ABSTRACT

Three important parts of an integrated plant are reactors, separators and a heat exchanger network (HEN) for heat recovery. Within the process engineering community, much attention has been paid to design of reactors, separators and HENs. This thesis, however, is devoted to *operation* and in particular to optimal operation of HENs.

The purpose of heat integration is to save energy, but the HEN also introduces new interactions and feedback in the overall plant. A good strategy for operation of HENs should, in addition to controlling the outlet temperatures to target values (setpoints), minimize the external energy consumption when disturbances and setpoint variations are encountered.

A prerequisite for optimization is that there are extra degrees of freedom left after regulatory control is implemented. It is shown that extra degrees of freedom may not always be utilized for energy optimization, and a quantitative expression for the degrees of freedom that can be utilized for optimization is presented. A simplified expression that is often valid is also deduced.

How to operate a HEN close to optimal may often be found from structural information alone. The thesis presents some improvements and generalizations of a structure based method that has been proposed earlier. Structural information is used to divide possible manipulations into three categories depending on how each manipulation affect the utility consumption. Using these three categories and two heuristic rules for operability, the possible manipulations are ordered in a priority table. This table is used to determine which manipulation should be preferred, and which manipulation should be selected if an active manipulation is saturated. It is shown that the implementation of the method may correspond to split-range control.

A method that in addition to structural information, also utilizes parametric information is proposed. This method is heavily inspired by the structural method, however, the optimal control structure is found through solving an integer programming problem. The control structure is found periodically during operation, and as for the structure based method, this can lead to a varying control structure. The basic model does not incorporate any controllability considerations. Two methods to include controllability are proposed. Both methods are based on extending the basic model with logical inference using additional constraints. In both cases, the result is a hierarchical strategy for operation that has been embedded into the model.

A third method that combines the use of steady state optimization and optimal selection of measurements is proposed. Steady state optimization is carried out periodically during operation to compute optimal setpoints for the secondary measurements. The setpoints for the primary measurements (outlet temperatures with target values) are not subject to optimization. However, extra manipulations may be used for energy optimization and this may be done by controlling some internal temperatures (secondary measurements). When unknown disturbances and model errors are present, the selection of which secondary measurements that are controlled affects how close to optimum the process can be operated. A procedure for selection of secondary measurements for processes where optimum is located at the intersection of constraints (which is typical for HENs) is presented.

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ABBREVIATIONS

These abbreviations are used throughout the thesis. The list is in alphabetical order.

AMTD	Arithmetic Mean Temperature Difference
DCS	Distributed Control System
DIC	Decentralized Integral Controllable/Controllability
DOF(s)	Degree(s) Of Freedom
HEN	Heat Exchanger Network
ILP	Integer Linear Programming
LMTD	Logarithmic Mean Temperature Difference
LP	Linear Programming
MILP	Mixed Integer Linear Programming
MIMO	Multiple Input - Multiple Output (multivariable system)
MINLP	Mixed Integer Non-Linear Programming
MPC	Model Predictive Control
NLP	Non-Linear Programming
ODE	Ordinary Differential Equations
PDE	Partial Differential Equations
PI	Proportional-Integral (controller)
PID	Proportional-Integral-Derivative (controller)
RGA	Relative Gain Array
RHP	Right Half Plane (right half of the complex plane)
SISO	Single Input - Single Output (monovariable system)