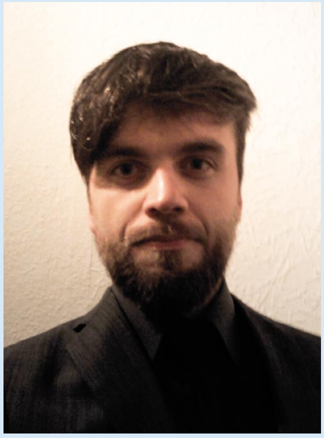
Calculation of Wind Farm Production Losses via MERRA Data in Consequence of Bat Based Temporary Wind Turbine Shut Downs



J. Raabe

J. Raabe, T. Schorer, J.-T. Junge; DEWI Oldenburg

ENGLISH

Summary

In the presented study a comparison of the difference between 10-minute wind speed data and MERRA data based on calculations of annual power losses is performed to determine if MERRA data are sufficient for that purpose and to detect the possible uncertainties of the applied procedures. Further comparisons are based on real production and wind speeds of nacelle anemometers from existing turbines. Furthermore, possible alternative calculation methods are compared in order to find a realistic procedure with reduced uncertainties and reliable data set to predict the losses of bat caused shut down scenarios. The study shows that in general the course of the wind speeds of MERRA data accompany the course of the wind speeds of 10-minute data from nacelle anemometers, but with an all in all higher level of wind speed values. With the use of scaling factors it is possible to level the bat shut down losses estimated via MERRA data with the estimated losses using 10-minute wind speed values from nacelle anemometers. However the uncertainties must be estimated as high because of the large amount of influencing factors. Furthermore, the difference of wind speed values of a single month can be quite high, which is mainly due to the aspect of the established high amount of peaks in the MERRA wind speed values.

Introduction

In the last years the impact of wind farms on bat populations became a significant problem for the wind farm shareholder because of the financial losses in consequence of bat protection regulations. Therefore, the calculation of the annual production losses due to bat based wind turbine shutdowns more and more often becomes a part of Wind Potential Analysis and Energy Yield Assessments. For the reason that different bat species only fly up to a specific wind speed there are often exact shut down wind speeds specified by the responsible permission departments. By adjusting the turbines' control software with the exact shut down wind speeds, annual production losses can be reduced compared to a complete shut down in the period of the bat activity. To accurately predict the possible losses high resolution wind

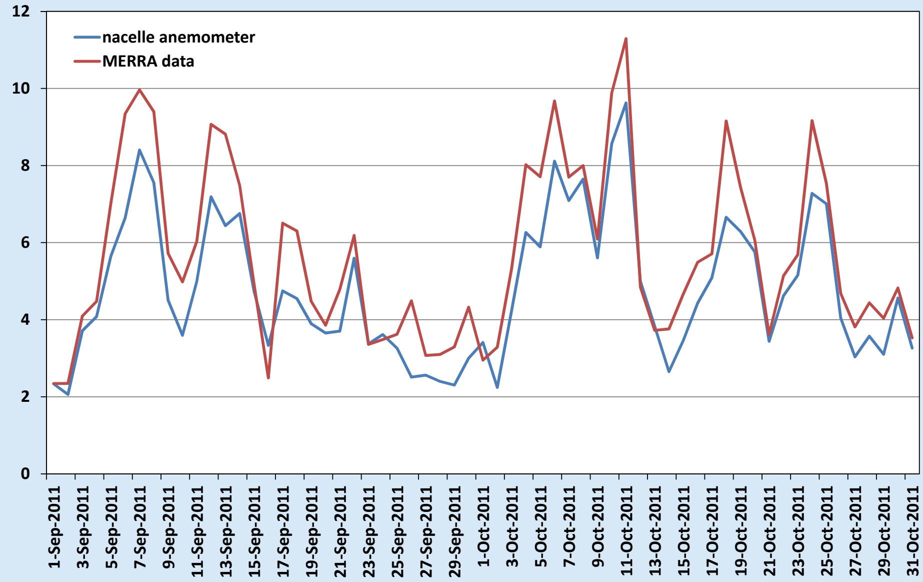


Fig. 1: Comparison of the daily wind pattern of MERRA data and nacelle anemometer data for an exemplary site

Overall losses based on a year						
shut down windspeed	**Hub height 105 metres**			**Hub height 140 metres**		
	Nacelle anemometer	MERRA data	Difference	Nacelle anemometer	MERRA data	Difference
6 m/s	17,7%	16,3%	**1,4%**	15,5%	14,2%	**1,3%**
7 m/s	23,4%	20,5%	**3,0%**	20,4%	18,3%	**2,1%**
8 m/s	28,2%	23,9%	**4,3%**	24,7%	22,0%	**2,7%**

Tab. 1: Overall downtimes based on a year for different hub heights and shut down wind speeds (average of all regarded sites)

Monthly losses for a hub height of 105 metres								
shut down windspeed	Data type/ Month	April	May	June	July	August	September	October
6 m/s	Nacelle anemometer	27,2%	24,7%	23,2%	21,4%	25,8%	27,7%	29,5%
	MERRA data	22,6%	22,5%	22,4%	20,7%	23,6%	26,9%	25,7%
	Difference	4,6%	2,1%	0,8%	0,7%	2,2%	0,8%	3,9%
7 m/s	Nacelle anemometer	35,5%	30,6%	28,5%	26,8%	32,1%	35,9%	40,0%
	MERRA data	31,7%	27,7%	27,1%	26,7%	30,6%	34,0%	36,3%
	Difference	3,8%	2,8%	1,4%	0,1%	1,5%	1,9%	3,7%
8 m/s	Nacelle anemometer	40,9%	34,2%	30,6%	30,4%	36,5%	40,9%	47,7%
	MERRA data	39,2%	32,9%	30,0%	30,9%	35,8%	40,3%	45,7%
	Difference	1,8%	1,3%	0,6%	-0,5%	0,6%	0,6%	2,0%

Tab. 2: Monthly downtimes for different shut down wind speeds (average of all regarded sites)

data is the most reliable database to determine the amount of wind speeds higher and lower than the shutdown wind speed. Considering the fact that energy yield assessments in Germany rarely base on wind measurements, but on monthly energy production of nearby turbines, high resolution data of wind speeds are often not available. MERRA data [1], with its worldwide coverage and one-hour resolution, might be considered as a possible database.

Methodology

To compare the MERRA wind speed data with 10-minute wind speed data from nacelle anemometers, five sites within different BDB-Index-Regions [2] of Germany were evaluated in order to cover a large bandwidth of different wind conditions and site characteristics. Depending on the different sites, the 10-minute wind speed values were available for the years 2009, 2010 and 2011. For the MERRA data the wind speed values for the years 1990 till 2011 were extracted for every site to cover the period of the different BDB-Index-Regions, which were needed for later analysis. The evaluated wind speed values of the MERRA data were recorded for a height of 50 meter above sea level in an hourly average data format. On the contrary the values for the 10-minute wind speed data were recorded at hub heights from 64 to 108 metres depending on the different sites.

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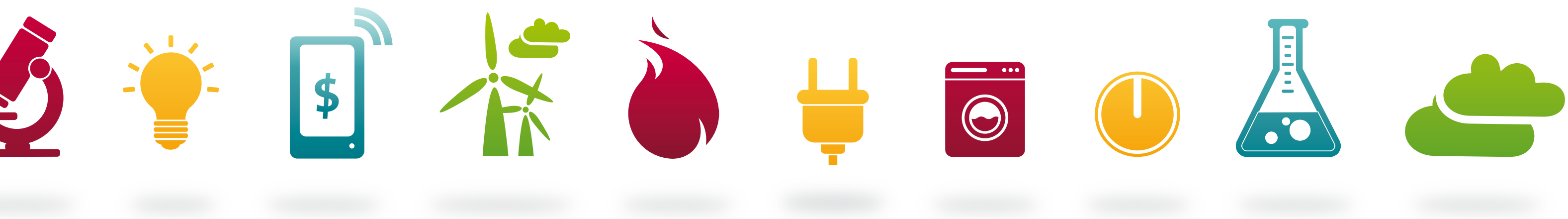

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Due to the flight times of the different bat species in Germany from April until October, the unmodified wind speed values of this period for the years 2009, 2010 and 2011 were compared in a first evaluation. Therefore the 10 minute wind speed data of the nacelle anemometer and the 1 hour wind speed values of the MERRA data were extrapolated to a daily mean value for better comparison. For further analysis of the MERRA wind speed level the 10 minute wind speed data of a met mast were compared with the MERRA data for an additional site.

In a second evaluation the MERRA wind speed values and the nacelle anemometer wind speed values of the evaluated sites were extrapolated to a height of 105 m and 140 m (currently most common modern wind turbine hub heights). Because these scaling based on a long term level, the values for the MERRA wind speed data and the 10-minute wind speed data had also be adjusted to a comparable long term level. In a last step the average wind speed values of the MERRA data were adjusted to the site specific wind meteorology. These long-term scaled and extrapolated wind speed values were implemented into a in-house tool created for the estimation of bat losses. With this tool the monthly losses for the evaluated month and the total loss based on a year were estimated for different scenarios. All calculations are based on a daily shut down period from 1 hour before sunset till sunrise using the site specific sunset and sunrise times.

Results

The comparison of the unmodified daily average MERRA wind speed values with the daily average 10-minute wind speed values of the nacelle anemometers show a higher average wind speed level of the MERRA data. Especially the high peaks of the MERRA data values at days with a high average wind speed are a noticeable difference. At the other hand there are also some peaks at days with a low average wind speed with amplitudes to the lower wind speeds. The larger part of these peaks lies within the windy months September and October. Fig. 1 shows an excerpt of the daily wind pattern for the months September and October for one of the evaluated sites.

A comparison of the average wind speed values of the evaluated sites shows that the level of the MERRA wind speed average is partly about 1 m/s higher than the wind speed average of the nacelle data. These differences would be increased if the values of the MERRA data would be extrapolated to the height of the nacelle anemometer. Similar results show the comparison of the MERRA data values with the 10-minute wind speed values of a wind measurement from an additional regarded site. Both data have a similar time course of the wind speed averages. The level of the MERRA data average wind values is still higher but with a smaller amount of high peaks.

Regarding the bat based losses using the proceeding described in the methodology part, the results show an overall good matching of MERRA data and the nacelle anemometer data (Tab. 1). The estimated losses using MERRA data are in average about 1 percent lower at shut down wind speeds of below 6 m/s. At shut down wind speed of below 7 and 8 m/s the difference between the use of MERRA data and nacelle anemometer data is higher, with about 3 to 4 percent difference for a hub height of 105 m and 2.5 percent difference for a hub height of 140 m in the average loss based on a year. For this shut down wind speed the already described peaks of the MERRA data seems to be a crucial factor.

It is important to note that these values show only the average losses of all regarded sites over the whole period including April till October. Regarding the reviewed month separately the difference between MERRA data and nacelle anemometer data are in part higher. First and foremost the losses in April and October are significant lower when using MERRA data. Tab. 2 shows the monthly average losses regarding all reviewed sites for a hub height of 105 meter. The evaluation for the hub height of 140 m shows a similar result.

Uncertainties

One of the possible sources of error is the different installed nacelle anemometers of the different wind turbine types. In this research the data from nacelle anemometers of different Enercon and Vestas wind turbines were evaluated. The wind data of the different nacelle anemometers show different trends in comparison with the MERRA wind speed data. Furthermore it is possible that WT nacelle anemometers do not have a steady free air flow or other technical limitations which could lead to lower measured wind speed values. Vice Versa the procedure of the assessment methods of MERRA wind speed values is not completely transparent and therefore some of the steps of this evaluation method may lead to an overestimation of the real wind speed values. Another uncertainty factor is the difference between 1 hour resolution data and 10-minute resolution data. The results are all time based and may differ from the energetic losses which arise from the annual course of the wind speeds. Therefore the differences in the results between MERRA data and nacelle Anemometer data might be lower.

References

[1] Rienecker, M. M., M.J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M.G. Bosilovich, S.D. Schubert, L. Takacs, G.-K. Kim, S. Bloom, J. Chen, D. Collins, A. Conaty, A. da Silva, et al., 2011. MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. Journal of Climate, Vol. 24, No. 14, 3624-3648. doi: 10.1175/JCLI-D-11-00015.1.

[2] Regionaler monatlicher Windindex der Betreiber-Datenbasis (BDB-Index), Vertrieb seit 01/2005: enveco GmbH, Grevener Strasse 61 c, 48149 Münster.