Practical Distillation Control

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The presentation highlights the practical experiences gained in adapting predictive control technology to solve a difficult distillation control problem.
Control of product impurity and product losses using off-line 8-hourly laboratory measurements combined with predictive inferential techniques avoids the need for on-line analysers and enables more consistent column performance.
Introduction of complex control technology offers benefits in terms of solution flexibility, but may pose potential operating and system management problems. Developing a hierarchical control strategy plus a simple operator interface helps to minimise operator complexity. Implementing a structured control engineering tool with a reliable communication interface minimises support costs.
The experience highlights that process inconsistencies are a major cause of performance problems and continuous control engineering support is needed.
It is therefore essential that the support control engineer be fully familiar with the process application, interactions and data inconsistencies.

Distillation control was initially developed using operator statistical process control (SPC) of product impurity and product loss. However, operating two SPC schemes proved to be difficult, due to the dynamic interactions between the product impurity and product loss controlled parameters. A combination of product quality SPC and product loss temperature controls was implemented which reduced the interactions, but further improvement was needed.

A data modelling study was carried out using statistical and neural network methods to infer the key impurity and the product loss concentrations.
However, column temperature and pressure were not found to be effective as key inferential parameters, due to low signal sensitivity to disturbance ratio and unreliable measurements. Also, feed rate, product specifications, column fouling and changes in feed composition effect the characteristics of the distillation column and cause different key impurities to be produced.

A model based predictive control scheme using the "Connoisseur" control technology was then considered. Basic plant identification required 38-days of data due to the long time constants; in excess of 12-hours, caused by the distillate rate being less than 1% of the feed rate. Dynamic predictions of concentrations were inferred from changes in base temperature, distillate flow and feed rate. An "Off-with-Inference" facility enables the model predictions to infer the dynamic changes anticipated from the control actions between the eight hourly laboratory analysis data which provides update for drift and model error.

To avoid repeating this time consuming plant testing for different rates, a fast real-time simulation was designed into the DCS. The second order plus delay transfer functions derived from step responses of the "Connoisseur" model were estimated for different feed rates. This allowed the "Connoisseur" adaption facility to be used with the fast DCS simulations to produce alternative controllers. The DCS simulation link also allowed all of the practical operational links, including watchdog safeguard's, to be developed and fully tested to enable the Connoisseur real-time plant controller to be commissioned without problems.

Development of an optimiser to set an economical balance between steam usage and product losses highlighted operating temperature constraint conflicts due to the fouling problems. It was difficult to decide what optimiser weightings were needed to offset the cost of repacking the column at an "optimum" frequency.
Operating cost per tonne is monitored and steam usage minimised using slow constraint pushing towards a minimum base temperature, which also reduces the risk of fouling the column packing. Meeting critical shipment times with an "in-spec" product tends to be given more priority than operating "nervously" close to finely optimised conditions with no time for any error recovery.

There is much scope involved in the Control of Distillation that has to cope with upstream process reaction disturbances; downstream variations in customer specifications and short notice changes in marketing demands.
Practical experience with predictive control shows that benefits can only be gained and sustained provided that resource expertise is allocated to maintain the performance and to continue developing additional control complexity to cater for different process scenarios. E.g. different process models may be needed for operating at low, medium and high rates and with three levels of product specification would requires nine different predictive controller options.
This represents continuing development cost, which needs to be balanced against the overall business benefits.

Further work is needed to translate dynamic models from rigorous distillation steady state models, which can then be entered into "Connoisseur". Also, to determine non-linear predictions utilising the neural network facility available in "Connoisseur" which could enable a single controller to perform over a wider operating range. There is potential for developing the "Connoisseur" rule-based Fuzzy Logic to provide sequence steps to handle the recovery from column upsets and enable quicker column start-ups. It is also possible to embody more complex knowledge to "adapt" the predictive controller for optimum performance under various prevailing circumstances.

Diagnosing root causes of process problems is also very time consuming and it can be difficult to determine if model mismatch, poor tuning or external upsets are responsible for specific control issues. It is anticipated that developments in "expert system analysis" could be utilised to evaluate and diagnose specific causes of prediction errors. Such techniques could also be beneficial for training by providing appropriate documentation references to understand complex system configuration, associated process knowledge and performance evaluation.