EXPERIMENTAL APPLICATION OF A NEURAL CONSTRAINED MODEL PREDICTIVE CONTROLLER BASED ON REFERENCE SYSTEM

A. G. MONTANDON[1], R. M. BORGES[2] and H. M. HENRIQUE[3,4]
School of Chemical Engineering/Federal University of Uberlandia. Av. João Naves de Ávila, 2121
Phone number: +55-34-3239-4292 Fax number: +55-34-3239-4188
POB 38408-100 Uberlandia - MG, Brazil
[4]Author to whom all correspondence should be addressed
E-mails: [1]amontandon@mic-br.com.br, [2]raquelmb@cefetes.br, [3]humberto@ufu.br

***Abstract* — The proposed constrained model predictive control (MPC) is based on a successive linearization of a neural model at each sampling time and the closed loop response is subject to a first order reference system as set of equality constraints. In addition the system inputs are subject to hard constraints. In order to satisfy both types of constraints simultaneously it was needed to include a slack vector in the equality constraints. This slack vector provides more flexibility in the control moves in order to render the solution of the optimization problem feasible. The proposed MPC was implemented in an experimental pH neutralization plant. Results showed a very satisfactory performance of the proposed strategy.**

***Keywords* — Model Based Control, Neural Control, Neural network Models, pH control, Real-Time Control Systems.**

I. INTRODUCTION

Global industrial competition has revealed the importance of the automatic control for industrial profitability and safety. In this fashion advanced control strategies are used to assure that processes can be operated safely in regions of the high product quality with low consumption of raw materials and energy. However the development of advanced control strategies is a very hard task mainly due to nonlinear behavior of the chemical processes.

Nonlinear processes have been controlled by linear controllers in spite of the fact that the vast majority of chemical processes is inherently nonlinear. The advantage of this approach is that an easy analytical solution of the control problem can be found and a low computational effort is demanded by linear controllers. However, the linear approach can be very limiting for highly nonlinear processes and it can drive the system to unstable solution. The use of nonlinear process models within the control strategy has been shown to provide the potential for significant improvement over linear controllers for nonlinear processes (Bequette, 1991; Henson and Seborg, 1997). Nonlinear model predictive control (NMPC) (Garcia and Morshedi, 1986; Garcia *et al.*, 1989; Gattu and Zafiriou, 1992) and input-output linearizing control (IOLC) are the most widely studied nonlinear control techniques for process control problems. NMPC offers many of the appealing features of linear model predictive control, including explicit compensation for input and output constraints (Meadows *et al.*, 1995). As compared to NMPC, IOLC offers several important advantages including transparent controller tuning and low computational requirements (Kravaris and Kantor, 1990). However, conventional feedback linearization techniques have neither constraint handling (Rawlings *et al.*, 1994) nor predictive capabilities. This has motivated the development of several modifications of the basic input-output linearization approach (Balchen and Sandrib, 1995; Kendi and Doyle, 1995). On the other hand, the nonlinear approach can result in a large computational effort that limits its use in practical applications.

The scope of this paper is to deal with nonlinear process by using a control technique which is computationally feasible for industrial and practical implementation. Feasible for industrial implementation means the controller must have low computational effort and, the most important, the solution of the optimization problem must be guaranteed. When we linearized the model we can transform the optimization problem into a quadratic programming problem and this type of optimization problem has convergence guaranteed in a finite number of iteration steps (low computational effort). If we use a nonlinear model directly in the optimization problem we can guarantee neither convergence nor feasibility of the solution and this is unacceptable for industrial and practical applications. This is one of prime problems in nonlinear MPC. In addition the computational effort is generally very large in a fully nonlinear approach and all MPC calculations must be done during a sampling time (10 seconds in the present case). In the present application we deal with process nonlinearities by using a successive linearization which showed to be effective in an experimental application.

The aim of this work is to present a nonlinear control technique which is computationally feasible for industrial implementation. The proposed strategy is a model predictive control technique (MPC) based on a successive linearization of the model via Taylor's series expansion at each sampling time following the Gattu and Zafiriou (1992) idea.

The cost function of the optimization problem is subject to a first order reference system and upper and lower limits in the inputs. In order to satisfy both