PCWG Validation Analysis

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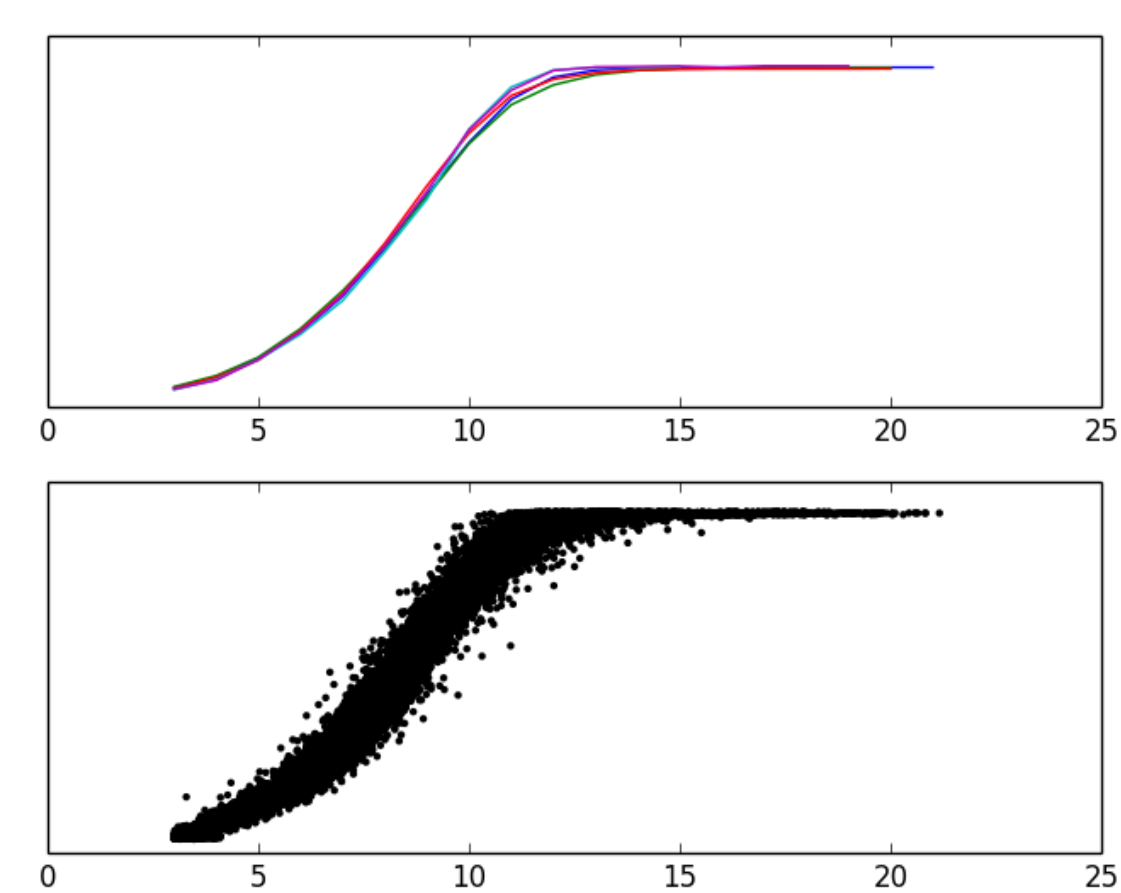
Wednesday 4th December 2013

Summary of Validation Analysis

- Data sets from five Power Performance tests have been re-analysed
- Tests cover wind farms across the UK with similar turbine types
- Summary of Instrumentation:
  - Reference wind speed at hub height, corrected using site calibration procedure and air density
  - Shear anemometers at the lower tip height and <5m below hub height
  - Reference wind direction, temperature, pressure and inflow angle
  - Turbine power transducer
  - Turbine OK, Running and grid frequency signals
  - Turbine and Reference logger quality signals

Summary of Validation Analysis (Filters)

- Summary of Filters:
  - Wind speed, direction, signal count and power as per original PP test
  - No temperature, TI, shear or inflow angle filters in this analysis
  - 4289 hours (~180 days) of data remain after filtering

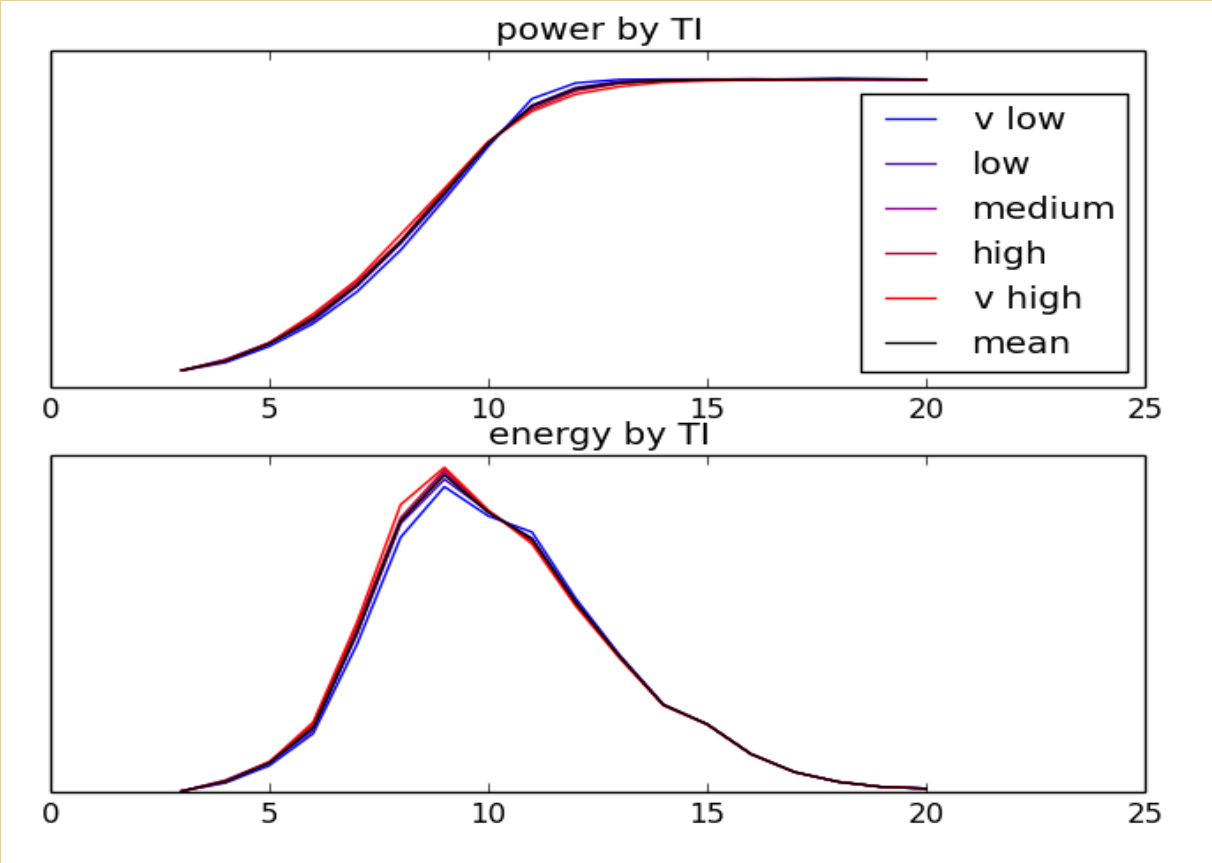


Which signals are related to power curve variation?

- The following procedure was done to find signals relevant to power curve variation:
  - Choose a signal which may be related to power curve variation (e.g. TI)
  - For each wind speed bin, split the data into 5 bins based on that signal. The split is done such that all bins have approx. the same amount of data.
  - Create 5 power curves from the 5 bins
  - Compare each power curve with the overall mean power curve by summing the absolute energy differences
  - Call the sum of these differences the **power curve variation**, normalise by specific energy and express as a percentage

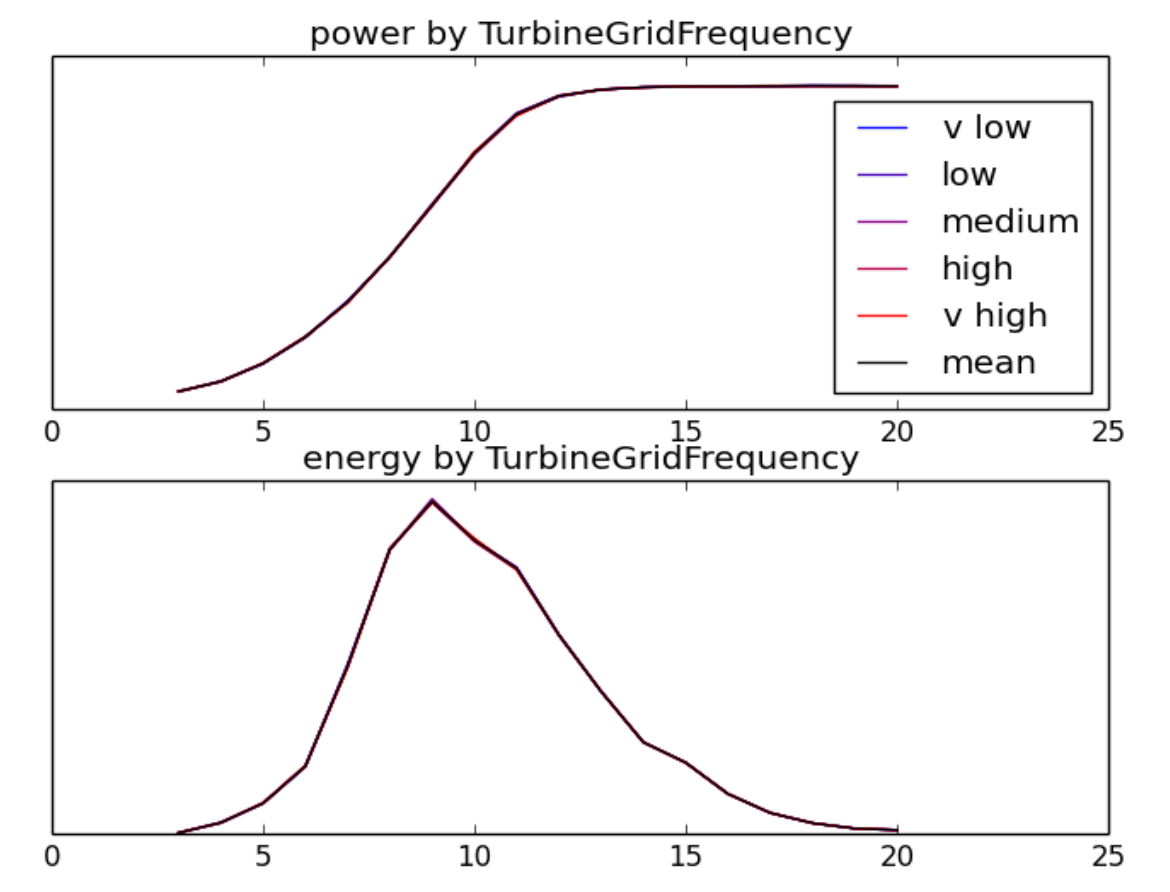
Power curve variation

- A large amount of power curve variation (9%) is associated with TI



Power curve variation

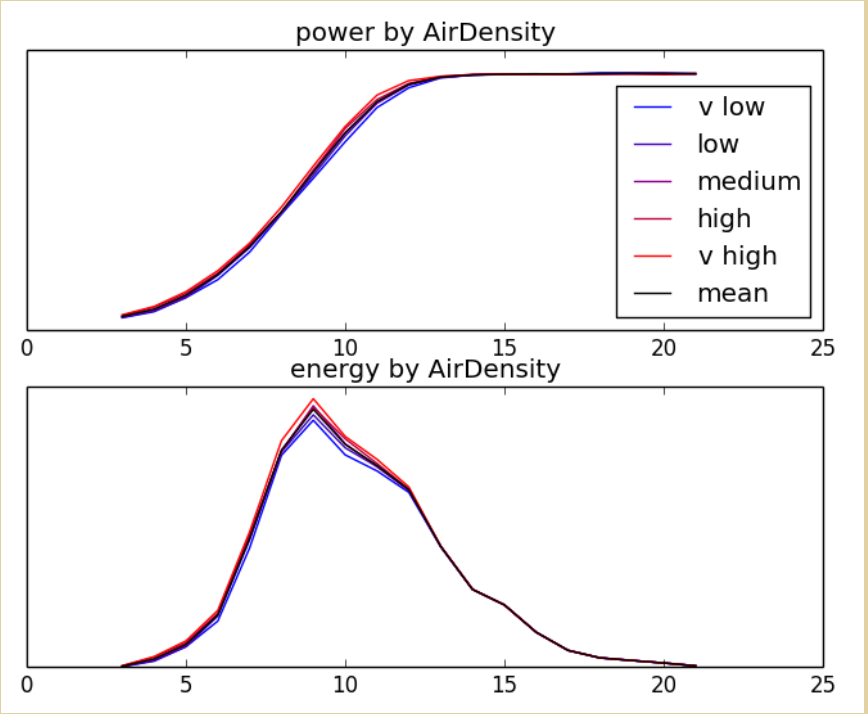
- A small amount of variation (1%) is associated with grid frequency



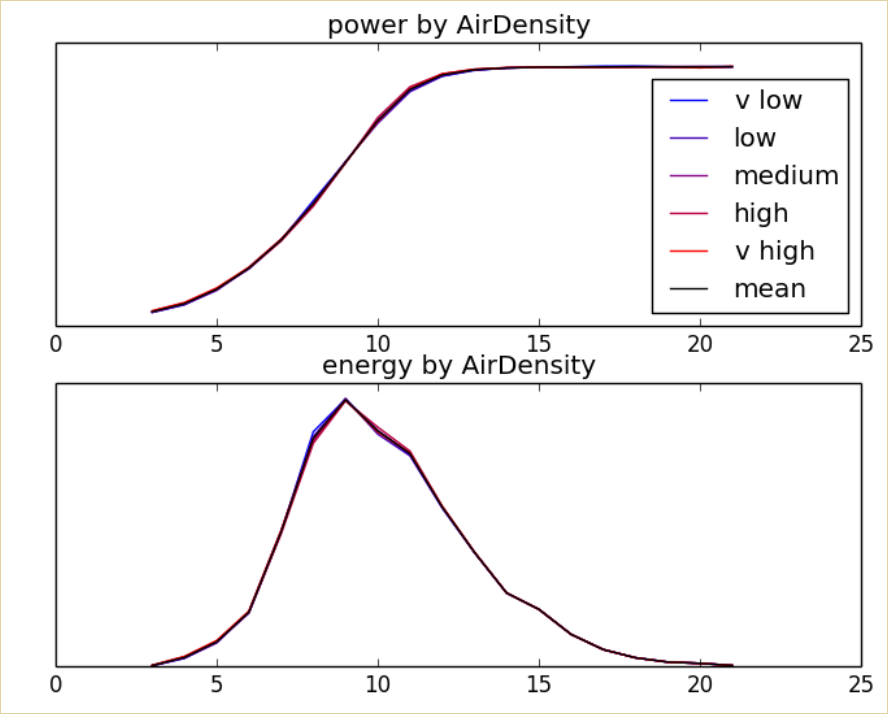
Power curve variation: air density correction

- Power curve variation can confirm the effect of a correction. For example, the standard air density correction.

Before air density correction:
10% variation

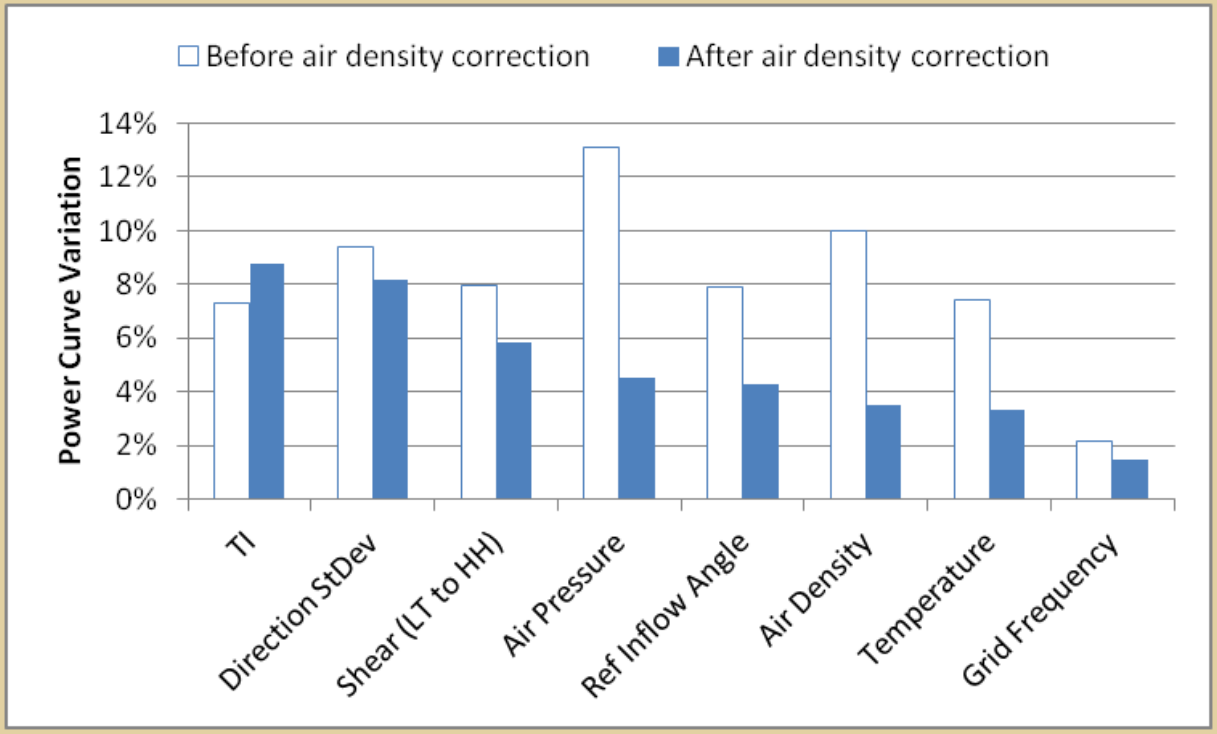


After air density correction :
3% variation



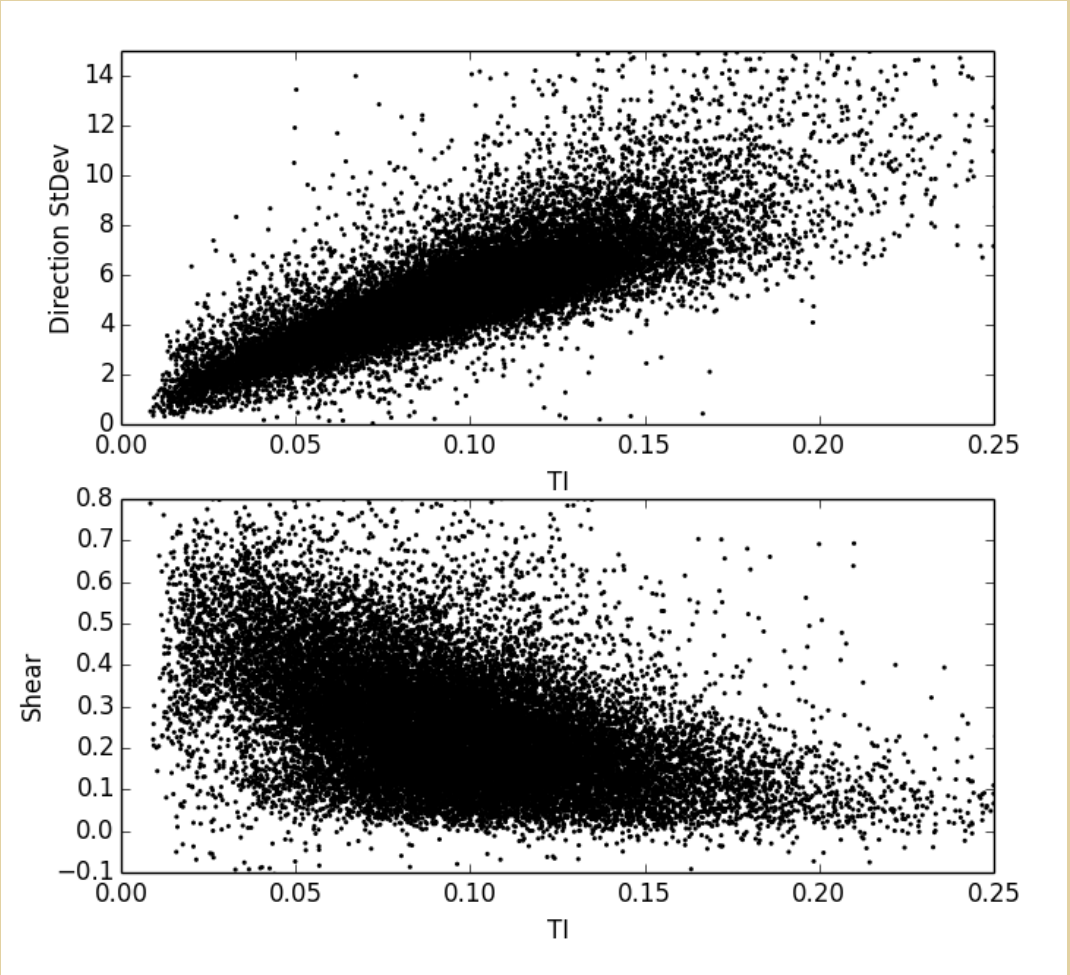
Power curve variation

- After air density correction, the top three signals relevant to power curve variation are:
  1. TI
  2. Wind Direction StDev
  3. Shear (LT to HH)



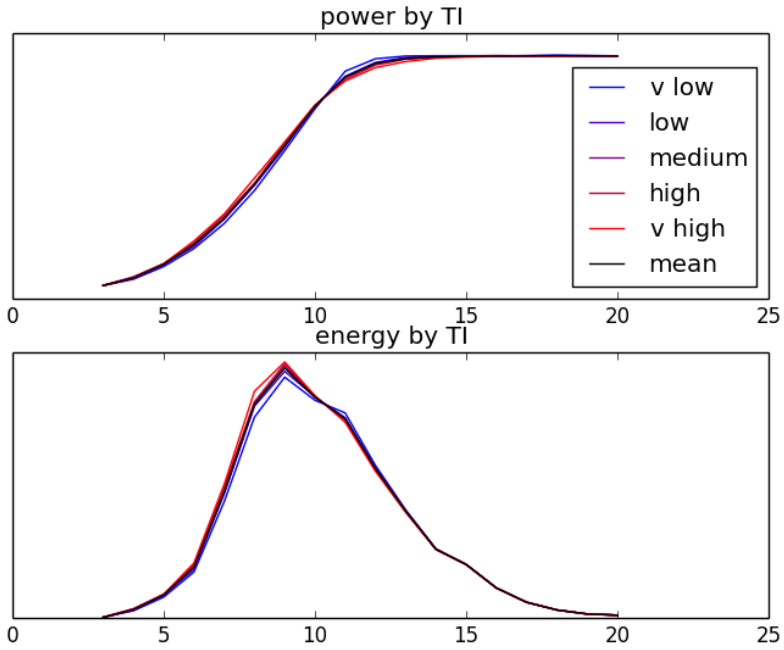
TI and StDev of Wind Direction

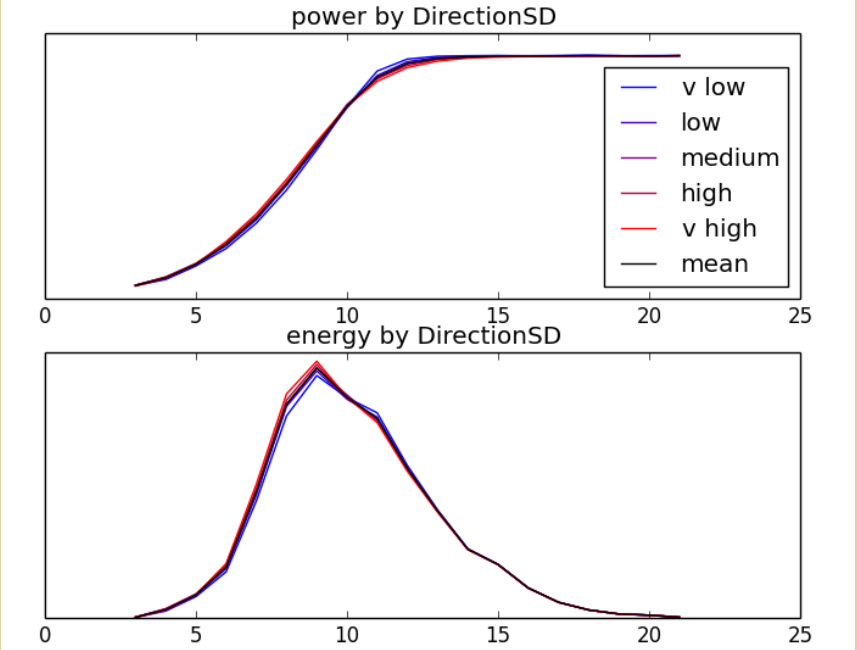
- r^2 is 0.6 for TI and Wind Direction StDev
- r^2 is 0.1 for TI and Shear



TI and Wind Direction StDev

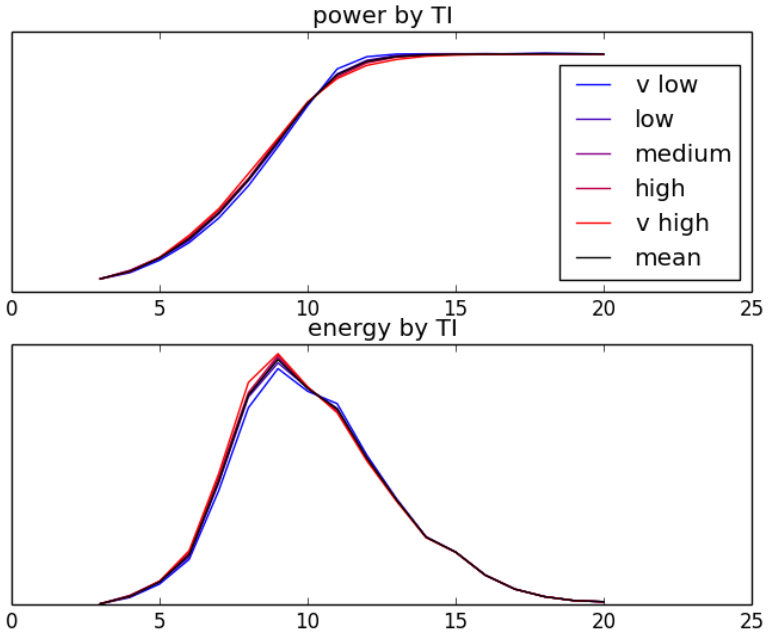
- The pattern of power curve variation is very similar when binning by TI and Wind Direction StDev

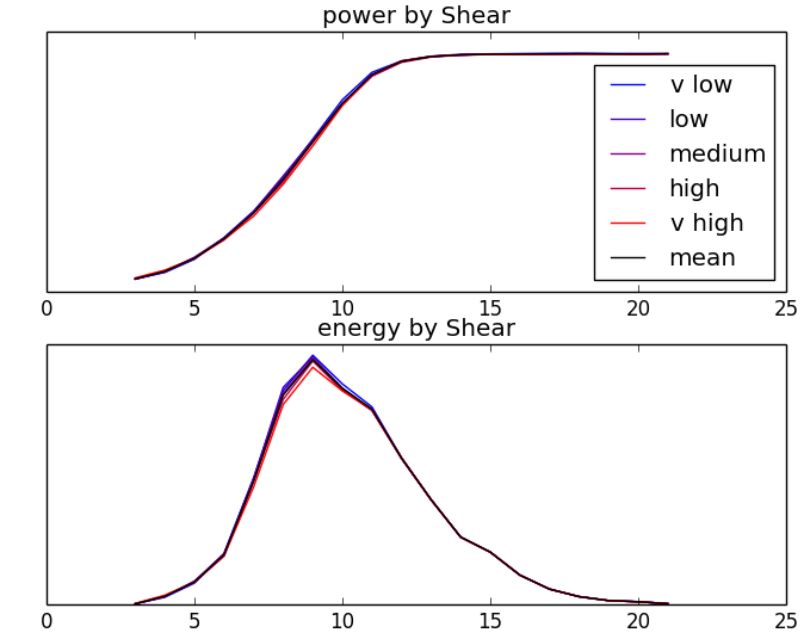




TI and Shear

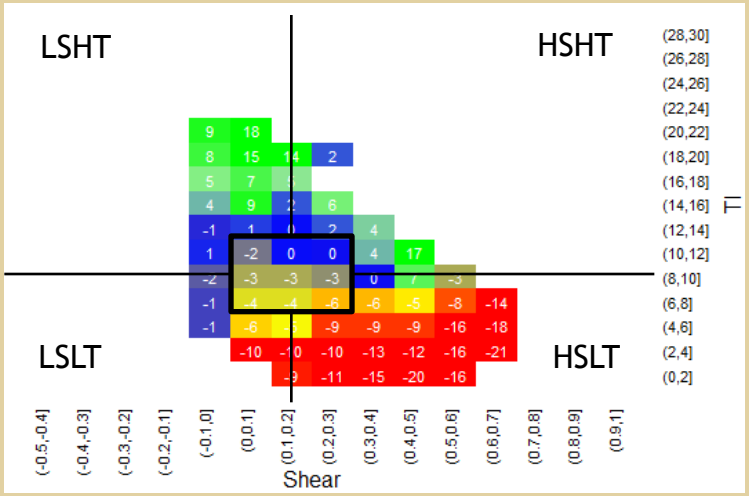
- The pattern of power curve variation is not similar when binning by TI and Shear



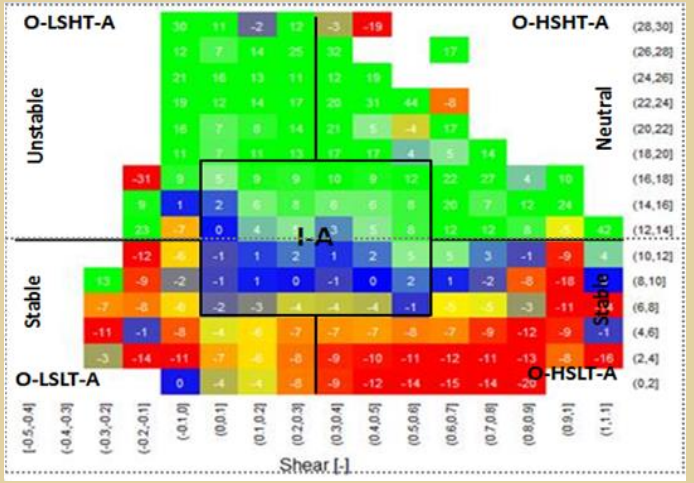


- Conclusion: focus on TI and Shear in more detailed power curve analysis

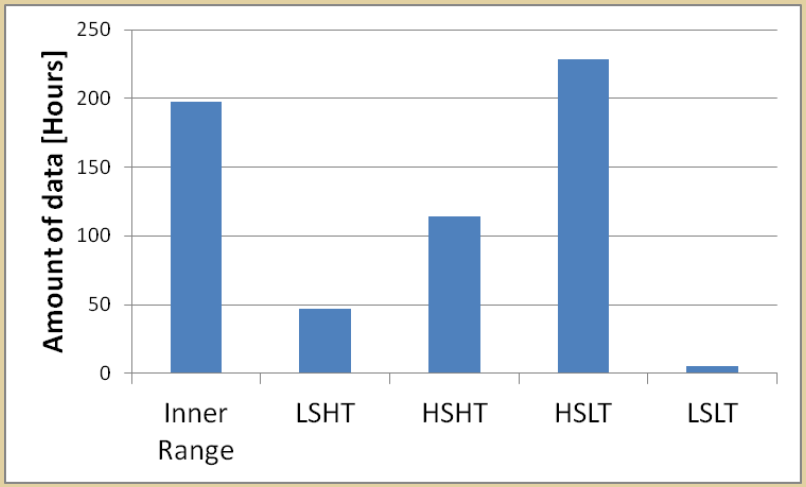
Effect of TI and Shear at Ankle

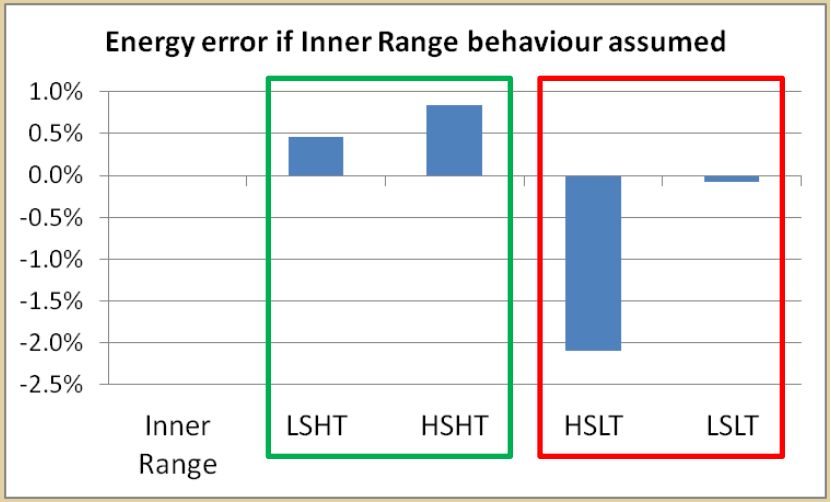


RES analysis

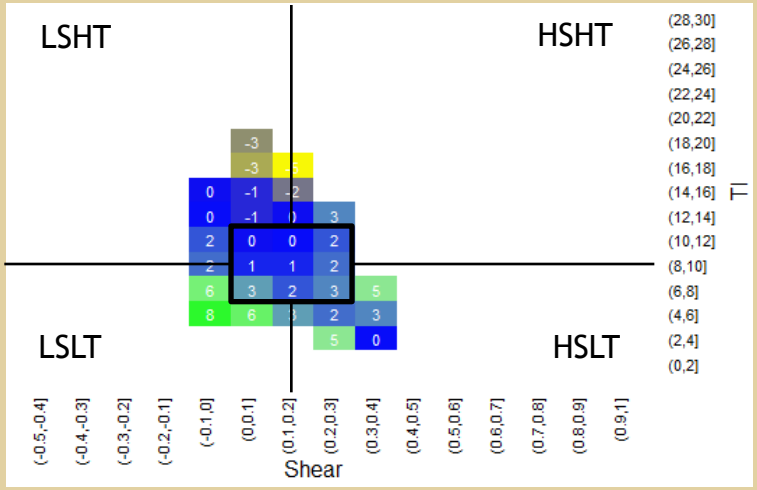


analysis from RePower

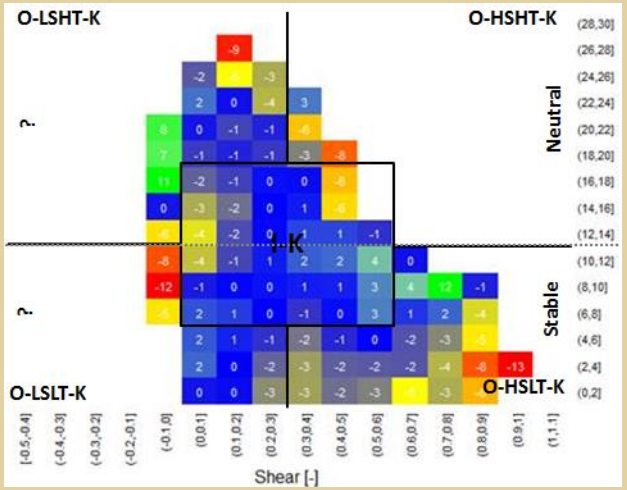




Effect of TI and Shear at Knee



RES analysis



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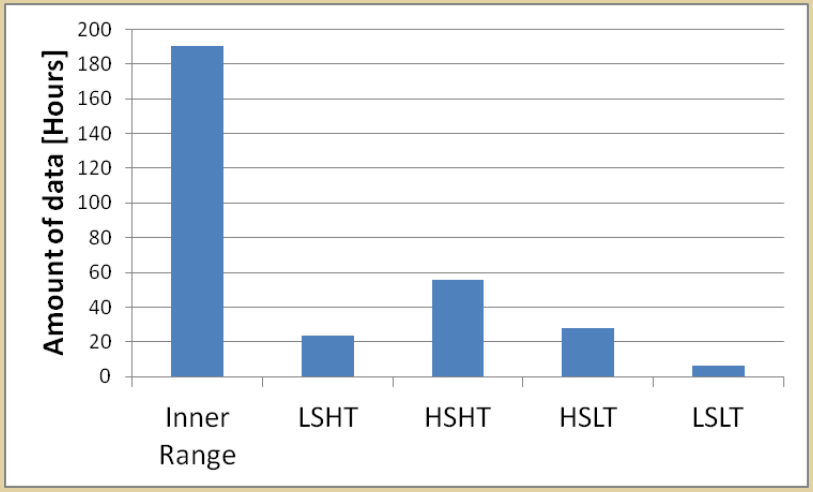
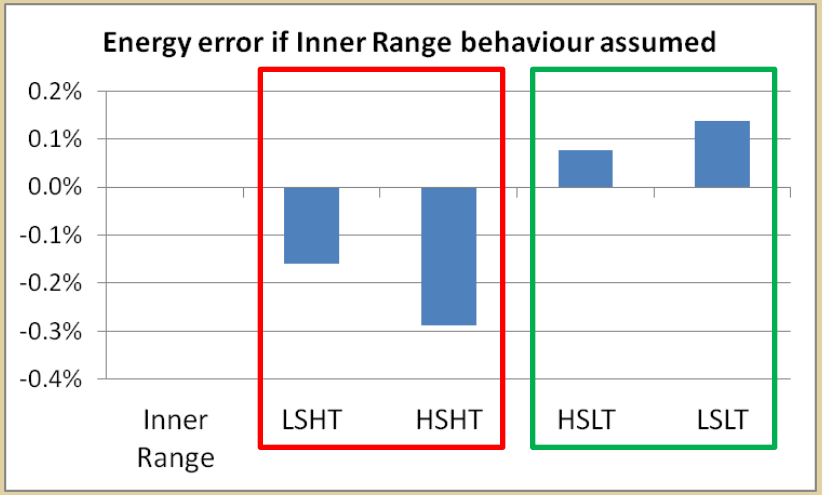
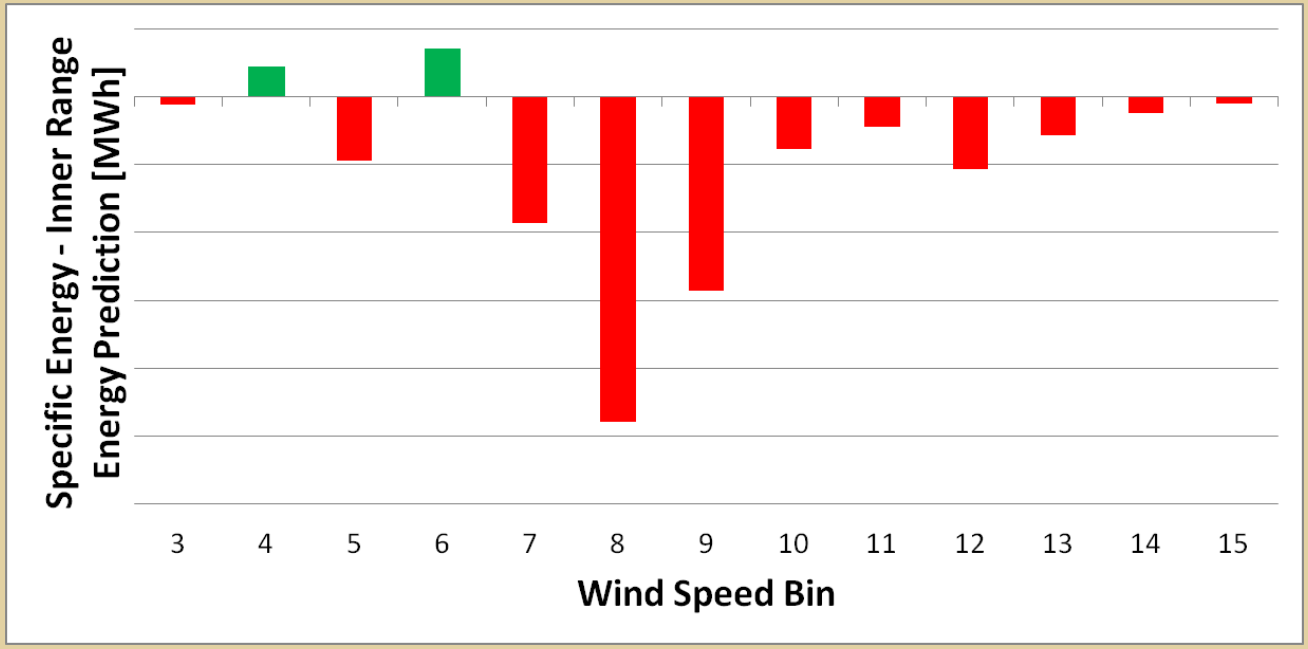




Effect of TI and Shear

- Overall Result:
  - Compared to an Inner Range Energy Prediction, the Specific Energy of this data set is **0.5% low** in total.
  - In this example most of the discrepancy is in the range 7-9 m/s



Conclusions

- Power curve variation was compared with a range of signals
  - Top 3 relevant signals are:
    1. TI
    2. Wind Direction StDev
    3. Shear
  - TI and Wind Direction StDev are highly correlated, TI and Shear are not
  - **TI and Shear are the correct signals to focus on** for this data set

- The effect of TI and Shear was explored at the ankle and the knee
  - Effects at ankle are larger than effects at ankle for specific regions
  - Sum of effects at knee are larger than ankle (less cancelling errors)

Next steps

- Infer Rotor Equivalent Wind Speed from the shear measurements in this data set
- Apply PCWG corrections for TI and Rotor Equivalent Wind Speed
- Re-calculate power curve variation
  - Have the PCWG corrections sufficiently reduced variation associated with TI and shear?
- Extend the data set to a wider variety of sites and turbine types


power for good

Summary of 10-minute statistics (~25000 rows of data)

	Air Density	Corrected Wind Speed Mean	Direction SD	Pressure	Ref Inflow Angle Mean	Shear	TI	Temperature
mean	**1.22**	**8.4**	**5.3**	**988**	**0.7**	**0.3**	**10%**	**9.0**
min	1.15	3.0	0.0	924	-15.9	-2.2	1%	-3.6
25%	1.21	6.4	4.0	979	-0.7	0.1	7%	5.7
50%	1.22	8.2	5.1	990	1.1	0.2	9%	8.0
75%	1.23	10.1	6.2	1000	1.7	0.3	12%	11.8
max	1.30	21.2	61.8	1024	17.6	4.2	64%	30.0