gPROMS Technologies

Mixed Integer Optimisation

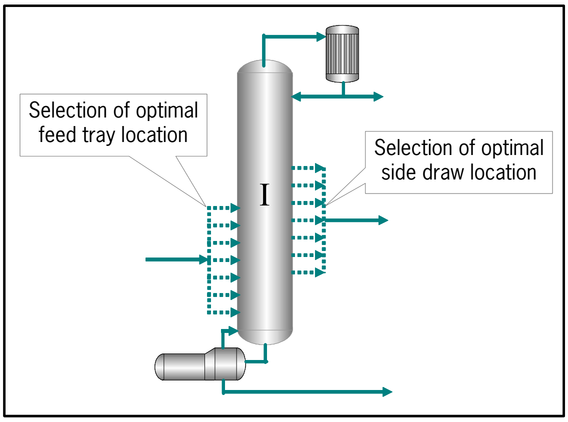
Taking discrete decisions into account

Mixed Integer Optimisation takes discrete as well as continuous decisions into account during steady-state or dynamic optimisation.

A major strength of gPROMS® has always been the power of its steady-state and dynamic **optimisation**. The optimisation capabilities have now been extended to take into account integer or discrete decisions using **Mixed Integer Optimisation (MIO)**. MIO can be applied to **both steady-state and dynamic** gPROMS models. The latter may also involve **discontinuous equations** such as those described by gPROMS IF and CASE equations.

There are many applications in chemical engineering where discrete decisions need to be considered. Typically examples are decisions on equipment or process configuration, where the number of stages or equipment items, the inlet and outlet locations, or the restriction to standard equipment sizes are key considerations.

Steady-state MIO example – design of continuous distillation columns



A typical MIO example is the steady-state design of a distillation column, where the number of trays and feed and side draw locations are key design decisions.

The MIO capability in gPROMS can be used to find the optimal configuration while simultaneously optimising continuous variables such as column diameter, reflux ratio and boil-up rate.

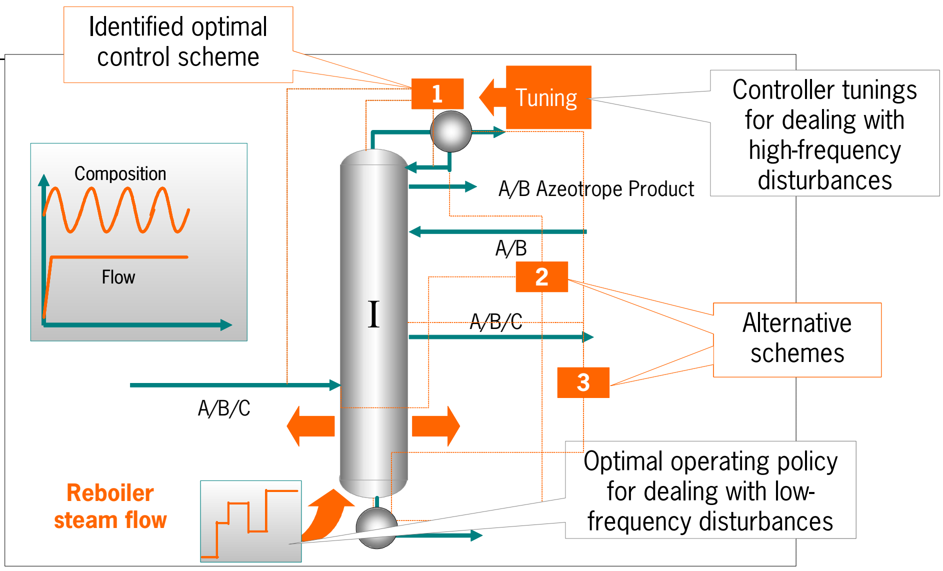
The objective function used in such an application is typically an economic one that includes both capital and operating cost.

Dynamic MIO example – selection of optimal control schemes

The selection of the optimal control scheme for handling all anticipated disturbances to a system is another key decision in process engineering.

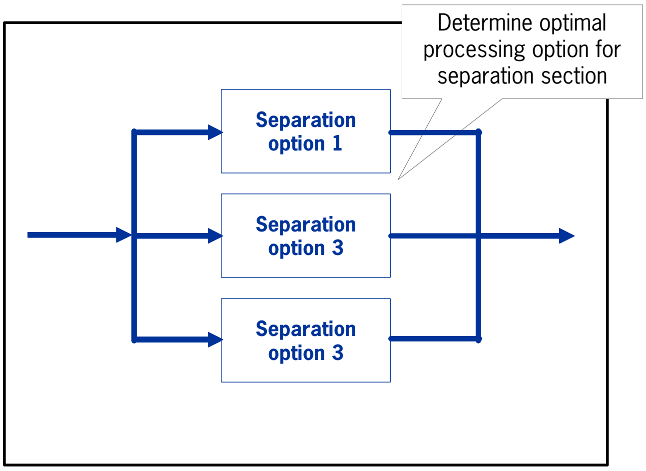
MIO can be used to select the best scheme while simultaneously providing optimal values for variables such as

- controller tuning parameters
- key equipment design parameters such as column diameters
- optimal operating policy (e.g. for startup).



The model company

Steady-state MIO example – process synthesis



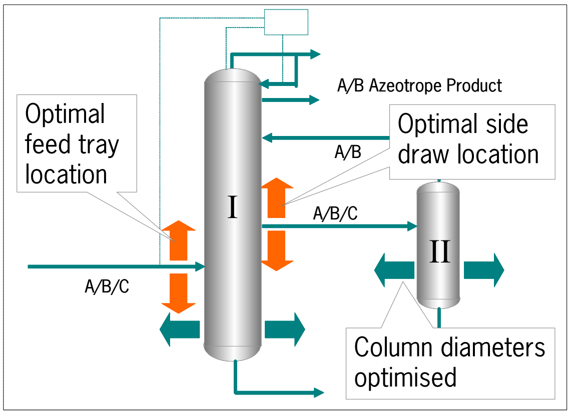
MIO can be used to determine the optimal process configuration from a number of proposed alternatives, taking into account

- equipment and process constraints
- product specification requirements
- annualised capital and operating costs

The "separation options" in the diagram on the left can be different configurations of distillation columns, for example, or entirely different separation processes (for example flash units or membranes)

MIO – the economic benefits

MIO opens new opportunities in advanced areas such as the simultaneous design of processes and their control systems, potentially leading to significant economic benefits – as illustrated by the case study shown below.



	Existing design	Design using MIO
Feed location	14	8
Draw location	22	18
Q column I (MW)	19.5	14.7
Q column II (MW)	0.87	2.45
Capital cost M$/year	0.63	0.56
Operating cost M$/year	4.37	3.56
Total cost M$/year	**5.00**	**4.12**

Types of integer decision in gPROMS optimisation

The MIO facilities in gPROMS cater directly for a number of discrete decision types, allowing a wide variety of engineering decisions to be included in the optimisation. Both **time-invariant and time-varying discrete decisions** are supported.

- **Integer** decisions – for example, the number of trays in a distillation column or the optimal number of reactors necessary to provide the required conversion and selectivity.
- **Binary** decisions – for example, to determine whether an item of equipment needs to be included or not; or to obtain an optimal "bang-bang" profile for a time-varying on-off control.
- **Enumerated** decisions – where the optimisation chooses an item out of a given set – for example, selecting a batch reactor out of a set of standard "off-the-shelf" sizes; or obtaining an optimal control profile for a "staged" heater, i.e. one that can operate only in certain distinct modes, e.g. OFF, LOW, MEDIUM or HIGH.
- "**Special Ordered Set of type 1 (SOS1)**" decisions, a set of binary decision variables from which only one may have a value of 1. An example is feed tray location in a distillation column, where a number of locations may be proposed but only one may be selected by the optimiser.