Development of Model Based Decoupler for Methanol Water Distillation Column

Lee Q.H.[1,] and Ahmad Z.[2,*]
[1,2]School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia, Seri Ampangan, 14300 NibongTebal, S.P.S., Pulau Pinang, Malaysia

*Corresponding author: chzahmad@eng.usm.my

Abstract: *This paper focused on finding the way to reduce the coupling interaction in the nonlinear multivariable separation methanol water process in distillation column. Model Based Decoupler PID-FANN (Feedforward Artificial Neural Network) was introduced in the distillation control system and compared with the PID-conventional decoupler. It was observed that PID-FANN was better than PID Conventional Decoupler. PID-FANN is superior in handling the loop interaction in MIMO control strategy. This supported by the performance evaluation using statistical analysis where the sum square error (SSE), integral of the time weighted absolute error (ITAE) and integral of the square error (ISE).*

Keywords: Distillation Column, Decoupling Control, Model Based Decoupler, PID-FANN, Robustness, Nonlinear System

1. INTRODUCTION

Distillation column is the most common unit operation and have received a tremendous interest over last decade which provides a very challenging example within the field of process dynamic and process control[1,2]. Distillation control is a challenging endeavour due to the inherent nonlinearity of distillation, multivariable interaction, the non-stationary behaviour and the severity of disturbances. The control of distillation columns has been subjects of frequent studies due to the ill conditioned nature of the distillation process[3]. The integration gives rise to a complex and nonlinear behaviour, and it is difficult to control the system. The strong coupling among control loops often invalidates conventional loop controllers[4]. Multi input multi output processes with strong coupling have attracted much attention of researchers because they are the most often encountered multivariable processes in industrial and chemical practice, and the conventional control system uses proportional integral derivative (PID) controllers to respectively regulate loops, because of their robustness, simplicity and effectiveness for a wide range of operating conditions. These features allow process engineers to operate it in a simple and straight forward manner. But conventional PID controller with fixed parameters can hardly adapt to time varying, nonlinear and coupling problems[5,6].

Therefore, decoupling control was introduced to reduce the coupling problem in the nonlinear system. How to achieve decoupling control of such processes has become a considerable topic in the field of control engineering. The proposed of this research is focused on finding the way to reduce the coupling interaction in the nonlinear multivariable process in binary distillation column.

Proportional Integral Derivative (PID) conventional decoupler has been the most popular control loop feedback mechanism since 1950s, and has been extensively used in controlling industrial processes. In addition to its capabilities, PID conventional decoupler can be implemented easily in industrial control processes. However PID decoupler normally suffer when dealing with highly nonlinear system, compare to single input single output(SISO) system, multi input multi output(MIMO) processes are more complicated in decoupler designing[7]. The main problem is the coupling between the multiple loops. The conventional PID decoupler is hardly efficient to eliminate the coupling in distillation column[8].

In this paper, dynamic or model based decoupler PID FANN was introduced in distillation control system and compared with the PID-conventional decoupler. FANN can approach nonlinear dynamic system with arbitrary accuracy. The objective of this paper is to show that PID FANN decoupler can overcome the coupling problem in distillation column. The paper is organized as follow; section II studies the methodology and modeling of the column. Section III shows the result and discussion for PID-conventional decoupler, PID FANN. Lastly, the conclusion of the paper is given in section IV.

2. METHODOLOGY

Figure.1 shows the flowchart of the model development in distillation column while Figure 2 shows the flow chart of the model based decoupler development of PID conventional, and PID-FANN decoupler. In this paper, a pilot plant distillation column was used to separate methanol and water which consisted of 15 trays, a reboiler and a condenser. A methanol-water binary mixture was used as feed to the column and it was fed at the eighth tray from the bottom which consists of 50 % methanol and 50 wt % water. The temperatures were measured at tray 2, tray 6, tray 10, tray 14 and the bottom and top products stream. The details design data of the column was provided in[9].

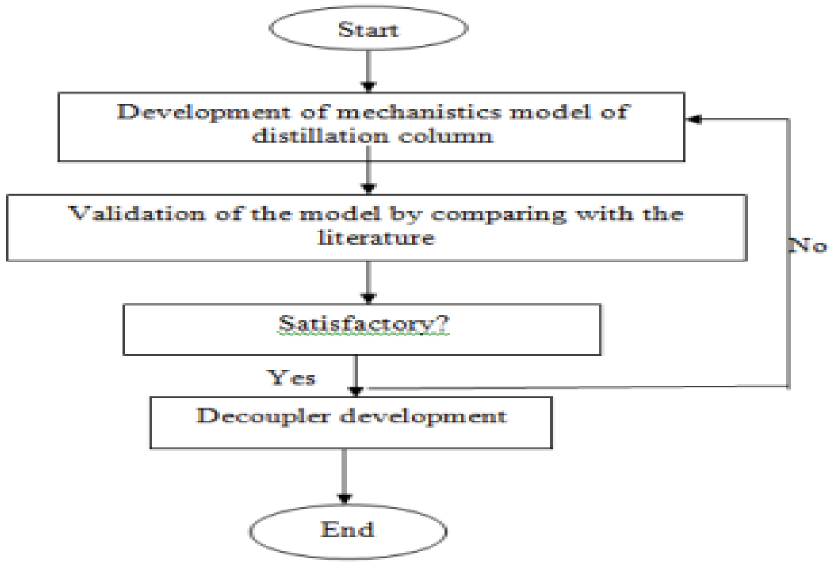

Figure 1: Flowchart of model development distillation column that was carried out for each case study respectively.

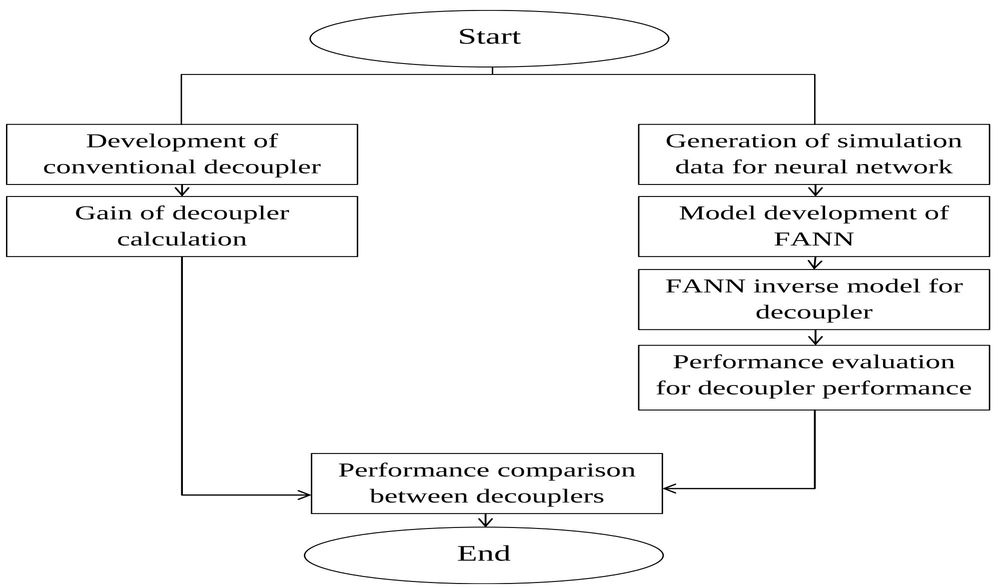

Figure 2: Flowchart of the model based decoupler development for distillation column.

PID-FANN decoupler consists of PID controller and feedforward neural network (FANN) model which use to reduce the loop interaction for dynamic distillation column. In Matlabsimulink, gensim can generate Simulink block for neural network simulation. Gensim(net,st) creates a Simulink system containing a block that simulates neural network net with a sampling time of st.Figure 3 and Figure 4 show inverse of feedforward neural network (FANN) and the simulink block of PID-FANN for this study.

The following Equation (1) shows the form of the inverse FANN model:

$$[u_1(t),u_2(t)]=f^{-1}[y_1(t),y_2(t)] \quad (1)$$

where U(t) is the output of inverse FANN
Y(t) is the input of inverse FANN

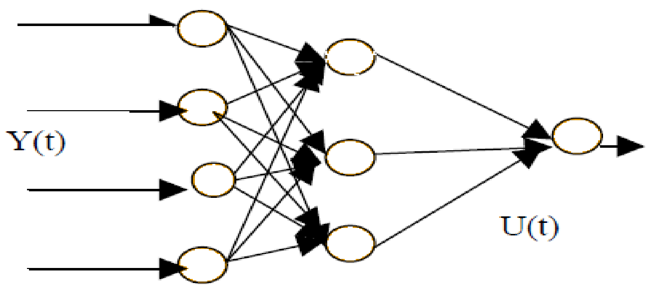

Figure 3: Inverse of Feedforward artificial neural network (FANN) for decoupling

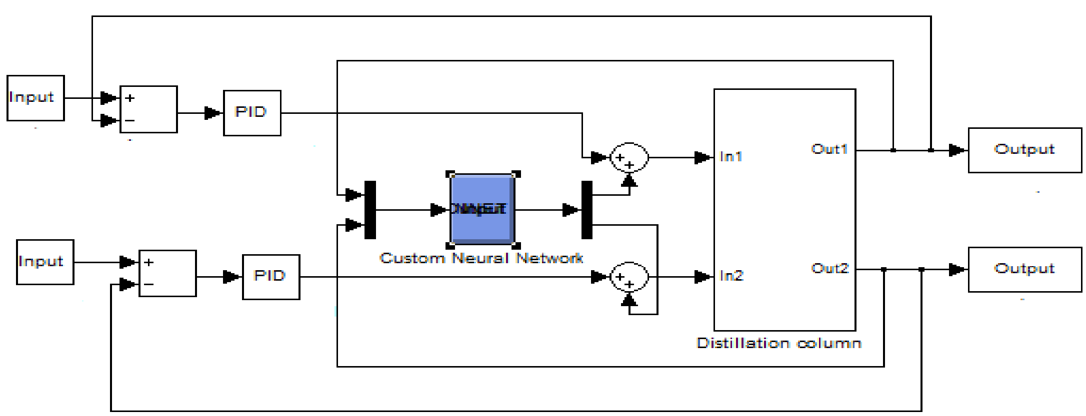

Figure 4: Simulink block of PID-feedforward artificial neural network decoupling

3. RESULTS AND DISCUSSION

Figure 5 shows the response of product composition of methanol (y_1) using PID Controller, conventional PID and PID FANN decoupler. Its shows that by using PID-FANN decoupler, y_1 composition obtain desired result robustness without any spike in loop 1 as compared with the result with the response from conventional PIDdecoupler and PID when y_2 set point in loop 2 was changed from 0.1 to 0.15 in time setting of 50 minutes. In addition, $y_1$was observed with the spike and take some time to settle down when conventional PID decoupler was used. This response was supported by the response of mv_1 shown in Figure 6.

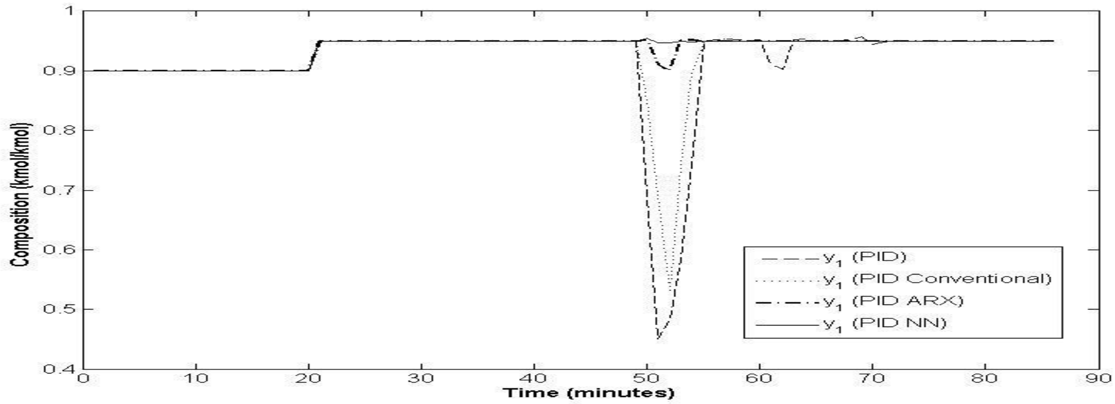

Figure 5: Comparison methanol composition (y_1) by using PID, PID Conventional and PID-FANN

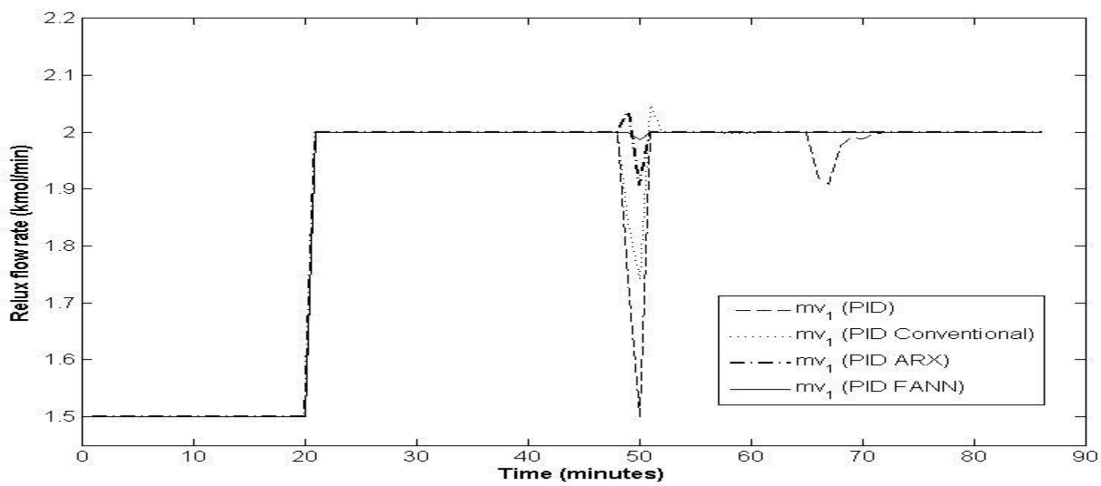

Figure 6: Comparison of mv_1 by using PID, PID Conventional Decoupler, and PID-FANN Decoupler

Figure 7 shows the response of water composition (y_2) using PID Controller, conventional PID decoupler and PID-FANN decoupler. It clearly shown that in PID-FANN decoupler, y_2 composition obtain desired result robustness in loop 2 without any spike as compared with the result by using conventional PID decoupler and PID when y_1 set point changed in loop 1 from 0.9 to 0.95 in time setting of 20 minutes. Morever y_2 has highest spike and take longer settling time when PID Controller was used. This response was supported by the response of mv_2 as shown in Figure 8. The performance of model based decoupler PID-FANN was consistent for each loops where it able to handle the interaction among the loops and consequently improve the performance of y's.

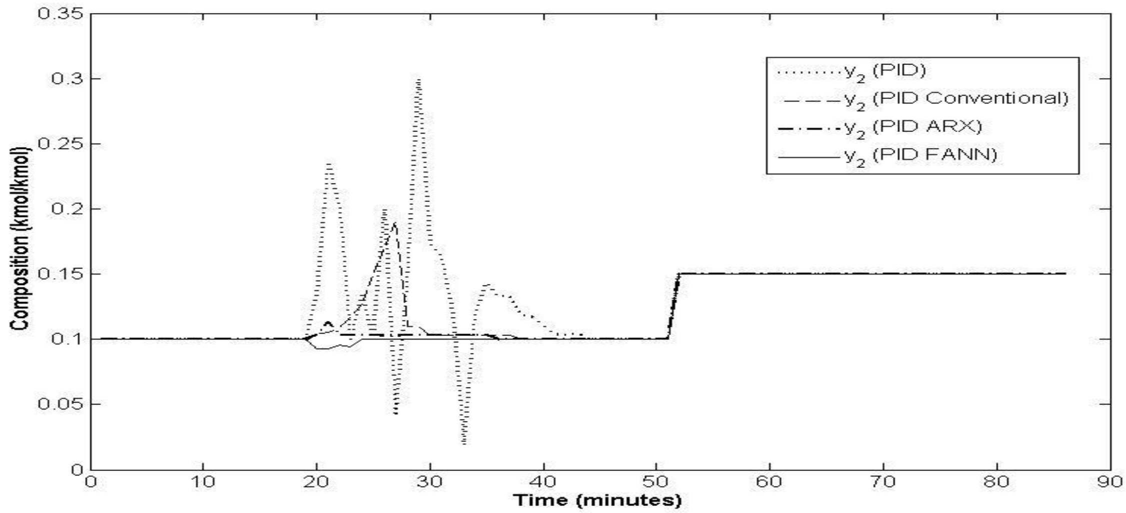

Figure 7: Comparison water (y_2) composition by using PID, PID Conventional and PID-FANN

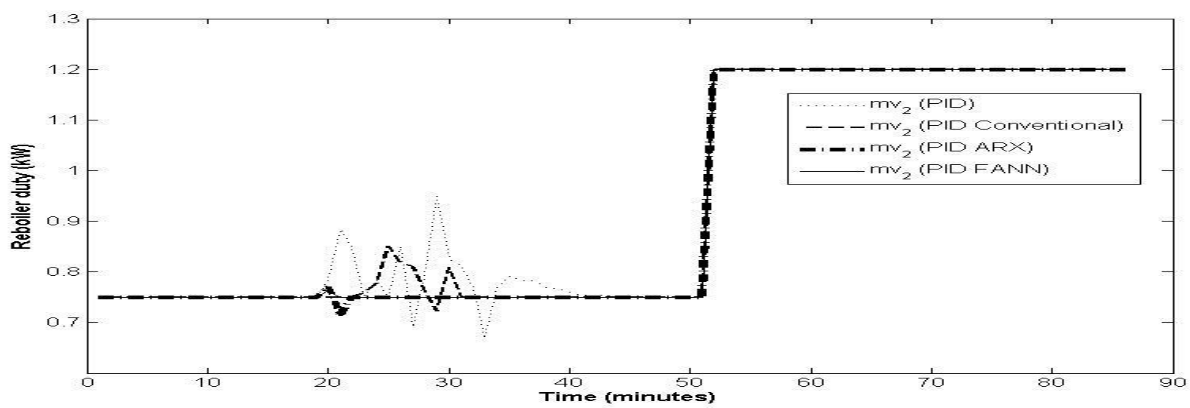

Figure 8: Comparison of mv_2 by using PID, PID Conventional Decoupler and PID-FANN Decoupler

In order to further analyse the result, integral of the square error (ISE), time weighted absolute error (ITAE) and Sum square error (SSE) were used. The integral of the square error (ISE) criterion penalizes large errors, while the integral of the time weighted absolute error (ITAE) criterion penalizes errors that persist for long periods of time. In general, the ITAE is the preferred criterion because it usually results in the most conservative controller settings. By contrast, the ISE criterion provides the most aggressive settings. Sum square error (SSE) was use as statistical analysis tool to determine the performance of PID Conventional decoupler and PID-FANN. Table 1 shows the sum square error (SSE), Table 2 shows the integral of the time weighted absolute error (ITAE) while Table 3 shows the integral of the squared error (ISE) when PID Conventional decouplerand PID-FANN decoupler were used. PID-FANN shown the lowest error in Sum square error (SSE), Integral of the time weighted absolute error (ITAE) and Integral of the square error (ISE) among others decouplers. This is due to PID-FANN had capability in terms of capturing the dynamics of the systems and consequently managed to reduce the loop interaction.

Table 1: Sum square error (SSE) for methanol water distillation column

Type of decoupler	SSE 1 (Loop 1)	SSE 2 (Loop 2)
PID Conventional	0.007591	0.3984
PID-FANN	0.006923	0.03827

Table 2: Integral of the time weighted absolute error (ITAE) for methanol water distillation column

Type of decoupler	ITAE 1 (Loop 1)	ITAE 2 (Loop 2)
PID Conventional	525	2.999e+004
PID-FANN	35.67	201.32

Table 3: Integral of the square error (ISE) for methanol water distillation column

Type of decoupler	ISE 1 (Loop 1)	ISE 2 (Loop 2)
PID Conventional	0.0126	1.258
PID-FANN	0.00516	0.0598

4. CONCLUSIONS

A decoupling control strategy for nonlinear system is developed in this paper based on conventional steady state gain PID decoupler and PID-FANNdecoupler.From the results, it can be concluded that PID-FANN are better in tracking the set point change, achieving minimum steady state error and rejection of loops interaction compared to conventional steady state gain PID decoupler. The results show the effectiveness, satisfactory control performance, stability and strong robustness of the proposed model based decoupler.

5. ACKNOWLEDGEMENTS

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