Bechmarks hosted by

Database on Wind Characteristics

Abstract

Some benchmarks with public interest have been identified, based on the contents of the Database of Wind Characteristics. The subject for the first benchmark is wind turbine power performance determination.

Contents

Introduction

During the recent ten years, several benchmarks have been formulated mainly with focus on the wind farm modelling, unfortunately based on confidential wind farm measurements. This document identifies benchmarks based on the contents of Database on Wind Characteristics. Such benchmarks is suitable for education or for training of students, personnel, validation of new methods, and verification of codes.

Benchmarks

The public benchmarks currently includes:

Wind turbine Power Performance analysis.

The analysis will include the following topics with reference to the standard ref. 1

1 Determination power, power coefficient curve and estimation of type A and type B uncertainty for each wind speed bin;
2 Estimation of annual energy production AEP including uncertainty.

Currently two different wind turbines from winddata.com have been prepared for the power performance analysis:

a. On a variable pitch and variable speed large wind turbine of 2750 kW with a rotor diameter of 92m, site=NM92. The benchmark has been detailed in **Appendix A,** which includes information about the test site, wind turbine, the measurement setup, description and introduction to the dataset.
b. A stall controlled wind turbine of 500 kW with a diameter of 41m, site = Nordtank (previously used for student exercises at DTU). The benchmark formulation is available on request from the admin”at”winddata.com.

References

[1] IEC 61400-12-1:2005 Wind turbines – Part 12-1 Power performance measurements of electricity producing wind turbines.
[2] Evaluation of measurement data — Guide to the expression of uncertainty in measurement, JCGM 100:2008 GUM 1995 with minor corrections.
[3] IEA Recommended Practices for wind turbine testing and evaluation 1. Power Performance Testing 2. Edition 1990

Appendix A: Definition of NM92 power performance benchmark

NM92 Introduction

PROJECT DESC. : Aalborg University (AAU) expressed their needs for providing students with an opportunity to conduct tests and experiments on a real wind turbine. For such a project, a data acquisition system represents an essential tool for observing the nature of the wind and the behavior of the wind turbine. AAU assigned Risoe National Laboratory to deliver a suitable data acquisition system on a NEG-Micon NM92/2750 kW wind turbine, which should facilitate monitoring, data management of sensor records and specific needs expressed from the wind turbine manufacturer (formerly NEG-Micon, now Vestas). The intended plans were to conduct tests on the experimental facility for a period of 2-3 years; the first year under management by NEG-Micon, and the following years to run the test facility for research activities under supervision from AAU in two consecutive years. The measurement program was performed by the former Risoe National Labs. Denmark, now DTU Wind Energy.

The information given in this document has been extracted from Winddata.com, supplemented with details on the instrumentation but details on the instrument calibration are not available. Values for the estimated uncertainty has been included, which enables an estimation of the uncertainty of the annual energy production, AEP.

Note: The power performance analysis could be performed according to the IEC standard [1] or the old IEA recommendation [3] otherwise, a simple guideline for the analysis is formulated at the end of this Appendix.

NM92 System information

Site documentation and photos are stored at Winddata.com, site=nm92 and details on the location is listed in Table 1.

Table 1: Site information.

Measurements		
Period: 36 days	Start: 19-11-2005	End: 25-12-2005
Locations		
wind turbine, WGS84	57.039028	10.075722
Mast, WGS84	57.039222	10.072389
Distance mast-wind turbine	207 m	2.3 x D
Mast-wind turbine direction	277°	
Sector identification	232°	322°

Note: the sector was determined as part of a previous sector analysis.

Table 2: Wind turbine information.

Wind turbine	**NM92**
Manufacturer	NEG-Micon
Power regulation	Var. pitch & rotor speed
No. Blades	3
Rotor diameter	92 m
Rotor area	6648 m²
Hub height	70 m
Start wind	3 m/s
Stop wind	25 m/s
Blades	
Type	LM44.8 P
Length	44.8m
Air brake	Full blade
Generator	Double fed - induction
Nominal Power	2750 kW

Table 3: Signals available for power performance analysis.

Instrument	**height**	**Type**	**Mounting**
Wind speed at hub height (ws70)	70 m	P2546a	Top mounted
Wind direction (wd68)	67.5 m	Vector F2919A	Boom mounted
Air temperature (TA68)	67.5 m	Pt100 sensor	
Atmospheric Pressure (Press)	3 m	PTB100B	
Power transducer	Tower bottom	NA	na
Current transformer x 3	Tower bottom	NA	na

NM92 Description of the dataset

Dataset= NM92PC.csv includes 1120 records equal of 187 hours within the specified flow sector.

Table 4: Header of NM92 datafile, Name=NM92PC.

runname	ws70m	ws70s	wd68m	powm	pows	pown	powx	ta68m	presm	ti70
	m/s	m/s	deg	kW	kW	kW	kW	DegC	hPa	%
200511190210	4.21	0.23	319.8	75.6	17.6	41.4	118.3	4.34	1023	5.46
200511190220	4.17	0.16	314.9	81.3	13.8	46	111.1	4.26	1023	3.84
200511190230	4.39	0.4	307.1	122.9	20.1	74.8	162.1	4.37	1023	9.11
200511190240	4.06	0.22	310.7	86	7.7	61.9	111.1	4.8	1023	5.42
200511190250	3.99	0.33	303.9	63.6	16.4	17.8	96	4.51	1023	8.27

Table 5: Definition of columns listed in Table 4.

Column	Values	Units	Height	Description
runname	200511190210	-	-	Start time for data recording, period=600 seconds
ws70m	4.21	m/s	70 m	Mean wind speed at hub height - measured on the mast
ws70s	0.23	m/s	70 m	Standard deviation for the wind speed at hub height.
wd68m	319.8	deg	68 m	Mean wind direction at 68 m - measured on the mast.
powm	75.6	kW	tower bottom	Mean active electrical power - high voltage
pows	17.6	kW	tower bottom	Standard deviation of the active power
pown	41.4	kW	tower bottom	Minimum active power
powx	118.3	kW	tower bottom	Maximum active power
ta68m	4.34	degC	68 m	Mean air temperature
presm	1023	hPa	68 m	Mean atmosperic pressure
ti70	5.46	%	70 m	Mean turbulence intensity - derived.

The dataset has been filtered to obtain:

1) Wind turbine online 100%
2) Inflow sector $\in$ [232;322deg]

Estimated parameters applicable for uncertainty estimation (NM92)

The combined uncertainty for each bin i: $u_{C,i} = \sqrt{s_i^2 + u_i^2}$
Category A uncertainty in the electric power: $S_i = S_{P,i} = \sigma_{P,i}/\sqrt{N_i}$
Category B uncertainty for each wind speed bin:

$$u_i = \sqrt{(u_{P,i}{}^2 + (c_{V,i} \times u_{V,i})^2 + (c_{T,i} \times u_{T,i})^2 + (c_{B,i} \times u_{B,i})^2}$$

Item	Standard uncertainty	Sensitivity factor
Category B, Uncertainties in Electric power	$U_{P,i}= \sqrt{(\mathbf{0.52\%} \times \boldsymbol{P_{i\_norm}} + \mathbf{6.93})}$	NA
Category B, Uncertainties in wind speed	$U_{V,i}=\sqrt{(\mathbf{0.011} + (\mathbf{0.032} \times \boldsymbol{V_i})^2 + (\mathbf{0.034} + \mathbf{0.034} \times \boldsymbol{V_i})^2)}$	$C_{v,i}= \lvert P_i-P_{i-1}\rvert/\lvert V_i-V_{i-1}\rvert$
Category B, Uncertainties in air temperature	$U_{T,i}$=2.1°K	$C_{T,i}=P_i/288.15$
Category B, Uncertainties in air pressure	$U_{B,i}$=3.0 hPa	$C_{B,i}=P_i/1013$

Note: the uncertainty values provided in this section is selected to obtain a realistic estimate of the AEP uncertainty while the instrument values are not available.

Sort guideline for a power performance analysis

1. Qualify the dataset
2. Normalize the dataset according to wt control method
3. Visualize dataset (min, mean, max and stdev) vs wind speed
4. Calculate bin averaged power
5. Calculated bin type A & B uncertainty
6. Estimate annual energy production (AEP) for a Rayleigh wind speed distribution, $\overline{V}$=4, 5, 6, 7, 8, 9, 10 & 11 m/s including standard uncertainty of AEP.

Data for NM92 analysis

The dataset name NM92PC.csv can be accessed in two different ways:

a) On request from admin"at"winddata.com or
b) Signup for a partner account to winddata.com and download the dataset from the ftp-server.

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