

# PREDICTING THE ENERGY OUTPUT OF WIND TURBINE BASED ON WEATHER CONDITION

## IBM NALAIYATHIRAN REPORT :

Submitted by,

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Maximum Marks	8 Marks



**Loyola Institute Of Technology And Science - [LITES],  
Kanyakumari**

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## **1.INTRODUCTION :**

Wind speed/power has received increasing attention around the earth due to its renewable nature as well as environmental friendliness.

With the global installed wind power capacity rapidly increasing, the wind industry is growing into a large-scale business. Reliable short-term wind speed forecasts play a practical and crucial role in wind energy conversion systems, such as the dynamic control of wind turbines and power system scheduling.

A precise forecast needs to overcome problems of variable energy production caused by fluctuating weather conditions.

Power generated by wind is highly dependent on the wind speed. Though it is highly nonlinear, wind speed follows a certain pattern over a certain period of time. We exploit this time series pattern to gain useful information and use it for power prediction.

### **1.1 PROJECT OVERVIEW :**

#### **Category:**

Machine Learning

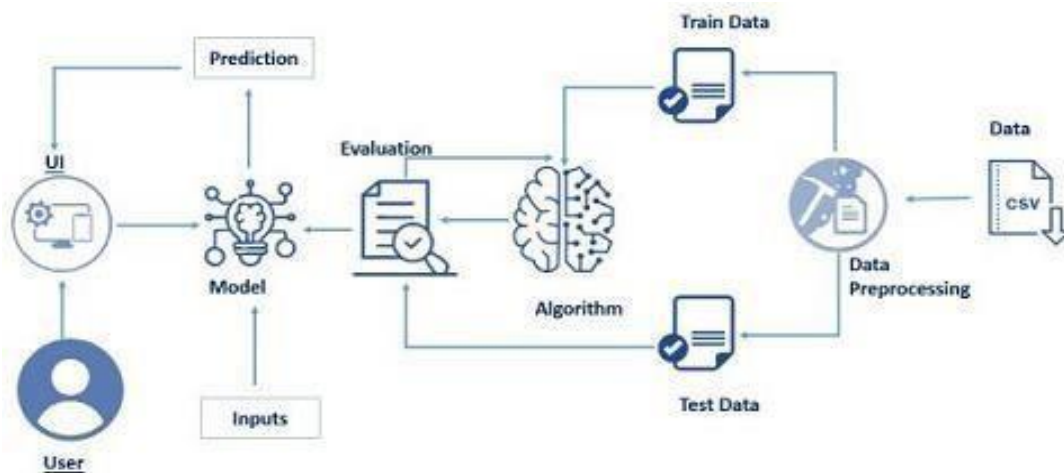
#### **Skills Required:**

Python, Python Web Frame Works, Python For Data Visualization, Data Preprocessing Techniques, Machine Learning, IBM Cloud, IBM Watson Studio, Python-Flask.

#### **Project Description:**

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. For a wind farm that converts wind energy into electricity power, a real-time prediction system of the output power is significant. In this guided project , a prediction system is developed with a method of combining statistical models and physical models. In this system, the inlet condition of the wind farm is forecasted by the auto regressive model.

## Technical Architecture:



### 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 :

We are going to deploy an application that will utilize multiple Watson AI Services including Cloud function, Watson Machine Learning and Node-RED/other web frame-work services. During the course of this project, we'll learn about combining Watson services, and how they can build interactive customer satisfaction interactive portals for prediction on current conditions.

### 1.2 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.

### 1.3 REFERENCE:

S.NO	TITLE	AUTHOR	YEAR	PROPOSED SYSTEM
1	A Multi-Step Prediction Method for Wind Power Based on Improved TCN to Correct Cumulative Error	Heifeng lu, Xun dou, Rong sun	2021	A Multi-step wind power prediction method was proposed by exploiting improved TCN to correct the cumulative error. First, multi-scale convolution (MSC) and self-attentiveness (SA) were adopted to optimize the problem that a single-scale convolution kernel of TCN is difficult to extract temporal and spatial features at different scales of the input sequence.
2	Remotely Sensed Winds and Wind Stresses for Marine Forecasting and Ocean Modeling	Mark A. Bourassa, Thomas Meissner, Ivana Cerovecki	2019	Remotely sensed surface winds (scalar winds and vector winds) with related material on surface stress, air-sea heat fluxes, currents, sea state, and precipitation.
3	Wind Generation Forecasting Methods and Proliferation of Artificial Neural Network	Muhammad Shahzad Nazir, Fahad Alturise, Sami Alshmrany	2020	Wind forecasting methods and the artificial neural network, The instrument used to measure wind assimilation is analyzed and discussed, accurately. The high forecasting accuracy could be achieved through proper handling and calibration of the wind-

				forecasting instrument and method.
4	Long term wind power forecast using adaptive wavelet neural network	Bhaskar-Kanna, Sn-Singh	2016	Mapping the NWP's wind speed and wind direction forecasts to wind power forecasts. Wind direction inherently being a circular variable, for better training and function approximation, a transformed version of wind direction variables are used as

				inputs.
5	Data mining for wind power forecasting	Lionel-Fugon, George-Kariniotakis, Jeremie-Juban	2008	Data Mining type of models for wind power forecasting. Models that are examined include neural networks, support vector machines, the recently proposed regression trees approach, and others. Evaluation results are presented for several real wind farms.

### 1.3.1.REFERENCES:

1. Luo H, Dou X, Sun R and Wu S (2021) A Multi-Step Prediction Method for Wind Power Based on Improved TCN to Correct Cumulative Error. *Front. Energy Res.* 9:723319. doi: 10.3389/fenrg.2021.723319.
2. Bourassa MA, Meissner T, Cerovecki I, Chang PS, Dong X, De Chiara G, Donlon C, Dukhovskoy DS, Elya J, Fore A, Fewings MR, Foster RC, Gille ST, Haus BK, Hristova-Veleva S, Holbach HM, Jelenak Z, Knaff JA, Kranz SA, Manaster A, Mazloff M, Mears C, Mouche A, Portabella M, Reul N, Ricciardulli L, Rodriguez E, Sampson C, Solis D, Stoffelen A, Stukel MR, Stiles B, Weissman D and Wentz F (2019) Remotely Sensed Winds and Wind Stresses for Marine Forecasting and Ocean Modeling. *Front. Mar. Sci.* 6:443. doi: 10.3389/fmars.2019.00443.
3. Nazir, Muhammad Shahzad, Fahad Alturise, Sami Alshmrany, Hafiz. M. J Nazir, Muhammad Bilal, Ahmad N. Abdalla, P. Sanjeevikumar, and Ziad M. Ali. 2020. "Wind Generation Forecasting Methods and Proliferation of Artificial Neural Network: A Review of Five Years Research Trend" *Sustainability* 12, no. 9: 3778. <https://doi.org/10.3390/su12093778>.
4. Bhaskar-Kanna, Sn-Singh, Long term wind power forecast using adaptive wavelet neural network(2016), doi.org/[10.1109/UPCON.2016.7894735](https://doi.org/10.1109/UPCON.2016.7894735).
5. Lionel-Fugon, George-Kariniotakis, Jeremie-Juban, Data mining and wind power

prediction(2008), Accepted 1 February 2012, Available online 29 March 2012.  
<https://doi.org/10.1016/j.renene.2012.02.015>.





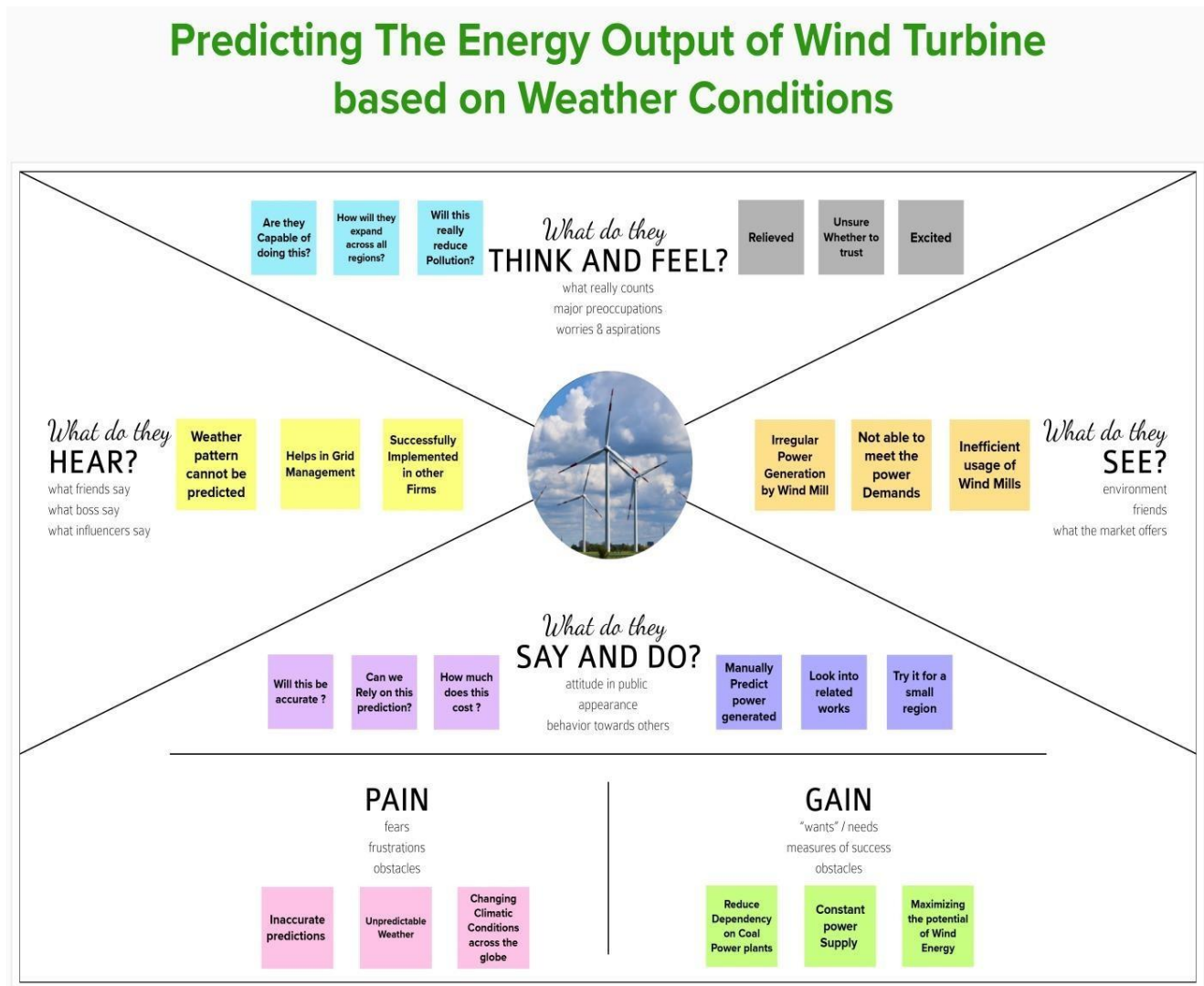
## 1.4 PROBLEM STATEMENT DEFINITION :

I am Manufacturer	I'm trying to Produce more amount of wind energy	But Don't know where to place the windmills	Because no analysis of the weather conditions	Which makes me feel concerned
I am A customer	I'm trying to Should have no power cuts and reliable energy	But I don't know whether wind energy is effective	Because no knowledge about the wind patterns in my region	Which makes me feel worried
I am organisation	I'm trying to production of wind energy	But I face overproduction and high cost issues	Because accurately can't able to predict the wind energy	Which makes me feel sad
I am a engineer	I'm trying to predict the energy output from the wind turbine	But it takes a long time	Because there is often error in the manual calculation	Which makes me feel Frustrated

### 3.IDEATION & PROPOSED

#### SOLUTION 3.1EMPATHY MAP

CANVAS:



### 3.2 IDEATION& BRAINSTORMING:

#### BRAINSTROM & IDEA PRIORITIZATION:

Use this template in your own brain storming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

Before you collaborate A little bit of preparation goes along way with this session. Here's what you need to do to get going.

#### Define your problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement. This will be the focus of your brainstorm.

#### Brainstorm

Write down any ideas that come to mind that address your problem statement.

**TIP**

You can select a sticky note and hit the pencil [switch to sketch] icon to start drawing.

**Group ideas**

Take turns sharing your ideas while clustering similar or related notes as you go. Once all sticky notes have been grouped, give each cluster a sentence-like label. If a cluster is bigger than six sticky notes ,try and see if you and break it up into smaller sub-groups.

**Prioritize**

Your team should all be on the same page about what's important moving forward. Place your ideas on this grid to determine which ideas are important and which are feasible.

### **After you collaborate**

You can export the mural as an image or pdf to share with members of your company who might find it helpful.

#### ***Team gathering***

Define who should participate in the session and send an invite. Share relevant information or pre work ahead.

#### ***Set the goal***

Think about the problem you'll be focusing on solving in the brainstorming session.

#### ***Learn how to use the facilitation tools***

Use the Facilitation Super powers to run a happy.

### **3.3 PROPOSED SOLUTION:**

#### **Proposed :**

Project team shall fill the following information in proposed solution template.

<b>S.No.</b>	<b>Parameter</b>	<b>Description</b>
1.	Problem Statement (Problem to be solved)	Our aim is to map weather data to energy production. The model prediction is then showcased on user interface to predict the energy output of wind turbine.
2.	Idea / Solution description	Our approach was to use a time series forecasting model that would generate point forecast of wind generation for the upcoming three days, for a wind turbine.
3.	Novelty / Uniqueness	It will be working on bad weather condition. Precise information on timing Fluctuation in weather conditions
4.	Social Impact / Customer Satisfaction	Wind energy jobs in rural communities in manufacturing, transportation and project construction.

5.	Business Model (Revenue Model)	<ul style="list-style-type: none"> <li>• Identifying most significant features for wind power prediction.</li> <li>• Continuous learning and model improvement by hybrid ensemble with data and function perturbation.</li> <li>• Predicting best time for wind farm energy utilization.</li> </ul>
----	--------------------------------	---

### **3.4 PROBLEM SOLUTION FIT:**

#### **1. CUSTOMER SEGMENT(S):**

Wind flows over the blades creating lift (similar to the effect on air plane wings), which causes the blades to turn.

The blades are connected to a drive shaft that turns an electric generator, which produces (generates).

#### **1. JOBS-TO-BE-DONE/PROBLEMS:**

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.

#### **3. TRIGGERS:**

The wind speed is always fluctuating and thus the energy content of the wind is also always changing. Exactly how large the variation is depends both on the weather and On local surface conditions and obstacles.

#### **4. EMOTIONS:**

##### **BEFORE / AFTER**

**Before:** who live in close proximity to wind turbines say they experience sleep disturbances, headaches and concentration problems.

**After:** Between working long hours, climbing turbines multiple times a day ,and dealing with extreme heat in the summer and cold in the winter.

#### **5. AVAILABLE SOLUTIONS:**

These residential windmills can generate electricity by churning the wind through its blades, which in turn rotates the turbine and generates power, which can meet the needs of a small family. The energy that is yielded from these wind turbines is clean, renewable, and are also cost-effective.

#### **6. CUSTOMER CONSTRAINTS:**

- Intermittent
- Low operating costs Noise and visual pollution Efficient use of land space
- Some adverse environmental impact
- Wind energy is a job creator

#### **7. BEHAVIOUR:**

The wind speed is always fluctuating and thus the energy content of the wind is also always changing.

Exactly how large the variation is depends both on the weather and on local surface conditions and

obstacles.

## **8. CHANNELS OF BEHAVIOUR:**

### **Online:**

An efficient automated approach to wind farm operation monitoring is presented.

### **Offline:**

Product is available for offline usage.

## **9. PROBLEM ROOT CAUSE:**

The degradation, weakening and de bonding of the adhesive layers (in the trailing or leading edges or on the spar/shell joint) is one of the main processes leading to wind turbine blade failure.

#### 10.YOUR SOLUTION:

Larger rotor diameters allow wind turbines to sweep more area, capture more wind, and produce more electricity. A turbine with longer blades will be able to capture more of the available wind than shorter blades—even in areas with relatively less wind.

## 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 and logging in by entering their user name and password.	Registration through Form.
FR-2	User Confirmation by validating the user name with respect to the password	Confirmation via pop-up Message.
FR-3	Displaying the further information about the application.	By selecting the about button the details of the application will be displayed.
FR-4	Validating the city name.	System checks whether the city entered by the user is present or not. If present it will collect the further details else it will display the pop up message as error in the city.
FR-5	Checking the data type of the value.	System checks for the data type of the value entered by the user.
FR-6	Validating all required fields.	Before predicting the output the system checks whether all the values are entered by the user and checks whether all values are correct.
FR-7	Displaying weather Conditionsfor a given city.	It displays the weather of the city which have Been selected.
FR-8	Displaying predicted Energyoutput power.	The predicted output will be displayed as amount of wind energy power generated.



#### 4.2. NON-FUNCTIONAL REQUIREMENTS:

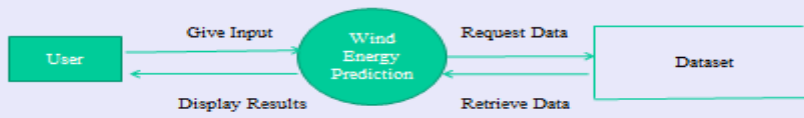
Following are the non-functional requirements of the proposed solution

FR No.	Non-Functional Requirement	Description
NFR-1	Usability	The system satisfies the user goals and the application is easy to use.
NFR-2	Security	The data provided to system will be protected from Attacks and unauthorized access
NFR-3	Reliability	The system will provide the consistency in output without producing an error.
NFR-4	Performance	The performance will never degrade even the work load is increased.
NFR-5	Availability	The application is available for 24*7
NFR-6	Scalability	The system can be used as web application as well as mobile application with a sufficient internet availability.

## 5. PROJECT DESIGN:

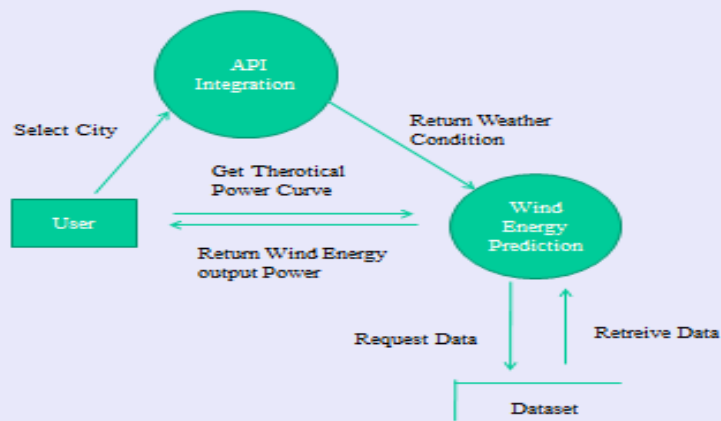
### 5.1. DATA FLOW DIAGRAMS:

Level 0



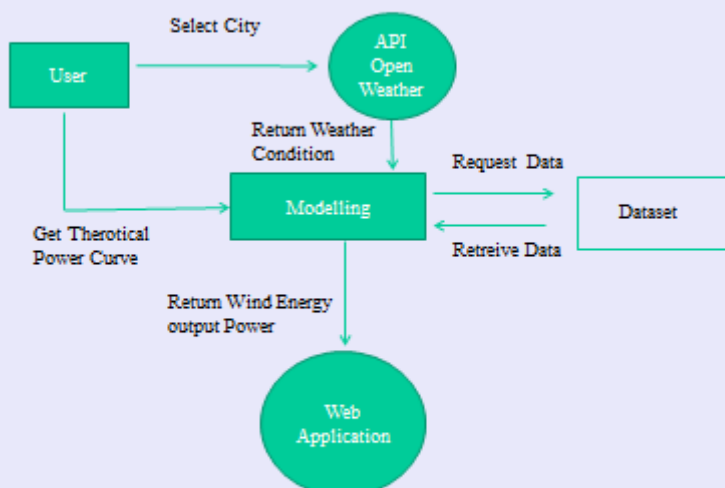
12 October 2022

Level 1



12 October 2022

Level 2



12 October 2022



## **5.2. SOLUTION & TECHNICAL ARCHITECTURE:**

### **Solution Architecture:**

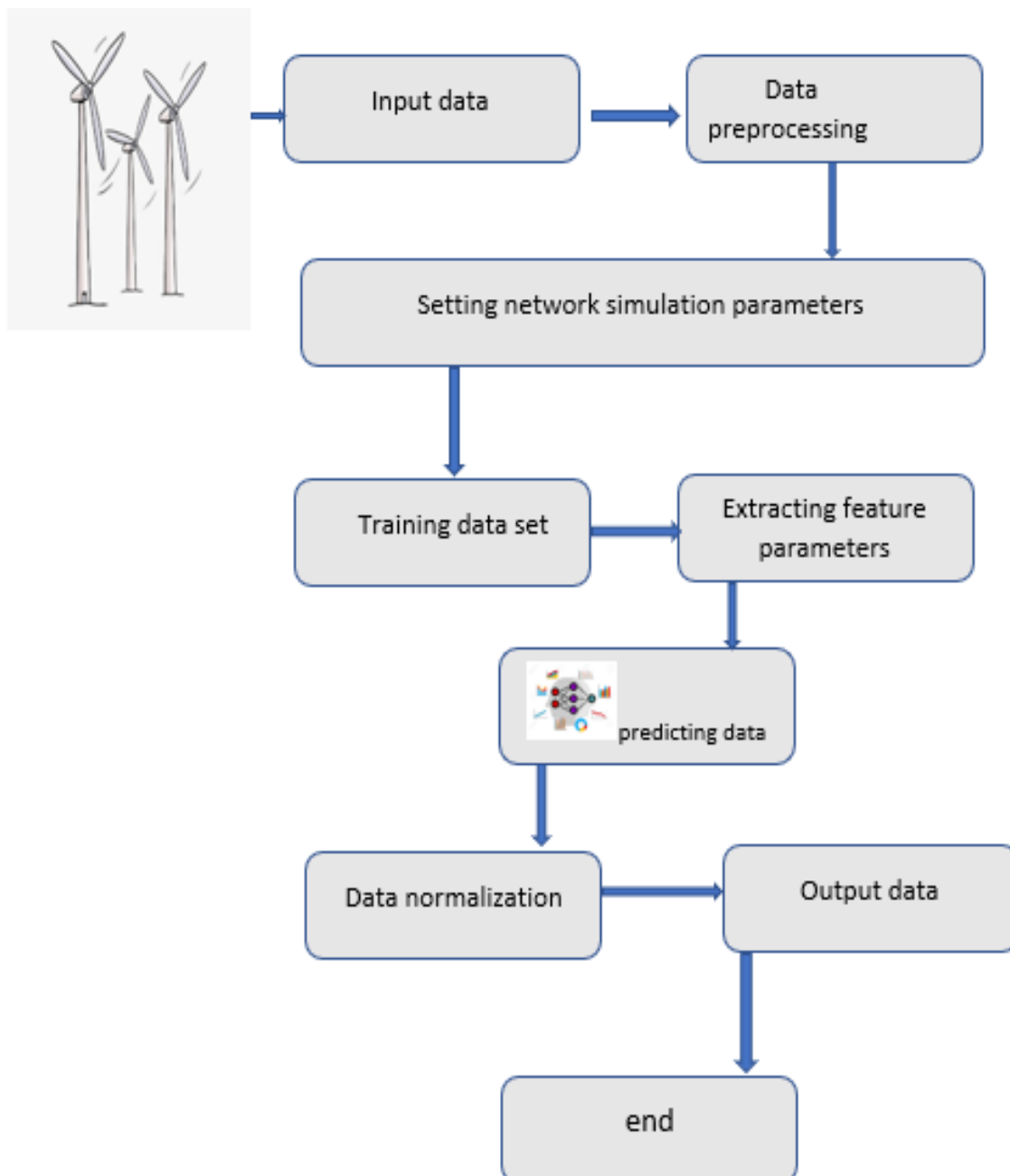
Solution architecture is a complex process – with many sub-processes – that bridges the gap between business problems and technology solutions. Its goals are to:

- 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 windfarm power output.
- The inlet condition of the wind farm is forecasted by the auto regressive model.
- We report on the correlation of the different variables for the energy output.

### **Example - Solution Architecture Diagram:**

Figure 1: Architecture and data flow

**Reference:** <https://github.com/SmartPracticeschool/IISPS-INT-3437-Predicting-the-Energy-Output-of-WindTurbine-Based-on-Weather-Conditions-Watson-Auto->

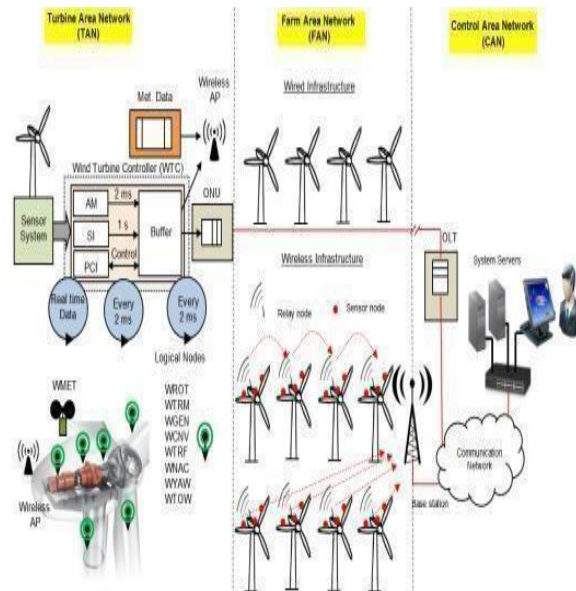


## Technical Architecture:

The Deliverable shall include the architectural diagram as below and the information as per the table1&table2

### Example: Predicting the energy output of wind farm based on weather conditions.

Reference: <https://www.mdpi.com/1996-1073/7/6/3900>



## Guidelines:

The proposed communication network architecture for the Smart-WPF consists of three networks :the turbine area network (TAN), the farm area network(FAN), and the control area network (CAN).

It consists of hierarchical architectures whereLevel1isasensor network in a single wind turbine, Level2 is the wind turbine-to-wind turbine interaction in the WPF, Level 3 is the local control center to wind turbine interaction, and Level 4 is the farm-to-farm interaction to optimize grid operation.

In order to implement hierarchical network architecture, a hybrid communication solution is considered. EPON-based architecture represents a wired solution, while ZigBee-

Pro is considered for the wireless solution. In this work, Levels1 and 2 are explained in more detail, while Levels 3 and 4 are out the scope of this work

## 4. PROJECT PLANNING & SCHEDULING:

### 4.1 SPRINT PLANNING & 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 email, password and conforming my password	5	High	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 1		USN-2	As a user, I will receive confirmation email once I have registered for the application	4	High	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 1		USN-3	As a user ,I can register for application through phone number.	4	Low	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 1		USN-4	As a user, I can register for the	3	Medium	Sundarapandiyan .k Selvakumar. E

			application through Gmail			Ramkumar.S Navaneethan.G
Sprint 1	Login(User)	USN-5	As a user, I can log into application by entering email& password	5	High	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 2	Dashboard	USN-6	Once I have logged in , I can see my dashboard.	6	Medium	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 2	Web access	USN-7	As a customer I can access the website to predict the weather conditions.	7	High	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 2	Prediction	USN-8	As a customer when I enter the weather details the website should predict the approximate weather conditions.	7	High	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 3	Analysis	USN -9	As a customer, I wish to store my prediction and make analysis.	10	Medium	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 3	Security	USN-10	As a customer I expect my data to be secured.	10	Medium	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G
Sprint 4	Database Access	USN- 11	An administrator I should maintain the website. And update the website regularly.	20	Low	Sundarapandiyan .k Selvakumar. E Ramkumar.S Navaneethan.G

## 4.2 SPRINT DELIVERY SCHEDULE:

Sprint	SprintStartDate	SprintEndDate(Planned)	Story PointsCompleted (ason PlannedEndDate)	SprintReleaseDate(Actual)	
Sprint-1	01 Nov2022	14 Nov2022	20	14 Nov 2022	
Sprint-2	07 Nov2022	14Nov2022	20	14 Nov2022	
Sprint-3	07Nov2022	15Nov2022	20	15 Nov2022	
Sprint-4	09 Nov2022	15Nov2022	20	15 Nov2022	



5. CODING & SOLUTIONING:  
5.1 FEATURE 1:

0	01/01/2018 00:00	380.047791	5.311336	416.328908259.994904
1	01/01/2018 00:10	453.769196	5.672167	519.917511 268.641113
2	01/01/2018 00:20	306.376587	5.216037	390.900016272.564789
3	01/01/2018 00:30	419.645904	5.659674	516.127569271.258087
4	01/01/2018	380.650696	5.577941	491.702972
		265.674286		
ActivePower(KW)				
WindSpeed(m/s)				
Theoretical_Power_Curve_(KWh)				
Wind_Direction_(°)				
dtype: int64				

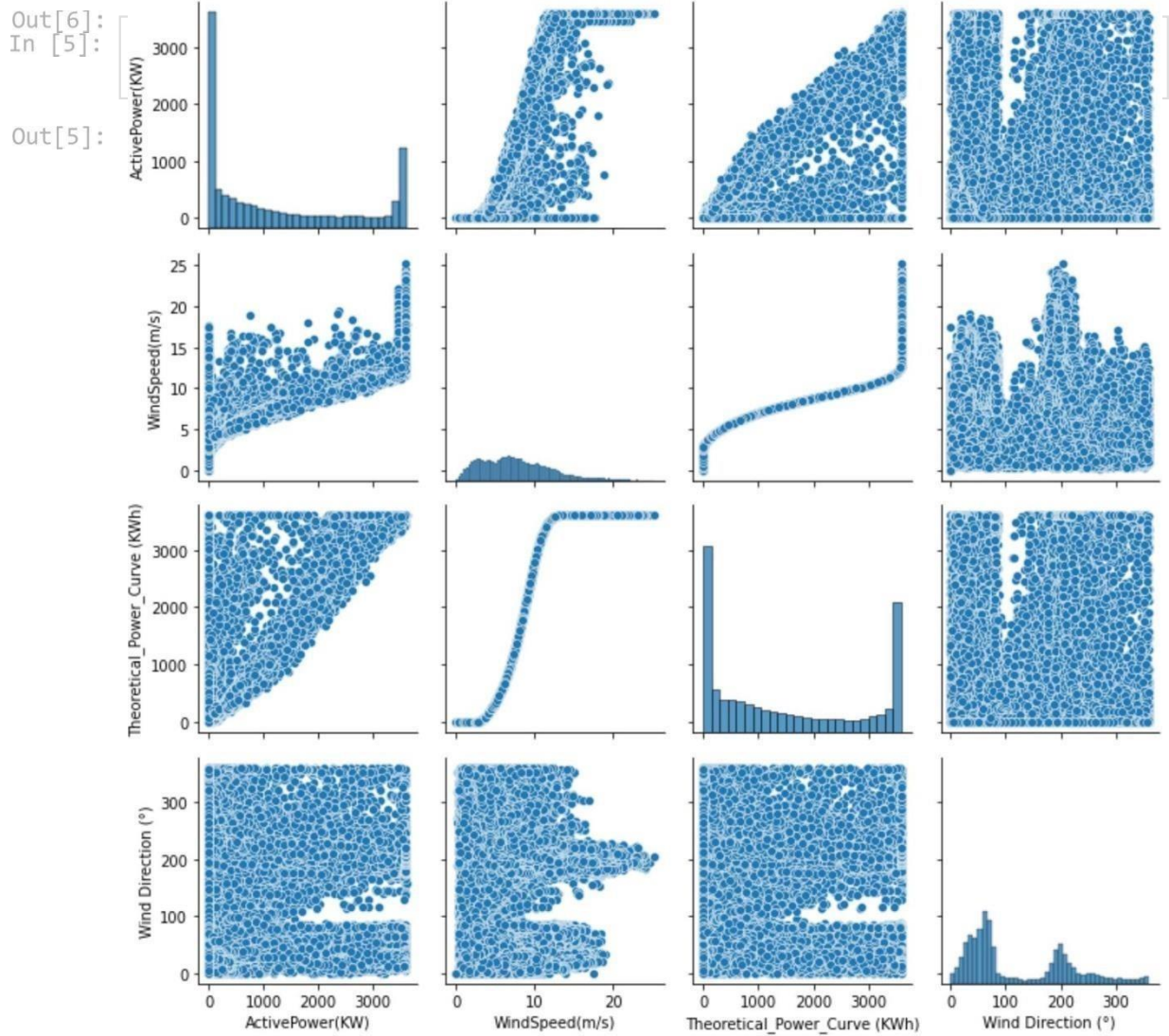
Saving Wind Dataset.csv to Wind Dataset.csv

```
In [2]: import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import joblib

Data Preprocessing
path = "Wind Dataset.csv"
df = pd.read_csv(path)
In [3]: df.rename(columns={"Date/Time":"Time", "LV ActivePower (kW)":"ActivePower(KW)",
                           "Wind Direction(°)":"Wind_Direction"},
                  inplace=True)
In [4]: df.head()
```

```
In [0]: Out[4]: rplot(df)
```

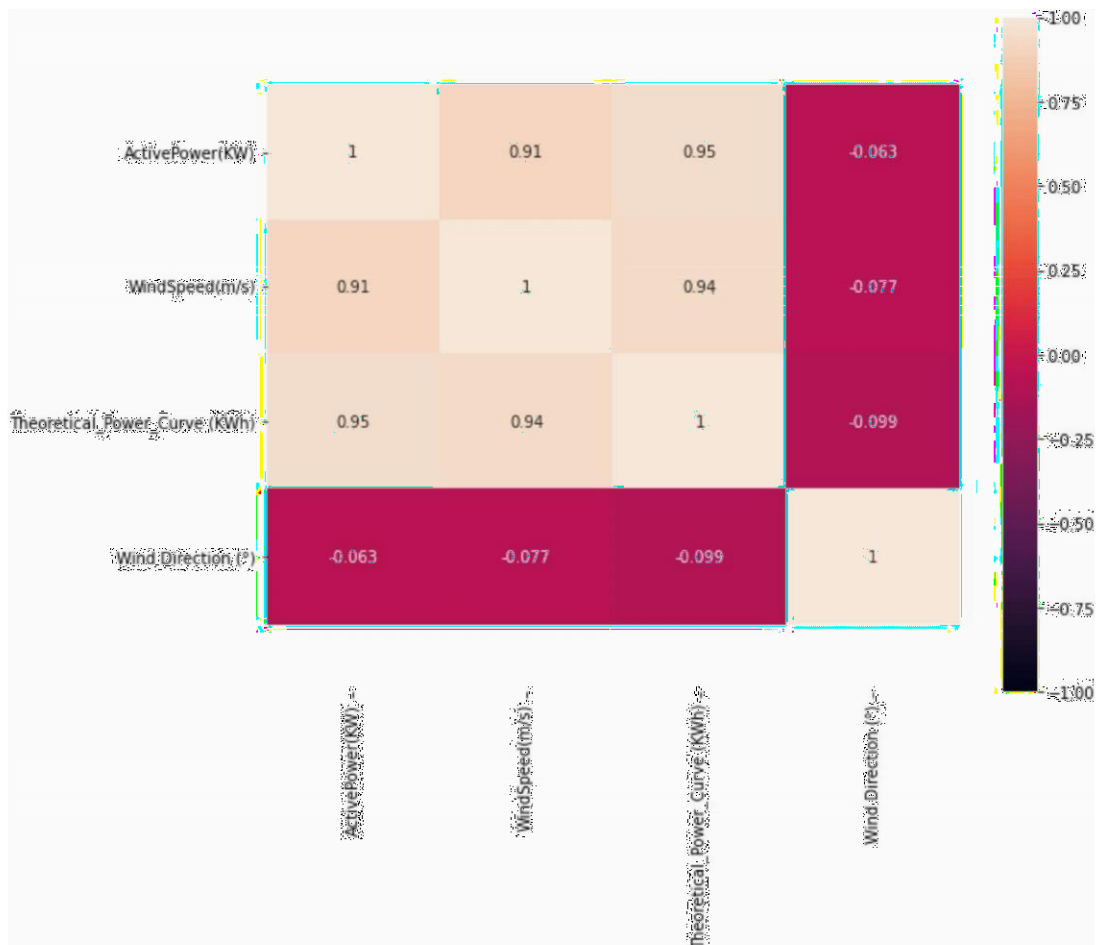
	Wind Direction (°)
ActivePower(KW)	-0.062702
WindSpeed(m/s)	-0.077188
Theoretical_Power_Curve (KWh)	-0.099076
Wind Direction (°)	1.000000



```
In [7]: plt.figure(figsize=(10, 8))
corr = df.corr()
ax = sns.heatmap(corr, vmin = -1,vmax = 1,annot = True)
bottom, top = ax.get_ylim()
ax.set_ylim(bottom + 0.5, top - 0.5)

print(corr)
```





```
In [83]:
```

```
df["Time"] = pd.to_datetime(df["Time"], format = "%d %m %Y %H %M", errors =
```

### Splitting the data to Train and Test

```
In [91]:
```

```
y = df["ActivePower(KW)"]
X = df[["Theoretical_Power_Curve (KWh)", "WindSpeed(m/s)"]]

from sklearn.model_selection import train_test_split
train_X, val_X, train_y, val_y = train_test_split(X, y, random_state=0)
```

### Model Building

```
In [92]:
```

```
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_absolute_error, r2_score

forest_model = RandomForestRegressor(n_estimators = 750, max_depth = 4, max_
forest_model.fit(train_X, train_y)
```

```
Out[92]:
```

```
RandomForestRegressor(max_depth=4, max_leaf_nodes=500, n_estimators=750,
random_state=1)
```

```
In [93]:
```

```
power_preds = forest_model.predict(val_X)
```



0.911349642890175

```
In [12]: joblib.dump(forest_model, "power_prediction.sav")
```

```
Out[12]: ['power_prediction.sav']
```

```
In [13]: df
```

```
Out[13]:
```

	Time	ActivePower(KW)	WindSpeed(m/s)	Theoretical_Power_Curve (KWh)	Wind Direction (°)
0	NaT	380.047791	5.311336	416.328908	259.994904
1	NaT	453.769196	5.672167	519.917511	268.641113
2	NaT	306.376587	5.216037	390.900016	272.564789
3	NaT	419.645904	5.659674	516.127569	271.258087
4	NaT	380.650696	5.577941	491.702972	265.674286
...	...	...	...	...	...
50525	NaT	2963.980957	11.404030	3397.190793	80.502724
50526	NaT	1684.353027	7.332648	1173.055771	84.062599
50527	NaT	2201.106934	8.435358	1788.284755	84.742500
50528	NaT	2515.694092	9.421366	2418.382503	84.297913
50529	NaT	2820.466064	9.979332	2779.184096	82.274620

50530 rows × 5 columns

## 6. TESTING:

### 8.1 TEST CASES:

TestingNo:1	Testing Type	Function Result
	Functionality testing	Yes
	Usability testing	Yes
	Interface testing	Yes
	Performance testing	Yes(medium)
	Security testing	Yes

TestingNo:2	Testing Type	Function Result
	Functionality testing	Yes
	Usability testing	Yes
	Interface testing	Yes
	Performance testing	Yes(medium)
	Security testing	Yes

TestingNo:3	Testing Type	Function Result
	Functionality testing	Yes
	Usability testing	Yes
	Interface testing	Yes
	Performance testing	Yes
	Security testing	Yes

TestingNo:4	Testing Type	Function Result
	Functionality testing	Yes
	Usability testing	Yes
	Interface testing	Yes
	Performance testing	Yes
	Security testing	Yes



7. RESULT:

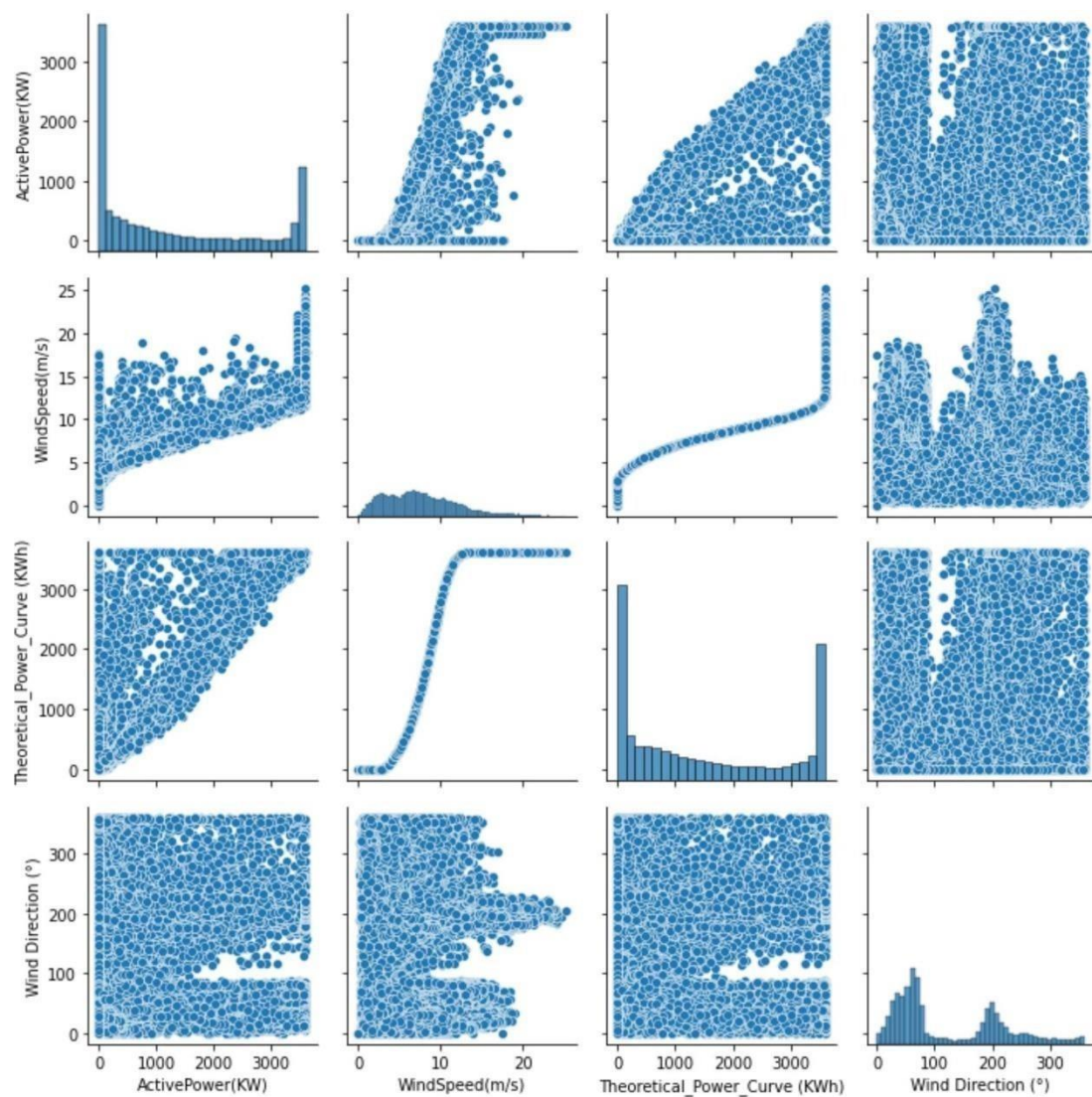
7.1 PERFORMANCE

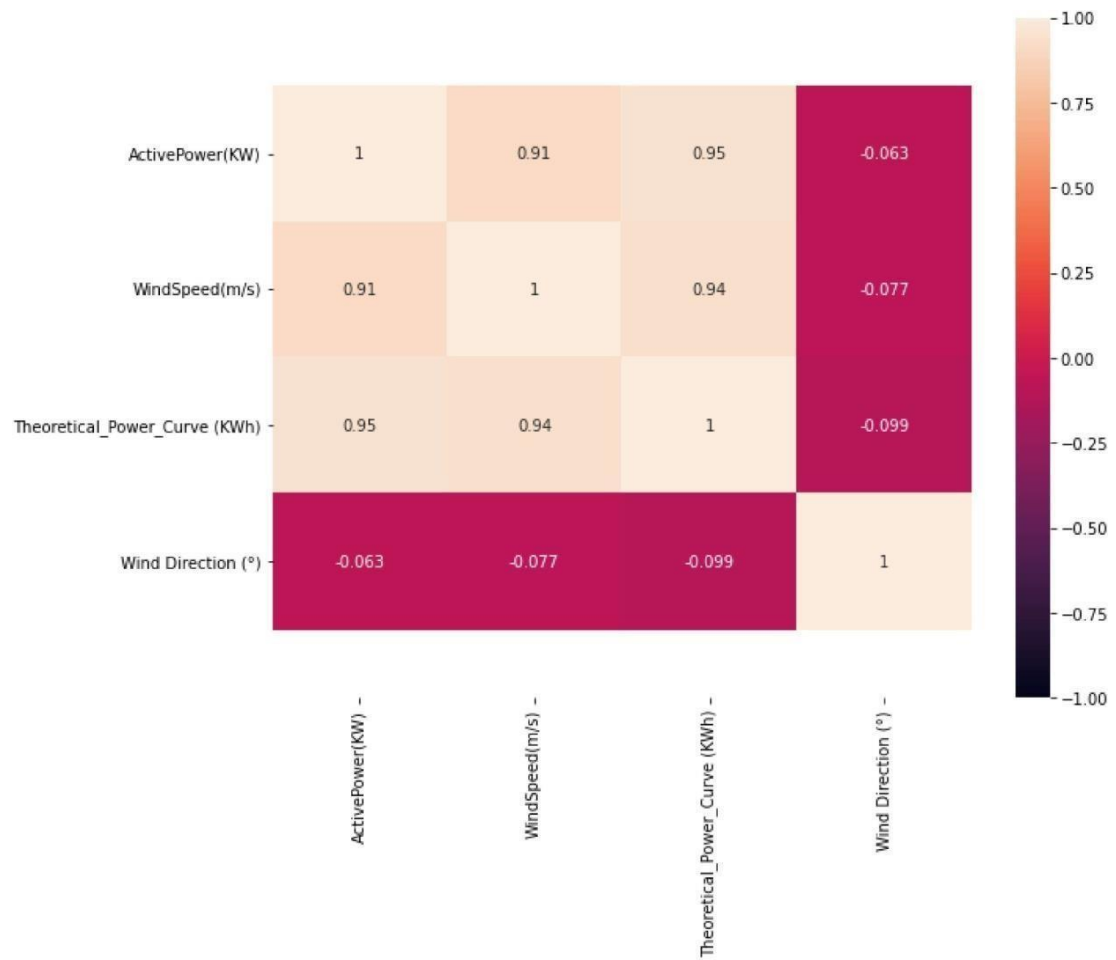
METRIES:DATA

PREPROCESSING:

---

	01 01			
0	2018	380.047791	5.311336	416.328908
	259.994904			
	00:00			
	01 01			
1	2018	453.769196	5.672167	519.917511
	268.641113			
	00:10			
Out[4]:	01 01			
2	2018	306.376587	5.216037	390.900016
	272.564789			
	00:20			
	01 01			
3	2018	419.645904	5.659674	516.127569
	271.258087			
	00:30			
	01 01			
4	2018	380.650696	5.577941	491.702972
	265.674286			





### MODEL BUILDING:

```
Out[10]: RandomForestRegressor(max_depth=4, max_leaf_nodes=500, n_estimators=750,
                                random_state=1)
```

We demonstrated that an off-the-shelf data modeling and variable selection tool can be used with mostly default settings to run the symbolic regression experiments as well as variable importance, variable contribution analysis, ensemble selection and validation.

## **12. FUTURE SCOPE:**

Most wind power forecasting models study ‘regular’ wind conditions.

The EU funded project called ‘Safe wind’ aims to improve wind power prediction over challenging and extreme weather periods and at different temporal and spatial scales.

Development activities are on-going to reduce error in the wind power prediction, to improve regionalized wind power forecasting for on - shore windfarms and to derive methods for wind power prediction for offshore wind farms.

It is possible that use of ensemble and combined weather prediction methods together may enhance forecasting.

If the error in wind power forecasting and prediction is reduced then electricity markets can trade with more certainty. Contract errors as a function of time in electricity markets can be as high as 39% for a forecasting lead time of 4 present a new tool called the WILMAR and ANEMOS scheduling Methodology (WALT) to reduce the number of thermal generators on stand-by or in reserve using the probability of generation outages and load shedding are system reliability criteria instead of generation adequacy based solely on generation outage.

The wind and load forecast errors are modelled using a Gaussian stochastic variable approach.

However, in another study it was found that the prediction errors do not satisfy the Kolmogorov Smirnov test for normal distribution.

In Carta , it was shown that, the use of auto correlated (and thus not independent) successive hourly mean wind speeds, though invalidating all of the usual statistical tests, has no appreciable effect on the shape of the pdf estimated from the data.

## **13. APPENDIX:**

### 13.1 SOURCE CODE:

#### ➤ **app.py**

```
import numpy as np
from flask import Flask, request, jsonify, render_template
import joblib
```

```

import requests

app = Flask(__name__)
model = joblib.load('Power_Prediction.sav')

@app.route('/')
def home():
    return render_template('intro.html')

@app.route('/predict')
def predict():
    return render_template('predict.html')

@app.route('/windapi', methods=['POST'])def
windapi():
    city = request.form.get('city')
    apikey = "a802b0f626c637d04185e582b5ad0d58"url =
"http://api.openweathermap.org/data/2.5/weather?q="+city+"&appid="+apikeyresp = requests.get(url)
    resp = resp.json()
    temp = str((resp["main"]["temp"])-273.15) + " °C"
    humid = str(resp["main"]["humidity"])+ " %" pressure =
    str(resp["main"]["pressure"])+ " mmHG"speed =
    str((resp["wind"]["speed"])*3.6)+ " Km/s"
    return render_template('predict.html', temp=temp, humid=humid,presure=pressure,
speed=speed)

@app.route('/y_predict', methods=['POST'])def
y_predict():
    """
    For rendering results on HTML GUI"""
    x_test = [[float(x) for x in request.form.values()]]prediction =
    model.ppredict(x_test) print(prediction)
    output = prediction[0]
    return render_template('predict.html', prediction_text="The energypredicted is {:.2f}
KWh'.format(output))

if __name__ == "__main__":app.run(debug=False)

```

## ➤ predict.html

```
<html>

  <head>
    <meta charset="UTF-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <meta http-equiv="X-UA-Compatible" content="ie=edge" />
    <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.7.2/css/all.css"
      integrity="sha384-
fnmOCqbTIWIlj8LyTjo7mOUStjsKC4pOpQbqyi7RrhN7udi9RwhKkMHpvLbHG9Sr"crossorigin="anonymous" />
    <link href="https://fonts.googleapis.com/css?family=Dosis"rel="stylesheet" />
    <link rel="stylesheet" href="static/css/main.css"/>
    <link rel="stylesheet" href="static/css/media.css"/>
    <link rel="stylesheet" href="static/css/items_grid.css"/>

    <title>Wind Energy Prediction</title>
    <style>
#page {
  max-width: 80%;
  margin: auto;
}
body {
  background-image: url(https://images2.alphacoders.com/753/753985.jpg);
  width: 100%;
  height: 100%;
  background-repeat: no-repeat;
  background-attachment: fixed;
  background-size: cover; overflow:
  hidden;
}
table {
  width: 100%;
  border-collapse: collapse;
}

.card {
  margin-right: auto;
  margin-left: 15%; width:
  300px;
```

```
box-shadow: 0 15px 25px rgba(129, 124, 124, 0.2);

border-radius: 5px;
backdrop-filter: blur(14px); background-color:
rgb(180, 180, 180);padding: 15px;
text-align: center;
}
.head {
top:0px; margin:0px;
left: 0px; right: 0px;
position: fixed;
background: #aeb90f; color:
white; overflow: hidden;
padding-bottom: 30px;font-
size: 2.25vw; width: 100%;
padding-left:0px; text-
align: center;padding-
top:20px;
}
.second{
top:80px;
bottom:0px;
margin:0px; left: 0px;
right: 0px; position:
fixed;padding: 0px;
width: 100%;

font-family:Georgia, serif;
color:black;font-
size:20px;
}
.inside{
top:80px;
bottom:0px;
margin:0px;
left: 51%;
right: 0%; position: fixed;
padding-left: 40px;
padding-top:8%;
```



```
padding-right:40px;

font-family:Georgia, serif;
color:#96f400;font-
size:20px;text-
align:justify;

}
.myButton{
border: none;
text-align: center;
cursor: pointer;
text-transform: uppercase;
outline: none;
overflow: hidden;
color: #fff;font-
weight: 700;font-size:
12px;
background-color: #183a1d;
padding: 10px 15px;margin: 0
auto;
box-shadow: 0 5px 15px rgba(0,0,0,0.20);
margin-left:17%;
}
input {
width:50%;
margin-bottom: 10px;
background: #e1eedd;
border: none;outline:
none;padding: 10px;
font-size: 13px;color:
#6c493a;text-shadow:
white;border: #6c493a;
border-radius: 4px;box-
shadow: white;
}
::placeholder {
color: black;
opacity: 1;
}

.left{
top:80px;
bottom:0px;
margin:0px;
```

```

        left: 0%;
        right: 45.5%; position:
        fixed; padding-left: 10%;
        padding-top: 5%;
        padding-right: 40px;

        font-family: bold, Georgia, serif;
        color: rgb(238, 255, 0);
        font-size: 25px;
    }

    select {
        width: 50%;
        margin-bottom: 10px;
        background: white; border:
        none; outline: none;
        padding: 10px;
        font-size: 13px; color:
        #183a1d; text-shadow:
        white; border: #6c493a;
        border-radius: 40px;
        box-shadow: white;
    }

input:focus { box-shadow: inset 0 -5px 45px rgba(100,100,100,0.4), 0 1px 1px rgba(255,255,255,0.2);
}


        table, th, td {
        border: 1px solid rgb(86, 72, 128);
        border-collapse: collapse;
        color: #3f00ff;
    }

@media screen and (max-width: 500px) {

    .left,
    .second,
    .third {
        width: 70%;
    }
}

```

```

</style>
</head>
<body>

    <header id="head">
    <div class="head">Predicting The Energy Output Of Wind TurbineBased On
Weather Condition</div>
    </header>

    <div class="second">
    <div class="left">

        <p style="padding: 8px; border: 1px solid rgb(0, 110, 255);width: 575px;"> GIVE
YOUR CITY NAME TO KNOW THE WEATHER CONDITIONS</p>

        <div style="margin-left:10%">
        <form action="{ { url_for('windapi') } }"method="post" >
            <select name="city" required >
                <option value="" selected>select City</option>
                <option value ="Ariyalur" > Ariyalur </option>
                <option value ="Andimadam" > Andimadam </option>
                <option value ="Coimbatore" > Coimbatore </option>
                <option value
="Chengalpattu" > Chengalpattu </option>
                <option value ="Cuddalore" > Cuddalore </option>
                <option value ="Chennai" > Chennai </option>
                <option value ="Dindigul" > Dindigul </option>
                <option value ="Dharmapuri" > Dharmapuri </option>
                <option value ="Erode" > Erode </option>
                <option value ="Karur" > Karur </option>
                <option value
="Kancheepuram" > Kancheepuram </option>
                <option value ="Krishnagiri" > Krishnagiri
</option>
                <option value
="Kallakurichi" > Kallakurichi </option>
                <option value ="Madurai" > Madurai </option>
                <option value ="Mayiladuthurai"
> Mayiladuthurai </option>
                <option value
="Nagapattinam" > Nagapattinam </option>
                <option value ="Kanyakumari" > Kanyakumari
</option>

```

```

        <option value="Namakkal" > Namakkal </option>
        <option value="Perambalur" > Perambalur </option>
        <option value="Pudukottai" > Pudukottai </option>
        <option value="Ramanathapuram"
> Ramanathapuram </option>
        <option value="Ranipet" > Ranipet </option>
        <option value="Salem" > Salem </option>
        <option value="Sivagangai" > Sivagangai </option>
        <option value="Tenkasi" > Tenkasi </option>
        <option value="Thanjavur" > Thanjavur </option>
        <option value="Theni" > Theni </option>
        <option value="Thiruvallur" > Thiruvallur
</option>
        <option value="Thiruvarur" > Thiruvarur </option>
        <option value="Tuticorin" > Tuticorin </option>
        <option value
="Trichirapalli" > Trichirapalli </option>
        <option value
="Thirunelveli" > Thirunelveli </option>
        <option value="Tirupathur" > Tirupathur </option>
        <option value="Tiruppur" > Tiruppur </option>
        <option value="Tiruvannamalai"
> Tiruvannamalai </option>
        <option value="The Nilgiris" > The
Nilgiris </option>
        <option value="Vellore" > Vellore </option>
        <option value="Viluppuram" > Viluppuram </option>
        <option value
="Virudhunagar" > Virudhunagar </option>

</select><br><br>
<div style="margin-left:-15%"><button type="submit"
class="myButton">Check the Weather Conditions</button></div>

</form>
</div>
<br>

<div class="card">
<table style="margin-left:2%; text-align:center; border-spacing:20px;">
    <tr>
        <td colspan="2" style="font-size:25px;">The weatherconditions of
the city are</td>
    </tr>
    <tr>

```

```

        <td>Temperature</td><td>{{temp}}</td>
    </tr>
    <tr>
        <td>Humidity</td><td>{{humid}}</td>
    </tr>
    <tr>
        <td>Pressure</td><td>{{pressure}}</td>
    </tr>
    <tr>
        <td>Wind Speed</td><td>{{speed}}</td>
    </tr>
</table>
</div>
</div>
<div class="inside">
    <div style="font-size:23px;font-weight:bold;">Predict the Wind
Energy!!</div>
    <br><br>
    <form action="{{ url_for('y_predict')}}"method="post">
        <input type="text" name="theo" placeholder="Theoretical
Power in KWh" required="required" />
        <input type="text" name="wind" placeholder="Wind Speed in
m/s" required="required" /><br><br>
        <button type="submit" class="myButton" >Predict</button>

    </form>

    <br>
    <br>
    {{ prediction_text }}

</div>

</div>

</body>

</html>

```

## Intro.html

```

<html>
    <head>
        <title>Wind Energy Prediction</title>

```

```
<style>
```

```
.header {  
    top:0px; margin:0px;  
    left: 0px; right: 0px;  
    position: fixed;  
    background: #a4a717; color:  
    rgb(255, 255, 255);overflow:  
    hidden;  
    padding-bottom: 30px;  
    font-family:Georgia, 'Times New Roman', Times, serif, serif;  
    font-size: 2.5vw; width:  
    100%; padding-left:0px;  
    text-align: center;  
    padding-top:20px;  
}
```

```
.second{  
    top:90px;  
    bottom:0px;  
    margin:0px; left: 0px;  
    right: 0px; position:  
    fixed;padding: 0px;  
    width: 100%;  
    background-  
image:url(https://i.pinimg.com/originals/c4/d2/f9/c4d2f98e88a85b702f8ff257d74714d8.gif);  
    background-repeat:no-repeat;  
    background-size: contain;  
}
```

```
.inside{  
    top:90px;  
    bottom:0px;  
    margin:0px;  
    left: 35%;  
    right: 0%; position: fixed;  
    padding-left: 40px;  
    padding-top:15%;  
    padding-right:40px;  
    background-color:#f5e3c5;opacity:  
    100%;  
    font-family:Georgia, serif;
```

```

        color:black; font-
        size:20px;
        text-align:justify;

    }
    .myButton{
        border: none;
        text-align: center;
        cursor: pointer;
        text-transform: uppercase;
        outline: none;
        overflow: hidden;
        color: #fff; font-
        weight: 700;font-size:
        15px;
        background-color: #6c493a;
        padding: 10px 15px; margin: 0
        auto;
        box-shadow: 0 5px 15px rgba(0,0,0,0.20);
    }
</style>
</head>
<body>

    <div class="header">Predicting The Energy Output Of Wind TurbineBased On Weather
    Condition</div>
    <div class="second">
        <div class="inside">A wind turbine turns wind energy into electricity using the
        aerodynamic force from the rotor blades, which worklike an airplane wing or helicopter rotor blade.
        <br><br>
        The amount of electricity generated by wind increased byalmost 273 TWh in
        2021 (up 17%), 45% higher growth than that achieved in2020 and the largest of all power generation
        technologies. Wind remains the leading non-hydro renewable technology, generating 1 870 TWh in
        2021,almost as much as all the others combined.
        <br><br><br>
        <a href="{ { url_for('predict') } }"><button type="button" class="myButton" >Click Here
        To Predict The wind Energy!</button></a>
    </div>

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

```