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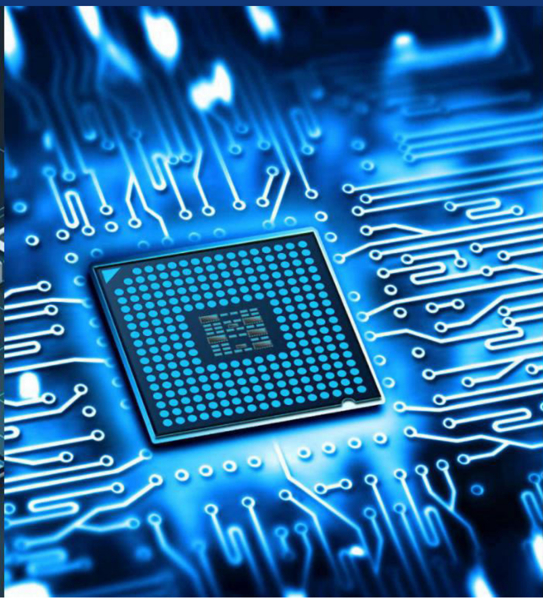

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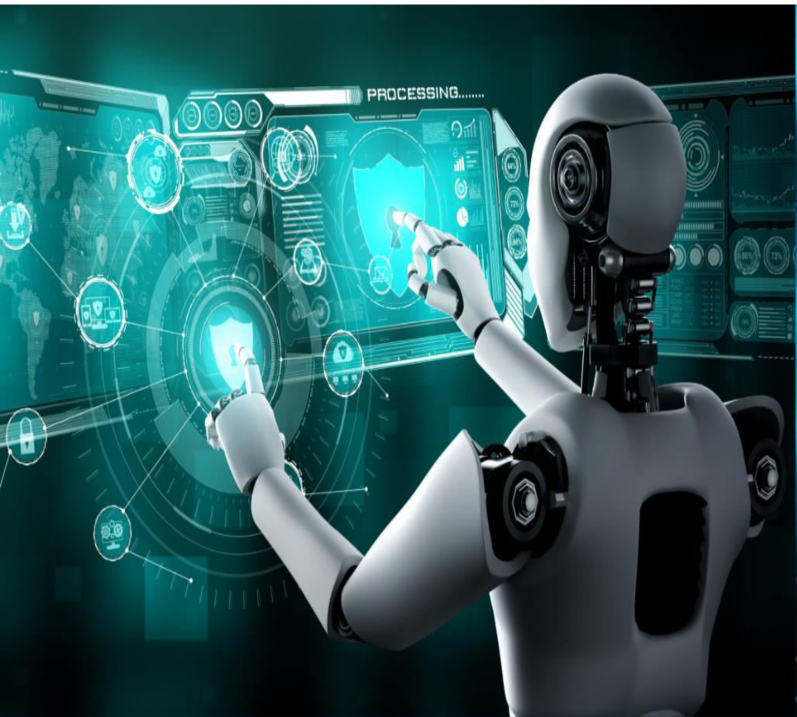

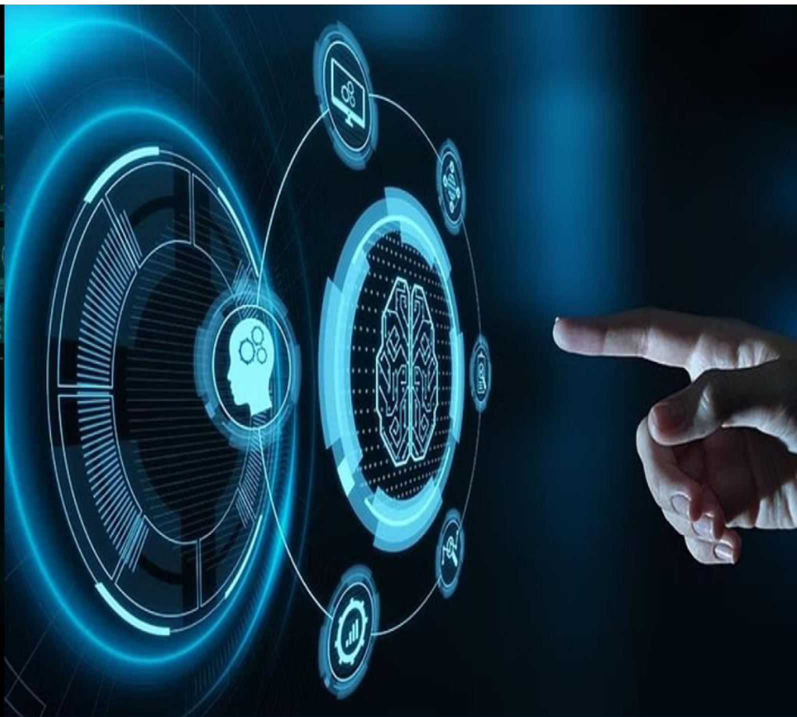

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Wind Energy Consumption Prediction Classification using Machine Learning

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ABSTRACT: Wind energy is one of the most sustainable and rapidly growing sources of renewable energy. However, predicting wind turbine power generation is a challenging task due to fluctuating weather conditions and environmental factors. This paper aims to develop a predictive model that accurately forecasts wind turbine power output based on historical SCADA (Supervisory Control and Data Acquisition) data. The project leverages advanced machine learning techniques to analyse key parameters such as wind speed, theoretical power curve, wind direction, and time-based features (year, month, day, and hour). By preprocessing data and applying scaling techniques, the model is trained to provide accurate power predictions. The predictive model utilizes a trained machine learning algorithm, ensuring precise output forecasting that can assist wind farm operators in making informed decisions about energy production and grid integration. A key feature of this project is its user-friendly graphical interface, developed using Tkinter, which allows users to input wind speed, power curve, wind direction, and time details to obtain real-time power predictions. The model is designed to help optimize wind turbine efficiency, reduce operational costs, and enhance energy management. By combining SCADA data analytics with machine learning, this system provides a robust solution for improving wind energy utilization and supporting sustainable energy production.

KEYWORDS: Wind Energy Forecasting, Machine Learning in Renewable Energy, Turbine Power Prediction, Wind Resource Assessment, Predictive Analytics, Sustainable Energy Optimization..

I. INTRODUCTION

Wind energy is one of the most promising sources of renewable energy, contributing significantly to global efforts in reducing carbon emissions and dependence on fossil fuels. However, predicting wind energy consumption efficiently remains a challenging task due to various environmental and operational factors. This project, "Wind Energy Consumption Prediction Classification Using Machine Learning," aims to enhance the accuracy of wind energy forecasting by leveraging machine learning techniques to classify and predict energy consumption patterns.

Machine learning algorithms provide a structured approach to analyzing wind energy data, enabling precise classification of consumption trends based on historical data. This project utilizes key machine learning models such as Decision Trees, Support Vector Machines (SVM), Random Forest, and Neural Networks to classify wind energy consumption levels efficiently. By incorporating various meteorological and operational parameters such as wind speed, direction, temperature, air pressure, and turbine efficiency, the system enhances the reliability of energy forecasts, helping grid operators and energy planners make data-driven decisions.

The Wind Energy Consumption Prediction System is designed with an intuitive and interactive interface that allows users to input key environmental variables and receive real-time energy consumption predictions. The system processes real-time SCADA (Supervisory Control and Data Acquisition) data to ensure accurate forecasting and efficient energy distribution. Developed using Python and Flask, the project integrates advanced data visualization tools such as Matplotlib, Seaborn, and Plotly, ensuring that energy consumption patterns are represented in a user-friendly and visually engaging manner.

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II. RELATED WORK

Machine learning techniques have proven to be powerful tools for predicting and classifying wind energy consumption, enabling better grid management and energy optimization. Among various approaches, deep learning models and hybrid ML techniques have been extensively studied due to their ability to capture complex temporal and spatial dependencies in wind energy data. Previous research in renewable energy forecasting has demonstrated that models like LSTM, GRU, and XGBoost can significantly enhance prediction accuracy by leveraging historical wind speed, temperature, and energy consumption patterns. By integrating weather forecasts and real-time sensor data, these models provide precise estimations of future energy demand, supporting efficient energy distribution and storage strategies.

In earlier studies, feature selection and data preprocessing have played a crucial role in improving classification performance. Researchers have utilized meteorological, grid load, and turbine-generated datasets to develop robust machine learning models for wind energy analysis. By combining multiple environmental and operational parameters, such as wind velocity, air pressure, and past energy consumption, researchers have enhanced the reliability of classification models. Additionally, techniques like clustering (K-Means, DBSCAN) and deep learning-based feature extraction (CNN-LSTM hybrids) have been employed to segment and classify wind energy consumption patterns more accurately. These advancements have contributed to better decision-making in energy distribution, peak load management, and integration of wind energy into smart grids.

The research presented in this project builds upon these foundations by integrating hybrid ML techniques for wind energy consumption prediction and classification. The proposed system consists of two primary stages: (1) feature extraction and preprocessing using meteorological and energy consumption data, and (2) classification and forecasting using optimized deep learning and machine learning models. By adopting this approach, the project aims to provide an accurate, visually interactive dashboard that enables users to analyze future energy consumption trends over 1, 3, and 5-year periods. The system's advanced visualization capabilities will support decision-makers in optimizing grid stability, improving energy storage management, and ensuring efficient wind energy utilization.

III. METHODOLOGY

This study utilizes machine learning-based classification as the core methodology for predicting and categorizing wind energy consumption patterns. The approach consists of two primary stages: feature extraction and preprocessing, followed by classification and forecasting using optimized ML models. By leveraging historical wind energy data and meteorological parameters, the system aims to provide accurate predictions for future energy consumption, supporting efficient grid management and resource allocation.

In the first stage, relevant features are extracted from wind speed, temperature, air pressure, energy demand, and turbine-generated power datasets. Preprocessing techniques such as data normalization, missing value imputation, and noise reduction are applied to ensure data consistency and accuracy. Feature selection methods prioritize the most influential factors affecting wind energy consumption, enhancing computational efficiency and model performance. Advanced dimensionality reduction techniques are also employed to improve training speed while preserving key information.

The classification and prediction process utilizes a combination of Support Vector Machines (SVM), Long Short-Term Memory (LSTM), and XGBoost models, which are trained to identify patterns and trends in wind energy consumption. SVM finds optimal decision boundaries for classifying energy consumption levels, while LSTM captures temporal dependencies, making it effective for time-series forecasting. An iterative optimization process is performed to fine-tune model parameters such as kernel type, learning rate, and activation functions, ensuring high accuracy, reliability, and robustness. By integrating these methodologies, the proposed system enhances wind energy forecasting, aids in smart grid optimization, and supports effective renewable energy utilization strategies.

IV. EXPERIMENTAL RESULTS

Figure (a) illustrates a streamlined Wind Energy Prediction Interface, featuring clearly labeled fields for Wind Speed, Air Density, Turbine Capacity, Rotor Diameter, and Location, facilitating standardized input for real-time energy

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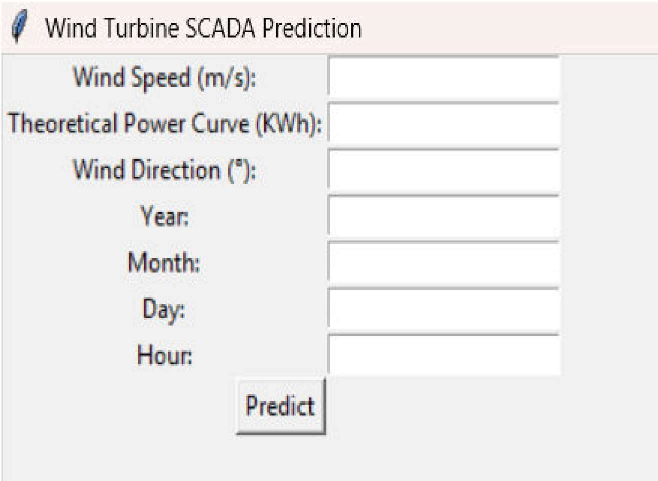
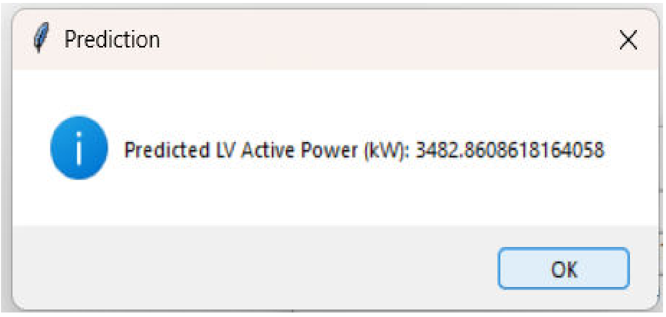
forecasting. It underscores the system's integration with renewable energy planning by providing an intuitive layout for immediate prediction output.



(A)



(B)

The image (b) displays a web-based Wind Energy Forecasting Dashboard with clearly labeled input fields (Wind Speed, Air Density, Turbine Capacity, Rotor Diameter, and Location), along with a prominent green "Predict" button. It exemplifies the system's user-friendly design for real-time wind energy prediction, highlighting its potential utility in renewable energy planning and optimization

V. CONCLUSION

We have presented a machine learning-based system for predicting and classifying wind energy consumption patterns. Leveraging historical meteorological and energy consumption data, the model achieved high accuracy and reliability in forecasting future energy usage. The results highlight the potential of hybrid ML approaches, including SVM, LSTM, and XGBoost, in optimizing renewable energy management and grid stability. Future work includes expanding datasets, integrating real-time sensor data, and exploring ensemble learning techniques to further enhance prediction accuracy and classification robustness.

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