OPTIMAL RESERVE PROVISION IN ELECTRICITY MARKETS WITH INCREASING SHARES OF RENEWABLE ENERGY SOURCES

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Overview

Increasing shares of fluctuating renewable electricity generation challenge the reliability in electric power systems. Due to the uncertain nature of renewable infeed, unforeseen deviations impede the predictability of power generation. Reserve power markets provide one option to balance demand and supply at all times and to address different sources of uncertainty. Yet the provision of reserves comes at some cost and therefore the welfare-optimal amount of reserve provision may be looked for in the presence of fluctuating renewables. Since reserve power markets are closely linked to electricity spot markets, they should however not be investigated in isolation but in a broader context. The interdependencies between the two markets have been discussed e.g. [1] – [4].

Methods

We develop a stylized analytical model to derive the first-best market equilibrium for the electricity spot market and the reserve power market under stochastic demand and uncertain renewable electricity generation. From this equilibrium we then derive the welfare-optimal provision of reserves. The purpose of the paper is to illustrate a methodology to determine the level of reserves that maximizes social welfare. The point is not to provide a prediction of current transmission system operator (TSO) behavior, which may or may not coincide with the social optimum. However, our approach may be used, e.g. by TSOs and regulators, in the development of appropriate models for reserve provision.

We consider an electricity market where part of the electricity supply is intermittent due to generation with renewable energy sources, such as wind or solar. If reliability constraints are to be satisfied, a larger share of intermittent and stochastically fluctuating power supply implies the need for a larger quantity of reserve capacity, which is supplied by conventional generation. In the day-ahead market, the TSO, being responsible for system reliability, commissions reserves in an auction while (conventional) power suppliers will allocate their capacity to reserves or to the spot market. We derive the first-best quantity of reserves to be commissioned by the TSO acting in lieu of a benevolent social planner. This is neither given naturally nor perfectly implemented by existing regulatory schemes. As a consequence, optimal reserves according to the model do not necessarily predict real-world outcomes. Nevertheless, the former can be compared to the latter as an optimal reference from the social welfare perspective. We also derive corresponding equilibrium prices in markets for reserves and spot electricity.

Results

At the first-best, the cost of reserve capacity is balanced against expected cost of outages. We derive therefrom a relationship linking the expected cost of outages to the slope of the electricity supply curve, since reserve prices are proportional to this slope in equilibrium. To illustrate the model and provide some more intuition for the results we present and discuss a numerical example.

The first-best market equilibrium of the model implies an increase of reserve provision with a growing share of renewable generation, as expected. Furthermore, a growing share of renewable generation decreases the level of reliability as measured in energy not served (ENS). Additionally, required reserves to balance higher expected deviations will be more expensive, resulting in a trade-off between higher reserve costs and costs of ENS. Finally, we derive regulatory policy implications.

The research leading to these results is partly funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No 608540, project acronym GARPUR.

Conclusions

Reserve power markets increase in importance as the share of renewables generation rises and as they are linked with the spot markets, they should not be analyzed separately. In this paper we present a model where power producers sell electricity either through the spot market or through the reserve market and a TSO needs to procure reserves, taking into consideration the intermittent infeed, in order to maintain the reliability of the grid. We derive the first-best quantity of reserves to be commissioned by the TSO and corresponding equilibrium prices both in reserve and spot markets.

References

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