Balancing Power Market Equilibria in Systems with high RES Penetration

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(1) Overview

Balancing electricity supply and demand in real time to guarantee a near-constant grid frequency (of e.g. 50 Hertz in Germany) has always been an issue in electricity markets. With increasing shares of renewable energy sources (RES), this will be even more complicated in the future.

As balancing power is often traded on markets, balancing power costs are important to both buyers (often TSOs) as a cost component and sellers such as power plant operators (as a revenue source). In another paper (Müsgens et al. 2011), we showed that the market equilibrium (and the resulting prices) on the balancing power market depends on the situation in the wholesale electricity market – and vice versa. On the one hand, reserving capacity for the balancing power market might mean a loss of opportunity on the wholesale market as the same capacity cannot be sold twice. On the other hand, many power plants have to be up and running to be able to provide balancing power. Hence, power plants with variable costs above the wholesale price might accept losses on the wholesale market if expected profits on the balancing power market (over-)compensate these losses. For these (and other reasons), both markets have to be solved simultaneously to compute correct market equilibria.

We developed a model which does exactly that. We took an investment and dispatch model (based on Lenzen et al. 2012) and extended the model to include different types of reserve markets. As we are interested in long term implications caused by high shares of RES, we analyze the time period until 2040.

(2) Methods

We develop a complex linear optimization model which optimizes both investment and dispatch decisions in the German power system with regard to day-ahead and balancing markets. While similar models have already been applied to other research questions in the past, we are the first to extend such a model to include balancing power market on a very detailed level. We differentiate two types of balancing power (secondary control and tertiary reserve). For both types, we model 7 stochastic realizations – with individual probabilities. The underlying model is a stochastic programming model with recourse. In a first step, the start-up and shut down decisions as well as capacity provision for regulating power for the plants are determined. In a second step, a previously uncertain deviation from the expected load level is revealed and the power plants in the model have to balance the deviation – without changing the previously determined start-up, shut down and capacity reservation decisions.

The model has a high time resolution. We calculate annual results for the period from 2014 to 2040. Each year has 4.380 different load levels (one load level for every two hours). The whole period is solved simultaneously to capture dynamic effects such as investment decisions, hydro (pump) storage dispatch and start-up and shut down decisions.

(3) Results

The following two figures show selected results. Figure 1 shows system marginal costs which can be used as a price estimator in a competitive electricity market. Figure 2 shows scatter plots with wholesale electricity prices and capacity prices for balancing power.

Other results we will present in the conference paper will be investments by year and technology, power plant dispatch and numerous other results related to balancing power markets.

Fig. 1: Model Results - Development of Wholesale Electricity Prices (Annual Average)

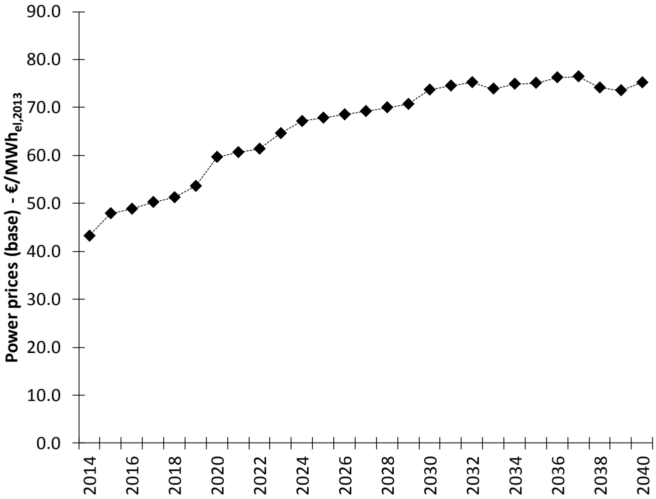
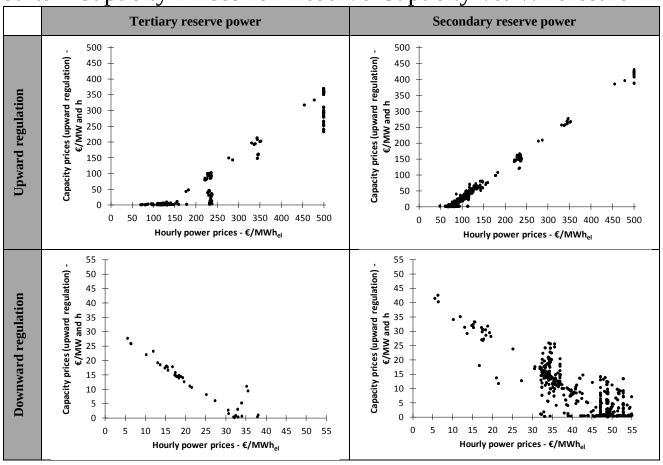


Fig. 2: Model Results - Capacity Prices for Reserve Capacity vs. Wholesale Prices (Year: 2030)



(4) Conclusions

We develop and apply a complex linear optimization model to compute simultaneous market equilibria for wholesale electricity markets and balancing power markets. Our model results confirm theoretical results that in equilibrium, the opportunity costs on the wholesale market are a crucial factor for the price of balancing power. Furthermore, our results show that balancing power prices (just as wholesale prices) will rise in the future as current German excess capacities decrease.

References

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