SECURITY ANALYSIS OF GENERATION SHIFT KEY METHODS IN THE EUROPEAN DAY AHEAD MARKET

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Overview

Recent European-level political directives are pushing to increase European exchange capacities to augment the overall social welfare, while maintaining satisfactory levels of electricity supply security. This desire to expand interconnections coincides with increasing system variability brought on by rising use of intermittent renewable energy sources. The European day ahead market uses a zonal market design with the flow-based method as the current EU Target Model [1].

The literature on the flow-based method has expanded significantly since it was put in place in the Central Western European (CWE) region in May 2015. The use of the flow-based method is expanding, currently under an external parallel run phase in the Nordic Capacity Calculation Region as well as in the CORE region, which encompasses 13 countries across central Europe.[1] Descriptions of the method can be found in [12]. A large part of the existing literature examines issues that can arise through the choices of discretionary parameters by transmission system operators (TSOs) [8] [5] [11]. There are also several studies that work to expand the current method, either through the explicit inclusion of HVDC lines [9] or transmission switching [6].

In particular, the generation shift keys (GSKs)—which map the effect of a change in zonal export or import position to respective nodes in the grid—have been examined in several instances. Currently these key parameters are generated largely through TSO experience. The different methods used by the German and Austrian TSOs are detailed in [14] and a more general description of the accepted methods can be found in [4]. Many articles comparing different GSK methods land on the somewhat unsatisfying conclusion that there is no universal "best" GSK [3] [10] and that it depends highly on the generation dispatch.

This study aims to add to this existing literature through an analysis of the security level of different flow-based domains computed using different GSKs. A special focus is given to the impact of forecast errors across seasonal and hourly variations. This will be accomplished through a simulation of a day ahead market with forecast errors followed by a security analysis phase.

Methods

To begin with, a literature review will be presented on the different GSK methods, both those already in use by existing TSOs and those proposed in the literature. Certain of these methods were then chosen to be analysed in case study on the RTS-GMLC network, a 73-node network with relatively high penetration of renewable energies.[2]

The study involves a combination of different optimization problems which aim to simulate a day ahead market followed by a redispatch phase. Curative topological actions[3] are included in the calculation of the flow-based domain as well as in the redispatch phase, while for the sake of simplicity, preventive actions are ignored. The first step of the model is the generation of a "base case" for each hour using a security constrained DC optimal power flow. This calculation gives a best guess at what will happen in real time and a point around which to create the linearized security domain. This is then followed by a flow-based calculation similar to the method used in the CORE region, with a coordinated optimization of curative topological remedial actions. The flow-based parameters are then calculated for each timestep with each of the different GSK methods. Offers are created based on the generator marginal costs and technical constraints of each plant in the system. The offers and the flow-based constraints are given to the market clearing algorithm, similar to EUPHEMIA [13].

Finally, an analysis of the security level of the market clearing result is performed. This module is a security constrained OPF[4], where generation variables are required dispatch modifications deduced from the market-cleared quantities to enforce network security. In this stage, the combined effects of GSK approximation and its ability to

[1] Austria, Belgium, Croatia, the Czech Republic, France, Germany, Hungary, Luxemburg, the Netherlands, Poland, Romania, Slovakia and Slovenia

[2] The network is described in [2] with the full data available at https://github.com/GridMod/RTS-GMLC.

[3] Some flexible buses and lines were added to the original RTS-GMLC network as described in [7].

cope with load and renewable generation forecast errors are assessed. In order to fully analyse the different GSK methods, the study is run across four two-week periods with high seasonal variations, using an hourly timestep.

Results

Building upon other studies analysing the differences between GSK methods, results highligh that the most suitable GSK for a given situation depends highly on the generation dispatch of the respective time period. Moreover, certain patterns can be identified when looking closer at the security level performance of the different methods. Results on the robustness of the different methods when faced with forecast error is also presented.

Conclusions

In this study, the security level of different generation shift key methods is analysed through a multi-phase analysis, mimicking the European day ahead market operation. While no GSK method is found to lead to more secure grid operation across all time periods, certain patterns emerge between the base case dispatch and the GSKs with the lowest cost of security. Further research can build on these results to analyse other aspects of the flow-based method.

References

[1] Amprion, apx, belpex, creos, elia, Transnet BW, EPEXSPOT, RTE, and Tennet. 2014. "Documentation of the CWE FB MC Solution As Basis for the Formal Approval-Request." https://www.cre.fr/en/content/download/11743/114579.

[2] Barrows, Clayton, Eugene Preston, Andrea Staid, Gord Stephen, Jean-Paul Watson, Aaron Bloom, Ali Ehlen, et al. 2020. "The IEEE Reliability Test System: A Proposed 2019 Update." *IEEE Transactions on Power Systems* 35 (1): 119–27. https://doi.org/10.1109/TPWRS.2019.2925557.

[3] Dierstein, Constantin. 2017. "Impact of Generation Shift Key Determination on Flow Based Market Coupling." In *2017 14th International Conference on the European Energy Market (EEM)*, 1–7. Dresden, Germany: IEEE. https://doi.org/10.1109/EEM.2017.7981901.

[4] ENTSO-E. 2016. "Generation and Load Shift Key Implementation Guide." https://docstore.entsoe.eu/Documents/EDI/Library/lsig/161027_MC_TOP_9a_Generation_and_Load_Shift_Key_Implementation_Guide_v2.pdf.

[5] Felten, Björn, Paul Osinski, Tim Felling, and Christoph Weber. 2021. "The Flow-Based Market Coupling Domain - Why We Can't Get It Right." *Utilities Policy* 70 (June): 101136. https://doi.org/10.1016/j.jup.2020.101136.

[6] Lete, Quentin, and Anthony Papavasiliou. 2020. "Impacts of Transmission Switching in Zonal Electricity Markets - Part II." *IEEE Transactions on Power Systems*, 1–1. https://doi.org/10.1109/TPWRS.2020.3015012.

[7] Little, Emily, Sandrine Bortolotti, Jean-Yves Bourmaud, Efthymios Karangelos, and Yannick Perez. 2021. "Optimal Transmission Topology for Facilitating the Growth of Renewable Power Generation." In *2021 IEEE Madrid PowerTech*, 1–6. Madrid, Spain: IEEE. https://doi.org/10.1109/PowerTech46648.2021.9495032.

[8] Marien, Alain, Patrick Luickx, Andreas Tirez, and Dominique Woitrin. 2013. "Importance of Design Parameters on Flowbased Market Coupling Implementation." In *2013 10th International Conference on the European Energy Market (EEM)*, 1–8. Stockholm, Sweden: IEEE. https://doi.org/10.1109/EEM.2013.6607298.

[9] Müller, Christoph, Andre Hoffrichter, Hans Barrios, Alexander Schwarz, and Armin Schnettler. 2017. "Integration of HVDC-Links into Flow-Based Market Coupling: Standard Hybrid Market Coupling versus Advanced Hybrid Market Coupling."

[10] Schönheit, David, Richard Weinhold, and Constantin Dierstein. 2020. "The Impact of Different Strategies for Generation Shift Keys (GSKs) on the Flow-Based Market Coupling Domain: A Model-Based Analysis of Central Western Europe." *Applied Energy* 258 (January): 114067. https://doi.org/10.1016/j.apenergy.2019.114067.

[11] Schönheit, David, Michiel Kenis, Lisa Lorenz, Dominik Möst, Erik Delarue, and Kenneth Bruninx. 2021. "Toward a Fundamental Understanding of Flow-Based Market Coupling for Cross-Border Electricity Trading." *Advances in Applied Energy* 2 (May): 100027. https://doi.org/10.1016/j.adapen.2021.100027.

[12] Van den Bergh, Kenneth, Jonas Boury, and Erik Delarue. 2016. "The Flow-Based Market Coupling in Central Western Europe: Concepts and Definitions." *The Electricity Journal* 29 (1): 24–29. https://doi.org/10.1016/j.tej.2015.12.004.

[13] EPEX SPOT–GME–Nord Pool–OMIE–OPCOM–OTE–TGE. 2016. "EUPHEMIA Public Description: PCR Market Coupline Algorithm."

[14] Amprion, apx, Tennet, Transnet BW. 2020. "Generation Shift Keys" https://www.jao.eu/sites/default/files/2020-04/CWE_FB_approval_DOC_GSK_Section_detailed.pdf

[4]This security analysis includes three stages: a nominal state (N), immediate post-contingency state (N-1) and a post-contingency state including curative remedial actions.