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Enhancing Wind Power Forecasting in the Spanish Market Through Transformer Neural Networks and Temporal Optimization

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Abstract-

The increasing penetration of renewable energy, and wind power in particular, requires accurate short-term forecasting to ensure grid stability, reduce operational uncertainty, and facilitate large-scale integration of intermittent resources. This study evaluates Transformer-based architectures for wind power forecasting using hourly generation data from Spain (2020–2024). Time series were segmented into input windows of 12, 24, and 36 h, and multiple model configurations were systematically tested. For benchmarking, LSTM and GRU models were trained under identical protocols. The results show that the Transformer consistently outperformed recurrent baselines across all horizons. The best configuration, using a 36 h input sequence with moderate dimensionality and shallow depth, achieved an RMSE of 370.71 MW, MAE of 258.77 MW, and MAPE of 4.92%, reducing error by a significant margin compared to LSTM and GRU models, whose best performances reached RMSEs above 395 MW and MAPEs above 5.7%. Beyond predictive accuracy, attention maps revealed that the Transformer effectively captured short-term fluctuations while also attending to longer-range dependencies, offering a transparent mechanism for interpreting the contribution of historical information to forecasts. These findings demonstrate the superior performance of Transformer-based models in short-term wind power forecasting, underscoring their capacity to deliver more accurate and interpretable predictions that support the reliable integration of renewable energy into modern power systems.

Index Terms- wind power forecasting; transformer models; deep learning; short-term forecasting; renewable energy integration; sustainable energy systems

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