Distributed Acoustic Sensing for Electric Grid Monitoring

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Introduction

- Electric grid monitoring ensures reliable and uninterrupted power supply.
- Traditional systems are costly and have delayed response times.
- Optical fibers in grid infrastructure can serve as distributed sensors.
- Distributed Acoustic Sensing (DAS) detects acoustic vibrations via light backscattering.
- Integration with IoT and ML enables real-time fault analysis and predictions.

Problem Statement

- Conventional grid monitoring is expensive and reactive.
- Manual checks delay fault response and increase outage time.
- Traditional sensors are maintenance-heavy and non-scalable.
- Optical fiber potential is underutilized.
- A low-cost, intelligent, and scalable system is required for real-time monitoring.

Objectives

- Implement DAS-based monitoring for detecting grid disturbances.
- Convert light fluctuations to electrical signals via photodetectors.
- Apply FFT to extract frequency patterns from signals.
- Transfer voltage data from Arduino to laptop via serial interface.
- Upload real-time data to ThingSpeak using laptop Python script.
- Use LSTM model for predictive maintenance and anomaly detection.

Step 1: Signal Detection and Cloud Upload

- **650nm laser** projects a focused beam into the environment.
- **BPW34 photodiode** detects light and outputs analog voltage.
- **Arduino Mega** reads and sends the signal to the laptop.
- Laptop Python script pushes data to **ThingSpeak (Cloud)**.
- Vibrations/faults disturb beam, altering signal intensity.

Step 2: Signal Processing and Prediction

- Signals are analyzed using **FFT** to extract frequencies.
- **LSTM model** learns from patterns and detects anomalies.
- Output: **Prediction score (0 to 1)** for abnormal signals.
- If score $> 0.3 \rightarrow$ **trigger alert email automatically**.
- Enables low-cost, real-time, and intelligent fault detection.

Components

1. **Laser (650nm):** Emits light into optical fiber to sense vibration.
2. **Photodetector (BPW34):** Converts light variations to voltage signals.
3. **Signal Amplifier (LM358):** Boosts weak sensor signals.
4. **Arduino Mega:** Reads and sends sensor data to laptop via serial.
5. **Laptop with Python Script:** Sends data to ThingSpeak and processes it.
6. **Cloud Platform (ThingSpeak):** Visualizes real-time data from grid.
7. **ML Model (LSTM):** Learns and predicts patterns in disturbance signals.

Methodology

Project Methodology

Step 1: Backscatter Detection

BPW34 photodiode detects backscatter signals from the optical cable.

Step 2: Signal Processing

Arduino Mega processes the raw signal from the BPW34 sensor.

Step 3: Data Transfer to Laptop

Signal data is sent from Arduino to the laptop via USB connection.

Step 4: Upload to ThingSpeak

The laptop uploads the processed signal data to the ThingSpeak cloud platform.

Step 5: LSTM Analysis

ThingSpeak data is used as input to the LSTM model to detect signal anomalies.

Step 6: Alert Trigger

If the model detects any anomaly, it sends an alert to the user immediately.

Research Gap

- Current monitoring systems lack integration with ML for early detection.
- DAS with IoT is still underexplored in power systems.
- Optical fibers are not widely used for real-time grid sensing.
- High cost and frequent calibration hinder traditional methods.
- Demand for scalable, affordable, intelligent monitoring solutions.

Novelty

- **DAS Integration:** Uses existing optical fibers to sense grid anomalies.
- **ML-based Prediction:** LSTM model predicts faults from signal data.
- **Laptop as Bridge:** Avoids extra modules by using laptop for data relay.
- **Cloud Integration:** Real-time updates to ThingSpeak for visualization.
- **Low-Cost Design:** Minimizes hardware while maintaining high accuracy.

Conclusion

Key Insights:

1. DAS for Monitoring: Leverages optical fiber for cost-efficient, scalable sensing.

2. Real-Time Data Transfer: Arduino and laptop ensure seamless data flow.

3. Cloud + ML: ThingSpeak + LSTM supports intelligent diagnostics.

4. Reduced Downtime: Enables early detection and proactive maintenance.

5. Adaptable System: Easily fits into existing electric grid infrastructure.

6. Affordable Deployment: Reduces reliance on bulky and expensive sensors.

Future Work

1. **Advanced Detectors:** Explore photodiodes with higher sensitivity.
2. **Extended Range:** Use lasers with greater reach and penetration.
3. **Enhanced Processing:** Run ML models on edge devices for faster inference.
4. **Multi-Point Monitoring:** Scale setup for multiple fiber paths.
5. **UI Dashboard:** Build intuitive dashboards for live grid health metrics.
6. **Energy Efficiency:** Optimize hardware and scripts for low power use.

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Thank You!

Questions?