Electric Energy Procurement for Large Industrial Consumers under Uncertainty in Electricity Price and Product Demand

In general, large industrial electricity consumers procure their required electricity through bilateral contracts or in the pool (day-ahead or real-time market). The main purpose of signing bilateral contracts is to hedge against uncertainty in electricity prices, whereas buying electricity in the pool provides the opportunity of demand side management, i.e. shifting load to low-price hours. Thus, there is a trade-off between these two purchasing options, and the challenge is to find the optimal energy procurement strategy.

This problem has been studied by Conejo et al. (2005), Carrión et al. (2007), and Zare et al. (2010). While Conejo et al. (2005) solve a deterministic mid-term energy procurement problem considering a set of bilateral contracts and hourly changing spot prices, Carrión et al. (2007) apply Stochastic Programming to account for uncertainty in the electricity spot prices. Uncertainty is also the focus of the work by Zare et al. (2010), who solve a similar problem by applying Information Gap Decision Theory. However, in these works, the production profile is fixed, which leaves no room for load shifting.

In this work, we solve the energy procurement problem considering detailed production scheduling decisions, which increases operational flexibility and allows us to shift load in order to take advantage of varying electricity prices. Based on the work by Mitra et al. (2012), we develop a mixed-integer linear programming (MILP) model that incorporates electricity contract options into the production scheduling model, and we apply a two-stage stochastic programming model to take uncertainty into account. Here, we not only consider uncertainty in the electricity prictes but also in the product demand, which is typically the main source of uncertainty in production planning.

In order to reduce the computational effort of solving the MILP stochastic program, we first apply scenario reduction techniques (Dupacova et al., 2003) to decrease the number of scenarios while retaining a good approximation of the probability distribution. Since the problem is still difficult to solve as already the deterministic problem involves up to 5,000 binary variables, 15,000 continuous variables and 12,000 constraints since it is defined on an hourly basis over a one-week horizon, we further develop a tailored solution method based on Benders Decomposition. We apply the proposed framework to a real-world industrial case study provided by Praxair and show the value of the stochastic solution.

References

Carrión, M., Philpott, A. B., Conejo, A. J. & Arroyo, J. M., 2007. A stochastic programming approach to electric energy procurement for large consumers. *IEEE Transactions on Power Systems,* 22(2), pp. 744-754.

Conejo, A. J., Fernadez-Gonzalez, J. J. & Alguacil, N., 2005. Energy procurement for large consumers in electricity markets. *IEE Proceedings - Generation, Transmission and Distribution,* 152(3), pp. 357-364.

Dupacova, J., Gröwe-Kuska, N. & Römisch, W., 2003. Scenario reduction in stochastic programming: An approach using probability metrics. *Mathematical Programming,* Volume Ser. A 95, pp. 493-511.

Mitra, S., Grossmann, I. E., Pinto, J. M. & Arora, N., 2012. Optimal production planning under time-sensitive electricity prices for continuous power-intensive processes. *Computers & Chemical Engineering*, Volume 38, pp. 171-184.

Zare, K., Moghaddam, M. P. & Sheikh El Eslami, M. K., 2010. Electricity procurement for large consumers based on Information Gap Decision Theory. *Energy Policy,* 38(1), pp. 234-242.