Optimization of Wind Turbine Performance: Integrating Evolutionary Based AI-Assisted Genetic Algorithms and XGBoost With Blade Element Momentum and Aero-Servo-Hydro-Elastic Simulations

Vasisht, Janak (School: H-B Woodlawn Secondary Program)

Installed wind power capacity has tripled in the last decade, motivating significant research in wind turbine performance optimization. Traditional optimization methods often evaluate blades and airfoils under a narrow range of wind speeds and angles, which is limiting because real wind varies in speed and direction. This research optimizes each two-dimensional airfoil cross-section of the International Energy Agency's (IEA) 15 MW offshore wind turbine blade to improve performance across the full range of operational wind conditions: 5–25 m/s and -30° to +30°. Airfoils are optimized using a surrogate-assisted genetic algorithm (SGA) with Class Shape Transformation (CST) parameterization. Performance is evaluated using an XGBoost-based fitness function that outputs a weighted lift-to-drag metric representing each airfoil's performance across all wind angles. One airfoil, the FFA-W3-211, achieved a lift-to-drag ratio nearly three times greater than the original. All 50 optimized airfoils were then used to reconstruct the turbine blade, while ensuring that twist, chord length, and other geometric characteristics were maintained to keep manufacturability. The optimized turbine was evaluated through aero-servo-hydro-elastic simulations across the operational ranges of wind speed and angle. The optimized blade produced significantly more power at wind speeds above 15 m/s. Based on measured hourly offshore wind speed data from the National Data Buoy Center (NDBC), the optimized turbine would generate approximately 2,236 MWh in additional annual energy per turbine. With 193 offshore turbines projected to be operational in the United States, this corresponds to an estimated $68.8 million in additional annual revenue.

Awards Won:

First Award of $6,000