Hawaiʻi Natural Energy Institute Research Highlights

Grid Integration

AI-Based Net-Load Forecasting Framework for Renewable-Rich Facilities

OBJECTIVE AND SIGNIFICANCE: Accurate net-load forecasting is essential for reliable and efficient energy management in facilities with significant renewable integration. This project introduces an artificial intelligence (AI)-driven forecasting framework to generate precise 24-hour-ahead predictions of electricity demand (gross load), solar photovoltaic (PV) generation, and net load at 15-minute resolution, with forecasts updated as new data become available.

BACKGROUND: As renewable energy penetration increases, net electricity demand has become more variable and harder to predict. This variability introduced by human activity, intermittent solar production, and changing weather conditions often leads to forecast uncertainty that traditional statistical or regression-based methods cannot fully capture.

By combining lightweight transformer architectures for load forecasting with AI-based PV forecasting models trained on temperature and irradiance features, the project delivers a unified, operational pipeline capable of generating complete gross load, PV, and net-load forecasts within one minute. Initially validated using high-resolution metered data from a building at the University of Hawaiʻi at Mānoa, this approach is readily adaptable to other campuses, facilities, and commercial complexes, providing a scalable, ready-to-deploy solution for data-aware, resilient, and sustainable grid operations that support Hawaiʻi's clean energy transition.

PROJECT STATUS/RESULTS: Building on HNEI's prior work in machine-learning-based load forecasting, this project advances that foundation by introducing an AI-driven approach for end-to-end net-load forecasting. The methodology combines advanced AI models with behavioral insights to better capture how energy use and solar production vary throughout the day and across weather conditions. By continuously learning from recent data, the system adapts to changing operating patterns, improving reliability, and making forecasts more applicable to real-world renewable systems. This initiative represents an important step toward practical, AI-enabled forecasting tools that support real-time energy management, battery control, demand response, and microgrid operations across a range of facilities and scales.

An operational prototype of the AI forecasting model has been developed to produce rolling 24-hour-ahead forecasts for gross load, PV generation, and net load at 15-minute resolution. Figure 1 illustrates the workflow and integration of the forecasting modules. The prototype, trained using one year of high-resolution metered data, effectively captures seasonal and weather-driven variability with strong accuracy. It achieves an average symmetric Mean Absolute Percentage Error (sMAPE) of approximately 6.8% for 24-hour forecasts, maintaining stable performance across both day and night periods.

Key advancements of this work include separate daytime and nighttime models, weekday-specific training, and anomaly-based normalization using the most recent seven days of data. The system produces full 24-hour forecasts in under one minute on a standard desktop CPU, with PV models pre-trained on GPU. The modular design supports integration of additional weather and distributed energy resource (DER) inputs. Ongoing work focuses on improving AI model training and feature engineering to further increase accuracy, robustness, and scalability for deployment in campus- and building-scale microgrids.

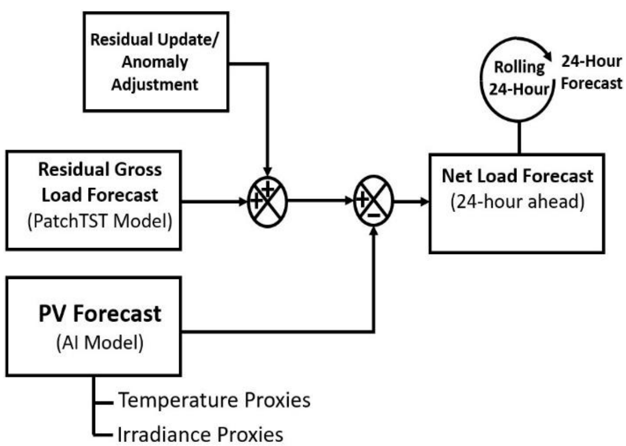

Figure 1. AI-based forecasting workflow integrating PatchTST load and PV models to generate rolling 24-hour-ahead net-load forecasts.

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