Wind Turbine Failure Analysis

Optimizing operations and predicting failures for enhanced efficiency.

Project Overview

Data-Driven Insights

Process and analyze vast data from turbine operations, gearbox, temperature, and performance.

Identify Patterns

Crucial for identifying failure patterns and boosting turbine efficiency.

Overcoming Challenges

Existing methods struggle with growing data volume and complexity.

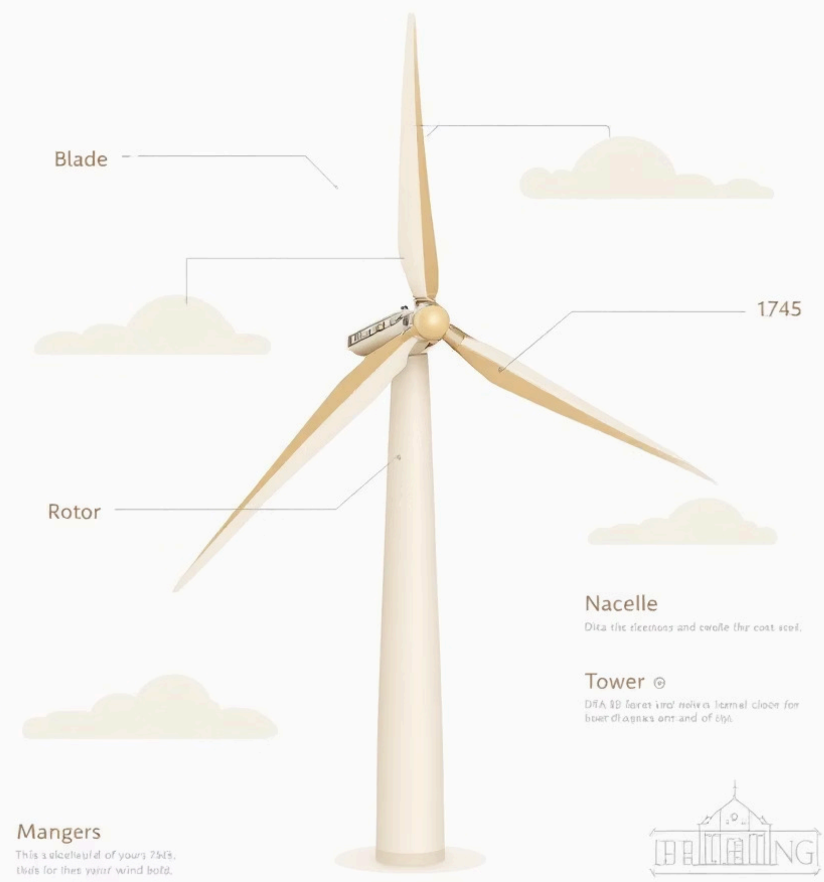
Dataset Summary

Dataset Snapshot

- Rows: 26,282
- Columns: 16

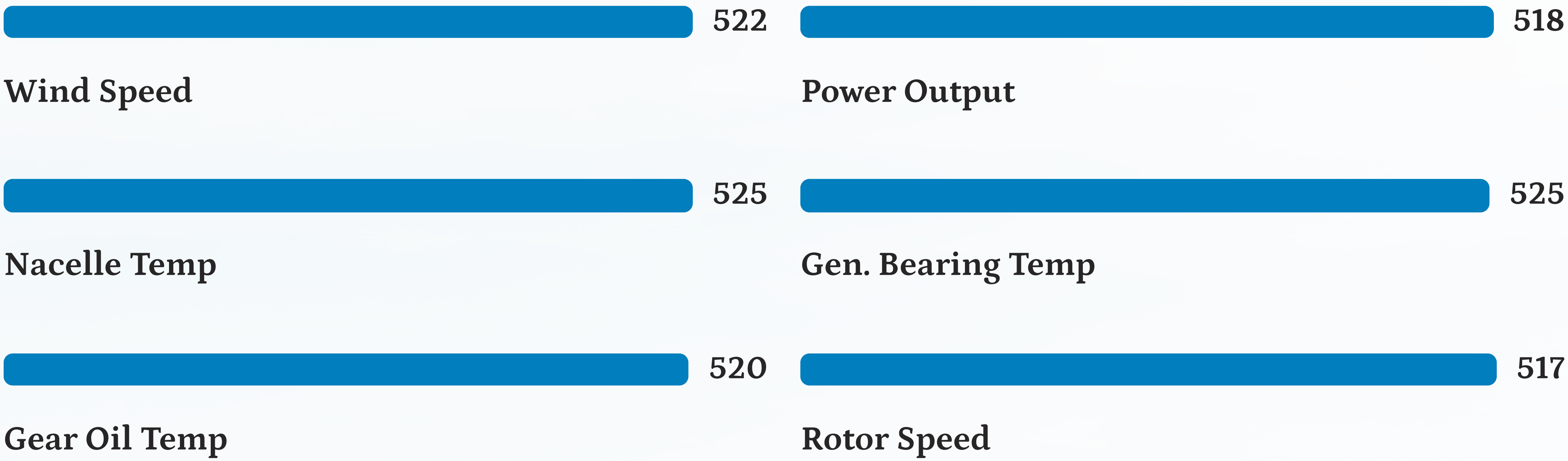
Key Features

- Date, Wind Speed/Direction
- Yaw Angle, Power Output
- Rotor/Generator Speed
- Ambient/Nacelle Temperatures
- Bearing/Gear Oil Temperatures
- Wheel Hub Temperature
- Failure Status (0=No, 1=Yes)



Missing Data Overview

Significant missing values across critical parameters.



Exploratory Data Analysis (EDA) in Python

Data Loading

Imported dataset using pandas.

Initial Exploration

Used `df.info()` and `.describe()` for structure and summary.

Missing Data Handling

Imputed null values, e.g., median rating for product categories.

Column Standardization

Converted columns to snake_case for readability.

Statistical Moments Analysis

First Moment Business

Mean and median values mined for dataset.

```
numeric_column.median()
```

```
Wind_speed                          11.614141
Power                              248.957796
Nacelle_ambient_temperature         10.045773
Generator_bearing_temperature       17.958251
Gear_oil_temperature                15.178296
Ambient_temperature                 10.256434
Rotor_Speed                         58.061232
Nacelle_temperature                 13.989083
Bearing_temperature                 16.047325
Generator_speed                     69.517202
Yaw_angle                            0.113390
Wind_direction                     181.112856
Wheel_hub_temperature               16.931774
Gear_box_inlet_temperature          15.026247
dtype: float64
```

Second Moment Business

Variance and standard deviation calculated.

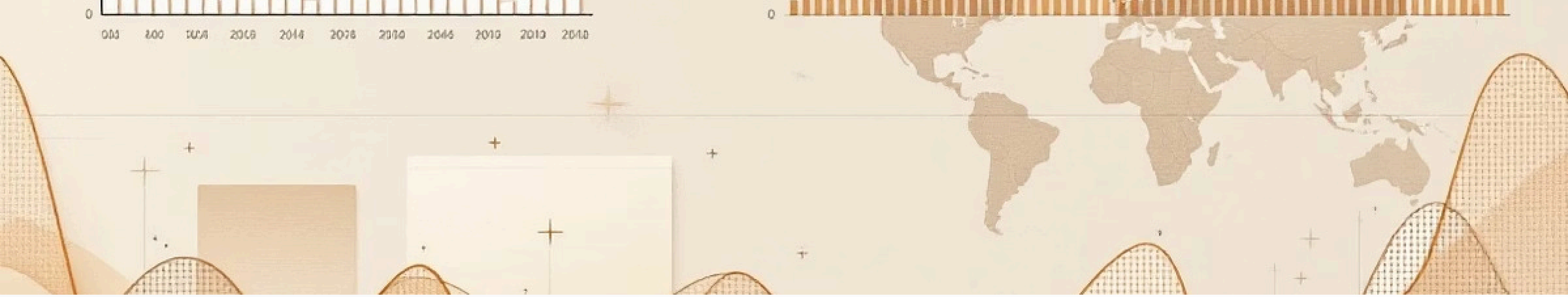
```
numeric_column.var()s
```

```
Wind_speed                              35.331681
Power                               202463.260355
Nacelle_ambient_temperature            116.151401
Generator_bearing_temperature          125.088928
Gear_oil_temperature                   149.500435
Ambient_temperature                    144.235116
Rotor_Speed                            913.606113
Nacelle_temperature                    120.116094
Bearing_temperature                    124.700632
Generator_speed                       1441.656091
Yaw_angle                             2690.232938
Wind_direction                       10718.886277
Wheel_hub_temperature                  119.947025
Gear_box_inlet_temperature             120.206290
dtype: float64
```

Calculating Standard Deviation for every column.

```
numeric_column.std()
```

```
Wind_speed                           5.944046
Power                              449.959176
Nacelle_ambient_temperature         10.777356
Generator_bearing_temperature       11.184316
Gear_oil_temperature                12.227037
Ambient_temperature                 12.009792
Rotor_Speed                         30.225918
Nacelle_temperature                 10.959749
```



Advanced Statistical Moments

Third Moment Business

Skewness analysis to understand data distribution asymmetry.

Calculating Skewness for every column.

```
numeric_column.skew()
```

```
Wind_speed                       0.777017
Power                            1.509172
Nacelle_ambient_temperature      0.001543
Generator_bearing_temperature    0.005980
Gear_oil_temperature             0.789811
Ambient_temperature              0.785104
Rotor_Speed                      0.779238
Nacelle_temperature             -0.002245
Bearing_temperature             -0.006273
Generator_speed                  0.771103
Yaw_angle                        0.002120
Wind_direction                  -0.003044
Wheel_hub_temperature            0.001998
Gear_box_inlet_temperature       0.003213
```

Fourth Moment Business

Kurtosis analysis for data peakedness and tail heaviness.

Calculating Kurtosis for every column.

```
numeric_column.kurtosis()
```

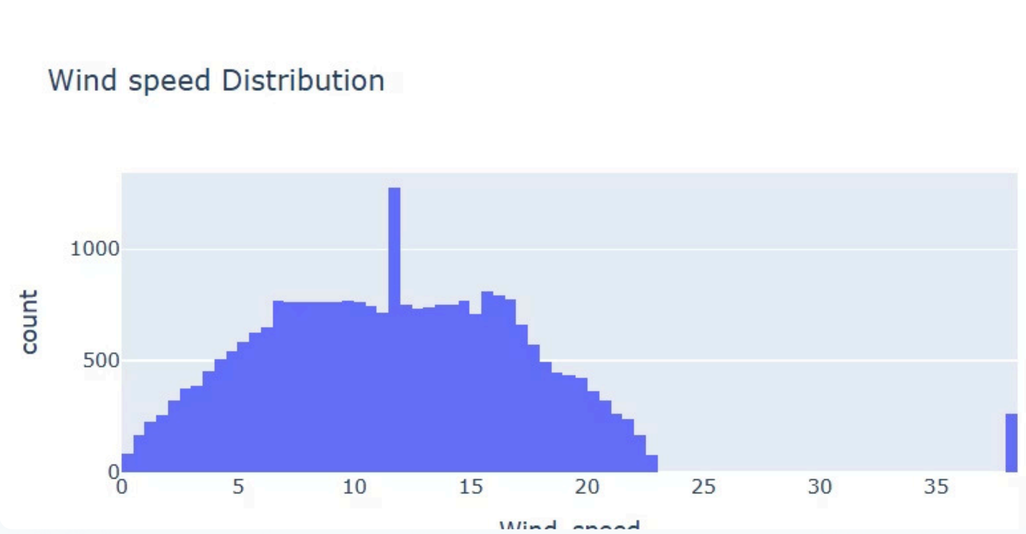
```
Wind_speed                       2.320709
Power                            2.627610
Nacelle_ambient_temperature     -1.398280
Generator_bearing_temperature   -1.210245
Gear_oil_temperature             2.057662
Ambient_temperature              2.003777
Rotor_Speed                      2.383055
Nacelle_temperature             -1.298763
Bearing_temperature             -1.196091
Generator_speed                  2.458637
Yaw_angle                       -1.197865
Wind_direction                  -1.189435
Wheel_hub_temperature           -1.304294
Gear_box_inlet_temperature      -1.306595
dtype: float64
```

Graphical Representation & Outlier Treatment

Wind Speed Distribution

Histogram to visualize data distribution.

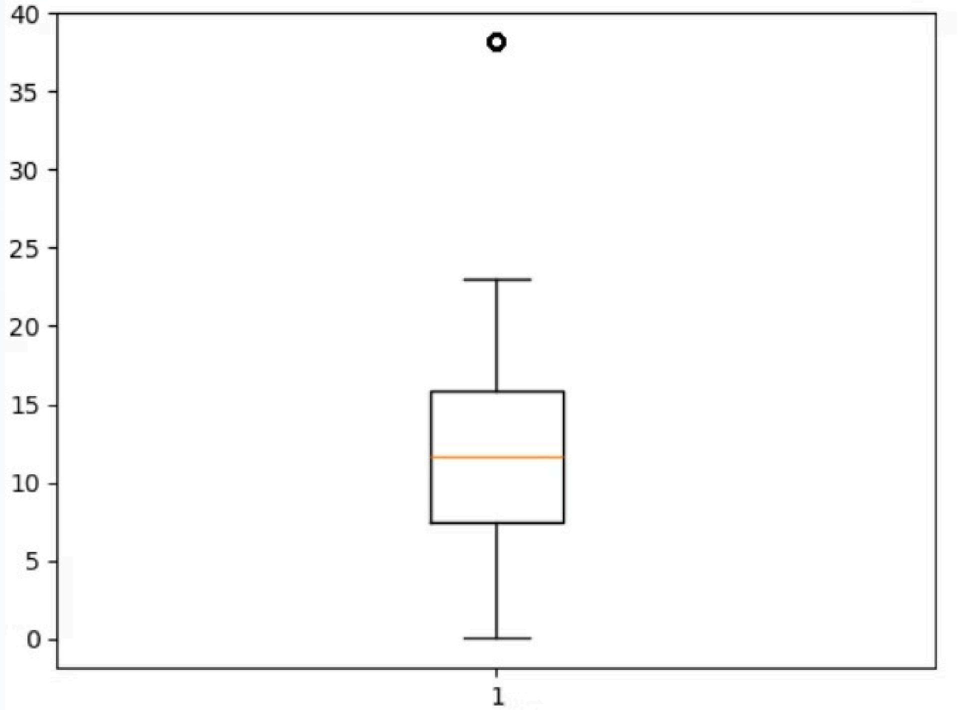
```
fig=px.histogram(data,x='Wind_speed',title='Wind speed Distribution')
fig.show()
```



Outlier Detection

Boxplot to identify outliers.

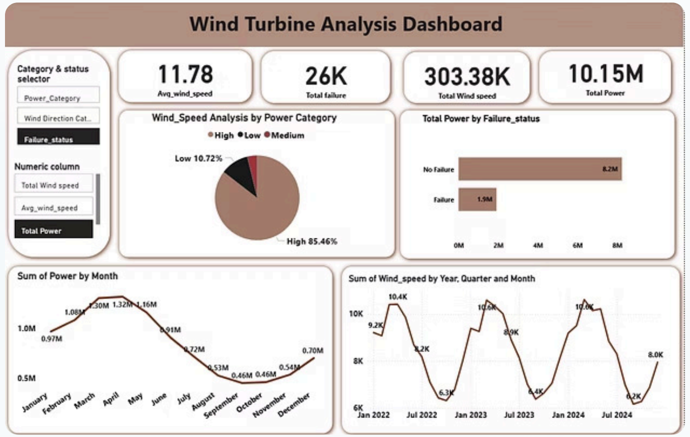
```
{'whiskers': [<matplotlib.lines.Line2D at 0x17a8057bd90>,
  <matplotlib.lines.Line2D at 0x17a8057bed0>],
 'caps': [<matplotlib.lines.Line2D at 0x17a80594050>,
  <matplotlib.lines.Line2D at 0x17a80594190>],
 'boxes': [<matplotlib.lines.Line2D at 0x17a8057bc50>],
 'medians': [<matplotlib.lines.Line2D at 0x17a805942d0>],
 'fliers': [<matplotlib.lines.Line2D at 0x17a80594410>],
 'means': []}
```

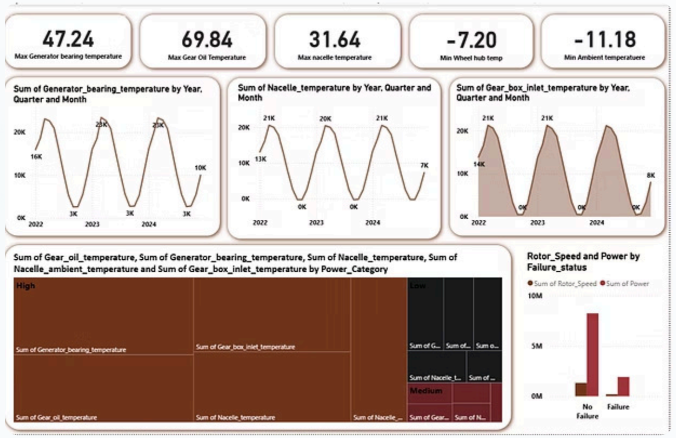


Winsorization method applied for outlier treatment.

Power BI Dashboard

Interactive insights into wind turbine failure analysis.





Business Recommendations

1

Optimize Maintenance

Schedule based on temperature/vibration patterns to reduce downtime.

2

Enhance Alignment

Monitor yaw angle for maximum power output.

3

Improve Cooling

Address high generator/gearbox temperatures with better systems.

4

Boost Efficiency

Analyze power vs. wind-speed curves; calibrate settings.

5

Failure Prediction

Create early warning alerts using failure status patterns.