Power Curve Working Group
What are the issues?

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SSE

The issues

- Power performance in the real world
- Mitigating the risk of underperformance
- Working closer

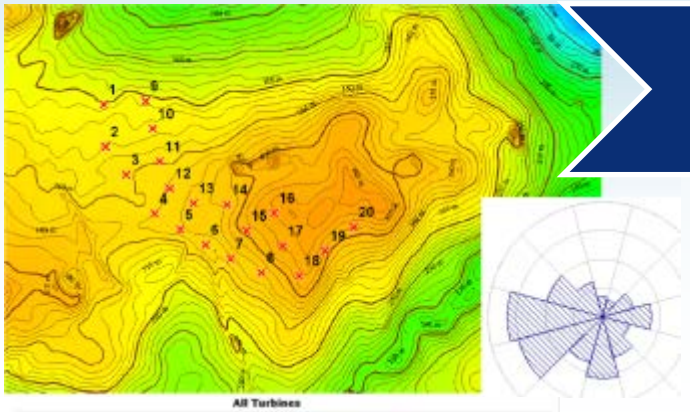
SSE Renewables welcomes the formation of this Working Group!

1) Power performance in the real world

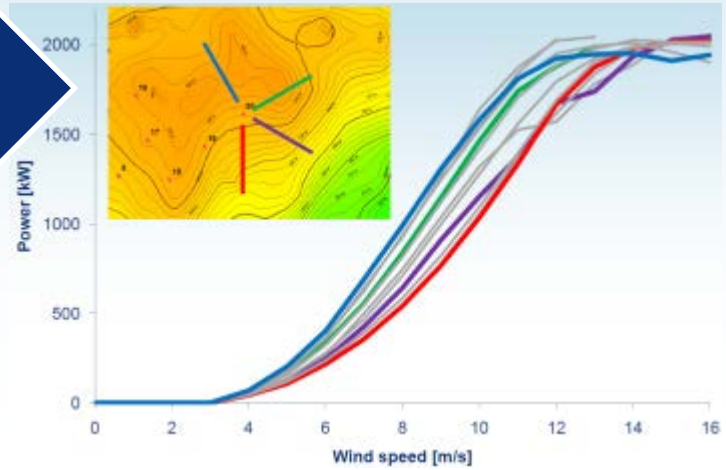
Weak performance: identifying, predicting

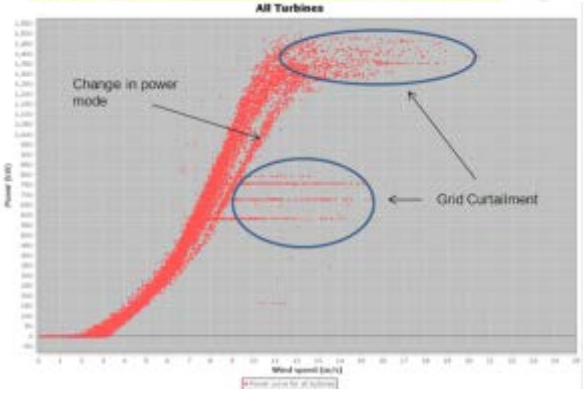
Performance tracking using 10 minute data: the ‘APA’ team in SSE

Wind Farm level



WTG level





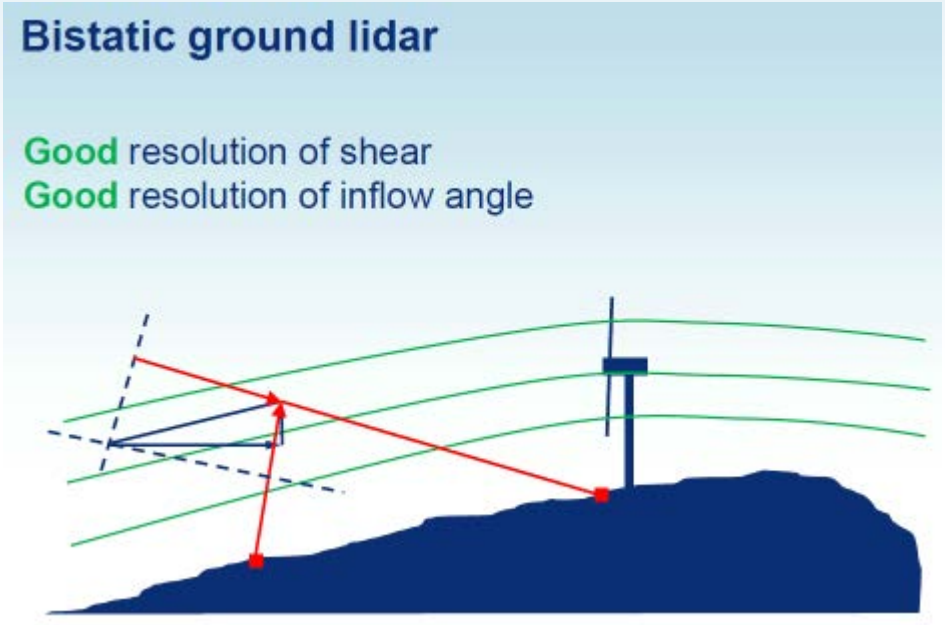
Establishing cause

Quantifying AEP impact

Establishing reasons for underpeformance

- Quantifying impact of conditions on power performance
- CFD and Remote Sensing both have a role to play
- Expensive

  e.g. Fairburn inflow angle study



- Validation across many sites required to inform loss factors

Turbine suitability analysis

- Excessive turbine fatigue loads are caused by:
  - High/negative shear
  - High turbulence (ambient, wake induced)
  - High inflow angle
- Mitigated by moving WTGs or curtailing/load control systems
- Just because a WTG location is warranted, doesn't mean it is optimal!
- SSE have evidence of OEMs curtailing/'turning down' a turbine's power curve despite location getting a "clean MLA"

- These adjusted power curves eventually become the norm

  → Feed into production based AEPs

  → Reduced NPV/IRR

  → Increases refinancing/divestment risk

Can we blame OEMs?

- No OEM wants to have to turn down WTGs (reputation, yield)
- Done to avoid excessive vibration trips hitting availability targets – which client uses as an incentive to the OEM
- And to avoid this happening:

- A clean MLA and high AEP wins tenders
- MLA only as good as the **data**, the **model** and the **scenario**
- We need more open and honest communication

SSE

2) Mitigating the risk of underperformance

Warranties and IPCTs

- Traditional approach to mitigating risk
- SSE current policy is to test each new turbine model bought
- Decision to test according to IEC 61400-12-1 (via an IPCT) is made according to risk profile of site (size, technology)

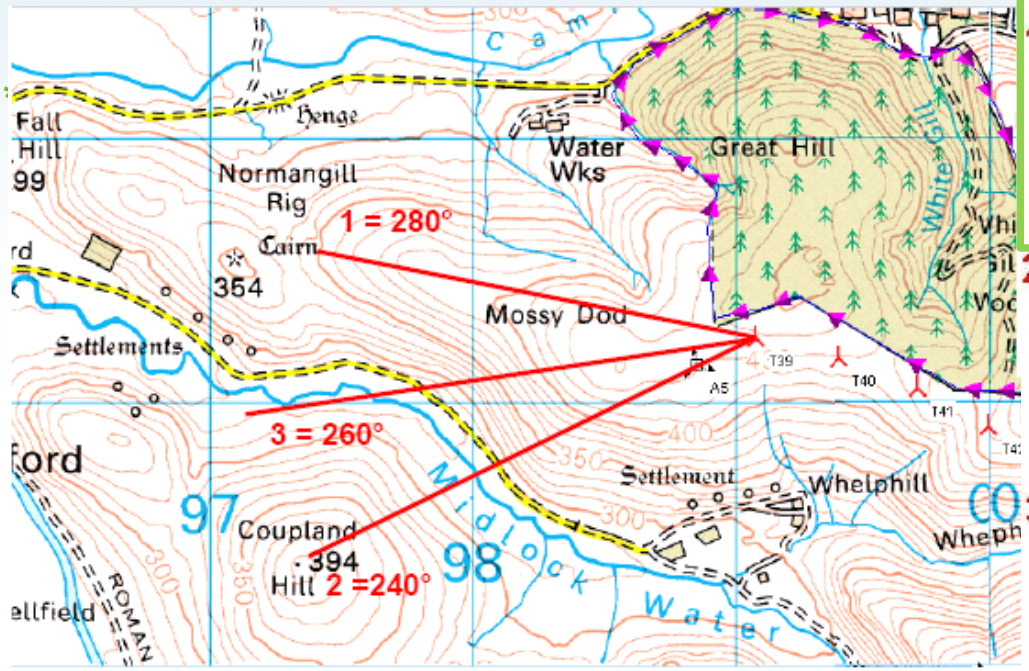
- **6 IPCTs carried out by SSE to date**
- **All in moderate – complex terrain**
- **“Successfully” argued against testing > 1 WTG**
- **Average efficiency: ~98%, this appears to match the industry average***

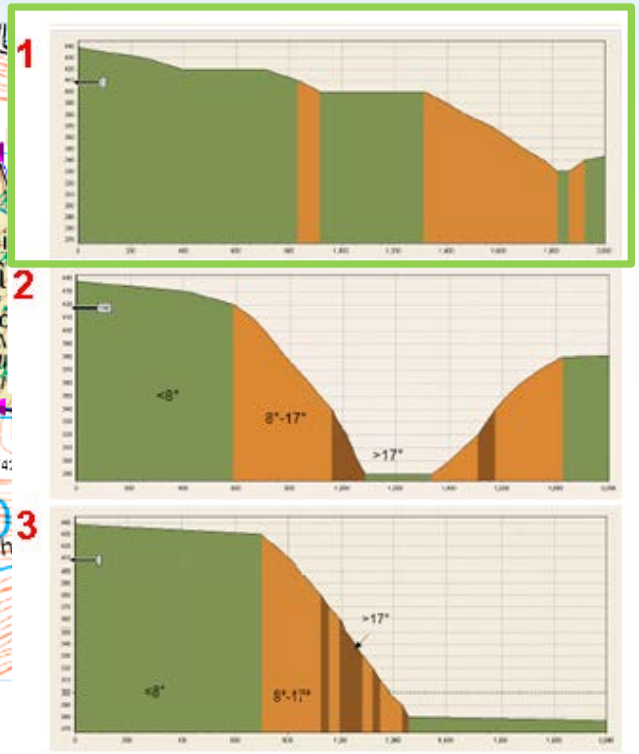
- Is this still a sufficient way of mitigating risk?

*** EWEA Lyon, July 2012, Keir Harman (GLGH)**

Independent Power Curve Tests

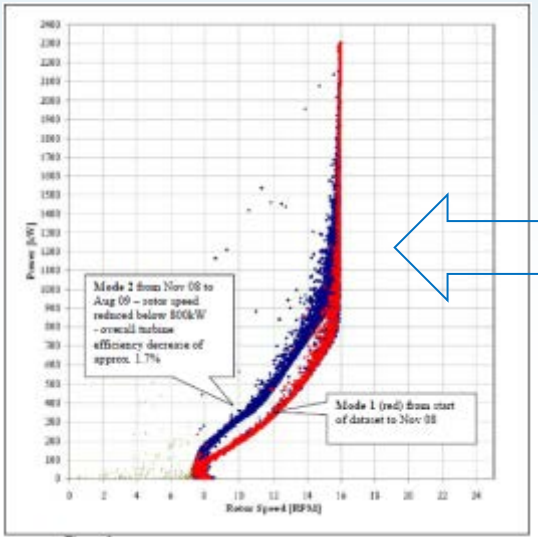
- Achieving IEC-61400-12-1 compliance rarely straightforward
- Site calibrations the norm for SSE sites
- Sectors restricted by shear, inflow, turbulence characteristics
- E.g. **Clyde**





Independent Power Curve Tests (2)

- **An IPCT doesn't mitigate the risk of underperformance**
  - Only based on 1 or a few WTGs
  - IPCT **always** achieves > 95%; (100% - uncertainty)
  - OEM can (and does) change pitch/rpm settings during WOM



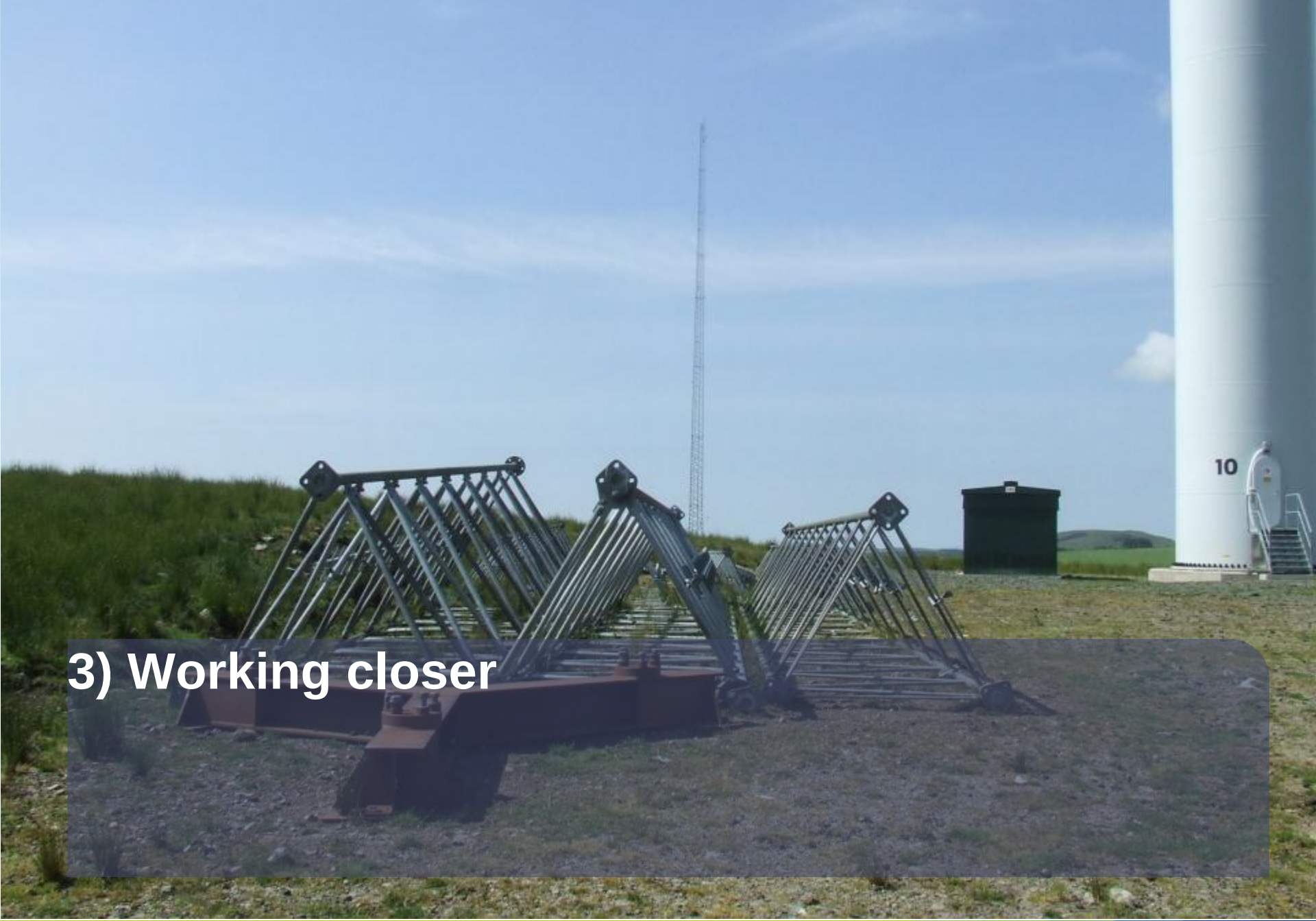
How to test Intelligent power control systems?
Settings can change every 10 minutes!

- **OEM often demands multiple test WTGs to mitigate risk → £££**
- **Benefits:** provides testers with a body of evidence for making pragmatic adjustments to AEPs

Alternative means of mitigating risk

- Move to yield-based warranties?
  - Involves a shift in paradigm away from incentivising high availability
- Operator's Power Curve Tests
  - A more flexible approach to 'IEC conditions' → more representative of actual conditions
  - Use of Remote sensing
  - Accept it won't form the basis of a warranty
- Apply pragmatic adjustments to AEPs
  - As an uncertainty or a loss factor?

- **Through better site design**
- We need more open and honest communication between Developers and OEMs



3) Working closer

Working closer

- Ideal: involve OEM in early design work → commercially feasible?
- Ambition: Move away from MLA being a black box...

RISK SHARING APPROACH

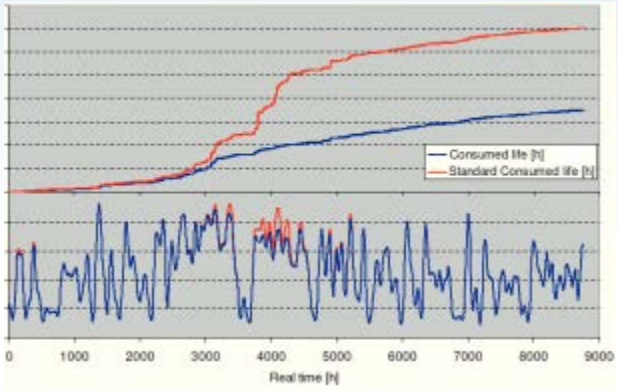
1. Developer provides LT wind climate **at each WTG**
   - CFD, RS, Lidar overfly data: **not just raw mast data**
   - Careful consideration given to which scenario presented
2. OEM works with developer to deliver:
   - *realistic* power curves for WF lifetime
   - optimised control strategy for yield, loading, noise.
   - Best and worst case scenarios presented (if applicable)
3. Resulting AEP is a hybrid of both parties' expertise
   - Consultant provides DD

Intelligent Power Control Systems

2 key types:

1. Load control systems 2. Yield improvement systems (OWFs)

- Former monitors and manages lifetime load cycle consumption. Allows WTG design envelope to be pushed.



- Both controlled by sensors in turbine detecting onerous/advantageous wind conditions and selecting power curves on sub 10 minute basis.

- **Excluded from IPCTs**
- **Little guidance on how to predict impact on AEP**
- **Difficult to assess actual impact**
- **Certification challenging**

Conclusions

- Not all sites look like Høvsøre!
- Warranties only offer limited assurance
- Quantifying effects of onerous wind conditions on power performance is challenging
- Incentivising availability can sacrifice yield
- MLAs have been too ‘black box’ to date
- Turbines are getting cleverer

- All parties have the ability to effect improvements