Nonlinear Model Predictive Control of a Distillation Column Using Wavenet Based Hammerstein Model

K. Ramesh, A. Hisyam, N. Aziz and S.R. Abd Shukor

***Abstract* - Distillation columns are fairly complex multivariable systems and needs to be controlled close to optimum operating conditions because of economic incentives. Nonlinear Model Predictive Control (NMPC) scheme is one of the best options to be explored for proper control of distillation columns. In the present work, a new wavenet based Hammerstein model NMPC has been developed to control distillation column. An experimentally validated equilibrium model was used as plant model in nonlinear system identification and in NMPC. Two multiple-input-single-output (MISO) wavenet based Hammerstein models are developed to model the dynamics of the distillation column. The nonlinear model parameters were estimated using iterative prediction-error minimization method. The Unscented Kalman Filter (UKF) was used to estimate the state variables in NMPC and the NLP problem was solved using sequential quadratic programming (SQP) method. The closed loop control studies have indicated that the performance of developed NMPC scheme was good in controlling the distillation column.**

***Key words* - *Distillation column*; *Nonlinear model predictive control*; *Sequential quadratic programming*; *Wavenet based Hammerstein model*.**

I. Introduction

Distillation columns are important processing units in petroleum refineries and other chemical processing industries (CPI) for separating feed streams, and for purification of final and intermediate product streams [1]. The separation needs relatively large amount of energy. Close control of distillation column improves the product quality, minimizes energy usage and maximizes the plant throughput and its economy [2]. Most of the industrial distillation columns are currently controlled by multiloop controllers based on linear models. Among the multivariable controllers, Model Predictive Control (MPC) is an important advanced control technique which can be used for difficult multivariable control problems [3]. MPC refers to the class of control algorithms in which dynamic process model is used to predict and optimize the process performance. The current generation of commercially available MPC technology is based on linear dynamic models, and is refereed by the general term linear model predictive control (LMPC). Many processes such as high purity distillation column, multi-grade polymer reactors are sufficiently nonlinear to preclude the successful application of LMPC technology [4]. This has led to the development of nonlinear model based controllers such as nonlinear model predictive control (NMPC) in which more accurate nonlinear model is used for process prediction and optimization.

Many authors have studied the performance of NMPC to control distillation column using different nonlinear models namely semi-rigorous reduced order model [5], NARX model [6], Hammerstein model [7], Recurrent Dynamic Neuron Network (RDNN) model [8] and grouped neural networks (GNN) model [9]. Foss et al. [10] in their case study on process modeling in Germany and Norway concluded that despite the commercially available modeling tools, the effort spent for all kinds of modeling activities is the most time consuming step in an industrial project where model based process engineering techniques are applied.

The NMPC problem formulation involves online computation of a sequence of manipulated inputs which optimize an objective function and satisfy process constraints. The development of NMPC techniques for large scale systems may require problem formulations which exploit the specific structure of the nonlinear model. Finally, NMPC requires online solution of a nonlinear program (NLP) at each iteration. The solution of such NLP problems can be very time consuming, especially for large scale systems. An additional complication is that the optimization problem generally is nonconvex because the nonlinear model equations are posed as constraints [11]. Consequently, NLP solvers designed for convex problems may converge to local minima or even diverge. So it is necessary to find out an improved solution algorithm for nonconvex NLP problems.

The vital parts of the present study are to develop suitable nonlinear model for distillation column, formulate NMPC problem and to find out an efficient optimization algorithm to be used with NMPC. Two multiple-input-single-output

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