Title

The market value and impact of offshore wind on the electricity spot market: Evidence from Germany

Author

Nikolaus Ederer

Vienna University of Technology - Faculty of Electrical Engineering and Information Technology
Gußhausstr. 25-29 - 1040 Vienna - Austria

Strabag OW EVS GmbH
Reeperbahn 1 (8. Stock) - 22041 Hamburg - Germany

+43 664 41 899 48
nikolaus.ederer@gmail.com

Note for reviewers

This article has just been accepted for publication by the international peer-reviewed journal *Applied Energy*. Thus, it will already be published in November. However, I am convinced that this article is highly interesting for stakeholders in the wind industry and could be a valuable contribution in the session "Integrating wind power into the electricity market".

Uniqueness

- First article to present market value of offshore wind
- First article to simulate the merit order effect caused by offshore wind

Highlights

- Market value of offshore wind based on feed-in and weather data is assessed.
- Merit order effect caused by wind energy is simulated for 2006 – 2014.
- Results indicate same impact of on- and offshore wind on market price and value.
- Steadier wind resource offshore imposes less variability on market price.
- Characteristic of variable wind feed-in cannot be blamed for price deterioration.

Introduction

Although the expansion of offshore wind has recently increased in Germany, as in other countries, it is still forced to defend its role in long-term energy policy plans, particularly against its onshore counterpart, to secure future expansion targets and financial support. The objective of this article is to investigate the economic effects of offshore wind on the electricity spot market and thus open up another perspective that has not been part of the debate about offshore vs. onshore wind thus far. A comprehensive assessment based on a large amount of market, feed-in and weather data in Germany revealed that the market value of offshore wind is generally higher than that of onshore wind (see Figure 1). Simulating the merit order effect on the German day-ahead electricity market for the short term and long term in the years 2006 – 2014 aimed to identify the reason for this observation and show whether it is also an indication of a lower impact on the electricity spot market due to a steadier wind resource prevailing offshore.

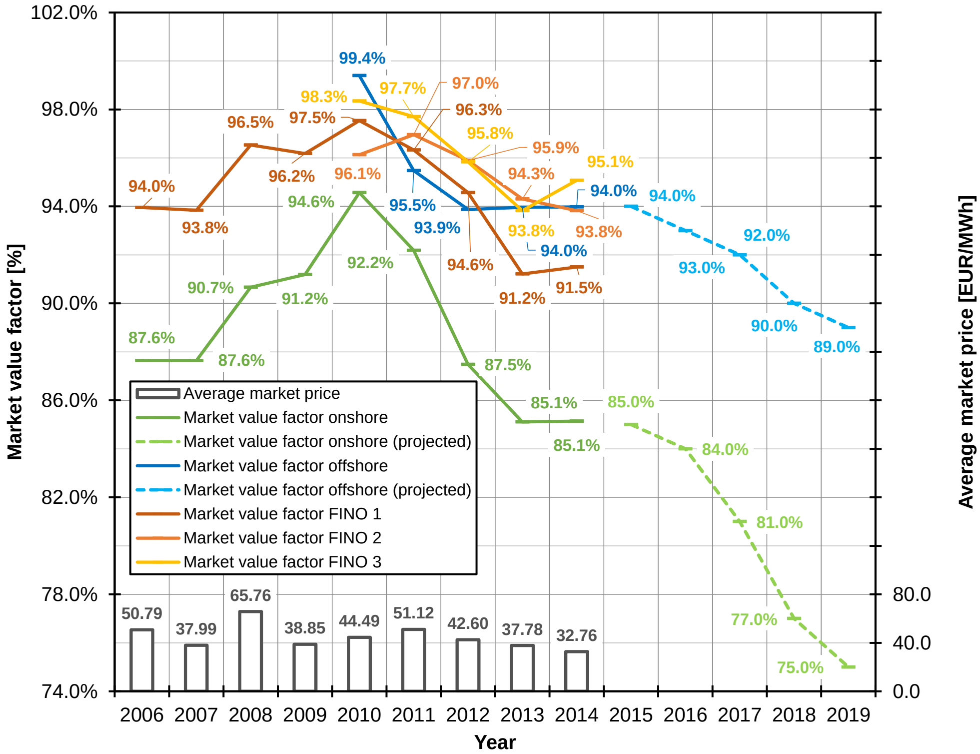

Figure 1: Market value of offshore wind in comparison with onshore wind in Germany.

Approach

The merit order effect (see Figure 2 (top)), which was simulated in the following, is based on the assumption that the demand curve is independent of the supply curve, which means that regardless of how much wind generation is traded on the day-ahead market the ask curve stays the same. This is in contrast to the bid curve. Due to the property of wind energy having near zero marginal costs and the support through subsidies, wind energy is offered at a low price. This results in a shift of the bid curve by the additional wind capacity q_{wind}, which in turn causes a shift of the market clearing and thus leads to a lower market clearing price p_{mc}^{wind}. The extent of this effect depends on the additional wind capacity and the shape and position of the bid and ask curve. The results presented in the following were obtained by simulating this shift exactly using the original bid and ask curves from the day-ahead market, feed-in curves for offshore and onshore wind and a calculated generation curve based on FINO 1 measurements for the years 2006 – 2014. The market impact was simulated for three levels of additional energy generation per year q_{add} – 5 TWh, 10 TWh and 15 TWh – from onshore and offshore wind, respectively. Applying the simulation to original data from the past ensured that the analysis is not falsified by a projection of input parameters. Thus the results reflect what would have happened if in the respective year a specific amount of onshore/offshore wind energy would have been added to the day-ahead market.

The first step was to determine the additional wind capacity for every hour of the year $q_{wind,h}$, which was obtained by calculating a multiplication factor α with which the wind feed-in of every hour of the year under consideration $q_{feed\_in,h}$ was multiplied aiming at an adjusted feed-in curve with a cumulative generation amount of the chosen level of additional energy per year:

$$\alpha = \frac{q_{add}}{\sum_{h=1}^{H} q_{feed\_in,h}} \quad (4)$$

$$q_{wind,h} = \alpha \cdot q_{feed\_in,h}, \qquad \forall h \quad (5)$$

Afterwards, the bid curve was simply shifted based on the additional wind capacity of the respective hour or, in other words, for every point on the aggregated bid curve the original price remained the same but the associated capacity was increased. Calculating the intersection with the original ask curve results in the simulated market clearing price p_{mc}^{wind}, which in turn enabled calculation of the market value. This methodology applied for every hour of the years under consideration ensured that the results represent an exact projection of reality without any simplification and generalisation. In contrast to the procedure for assessing the short-term impact described up to now, the long-term impact, i.e., wind replacing base load capacity (see Figure 2 (bottom)), was simulated by shifting the bid curve for a capacity $q_{\Delta,h}$, which is the difference between $q_{wind,h}$ and the base load generation capacity per hour q_{base_load} that is replaced:

$$q_{\Delta,h} = q_{wind,h} - q_{base\_load}, \qquad \forall h \quad (6)$$

The latter was calculated for each hour by simply dividing the level of additional energy generation per year by the number of hours of the year under consideration:

$$q_{base\_load} = \frac{q_{add}}{H} \quad (7)$$

Hence, in the long-term simulation the market clearing was shifted to higher (lower) capacities $q_{mc}^{\Delta,high\ wind}$ ($q_{mc}^{\Delta,low\ wind}$) in hours of high (low) wind generation $q_{\Delta,high\ wind}$ ($q_{\Delta,low\ wind}$) resulting in a lower (higher) market clearing price $p_{mc}^{\Delta,high\ wind}$ ($p_{mc}^{\Delta,low\ wind}$). This opens up another perspective of the issue of decreasing electricity market prices due to a rapid expansion of non-dispatchable renewable energy generation units because it enables to distinguish between the effect caused by the variable characteristic of the renewable energy source (long-term simulation) and, on the other hand, the effect of excess supply (difference between short-term and long-term simulation).

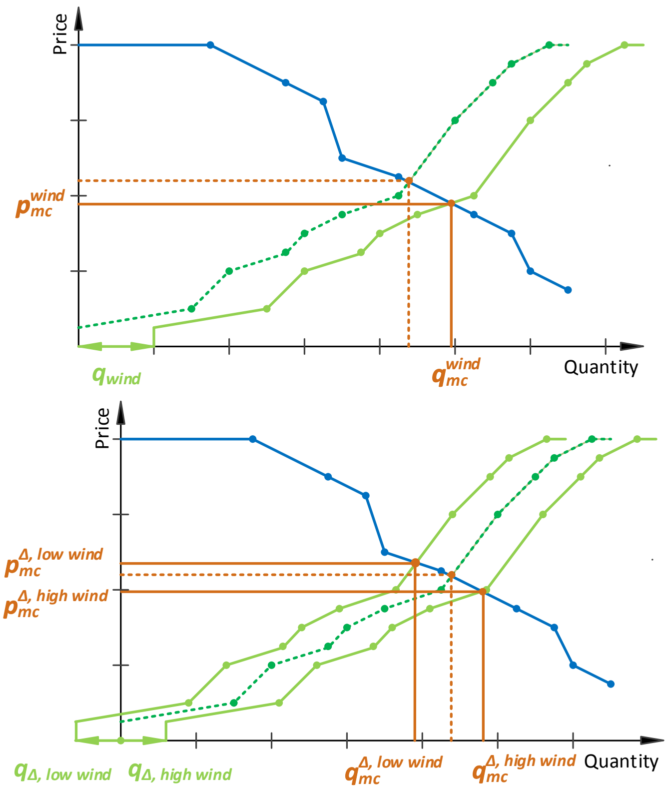

Figure 2: Simulating the merit order effect in the short term (top) and in the long term (bottom).

Results & Conclusion

Although a comprehensive assessment has revealed that the market value of offshore wind is in general higher compared with onshore wind, the results of the simulation suggest that the impact of additional energy amounts on the market value is rather the same. This allows to conclude that the only reason for the lower market value of onshore wind is the large amount of operational capacity already available, i.e., due to the limited spatial spread of the wind farms (most of them are located in northern Germany) the merit order effect is intensified during high wind periods. A similar conclusion can be drawn for the impact on the spot market price – there is an effect but it is very much the same for onshore and offshore wind. However, in addition to the results of the short-term analysis showing the expected decrease in the market price subject to an additional amount of energy, the simulation of the long-term impact revealed an interesting aspect beyond the evaluation of onshore versus offshore wind electricity. The results suggest that if the additional amount of wind energy replaces the same amount of energy provided by base load power plants, the market price would not change and thus the only reason for a decreasing market price is the excess of supply (see Figure 3). This is remarkable because publications in this field tend to link the expansion of renewable energy with a decreasing market price. Although the reason might lie in how research questions are formulated, it casts a shadow on the German energy turnaround. The simulation demonstrated that the impact on the spot market price is not related to the property of renewable energy feed-in but to the consequence of a rapid expansion of renewable electricity supply without the envisaged concomitant phase-out of coal and nuclear power plants.

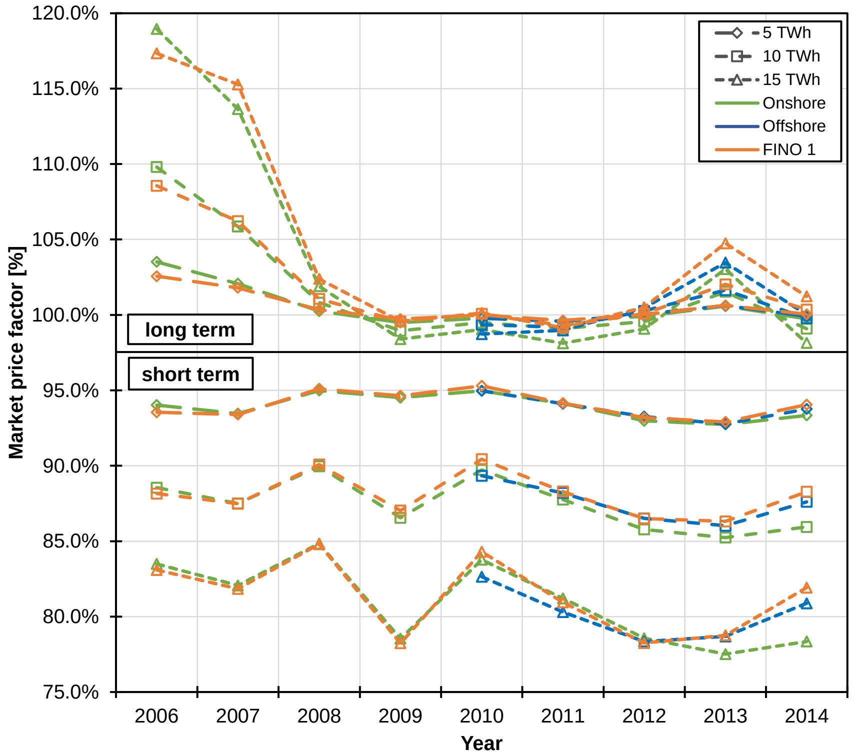

Figure 3: Market price factor in case of adding 5/10/15 TWh in the short term (bottom) and long term (top).

Nevertheless, a difference between onshore and offshore wind in terms of variability imposed on the electricity spot market was determined. The steadier wind resource prevailing offshore seems to result in less variability induced by the feed-in on the spot market price compared with its onshore counterpart (see Figure 4). Because increasing volatility entails significant challenges for the electricity market environment – i.e., increased risks, negative market price and its consequences, support of unwanted peak-load power plants and the necessity of increased reserve capacity – this finding is indeed an argument in favour of offshore wind.

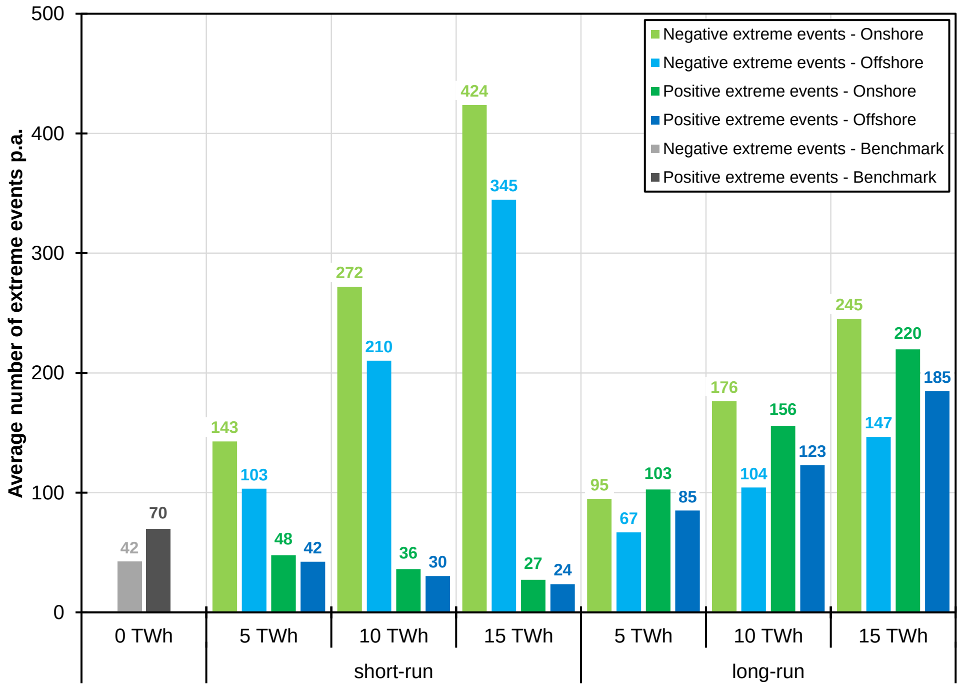

Figure 4: Average number of negative (market price < 0) and positive (market price > 2 x average market price) extreme events p.a. in the years 2010-2014.

References

[1] Ederer, Nikolaus. The market value and impact of offshore wind on the electricity spot market: Evidence from Germany. Applied Energy 2015; *Accepted*.