**Applying Stochastic Optimization to Demand-Side Management of a Combined Heat and Power Plant.**

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**Highlights**

* Development of an MILP model for Industrial Demand Side Management.
* Approximation of Multi-stage problems as a series of two-stage problems.
* Novel aggregated formulation for power contract optimization.
* Application of risk measures to an industrial-size power plant.

**1. Introduction**

Integrated production sites in the chemical industry typically consist of many large-scale plants which are highly interconnected through material (e.g. base chemicals or intermediates) and utility networks [1]. A power plant is of major significance, as it provides utilities to the plants, e.g. electricity and process steam. Furthermore, power plants are able to collect off-gases from other plants and use them as fuels. The importance of power plants is also acknowledged by the European Union with the CHP Directive (Directive 2004/8/EC, 2004) that sets a framework to promote growth of cogeneration plants.

In this work we address the integrated electricity procurement and operation of a power plant that supplies steam and power to a chemical process and interacts with the power grid. Adopting a stochastic mixed-integer programming formulation, the aim of this work is to optimally determine for a planning horizon of one week:

* the amount of electricity purchased from power contracts;
* a daily day-ahead commitment with hourly discretization to purchase electricity from the day-ahead market under time-sensitive prices;
* the hourly production levels of steam and electricity;
* the amount of fuels stored and the off-gases incinerated.

**2. Methods**

To integrate electricity procurement and operation of the power plant, we adopted a multi-stage stochastic mixed-integer programming approach taking into account day-ahead electricity price uncertainty [2, 3]. To overcome the large computational effort needed to solve an industrial-size multi-stage stochastic program, we adopt an approximation strategy that solves a series of two-stage stochastic programs within a rolling-horizon framework. The rolling horizon framework not only reduces the problem size but also makes it possible to react to new information available regarding the amount of off-gases to be incinerated. The proposed approximation strategy drastically reduces the computational burden and renders possible the application of multi-stage programs to industrial-size optimization problems.

Considering even a low probability of large losses as not acceptable, we integrate the concept of risk into the optimization problem adopting the Conditional-Value at Risk measure.

**3. Results and discussion**

Fig.1 shows the electricity purchase profiles and the electricity produced by the power plant obtained solving the proposed multi-stage stochastic program with the described approximation strategy. The risk-averse solution follows the time-sensitive electricity price and purchases electricity from the power contracts when the price variation is higher to reduce the risk measure. The computation of a positive Value of the Stochastic Solution estimates the savings that the power plant could obtain adopting a stochastic formulation instead of a deterministic one.

**Figure 1.** Optimal electricity procurement.

**4. Conclusions**

This work addresses the integrated electricity procurement and operation for an industrial-size power plant. A multi-stage mixed-integer stochastic program is proposed to model electricity commitments taking into account electricity price uncertainty. An approximation strategy is proposed to solve efficiently industrial size optimization problems.

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**References**

1. Wenzel et al, “Optimal resource allocation in industrial complexes by distributed optimization and dynamic pricing”, Automatisierungstechnik 2016; 64(6): 428–442
2. Leo, E and Engell, S. “Multi-stage integrated electricity procurement and production scheduling.” In: International Symposium on Process Systems Engineering – PSE 2018.
3. Leo, E and Engell, S. “Integrated day-ahead energy procurement and production scheduling“ Automatisierungstechnik 2018;66(11):950–963
4. Mitra, S et al. “Optimal scheduling of industrial combined heat and power plants under time-sensitive electricity prices.” In: Energy 54 (2013), pp. 194–211.