Presentation of Nørrekær Enge wind farm and Nordtank 300 kW Wind turbine

Prepared by

Kurt S. Hansen, DTU Wind Energy; kuhan@dtu.dk

1. INTRODUCTION

This description has been prepared for IEA Wakebench and presents the main properties of the coastal located Nørrekær Enge II wind farm. The wind farm was replaced by a cluster of 2.3MW wind turbines in 2009 and is owned by Vattenfall AB.
Power production and yaw misalignment angles were measured for all turbines, detailed turbulence measurements were done simultaneously upstream of the farm and deep inside the farm along two 58-m masts. The two turbines closest to the masts were instrumented with strain gauges. The data consists of continuously collected averages of all sensors, together with representative fast sampled time series taken for a large number of preselected conditions. The statistics from Nørrekær Enge II wind farm can be used as input for 1) analyzing flow conditions inside the wind farm and 2) simulating flow conditions inside the wind farm.

Location of Nørrkær wind farm

Figure 1: Wind farm location in the northern part of Jutland, Denmark.

The wind farm dataset is limited to three channels from each wind turbine and two pairs wind speed and wind direction signals referring to the masts.

2. SITE DESCRIPTION

The Nørrekær Enge II Windfarm, containing 42 x 300 kW Nordtank turbines, is located in the Northern part of Jutland, on the south bank of the Limfjord, about 36 km west of Alborg and 8 km north east of the town Løgster. The terrain is old seabed and extremely flat, about 1 m above sea. The local terrain is however surrounded by small villages and significant terrain, with features up to 40 m in height, immediately to the south of the site. West of the site are farm buildings, rows of trees and another windfarm: the Nørrekaer Enge Windfarm, consisting of 36 x 150 kW Nordtank turbines. Immediately north of the site there is water, Limfjord as shown in Figure 1.

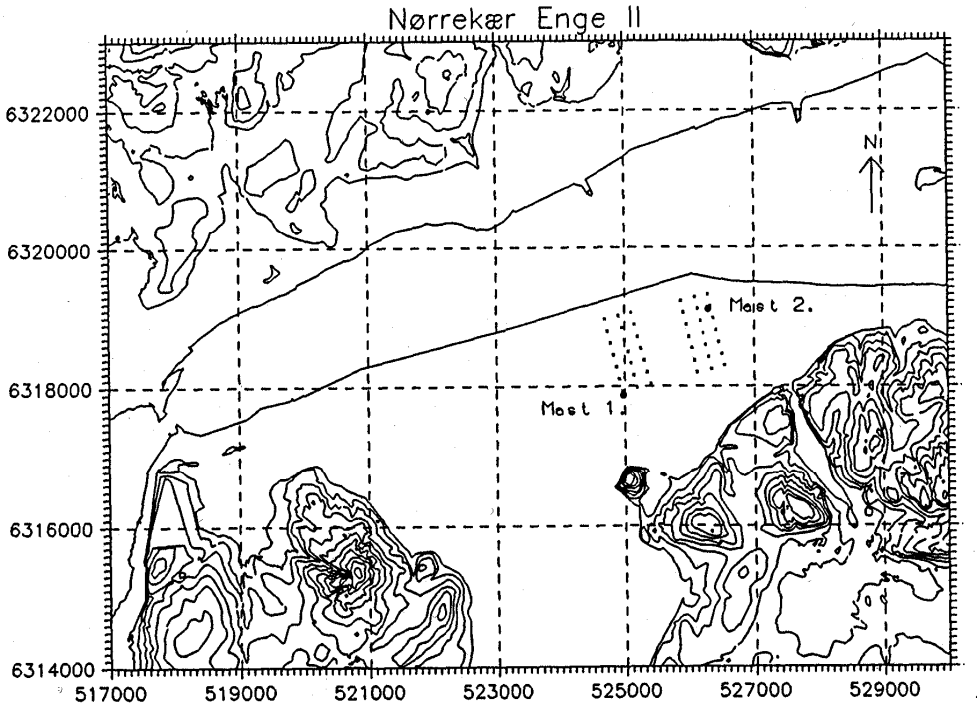

Figure 2: Digitized contour map of Nørrekæer Enge II wind farm.
Distances is in meters and the heights between contours is 5 meter.

Unfortunately the digitized contour map, shown in Figure 2, roughness maps in Figure 3 and farm layout Figure 4 only exits as printed / scanned maps.

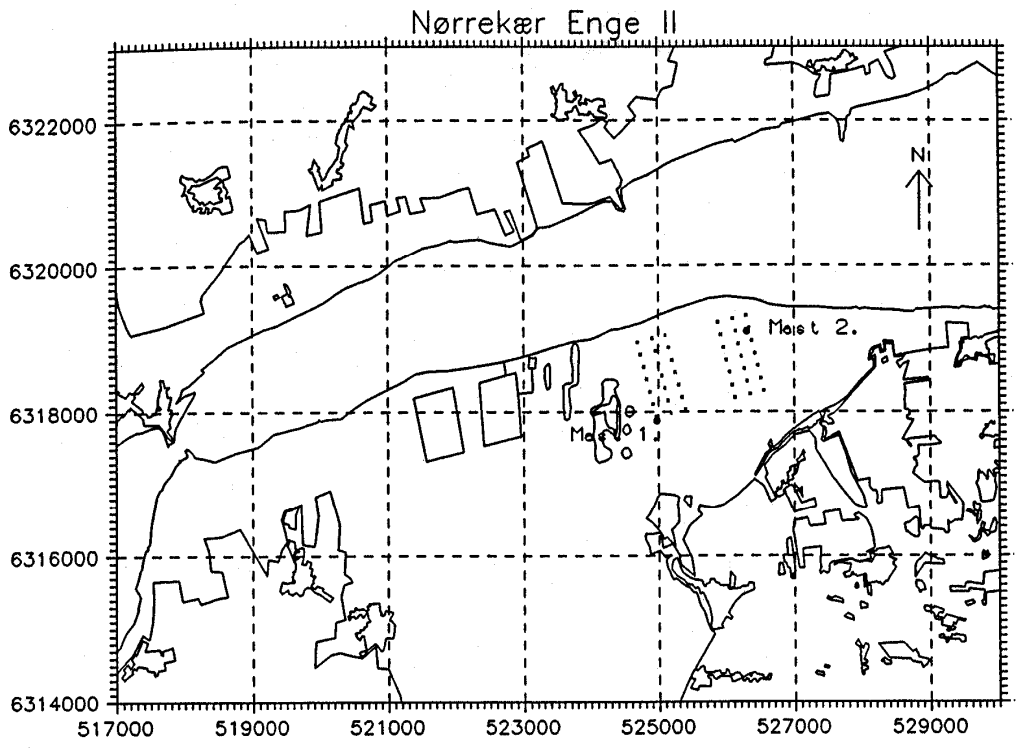

Figure 3: Digitized roughness map of Nørrekær Enge II, distances in meters.
Roughness areas: villages = 0.9; Forest = 0.8, other wind farm = 0.665, hedges=0.2, meadows 0.03, sea=0.0 and the four farms south west of the wind farm = 0.6.

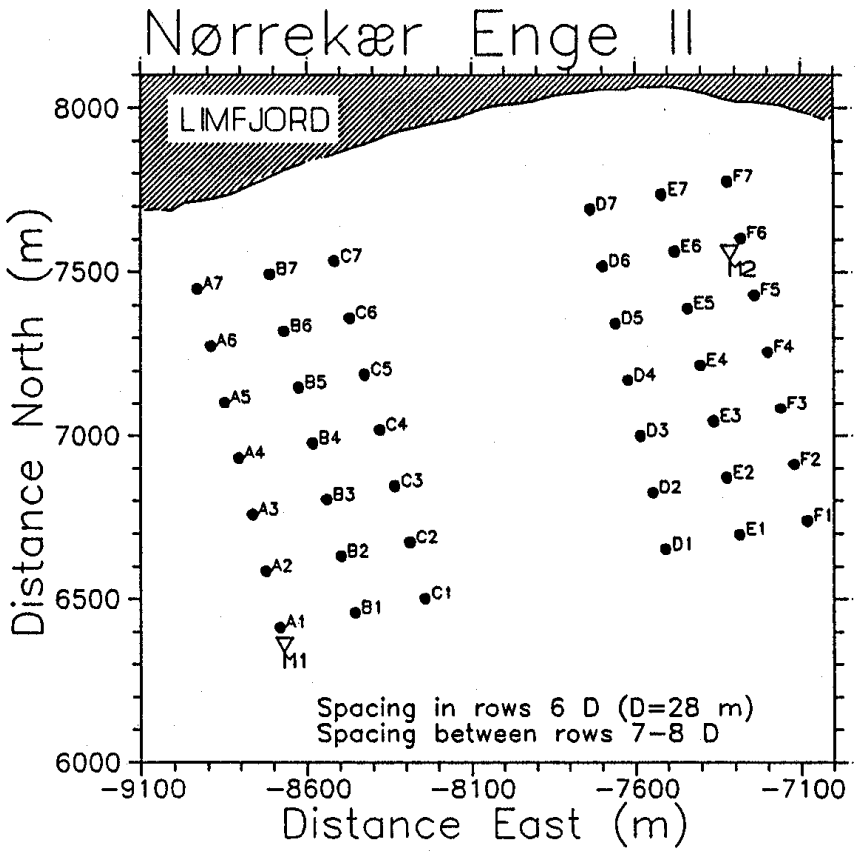

Figure 4: The geometrical layout of the Nørrekær Enge wind farm II.

3. INSTRUMENTATION

Mast 1 (M1) at A1 is placed along the row of turbines A1 - A7 (orientation 165°), 55 m south of turbine Al. The second mast (M2), near F6 is placed on the line between F6 and E5 (orientation 216°), 55 m from F6 and the booms on both masts are perpendicular to the line F6 - E5.

3.1 Mast Instrumentation

The two meteorological masts are instrumented primarily for measuring profiles of mean speed, turbulence and temperature. For the prevailing south westerly wind direction, M1 is an upstream mast, unaffected by wakes from wind turbines. In contrast M2 is located deep in the park and typically experiences wakes from a number of wind turbines. These two different roles are reflected somewhat in the instrumentation of the masts, with significantly more turbulence instrumentation on the wake mast (M2). The instrumentation for each of the two masts is described below.

3.1 Mast M1

Cup anemometers (3, 10, 23, 31, 44 and 58m)
These are based on the standard Rise 70 type but have been modified in an attempt to improve the symmetry of the angular response. Prior to installation at Nørrekær Enge II but following a 2 month "run-in" period, the cups were individually calibrated in a wind tunnel.
Boom arrangements: Pointing 312°.
Wind direction vanes (10 and 31m)
The wind direction vanes used were the Rise model 80 coupled with the Rise P1255 wind direction transmitter.
Temperature difference (23 – 3 m and 58-3 m)
Absolute temperature (3m)
Rain

3.2 Mast M2

Boom arrangement: pointing 306°
Cup anemometers (3, 10, 16, 23, 31, 31S, 44, 44S and 58m)
Wind direction vanes (34m)
Sonic anemometers (23 and 58m)

3.3 Wind turbines

Power measurements: DEIF power converter has been used to measure the gross power output, not taken taking into account the wind turbine self consumption.
Nacelle wind speed: has been extracted form the wind turbine controller.
Nacelle yaw misalignment angle: has been extracted form the wind turbine controller.

Table 1: Specification for the Nordtank 300 kW

Type	Nordtank NTK 300F
Number of turbines	42
Blade no. and position	3 upwind
Power control	Stall
Rotor diameter	28.0 m
Blades	LM 12H
Rotor speed	39 rpm
Swept area	616 m²
Hub height	31 m
Yaw system	Wind vane and yaw motor
Rated power	300 kW
Generator type	Asynchronous, 4-poles
Rated wind speed	15.2 m/s

Table 2; Official power curve for NTK 300F, D=28m

wind speed [m/s]	power [kW]	cp	ct
1			0.10
2			0.10
3			0.10
4	0.0		0.80
5	1.7	0.036	0.82
6	21.2	0.260	0.85
7	46.9	0.363	0.82
8	77.4	0.401	0.78
9	113.9	0.414	0.74
10	152.5	0.404	0.68
11	191.4	0.381	0.62
12	226.6	0.348	0.55
13	262.9	0.317	0.49
14	290.8	0.281	0.43
15	311.0	0.244	0.38
16	325.4	0.211	0.32
17	330.7	0.178	0.28
18	329.0	0.150	0.25
19	336.3	0.130	0.21
20	338.0	0.112	0.20
21	322.9	0.092	0.19
22	318.9	0.079	0.17
23	317.0	0.069	0.15
24			0.15
25			0.14

REFERENCES

[1] Højstrup, J. et.al. 1993, Full scale Measurements in Wind-Turbine Arrays. Nørrekær Enge II. CEC/JOULE, Risø national Laboratory, Risø-I-684(EN); Data is available from www.winddata.com

[2] Nordtank 300F specification;
http://file.seekpart.com/keywordpdf/2011/3/22/201132284726738.pdf

Annex A: wind turbine coordinates

Item	m	m	x-D	y-D
A1	524961	6317929	0.00	0.00
A2	524915	6318100	-1.62	6.13
A3	524870	6318272	-3.24	12.25
A4	524825	6318443	-4.86	18.38
A5	524779	6318615	-6.47	24.51
A6	524734	6318786	-8.09	30.63
A7	524689	6318958	-9.71	36.76
B1	525186	6317979	8.04	1.81
B2	525140	6318150	6.39	7.93
B3	525094	6318322	4.75	14.05
B4	525047	6318493	3.10	20.17
B5	525001	6318665	1.46	26.29
B6	524955	6318836	-0.19	32.41
B7	524909	6319007	-1.84	38.53
Cl	525398	6318027	15.64	3.51
C2	525349	6318198	13.88	9.61
C3	525300	6318368	12.11	15.70
C4	525250	6318539	10.35	21.80
C5	525201	6318710	8.59	27.89
C6	525152	6318880	6.82	33.99
C7	525102	6319051	5.06	40.08
D1	526128	6318191	41.70	9.36
D2	526087	6318363	40.21	15.52
D3	526045	6318536	38.72	21.68
D4	526003	6318708	37.23	27.84
D5	525961	6318880	35.74	33.99
D6	525919	6319053	34.24	40.15
D7	525878	6319225	32.75	46.31
El	526349	6318240	49.59	11.14
E2	526307	6318413	48.08	17.29
E3	526265	6318585	46.57	23.44
E4	526222	6318757	45.06	29.60
E5	526180	6318929	43.55	35.75
E6	526138	6319102	42.04	41.90
E7	526095	6319274	40.52	48.05
F1	526553	6318286	56.87	12.77
F2	526509	6318458	55.31	18.91
F3	526466	6318630	53.75	25.05
F4	526422	6318802	52.19	31.20
F5	526378	6318974	50.63	37.34
F6	526334	6319146	49.07	43.48
F7	526291	6319318	47.51	49.62
M1	524975	6317875	0.50	-1.90
M2	526303	6319101	47.93	41.88

Where x-D and y-D is the turbine location with reference to A1, unit = diameters
M1, M2 are the masts location, UTM Zone=32.