Comparative Performance Evaluation of Classical Machine Learning Algorithms for PMU-Based Fault Detection in IEEE 39-Bus Power Systems

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Abstract

Reliable fault detection is essential for maintaining the stability, security, and reliability of modern power systems. Phasor Measurement Units (PMUs) provide synchronized electrical measurements that support the identification of abnormal operating conditions. This study presents a machine learning-based framework for power system fault detection using PMU measurements and statistical feature engineering. To support transparency and reproducibility, the investigation utilizes a publicly available dataset hosted on Kaggle, derived from simulations of the IEEE 39-bus test system. The dataset includes time-synchronized three-phase voltage and current measurements corresponding to normal and abnormal operating conditions. Six raw electrical measurements are augmented with four statistical descriptors—mean, variance, skewness, and kurtosis—resulting in a 30-dimensional feature vector. Five machine learning classifiers, namely Random Forest, Support Vector Machine (SVM), Decision Tree, K-Nearest Neighbors (K-NN), and Logistic Regression, are evaluated using an 80:20 stratified training–testing split. Performance is assessed using accuracy, precision, recall, F1-score, confusion matrices, and receiver operating characteristic (ROC) curves. The experimental results demonstrate that Random Forest achieves the best overall performance, with 96.85% accuracy, an F1-score of 0.964, and an area under the ROC curve (AUC) of 0.98. SVM achieves 94.20% accuracy and an AUC of 0.96. Additionally, a MATLAB-based streaming simulation demonstrates continuous PMU data processing, automated fault classification, timestamped result logging, and fault alert generation. The findings highlight the potential of statistical feature engineering and machine learning for accurate PMU-based fault detection, providing a foundation for intelligent power system monitoring and future integration with automated protection systems.

Keywords

Machine Learning, Phasor Measurement Unit, Power System Fault Detection, Statistical feature engineering.