Grand Challenges
FOR CONTROL

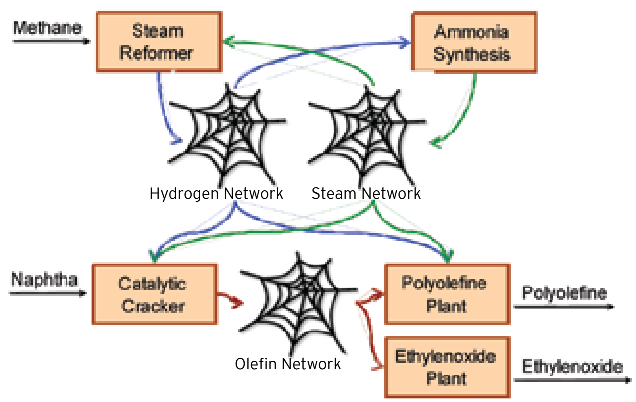
Process Manufacturing Networks

Growing competition on the global scale, the transition from supply-driven to demand-driven markets, and tightening of process safety and environmental regulations are all placing increasing pressure on process manufacturing and operations. Leveraging the full economical potential of a process plant while maintaining a high level of sustainability requires the supply-chain-conscious optimization of plant operations in real time. Optimal plant operation must accommodate both the interactions with other plants in the associated supply chain and the dynamics of raw material, energy supply, and product demand. In particular, availability and prices of raw materials and energy may change quickly in global markets. Furthermore, production is faced with an increasing diversity of product types and grades.

A Manufacturing Site as a Network

Figure 1 shows a network of chemical plants on a production site. The nodes refer to plants such as a polyolefin plant, a catalytic cracker, and a steam reformer. The network linking these plants is structured into a steam network, a hydrogen network, and an olefin network. For example, the catalytic cracker node is a consumer of hydrogen and steam and a producer of olefin.

Figure 1



Integrated Production

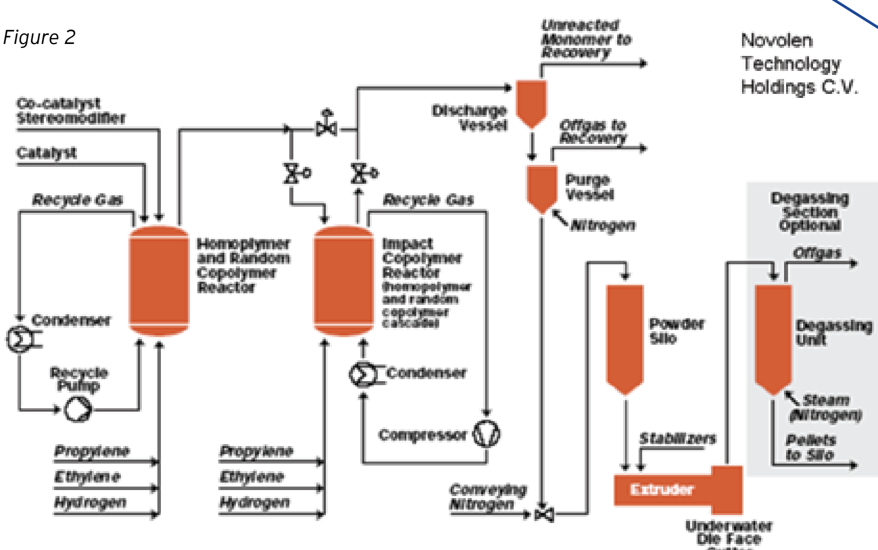
The interconnection between different process plants and between the units of a single plant account for efficient energy integration and for a largely complete recycling of materials. BASF's Verbund concept, for example, implements a tight integration of all chemical plants at one site.

Such an integrated production site can be visualized by a set of nodes, each representing a chemical plant, connected to diverse networks. Each node of such a network forms a complex network itself comprising units, sensors, controllers, and actuators, along with their material and information connections.

A Plant as a Network

Figure 2 is an example flow sheet for the polyolefin process. This complex network of a single plant is embedded into the network of plants on a production site. Altogether, a large-scale and strongly nonlinear hierarchical network control problem is formed, typically characterized by widely varying time scales, discrete-continuous dynamics, and a large number of controlled and manipulated variables.

Figure 2



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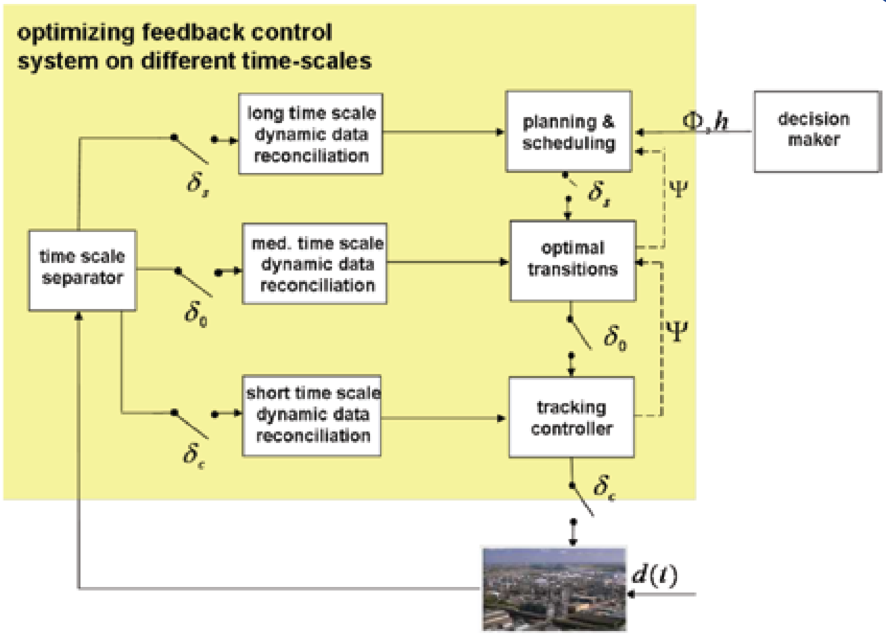
Challenges—Dynamic, Real-Time Optimization and Control

Optimization and control algorithms not only have to treat extremely large-scale, nonlinear, and nonconvex optimal control problems with widely varying time scales and long control horizons, but they also have to cope with discrete decisions to adjust the control strategy. Such algorithms must exploit the structure of the problem, which stems from the hierarchical nature of the network and the model structure of the individual units. Decomposition strategies are essential, but they must take into account the strong interactions between the units of the plant network and between the plants in the site network.

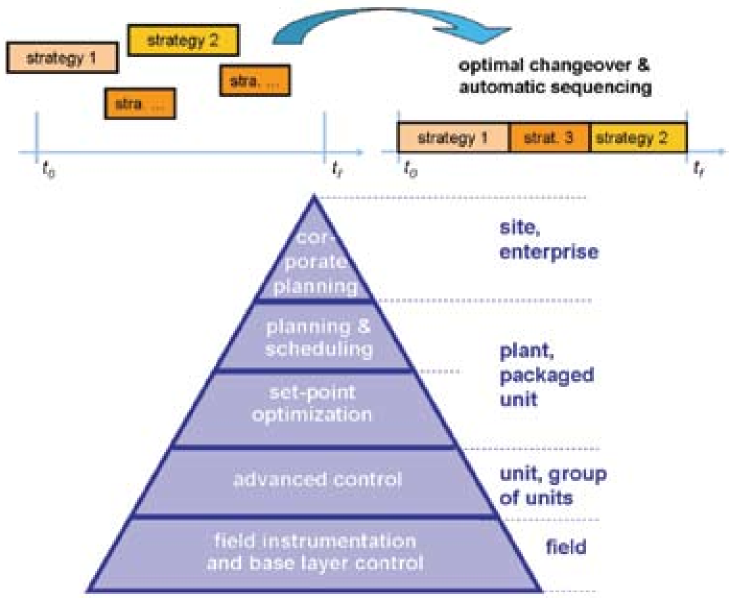


Challenges—Planning and Scheduling

Real-time business decisions relate to operational strategies such as the start-up or shutdown of a unit in a plant, the production schedule of the diverse product types and grades, and the transitions between the resulting campaigns. The control and optimization schemes have to be robustly feasible and optimal despite the unavoidable uncertainty in the availability and prices of energy and raw materials, the prediction of time-varying demand of the different product types, and the usual disturbances.

Challenges—Modeling

Given the complexity of an integrated site, modeling represents the major challenge and bottleneck for the rollout of model-based control and real-time optimization techniques. The acquisition of process knowledge, casting it into hybrid first-principles/data-driven models, adjusting the models to the real plant, managing the unavoidable model uncertainty, and maintaining these models over time constitute the major challenges, not only from a technological but also from an organizational perspective. Obviously, modeling and the representational formalisms have to account for the functional separation in the different layers and their interrelations in the network hierarchy.



And there's much more!

Solutions to any of the challenges posed for the development of methodologies and algorithms for optimal operation of chemical process systems may be applied to any other hierarchical network problem. Prominent examples include freshwater supply or wastewater networks, gas distribution networks, and electrical power networks, to mention only a few.