GridStrainPH: An Explainable AI Framework for Forecasting Energy Demand Shocks and Grid Vulnerability in the Philippines

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Abstract

Electricity demand analysis is essential for maintaining reliable and efficient power-system operations, particularly in developing economies where consumption patterns are influenced by economic, demographic, and regional changes. Conventional forecasting methods may be inadequate for identifying nonlinear relationships and structural variations in electricity consumption. This study presents GridStrainPH, a machine-learning framework for detecting statistically defined electricity-demand shock events in the Philippines. Using publicly available datasets from the Philippine Department of Energy, multiple energy reports were integrated through a unified preprocessing pipeline involving data cleaning, normalization, regional mapping, and feature engineering. The process produced a consolidated dataset comprising 5,237 observations, including 4,956 normal-condition observations and 281 shock-event observations. Sector-normalized distributional thresholds were used to define demand shocks, with observations classified as shocks when their standardized deviation reached or exceeded two standard deviations from the sector-level mean. The problem was formulated as a binary classification task and evaluated using a Random Forest classifier with an 80:20 stratified train-test split. The model achieved an accuracy of 92.94% and a receiver operating characteristic area under the curve of 0.8751. However, its performance in detecting minority-class shock events remained limited, achieving a precision of 0.24, recall of 0.22, and F1-score of 0.23. These findings indicate that overall accuracy is insufficient for evaluating rare-event detection under class imbalance. Nevertheless, the model demonstrates meaningful class-separation capability and provides a foundation for data-driven monitoring of abnormal electricity-consumption behavior. GridStrainPH reframes electricity demand analysis as a statistical-event detection problem and offers a decision-support approach for strengthening demand-management planning and future grid-resilience assessment in the Philippines.

Keywords: electricity demand, energy analytics, machine learning, power systems, random forest