## Turbine Supply Agreements or

What do all those little words mean at the bottom of the contract

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# What is a TSA Noise Wise?

- A specification of the noise emission level of a wind turbine which includes:
- L<sub>WA</sub>
- Tonality
- Additional Character?
- Operational Noise Levels at a Receptor!!!!



## Why do we need a TSA?

- How are we to rely on Noise Predictions
  for EIA?
- How confident are we in the level predicted?
- How are we to know that operational noise levels will meet any Permit Conditions?
- What about the character of the sound?



### Sound Power Level $L_{WA}$ Where does this information come from?

Supplied by the Manufacturer based upon

- Proto-type Wind Turbines
- Operational Wind Turbines
- Measurements undertaken in accordance with IEC 61400-11
- Proto-type Measured Data with calculated corrections for final version
- Magic!



# Typical TSA L<sub>WA</sub> Derivation

- Measurements in accordance with IEC 61400-11
- Full Test Report Preferred
- Summary Sheet as a minimum
- More than 1 turbine test allows an assessment of declared  $L_{WA}$  in accordance with IEC 61400-14.



# **TSA Warranted Level**

Typical for Warranted Level to have measurement conditions specified which can include the following:

•A specified turbulence intensity: Typically < 15%

•A specified inflow angle: Typically  $< \pm 2 - 4^{\circ}$ 

•A specified wind shear exponent: m = 0.12 – 0.16



# **Turbulence Intensity**





# **Turbulence Intensity**



Figure 2-14 Downstream development of wake behind a wind turbine. Upper Figure:  $U_0 = 6 \text{ m/s}$ ; Middle Figure:  $U_0 = 10 \text{ m/s}$ ; Lower Figure:  $U_0 = 14 \text{ m/s}$ . In all figures the rotor is located to the left.

Dynamic wake meandering Modeling Risø-R-1607(EN)



# **Turbulence Intensity**





Dynamic wake meandering Modeling Risø-R-1607(EN)



Figure 3-13 Computed and measured 2.5D downstream mean wake turbulence intensity profiles corresponding to an ambient mean wind speed equal to 10 m/s and to an ambient turbulence intensity equal to 9%. From [2].

# Inflow Angle



Inflow angle will change angle of attack and as a result can result in an increase in blade noise and/or stall



$L_{\it slope}/H_{\it slope}$	$H_{sep}$
0	0
1	0.15 H <sub>slope</sub>
2.512	0.3 H <sub>slope</sub>
4	0.15 H <sub>slope</sub>
≥5	0

Streamwise Velocity (ms<sup>-1</sup>)



Flow separation can occur in presence of terrains with slopes of approx. 20°.

# Wind Shear: Diurnal Variation

In general, noise complaints are associated with early evening or night-time operation.

Wind shear exponents greater than m = 0.12 -0.16 typically occur at these times!





# Wind Shear: Topographical

#### Strange wind shear phenomena due to terrain



### Meeting the TSA Environmental Measurement Conditions



Effects of complex wind regimes on turbine performance – AWEA Windpower, Chicago, May 2009

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## Acceptance Measurements for Wind Turbine

- Requires specific conditions to be met for acceptance by supplier
- The conditions may not be possible on some sites!
- The conditions may not relate to the time when complaints are received off site at a noise sensitive receptor, i.e. does the L<sub>WA</sub> warranted relate to the L<sub>WA</sub> at the time of complaint?



## **Declare Sound Power Level Warranties**

- To be welcomed as a means of defining the acceptability of the supplied wind turbine
   BUT
- Applying the method within IEC 61400-14 does bring a necessary measurement requirement!



#### standard deviation of reproducibility $\sigma_{R}$ ۲

standard deviation of noise emission values obtained under reproducibility conditions, i.e. the ۲ repeated application of the same noise emission measurement method on the same wind turbine at different times and under different conditions (different wind directions, different personnel, different apparatus)

#### standard deviation of production $\sigma_{P}$ ۲

- standard deviation of measured noise emission values obtained at different turbines from a batch, ۲ using the same noise emission measurement method under repeatability conditions (same operators, same apparatus)
- Assume .
- σ<sub>R</sub> = 0.9 dB
- σ<sub>P</sub> = 0.5 dB
- .

Total Standard Deviation  $\sigma_{t} = \sigma = \sqrt{\left[\frac{n+1}{n}\right]^2 (\sigma_R^2 + \sigma_P^2)}$ 

K = 1.645  $\sigma_t$  = reflects a probability of 5 % that an apparent sound power level measurement • result made according to IEC 61400-11 performed at a turbine of the batch exceeds the declared value













- Single measurement of a turbine installed at a site will need to exceed warranted level by at least 2.4+ dB before it might be considered non-compliant.
- The greater the number of turbines measured on site, the greater the confidence in the derived  $\rm L_{\rm WA}$

but

- Increased numbers of turbines tested will have a diminishing benefit
- It has been suggested that K < 1.5 dB within some documents!



## TSA Tonality

#### Warranty Options include

- Measurement at Reference Location 1 and/or Optional Locations 2 4.
- At Receptor Locations!

#### Acceptability Criteria (at Reference Location)

- No tone greater than  $\Delta L_{a,k} < 2.0 \text{ dB}$  (IEC 61400-11)
- FGW-Guideline <sup>[1]</sup> (without taking into account any tonality  $K_{TN} \le 2 \text{ dB}$ )

#### Acceptability Criteria (at Receptor Location)

- ETSU-R-97 Tonal Assessment Method Penalty System applied to derived  $L_{\rm WA}$  (in UK)
- Some times there is NO TONALITY WARRANTY!!!!!!!!!



Technische Richtlinie für Windenergieanlagen – Teil 1: Bestimmung der Schallemissionswerte; Editor: Fördergesellschaft Windenergie e. V.; Revision 17, 2006-07-01

## **TSA Audible Characteristics**

- Modulation of Aerodynamic Noise Method proposed within FGW Guideline following Impulsive Noise Assessment Method.
- Debateable whether such a test is relevant at the reference measurement location for  $L_{WA}$  determination,
- DIN 45645-1 Determining noise rating levels from measured data. Part 1: Environmental Noise. Measurements to be undertaken at the receptor location.
- Low Frequency?
- Thumping?
- Noise when parked?



# TSA – You need one

- Specifies L<sub>WA</sub>
- Specifies tonal noise emissions
- Specifies clearly environmental conditions for any compliance measurement;
- Specifies criteria for a breach of TSA Noise Guarantee





