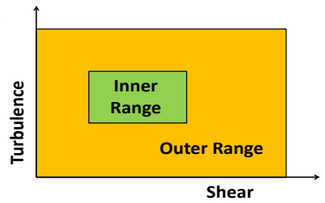
Power Curve Working Group 2015 Roadmap

Background: Reasons For Action

• **Real world wind conditions** are composed of both inner range and outer range wind conditions:

- **Inner range conditions** refers to moderate shear and moderate turbulence.
- **Outer range conditions** refers to high turbulence, low turbulence, high shear, low shear etc.



• **Outer range conditions are relatively frequent** and therefore the calculation of turbine power output in outer range conditions is an important consideration in wind energy resource assessment.

• There are **no industry consensus methods** for predicting wind turbine power output in outer range conditions for the purposes of resource assessment.

• **Power performance tests and associated warranties** are **normally limited to** a relatively narrow range of idealised conditions i.e. **inner range conditions.**

Current Wind Industry State

• There are no industry consensus methods for predicting wind turbine power output in outer range conditions for the purposes of resource assessment.

• Power performance tests and associated warranties are normally limited to a relatively narrow range of idealised conditions i.e. inner range conditions.

• The lack of a validated industry consensus methods for predicting power output in outer range conditions (for resource assessment applications) increases the risk perceived by wind energy investors.

• The failure to consider outer range conditions in power performance tests increases the risk perceived by wind energy investors.

Target Wind Industry State

• Well document and validated consensus methods for predicting wind turbine power output in outer range conditions for the purposes of resource assessment.

• Open source benchmarks (e.g. Excel examples) available for all validated consensus methods.

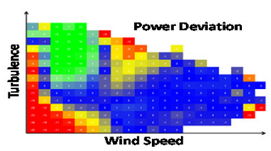
• Open source tools (which comply with benchmarks) available for all validated consensus methods.

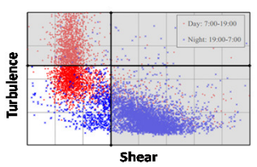
• Power performance tests routinely make some consideration of outer range conditions.

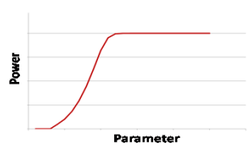
• Harmonised communication of power curve information so that corrections for outer range conditions can be unambiguously applied.

• Consensus methods embedded in real world resource assessment industry practice. Reduced resource assessment risk perceived by wind energy investors.

• Reduced power performance risk perceived by wind energy investors.







Reasons for gap between current and target

• REWS and turbulence renormalisation methods are helpful, but do not fully solve the problem.

• There are no industry standard tools for applying existing methods for modelling power output in outer range conditions.

• Several empirical (proxy) methods are available which tie observed turbine performance to key (frequently measured) parameters such as turbulence intensity and lower rotor shear exponent. However, there is a lack of industry consensus regarding which proxy methods are best.

• No objective criteria for evaluating performance of correction methods.

• Minimal data/intelligence sharing between key stakeholders.

• Current power curve documentation can make the application of corrections for outer range conditions difficult e.g. it can be hard to tell if a power curve is defined for hub wind speed, rotor equivalent wind speed or both.

• Currently there is currently no consensus method to extrapolate conclusions at the test turbine to all turbines e.g. extrapolation of shear and turbulence to all turbine locations

• Confusion over contractual and resource assessment contexts inhibits progress on is of turbine performance in non-standard conditions.

PCWG 2015 Actions

• Define trial methods and validate them (including new and novel methods) e.g. REWS, RAWS, site/conditions specific power curves, turbulence renormalisation, power deviation matrix, production by height, modified turbulence renormalisation method.

• Implement PCWG data/intelligence sharing initiate to provide a platform for developing and validating trial correction methods. As part of sharing initiative develop objective criteria/framework for testing corrections for non-standard conditions.

• Develop open source benchmarks (e.g. Excel examples) for applying trial methods so that methods are well understood. Where appropriate perform round robin exercises to develop consensus understanding e.g. Power Curve Deviation Matrix and REWS with Inflow Round Robins

• Develop open source python tools so that trial methods can be applied to many datasets efficiently:
  - Power Curve Deviation Matrix Implemented
  - Rotor Equivalent Wind Speed Considering Inflow Implemented

• Promote application of Inner/Outer range concept for power performance tests by sharing experiences.

• Develop a document to harmonise the communication of power curve information. Document should express requirements for site specific power curves and/or power deviation matrices from a developer/consultant (required outputs) and manufacturer (required inputs) perspective. Document should difference between the resource assessment and contractual contexts.

• Develop methods for applying corrections for non-standard conditions across a wind farm in order to reduce 'by turbine errors' and facilitate the design of better wind farms.

Observations

- No clear consensus method for determining long term representativeness of measured shear, turbulence etc.
- No existing consensus method for modelling turbine performance in non-standard conditions in wake conditions.
- No metric for describing both the energy context and 'bending' of a shear profile.