Strategic behaviour in flexibility markets: new games and sequencing options

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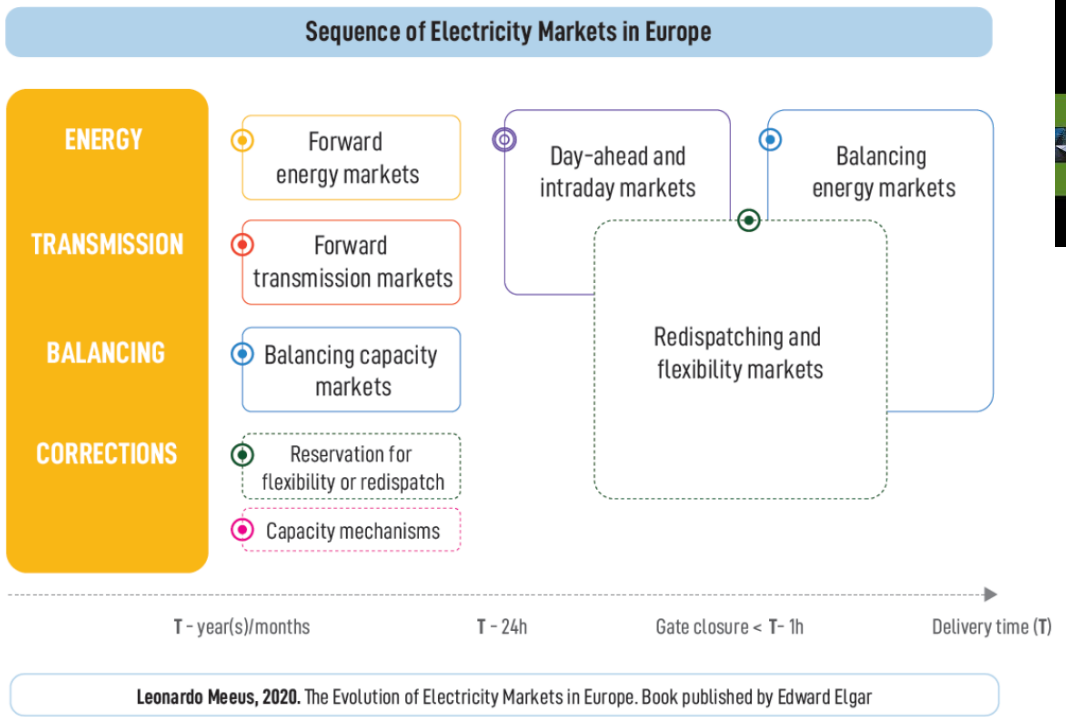
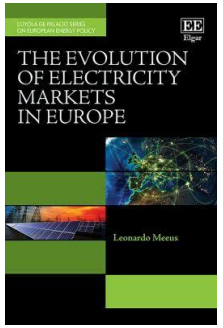
Where do flexibility markets fit in the current European electricity market sequence?





Literature review

Market sequencing options

- Important open issue
  - Burger, S. P., Jenkins, J. D., Battle, C. & Pérez-Arriaga, I. J., 2019. Restructuring Revisited Part 2: Coordination in Electricity Distribution Systems. The Energy Journal, Volume 40(3), pp. 55-76. https://doi.org/10.5547/01956574.40.3.jjen
  - Hadush, S. Y. & Meeus, L., 2018. DSO-TSO cooperation issues and solutions for distribution grid congestion management. Energy Policy, Volume 120, pp. 610-621. https://doi.org/10.1016/j.enpol.2018.05.065
- Taxonomy of sequencing options
  - CEDEC, E.DSO, ENTSO-E, Eurelectric & GEODE, 2019. TSO-DSO Report: an integrated approach to active system management.
  - Gerard, H., Puente, E. I. R. & Six, D., 2018. Coordination between transmission and distribution system operators. Utilities Policy, Volume 50, pp. 40-48. https://doi.org/10.1016/j.jup.2017.09.011
  - Le Cadre, H., Mzeghani, I. & Papavasiliou, A., 2019. A game-theoretic analysis of transmission-distribution system operator coordination. European Journal of Operational Research, Volume 274(1), pp. 317-339. https://doi.org/10.1016/j.ejor.2018.09.043
  - Vicente-Pastor, A., Nieto-Martin, J., Bunn, D. W. & Laur, A., 2019. Evaluation of Flexibility Markets for Retailer-DSO-TSO Coordination. IEEE transactions on power systems, Volume 34(3), pp. 2003-2012. https://doi.org/10.1109/TPWRS.2018.2880123

The inc-dec game

- Analytical analysis
  - Stoft, S., 1998. Gaming Intra-Zonal Congestion in California.
  - Dijk, J. & Willems, B., 2011. The effect of counter-trading on competition in electricity markets. Energy Policy, Volume 39(3), pp. 1764-1773. https://doi.org/10.1016/j.enpol.2011.01.008
  - Holmberg, P. & Lazarczyk, E., 2015. Comparison of congestion Management Techniques: Nodal, Zonal and Discriminatory Pricing. The Energy Journal, Volume 36(2), pp. 145-166. https://doi.org/10.5547/01956574.36.2.7
- Numerical analysis
  - Hirth, L. & Schlecht, I., 2019. Market-Based Redispatch in Zonal Electricity Markets: Inc-Dec Gaming as a Consequence of Inconsistent Power Market Design (not Market Power), Kiel, Hamburg: ZBW – Leibniz Information Centre for Economics.
  - Sarfati, M., Hesamzadeh, M. R. & Holmberg, P., 2019. Production efficiency of nodal and zonal pricing in imperfectly competitive electricity markets. Energy Strategy Reviews, Volume 24, pp. 193-206. https://doi.org/10.1016/j.esr.2019.02.004
  - Sarfati, M. & Holmberg, P., 2020. Simulation and Evaluation of Zonal Electricity Market Designs. Electric Power Systems Researcht, Volume 185. https://doi.org/10.1016/j.epsr.2020.106372.

Overview

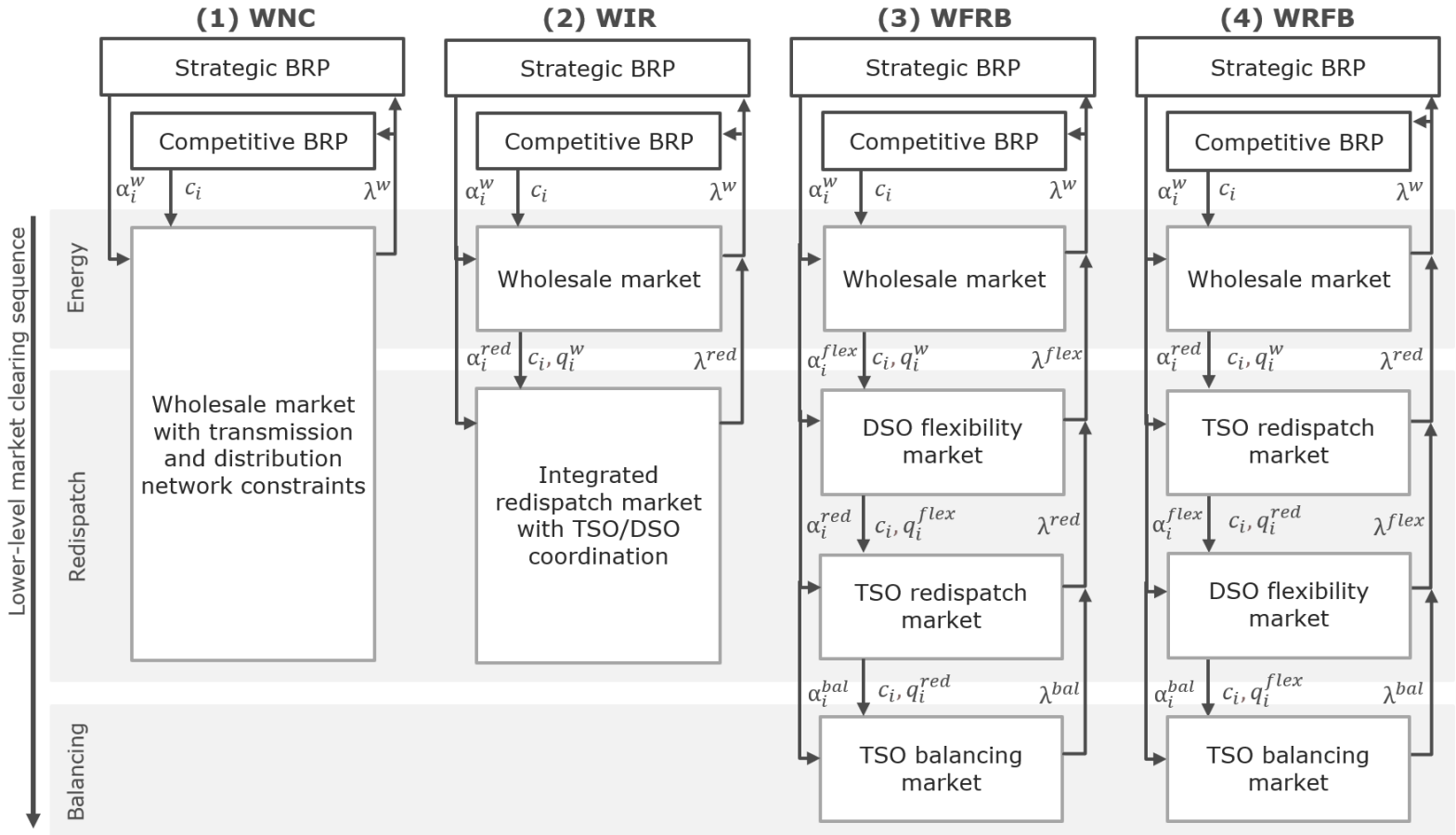
Structure of analysis

- Perfect competitive reference power system
- Strategic behaviour with old and new games
- Impact of market structure on the performance of sequencing options
- Limitations of the model

Findings

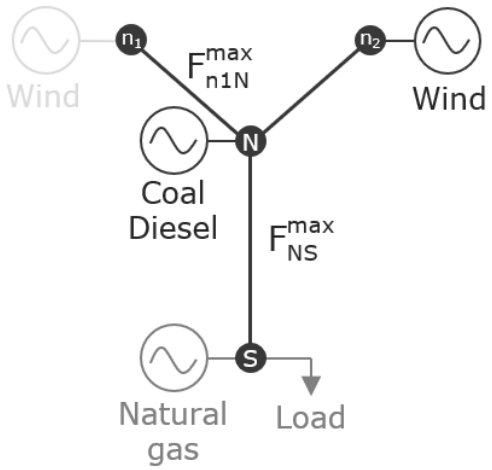
- Flexibility market can trigger new games that can already be performed by small players, and therefore are a real concern for market surveillance
- Nodal pricing performs best, but there is no clear second best under the alternative market sequencing options

Methodology

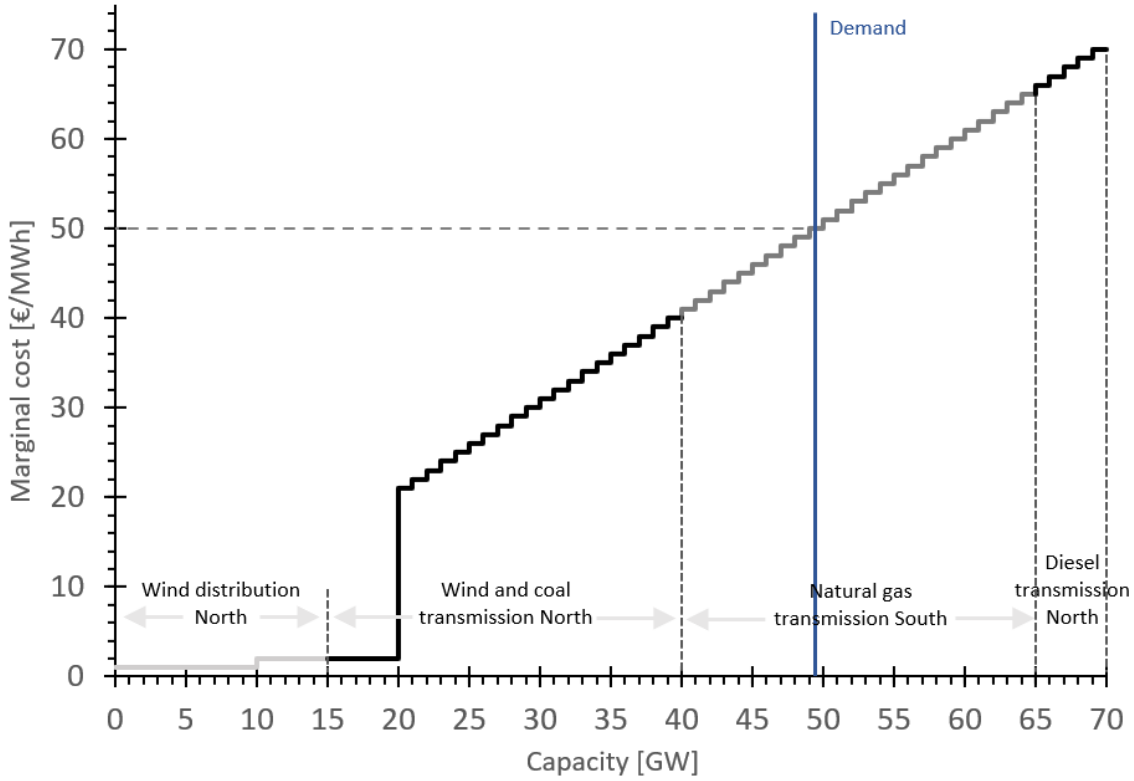


Reference power system

Power network



Merit order curve



The perfect competitive reference case

- Same generation costs for each sequencing option
- Similar redispatch costs among sequencing options
- Lowest costs towards consumers under nodal pricing

	WNC	WIR	WFRB	WRFB
Generation costs [k€]	1426.00	1426.00	1426.00	1426.00
Wholesale market clearing [k€]	2955.00	2463.50	2463.50	2463.50
+ congestion management [k€]	-1069.00 (congestion rent)	619.50 (redispatch costs)	414.75 (redispatch costs)	493.50 (redispatch costs)
= Total cost towards consumers [k€]	1886.00	3082.00	2877.25	2956.00

Types of strategic behaviour

Old games

I. Price-setter game
II. Underbidding game via the wholesale market and downwards redispatch market
III. Overbidding game via the wholesale market and upwards redispatch market

New games

IV. Overbidding game via the wholesale market, upwards redispatch market, and balancing market
V. Overbidding game within the downwards integrated redispatch market
VI. Overbidding game via the downwards redispatch market and balancing market

Game type (I-VI)	Strategic coal units 24-25 €/MWh	Strategic natural gas units 45-46 €/MWh	Strategic natural gas units 57-58 €/MWh	Strategic diesel units 67-68 €/MWh
WNC			I.	
WIR	V.	III.	I.	II.
WFRB		IV.	I.	II.
WRFB	VI.	III.	I.	II.

- Driving up market prices within the market (I.)
- Creating and solving additional congestion between two markets (II.)
- Pursuing activation in the most profitable market(s) of the total market sequence (III.-VI.)

Impact of the market structure: Monte Carlo simulation

Strategic BRP size [-] # runs [-]	Median total cost towards consumers [k€] Average total cost towards consumers [k€] WNC	WIR	WFRB	WRFB
Perfect competition	1886.00 1886.00	3082.00 3082.00	2877.25 2877.25	2956.00 2956.00
1 – 5 # 65	1895.75 1898.57	3082.00 3102.20	2877.25 2893.12	2956.00 2969.93
6 – 10 # 84	1925.50 5390.24	3141.38 4441.53	2916.00 3136.42	2996.50 3769.56
11 – 15 # 89	1974.75 20963.75	3230.88 12052.77	3004.00 5977.40	3080.25 11624.56
16 – 20 # 87	60000.25 55641.36	32096.75 24569.56	3200.00 12274.83	28951.25 19955.65

- Even small players can exercise market power
- Nodal pricing outperforms the other market sequences, but the price-setter game of larger strategic players can cause great distortions

Limitations of the model

Overestimation of strategic behaviour

- Reference power system
- Reservation of flexibility
- Risk averse behaviour of the flexibility provider
- Demand response

Underestimation of strategic behaviour

- Reference power system
- Strategic behaviour of system operators

Recap of the conclusions

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Full working paper available at https://www.mech.kuleuven.be/en/tme/research/energy-systems-integration-modeling/pdf-publications/wp-esim2021-5