Large-scale optimisation of production and logistics in chemical plants

The problem

- INEOS in Köln operates a large number of production plants that are linked by streams of intermediates and carriers of energy.
- The overall performance and efficiency of the site depends on the coordination of the individual plants and the coordination of external logistics via barges, trains and pipelines.
- An example of such site-wide integrated optimisation is the ammonia network of INEOS in Köln.

The solution

- A site-wide optimisation model composed of modules for plants and equipment as e.g. tanks and compressors was developed.
- An economic objective is optimised which incorporates the cost of raw materials, prices of power and gas, and operating costs.
- Logistic constraints such as the arrival of ships with raw materials and the delivery of products are considered.
The problem

Coupled production systems and logistics
INEOS in Köln operates a large number of production plants that are coupled by networks of shared resources. The ammonia network consists of an ammonia plant (P1), a nitric acid plant (P3) and two acrylonitrile plants (P4a, P4b). The ammonia produced in P1 can be compressed (C1, C2) and stored (Tc1, Tc2) or sent to buffer tanks (Tb1a, Tb1b, Tb3). The stored ammonia is heated before it enters the buffer tanks from which the ammonia consuming plants are fed. Additionally, ammonia can be imported from and exported to the buffer tanks via barges or train vessels.

Discrete events such as the arrival of empty or loaded barges need to be taken into account by driving the network to a state in which filling or unloading of ammonia via the available connections is possible. The need for energy-intensive compressing for long-term ammonia storage encourages scheduling the compressor operation such that low prices of electricity are exploited while satisfying the future demands. (Fig.1)

The solution

A flexible planning tool for the ammonia network
The work in CoPro between TU Dortmund and INEOS in Köln resulted in a production planning tool for the ammonia network which provides optimal production plans for different possible scenarios and optimisation targets. The tool can be used for short and medium-term planning. The temporal resolution can be adjusted between hours and days. It has an intuitive user interface and data on the current and the expected situation can be retrieved from multiple sources.

The optimisation uses mixed-integer linear programming. The component models are available in a model library and can be parameterised easily. The goal of the optimisation is the economically best possible operation while meeting the logistic constraints. Constraints on the ramping up and down of plants are also included.

An optimisation of a monthly production plan based on historical reference data for the production targets and the external conditions of a full month was performed to test the power of the tool. All logistic events and the monthly production targets for the plants were fixed and the degrees of freedom were the production rates of the plants and compressors. The result showed potential savings of about 25% of the cost for the liquefaction of ammonia. (Fig. 2)

Another use case was to predict the scheduling of train vessels for a variety of customers with individual preferences depending on the arrival dates of barges with raw materials and the constraints caused by the operation. This scenario was motivated by the low level of river Rhine in 2018. It illustrates the benefit of the tool as an aid for the planners to react quickly to changing situations.

The solution can be transferred to other applications with connected plants, multiple shared resources and logistic constraints, using the developed model library and the general solution strategy. The integration with other software systems is facilitated by the use of LeiKon Intec Suite.

The summary

Optimal production planning for coupled plants
The new tool for the production planning in integrated chemical production networks allows planners to find optimal solutions for various production and logistics scenarios quickly, taking into account plant dynamics and constraints, storage management, and import and export logistics. The results and their visualisation support the planners in creating feasible, cost and energy-efficient production plans and in making reliable promises of deliveries. If the plans are, according to the experience of the planners, not compatible with constraints which were not explicitly considered in the optimisation, they provide a good starting point for manual adaptations.

The developers

Simon Wenzel, M.Sc.
Process Dynamics and Operations Group
Department of Biochemical and Chemical Engineering
TU Dortmund
44221 Dortmund, Germany
simon.wenzel@tu-dortmund.de

Yannik-Noel Misz, M.Sc.
Process Dynamics and Operations Group
Department of Biochemical and Chemical Engineering
TU Dortmund
44221 Dortmund, Germany
yannik.misz@tu-dortmund.de

Keivan Rahimi-Adli, M.Sc.
Project Engineer
Commercial Energy Management
INEOS Manufacturing Deutschland GmbH
Alte Straße 201
50769 Cologne, Germany

Further information

Prof. Dr. Sebastian Engell, TU Dortmund, sebastian.engell@tu-dortmund.de
Benedikt Beisheim, M.Sc., INEOS, benedikt.beisheim@ineos.com