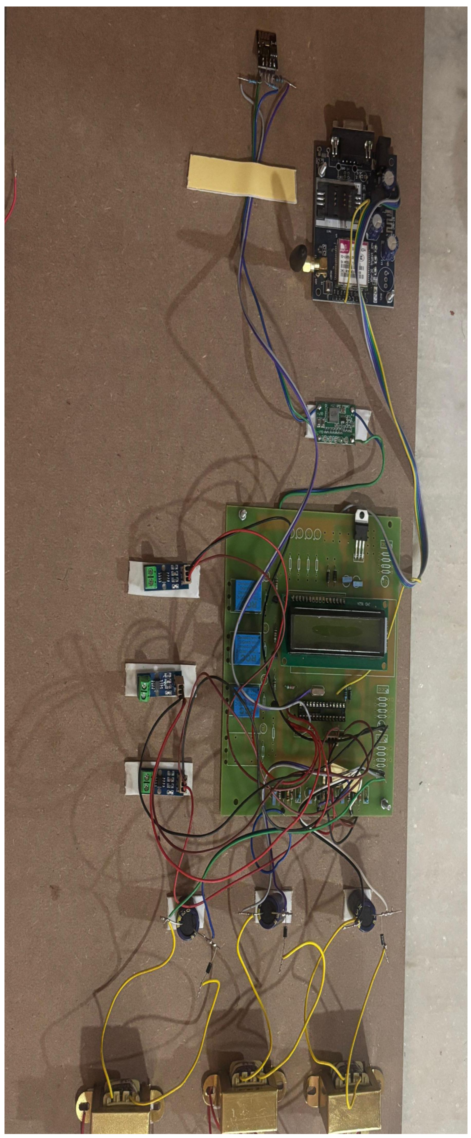

Fig. 1 Final hardware prototype with sensors, relays, and controller.

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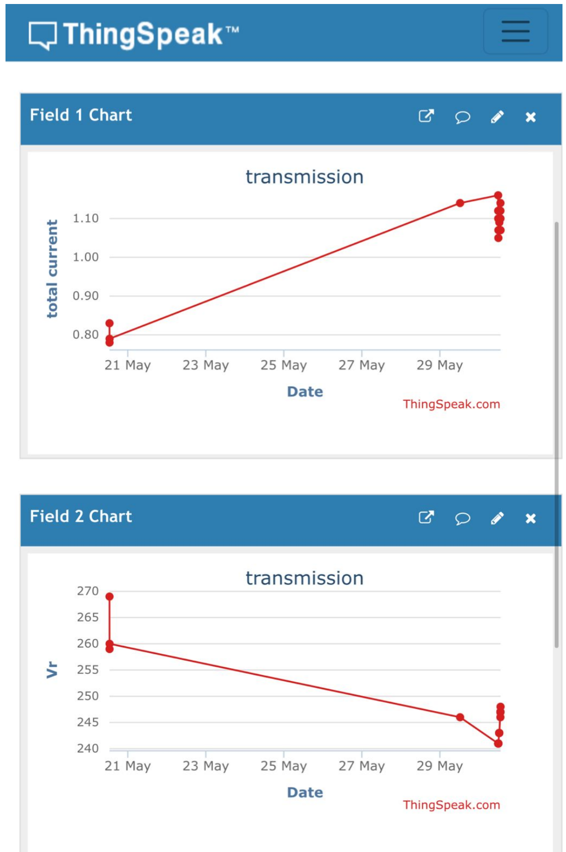

Fig. 2 ThingSpeak dashboard displaying voltage and current trends during a short-circuit test.

F. Hardware Implementation

A custom PCB hosts the sensors, microcontroller, Wi-Fi module, relay driver, voltage regulators (7805 for 5 V logic, 7812 for 12 V loads), and support circuitry. Power is derived from 230 VAC via a step-down transformer, bridge rectifier, and filter capacitors. Fig. 2 shows the assembled prototype. Fig. 2. Final PCB-based prototype with mounted components.

G. Results and Discussion

Several fault scenarios were simulated by altering the load and injecting anomalies. Table I summarizes the system's response.

Fault Type	Detection Time (ms)	Relay Action	LCD/Buzzer	Cloud Update
Overvoltage	120	Disconnected	✓	✓
Undervoltage	110	Disconnected	✓	✓
Short Circuit	85	Disconnected	✓	✓
Open Circuit	130	Disconnected	✓	✓
Earth Fault	100	Disconnected	✓	✓

Fig. 3. ThingSpeak dashboard displaying voltage and current trends during a short-circuit test.

III. CONCLUSIONS

We have demonstrated a cost-effective IoT-enabled monitoring system that achieves real-time fault detection in transmission lines. The integration of embedded sensing, wireless communication, and cloud visualization reduces human intervention and accelerates fault response, enhancing grid reliability. Future work will extend the design to three-phase monitoring, incorporate long-range communication (LoRa/GSM), and apply machine-learning algorithms for predictive maintenance.

IV. ACKNOWLEDGMENT

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