Estimating Power Generation from Wind Forecasts

Project Overview

Objectives and Road Map

- **Key Objective** : Estimate statistical model to predict the power output (kW) of wind turbine based on weather forecasts at fixed zeroth hour lead times.
- **Road Map**
  - Background & Context
  - Data Compilation
  - Exploratory Data Analysis
  - Statistical Modeling

Background & Context

- Utilities and renewable energy market entrepreneurs require weather **dependent** electrical power forecasts.
- Historic electrical forecasts are based on ideal weather and machinery conditions, such as constant periodic wind patterns.
- A precise energy forecast can overcome problems of variable energy production caused by fluctuating weather and wind conditions.

Data Source Review

Data	Source	Features
Weather	National Weather Forecast	Wind Speed,Direction, Precipitation,Temperature … eat
Electrical Power	SCADA (supervisory control and data acquisition)	Kilowatt readings in ten second intervals

Data Compilation

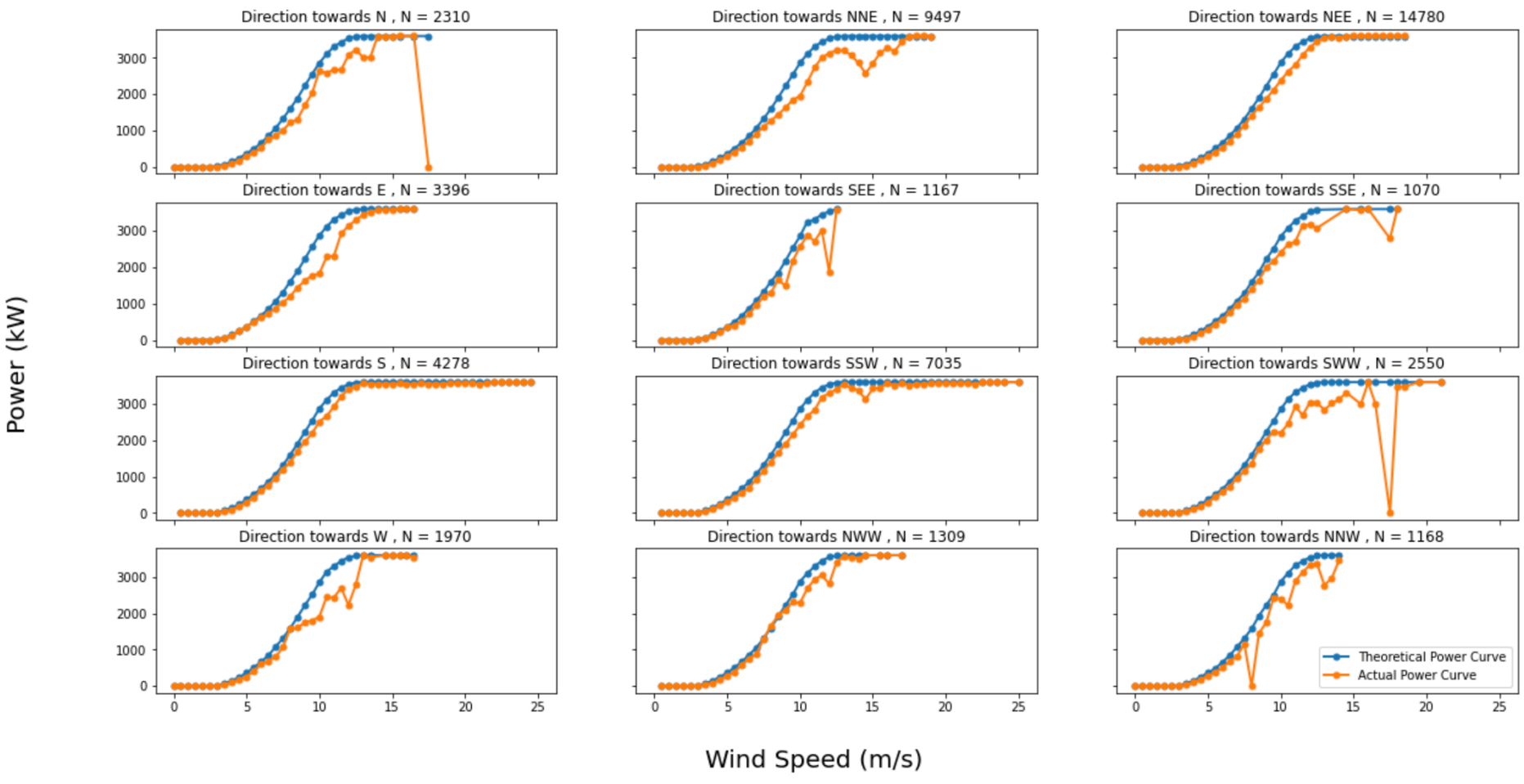
Data table example

Date/ Time	Grid	Active Power (kWh)	Wind Speed (m/s)	Wind Direction (Degrees)	Theoretical Power Curve (KWh)
01/01/2018 00:00	1	380.04	5.31	259.99	416.32
01/01/2018 00:10	1	453.76	5.67	268.64	519.91
…		…	…	…	…
31/12/2018 23:50	99	2820.46	9.97	271.25	2779.18

* Dataset defined at the grid/minute resolution
* 12 Month period captured in data set across 99 grids breaking up service territory
* Theoretical Power Curve represents “null” historic model

Exploratory Data Analysis

Power Generation and Weather



- Power generation was aggregated to wind speed windows across all aspects

- Across all cardinal directions (N - NW), a **nonlinear positive trend** is observed between wind speed and power generated.

- Below 4 m/s, nearly no power is generated
- Above 12 m/s, power generation is maximized
- **Theoretic Power tends to overestimate (ideal conditions)**

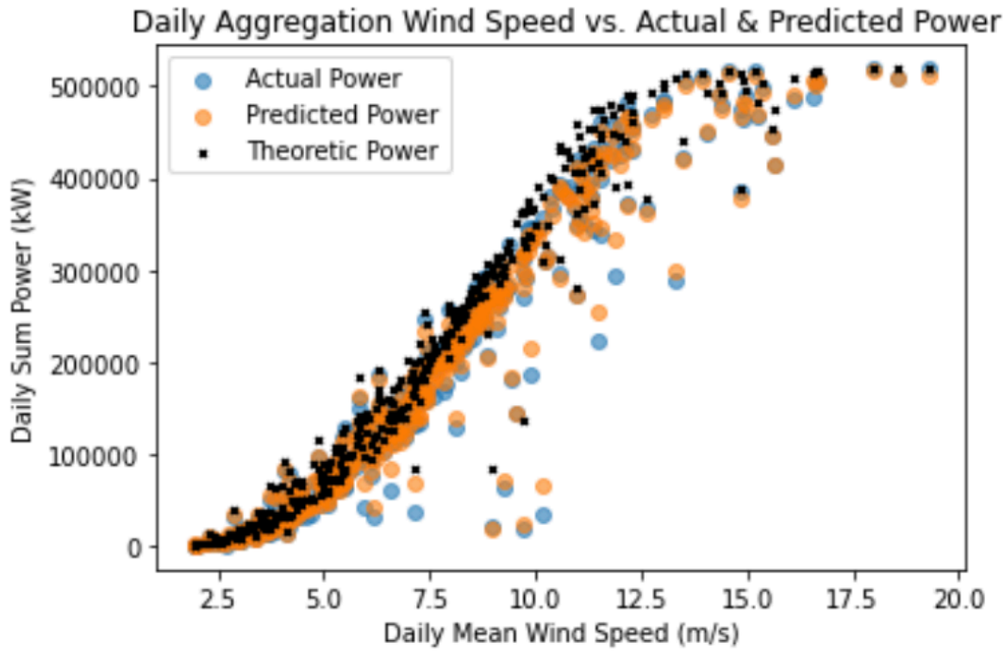
Statistical Modeling

- A random forest regressor was trained on a 70-30 train-test split
- Wind speed produced highest levels of contributions on nodal splits
- Max Depth of 9 nodes
- Validation R2 = 0.96

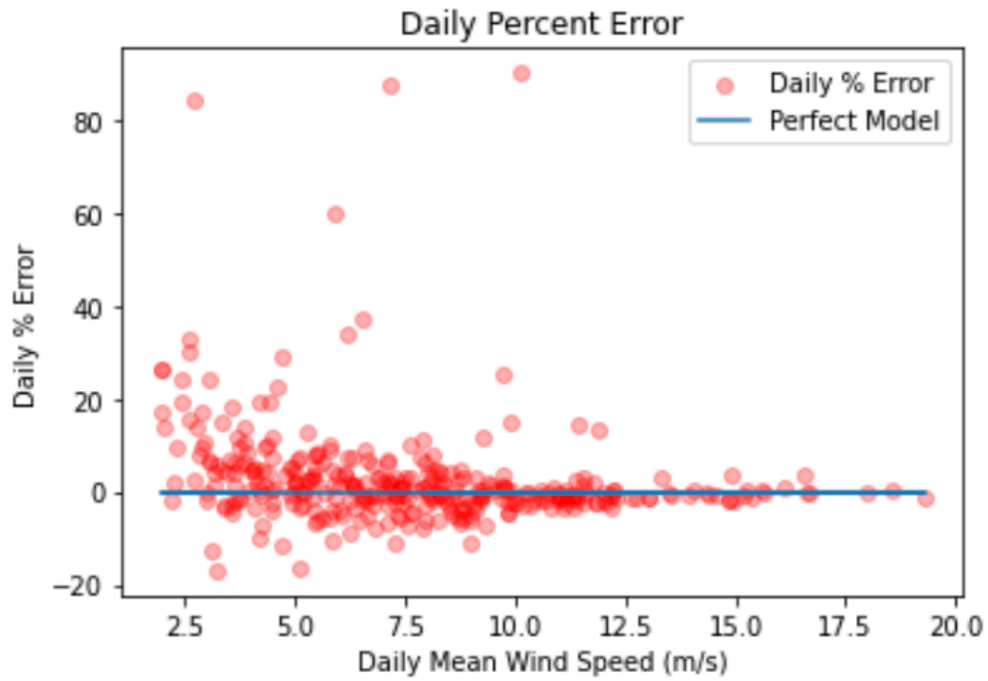
Rank	Feature	Relative Importance
1	Avg. Wind Spd	0.92
2	Day	0.03
3	Wind Dir	0.02
4	Month	0.01
5	Hour	0.01

Model Evaluation & Diagnosis

- Nonlinear model **captures variability of power** generated within bounds of ground truth.
- R2 of daily power estimates : 0.98



- Highest degree of error present at low wind speeds wind speeds
  - **Model overestimates power generation**



Next Steps & Future Work

- Discuss results and incorporate feedback into future analysis
- Evaluate efficacy of model across territory (per grid)
- Incorporate forecast data with greater lead times (1 - 72 hour)
- Incorporate full weather forecast into model training
- Investigate nodal variability regime.

Thanks for collaborating with us!