A Discrete-Time Scheduling Model for Continuous Power-intensive Process Networks with Various Electricity Contracts

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In the era of Smart Grid, efficient scheduling models for industrial power-intensive processes are crucial.

- In the context of Demand Side Management, industrial power-intensive processes can achieve large benefits by optimizing their power consumption.
- The plant’s flexibility can be used to shift load depending on the time-sensitive prices and the conditions of the electricity contracts.

We develop a discrete-time scheduling model for general continuous power-intensive process networks considering various electricity contracts.
To model the process network, we apply the concept of the state-task network (STN).

- **Two types of nodes:**
  - **State** nodes: feeds, intermediates, products
  - **Task** nodes: processing steps

- **Diagram:**
  - **Heating**
  - **Reaction 1:**
    - Node 2
    - Output: D
  - **Separation**
    - Node 3
    - Output: E
  - **Reaction 2:**
    - Node 4
    - Output: C
  - **Equipment (units) is not shown in the STN**
  - **Storage = accumulation of material in states**
  - **Two streams entering the same state have the same quality (P, T)**
Each equipment unit is modeled as a set of Convex Region Surrogate (CRS) models.

- Assume that a piece of equipment can run in different operating modes.
- The feasible region of each operating mode is expressed as a union of convex regions in the state space.
- For each region, the required power consumption is a linear function of the states.
- Can be stated as a nested disjunction, which can be reformulated as a set of MILP constraints.

We apply a discrete-time formulation to model transitions between operating modes\(^1\).

- The time horizon is divided into time periods of equal length (typically one hour)

\[
\begin{align*}
-\theta^u + 1 & \quad 0 \quad 1 \quad 2 \quad t^f - 1 \quad t^f \\
\Delta t & \quad \text{Scheduling horizon } \bar{T}
\end{align*}
\]

- For every time period, operating mode and production rates are determined
- Constraints on mode transitions can be imposed

A large variety of electricity contracts can be modeled by using a block contract formulation.

- Assigns prices to every time period
- Tracks cumulative power purchases for predefined meter reading times
- Can accommodate discount prices that depend on the amount of power purchased
- Can accommodate penalties for under- and overconsumption
Air Separation Case Study: State-Task Network
Air Separation Case Study: Results