Fast and Accurate Solar Power Generation Forecasting Using Advanced Deep Learning: A Novel Neural Basis Expansion Analysis Framework

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Abstract

Accurate short-term forecasting of photovoltaic (PV) power generation is essential for maintaining the stability and efficiency of modern power grids. However, conventional statistical and regression-based methods often fail to capture the nonlinear and stochastic patterns of solar generation data, leading to unreliable forecasts and operational inefficiencies. This study addresses these challenges by systematically benchmarking eight deep learning architectures for PV power forecasting, including Long Short-Term Memory (LSTM), Temporal Convolutional Network (TCN), Transformer, Temporal Fusion Transformer (TFT), TiDE, N-HiTS, DLinear, and Neural Basis Expansion Analysis for Time Series (N-BEATS). Real-world 15-minute interval PV data from 2018 to 2019 were used to evaluate the models in terms of forecasting accuracy, parameter efficiency, training time, and memory usage. Results demonstrated that compact variants of the N-BEATS architecture, specifically the optimized G-NBEATS and I-NBEATS models, delivered the highest predictive performance, achieving R^2 scores of 98.7% and 98.5%, respectively. These models substantially reduced computational demands, lowering parameter counts by up to 98% relative to N-HiTS (3.1 M parameters), training times by over 90% compared to Transformer and TFT model (> 2300 s), and peak GPU memory usage by more than 95% relative to Transformer (997.67 MB VRAM). Qualitative assessments further confirmed their ability to accurately capture both diurnal ramp patterns and seasonal transitions. This study introduces a lightweight, deployable forecasting framework that combines high accuracy with low computational cost, offering practical solutions for real-time solar power prediction in resource-constrained environments.

Author keywords

Deep learning; green energy; hyperparameter optimization; neural networks; photovoltaic systems; power generation; renewable energy sources; smart grids; solar power generation; time series analysis

Indexed keywords

Engineering controlled terms

Big data; Convolutional neural networks; Deep neural networks; Expansion; Forecasting; Learning systems; Long short-term memory; Memory architecture; Natural resources; Smart power grids; Solar energy

Engineering uncontrolled terms

Deep learning; Green energy; Hyper-parameter optimizations; Neural-networks; Photovoltaic systems; Power- generations; Renewable energy source; Smart grid; Time-series analysis

Engineering main heading

Solar power generation; Time series analysis

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