Julia Michaelis, Patrick Plötz and Sebastian Müller

THE INFLUENCE OF INDIVIDUAL WIND FEED-IN TIME SERIES ON ELECTRICITY SPOT MARKET PRICES AND THEIR EFFECT ON THE ECONOMIC EVALUATION OF STORAGE SYSTEMS

Julia Michaelis, Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48, 76139 Karlsruhe, Germany, Phone: +49-7216809463, e-mail: julia.michaelis@isi.fraunhofer.de
Patrick Plötz, Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48, 76139 Karlsruhe, Germany, Phone: +49-7216809289, e-mail: patrick.ploetz@isi.fraunhofer.de
Sebastian Müller, Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48, 76139 Karlsruhe, Germany, Phone: +49-7216809167, e-mail: sebastian.mueller@isi.fraunhofer.de

Overview

As the feed-in of renewable energy sources (RES) depends on climate and weather conditions, the electricity generation is characterised by strong fluctuations. The analysis of wind feed-in for historical years showed significant differences between the years 2006 until 2012 e.g. with regard to phases of low feed-in (Plötz and Michaelis 2014). The feed-in of RES affects the price formation at the European Energy Exchange EEX, as German laws grant a priority dispatch and fixed feed-in tariffs for electricity by RES. Already today, situations occur when RES set the price e.g. when high feed-in coincides with low electricity demand, and during phases of low feed-in, when hours of high demand cause price peaks. In general, feed-in of wind reduces the price level but increases the price volatility (Ketterer 2014). As installed wind power will increase in the future, the influence of wind on spot market prices will grow and should be taken into account when simulating future scenarios. But many fundamental models simulate future spot market prices based on a single historical year for feed-in of RES, so a general statement for investment decisions is hardly possible. A comparison of simulated spot market prices based on different feed-in years of wind has – to our knowledge – not been analysed yet. Therefore, this paper analyses the influence of historical time series for wind feed-in that are used for the simulation of spot market prices in 2030, using a fundamental model for Germany. Afterwards, the simulated spot market prices serve as input for an optimization model of pumped hydro energy storage (PHES) in order to analyse the influence of the simulated price time series on the economic evaluation of storage systems. Time series of PV feed-in are not considered as they show more regular characteristics as wind.

Methods

We set up a fundamental model for the German Electricity System that matches hourly demand and supply to simulate the merit order curve for a given scenario. For a detailed classification and description of fundamental models see (Weber 2005; Ventosa et al. 2005). The model is linked to a database of installed capacities of conventional power plants and RES. The fluctuating character of wind and PV is considered in form of generation profiles based on feed-in time series or detailed meteorological data. Assumptions for the availability of power plants, price developments of energy carriers and CO_2 allowances as well as electricity demand serve as main input for future scenarios. We calibrated the model by simulating electricity prices for 2012 and obtained comparable results like other fundamental models, see (Genoese 2013). The mean average error is about 6.68 €/MWh and the root mean square error is about 12.25 €/MWh. In order to analyse the influence of wind feed-in years on future price simulation, we created a scenario for 2030 based on (Nitsch et al. 2010). We did seven simulations that are only different in terms of the chosen year for wind feed-in and the corresponding electricity demand. The time series show the characteristics of wind-feed in and electricity demand for the years from 2006 until 2012[1]. The simulated price time series were compared afterwards by conducting statistical analyses and tests. Furthermore, they serve as input for an optimization model for PHES that maximizes the contribution margin of the storage system for one year. A comparable approach for such a model is described in (Keles et al. 2012).

Results

The chosen scenario for 2030 relies on the assumption of a strong increase in CO_2 and fuel prices, so the mean spot price for different wind years reaches an average value of about 62 €/MWh which is clearly higher than the present price level. These results are consistent with other spot market price simulations for comparable scenarios, see (Genoese

[1] Onshore wind feed-in and electricity demand time series for Germany are available on www.netztransparenz.de. Calculation of offshore wind feed-in time series is based on meteorological data by using an approach of McLean (2008).

2013). We used a two-sample Kolmogorov-Smirnov test and found statistical evidence that most of the distributions of the simulated spot market prices for different wind years are significantly different (at 5% significance level). Furthermore we see that monthly average prices differ much for these years, so we conclude that the characteristic of wind feed-in has strong influence on prices. This is further validated through a high coefficient of correlation between wind feed-in and prices. However, average prices of about 62 €/MWh and standard deviations of about 41 €/MWh for every wind year show only slight differences as temporal price variations during the year are smoothed for this indicator. In order to examine the distribution of prices, we analysed phases of small and high prices. In average, there are 168 phases of high prices above 110 €/MWh and 188 phases of low prices below 5 €/MWh with an average duration of 5 or 8 hours. The maximum durations of these phases show considerable disparities between some wind years by a factor of two.

In order to analyse the impact of the simulated price time series on the economic evaluation of energy technologies, we use an optimization model for PHES. The technical design of the storage system is about 500 MW_{el} of electrical power and 4000 MWh_{el} of storage capacity. We assumed a specific investment of 735 €/kW_{el} and an efficiency of 78%. Figure 1 shows that costs and revenues differ with regard to the different wind years. For wind years 2008 and 2009, annual costs and revenues are almost equal, whereas for wind year 2011 a deficit of almost 7 million €/a occurs.

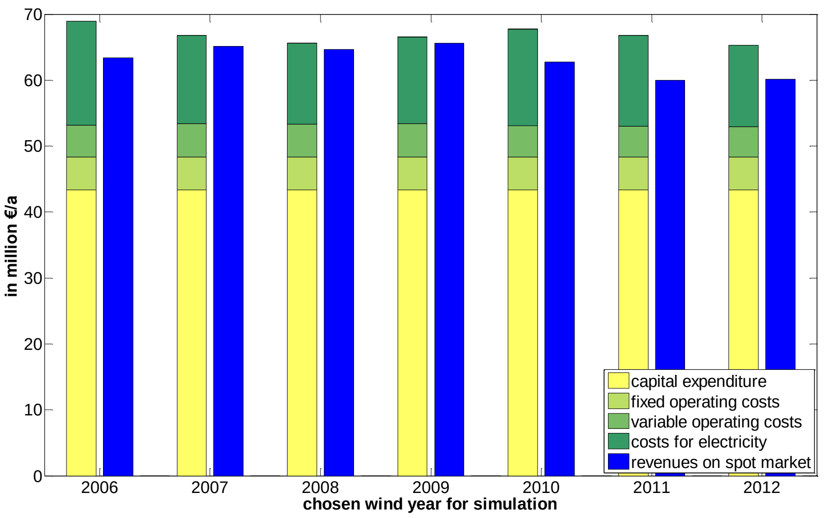

Figure 1:Economic result of storage optimization for 2030 with different wind years

Conclusions

We simulated and analysed spot market prices in dependence of different wind years for a future scenario of the German Electricity System in 2030 by using a fundamental model and historical feed-in series for wind. The results confirm our hypothesis that the wind year has significant influence on the distribution of prices. This is becoming apparent when monthly average prices and phases of small and high prices are considered. However, the average values for the whole year show only slight differences. But as the duration and distribution of high and low prices over time is important for the evaluation of flexible technologies like storage or controllable power plants, the choice of the wind year has influence on possible investment decisions. This is becoming clear by using the simulated spot market prices for 2030 for an optimization model for PHES that shows different results for the single wind years.

References

Genoese, Fabio (2013): Modellgestützte Bedarfs- und Wirtschaftlichkeitsanalyse von Energiespeichern zur Integration erneuerbarer Energien in Deutschland. Karlsruhe, KIT Scientific Publishing.

Keles, Dogan; Hartel, Rupert; Möst, Dominik; Fichtner, Wolf (2012): Compressed-air energy storage power plant investments under uncertain electricity prices: an evaluation of compressed-air energy storage plants in liberalized energy markets. In: *Journal of Energy Markets* 5 (1), S. 53–84.

Ketterer, Janina C. (2014): The impact of wind power generation on the electricity price in Germany. In: *Energy Economics* 44, S. 270–280. DOI: 10.1016/j.eneco.2014.04.003.

McLean, J. R. (2008): WP2.6 - Equivalent Wind Power Curves. TradeWind Consortium.

Nitsch, Joachim; Pregger, Thomas; Scholz, Yvonne (2010): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Deutsches Zentrum für Luft- und Raumfahrt DLR, Fraunhofer Institut für Windenergie und Energiesystemtechnik IWES, Ingenieurbüro für neue Energien IFNE. Stuttgart, Kassel, Teltow.

Plötz, Patrick; Michaelis, Julia (2014): The probability of long phases without wind power and their impact on an energy system with high share of renewable energies. Dresden, Enerday 2014, 11.04.2014.

Ventosa, Mariano; Baıllo, Alvaro; Ramos, Andrés; Rivier, Michel (2005): Electricity market modeling trends. In: *Energy policy* 33 (7), S. 897–913.

Weber, Christoph (2005): Uncertainty in the electric power industry. Methods and models for decision support. New York: Springer (International series in operations research & management science, 77).