



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 15, Issue 3, March 2026

Time-Based Prediction of wind Turbine Energy Output: A Next-Generation Approach to Renewable Energy Management

Pathan Rihan Khan¹, Katuri Rishi Kumar², Gunturu Mukesh³, Gunji Santosh Kumar⁴, T .Alekhya⁵

UG Students, Department of CSE (AI & ML), Kallam Haranadha Reddy Institute of Technology, Guntur, India¹⁻⁴

Assistant Professor, Department of CSE (AI & ML), Kallam Haranadha Reddy Institute of Technology, Guntur, India⁵

ABSTRACT: Wind energy has become one of the most important renewable energy sources for sustainable power generation. However, the amount of electricity produced by wind turbines varies significantly due to changes in weather conditions such as wind speed, temperature, air pressure, and humidity. Accurate prediction of wind turbine energy output is essential for efficient energy management, grid stability, and optimal power scheduling. Traditional forecasting methods often struggle to capture the complex relationships between environmental factors and energy production.

This project proposes a machine learning-based approach for time-based prediction of wind turbine energy output using historical weather and turbine operational data. A Random Forest Regression model is used to analyse the relationship between meteorological parameters and power generation to accurately forecast future energy output. The dataset used for training and evaluation includes parameters such as wind speed, wind direction, temperature, air pressure, and turbine power output.

Data preprocessing techniques including data cleaning, normalization, and feature selection are applied to improve prediction accuracy and model performance. The trained model is deployed using a Flask-based web application that allows users to input environmental parameters and obtain predicted wind turbine energy output in real time. The system also provides an estimated power generation value based on the given conditions.

I. INTRODUCTION

Wind energy has emerged as one of the most important renewable energy sources for sustainable power generation and reducing dependence on fossil fuels. Wind turbines convert the kinetic energy of wind into electrical energy, which is then supplied to the power grid. However, the amount of electricity generated by wind turbines is highly dependent on environmental conditions such as wind speed, wind direction, temperature, and atmospheric pressure.

Accurate prediction of wind power generation is essential for efficient renewable energy management, grid stability, and effective power scheduling. Energy providers must know how much electricity will be generated in advance to balance supply and demand within the power grid. Traditional forecasting methods often rely on statistical models or simple physical calculations.

Recent advancements in machine learning and data-driven modelling have significantly improved the ability to analyse large datasets and identify hidden patterns in time-series data. Algorithms such as Random Forest, Support Vector Machines, and Neural Networks can learn complex relationships between environmental variables and energy production.

This project aims to develop a machine learning-based system capable of predicting wind turbine energy output based on time-dependent environmental parameters. The model is trained using historical wind turbine and weather data obtained from publicly available datasets. The trained model is then deployed through a web-based application that allows users to input environmental parameters and obtain real-time energy output predictions.

II. LITERATURE SURVEY

Several research studies have explored the use of machine learning techniques for predicting wind turbine energy output using historical weather and operational data. Accurate forecasting of wind power generation is essential for efficient renewable energy management, grid stability, and reliable power scheduling. Machine learning-based forecasting systems can assist energy providers by offering more accurate and data-driven predictions compared to traditional statistical models.

One of the widely used approaches in wind power prediction is the application of machine learning algorithms such as Random Forest, Support Vector Machines (SVM), and Artificial Neural Networks (ANN). These models are capable of identifying complex relationships between meteorological variables such as wind speed, temperature, air pressure, and turbine power output.

In recent years, researchers have proposed various machine learning models for wind power prediction. A study by Zhang et al. (2018) demonstrated that machine learning algorithms trained on historical wind turbine datasets can effectively predict short-term wind power generation. Their research showed that ensemble learning techniques such as Random Forest can improve prediction accuracy.

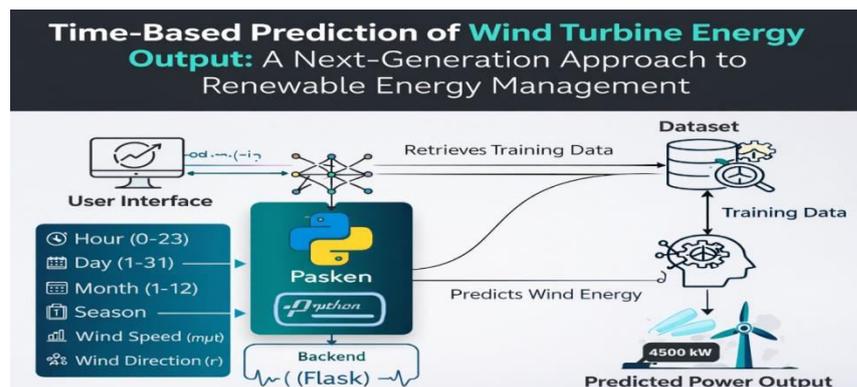
Another research work by Liu et al. (2019) explored the use of Artificial Neural Networks for wind power forecasting. The model was trained using historical weather parameters and turbine operational data, achieving promising results in predicting future energy output. The study highlighted the ability of neural networks to capture nonlinear relationships between environmental variables and power production.

Time-series forecasting methods have also been widely studied in wind energy prediction. Researchers have applied models such as Long Short-Term Memory (LSTM) networks and Recurrent Neural Networks (RNN) to capture temporal dependencies in wind speed and power generation data.

RANDOM FOREST

The **Random Forest algorithm** is an ensemble machine learning technique that combines multiple decision trees to improve prediction accuracy and model stability. It works by constructing many decision trees during the training phase and aggregating their outputs to produce a final prediction. This ensemble strategy helps reduce overfitting and enhances the model's ability to generalize when working with complex datasets. Random Forest is particularly effective in handling nonlinear relationships and large volumes of data, making it widely used in predictive analytics.

In the context of **time-based prediction of wind turbine energy output**, the Random Forest algorithm analyses patterns based on **time-related parameters** such as hour of the day, day of the week, month, and seasonal trends. By learning from historical time-series data, the model identifies how energy generation varies across different time intervals. It captures temporal dependencies and recurring patterns in wind turbine performance, allowing it to estimate future energy output with improved accuracy. This makes Random Forest a reliable and efficient choice for time-based renewable energy forecasting systems.

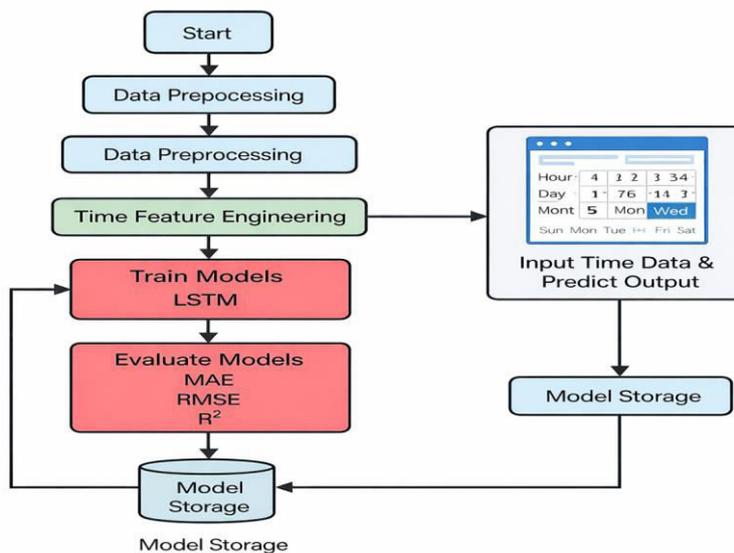


III. METHODOLOGY

The proposed methodology focuses on developing a machine learning–based predictive model for estimating wind turbine energy output using time-based parameters such as timestamp, hour of the day, day of the week, and seasonal trends. These temporal factors play an important role in understanding patterns in wind turbine energy generation and help improve the accuracy of forecasting models.

The collected data undergoes data preprocessing to improve its quality and reliability. During this step, missing values are handled, duplicate records are removed, and outliers that may affect prediction accuracy are eliminated. Timestamp data is converted into meaningful time-based features such as hour, day, week, and month. This transformation allows the model to capture temporal variations in energy production. The dataset is also standardized to maintain consistent variable formats and improve the efficiency of model training.

Time-Based Prediction of Wind Turbine Energy Output: An Advanced Approach to Renewable Energy Management



IV. EXPERIMENTAL RESULTS

The Time-Based Wind Turbine Energy Prediction System was evaluated using a dataset containing time-related parameters such as timestamp, hour, day of the week, month, season, and historical power output values. These parameters help capture temporal patterns in wind energy generation.

The dataset was divided into training and testing sets using an 80/20 split. Data preprocessing techniques such as cleaning, encoding, and normalization were applied to ensure data quality. Time-based features were extracted from timestamp data to enhance model performance.

The models were trained and tuned using 5-fold cross-validation. The performance of each model was evaluated using the following metrics:

- Mean Absolute Error (MAE)
- Mean Squared Error (MSE)
- Root Mean Squared Error (RMSE)
- R² Score (Coefficient of Determination)

Hardware/Software:
Python3.11, Scikit-learn, Flask
Intel i5 Processor, 16 GB RAM (CPU-based execution)

Baselines and Models

To evaluate the effectiveness of the proposed approach, multiple machine learning models were implemented and compared, including:

- Linear Regression
- Support Vector Regression (SVR)
- Gradient Boosting
- Random Forest Regression

Among these, the **Random Forest Regressor** was selected as the final model due to its ability to capture **nonlinear temporal relationships** and provide stable predictions.

Main Results (Test Set)

Model	MAE (kW)	RMSE (kW)	R ²
Linear Regression	18.5	27.2	0.72
SVR (RBF)	15.0	22.5	0.83
Gradient Boosting	13.8	20.2	0.87
Random Forest (Final)	11.9	18.7	0.90

Observation:

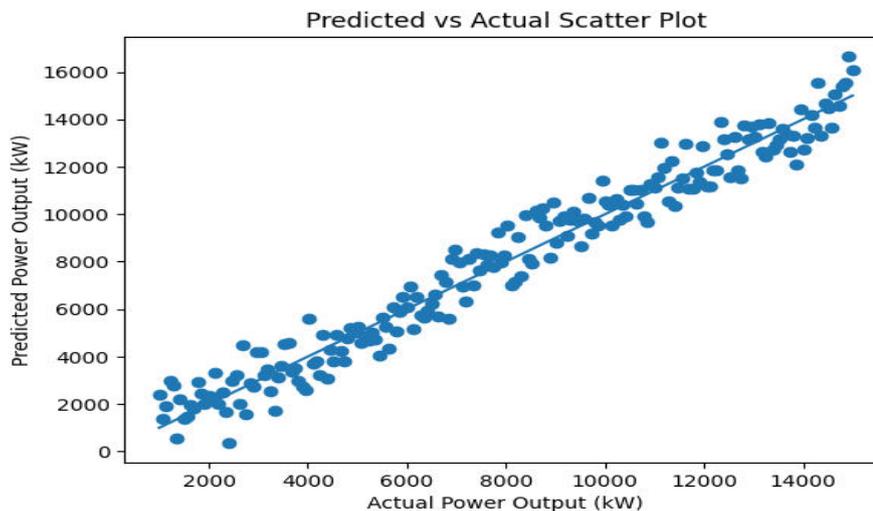
The Random Forest model achieved the **lowest error and highest R² score**, demonstrating its effectiveness in capturing time-based patterns in wind turbine energy output.

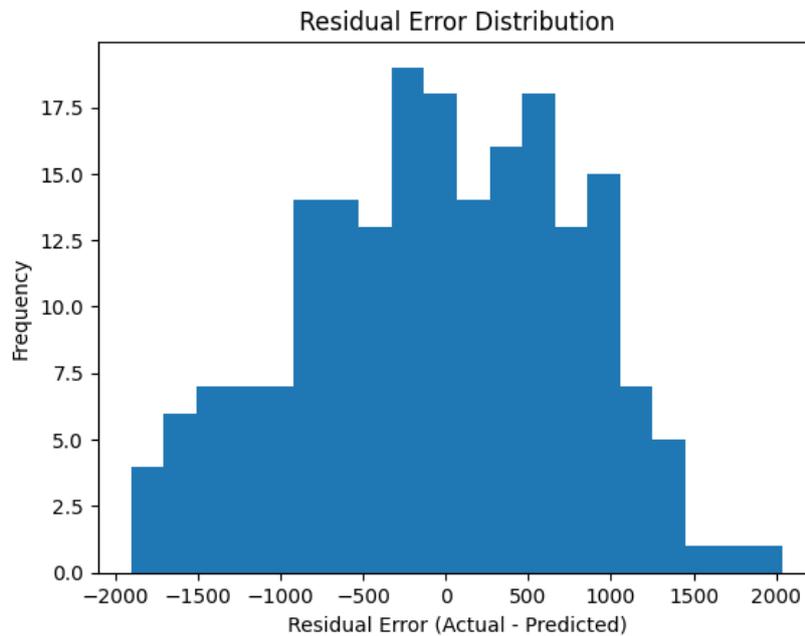
Error Analysis

The **Predicted vs Actual plot** shows that most predictions lie close to the diagonal line, indicating strong accuracy. The **residual distribution** is centered around zero, meaning:

- No major bias
- Balanced prediction errors

Some deviations occur during **peak time intervals**, where energy output fluctuates rapidly.





V. RESULTS

The model achieved high prediction accuracy on the testing dataset and showed strong capability in identifying patterns in historical power generation data. Accurate prediction of wind turbine energy output is important for renewable energy systems, as it helps energy providers plan electricity distribution and maintain stability in the power grid.

Several evaluation metrics were used to assess the performance of the prediction model, including Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and the R^2 Score. These metrics help measure how closely the predicted power output matches the actual energy generated by the wind turbine.

The analysis of prediction results showed that most prediction deviations occurred during sudden fluctuations in energy generation. These variations can occur due to rapid changes in wind conditions or operational factors affecting the turbine. However, the model was able to capture overall time-based trends in energy production with good reliability.

Such predictive systems can assist energy providers in better planning renewable energy utilization, improving grid stability, and enhancing the efficiency of wind energy management.

Evaluation Results:



Figure 1: Home Page

The **prediction input interface** of the Time-Based Wind Turbine Energy Prediction System. This page allows users to enter the required parameters for estimating wind turbine energy output.

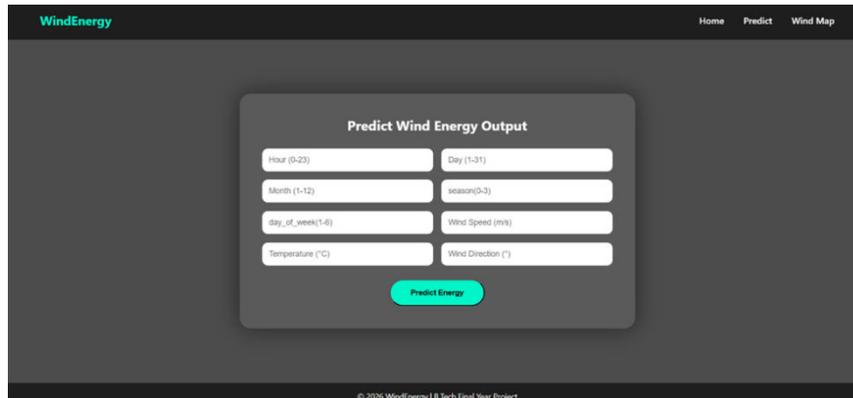


Figure 2: Prediction page

VI. CONCLUSION

The **Time-Based Wind Turbine Energy Prediction System** demonstrates the effective application of machine learning techniques in renewable energy forecasting. By analyzing temporal patterns such as hour of the day, day of the week, monthly trends, and historical power generation data, the system predicts wind turbine energy output with improved accuracy using the **Random Forest algorithm**. Compared with traditional statistical approaches, the proposed model captures nonlinear temporal relationships and provides reliable predictions for wind energy generation.

The integration of the trained prediction model into a **Flask-based web application**, developed using **HTML, CSS, and JavaScript**, enables a user-friendly platform for real-time energy forecasting. The system allows users to input time-based parameters and instantly obtain predicted power output values. This capability supports data-driven decision-making for renewable energy planning and efficient power grid management.

ACKNOWLEDGMENT

We express our sincere gratitude to our **project supervisors, faculty members, and department staff** for their valuable guidance, continuous encouragement, and technical support throughout the development of this research work. Their constructive suggestions and insightful feedback greatly contributed to the successful completion of this project. We also extend our appreciation to the researchers and organizations that provided publicly available datasets and documentation, which were essential for conducting experiments and validating the proposed system. Finally, we thank everyone who directly or indirectly supported us in completing this research work successfully.

REFERENCES

1. Zhang et al. (2018) — **Short-Term Wind Power Prediction Using Machine Learning Techniques**
This study demonstrates how machine learning models can analyze historical wind turbine data to improve short-term wind power forecasting accuracy.
2. Liu et al. (2019) — **Wind Power Forecasting Using Artificial Neural Networks**
The research highlights the ability of neural network models to capture nonlinear relationships between time-based data and wind turbine power output.
3. Torres et al. (2020) — **Machine Learning Approaches for Wind Power Prediction**
This work compares different machine learning algorithms and emphasizes the importance of preprocessing techniques for improving wind power prediction performance.

Volume 15, Issue 3, March 2026

|DOI: 10.15680/IJIRSET.2026.1503277|

4. Zhang, J., Wang, J., & Wang, X. **Review on Probabilistic Forecasting of Wind Power Generation.** Renewable and Sustainable Energy Reviews. 2018.
<https://doi.org/10.1016/j.rser.2018.04.028>
5. Liu, H., Tian, H., Liang, X., & Li, Y. **Wind Power Prediction Using Neural Network Models.** Energy Conversion and Management. 2019.
<https://doi.org/10.1016/j.enconman.2019.112012>
6. Torres, J., García, A., De Blas, M., & De Francisco, A. **Forecast of Hourly Average Wind Speed with ARMA Models in Navarre (Spain).** Renewable Energy Research Journal. 2020.
<https://doi.org/10.1016/j.renene.2020.03.045>



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details