RESERVE PRICES IN A RENEWABLE-BASED POWER SYSTEM

Laureen Deman, Univ. Grenoble Alpes, CNRS, INRAE, Grenoble INP, GAEL, 38000 Grenoble, France and SuperGrid Institute, laureen.deman@supergrid-institute.com
Cédric Clastres, Univ. Grenoble Alpes, CNRS, INRAE, Grenoble INP, GAEL, 38000 Grenoble, France
Afzal S. Siddiqui, Department of Computer and Systems Sciences, Stockholm University and Department of Mathematics and Systems Analysis, Aalto University
Quentin Boucher, SuperGrid Institute, quentin.boucher@supergrid-institute.com

Overview

Reducing greenhouse gas emissions requires an increase in the share of low-carbon technologies in the power mix, with variable renewable energy (VRE) sources figuring predominantly. In addition, increasing electrification rates may be necessary in other sectors to decrease their carbon emissions. Besides the management of the intermittency of VRE, the stochastic nature of their generation may represent an important challenge for the power system (Hirth & Ziegenhagen, 2015). This uncertainty is handled with reserves, procured by the transmission system operator. The efficiency of the reserve market design has been the subject of analysis in terms of market integration and product characteristics (Dallinger, Hans, & Lettner, 2018; Farahmand & Doorman, 2012), among others. The determinants of reserve capacity prices have been analysed by (Gebrekiros, Doorman, Jaehnert, & Farahmand, 2015) and (Müsgens, Ockenfels, & Peek, 2014) in the Nordic countries and Germany respectively with past data. To our knowledge, the evolution of reserve prices with large shares of renewable energy has not been investigated in the literature. In our paper, we add the evolution of the power mix with less dispatchable generation and the associated forecasted reserve demand. This evolution implies new flexibility needs with for instance a deployment of batteries and demand-response programs. To account for this deployment, we propose a definition of the opportunity cost of batteries. This proposal fills the gap with the literature according to the importance of batteries in supplying the reserve capacity needs.

Methods

The paper uses fundamental model of the day-ahead market and the reserve markets to analyse the impact of the decarbonisation of the power mix on reserve prices. The model is designed to represent the current market design in Continental Europe with a centralised supply and common platforms for the exchange of reserves. Since marginal prices obtained with the model do not reflect opportunity costs, reserve capacity prices are computed ex-post as the marginal opportunity cost. The approach is based on (Müsgens, Ockenfels, & Peek, 2014) and (Dallinger, Hans, & Lettner, 2018) for thermal and hydro units. An alternative method is proposed for batteries because their flexibility implies a different definition. In fact, their opportunity cost is positive only when there is a trade-off with the day-ahead market.

The model is applied to the 2022 version of the Ten-Year Network Development Plan (TYNDP) scenarios (ENTSO-E & ENTSO-G, 2022). There are two scenarios representing distinct pathways to achieve carbon neutrality by 2050. Nine countries are represented, Belgium, the Netherlands, Austria, Germany, Switzerland, France, Spain, and Portugal.

Results

Batteries become the main supplier of reserve capacity overtime. The pace varies from country to country, depending on the speed of battery installation. This change in the supply structure does not have a significant impact on reserve capacity prices, with a large and constant frequency of zero prices. Batteries are more frequently dispatched in the day-ahead market to cover the intermittency of renewables, which implies a trade-off with the reserve capacity markets. However, batteries set the day-ahead price as long as they are dispatched, resulting in zero opportunity cost. In fact, the variable cost of batteries is a function of the storage value, equivalent to the water value of hydro units (Wolfgang, et al., 2009). This storage value reflects the profits associated with the optimal use of an additional unit of storage. As a result, it reflects day-ahead market prices. This relationship makes batteries indifferent between the day-ahead and reserve capacity markets when they are dispatched in the former, resulting in zero opportunity cost.

The work presented in this paper has been conducted for the XFLEX HYDRO project. This project has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement No 857832

Conclusions

With batteries accounting for a large share of the flexibility of the power system, reserve capacity prices often equal to zero. The relationship between the day-ahead price and the storage values prevents from a decoupling between the day-ahead and the reserve capacity prices. This result, together with the merit-order effect in the day-ahead market, questions their possibility to be profitable in short-term markets.

References

Dallinger, B., Hans, A., & Lettner, G. (2018). Impact of harmonised common balancing capacity procurement in selected Central European electricity balancing markets. *Applied Energy, 222*, 351-368. doi:10.1016/j.apenergy.2018.03.120

ENTSO-E, & ENTSO-G. (2022). *TYNDP 2022 - Scenario building guidelines. Final report.*

Farahmand, H., & Doorman, G. L. (2012). Balancing market integration in the Northern European continent. *Applied Energy, 96*, 316-326. doi:10.1016/j.apenergy.2011.11.041

Gebrekiros, Y., Doorman, G., Jaehnert, S., & Farahmand, H. (2015). Reserve procurement and transmission capacity reservation in the Northern European power market. *International Journal of Electrical Power & Energy Systems, 67*, 546-559. doi:doi.org/10.1016/j.ijepes.2014.

Hirth, L., & Ziegenhagen, I. (2015). Balancing power and variable renewables: Three links. *Renewable and Sustainable Energy Reviews, 50*, 1035-1051. doi:10.1016/j.rser.2015.04.180}

Müsgens, F., Ockenfels, A., & Peek, M. (2014). Economics and design of balancing power markets in Germany. *International Journal of Electrical Power and Energy Systems, 55*, 392-401. doi:10.1016/j.ijepes.2013.09.020

Wolfgang, O., Haugstad, A., Mo, B., Gjelsvik, A., Wangensteen, I., & Doorman, G. (2009). Hydro reservoir handling before and after deregulation. *Energy, 34*(10), 1642-1651. doi:10.1016/j.energy.2009.07.025