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Generalized Predictive Control of a Multivariable pH Neutralization Process using Independent Model Approach

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***Abstract*— Generalized Predictive Control using an Independent model approach (GPCI) is an effective method to solve the control problem of uncertain nonlinear systems due to its insensitivity to model uncertainties. Thus, due to the robustness of GPCI, one model instead of multi-model methods can be sufficient. Extreme nonlinearity and exhibition of severe interaction effects of multivariable pH processes makes it an appropriate test bed for evaluation of advanced controllers such as GPCI. In this paper, GPCI strategy is applied to this process and the simulation results demonstrate the effectiveness and validity of the method.**

Keywords* —Generalized Predictive Control; Independent Model; Multivariable Control; Multivariable pH Neutralization Process.

I. INTRODUCTION

The GPC method was proposed by Clarke at al. [1, 2] in 1987 and has become one of the widely used Model Predictive Control (MPC) methods in both industry and academia. Note that, acronym MPC is used to denote all types of predictive control methods such as GPC.

In this paper, we employ a multivariable GPC algorithm based on the Independent Model (IM) approach [3]. The state-space model of GPCI is used. GPCI is robust to model uncertainty compared with other GPC methods; as a result of this property, it is effective to solve the problem of controlling uncertain nonlinear systems. Multi-model approach is an effective method to solve the problem of controlling highly nonlinear systems with a wide operating range. In this paper, it is shown that if GPCI is utilized as the controller, one model will be sufficient and consequently there will be no switching involved.

pH neutralization process is a complex system with high nonlinearity, uncertainty in model and presence of unmeasured disturbances. Exhibition of severe interaction effects of multivariable pH processes makes it more difficult to control. pH process is widely used in chemical processing, neutralization of wastewater, biotechnological processes and precipitation [4, 5].

In this paper, a typical multivariable pH neutralization process [6, 7] is presented in details. There are a great number of papers in recent years [8, 9, 10, and 11], which deal with pH control approaches. However, most of these strategies have been targeting single input single output (SISO) pH processes and not much has been devoted to multivariable pH processes.

The GPCI method is introduced in section 2. In section 3, after introducing a multivariable pH process, an identification approach is used to demonstrate some useful information about the properties of this nonlinear system. Using these properties, a linear model is chosen as a nominal model of the system for use in prediction. Finally, the presented GPCI algorithm is tested via a MIMO pH neutralization process plant.

II. STATE-SPACE GPCI ALGORITHM

A multivariable GPCI algorithm based on an independent model in state-space configuration is introduced in [3]. Consider the state-space model as

$$\begin{aligned} \hat{\mathbf{x}}_{k+1} &= A\,\hat{\mathbf{x}}_k + B\,\mathbf{u}_k \\ \hat{\mathbf{y}}_k &= C\,\hat{\mathbf{x}}_k \end{aligned} \quad . \tag{1}$$

Where, $\hat{\mathbf{x}}$ denotes the model state vector, $\hat{\mathbf{y}}$ denotes the model outputs and $\boldsymbol{u}$ denotes the process inputs and A, B, C are the matrices defining the state-space model. Note that the IM is a process model such as (1) which operates simultaneously with the real process using the same inputs as shown in Fig.1. Where, $\mathbf{y}$ denotes the process output and $\hat{\mathbf{y}}$ is the IM output. Clearly, the advantage of using IM in state-space model is that an observer is not required.

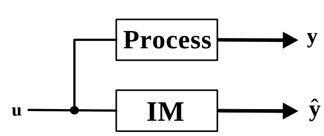

Fig. 1. Independent model (IM).

There are mainly two means of setting up a state-space based predictive control law, the state augmentation as in performance index (2) or no state augmentation and performance index (3). State augmentation method is found in many literatures [12, 13] in details. Here the second criterion (3) is chosen due to its robustness to model uncertainties.

$$J = \sum_{i=n_w}^{n_y} \left\| r_{k+i} - y_{k+i} \right\|_2^2 + \lambda \sum_{i=0}^{n_u-1} \left\| \Delta u_{k+i} \right\|_2^2 . \tag{2}$$