Wind Power Data for Grid Integration Studies

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OVERVIEW

• Introduction
• Obtaining wind data for integration studies
  – Pure observations and MCP
  – Data mining
  – Numerical weather simulation
• Converting wind data to power data
  – Manufacturers’ rating curves
  – Farm-wide rating curves
  – Assumption of non-correlation
  – Probabilistically modelling power output from an individual turbine
INTRODUCTION

• There are a number of ways of performing integration studies, this presentation does not dwell on the specifics of integration studies.
• Instead, it deals solely with the wind power data that is the fundamental basis of all integration studies.
• There are several ways to obtain wind data and several ways to convert that data into power data, unfortunately neither data acquisition nor conversion is trivial.
To obtain sufficient wind data, it is important to first understand what exactly is required:
— Temporal resolution,
— Spatial resolution and
— Quantity of data.

**Temporal Resolution**: A survey of U.S. integration studies showed that the most common resolution was ten-minute data.

- This data can then be averaged over longer periods to perform load following analysis (e.g. hourly).
- It is also important to ensure that the temporal statistics (such as diurnal behaviour) is accurate.
**Spatial resolution:** Defining the required spatial resolution is slightly more difficult. This can depend largely on the methods used to obtain the wind data and the nature of the study.

**Quantity of data:** The quantity of data is also difficult to define in a general sense. To be effective it must be at least one year to capture the seasonal effects of demand and wind profiles. More than a year is useful and energy constrained systems (such as most hydro-based systems) tend to use more than one year in their integration studies.
OBTAINING WIND DATA

• There are several methods to obtain wind data:
  – Observations
  – Data Mining
  – Numerical Weather Simulations

• The most straightforward and reliable way to obtain wind data is through on-site observations, but are not usually available.

• Data mining is flexible, but its ability to downscale the weather is limited.

• The NWP models use physical conservation of energy equations and this allows more realistic downscaling of the data.
• Converting windspeed data to power data can also be done several ways,
  – Directly aggregated manufacturer’s rating curve
  – Empirical farm-wide rating curve
  – Non-correlation of turbines at high temporal sampling
  – Correlated turbines through probabilistic modelling

• Unfortunately, choosing between these options is not straightforward either…
• Simple upscaling of manufacturer’s rating curves do not model farm-wide smoothing relationships.
• “Farm-wide” rating curves are developed from empirical data for an entire farm and thus are subject to farm specifics (size and layout).
• The assumption of non-correlation is flawed as adjacent turbines are correlated - even at the minutes-scale.
• Furthermore, all of these techniques require wind to power conversion to be deterministic…
CONVERTING WIND TO POWER DATA

- Minutes-scale variation of windspeed vs power output at a single turbine

- Conclusion: The conversion of windspeed to power output is not deterministic (at this timescale).
• One alternative is to use probabilistic modelling.
• This paper introduces *SCORE*, the Statistical Correction to Output from a Record Extension.
• SCORE is built on the concept that accurately modelling an individual turbine will result in accurately modelling the entire wind farm.
• *However*, it is important to note that SCORE is designed to operate in a *probabilistic* manner and so it may not be right at any given moment, but it should provide *statistically* correct data.
NWP Wind Data

Theoretical Power Output at Gridpoint

Link Turbines to NWP Points

Power Output Time-Series from Each Turbine

\[ \sum \]
Sum over No. turbines

Ten-Minute Cumulative PDF Suite

Hourly “Corrected” Power Output

Hourly Cumulative PDF Suite

Limit to nameplate min. and max.

SCORE Probabilistically Corrected Power Output
• The PDFs are used to “correct” the power output at each individual turbine.
• Treating the turbines individually may seem like treating them as though they are uncorrelated…
• But:
  – The probabilistic model provides a difference value from the theoretical output, meaning the turbines are clearly still correlated.
  – The models are based on NWP-size area-averaged windspeed and thus accounts for turbine spatial correlations directly.
• Example PDFs from ten turbines at a few different farms - showing consistency of behaviour.

Sample Set of Histograms of Deviations from the Manufacturer's Rating Curve

Counts

Normalised difference from manufacturer’s rated output
• Example trace contrasting partial farm data versus entire farm data at Aubrey Cliffs.
Public validation of SCORE is difficult as it needs accurate, publicly available, turbine data over a representative period.

However, the following slides present qualitative validation results (which is reasonable as it is just a probabilistic model anyway).

The graphics will be based on State Transition Matrices (STMs) showing the probability of changing from one state to another (i.e. 0-10% to 40-50%).
SCORE VALIDATION

States:
1 = 0–10%
2 = 10–20%
3 = 20–30%
4 = 30–40%
5 = 40–50%
6 = 50–60%
7 = 60–70%
8 = 70–80%
9 = 80–90%
10 = 90–100%

Representation of Actual State Transition Matrix
SCORE VALIDATION

Modelled Windspeed Converted to Power Using SCORE

Obs. Speed to Power

Observed Windspeed Converted to Power Using Power Curve

NWP Speed to Power

Modelled Windspeed Converted to Power Using Power Curve
CONCLUSION

• Appropriate data is key to integration studies.
• Obtaining appropriate wind data is not trivial - although the best option is to use a NWP model.
• Converting wind to power data is also not trivial.
• To this end the SCORE methodology was described which can statistically “correct” the data to behave similarly to a real wind project.
• SCORE has now been used to model over 6500MW of potential wind installation for integration studies.