

Power Curve Working Group: Inner-Outer Range Proposal

Inner-Outer Range Proposal (Dec 2013)

The Power Curve Working Group (PCWG) believes that there is substantial value in the concept of defining power curve warranties with respect to two ranges:

- **Inner Range:** the range of conditions for which one can expect to achieve an Annual Energy Production (AEP) of 100% (relative to a reference power curve).
- **Outer Range:** the range of conditions for which one can expect to achieve an AEP of less than 100%. Stated another way the outer range is the range of all possible conditions excluding those in the inner range.

It is envisaged that suppliers may offer some level of reduced warranty for the outer range defined by the factor R such that:

- **R = (Warranty level in Outer Range) / (Warranty level in Inner Range)**

The inner and outer ranges are represented schematically in Figure 1.

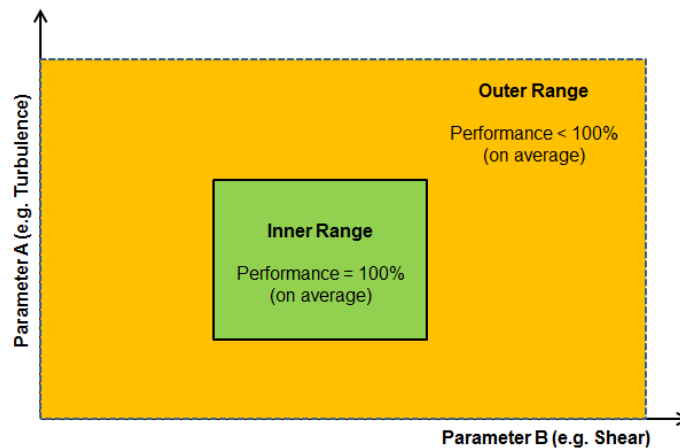


Figure 1. Schematic representation of the Inner-Outer range proposal.

The inner range would thus be defined by a sequence of criteria of the form:

General Inner Range Definition	Example Inner Range Definition
<p>IF the following criteria are all satisfied</p> <ul style="list-style-type: none"> • Lower Limit A ≤ Parameter A ≤ Upper Limit A • Lower Limit B ≤ Parameter B ≤ Upper Limit B • (... additional criteria as required) <p>THEN a time period belongs to the inner range</p> <p>ELSE a time period belongs to the outer range</p>	<p>IF the following criteria are both satisfied</p> <ul style="list-style-type: none"> • 0 ≤ Shear Exponent ≤ 0.35 • 6% ≤ Turbulence Intensity ≤ 20% <p>THEN a time period belongs to the inner range</p> <p>ELSE a time period belongs to the outer range</p> <p>where:</p> <ul style="list-style-type: none"> • The shear exponent is defined from the lower blade tip to the hub height. • The turbulence intensity is defined at hub height.

A power performance test would analyse all the data in both the inner and outer ranges and derive:

- **AEP_{Reference}(u)**: The reference AEP per wind speed bin. Calculated from the reference power curve and reference wind distribution.
- **AEP_{measured}(u)**: The measured AEP per wind speed bin. Calculated from the measured power curve (combined for both the inner and outer ranges) and the reference wind distribution.
- **F(u)**: The fraction of data in the outer range per wind speed.

The warranty test would thus be performed as follows

Warranty Test Using Inner-Outer Range Concept	
IF	$\sum AEP_{\text{measured}} \geq \sum \{ (1 - F) \times W \times AEP_{\text{Reference}} + F \times R \times W \times AEP_{\text{Reference}} \}$
	Then Test Passes
	Else Test Fails

where the summation is performed over all wind speed bins and **W** is the Inner Range Warranty level e.g. 95% or (100% - Uncertainty).

The PCWG considers the Inner-Outer Range Concept to have the following advantages:

- It is a pragmatic approach which is easy to define and simple to apply.
- It defines clear limits beyond which performance degradation can be expected.

The PCWG considers that the Inner-Outer range proposal can be applied now in contractually defining warranties. The PCWG has demonstrated via a round robin exercise that the Inner-Outer concept is both simple to understand and can be applied by a broad range of organisations consistently. The Inner-Outer range concept can be used in compliment with the Rotor Equivalent Wind Speed method e.g. by broadening the Inner Range definition if Rotor Equivalent Wind Speed is used in place of Hub Height Wind Speed.

Notes on the Power Curve Working Group

The Power Curve Working Group (PCWG) is a collaboration of over 40 wind energy organisations, encompassing developers, manufacturers, consultants and research institutions. The group aims to find practical and meaningful ways of predicting turbine performance in ‘real world’ atmospheric conditions e.g. high/low shear, high/low turbulence, vertical wind veer etc. In addition to this primary goal the PCWG also seeks to find practical measures that will help define turbine warranties which are meaningful with respect to the broader range of atmospheric conditions. The group first met in December 2012 and aims to complete its roadmap in 2014. A key principle of the group is openness and makes the proceedings of all of its meetings publically available¹.

¹ See <http://www.ewea.org/events/workshops/resource-assessment-2013>