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Norwegian Research Centre for Offshore Wind Technology

Wind Turbine Power Performance Verification by Anemometer on the Nacelle

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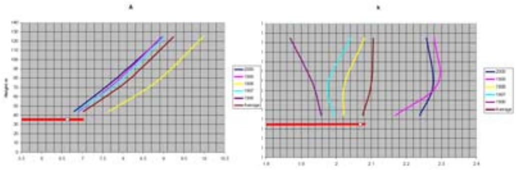
Introduction:

The power curve verification is important for both power output optimization and contractual promising check for wind energy producers. However, the traditional power curve verification by IEC61400-12A is costly and time consuming due to the meteorological metmast tower installation on test sites. The newly published IEC61400-12**B** gives the possibility of verifying the power curve and AEP (Annual Energy Production) by the existing anemometers on the wind turbine nacelle. The purpose of this project is to investigate how is the validation of power performance method by IEC61400-12B under different weather conditions (wind shear / temperature / Turbulence intensity / wind direction variation) and different types of terrain (Complex or flat terrain at site).

The 5 cup anemometer types for performance evaluation.

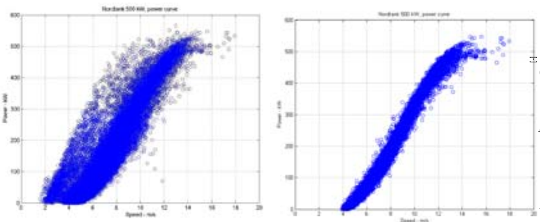
Test Turbine and Test Site :

Determine free, undisturbed sectors. Surrounding landscape, terrain, obstacles influence power production.

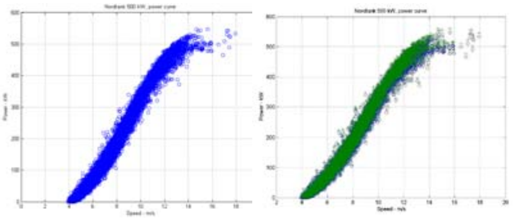


A=6.7 K =2.07

Unvalid Wind Direction Data Elimination.



Discard data where anemometer is within WT downstream sector. Discard data affected by obstacles. Manually discard wrong data due to abnormal WT operation or measurement system errors.



$$t2 = t + 273.15$$

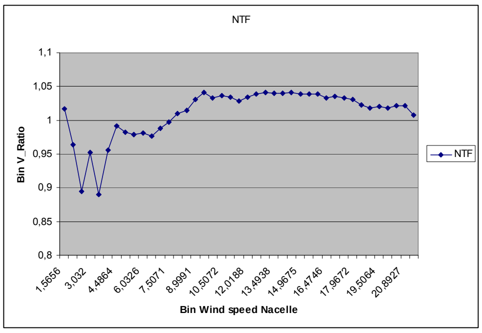
$$\rho = 1.225\left(\frac{288.5}{t2}\right)\left(\frac{p}{1013.3}\right)$$

$$P2 = P\left(\frac{1.225}{\rho}\right)$$

P2 = Power corrected to standard conditions (15°C, 1013 mBar)
P = Uncorrected (measured) power
ρ = Test air density
t2 = Air temperature, degrees Kelvin
t2 = t + 273.15, where
t = air temperature (measured) in degrees C
p = Barometric pressure (measured), mbar

Nacelle Transfer Function (NTF)

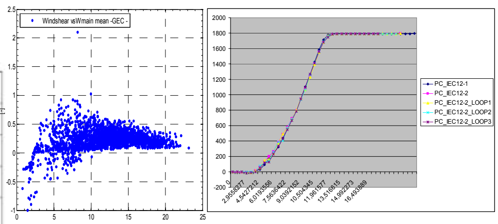
The NTF is the relationship between the measured wind speed on nacelle and the actual wind speed when it is free stream.



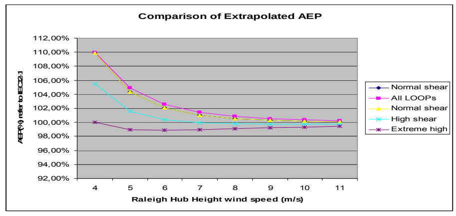
Wind Shear's Influence to Power Curve & AEP

Wind shear is the change in wind speed or direction with height in the atmosphere. The data was divided into 3 groups, representing the different wind shear scope to compare the power curves.

Extreme high	≥0,4 (LOOP 3)
High	0.4≥ Wind Shear ≥0.3 (LOOP 2)
Normal	0.3> Wind Shear ≥0.1 (LOOP 1)
Low	0.1> Wind Shear

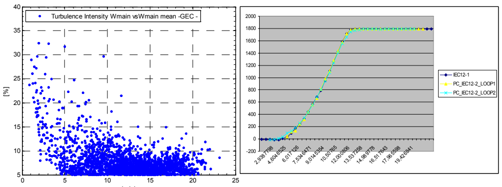


In the higher wind speed sections, different wind shear did not bring significant impact to the NTF based Power Curve. In lower wind speed, different wind shear brings slight deviation to power curve & AEP.



Turbulence Intensity (TI) Influence to Power Curve

Low TI: (0, 8), Normal TI: (8, 15), High TI: (15, :)



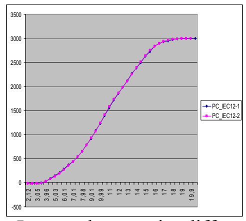
Turbulence Intensity distribution Power Curve comparison

Extrapolated AEP							
		All LOOPs		Low TI 0-8		Normal TI 8-15	
	IEC 12-1	IEC 12-2		IEC 12-2		IEC 12-2	
4	1030,48	1133,21	109,97%	1027,41	99,70%	1113,8	**108,09%**
5	2244,56	2355,23	104,93%	2235,01	99,57%	2312,77	**103,04%**
6	3698,97	3794,96	102,60%	3690,62	99,77%	3741,37	**101,15%**
7	5180,37	5255,64	101,45%	5174,99	99,90%	5198,32	**100,35%**
8	6549,01	6605,45	100,86%	6546,26	99,96%	6548,36	**99,99%**
9	7731,73	7773,37	100,54%	7730,88	99,99%	7718,58	**99,83%**
10	8692,33	8723,03	100,35%	8692,76	100,00%	8671,54	**99,76%**
11	9417,43	9440,22	100,24%	9418,66	100,01%	9392,43	**99,73%**

Different TI did not bring significant impact to the NTF based Power Curve by IEC61400-12B.

Complex Terrain NTF Analysis

Hilly test site presents obstacles and neighbouring WT. Site calibration was executed according IEC61400-12-1 due to topographical variations of complex terrain.



	Extrapolated AEP		
	IEC 12-1	IEC 12-2	
4	1162,182	1122,475	**103,54%**
5	2400,455	2363,007	**101,58%**
6	3975,519	3948,763	**100,68%**
7	5752,792	5738,731	**100,25%**
8	7586,19	7583,771	**100,03%**
9	9339,064	9346,15	**99,92%**
10	10896,26	10910,56	**99,87%**
11	12177,95	12197,39	**99,84%**

In complex terrain, different wind shear brings slight deviation to power curve & AEP.

Conclusions:

- The IEC61400-12B power performance evaluation method has acceptable variation with IEC61400-12A.
- Different wind shear / temperature / Turbulence intensity / wind direction variation and different types of terrain (complex or flat) will NOT bring significant deviation to power curve & AEP. (less than 3.54% at wind speed 4m/s @ complex terrain.)

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