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Modeling of the power generation from wind turbines with high spatial and temporal resolution

Reinhold Lehneis, David Manske, Björn Schinkel, and Daniela Thrän*

Introduction

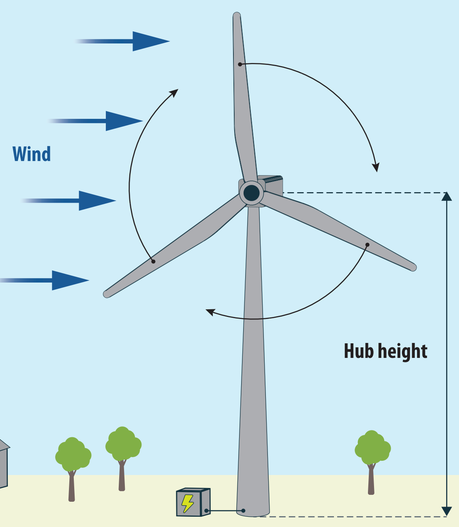
The share of wind power in the generation of electricity has increased significantly in recent years and, despite its volatility, variable energy from wind turbines has become an essential pillar for the power supply in many countries around the world. To investigate the manifold effects of increasing variable renewables, detailed power generation data from wind turbines with high spatial and temporal resolution are often mandatory. The lack of freely accessible feed-in time series, for example due to data protection regulations, makes it necessary to determine the wind power feed-in for a required region and period with the help of numerical simulations.

Simulation model

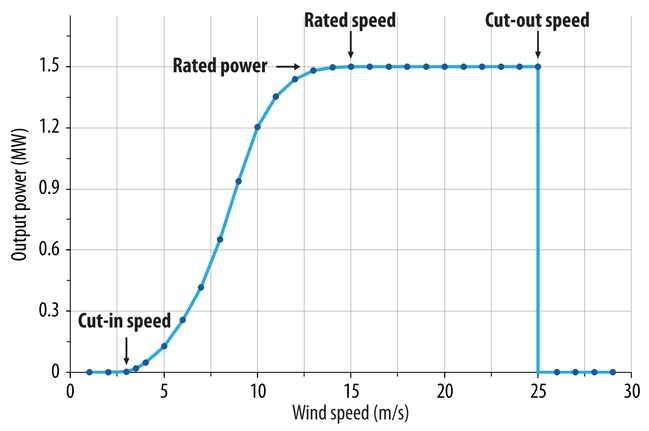
This study shows how such a numerical simulation can be developed using publicly available wind turbine [1] and weather data [2]. Herein, a novel model approach is used for the wind-to-power conversion, which utilizes a sixth-order polynomial for the specific power curve of a wind turbine. After such an analytical representation is derived for a required turbine, its output power can be easily calculated using the wind speed and air temperature at its hub height.

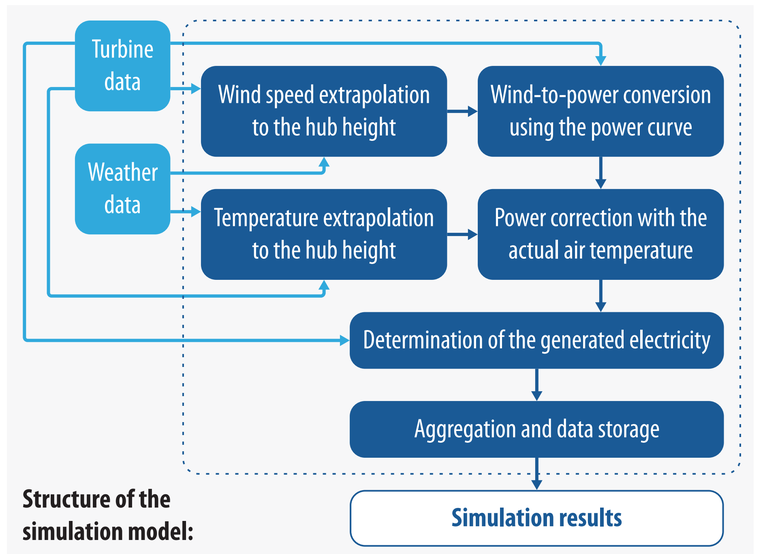
Required turbine data:
- Geographical location
- Rated power & hub height
- Specific power curve
- Date of (de-)commissioning

Required weather data:
- Wind speed at 10 m
- Air temperature at 2 m
- Spatial resolution of few km
- Temporal resolution of 1 h



Typical power curve of a wind turbine using the example of a General Electric GE 1.5sl [3]:

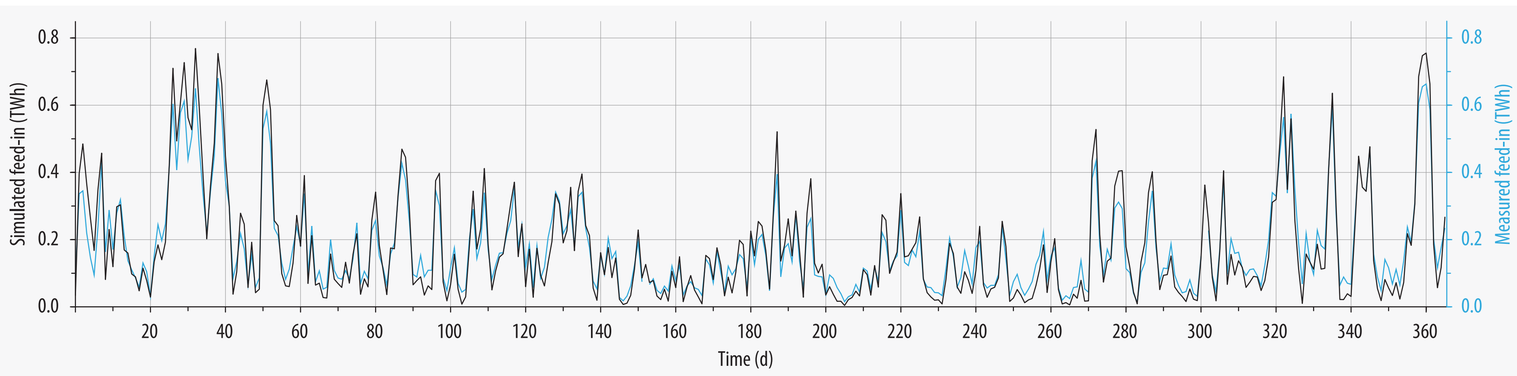




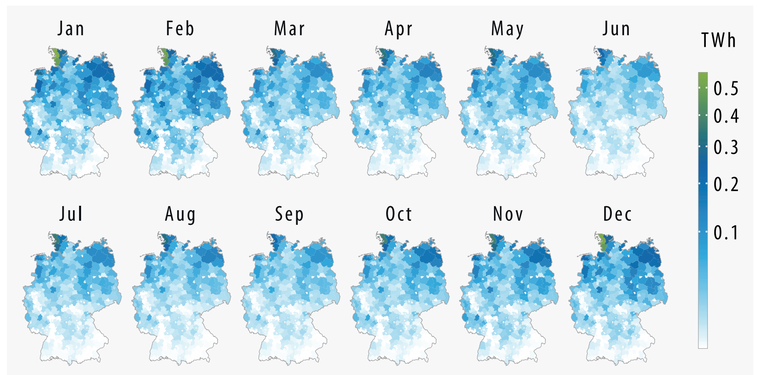
Structure of the simulation model:

Preliminary results

For proof of concept and model validation, measured feed-in data of a geographically and technically known wind turbine were compared with the simulated time series at a high temporal resolution of 10 minutes showing a good agreement. After this successful validation, the numerical simulation was carried out for an ensemble of almost 26 thousand onshore wind turbines in Germany for the year 2016 with a total capacity of about 44 GW. Herein, the electricity generation of each wind turbine in the ensemble was simulated individually.



Simulated power generation and measured feed-in data [4] for the whole of Germany for 2016, aggregated from an hourly into a daily resolution.



Aggregated monthly power generation at county level in Germany for 2016.

Conclusion

The presented simulation model can be a very promising alternative to calculate highly resolved power generation data from wind turbines. It can be also applied to other countries without any changes, if the required wind turbine and weather data are available. Moreover, the simulation model can be carried out with different weather products, which possess various resolutions and cover different areas around the world.

References

[1] Eichhorn M., Scheftelowitz M., Reichmuth M., Lorenz C., Louca K., Schiffler A., Keuneke R., Bauschmann M., Ponitka J., Manske D., and Thrän D. Spatial Distribution of Wind Turbines, Photovoltaic Field Systems, Bioenergy, and River Hydro Power Plants in Germany. Data (2019) https://www.mdpi.com/2306-5729/4/1/29
[2] Weather data via the open-access web interface of the Photovoltaic Geographical Information System (2019) https://ec.europa.eu/jrc/en/pvgis
[3] The Wind Power, Wind Energy Market Intelligence (2020) https://www.thewindpower.net/
[4] SMARD - Strommarktdaten, Stromhandel und Stromerzeugung in Deutschland, Bundesnetzagentur (2019) https://www.smard.de/

*Contact

Dr. Reinhold Lehneis
E-Mail: reinhold.lehneis@ufz.de
Phone: +49 341 2434-567
Helmholtz Centre for Environmental Research – UFZ
Permoserstraße 15 | 04318 Leipzig | Germany