PROCESS DESIGN AND CONTROL

Multivariable Inferential Feed-Forward Control

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Two multivariable inferential feed-forward control strategies are proposed in this paper. In the first strategy, the effects of disturbances on the primary process variables are inferred from uncontrolled secondary process variables that are measured on-line. In the second approach, the effects of disturbances on the primary process variables are inferred from the manipulated variables for those controlled secondary process variables that have fast dynamics. The proposed strategies are particularly useful in situations where some disturbances cannot be easily and quickly measured. Robustness analysis of the inferential feed-forward controllers and the selection of appropriate secondary measurements are discussed. Structured singular value analysis is used in assessing the robustness of the inferential feed-forward control systems. The performance characteristics of the two inferential feed-forward control systems are demonstrated by application to a simulated methanol−water separation column. In the first system, the effects of disturbances in feed composition (and feed rate) are inferred from tray temperatures, whereas in the second system, the disturbance effects are inferred from inventory manipulations. Nonlinear dynamic simulation results demonstrate the superior performance of these strategies. Robustness analysis shows that using multiple tray temperatures can improve the robustness of the inferential feed-forward controller, and this conclusion is confirmed by simulation.

1. Introduction

The primary function of a process control system is to maintain the controlled process variables at their desired values in the presence of disturbances. Process plants can have large time constants and long time delays. Substantial measurement delays in some process variables such as composition often exist. When long time delays or large time constants between the disturbances and the controlled variables exist, the effects of disturbances might not be satisfactorily rejected through feedback control alone. A strategy widely used in process control is feed-forward control,[1−3] in which disturbances are measured and anticipatory control actions are taken before the controlled variables are actually affected by disturbances. In many situations, however, disturbances in some variables, such as composition, cannot be easily measured. In such cases, it would not be feasible to implement feed-forward control.

In many process plants, there are usually some secondary process variables that are measured on-line and that might or might not be controlled. The correlation between disturbances and some uncontrolled secondary process variables make it possible to infer disturbance effects from these variables. If the secondary process variables are controlled, then the changes in their manipulated variables can be used to infer the effects of disturbances. On the basis of these inferred disturbances, feed-forward control can be implemented indirectly. For example, Yu and co-workers[4−6] proposed an indirect feed-forward control strategy in which the effects of disturbances were inferred from changes in uncontrolled secondary process variables. McAvoy et al.[7] proposed a nonlinear inferential cascade control to consider the nonlinear aspects in many industrial processes.

This paper presents two methods for implementing inferential feed-forward control. In the first method, the effects of disturbances are inferred from the measurements of certain uncontrolled secondary process variables that can be measured easily. In the second method, the effects of disturbances are inferred from the manipulated variables associated with fast secondary controlled variables. Although the first approach shares some common ideas with the indirect feed-forward control strategy of Yu and co-workers,[4−6] some important aspects, such as robustness analysis, that were not addressed by them are discussed here.

The inferential feed-forward control strategies proposed here differ from the inferential control widely reported in the literature.[8−11] In inferential control, the variables to be controlled cannot be measured quickly enough or, in some cases, cannot be measured at all. These variables are estimated using some readily available process variables such as temperatures, pressures, and flows, and then, the estimated values are used in feedback control loops. In the inferential feed-forward control schemes proposed here, some disturbances cannot be measured fast enough for feed-forward control

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