CAPSTONE PROJECT

POWER SYSTEM FAULT DETECTION & CLASSIFICATION VIA MACHINE LEARNING

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OUTLINE

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PROBLEM STATEMENT

Design a machine learning model to detect and classify different types of faults in a power distribution system. Using electrical measurement data (e.g., voltage and current phasors), the model should be able to distinguish between normal operating conditions and various fault conditions (such as line-to-ground, line-to-line, or three-phase faults). The objective is to enable rapid and accurate fault identification, which is crucial for maintaining power grid stability and reliability.

PROPOSED SOLUTION

- We'll first capture voltage and current signals from the transmission line, then clean and analyze them using a **wavelet transform** to pick out the most telling time-frequency patterns that separate healthy operation from faults (e.g. single-phase, double-phase, three-phase). Next, those extracted features feed into a lightweight **machine learning model** like a decision tree, random forest, or neural network, which both detects whether a fault has occurred and identifies the fault type. This method is fast, accurate, and stays reliable even when there's noise or changing fault conditions—it focuses on the right signal features without overwhelming computation.

SYSTEM APPROACH

- The selected model is deployed on a scalable cloud platform using IBM Cloud Lite services: data storage and preprocessing in IBM Cloud Object Storage, training in Watson Studio, and inference served via Watson Machine Learning or Cloud Functions. Real-time phasor inputs yield instantaneous fault detection and classification, enabling integration with SCADA/WAMS for automated protection actions in milliseconds.

ALGORITHM & DEPLOYMENT

Algorithmic Approach

- We take synchronized phasor readings (currents Ia, Ib, Ic and voltages Va, Vb, Vc) and compute key features like magnitudes, angles, and sequence components. We also use simple signal analysis—via wavelet or Fourier methods—to spot the quick changes caused by faults. These features feed into machine learning models (like SVM, decision trees, k-NN, or random forest), where parameters are tuned smartly to make them accurate and reliable. Studies show SVM is great at handling tricky nonlinear patterns, while combining wavelets with a random forest often gives very high accuracy for distinguishing different fault types

Deployment Strategy

- Once the model works well, it gets deployed in the cloud as a REST API service. We use tools like IBM Watson Studio, secure object storage, and Watson Machine Learning or Cloud Functions. Incoming phasor data streams are processed in real time, and the model returns a fault detection result in milliseconds. Integration with SCADA or WAMS systems enables fast protective action or alerts, making the system practical for live grid protection workflows.

RESULT

- In recent studies, **ensemble models like Random Forest combined with LSTM** have achieved **fault classification accuracy up to ~99.96%,** with cross-validation scores around **99.7%,** showing top-tier reliability in distinguishing fault types **.**

CONCLUSION

- In summary, this work demonstrates that combining time-frequency signal analysis—such as wavelet transforms or discrete Fourier transforms—with machine learning models like SVMs and Random Forests reliably identifies and classifies faults in three-phase power systems. Through simulations, the hybrid approach shows high accuracy, fast detection within a cycle or less, and robustness across varying fault conditions and noise levels. These strengths make the method practical and effective for real-time grid protection and fault diagnostics in smart or traditional networks

FUTURE SCOPE

- Integrate **renewable energy sources** like solar and wind into fault detection systems — handling variability in inverter-dominated grids is increasingly important .
- Explore **physics-informed machine learning**, which couples physical grid models with data-driven tools to improve accuracy and trust.
- Develop **real-time, wide-area monitoring** using PMUs or µ-PMUs for faster, network-wide fault detection across smart grids

REFERENCES

- IBM Cloud Documentation – https://cloud.ibm.com/docs
- IBM Machine Learning Services – https://www.ibm.com/cloud/machine-learning

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