Application of FFT and Fourier Regression Methods to Predict Wind Patterns in Ogan Ilir Regency and Identify Possible Development of Wind Power Plant

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1. Abstract

Wind Power Plant is a renewable energy that could help preserve the environment in the long run. One of the district in Indonesia’s South Sumatera province, Ogan Ilir, have been having a strong wind phenomenon for the last couple of weeks. Data taken from Indonesia’s Badan Pusat Statistik (Central Statistics Agency) about wind speed in Ogan Ilir can be processed and identified for potential of Wind Power Plant using the numeric methods of Fast Fourier Transformation and Fourier Regression with the help of Matlab software. In this study, the potential of having wind power plant in Ogan Ilir is low as there is not enough strong wind to keep the turbines generating power throughout the entire year.

Keywords: *Fast Fourier Transformation (FFT), Fourier Regression, Ogan Ilir Wind Power Plant, Matlab*

2. Introduction

Indonesia is a productive country in maritime terms (Rachman et al., 2024). This implies that Indonesia's territorial waters must have enough wind power for fishermen to sail their ships. Wind is a driving factor in ecology (Viúdez-Moreiras et al., 2022). The ecology and evolution of plants are influenced by wind (Kling & Ackerly, 2021). Energy production from wind farms is considered environmentally friendly because the conversion of wind energy into electricity does not produce direct emissions of hazardous materials (Kanser et al., 2020).

Ogan Ilir is one of the regencies in South Sumatra Province. Ogan Ilir is located on the eastern Sumatra route and its center of government is located about 35 km from Palembang City. This regency is a division of Ogan Komering Ilir Regency. Geographically, the term OGAN ILIR is associated with the existence of its territory located in the lower reaches of the Ogan River (oganilirkab.go.id/page/sejarah-ogan-ilir, 2022). In recent weeks, Ogan Ilir has experienced strong winds, which have significantly impacted daily activities in the region. This geographical conditions highlights the crucial role of wind forecasting in predicting and mitigating potential risks.

Based on research conducted by Valdivia-Bautista, et al., (2023), forecasting wind is one of the most important thing for reducing the negative impact of wind energy. Compared to the common forecasting methods, such as ARX, ARMA, ARIMA, ANN, ADALINE, FNN, MLP, RNN, and RBF, simpler approaches like Fast Fourier Transform (FFT) and Fourier regression offer an alternative perspective in wind speed forecasting. While traditional statistical and machine learning models rely on time series decomposition, autoregressive structures, or neural network training, FFT and Fourier regression focus on frequency domain analysis to capture periodic patterns in wind speed data. These methods can be computationally efficient and effective in cases where wind speed exhibits strong seasonal or cyclical components. However, their predictive accuracy may be limited when dealing with highly irregular or nonlinear patterns compared to deep learning and adaptive models that can better capture complex dependencies in the data. As such, the prediction of regional wind power generation is a particularly important (Li, et al., 2024). Even more so, as the regions with the highest wind energy potential in Indonesia are found in East and West Nusa Tenggara (www.asiawind.org, 2025), while the subject of this research is located in quite western part of Indonesia.

Mardianto, et al. (2021) said that Fourier Series are popular for modeling in mathematics and statistics, especially in relation to periodic functions, as it is a flexible approach that evaluates data patterns with seasonal oscillations or seasonal trends. Fourier Regression models can be applied in various case such as encryipting (Riccomagno, et al., 1997). The Fourier network regression model in this study demonstrates its ability to accurately forecast three important meteorological variables (Al-Aboosi, et al., 2024). Fourier transform can be implemented in various cases. In the case of (Khan, et al., 2021) Fourier can even be used to find solutions without trigonometric functions. FFT method proves to be an efficient tool for studying complex mechanical systems (Yavus and Karagulle, 2021). FFT method can be utilized as an innovative approach as done in another journal by (Wang, et al., 2023). The Fast Fourier Transform (FFT) algorithm is an efficient method and essential for various applications, including registration and analysis (Ewaidat, et al., 2024).

3. Experimental Section

The availability and quality of observational data are crucial for analysis (Wati, et al., 2025). As such, the data used in this research is gathered from Indonesia's Central Statistics Agency official website, a non-ministerial government institution that responsible directly to the President (ppid.bps.go.id). To analyze the collected data effectively, MATLAB is utilized to process and apply numerical methodsto ensure accurate pattern identification and system optimization.

MATLAB is a programming and numeric computing platform used by millions of engineers and scientists to analyze data, develop algorithms, and create models (www.mathworks.com). MATLAB can perform complex numerical calculations including the application of the Fourier Transform (Yoon, et al., 2020). MATLAB offers several advantages in system analysis and optimization (Hemeida, et al., 2024).

Months	Observation of Wind Velocity By Months at Climatology Station Class I Palembang (Knots)								
	Minimum			Average			Maximum		
	2023	2022	2021	2023	2022	2021	2023	2022	2021
January	-	-	1,00	2,70	3,20	11,00	10,00	13,00	17,69
February	-	-	1,00	3,40	3,90	11,00	14,00	2,00	2,60
March	-	-	1,00	2,70	3,20	11,00	10,00	9,00	24,60
April	-	-	1,00	1,40	3,00	2,08	10,00	9,00	22,16
May	-	-	1,00	1,20	2,60	1,66	6,00	8,00	20,80
June	-	-	1,00	1,90	2,10	1,79	8,00	7,00	23,70
July	-	-	1,00	2,00	2,50	2,40	7,00	27,00	22,80
August	-	-	1,00	2,70	2,70	2,42	7,00	11,00	22,80
September	-	-	1,00	3,70	2,90	4,97	11,00	13,00	21,58
October	-	-	1,00	2,80	3,00	2,20	8,00	8,00	15,00
November	-	-	1,00	1,30	2,60	1,90	10,00	7,00	10,60
December	-	-	1,00	1,50	1,80	5,00	10,00	9,00	25,20

Information Data :

Source: Meteorological, Climatological, and Geophysical Agency

Picture 3.1 Ogan Ilir Datasets from Indonesia's Statistical Agency Website

The basic equation used models the data y(t) with the basis functions:

$$y(t) = a_0 + \sum_{n-1}^{N}[a_n cos(n\omega t) + b_n sin(n\omega t)] \quad (1)$$

In the code, the design matrix X is constructed with the first column consisting of ones (for a_0), followed by columns of cos(nωt) and sin(nωt) for n=1,…,N. The coefficients are obtained through least squares regression (using the backslash operator in MATLAB), which mathematically aligns with the explained approach.

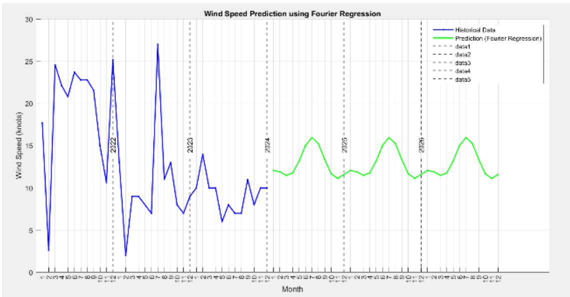
FFT (Fast Fourier Transform)

The basic formula is:

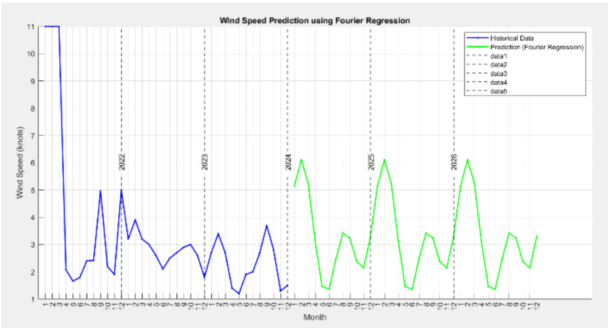
$$X[k] = \sum_{n=0}^{N-1} x[n]e^{-j\frac{2\pi}{N}kn}, k = 0,1,\ldots,N-1 \tag{2}$$

The code uses the built-in FFT function to compute the Fourier transform of the wind speed data. Subsequently, the result is scaled to obtain a one-sided spectrum, in accordance with standard FFT processing.

4. Results and Discussion

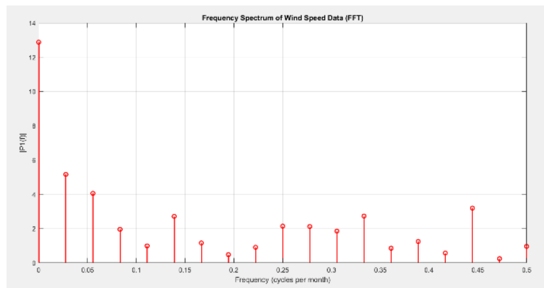


Picture 4.1 Maximum Wind Speed Prediction Using Fourier Regression in Matlab Software

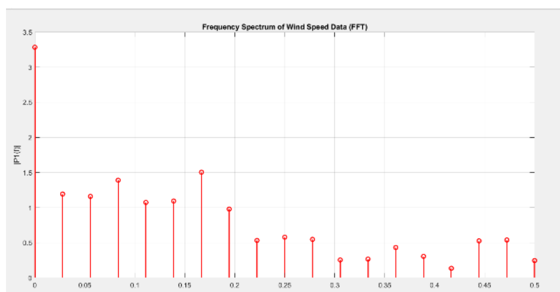


Picture 4.2 Average Wind Speed Prediction Using Fourier Regression in Matlab Software

The first figure, titled “Wind Speed Prediction using Fourier Regression,” depicts both the historical wind speed data (in blue) and the model-based forecasts (in green) over a three-year horizon. Vertical dashed lines denote yearly boundaries, providing clear demarcations of the historical period (2021–2023) and the forecasted period (2024–2026). The model’s use of two harmonics (N=2) and a fundamental annual frequency captures the principal seasonal pattern while also incorporating secondary fluctuations, resulting in a sinusoidal forecast that reflects an anticipated cycle of peaks and troughs. Although the forecast provides a strong representation of broad seasonal trends, it may not fully capture abrupt short-term anomalies or sharp transitions in wind speed. Overall, the FFT analysis confirms the presence of a dominant annual cycle in the data, while the Fourier regression approach leverages this periodicity to offer a forward-looking projection of wind speeds that is particularly useful for applications in meteorology, renewable energy, and risk mitigation planning.



Picture 4.3 Maximum Wind Speed Prediction Using Fast Fourier Transformation in Matlab Software



Picture 4.4 Average Wind Speed Prediction Using Fast Fourier Transformation in Matlab Software

The second figure, labeled “Frequency Spectrum of Wind Speed Data (FFT),” presents the one-sided amplitude spectrum |P1(f)| of the historical wind speed measurements as a function of frequency (in cycles per month). Each red stem corresponds to a distinct frequency component, with its height indicating the relative amplitude of that component. Notably, the plot often reveals a prominent peak near 0.083 cycles/month, corresponding to a 12-month cycle (one cycle per year), which underscores the strong seasonal periodicity in the wind speed data. Additional smaller peaks represent higher-frequency oscillations that may reflect more nuanced or shorter-term variations.

5. Conclusion

The application of the FFT method successfully identified periodic patterns in wind speed in Ogan Ilir Regency, the running results showed that there were predictable seasonal fluctuations. And the use of Fourier regression to produce a prediction model in the form of an accurate graph for wind speed variations, with a low average error compared to actual data. The combination of these two methods has proven effective in analyzing wind patterns and can be used as a planning tool for the development of wind power plants (PLTB), and predicting natural disasters, and other planning that is beneficial to humans. From the results of the analysis, it was found that the wind speed pattern in Ogan Ilir Regency has an average wind speed, which is lacking for planning wind power plants (PLTB), although the wind speed is low, it is still possible to build PLTB with the use of new, more advanced technology to create PLTB with wind turbines that can operate at low to medium wind speeds. The contribution and advantages of this study itself are studies that can contribute to the development of data-based predictions for the renewable energy sector in Indonesia, especially for the utilization of wind energy. In the frequency spectrum analysis-based approach, it can provide more insight than conventional statistical methods. The results of this study can be a reference for policy makers, academics, and investors in evaluating the feasibility of developing PLTB in the Ogan Ilir region or other areas with similar wind characteristics. In order to see wind changes that occur in a short time, it is recommended to collect data over a longer period of time and use more detailed data, such as hourly or daily. Additionally, wind speed predictions can become more accurate if some more sophisticated modeling techniques are used. This will improve energy planning and improve understanding of wind patterns.

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