PROJECT REPORT

Predicting the energy output of wind turbine based on weather condition

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INDEX:

1. Introduction

1.1 Project Overview

Wind energy plays an increasing role in the supply of energy worldwide.

The energy output of a wind farm is highly dependent on the weather conditions present at its site. We take energy prediction based on weather data and analyze the important parameters as well as their correlation on the energy output. To deal with the interaction of the different parameters, we use random forest regression of machine learning algorithms. The model obtained for energy prediction gives a very reliable prediction of the energy output for supplied weather data.

1.2 Purpose

♣ Accurate wind power forecasting reduces the need for additional balancing energy and reserve power to integrate wind power.

♣ For a wind farm that converts wind energy into electricity power, a real-time prediction system of the output power is significant.

♣ Wind energy plays an increasing role in the supply of energy worldwide

2. Literature Survey

2.1 Existing problem

♣ Turbines produce noise and alter visual aesthetics: Wind farms have different impacts on the environment compared to conventional power plants, but similar concerns exist over both the noise produced by the turbine blades and the visual impacts on the landscape .

♣ Sound and visual impact are the two main public health and community concerns associated with operating wind turbines. Most of the sound generated by wind turbines is aerodynamic, caused by the movement of turbine blades through the air.

2.2 References

[1] J. Kawahara and G. Hamarneh, “Multi-resolution-tract CNN with hybrid pretrained and skin-lesion trained layers,” in International Workshop on Machine Learning in Medical Imaging, pp. 164–171, Springer, New York, NY, USA, 2016.

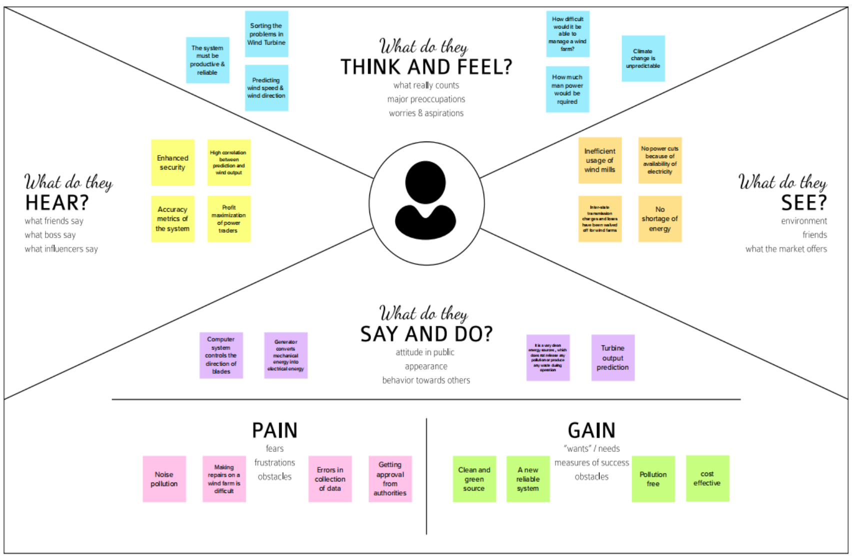
[2] S. Verma, M. A. Razzaque, U. Sangtongdee, C. Arpnikanondt, B. Tassaneetrithep, and A. Hossain, “Digital diagnosis of Hand, Foot, and mouth disease using hybrid deep neural networks,” IEEE Access, vol.
9, pp. 143481–143494, 2021.

[3] P. P. Rebouças Filho, S. A. Peixoto, R. V. Medeiros da Nobrega´ et al., “Automatic histologically-closer classification of skin lesions,” Computerized Medical Imaging and Graphics, vol. 68, pp. 40–54, 2018.

2.3 Problem Statement Definition

Wind power generation differs from conventional thermal generation due to the stochastic nature of wind. Thus, wind power forecasting plays a key role in dealing with the challenges of balancing supply and demand in any electricity system, given the uncertainty associated with the wind farm power output. Accurate wind power forecasting reduces the need for additional balancing energy and reserve power to integrate wind power

3.1 Empathy Map Canvas



3.2 Ideation and Brainstorming

3.3 Proposed Solution

The project team shall fill in the following information in the proposed solution template.

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	To predict the energy output of wind turbines.
2.	Idea / Solution description	In this project, a Machine learning approach is proposed for the power prediction of wind turbines based on wind flow and a prediction system is developed with a method of combining statistical models and physical models. In this system, the future prediction of wind farm is forecasted by the autoregressive model.
3.	Novelty / Uniqueness	➢ Finding weather conditions using city names can be performed on the same page. so that accurate prediction can be possible. ➢ Neat and clear GUI should be developed.
4.	Social Impact / Customer Satisfaction	➢ Energy suppliers are interested in accurate predictions, as they can avoid overproduction. ➢ Predicting wind energy will reduce the use of nuclear power sources and traditional sources of energy such as coal and oil. ➢ These will rapidly decrease the co_2 emission.
5.	Business Model (Revenue Model)	➢ Cost-efficient. ➢ Time consumption is very low. ➢ Easily portable. ➢ Only internet is required. ➢ This application is reliable. ➢ Easy to use.
6.	Scalability of the Solution	This website can be accessed by everyone who needs information regarding this prediction.

3.4 Problem Solution

CUSTOMER SEGMENTS(S) Electricity providers, industrialists, the government, and ordinary people	**CUSTOMER LIMITATIONS** • Which city energy do they want to predict • Internet connection • Web browser	**AVAILABLE SOLUTIONS** *(PROS AND CONS)* • A website is created which shows the accurate prediction of wind energy • Pros – reduce overproduction • Cons – web application
PROBLEMS/ PAINS *(ITS FREQUENCY)* • Prediction of future wind direction and wind speed • No proper platform for wind energy prediction	**PROBLEM ROOT/ CAUSE** • Existing solutions do not satisfy the customer's expectation • it tends to more customers to invest in windmills.	**BEHAVIOR ITS INTENSITY** Need to study more about wind power forecasting.
TRIGGERS TO ACT • Most energy suppliers are satisfied with renewable energy resource • It will reduce the emission of co_2. • Accurate prediction needed	**YOUR SOLUTION** A website is developed with a combination of ML algorithms that predicts wind energy using wind speed and wind direction The website has a user-friendly interface which means anyone can able to access the website and make benefit from it.	**CHANNELS OF BEHAVIOR** *(ONLINE)* Try to search it on google, YouTube, WhatsApp, and other platforms.
EMOTIONS *(BEFORE/ AFTER)* Before - Guilty, Frustrated After – Satisfied, Calm, happy		*OFFLINE* Ask field experts, and energy suppliers and refer to books in the library

4. Requirement Analysis

4.1 Functional requirements

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	User Registration	Registration through Form
FR-2	User Confirmation	Confirmation via Email
FR-3	Essentiality	• City name • Wind speed • Wind direction • Weather condition
FR-4	Output	Energy Predicated in KWh

4.2 Non-Functional requirements

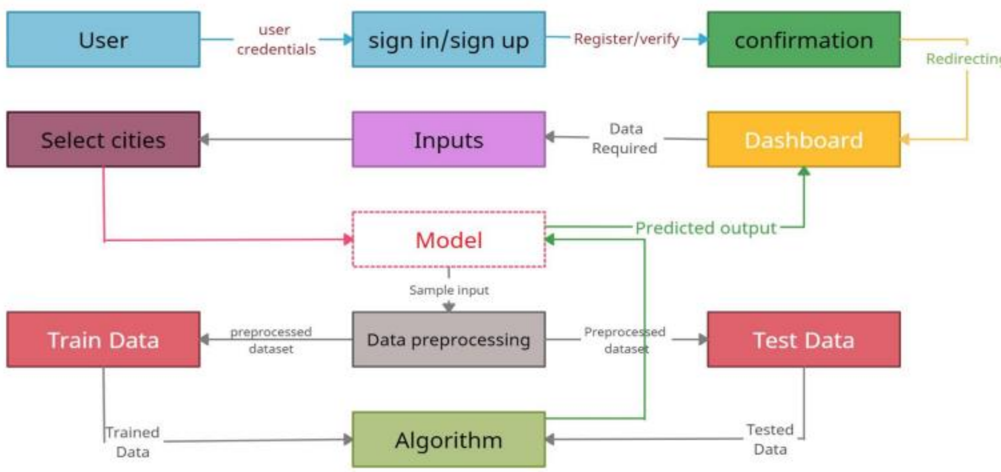
Following are the non-functional requirements of the proposed solution.

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	• Easy to learn • User friendly • Efficient
NFR-2	**Security**	Privacy - User can have Own accounts to secure their data.
NFR-3	**Reliability**	Wind Energy is reliable because it is both unlimited and domestic
NFR-4	**Performance**	Accuracy is high due to combination of multiple ML models to predict the output .
NFR-5	**Availability**	This is a web based application so we can access in any device that have a web browser with good Internet facility.
NFR-6	**Scalability**	It can be extended further to provide API which can be used by third party organisations such as Industries, Power suppliers , Governmental ,etc.

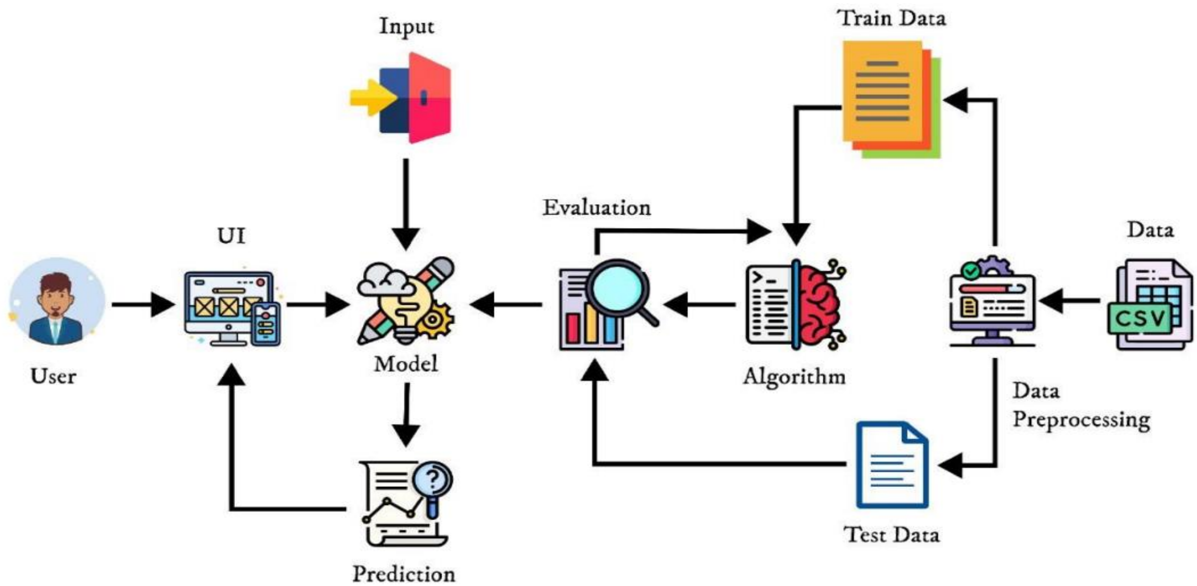
5. Project Design

5.1 Data Flow Diagram

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.



5.2 Solution and Technical Architecture



5.3 User Stories

Use the below template to list all the user stories for the product.

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	Sprint-1
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1
	Login	USN-3	As a user, I can log into the application by entering email & password	I can access the dashboard	High	Sprint-1
	Dashboard	USN-4	User can get information about wind energy. He can able to see a button called predict energy by clicking the button he can give input.	I can predict for single sample	High	Sprint-1
Customer (Web user)		USN-5	Once I enter the Dashboard I can give input values by choosing a city	I can predict the energy production of selected city	High	Sprint-1
		USN-6	As a user I can get visual representation of the prediction	I can have single output	High	Sprint-1
		USN-7	As a user I can view the detailed report of my prediction	I can access details of my process and prediction	Medium	Sprint-1
Customer Care Executive	Documentation	USN-8	As a helper I can refer the documentation for support and guidance	I can use user manual for guidance	Medium	Sprint-1,2, 3,4
Administrator	Settings	USN-9	As a developer I can access dashboard's settings and view the API token	I can view the API token for creating request	Low	Sprint-4
	Feedback	USN-10	As a developer I can able to view user feedbacks	I can customize these web page based on feedback	Medium	Sprint-4

6. Project Planning and Scheduling

6.1 Sprint Planning and Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email and password, and confirming my password.	5	High	BALAJI S
Sprint-1		USN-2	As a user, I can register for the application through a Mobile number.	3	Low	ARAVINDAN S
Sprint-1		USN-3	As a user, I can register for the application through Gmail	4	Medium	ARAVIND NAGARAJAN R
Sprint-1	Login	USN-4	As a user, I can log into the application by entering my email & password	5	High	ALDRIN JEFFERSON R
Sprint-2	Select City	USN-5	As a user, I should select the city to find the weather details of that city.	5	High	BALAJI S
Sprint-2	Weather Details	USN-6	As a user, I can view the current weather conditions of the selected city.	5	High	ARAVINDAN S
Sprint-3	User Input	USN-7	As a user, I should give the theoretical power and wind speed to predict the energy output.	5	High	ARAVIND NAGARAJAN R
Sprint-4	Energy Output	USN-8	As a user, I can view the predicted energy output of wind Turbines.	5	High	ALDRIN JEFFERSON R

Sprint-3	User details	USN-9	As an admin, I should store the details of the user.	6	Medium	BALAJI S
Sprint-2	Data Pre-Processing	USN-10	As an admin, I should clean and pre-process data using pandas.	5	High	ARAVINDAN S
Sprint-2		USN-11	As an admin, I should train and test the dataset using sklearn.	5	High	ARAVIND NAGARAJAN R
Sprint-3	Model Building	USN-12	As an admin, I should predict the accuracy of data using supervised machine learning.	12	High	ALDRIN JEFFERSON R
Sprint	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Story Points**	**Priority**	**Team Members**
Sprint-4	API	USN-13	As an admin, I should connect the presentation tier, logic tier, and data tier using python flask.	10	High	ALDRIN JEFFERSON R
Sprint-4	Notification	USN-14	As an admin, I should send the prediction chart via mail	5	Medium	ARAVIND NAGARAJAN R

6.2 Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	17	8 Days	22 Oct 2022	29 Oct 2022		
Sprint-2	20	4 Days	31 Oct 2022	03 Nov 2022		
Sprint-3	23	5 Days	04 Nov 2022	08 Nov 2022		
Sprint-4	20	4 Days	09 Nov 2022	12 Nov 2022		

7. Coding and Solutioning

App.py

import flask

from flask import request, render_template

```
from flask_cors import CORS
import joblib
import pandas as pd
from xgboost import XGBRegressor
app = flask.Flask(__name__, static_url_path='')
CORS(app)

@app.route('/', methods=['GET'])
def sendHomePage():
    return render_template('index.html')

@app.route('/predict', methods=['POST'])
def predictSpecies():
    ws = float(request.form['ws'])
    wd = float(request.form['wd'])

    X = [[ws,wd]]
    xgr=XGBRegressor()
    df = pd.DataFrame(X, columns=['WindSpeed(m/s)','WindDirection'])
    xgr.load_model('static/model/test_model.bin')
    result = xgr.predict(df)[0]
    print(result)
    return render_template('predict.html',predict=result)

if __name__ == '__main__':
    app.run()
```

Index.html

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8" />
    <meta http-equiv="X-UA-Compatible" content="IE=edge" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <title>WIND TURBINE ENERGY PREDICTION</title>
    <link rel="stylesheet" href="{{ url_for('static', filename='css/index.css') }}">
  </head>
  <body>
    <div class="container">
      <div class="glass">
        <h1 class="text" >WIND TURBINE <br>ENERGY PREDICTION</h1>
      <h2 class="text">Using XGBoost Model</h2>
        <br>
      <form method="POST" action="/predict">
        <p class="text">Wind Speed</p>
        <input name="ws" required />
        <p class="text">Wind Direction</p>
        <input name="wd" required />
        <br />
        <br />
        <button type="submit" class="submit">Submit</button>
      </div>
```

```
    </div>
  </body>
</html>
```

Predict.html:

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta http-equiv="X-UA-Compatible" content="IE=edge">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <link rel="stylesheet" href="./css/index.css" />
    <title>Prediction</title>
</head>
<body>

    <div class="container">
        <div class="glassdoor">
            <h1 class="text">The predicted Output power is</h1>
            <h1 class="highlight">{{predict}}</h1>
            <a href="/" class="submit">Go Back</a>
        </div>
      </div>
</body>
</html>
```

Index.css

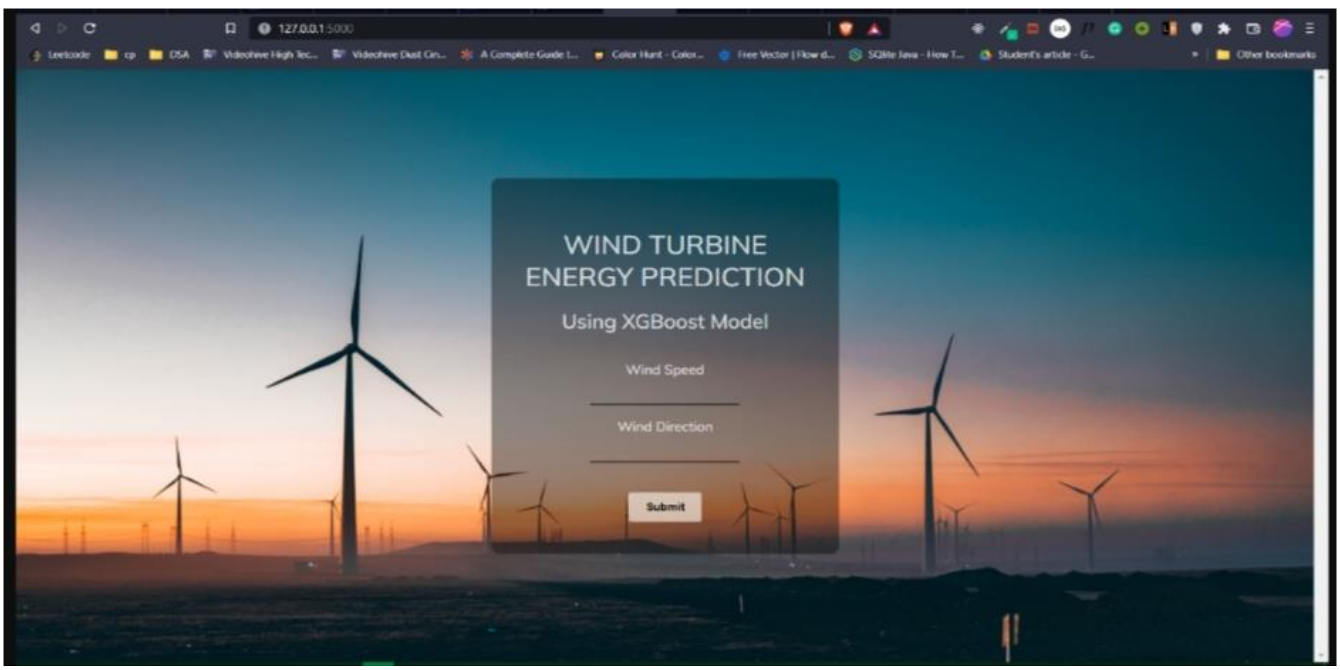
```
@import
url('https://fonts.googleapis.com/css2?family=Mulish:ital,wght@0,400;0,500;0,600;1,400;1,500
;1,600&display=swap');

html,
body {
  overflow-y: scroll;
  overflow-x: hidden;
  padding: 0;
  margin: 0;
}
body {
  height: 100vh;
  width: 100vw;
}
body {
  scrollbar-gutter: 10px;
}
.container {
  height: 100%;
  width: 100%;
  background-image: url("4.jpg");
  background-size: cover;
  background-repeat: no-repeat;


}
```

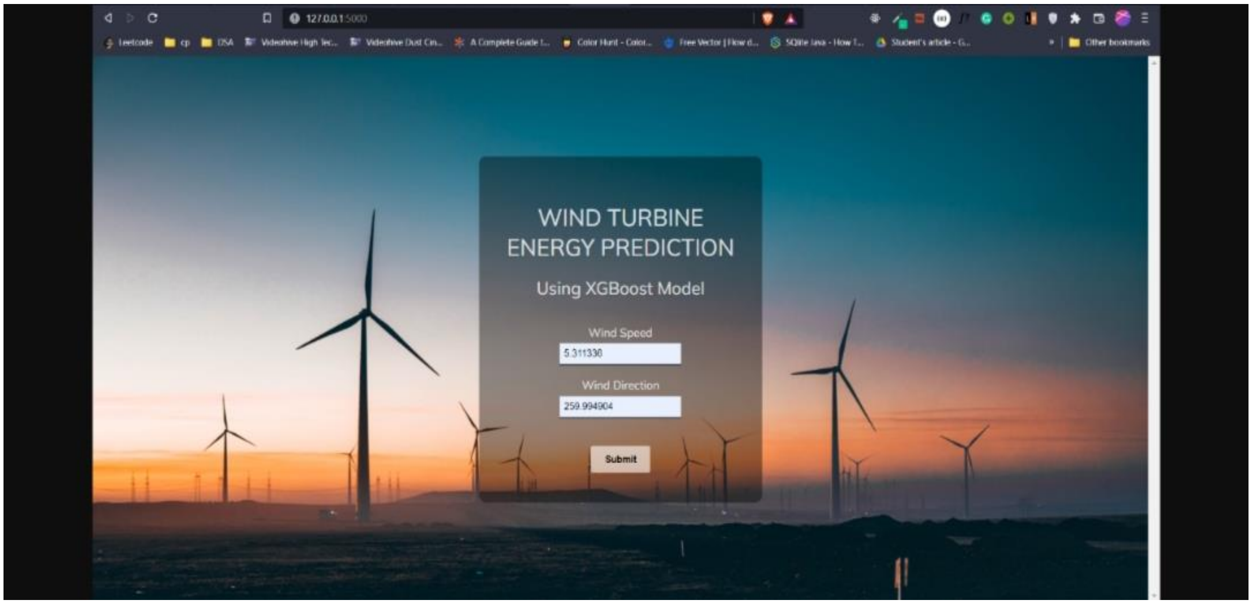
```
.container,form{
    display: flex;
    justify-content: center;
    align-items: center;
    flex-direction: column;
}
.glass,.glassdoor{
    padding: 40px;
    background-color: rgba(0,0,0,.4);
    border-radius: 10px;
}
.glassdoor{
    height: 200px;
    display: flex;
    flex-direction: column;
    align-items: center;
    justify-content:space-evenly;
    gap:10px;
}
input{
    margin-top: 5px;
    outline: 0;
    border: none;
    border-bottom: rgba(0,0,0,.7) 2px solid;
    background: transparent;
    padding: 6px;
    color:white;
}
input:focus{
```

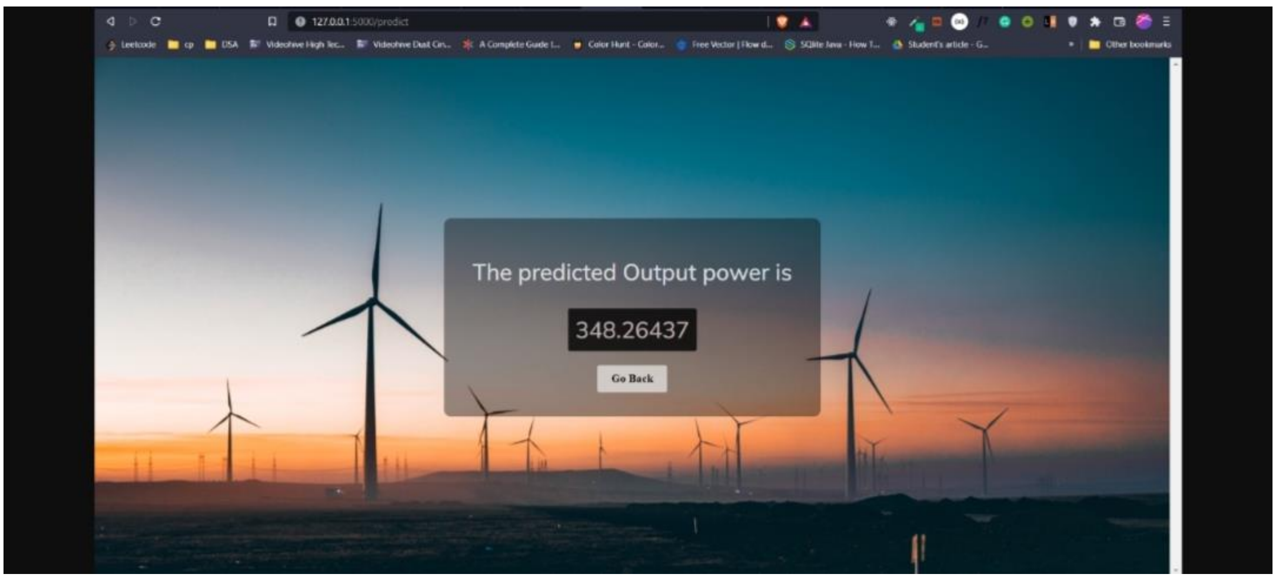
```
    margin-top: 5px;
    background-color: rgba(0,0,0,.45);
    border-bottom: transparent 2px solid;
    border: none;
    outline: 0;
    border-radius: 4px;
    padding: 6px;
}

.text{
    font-family: "Mulish";
    color:rgba(255,255,255,.8);
    margin-bottom: 0;
    font-weight: 500;
    text-align: center;
}
.highlight{
    font-family: "Mulish";
    color:rgba(225, 214, 214, 0.8);
    margin-bottom: 10px;
    font-weight: 500;
    padding: 10px;
    background-color: rgba(0,0,0,.8);
    border-radius: 3px;
}
.submit{
    padding:10px 20px;
    border-radius: 3px;
    border: 0;
```

```
    background-color:rgba(255,255,255,.6);
    font-weight: 600;
}
.submit:hover{
    cursor: pointer;
}
a{
    outline:none;
    text-decoration: none;
    color:inherit;
}
```

OUTPUT:




WIND TURBINE
ENERGY PREDICTION
Using XGBoost Model
Wind Speed
5.311330
Wind Direction
259.994904
Submit


The predicted Output power is
348.26437
Go Back

10. ADVANTAGES& DISADVANTAGES:

ADVANTAGES:

o Weather Underground Services provide very accurate Historical Weather Data which increased the accuracy of model.

o Website is more convenient to use due to zero storage.

o With Choosing city, Website can accurately predict power output using weather condition.

DISADVANTAGES:

♣ Weather API is paid and the free version provide limited API requests per day.

♣ Android Website can be deployed on IBM Cloud.

♣ No free server available on IBM Cloud for deploying Backend

10. Conclusion

Thus accurate wind power forecasting plays a key role in dealing with the challenges of power system operation under uncertainties in an economical and technical way. This unique approach would surely open up new avenues and make wind farm data more reliable and precise.

In our application only weather parameters are considered.

More updations can be done in the future if the application needs requirements.

Hopefully, the power of Machine Learning would boost the mass adoption of wind power and turn it into a popular alternative to traditional sources of electricity over the years

11. Future Scope

- Despite our model giving good results, we can add robustness to it by making it do the predictions for a greater time in the future.
- Our model can be scaled by governments by training our model with their data with better enhancements.
- Features like humidity and climatic changes should be considered to achieve better predictions.

12. Appendix

Git hub link:

https://github.com/IBM-EPBL/IBM-Project-3774-1658602298.git