PREDICTING THE ENERGY OUTPUT OF WIND TURBINE BASED ON WEATHER CONDITIONS

INDEX

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ROAD MAP

1.Work Distribution

2.Data Collection

4.Model Design

3.Data Pre-processing

5.Application Design

WORK DISTRIBUTION

- Name: Sanjai V S

Task: Website Design

- Name: Sudharson V K

Task: Data Visualization and Demo Video

- Name: S Jeya ganesh

Task: Data Collection and Data Pre-processing

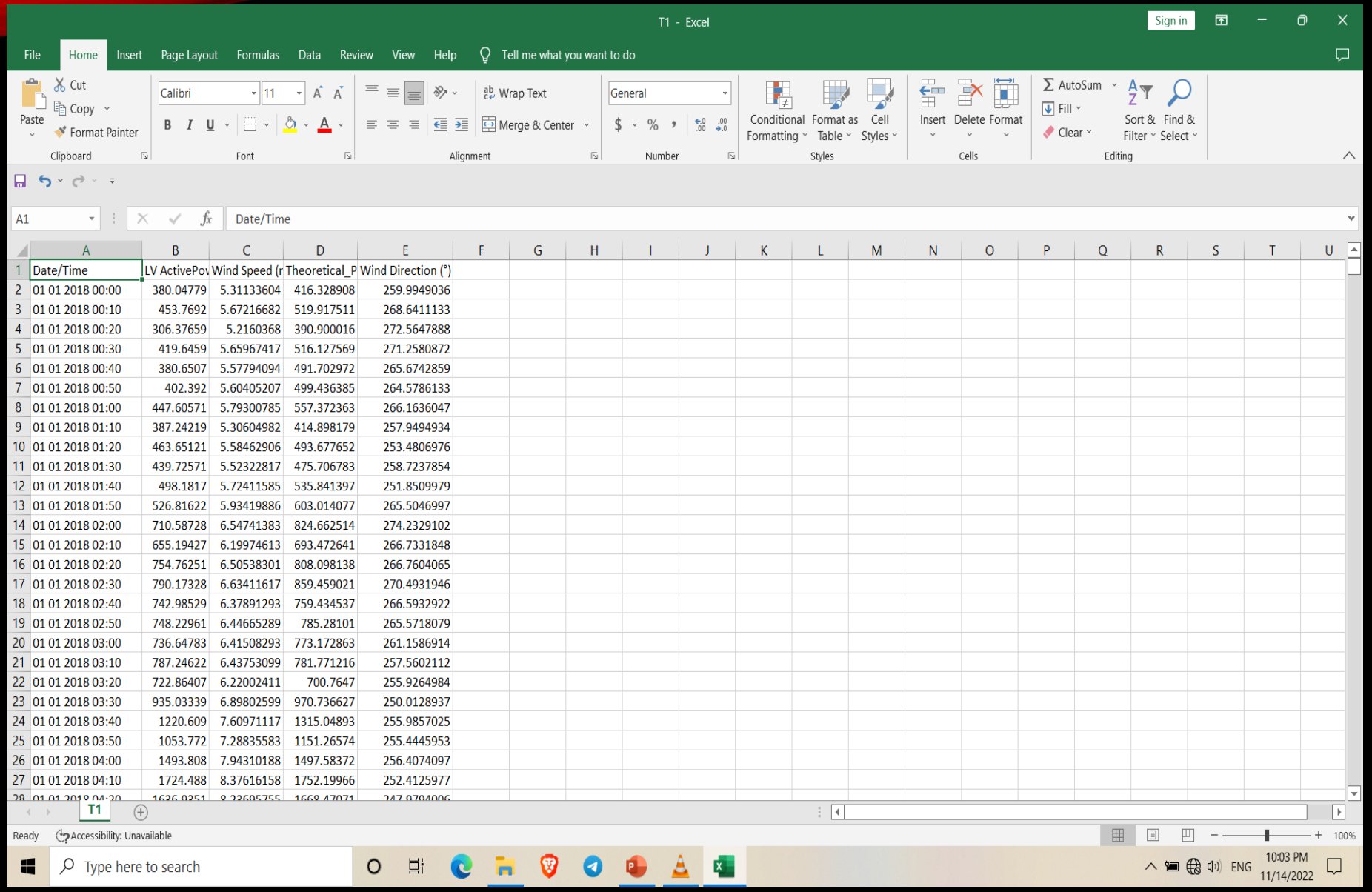
- Name – Lakshmi Kadhanvelu

Task: Presentation and Report and Task Assigning

DATA COLLECTION

- We used the wind turbine dataset from Kaggle provided in the description of the problem and downloaded the weather conditions data of the same place and of the same time from the web.

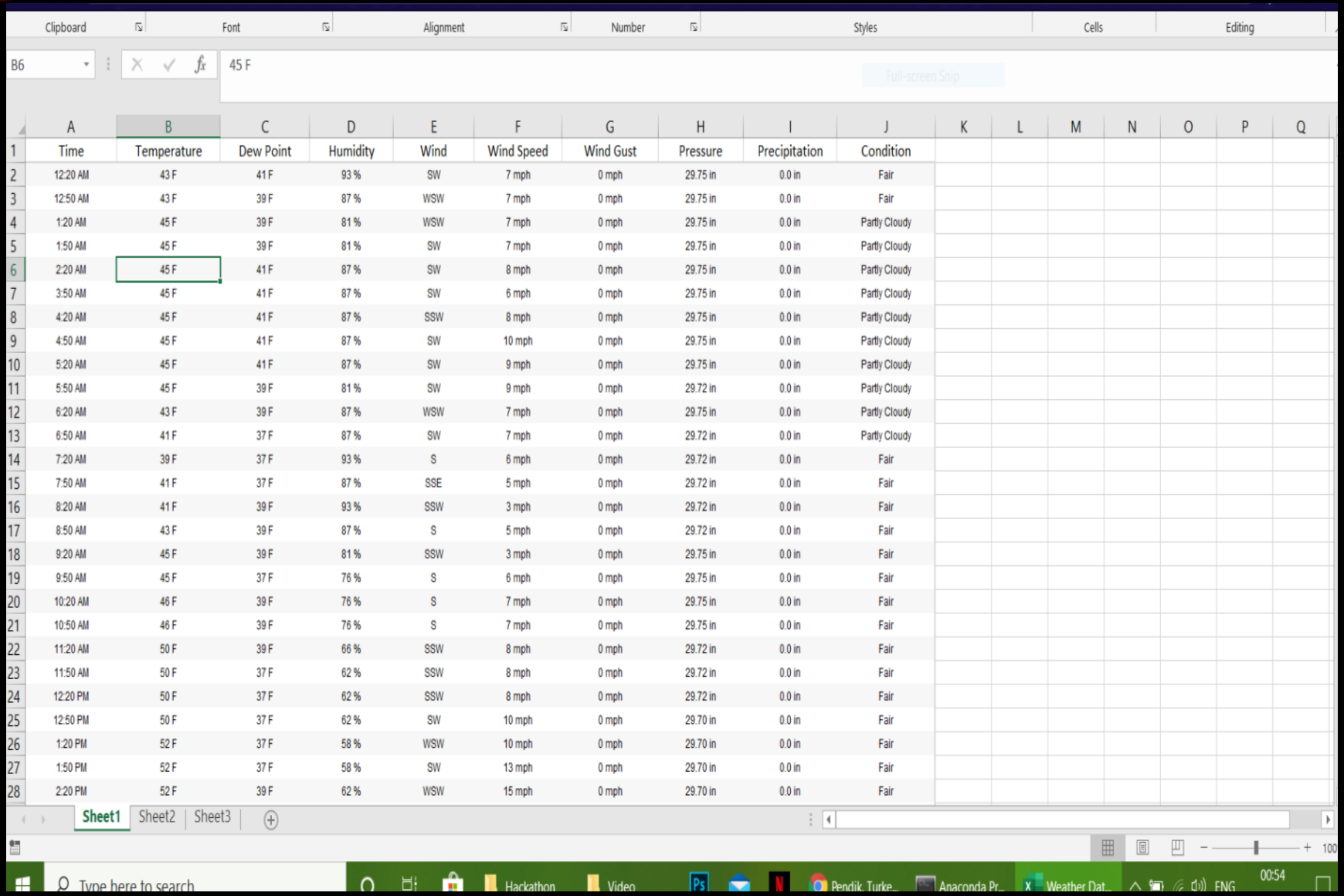
KAGGLE DATA



T1 - Excel

	Date/Time	LV ActivePo	Wind Speed (r	Theoretical_P	Wind Direction (°)
2	01 01 2018 00:00	380.04779	5.31133604	416.328908	259.9949036
3	01 01 2018 00:10	453.7692	5.67216682	519.917511	268.6411133
4	01 01 2018 00:20	306.37659	5.2160368	390.900016	272.5647888
5	01 01 2018 00:30	419.6459	5.65967417	516.127569	271.2580872
6	01 01 2018 00:40	380.6507	5.57794094	491.702972	265.6742859
7	01 01 2018 00:50	402.392	5.60405207	499.436385	264.5786133
8	01 01 2018 01:00	447.60571	5.79300785	557.372363	266.1636047
9	01 01 2018 01:10	387.24219	5.30604982	414.898179	257.9494934
10	01 01 2018 01:20	463.65121	5.58462906	493.677652	253.4806976
11	01 01 2018 01:30	439.72571	5.52322817	475.706783	258.7237854
12	01 01 2018 01:40	498.1817	5.72411585	535.841397	251.8509979
13	01 01 2018 01:50	526.81622	5.93419886	603.014077	265.5046997
14	01 01 2018 02:00	710.58728	6.54741383	824.662514	274.2329102
15	01 01 2018 02:10	655.19427	6.19974613	693.472641	266.7331848
16	01 01 2018 02:20	754.76251	6.50538301	808.098138	266.7604065
17	01 01 2018 02:30	790.17328	6.63411617	859.459021	270.4931946
18	01 01 2018 02:40	742.98529	6.37891293	759.434537	266.5932922
19	01 01 2018 02:50	748.22961	6.44665289	785.28101	265.5718079
20	01 01 2018 03:00	736.64783	6.41508293	773.172863	261.1586914
21	01 01 2018 03:10	787.24622	6.43753099	781.771216	257.5602112
22	01 01 2018 03:20	722.86407	6.22002411	700.7647	255.9264984
23	01 01 2018 03:30	935.03339	6.89802599	970.736627	250.0128937
24	01 01 2018 03:40	1220.609	7.60971117	1315.04893	255.9857025
25	01 01 2018 03:50	1053.772	7.28835583	1151.26574	255.4445953
26	01 01 2018 04:00	1493.808	7.94310188	1497.58372	256.4074097
27	01 01 2018 04:10	1724.488	8.37616158	1752.19966	252.4125977

WEATHER DATA



Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precipitation	Condition
12:20 AM	43 F	41 F	93 %	SW	7 mph	0 mph	29.75 in	0.0 in	Fair
12:50 AM	43 F	39 F	87 %	WSW	7 mph	0 mph	29.75 in	0.0 in	Fair
1:20 AM	45 F	39 F	81 %	WSW	7 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
1:50 AM	45 F	39 F	81 %	SW	7 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
2:20 AM	45 F	41 F	87 %	SW	8 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
3:50 AM	45 F	41 F	87 %	SW	6 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
4:20 AM	45 F	41 F	87 %	SSW	8 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
4:50 AM	45 F	41 F	87 %	SW	10 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
5:20 AM	45 F	41 F	87 %	SW	9 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
5:50 AM	45 F	39 F	81 %	SW	9 mph	0 mph	29.72 in	0.0 in	Partly Cloudy
6:20 AM	43 F	39 F	87 %	WSW	7 mph	0 mph	29.75 in	0.0 in	Partly Cloudy
6:50 AM	41 F	37 F	87 %	SW	7 mph	0 mph	29.72 in	0.0 in	Partly Cloudy
7:20 AM	39 F	37 F	93 %	S	6 mph	0 mph	29.72 in	0.0 in	Fair
7:50 AM	41 F	37 F	87 %	SSE	5 mph	0 mph	29.72 in	0.0 in	Fair
8:20 AM	41 F	39 F	93 %	SSW	3 mph	0 mph	29.72 in	0.0 in	Fair
8:50 AM	43 F	39 F	87 %	S	5 mph	0 mph	29.72 in	0.0 in	Fair
9:20 AM	45 F	39 F	81 %	SSW	3 mph	0 mph	29.75 in	0.0 in	Fair
9:50 AM	45 F	37 F	76 %	S	6 mph	0 mph	29.75 in	0.0 in	Fair
10:20 AM	46 F	39 F	76 %	S	7 mph	0 mph	29.75 in	0.0 in	Fair
10:50 AM	46 F	39 F	76 %	S	7 mph	0 mph	29.75 in	0.0 in	Fair
11:20 AM	50 F	39 F	66 %	SSW	8 mph	0 mph	29.72 in	0.0 in	Fair
11:50 AM	50 F	37 F	62 %	SSW	8 mph	0 mph	29.72 in	0.0 in	Fair
12:20 PM	50 F	37 F	62 %	SSW	8 mph	0 mph	29.72 in	0.0 in	Fair
12:50 PM	50 F	37 F	62 %	SW	10 mph	0 mph	29.70 in	0.0 in	Fair
1:20 PM	52 F	37 F	58 %	WSW	10 mph	0 mph	29.70 in	0.0 in	Fair
1:50 PM	52 F	37 F	58 %	SW	13 mph	0 mph	29.70 in	0.0 in	Fair
2:20 PM	52 F	39 F	62 %	WSW	15 mph	0 mph	29.70 in	0.0 in	Fair

Data pre-processing

- Activity 1 : Taking care of the missing data
- Solution - The missing data is less than 3% of the total data so we have filled the missing data by the average value of the respective column data.
- Activity 2 : Feature scaling
- Solution - Weather data has a scale of 30 minutes while the wind turbine data from Kaggle has a scale of 10 minutes so in order to merge both the data's we have converted each of them into the same scale (i.e. scale of 30 minutes). Then we merged both the data's into one and obtained our final data.

Handle Missing Data and Merging the data

DATA PRE-PROCESSING

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

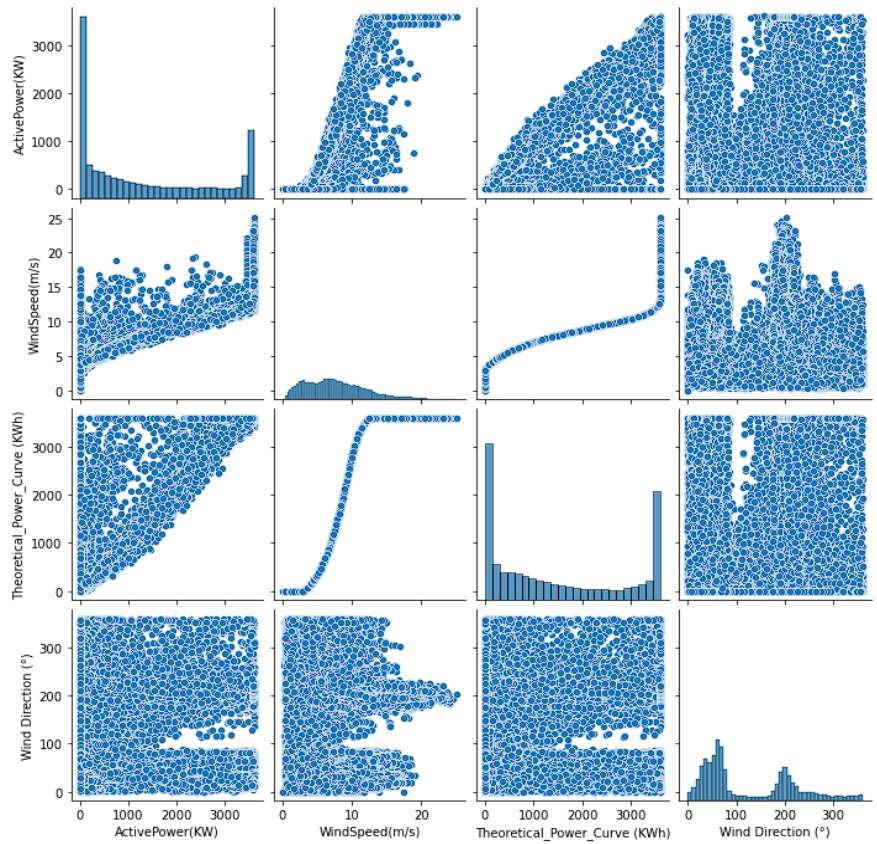
In [3]:
```
path = "T1.csv"
df = pd.read_csv(path)
df.rename(columns={"Date/Time":"Time",
                   "LV ActivePower (kW)":"ActivePower(KW)",
                   "Wind Speed (m/s)": "WindSpeed(m/s)",
                   "Wind Direction(°)":"Wind_Direction"},
                   inplace=True)
```

In [4]:
```
df.isnull().sum()
```

Out[4]:
```
Time                          0
ActivePower(KW)               0
WindSpeed(m/s)                0
Theoretical_Power_Curve (KWh)    0
Wind Direction (°)            0
dtype: int64
```

- **Activity 3:** Visualization of the Data
- **Solution-** We analyzed the data and studied the impact of different features on output (active power). With the results we achieved, we eradicated all the unnecessary features from the model

```
In [4]: sns.pairplot(df)
Out[4]: <seaborn.axisgrid.PairGrid at 0x155c46e1d00>
```



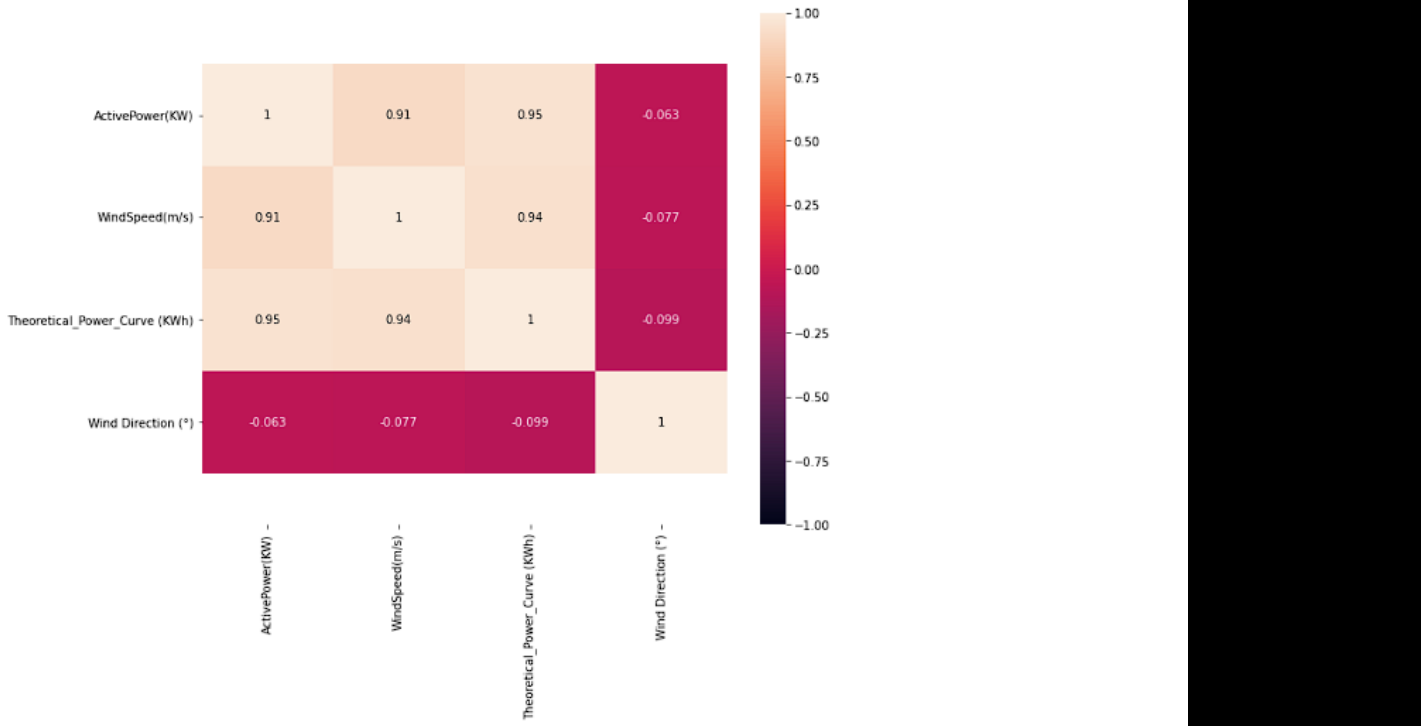
In [5]:
```
plt.figure(figsize=(10, 8))
corr = df.corr()
ax = sns.heatmap(corr, vmin = -1,vmax = 1,annot = True)
bottom, top = ax.get_ylim()
ax.set_ylim(bottom + 0.5, top - 0.5)

print(corr)
```

```
                                ActivePower(KW)  WindSpeed(m/s)  \
ActivePower(KW)                        1.000000        0.912774
WindSpeed(m/s)                         0.912774        1.000000
Theoretical_Power_Curve (KWh)          0.949918        0.944209
Wind Direction (°)                    -0.062702       -0.077188

                                Theoretical_Power_Curve (KWh)  \
ActivePower(KW)                                      0.949918
WindSpeed(m/s)                                       0.944209
Theoretical_Power_Curve (KWh)                        1.000000
Wind Direction (°)                                  -0.099076

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



Model Design

- **Activity 1**: Deciding parameters or features
- **Solution-** With the results we achieved we have selected following as our features for the model :

  1.Wind Speed

  2.Temperature

  3.Humidity

  4.Pressure

- **Activity 2:** Separating Training and Testing data from the data set
- **Solution-** This process will be done inside the model file itself by using the train_test_split library in the sklearn package of python.

- **Activity 3**: Developing the model
- **Solution**- We use the boosted trees regressor model to train and evaluate the model using TensorFlow. We decided to train the model using 120 trees to optimize the model and preventing it from underfit also we have used entire batch of training data to train so that model can accurately be trained.

APPLICATION DESIGN

- **Our initial plans included building the website in Html, but we wanted to provide our end-user the solution in single click, . We used Flask and Html framework for designing the UI of the website and Juypter Python for the back-end.**

- **Activity 1:** Build the UI
- **Solution-** We used Flask and Html to design our Website. Flask reduces code development time to huge extent because of its UI and html access. It allows seeing the applied changes almost instantly, without even losing the current application state. Apart from this, development in Flask is very easy because it uses the unique Widget tree model. Everything in Flask UI is just a Libraries. “App route" widget is the root widget of the website and all the other libraries become its children in hierarchial pattern.

FLASK DISPLAYING HIERARCHY

In [1]:
```
import numpy as np
from flask import Flask, request, jsonify, render_template
import joblib
import requests
```

In [2]:
```
app = Flask(__name__)
model = joblib.load("power_prediction.sav")
```

In [3]:
```
@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 = "d8484354b9e388875c48dae8d0d09cd1"
    url = "http://api.openweathermap.org/data/2.5/weather?q=" + city + "&appid=" + apikey
    resp = requests.get(url)
    resp = resp.json()
    temp = str(resp["main"]["temp"]) +" °C"
    humid = str(resp["main"]["humidity"]) + " %"
    pressure = str(resp["main"]["pressure"]) + " mmHG"
    speed = str(resp["wind"]["speed"]) + " m/s"
    return render_template('predict.html', temp=temp, humid = humid, pressure=pressure, speed = speed)
```

In [4]:
```
@app.route('/y_predict',methods = ['POST'])
def y_predict():
    x_test = [[float(x) for x in request.form.values()]]

    prediction = model.predict(x_test)
    print(prediction)
    output = prediction[0]
    return render_template('predict.html',prediction_text = 'The energy predicted is {:.2f} KWh'.format(output))
```

In [ ]:
```
if __name__ == "__main__":
    app.run(debug=False)
```

```
 * Serving Flask app "__main__" (lazy loading)
 * Environment: production
   WARNING: This is a development server. Do not use it in a production deployment.
   Use a production WSGI server instead.
 * Debug mode: off
 * Running on http://127.0.0.1:5000/ (Press CTRL+C to quit)
```

- Flask also has a huge library support for design and performance along with detailed documentation of each on Flask Libraies. It has no database

- A great emphasis has been put on developing the elegant UI of the website. We have used Brown theme. Through our Website we can predict the power generated by windmill for next 72 hours (on hourly basis) on any user input coordinates and current weather condition.

- Also a database of 50 cities in the India has been fed to the app which can be exploited using "**Search for weather condition**" button. User can search for the name of the cities and find the power that can be generated there. The app also provides the next 72 hour prediction of weather conditions at that particular coordinate.

HTML CODE FOR INTRO

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

                .header {
                        top:0px;
                        margin:0px;
                        left: 0px;
                        right: 0px;
                        position: fixed;
                        background: #6c493a;
                        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%;
                        background-image:url(https://c1.wallpaperflare.com/preview/623/531/630/596ca965a2e3f.jpg);
                        background-repeat:no-repeat;
                        background-size: contain;
                }
                .inside{
                        top:80px;
                        bottom:0px;
                        margin:0px;
                        left: 45%;
                        right: 0%;
                        position: fixed;
                        padding-left: 40px;
```

```
                        position: fixed;
                        padding-left: 40px;
                        padding-top:8%;
                        padding-right:40px;
                        background-color:#F2D19A;
                        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: 12px;
                          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 Turbine Based On Weather Condition</div>
                <div class="second">
                        <div class="inside">Renewable energy, such as wind and solar energy, plays an increasing role in the supply of energy worldwide. This trend will continue because glo
However, levels of production of wind energy are hard to predict as they rely on potentially unstable weather conditions present at the wind farm. In particular, wind speed is crucial for e
                <br><br><br>
                <a href="{{url_for('predict')}}"><button type="button" class="myButton" >Want to predict the energy??</button></a>
                </div>


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

Advantages and Disadvantages

ADVANTAGES

- Weather Underground Services provide very accurate Historical Weather Data which increased the accuracy of model.
- Website is more convenient to use due to zero storage.
- 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.

Conclusion

- In this project, we used Weather Underground services (subsidiary of IBM) to get accurate historical weather data. For merging this data with Windmill data we learned some Data Analysis concepts. We analyzed several ML models, and chose Random Tree Regressor to develop this model. This project gave us deep insight about the Flutter framework. We integrated the app with model and Weather API using REST API and Flask Back-end. The accuracy of Random Tree Regressor model for this project is 85%.

References

- Wind Power Data:
  https://www.kaggle.com/berkerisen/wind-turbine-scada-dataset
- Weather Data
  https://www.wunderground.com
- Data Science
  https://www.youtube.com/watch?v=CmorAWRsCAw&list=PLeo1K3hjS3uuASpe-1LjfG5f14Bnozjwy

- Climacell API
  https://www.climacell.co/weather-api/
- Flask
  https://flask.palletsprojects.com/en/1.1.x/
- Flutter
  https://flutter.dev/