Weather-Based Prediction of Wind Turbine Energy

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1. Introduction

- **Project Title: Wind Turbine Energy Prediction**
- **Team Members:**
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  - **Divya Sri Padala**

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2. Project Overview

- **Purpose:**
  The purpose of this project is to build a machine learning–based system that predicts wind turbine energy output using historical turbine data and live weather inputs.
- **Features:**
  - **Data preprocessing and cleaning.**
  - **Random Forest regression model for prediction.**
  - **Flask-based web dashboard for user interaction.**
  - **Integration with OpenWeather API for real-time weather data.**
  - **Visualization of actual vs predicted power outputs.**

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3. Architecture

- **Frontend:**
  Flask templates (HTML, CSS, JavaScript) used for UI design and dashboard visualization.
- **Backend:**
  Python Flask application handling API requests, ML model predictions, and weather data integration.
- **Database:**
  Local CSV dataset (T1.csv) for training and testing. Model stored as .sav file using Joblib. Future scope includes cloud database integration (MongoDB Atlas / AWS RDS).

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4. Setup Instructions

- **Prerequisites:**
  - **Python 3.9+**
  - **Flask**
  - **Pandas, NumPy, Scikit-learn, Matplotlib**
  - **Joblib**
  - **OpenWeather API key**
- **Installation:**

1. **Clone the repository.**
2. **Install dependencies using pip install -r requirements.txt.**
3. **Set up environment variables (API key for OpenWeather).**
4. **Run the Flask server with python app.py.**

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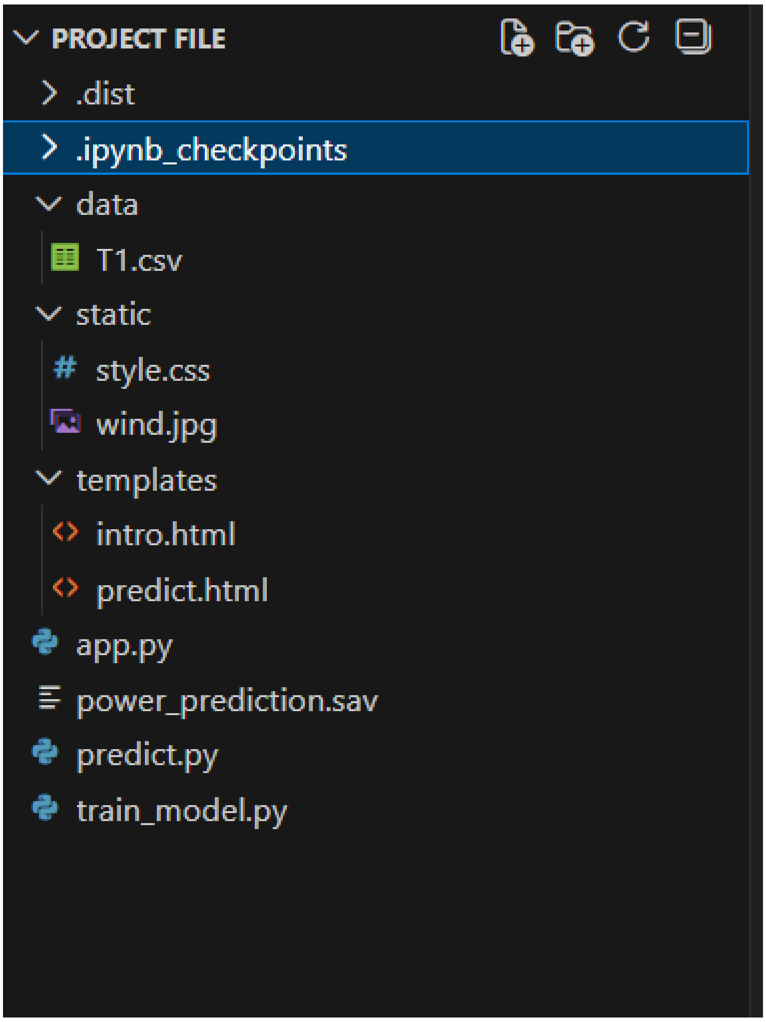
5. Folder Structure

- **Client (Frontend):**

    - templates/ → HTML files (intro page, dashboard).
    - static/ → CSS, JS, and images.
- Server (Backend):
    - app.py → Flask application.
    - model_training.py → ML model training script.
    - power_prediction.sav → Saved Random Forest model.
    - data/ → Dataset files.



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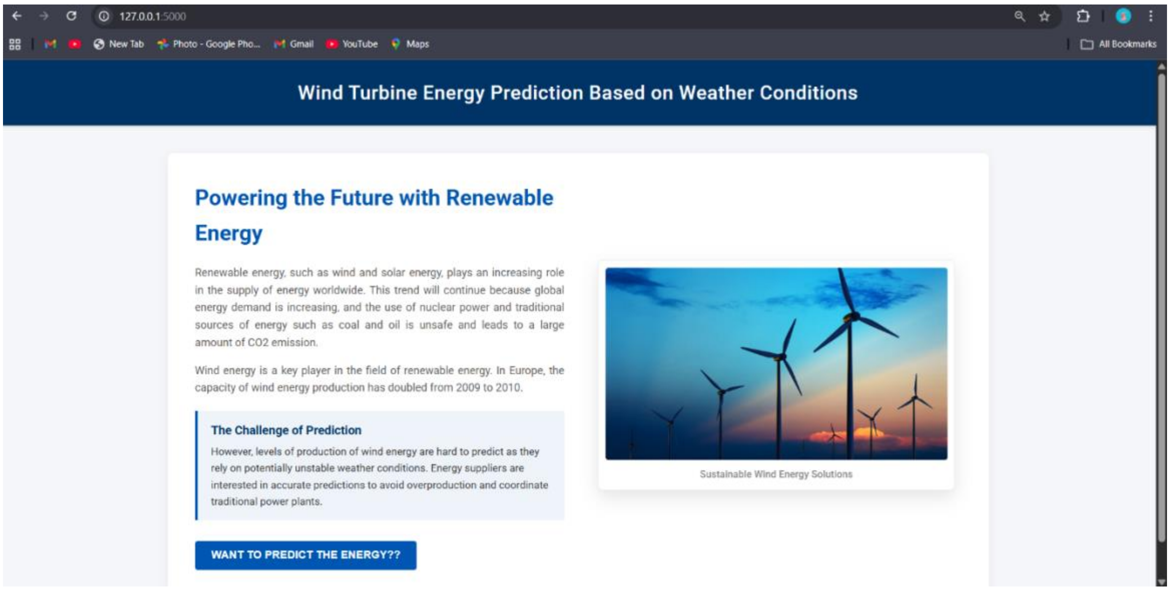
6. Running the Application

- Frontend: Runs automatically via Flask templates.
- Backend: Start with python app.py.
- Access at http://127.0.0.1:5000/.



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7. API Documentation

- **Endpoint 1: /predict**
  - **Method: POST**
  - **Parameters: TheoreticalPower, WindSpeed**
  - **Response: Predicted Active Power**
- **Endpoint 2: /weather**
  - **Method: GET**
  - **Parameters: City name**
  - **Response: Weather data (temperature, humidity, pressure, wind speed)**

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8. Authentication

- **Currently open access.**
- **API key required for OpenWeather API integration.**
- **Future scope: JWT-based authentication for secure access.**

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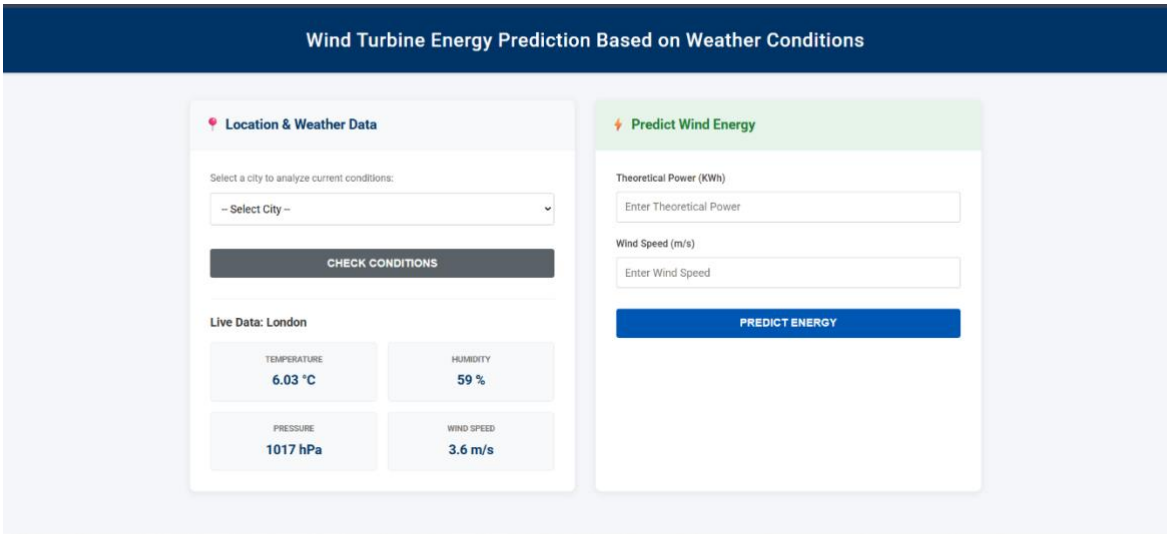
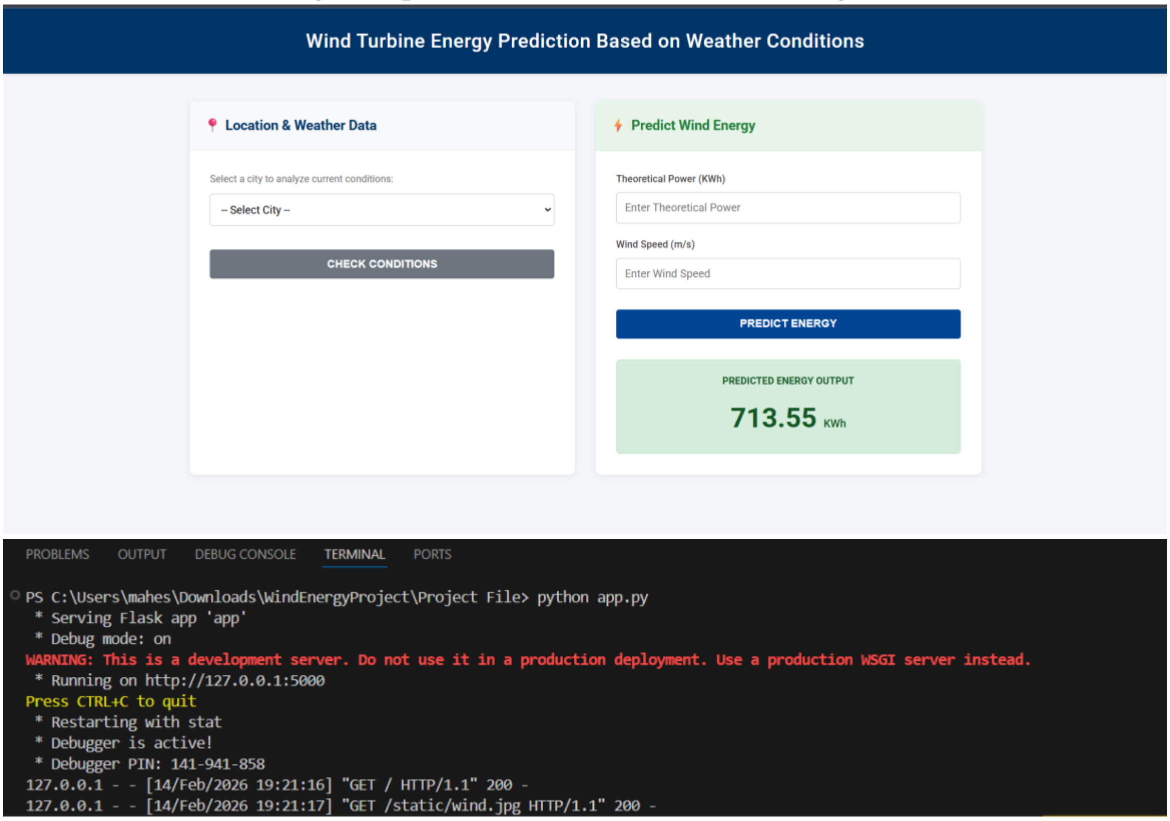
9. User Interface

- **Intro page with project overview.**
- **Dashboard with:**
  - **Weather data display.**
  - **Prediction module.**
  - **Visualization graphs.**



10. Testing

- **Unit testing for ML model predictions.**
- **API testing for weather data retrieval.**
- **Functional testing for input validation and dashboard navigation.**



11. Screenshots or Demo

- **Scatter plot of actual vs predicted power.**
- **Dashboard screenshot showing weather + prediction results.**
- **Line chart trends of wind speed vs power output.**

12. Known Issues

- **Limited dataset size may affect generalization.**
- **API errors if invalid city names are entered.**
- **No authentication for dashboard access (future enhancement needed).**

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13. Future Enhancements

- **Deploy on cloud (AWS/GCP/Azure).**
- **Add JWT authentication for secure access.**
- **Expand dataset for improved accuracy.**
- **Add more visualizations (heatmaps, time-series forecasting).**
- **Integrate grid demand APIs for real-time energy balancing.**

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14. Conclusion

The **Wind Turbine Energy Prediction project** successfully demonstrates the application of machine learning and data-driven techniques to solve a real-world renewable energy challenge. By leveraging historical turbine data, preprocessing methods, and a **Random Forest regression model**, the project achieves strong predictive accuracy, enabling stakeholders to forecast energy output with confidence.

The integration of a **Flask-based dashboard** and **OpenWeather API** ensures that predictions are not only technically sound but also accessible and user-friendly. Visualizations such as scatter plots, line charts, and correlation heatmaps further enhance interpretability, making the solution practical for energy companies, wind farm operators, and grid managers.

Through structured **Agile sprint planning, backlog management, and performance testing**, the project was executed with clarity and measurable progress. Testing confirmed the robustness of the model, while defect analysis and bug tracking highlighted areas for improvement.

Ultimately, this project provides a scalable foundation for future enhancements, including cloud deployment, advanced authentication, expanded datasets, and integration with grid demand APIs. It stands as a strong example of combining **data science, software engineering, and agile methodology** to deliver a solution that addresses both technical and customer-centric needs in the renewable energy sector.