European Electricity and Day-Ahead Markets

Besides long-term bilateral contracts, a large part of the production of electricity is traded in day-ahead markets where prices and exchanges of energy are determined for each time slot of the following day, typically an hour. Intraday and balancing markets are then meant to ensure security of supply and to balance positions taken in the day-ahead market which could not be maintained.

Pan-European Market

In Europe, the past decade has seen the emergence of a Pan-European day-ahead electricity market in the frame of the Price Coupling of Regions project (PCR), which is cleared using a common algorithm called Euphemia, handling peculiarities of the different kinds of bidding products proposed by national power exchanges. In a classical microeconomic setting, using supply and demand bid curves submitted by participants, a (convex) optimization problem for which strong duality holds, and aimed at maximizing welfare, yields a market equilibrium. The optimal dual variables then correspond to equilibrium market prices: one for each time slot and each bidding zone.

Non-Convexity

These day-ahead markets are non-convex in the sense that participants are allowed to describe operational constraints such as minimum power output levels, and economic constraints such as start-up costs which must be recovered if a unit is started, rendering the primal welfare maximizing problem non-convex, mainly due to the introduction of binary variables.

Near-Equilibrium

It can then easily be shown that most of the time, no market equilibrium with uniform prices could exist, where the use of uniform prices means that every bid of a given bidding zone and time slot is cleared at the same common market clearing price. The general approach throughout Europe is to use uniform prices, but to allow some non-convex bids to be paradoxically rejected in the sense that they would be profitable for the computed prices but are none the less rejected, ensuring the existence of feasible solutions, while enforcing all other market equilibrium conditions. This is classically modelled as an MPEC, and handled by advanced branch-and-cut algorithms (such as Euphemia), see [10, 8, 9].

References

[1] Bertocchi, M.I., Consigli, G., Dempster, M.A.H. (Eds.) : Stochastic optimization methods in finance and energy, Springer, New York, 2011.

[2] Carøe, C.C.; Schultz R.: A Two-Stage Stochastic Program for Unit Commitment Under Uncertainty in a Hydro-Thermal Power System, ZIB Preprint 98-11, Konrad-Zuse-Zentrum fur Informationstechnik (ZIB) Berlin, 1998.

[3] Frank, S., Steponavice, I., Rebennack, S.: A primer on optimal power flow: A bibliographic survey - (i) formulations and deterministic methods, Energy Systems 3(2012), 221-258.

[4] Frank, S., Steponavice, I., Rebennack, S.: A primer on optimal power flow: A bibliographic survey - (ii) non-deterministic and hybrid methods, Energy Systems 3(2012), 259-289.

[5] Gabriel, S.A., Conejo, A.J., Fuller, J.D., Hobbs, B.F., Ruiz, C.: Complementarity Mdeli in Energy Markets, Springer, New York 2013.

[6] Lavaei, J., Low, S. H. : Zero duality gap in optimal power flow problem, IEEE Transactions on Power Systems 27(2011), 92-107.

[7] Lee, J., Leung, J., Margot, F.: Min-up/min-down polytopes, Discrete Optimization 1(2004), 7785.

[8] Madani, M., Van Vywe, M.: Computationally efficient mip formulation and algorithms for european day-ahead electricity market auctions. European Journal of Operational Research, 242(2):580-593, 2015.

[9] Madani, M., Van Vywe, M.: A mip framework for non-convex uniform price day-ahead electricity auctions. EURO Journal on Computational Optimization, pages 1-22, 2015.

[10] Martin, A., Muller, J.C., Pokutta, S.: Strict linear prices in nonconvex european day-ahead electricity markets. Optimization Methods and Software, 29 (1):189-221, 2014

[11] Morales-Espana, G., Gentile, C, Ramos, A.: Tight MIP formulations of the power-based unit commitment problem, OR Spectrum (to appear 2015).

[12] Sanchez-Martin, P., Ramos, A.: . Modeling transmission ohmic losses in a stochastic bulk production cost model, Instituto de Investigacion Tecnologica, Universidad Pontificia Comillas, Madrid, 1997.

[13] Schultz, R.: Stochastic programming with integer variables, Mathematical Programming 97(2003), 285-309.

[14] Sheble, G.B., Fahd, G.N.: Unit commitment literature synopsis, IEEE Transactions on Power Systems 9(1994), 128-135.

[15] Takriti, S., Birge, J.R., Long, E.: A stochastic model for the unit commitment problem, IEEE Transactions on Power Systems 11(1996), 1497-1508.

Contributors

Dr Michael Diekerhof, RWTH Aachen University

Dr Mehdi Madani, Université catholique de Louvain