



**Wind Speed Correction Matrix for
Wake Shading Effects on a Wind
Measurement located in the Vicinity
of a Wind Farm
at the Site Minas (Uruguay)**

- Draft of Final Report -

DEWI-GER-WP14-03482-01.00

Service	Wind Speed Correction Matrix for Wake Shading Effects on a Wind Measurement located in the Vicinity of a Wind Farm
Site	Minas (Uruguay)
Offer	21004305
Report	DEWI-GER-WP14-03482-01.00
Status	Draft of Final Report
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Oldenburg, 2014-05-12

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1. Introduction

The customer is planning the installation of a wind farm at the site Minas. It is planned to permanently operate a wind measurement mast in the wind farm.

The aim of the following calculation is to determine a wind speed correction matrix for the wake effects caused by the wind farm Minas.

As topographical input a simplified height contour and roughness map based on satellite data have been used. The meteorological input data are measurement mast data from the region.

For this report, all coordinates of wind energy converters and the measuring mast are presented in UTM WGS84 south, zone 21 coordinates.

The planned wind farm consists of 14 wind turbines of the type Vestas V112 – 3.0 MW with a hub height of 84 m. The coordinates are shown in Table 1. Figure 1 shows a map of the wind farm site Minas.

The measurement mast Minas is located at the position UTM WGS84 south, zone 21 E 656'396, N 6'184'547. Two correction matrixes have been generated for the measurement heights of 84 m and 100 m. The position of the measurement mast is shown in Figure 1.

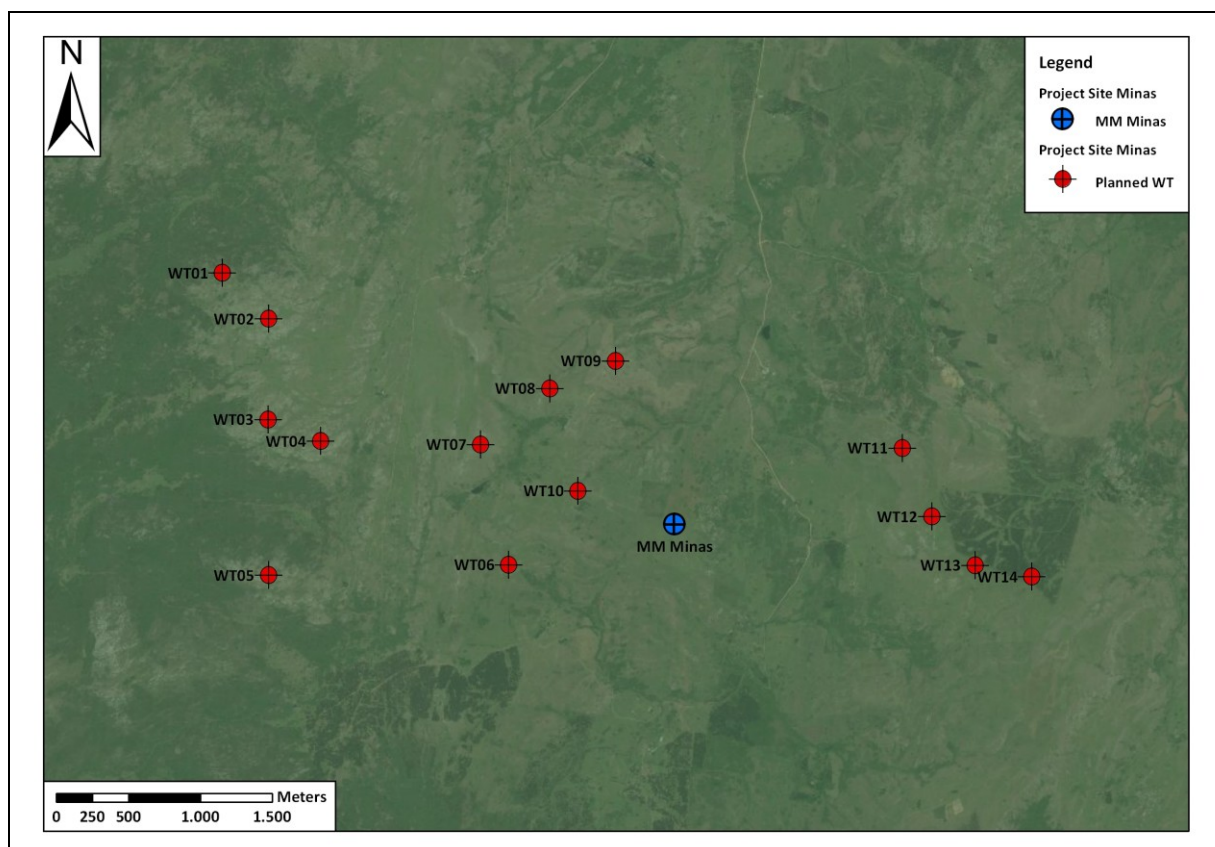


Figure 1: Map of the wind farm site Minas. The positions of the wind turbines and of the measurement mast are marked.

	Coordinates WGS84 south zone 21	
	E [m]	N [m]
WT01	653255	6186294
WT02	653574	6185975
WT03	653572	6185276
WT04	653935	6185126
WT05	653574	6184196
WT06	655243	6184267
WT07	655048	6185103
WT08	655527	6185492
WT09	655985	6185683
WT10	655724	6184781
WT11	657975	6185079
WT12	658181	6184602
WT13	658482	6184265
WT14	658876	6184185

Table 1: Coordinates of the wind turbines in the wind farm Minas.

2. Wind Speed Correction Matrix

2.1. Input data and Description of the Calculation Method

As meteorological input data measurement mast data in the region has been taken. Based on these meteorological data, a wind resource grid has been calculated for the height levels of 84 m and 100 m (WASP RSF file). The power curve and the thrust curve of the Vestas V112 – 3.0 MW have been used as shown in Figure 2.

For the calculation, the power curves have been changed to take into account the following effects:

- The cut-out wind speed of the wind turbine is assumed according to information from the manufacturer. If the cut-out wind speed given by the manufacturer is valid for another averaging time as ten minutes, it has been recalculated to a ten minutes average. Furthermore, the high-wind speed hysteresis has been taken into account. The cut-out wind speed has been determined to 24.3 m/s due to these effects.
- Due to the temperature conditions and the height level of approximate 410 m above sea level (including hub height of 84 m) the mean air density is estimated to be about 1.17 kg/m³. The power curves have been corrected analogue to IEC standard to the stated air density for each single position.

The shading effects were calculated with the software Windfarmer 3.6.2. As wake model the Eddy Viscosity model has been applied [4]. The calculations have been performed for a wind speed resolution of 1 m/s and a wind direction resolution of 5°.

Finally a correction matrix has been generated for the mast Minas for the measurement heights 84 m and 100 m.

Manufacturer, Type: Vestas V112-3.0MW

Hub height: 84, 94, 119 m Rotor diameter: 112 m
Rated power: 3000 kW Power limitation: pitch
Generator-Type: synchronous Rotor speed: 12.8 rpm
Number of blades: 3 Rotor blade: Vestas

Power curve: theoretical, Vestas, 10/12/2013

Air density: 1.225 kg/m³

Type of anemometer for measurement of the powercurve: -

Thrust curve: theoretical, according to manufacturer, 10/12/2013

Comment: The values of a theoretical power curve might be uncertain to a significant extent which leads to uncertainties in the calculated energy yield, also. We recommend to demand a power curve from the manufacturer, which is measured and certified according to 'IEC61400-12' and 'MEASNET'.

Wind Speed [m/s]	Electrical Power [kW]	power coefficient cp [-]	Wind Speed [m/s]	thrust coefficient [-]
3.0	26.0	0.160	3.0	0.901
3.5	73.0	0.282	3.5	0.847
4.0	133.0	0.344	4.0	0.821
4.5	207.0	0.376	4.5	0.815
5.0	302.0	0.400	5.0	0.812
5.5	416.0	0.414	5.5	0.808
6.0	554.0	0.425	6.0	0.805
6.5	717.0	0.433	6.5	0.801
7.0	907.0	0.438	7.0	0.798
7.5	1126.0	0.442	7.5	0.795
8.0	1375.0	0.445	8.0	0.794
8.5	1652.0	0.446	8.5	0.795
9.0	1958.0	0.445	9.0	0.786
9.5	2282.0	0.441	9.5	0.760
10.0	2585.0	0.428	10.0	0.713
10.5	2821.0	0.404	10.5	0.642
11.0	2997.0	0.373	11.0	0.564
11.5	3050.0	0.332	11.5	0.478
12.0	3067.0	0.294	12.0	0.407
12.5	3074.0	0.261	12.5	0.352
13.0	3075.0	0.232	13.0	0.307
13.5	3075.0	0.207	13.5	0.270
14.0	3075.0	0.186	14.0	0.240
14.5	3075.0	0.167	14.5	0.215
15.0	3075.0	0.151	15.0	0.193
15.5	3075.0	0.137	15.5	0.174
16.0	3075.0	0.124	16.0	0.158
16.5	3075.0	0.113	16.5	0.144
17.0	3075.0	0.104	17.0	0.132
17.5	3075.0	0.095	17.5	0.121
18.0	3075.0	0.087	18.0	0.111
18.5	3075.0	0.080	18.5	0.102
19.0	3075.0	0.074	19.0	0.095
19.5	3075.0	0.069	19.5	0.088
20.0	3075.0	0.064	20.0	0.082
20.5	3075.0	0.059	20.5	0.077
21.0	3075.0	0.055	21.0	0.072
21.5	3075.0	0.051	21.5	0.067
22.0	3075.0	0.048	22.0	0.063
22.5	3075.0	0.045	22.5	0.059
23.0	3075.0	0.042	23.0	0.056
23.5	3075.0	0.039	23.5	0.053
24.0	3075.0	0.037	24.0	0.050
24.5	3075.0	0.035	24.5	0.047
25.0	3075.0	0.033	25.0	0.044

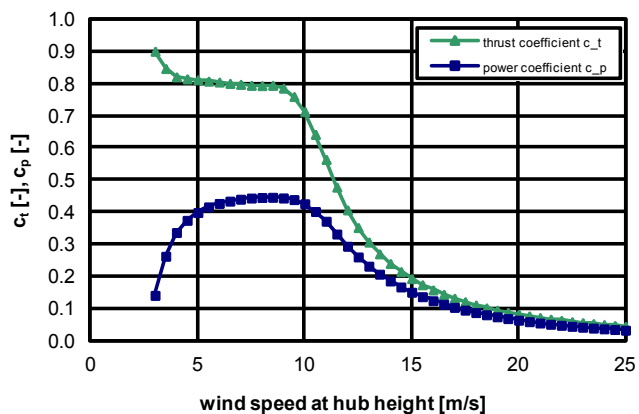
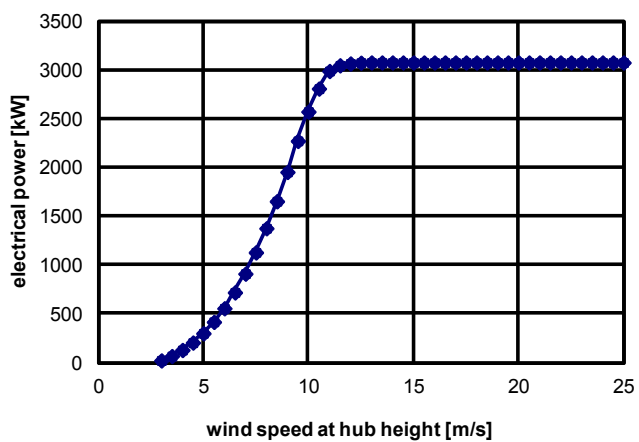


Figure 2: Power curve used for wind farm Minas.

2.2. Correction Matrix

A correction matrix with a resolution of 1 m/s in wind speed and 5° in wind direction has been generated (Table 2). It gives a scaling factor for each wind speed and wind direction combination. The scaling factor has to be multiplied with the measured data in order to correct the shading effects due to the wind turbines in the wind farm Minas. The correction matrix will be provided to the client additionally as excel file.

The wind speed reduction by the wind farm is largest for wind speeds of the partial load region of the power curve. Here the largest share of the wind energy is converted by the wind turbines. With higher wind speeds the shading effects decrease.

The wind turbine WT10 located north-west of the mast in a direction of 290° has the largest shading effects on the wind measurements on the mast Minas. The distance is 720 m corresponding to 6.4 D.

Apart from WT10 mainly the wind turbines WT06 (in 255°) and WT09 (in 340°) have distinct shading effects on the wind measurements. Additionally the wind turbines WT11 to WT14 in east direction have shading effects on the measurements.

For a permanent operation of the mast in the wind farm the mast position is suited with a sufficient large distance to the planned wind turbines. Its position is within the wind farm.

If the matrix is applied on the wind mast data then the mast position is suitable for a permanent operation mast.

Due to the simplified topographical and meteorological input data the uncertainty of the correction matrix is enlarged.

[illegible]

[illegible]

3. General Comments and Notes

The results are based on the data submitted, the site description, the restrictions and the prerequisites mentioned throughout the report.

The input data for the calculations were checked for consistency and plausibility. This does not rule out possible errors in the measurement or data processing procedure, especially if the data are not processed solely by DEWI GmbH.

DEWI GmbH does not guarantee for the calculated wind conditions or the calculated energy yield. The results documented in this report relate only to the items under investigation. A partial duplication of this report is not allowed without a written permission of DEWI GmbH.

4. Appendix

4.1. Used Software

DEWI used among several tools and programs for evaluation and correlation of the wind data the following software for the investigation in hand:

- Wind Atlas Analysis and Application Program (WASP), version 5.01, build 81110, Risø National Laboratory, Roskilde, Denmark.
- Garrad Hassan and Partners Limited; Windfarmer, Bristol, 1997 – 2011, version 3.6.2.
- ArcGIS version 10, geographic information system, Esri, <http://www.esri.com/software/arcgis/>

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