Development of a Systematic Approach for Plant-Wide Control System Design

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Traditionally, control structures are designed based upon heuristic methods that do not use the process knowledge in a systematic manner. In this work, a systematic, model-based approach for control structure design has been developed by significantly enhancing the methodology proposed by Skogestad[1]. The approach is a two-stage method starting with a top-down analysis and ending with a bottom-up design. In the first stage, a top-down approach is taken to generate a list of manipulated, control, and disturbance variables considering a scalar operation objective and other process constraints. In the second stage, a bottom-up approach is used for designing the control system taking into account the results from the previous stage.

In the first stage of the plant-wide control system design approach, controlled variables are selected for their self-optimizing control performance and controllability while ensuring satisfactory performance in terms of dead-time and closed loop interactions. This work has considered both self-optimizing and control performance as well as addressed issues related to loop-interactions and superstructure constraints. Our proposed method involves a three-stage procedure: *a priori* analysis, controlled variable selection, and *a posteriori* analysis. The developed methodology can be deployed to large-scale process systems. This approach results in a large-scale, constrained, mixed-integer multi-objective optimization problem. For solving this problem, a parallelized, bi-directional branch and bound algorithm with dynamic search strategies has been developed to solve the problem on large computer clusters.

In the next stage, the focus is on the development of a rigorous, model-based approach for the selection of secondary controlled variables. A partially controlled plant analysis is undertaken to determine the optimal secondary controlled variables. Here a systematic three-stage approach is proposed that addresses issues of controllability and economic performance of the control system. The first stage involves the generation of an initial set of candidate secondary controlled variables and the generation of selection constraints. During the second stage, secondary controlled variables are selected to minimize integral absolute errors (IAEs) of the primary controlled variables subject to minimal loop interactions as determined by a relative gain array analysis. Finally, during the third stage, control performance of the secondary controlled variables is evaluated at off-design operations using a nonlinear process model.

Finally, the design of the supervisory control layer is completed. Gramian-based interaction measures are used to determine the optimal form of the supervisory control that balances controller complexity with control performance. Finally, model-based advanced controllers are designed for supervisory control.

The methodology is applied to an integrated gasification combined cycle (IGCC) power plant with CO_2 capture. This plant should be operated optimally in the face of disturbances without violating operational and environmental constraints. The process models are developed in Aspen Engineering Suite while the algorithms for control structure selection and the controllers are implemented in Matlab.

1. Skogestad, S., “Control structure design for complete chemical plants”, *Computers and Chemical Engineering*, 28, 219-234, 2004