Turnaround Optimization of Continuous Chemical Plants

Motivation

- Large companies spend millions on turnarounds annually
- Potential for significant savings
- Practical limitations on manpower
  - Maintenance personnel typically contract workers
  - Infrequent spikes in manpower utilization
- Most scheduling is done using scenario-based analyses

Scope of study

- Problem features
  - Continuous processes
  - Multi-year horizon
  - Planned maintenance
  - Intermediate inventory buffers
  - Site-wide scope
- Objective: Maximize NPV subject to
  - Network flow constraints
  - Inventory constraints
  - Manpower limits
  - Turnaround durations and frequencies

Turnaround optimization

- Maintenance is defined as
  “the combination of all technical and associated administrative actions intended to retain an item in, or restore it to a state in which it can perform its required function” [1]
- Turnaround optimization—Finding the optimal sequence of tasks in a turnaround envelope
- Involves consideration of:
  - Site-wide network structure
  - Flows and inventory levels
  - Turnaround resources

Example network

Challenges

- Combinatorics
  - Scheduling requires discrete decisions
  - Large number of units, and large time horizon \(\Rightarrow\) large number of binaries

- Uncertainty
  - Component failure rates, Lengths of turnarounds
  - Unit reliability, supply and demand variability within plant network
  - \(>\ 100\) uncertain parameters \(\Rightarrow\) potentially too large for stochastic programming

- How do we
  - Choose right level of network abstraction?
  - Choose right time discretization?
  - Capture uncertainties?

Approach

- MILP
  - Useful for finding solutions to large-scale combinatorial problems with constraints

- Discrete-event simulation
  - Useful for capturing rule-based logic, priorities, variability in operations

Use best features of both approaches

Results – Gantt chart
Results – Manpower utilization

Manpower Utilization

- Envelope turnarounds occur together
  - Intuitive, as they are adjacent in site network
- Red envelope decoupled
  - Possibly due to potential of market interaction for raw materials
- Staggering of turnarounds (Unit 17)
  - Due to manpower limitations
  - Manpower intensive unit coupled 2nd turnaround
- Separation of turnarounds across years
  - Spread helps short-term financial results
  - Balances use of manpower

Analysis of results

Summary and future work

- Demonstrated a hybrid optimization and simulation strategy to trade-off tractability and real-world practicality
- Provided general-purpose tool for analyzing sites for long-term turnaround planning
- Future work
  - Short-term scheduling to capture hourly/daily effects such as ramping, manpower allocation, etc.
  - Rolling horizon scheme as opposed to cyclic schedule