Wind Power Data for Grid Integration Studies

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Panel on Wind 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.

OBTAINING WIND DATA

- 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.
  - ó This data can then be averaged over longer periods to perform load following analysis (e.g. hourly).
  - ó It is also important to ensure that the temporal statistics (such as diurnal behaviour) is accurate.

OBTAINING WIND DATA

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- *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.
  - ó 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

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- 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 WIND TO POWER DATA

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- 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…

CONVERTING WIND TO POWER DATA

- 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

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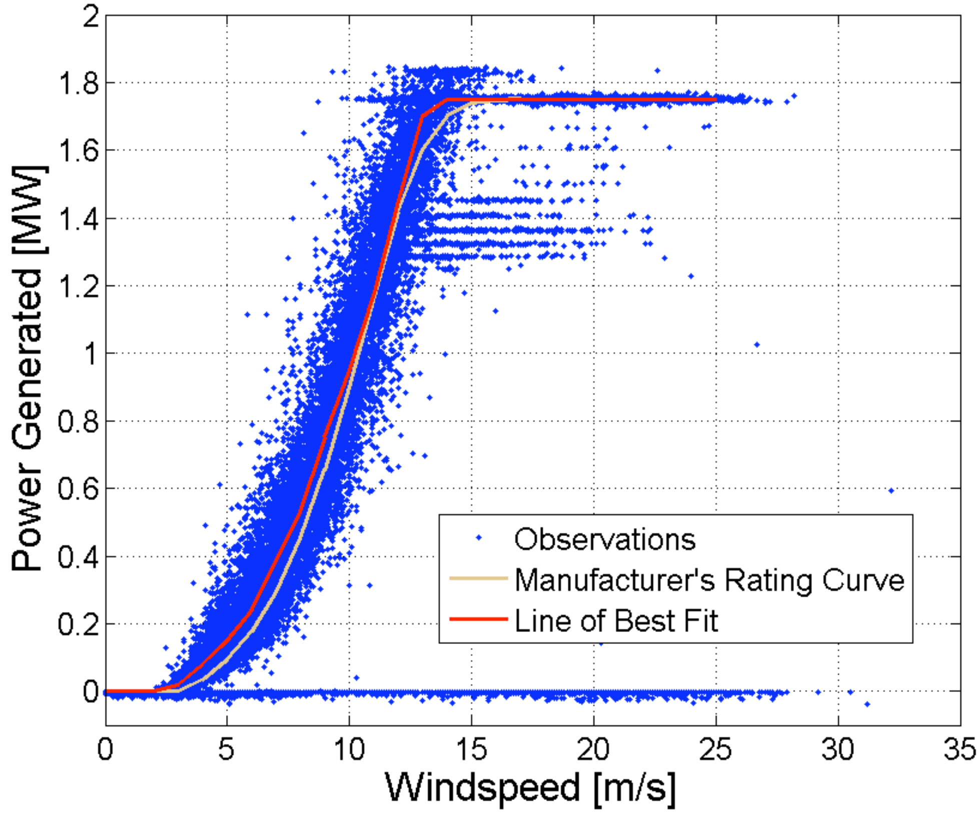
- Minutes-scale variation of windspeed vs power output at a single turbine



- Conclusion: The conversion of windspeed to power output is not deterministic (at this timescale).

CONVERTING WIND TO POWER DATA

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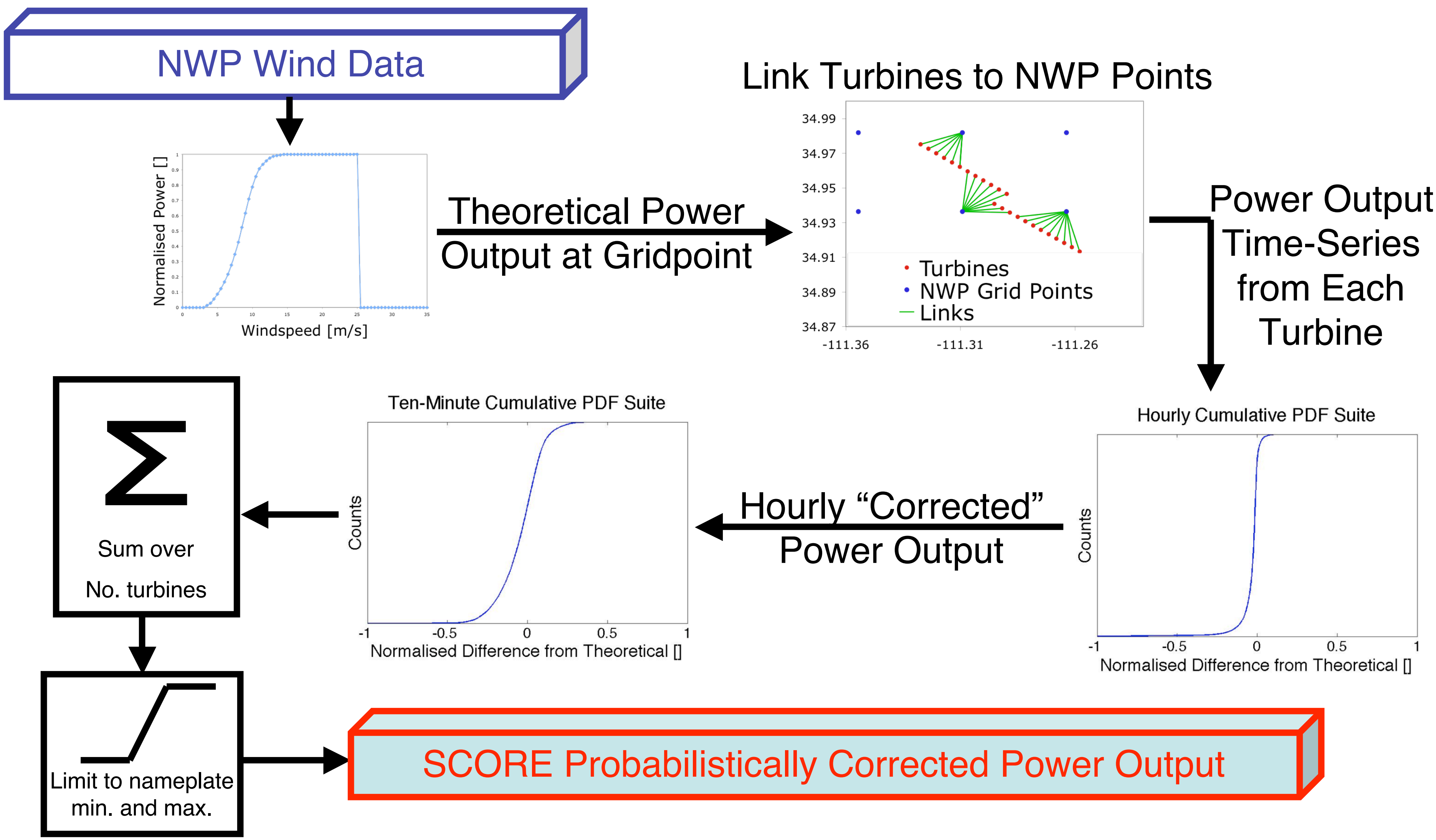
- One alternative is to use probabilistic modelling.
- This paper introduces *SCORE*, the Statistical Correction to Output from a Record Extension.
- SCORE is built on the concept that accurately modelling an individual turbine will result in accurately modelling the entire wind farm.
- *However*, it 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.

SCORE FLOW DIAGRAM



DEVELOPING SCORE

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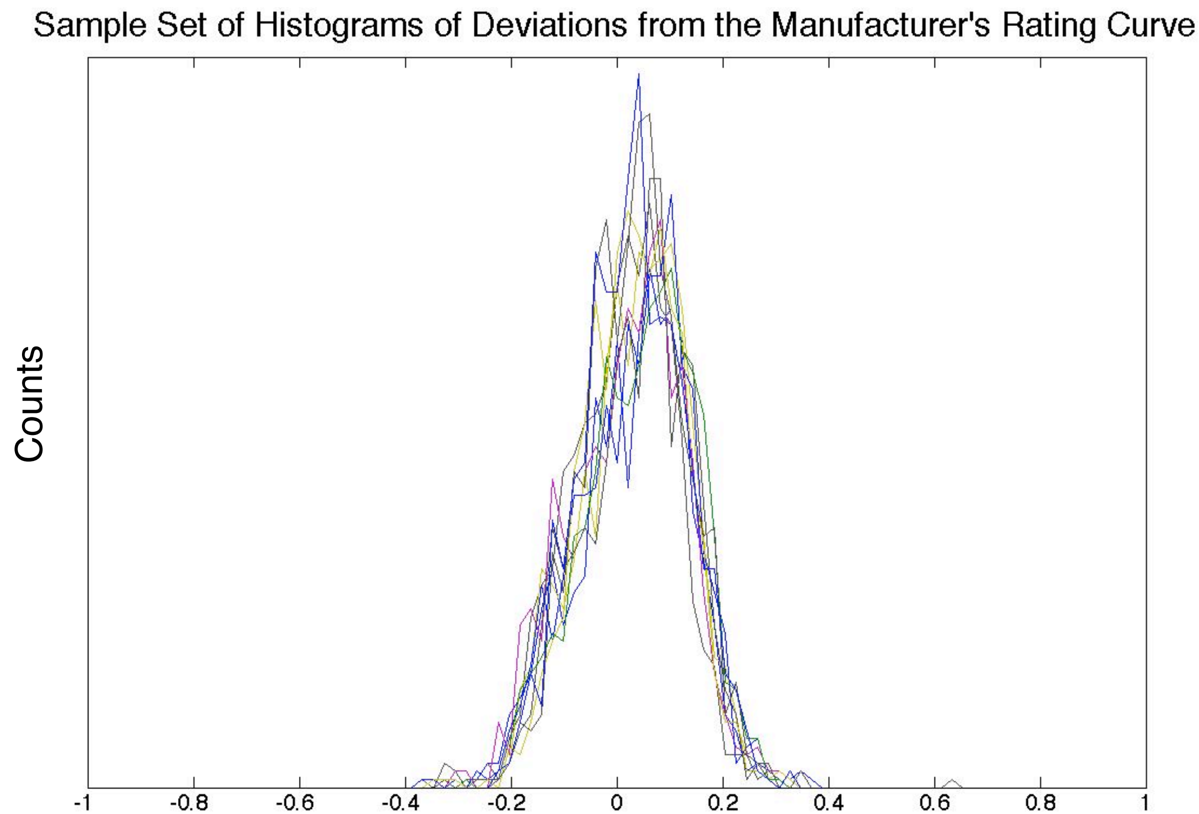
- The PDFs are used to “correct” the power output at each individual turbine.
- Treating the turbines individually may seem like treating them as though they are uncorrelated…
- But:
  - The probabilistic model provides a difference value from the theoretical output, meaning the turbines are clearly still correlated.
  - The models are based on NWP-size area-averaged windspeed and thus accounts for turbine spatial correlations directly.

DEVELOPING SCORE

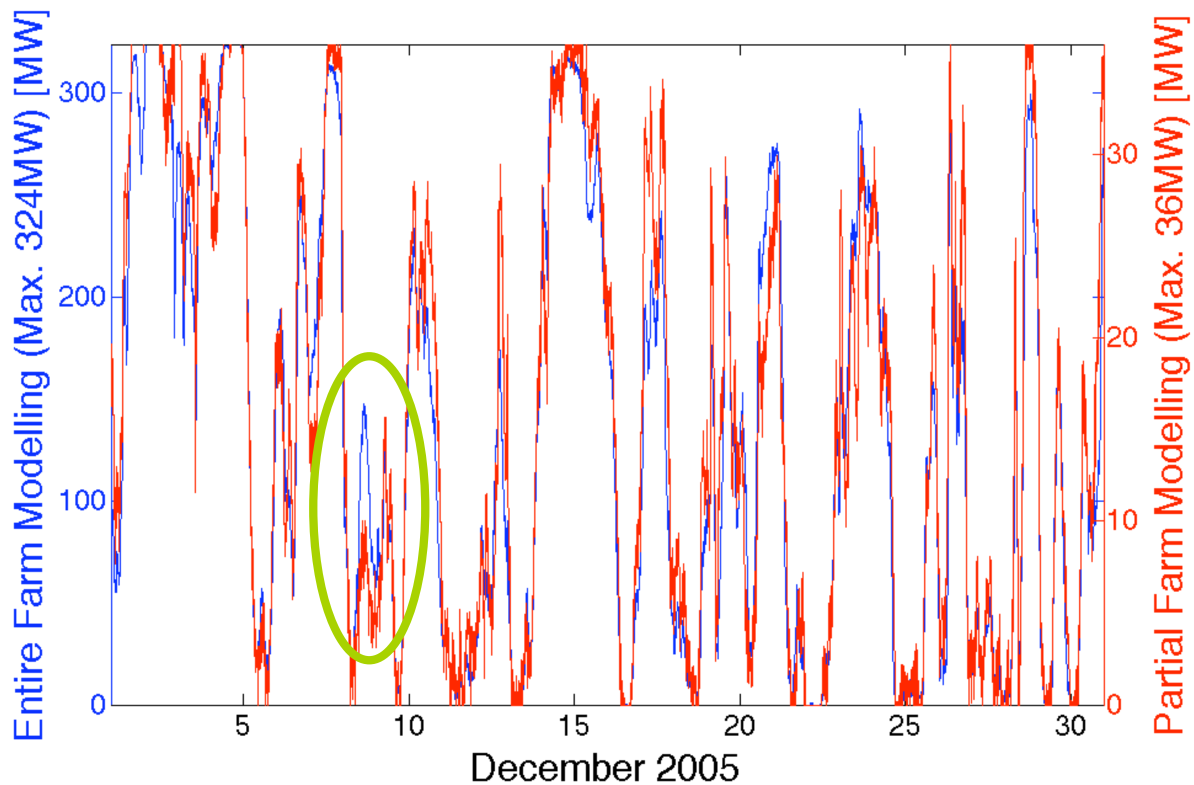
- Example PDFs from ten turbines at a few different farms - showing consistency of behaviour.



Normalised difference from manufacturer’s rated output

EXAMPLE OUTPUT

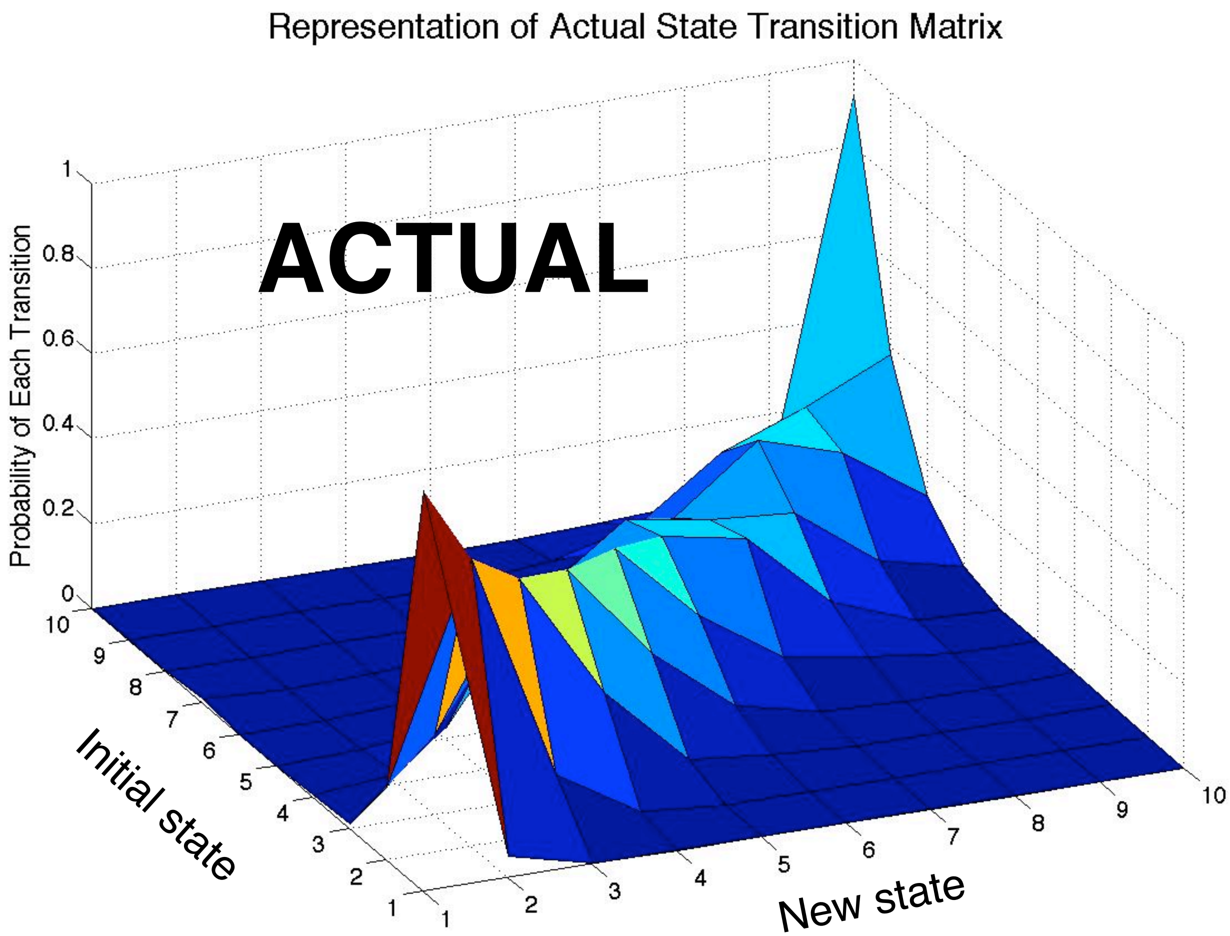
- Example trace contrasting partial farm data versus entire farm data at Aubrey Cliffs.



SCORE VALIDATION

- 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%).

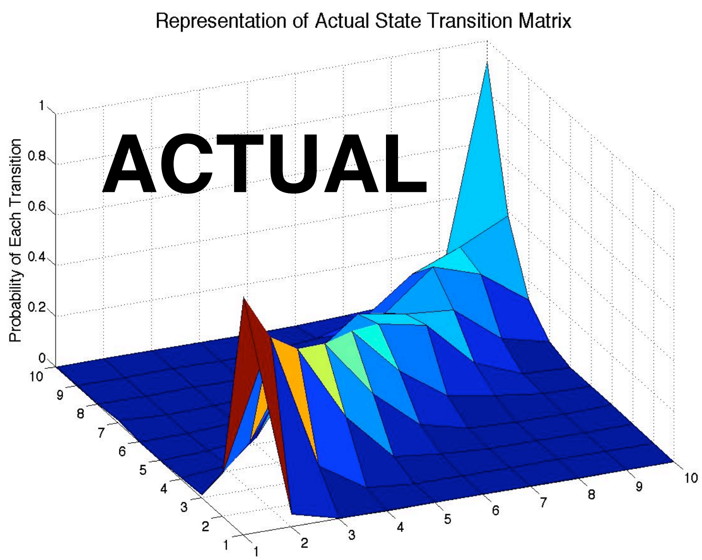
SCORE VALIDATION

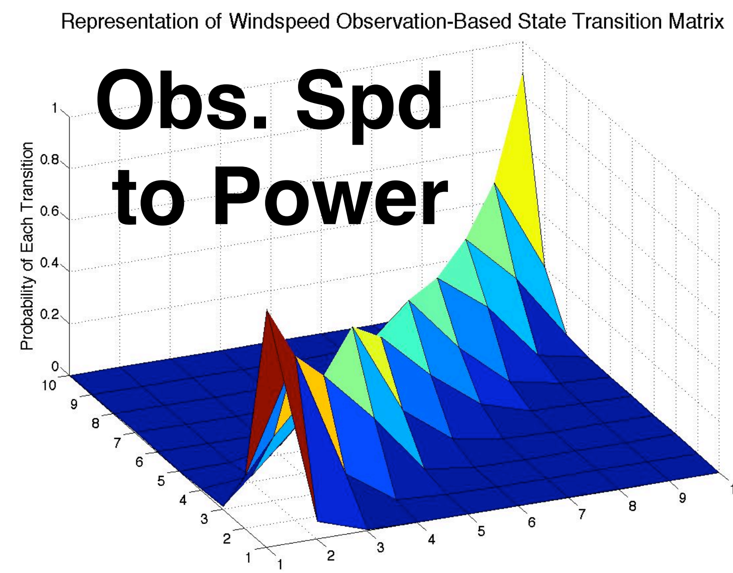


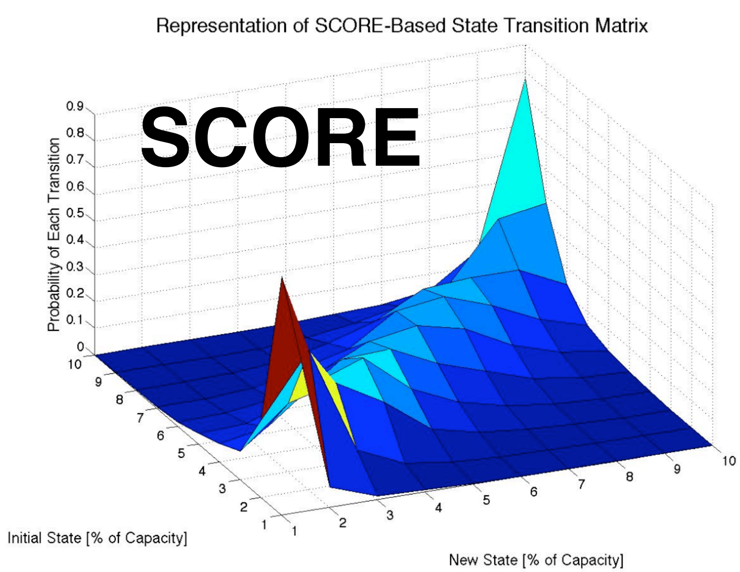
States:

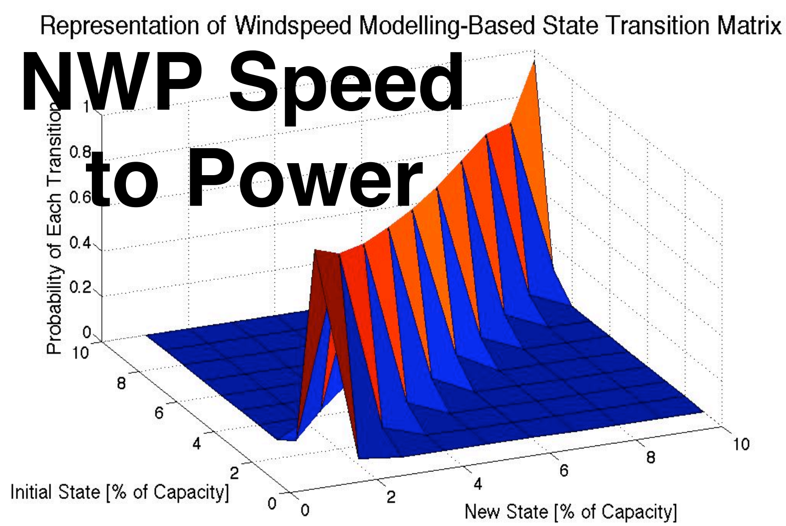
1 = 0-10%
2 = 10-20%
3 = 20-30%
4 = 30-40%
5 = 40-50%
6 = 50-60%
7 = 60-70%
8 = 70-80%
9 = 80-90%
10= 90-100%

SCORE VALIDATION

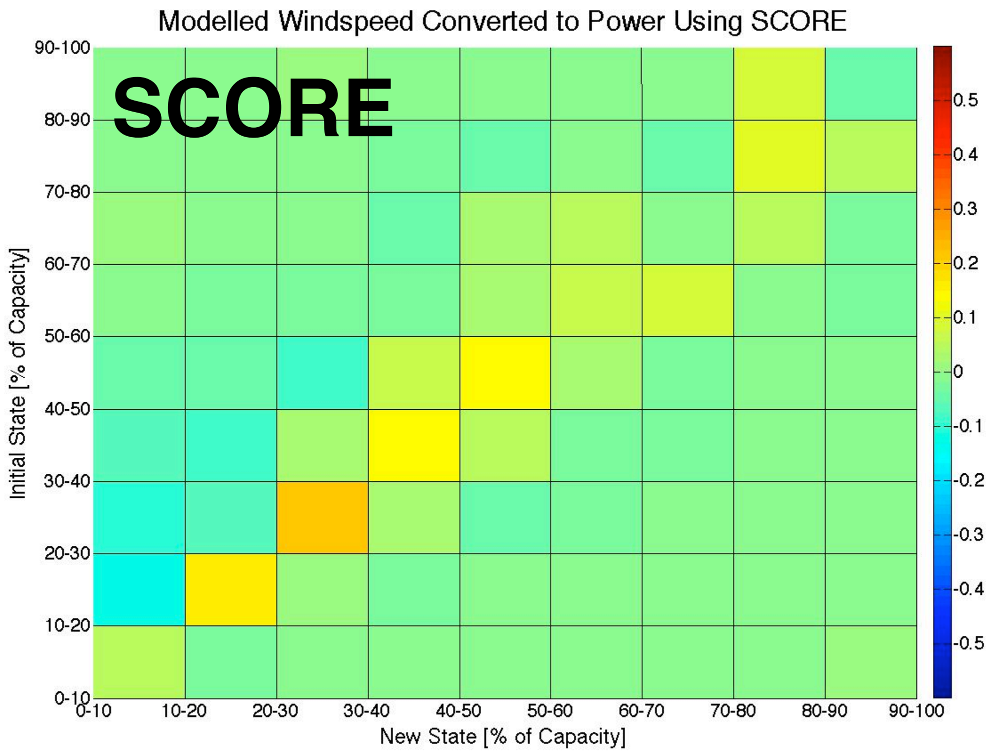


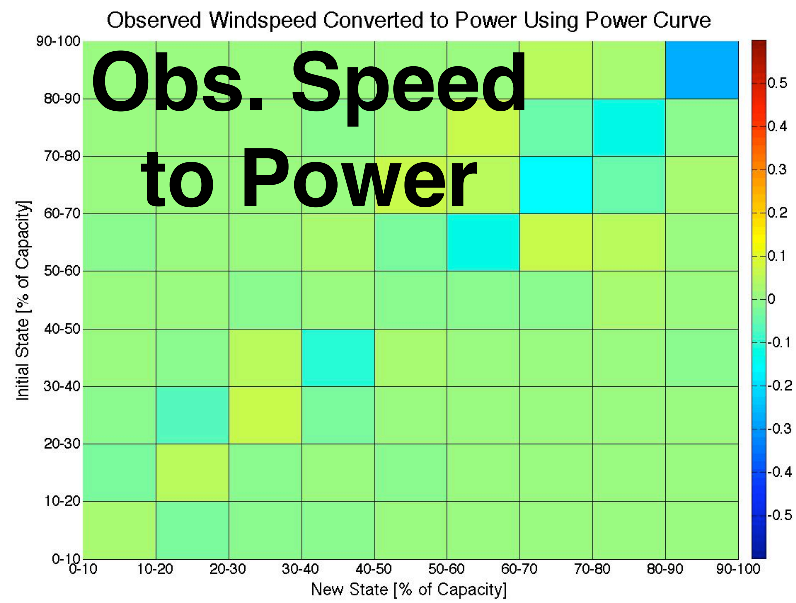


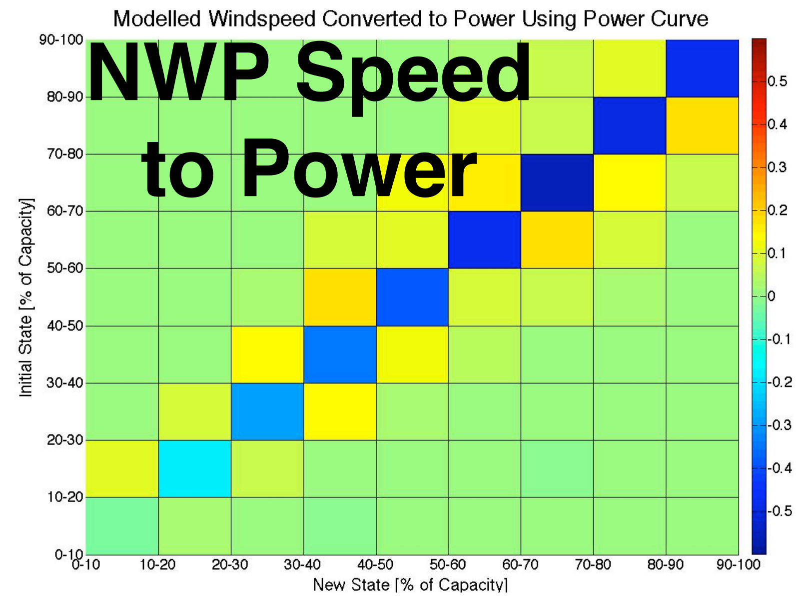




SCORE VALIDATION







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.