World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:19, No:01, 2025

Development of Sustainable Wind Speed Forecasting Framework for Wind Energy Farms

Authors : Mohammed Bou-Rabee

Abstract : The significance of wind energy is rising as the global world shifts toward clean and renewable energy sources. Wind energy generates electricity without releasing greenhouse gases, making it a feasible substitute for fossil fuels. This contributes to the reduction of carbon emissions, mitigates climate change, and enhances air quality. Wind energy, unlike fossil fuels, is a renewable resource. Investing in wind energy allows nations to reduce their reliance on imported fossil fuels, improving their energy security. This technique ensures stable energy costs while safeguarding economies from the volatility of oil and gas markets. Recent technological advancements have markedly decreased the cost of wind energy over the past few decades, establishing it as one of the most cost-effective sources of new electricity in many regions globally. These advancements have significantly enhanced turbine efficiency, augmented energy output, and reduced costs. The fluctuating characteristics of wind energy present an ongoing research challenge that has captivated the whole scientific community. Accurate forecasting of wind energy is essential for effective wind farm operation and management, smart grid stabilization, optimizing energy storage, investment and financial planning, and improved participation in energy markets. The extraction of wind energy depends on several factors, with wind speed being the most critical, as it directly affects the power output of a wind turbine. A wind turbine generates energy exponentially with wind velocity, exhibiting a cubic relationship. In addressing these research challenges, we have developed an efficient wind speed forecasting system employing advanced machine learning (ML) and statistical techniques. We created a hybrid time series forecasting model using an ensemble learning approach that integrates a Light Gradient Boosting Machine (LGBoost), Extreme Gradient Boosting (XGBoost), and Bayesian Linear Regression (BLR). We then utilized the Random Forest (RF) technique for feature selection. The model can predict wind speed with a minimum mean square error (MSE) of 0.096 and a maximum R^2 score of 0.924.

Keywords : wind energy, renewable resource, turbine efficiency, affects power
Conference Title : ICDRE 2025 : International Conference on Desalination and Renewable Energy
Conference Location : Bangkok, Thailand
Conference Dates : January 23-24, 2025