Power Curve Working Group #2: (Brande)

Operational Power Curve test in complex terrain

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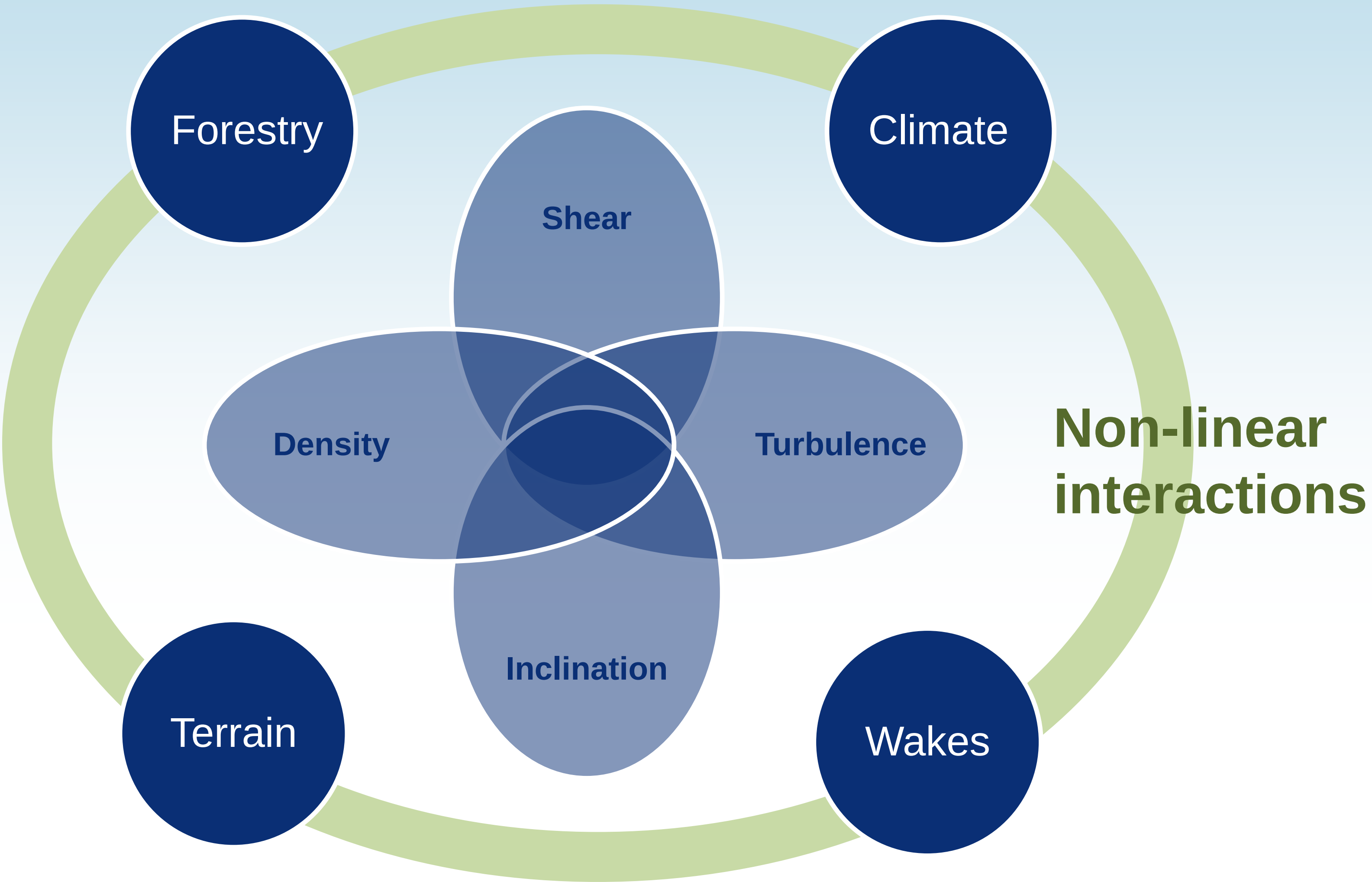
12 March 2013

SSE

Complex flow effects



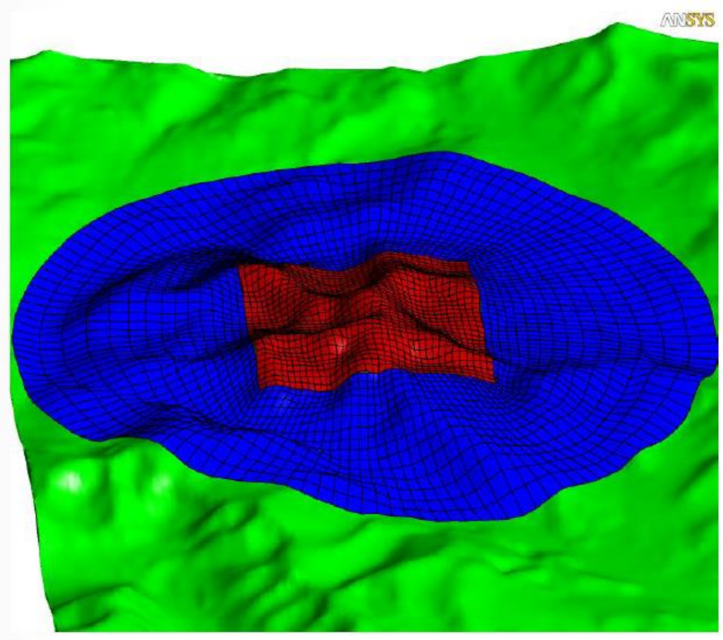
SSE approach to Power Curves

1. Engage with TS during MLA to ensure inputs are valid (additional RS data, CFD checks,)
2. Ascertain how 'site specific' power curves are
3. Carry out internal PCTs where possible
4. Participate in EWEA Power Curve Working Group

Tools

1. **Mast & SCADA analysis (PPT, PBEPEs)**

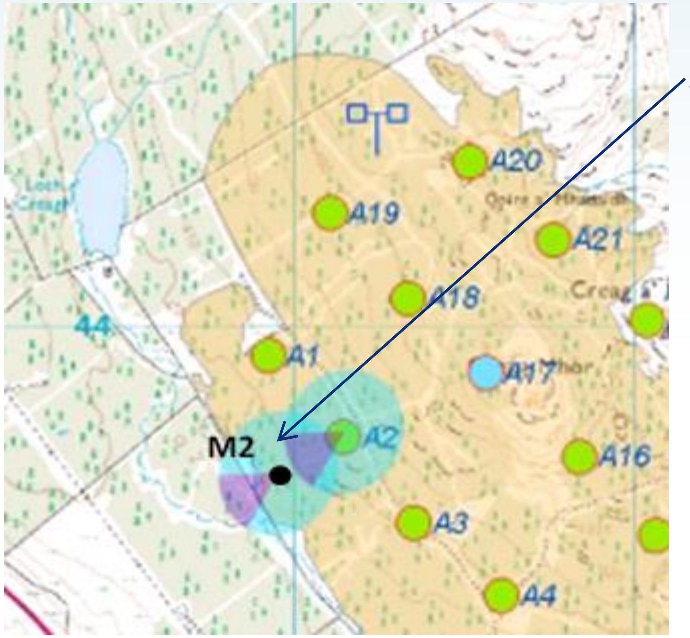
2. **CFD to confirm flow conditions (pre and post construction)**



3. **LIDAR to confirm power performance of multiple WTGs**

Operator's PCT: Onshore WF #1

- Complex site with extensive forestry
- 1 WTG chosen for IPCT (to feed into TS warranty)
- Site Calibration completed
- Delays to test → decided to carry out test internally



Brown shading = clear felled

A2 → M2: 300m; M2 → forestry edge: 30m; Trees 10m in height

Reference mast pointing towards 250° with forestry boundary beyond

AIMS/Methodology

AIMS

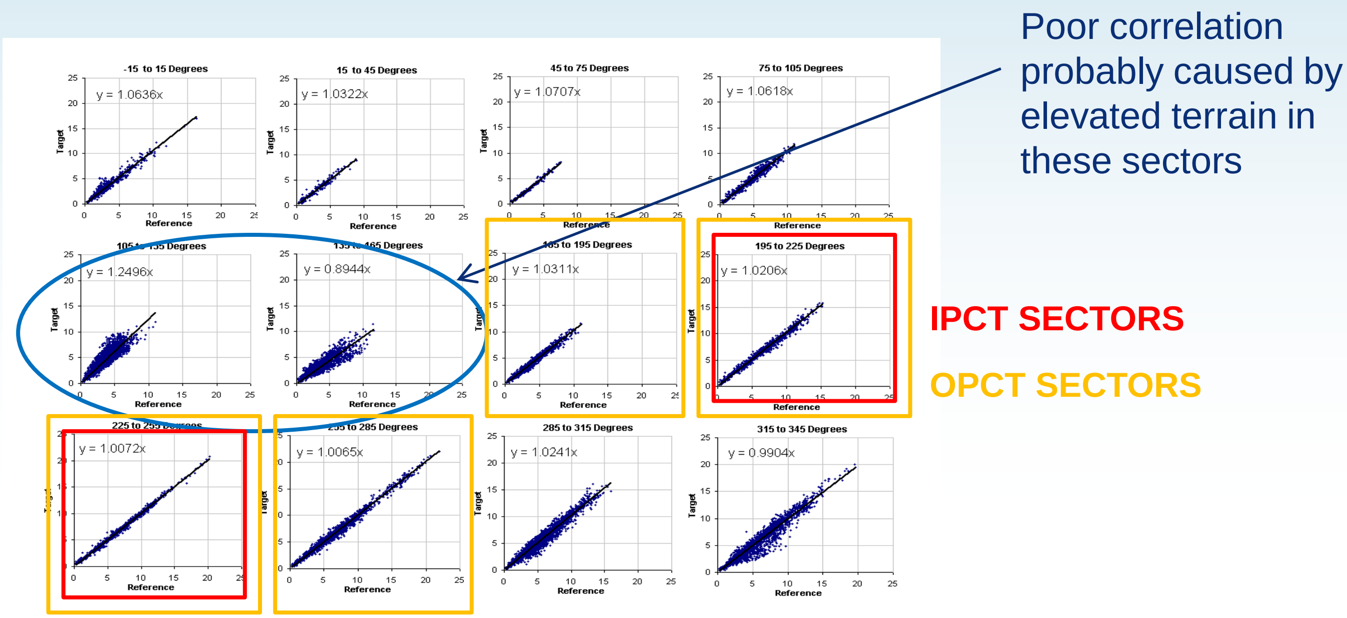
1. To quantify the effects of so called 'complex' wind conditions (such as high shear, high turbulence and high vertical wind speed) on turbine power performance
2. To understand likelihood of IPCT failure
3. To develop methodology for future "OPCTs"

METHOD

1. Site visit to check forestry
2. Compare wind climate at Turbine Base and Test mast
3. Apply speed ups derived during Site Calibration → synthesize Observed power curves based on freestream winds
4. Filter PCs on Shear, TI, flow inclination (from U/sonics)
5. Calculate MAEP

Results (1)

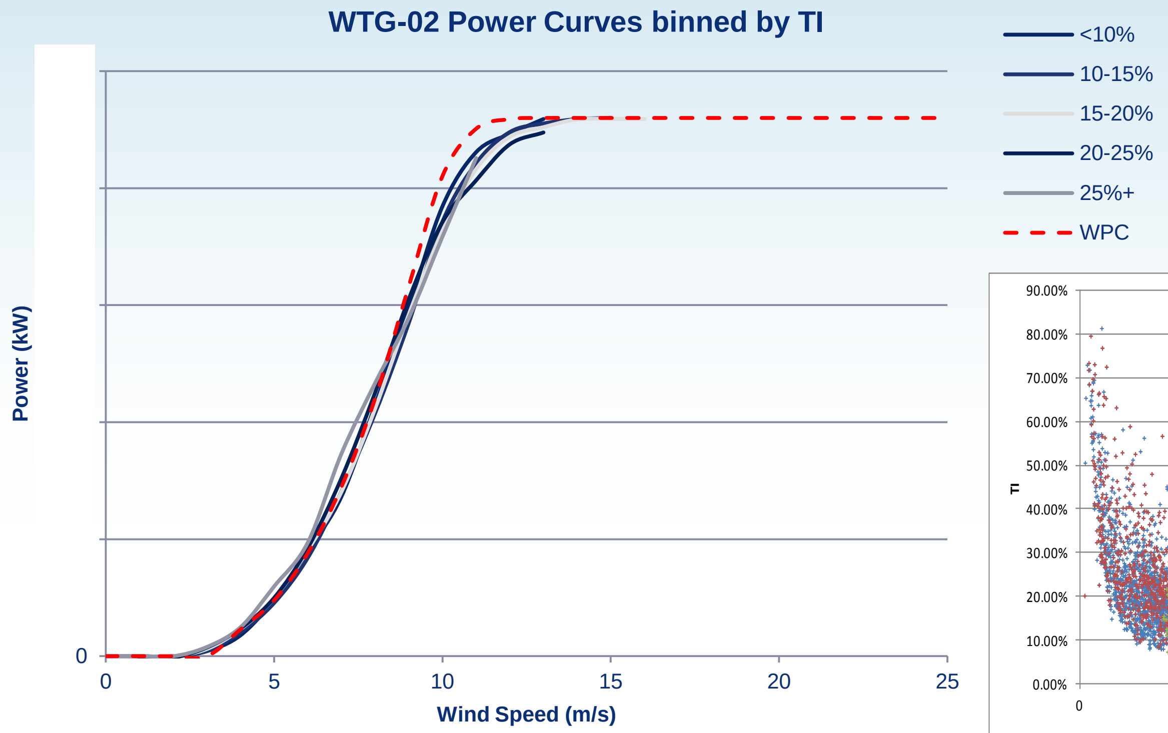
- Data from June – November used
- Test and Turbine MWS data generally correlated well

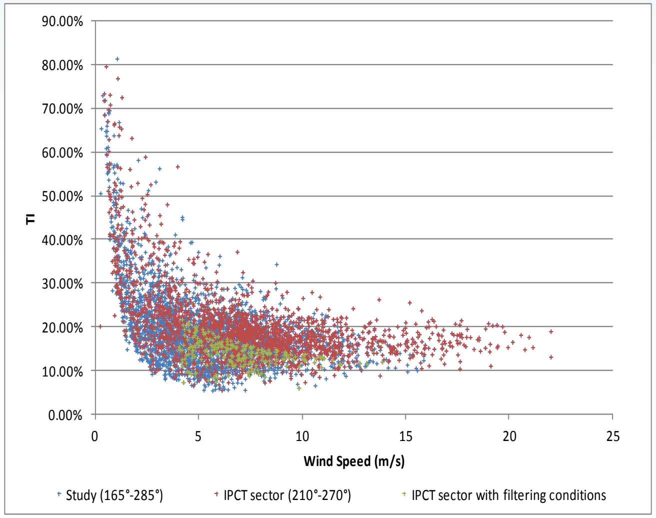


- Shear and TI only correlated well in Sectors 7 – 10
- Flow inclination – no correlation. Terrain too different.
- OPCs synthesised using SSE SCADA analysis toolset

Results (2)

- Binned by TI (S7 → 10)

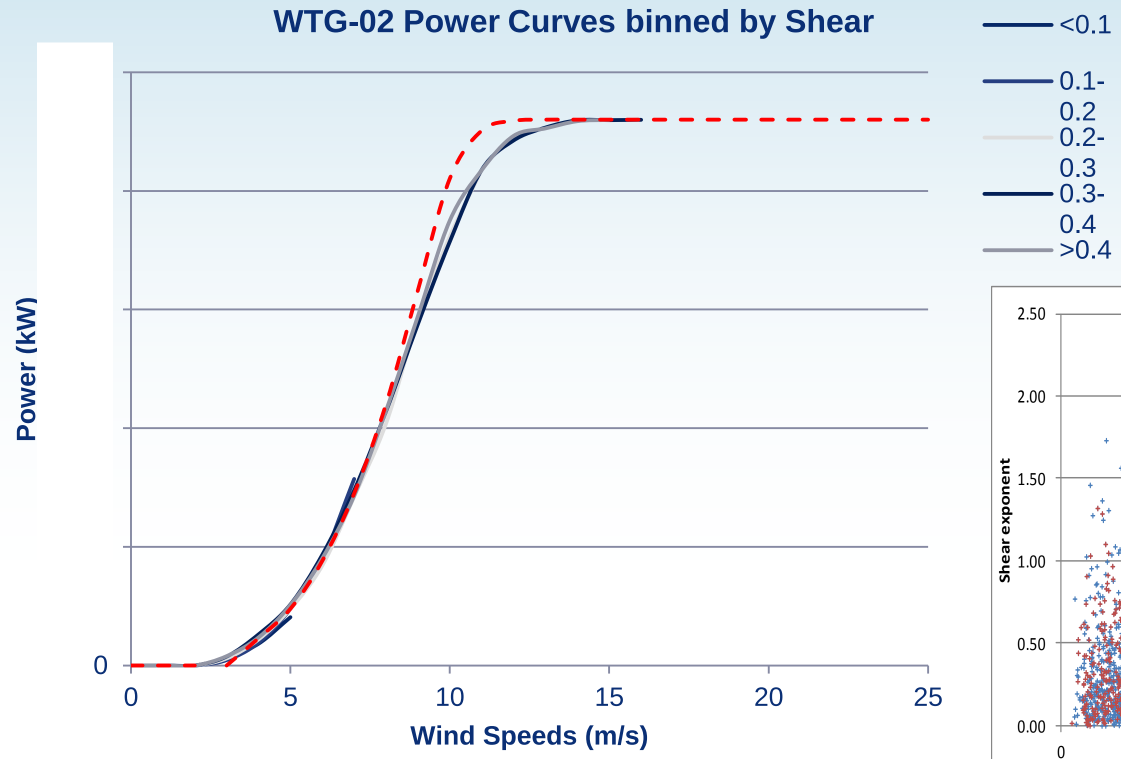


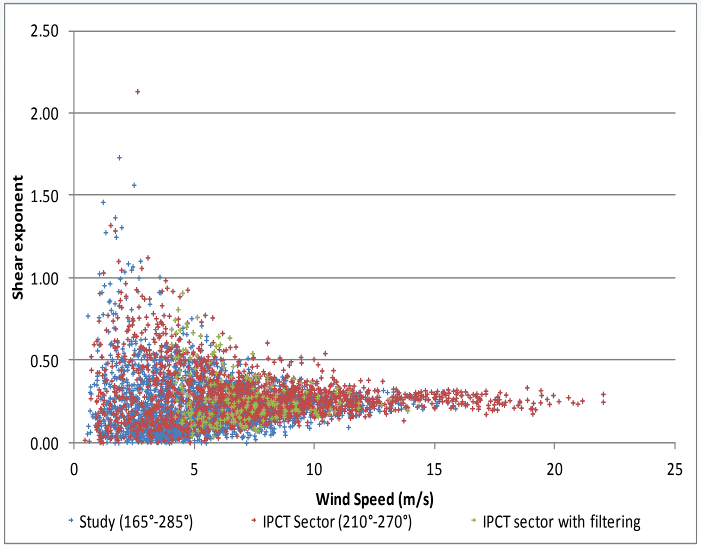


- CTI @ 15 m/s for OPCT sectors: 18.5%

Results (3)

- Binned by shear (S7 → 10)

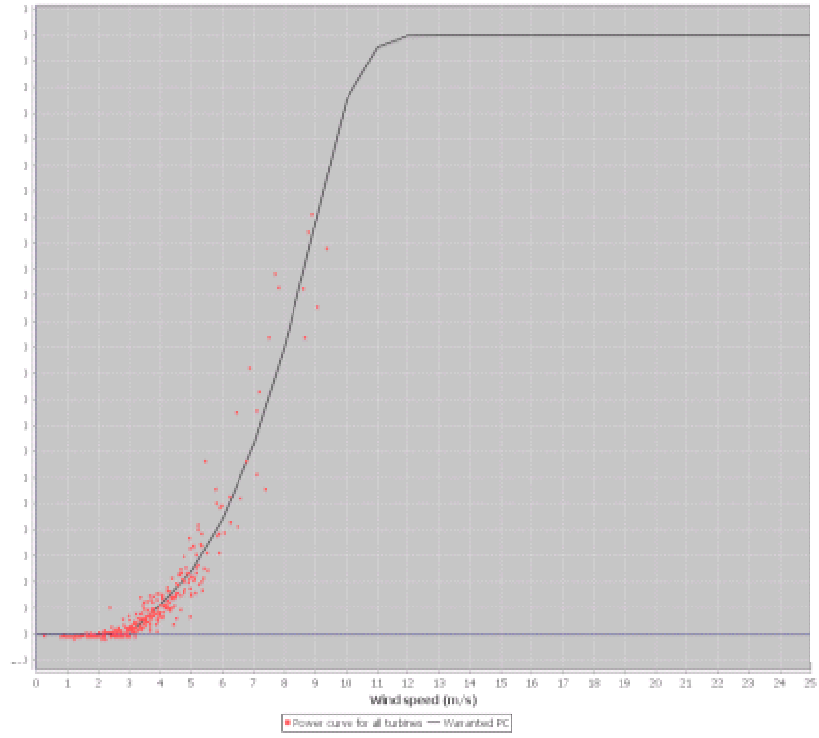




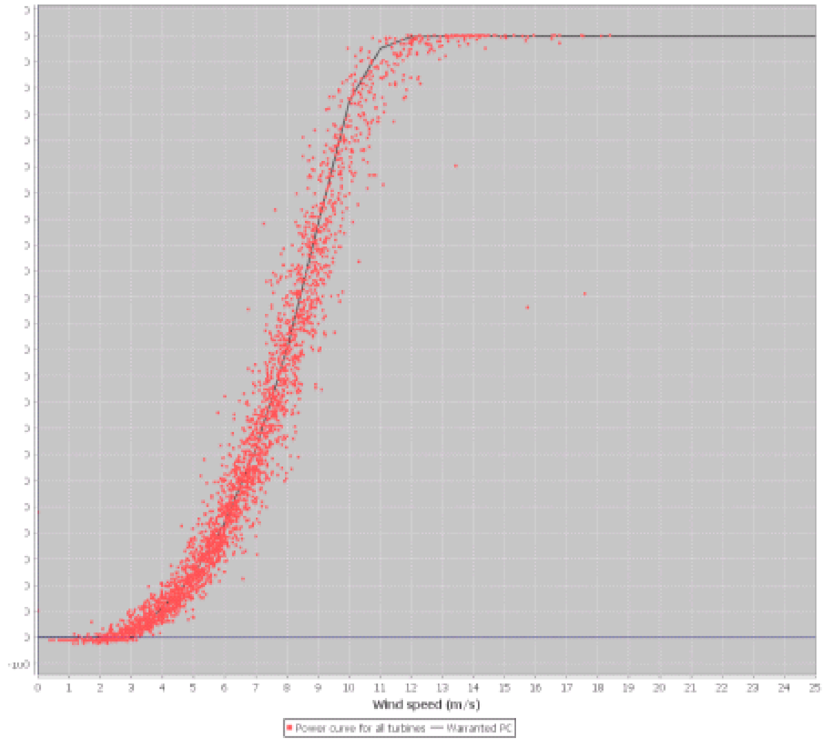
- Average shear: 0.3 (OPCT sectors, 4-18 m/s

Results (4)

- Lack of IEC “normal” shear data an issue…



WTG-02 Power Curve: Shear 0.1 - 0.2



WG-02 Power Curve: Shear >0.4

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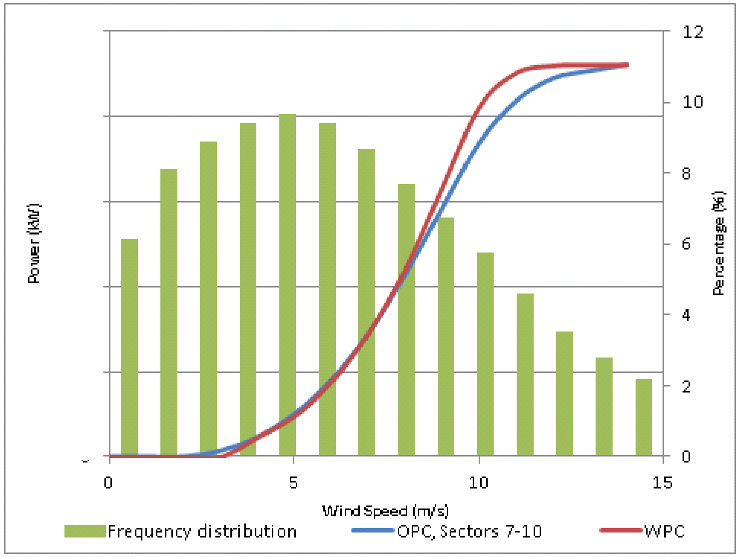
Results (5)

- **Measured vs Warranted AEP**

Direction sector	OAEP/WAEP
Sector 7	96.18%
Sector 8	93.76%
Sector 9	96.81%
Sector 10	97.44%
Sectors 7-10	**96.11%**



Observed power curve (OPC) for WTG-02 (Sectors 7-10) compared to WPC

- **Test WTG appears likely to pass (just)**
- **Assuming sufficient compliant data can be collected**

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Conclusions

- TI reducing power at knee
- Effects of shear less clear, hampered by lack of low shear data (!)
- Overall performance deficit from the WPC above 8m/s is evident
- Mean shear exponent and the characteristic TI significantly greater than IEC limits due to the close proximity of the forestry to the west.
- The IPCT as agreed will not give a complete picture of the turbine operation on the site, if indeed it can capture sufficient data to complete the test before anemometer calibrations expire.
- Future OPCTs will need larger non-wake affected sectors in order to draw conclusions on forestry's impacts

Galion LiDAR deployment

- Galion to be located at base of PPT WTG to supplement OPCT and IPCT data
- Two types of scan to be used:
    1. Arc scan measurement to coincide with HH anemometer on test mast (3D upstream of WTG)
    2. Range Height Indicator scans to produce cross sections of the inflow in a vertical plane
- Scan type 1: primarily for verification
- Scan type 2: to derive rotor equivalent wind speeds, shear to rotor tip, flow inclination
- Power Curves derived from mast and LiDAR to be compared
- Reports to comply with the requirements of IEC 61400-12-1:2005 and Annex L of the current draft 2nd edition of IEC 61400-12-1 (reporting requirements for Lidar)