Abstract

This Paper aims to develop an **AI-assisted wind turbine optimization model** that dynamically adjusts blade angles to maximize power output while minimizing wear and tear. Traditional wind turbines often rely on fixed or periodically updated blade angles, leading to inefficiencies in power generation and increased operational stress. By integrating fuzzy logic and machine learning techniques, this work addresses key challenges in turbine optimization, including fluctuating wind conditions and high computational demands.

The methodology leverages historical wind turbine data, including wind speed, blade angles, and power output, to train predictive models. The power output is calculated using the equation:

$$\frac{1}{2} \cdot \rho \cdot A \cdot V_w^3 \cdot C_p$$

where P is the power output, ρ is the air density, A is the rotor swept area, Vw is the wind speed, and Cp is the power coefficient. Fuzzy logic computes a Wear and Tear Index (WTI) based on wind speed fluctuations (ΔV), blade angle change rates (Δθ), and operational stress. The optimal blade angle (θ) is predicted to maintain the angle of attack (α), governed by:

$$\alpha = \phi - \theta$$

$$\phi = \mathbf{tan}^{-1}\left(\frac{V_\omega}{\omega r}\right)$$

where ϕ is the flow angle, ω is the angular velocity, and r is the radial distance.

Key algorithms tested include **Random Forest** and **Gradient Boosting**, evaluated using metrics such as **Mean Absolute Error (MAE)** and **Mean Squared Error (MSE)**. Results show a significant improvement in power output efficiency, with an MAE of **0.4145** and an MSE of **0.2694**, demonstrating the potential for sustainable wind energy solutions through AI-assisted optimization.