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THE ENVIRONMENT AND WIND ENERGY PRODUCTION BY ANALYZING NOISE FILTERING IN WIND SIGNALS TO IMPROVE THE EFFICIENCY OF ENERGY SYSTEMS

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INTRODUCTION

- **Noise filtering** is a critical process for enhancing the accuracy and efficiency of signals captured by wind sensors, which are used to monitor and optimize the performance of wind energy systems.
- Wind signals are often contaminated by noise and interference, which complicates data analysis and hinders accurate decision-making regarding energy production and turbine maintenance.
- This research focuses on the application of digital filters to improve signal quality and increase turbine performance.

THE RESEARCH PROBLEM

What is the problem?	• Wind signals are often contaminated by noise and interference, which complicates data analysis and hinders accurate decision-making regarding energy production and turbine maintenance.
What is the impact of this problem?	• The noise from wind turbines can have negative impact on the wind energy production and on the residents that live near the turbines.
Why should this problem be minimized?	• Better energy management, reducing operational costs, promoting sustainability of wind energy systems.
How to minimize the problem?	• Wind turbine projects should be carefully planned and managed, considering acceptable noise levels and distances from residential areas.

METHODOLOGY

- Finite Impulse Response (FIR) filters
- Infinite Impulse response (IIR) filters
- Wavelet transform
- Kalman filters

EXPERIMENTAL RESULTS

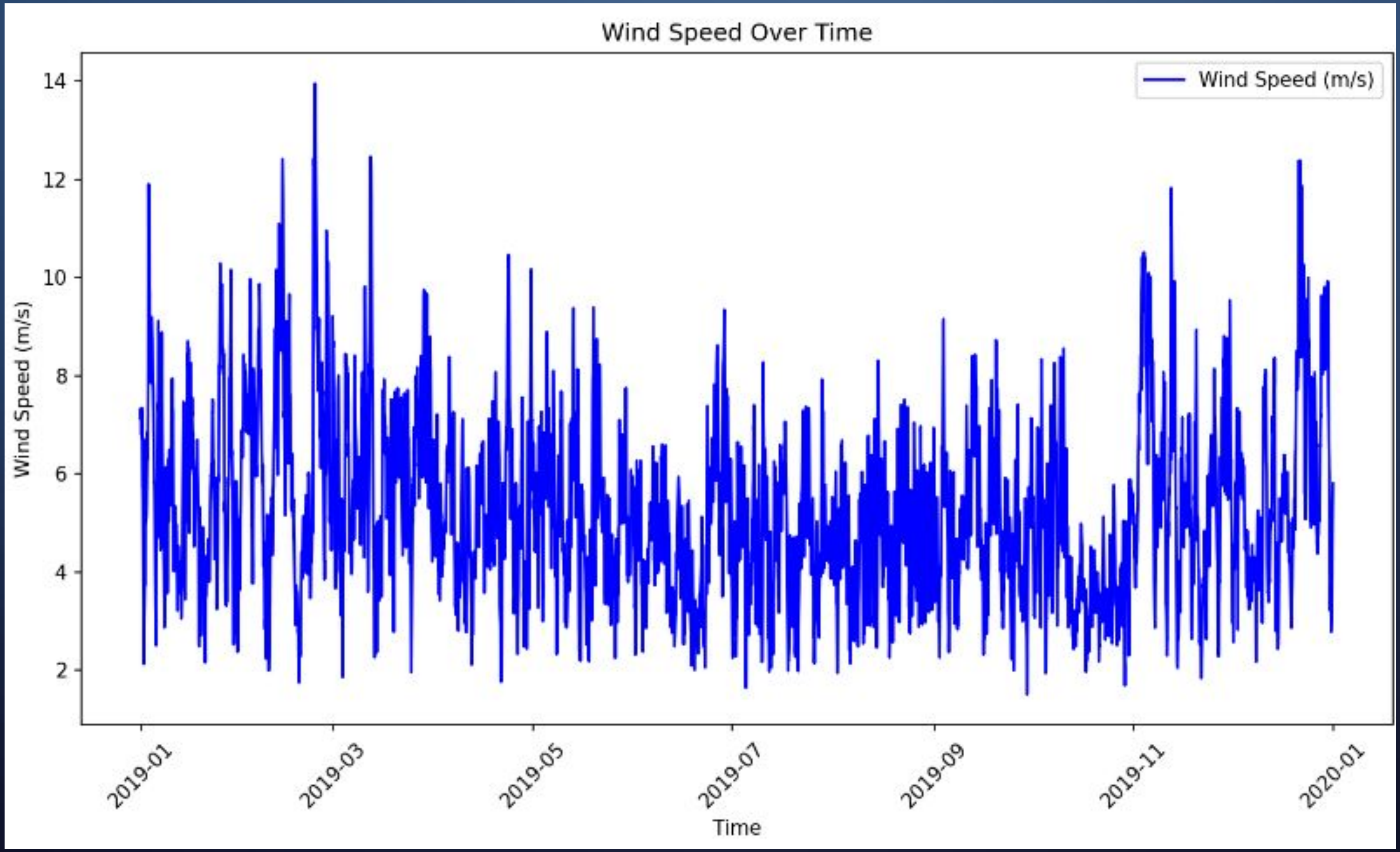
Data: wind speed dataset (raw and filtered data).

Objective: evaluate the effectiveness of different noise reduction methods in enhancing the quality of the wind speed signals by analyzing data and quantify the impact of the noise using statistical measures.

Methods: visualization of the noise reduction models by comparing the actual and the predicted wind energy production values

Findings: closer match indicates more accurate model while greater discrepancies suggest that the model may not effectively replicate the true energy production trends.

RAW DATA ANALYSIS

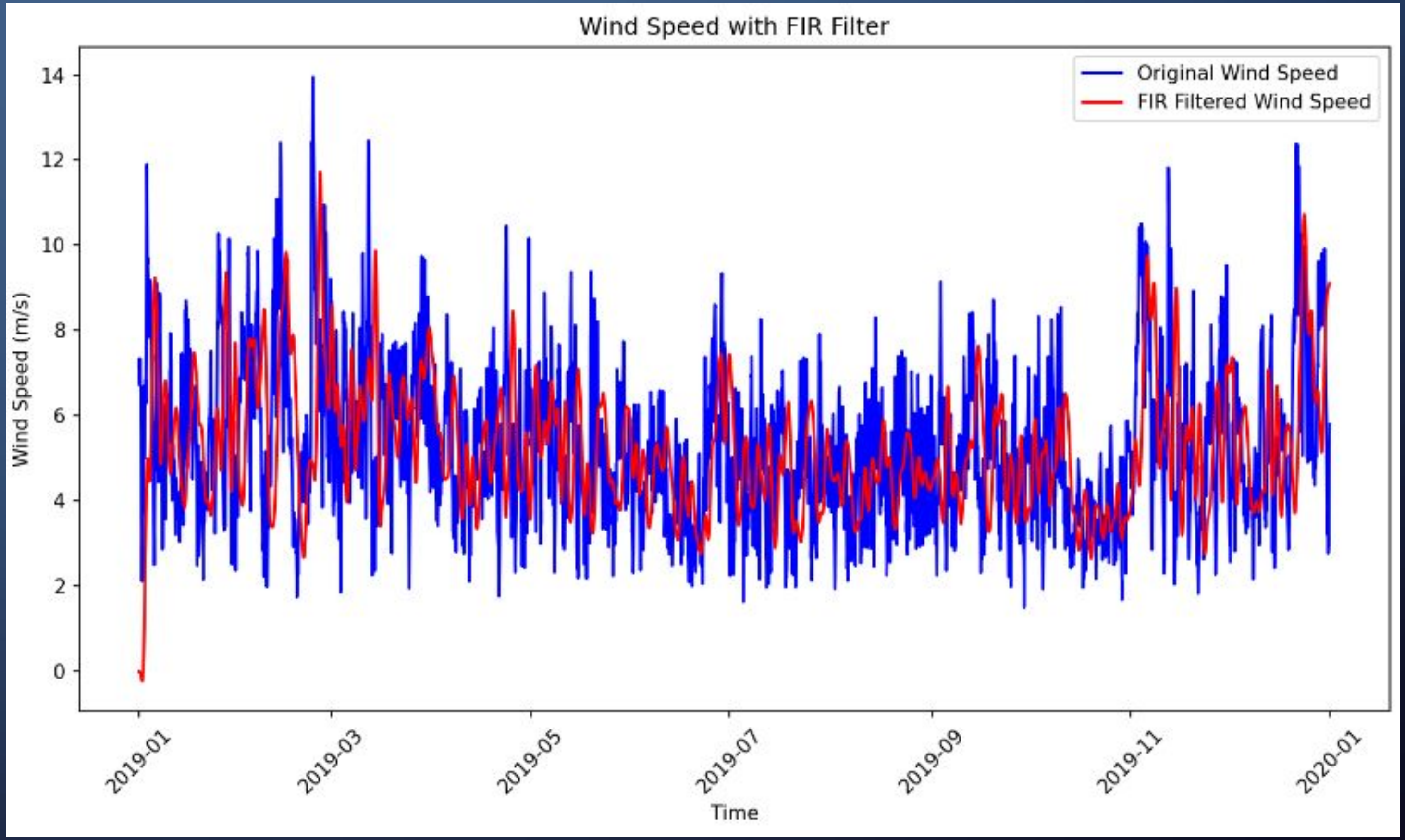


WIND SPEED WITH FIR FILTER

Blue line – original wind speed

Red line – FIR filtered wind speed

Result: the FIR filter effectively removes high frequency noise while keeping the important patterns in the wind speed variations.

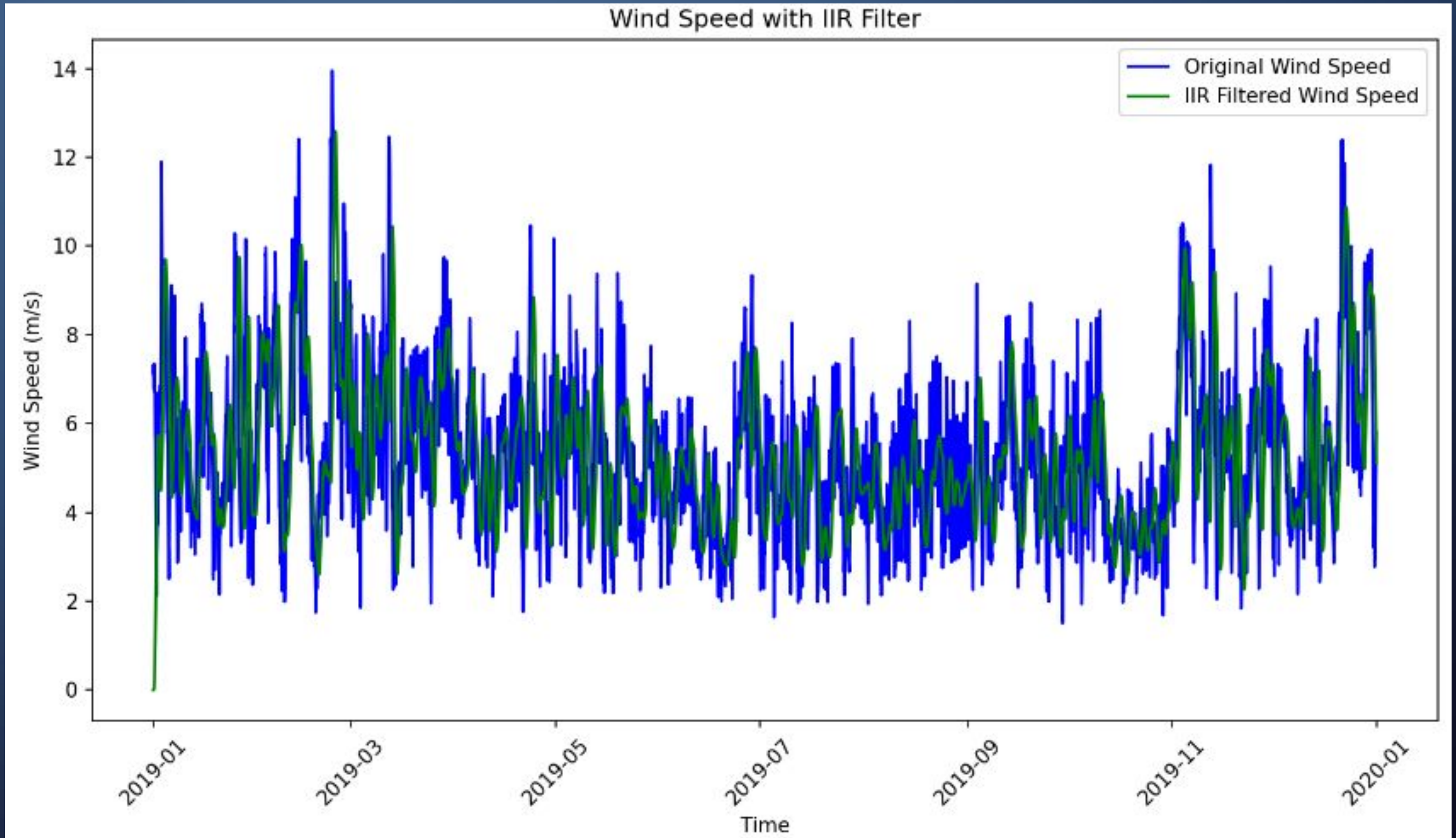


WIND SPEED WITH IIR FILTER

Blue line - the original, unfiltered wind speed measurements

Green line - filtered wind speed using the IIR approach

Result: IIR filters tend to provide better frequency response with fewer coefficients.

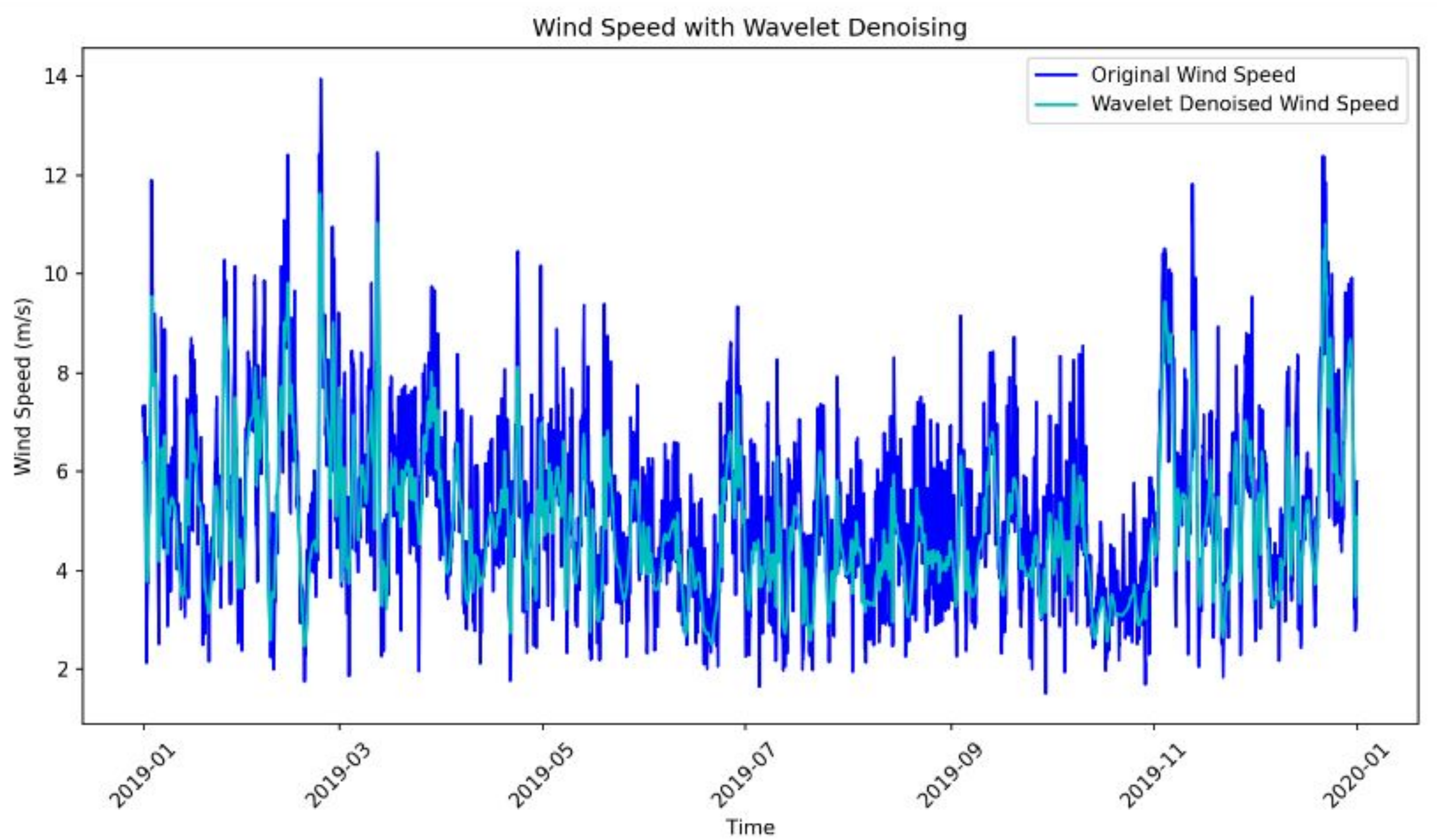


WIND SPEED WITH WAVELET DENOISING

Blue line - the original wind speed readings

Cyan line – denoised signal

Result: this technique effectively smooths the data while preserving the key fluctuations in wind behavior

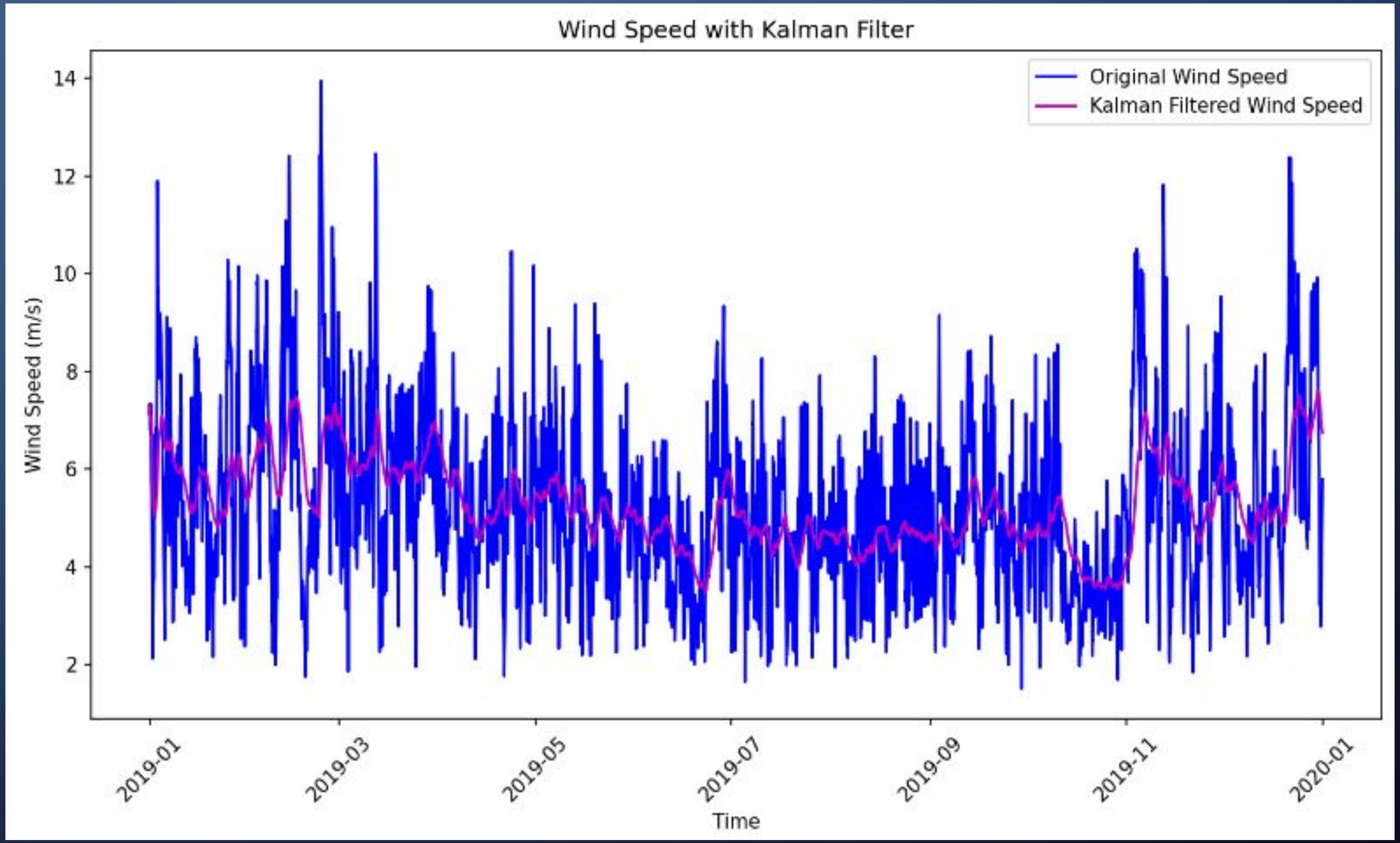


WIND SPEED WITH KALMAN FILTER

Blue line - the original wind speed

Pink line – Kalman filtered wind speed

Result: dynamically adjusts its predictions based on past values and measurement uncertainties, making it particularly effective for tracking time-series data like wind speed



COMPARISON OF THE FILTERS

Finite Impulse Response (FIR) filters

- Ideal choice when the signal integrity is a priority.
- Fixed coefficients and rely only on past input values
- Computationally expensive compared to IIR filters
- Less suitable for real-time applications where computational efficiency is crucial

Infinite Impulse response (IIR) filters

- Efficient in removing unwanted noise using fewer coefficients
- Perfect for real-time applications where computational resources are limited
- The output depends on the current and past outputs enabling stronger noise reduction effect for lower cost
- Downside: phase distortion, instability

Wavelet transform

- Decomposes the signal into different frequency components allowing selective noise removal
- Superior when dealing with non-stationary signals
- Adapts different frequency bands, ensuring that the essential components of the signal remain intact
- Limitation: can introduce distortions in regions with sharp signal transitions

Kalman filters

- Can dynamically adapt to changes in the system
- Continuous updates its internal model based on new observation
- Advantage: ability to minimize noise while preserving the true underlaying signal
- Provides optimal estimation of the system state
- Disadvantage: higher cost, knowledge of the systems noise characteristics

CONCLUSION

- Noise filtering is essential for improving the quality of wind data.
- Enhancing wind signals directly impacts the efficiency of energy systems.
- Environmental conditions play a crucial role in turbine performance.
- The use of advanced digital filtering methods enables more reliable forecasting.
- An interdisciplinary approach enhances energy management.
- This study contributes to the development of more efficient green technologies and supports the sustainable management of energy resources, serving as a foundation for future research in artificial intelligence and energy system modeling.

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THANK YOU FOR YOUR ATTENTION

QUESTIONS?