Comparative Performance Analysis of Fuzzy Logic Based Controller and PID Controller for Multivariable Distillation Column

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Abstract- *The objective of present work is to perform the comparative analysis of the performances of PID Controller and Fuzzy Logic Controller for Distillation Process. This has been done by the use of MATLAB and Simulink and comparison results infer that Fuzzy Logic Controller depicts improved set point tracking and lesser steady state error as compared to conventional PID Controller for the selected process.*

Keywords- Fuzzy Logic Controller, PID Controller, MATLAB/Simulink,

I. INTRODUCTION

The industrial process which has been taken up in this research is the Distillation Column process with severe multivariable interactions. The strong interactions between inputs and outputs are difficult to analyze. It is one of the unit operations of chemical engineering. Fractionating columns are widely used in the chemical process industries where large quantities of liquids have to be distilled.

Distillation is one of the most common and energy-intensive separation processes. In a typical chemical plant, it accounts for about 40% of the total energy consumption.[6] Industrial distillation is typically performed in large, vertical cylindrical columns (as shown in Figure 2) known as "distillation towers" or "distillation columns" with diameters ranging from about 65 centimeters to 6 meters and heights ranging from about 6 meters to 60 meters or more.

There have been many researches in the field of quality comparisons of the Conventional and Fuzzy controllers in the recent times.

Although PID Controller is most widely used in the industry. The popularity of PID Controller can be attributed partly to their functional simplicity and partly to their robust performance. But for a complex process with complex multiple interactions of variables, Fuzzy Logic Controller is more effective control scheme than PID.

Tukaram R. Kumbhar et al. presented FPGA implementation of a Fuzzy Logic Controller using VHDL for temperature control. They compared its functionality and output with the models based on C and Matlab for different input conditions [18].O.P Verma and H. Gupta designed a water bath temperature controller based on fuzzy logic [19].M. R. Sarmasti Emami focused on the applications of fuzzy logic in various chemical processes like combustion process, separation process, in PH control, furnace control, and reactor control, detection of chemical agents and in chemical kinetics [20].

Dharmendra kelde et al. presented image forensic techniques which use natural properties of image to determine forgery or detect tampering [3]. Rahul et al. introduced an agent based modelling and simulation (ABMS) approach for modelling a fuzzy controller for highway entrance ramp monitoring and controlling. They designed a controller considering varying levels of congestion, a downstream control area, changing occupancy levels, upstream flows and a distributed detector array in its rule base [4].

P. Singhala et al. gave the design of a low cost temperature control system using fuzzy logic where the Fuzzy controller calculates error between set point value and current value which is considered as input function of fuzzy logic. The fuzzification process calculates it membership. The Defuzzification process is made to calculate the PWM actual value for heater and fan which is output of the temperature control system [13].

Plant Model

The case study that has been taken up in this project is the Wood Berry distillation column to separate a mix of methanol and water. The goal is to control the distillate composition xD and bottoms composition xB. The two manipulated variables are reflux R ,paired with xD and vapour boilup V, paired with xB. The considered plant model for controller design is presented below[21],

$$\begin{bmatrix} x_D \\ x_B \end{bmatrix} = \begin{bmatrix} \frac{12.8\,e^{-s}}{16.7\,s+1} & \frac{-18.9\,e^{-3s}}{21\,s+1} \\ \frac{6.6\,e^{-7s}}{10.9\,s+1} & \frac{-19.4\,e^{-3s}}{14.4\,s+1} \end{bmatrix} \begin{bmatrix} R \\ V \end{bmatrix}$$

Every element of the transfer matrix of this plant has a first order plus dead time (FOPDT) form.

PID Controllers

PID controller represents the simplest form of controller that utilizes Derivative and Integral operations on the system. PID controllers have several important functions. They have the ability to eliminate steady-state error through the integral action, and they can cope up with actuator saturation, if used with anti-windup. The simplest form of PID controller output can be represented by equation:

$$CO = K_p e + Ki\int e\,dt + Kd\frac{de}{dt} + bias$$

where, Kp=Proportional constant,
Ki=Integral time constant,
Kd=Derivative time constant,
e=error,
CO=Controller output

Fuzzy Logic Controllers

Fuzzy logic emulates the human reasoning and logical thinking in a systematic and mathematical way. It provides an instinctive or perspective way to implement decision making, diagnosis and implementation of control system.

FLC differs from conventional control methods it incorporates a simple rule-based approach to solve the control problem rather than modeling the system mathematically. An FLC is designed by representing the input and the output of the controller using membership functions (MFs) within the range of their possible values (universe of discourse), and mapping the input into the output using the rules. Depending on the input, the fuzzy controller gives an output according to both the membership functions and rules.

II. DESIGN CONSIDERATIONS

[1] PID Control

The Simulink model of the control system based on PID controller for the considered distillation column plant is presented in Fig 1.

The input to the the PID controller1 is error in distillate composition xD and its output is the reflux R.The input to the PID controller 2 is the error in bottoms composition xB and its output is the vapour boilup V.The step responses of this controller for xD and xB are depicted in Fig.3 and Fig. 4 showing poor setpoint tracking with very large steady state error.

The responses reveal that this process is so complex in nature that it can not be controlled by a conventional PID controller.

[2] Fuzzy Control

The Simulink model of the control system based on Fuzzy controller for the considered distillation column plant is presented in Fig 2. The two inputs to the the Fuzzy controller are the error in distillate composition xD and the error in bottoms composition xB.The two outputs are the reflux R and the vapour boilup V.The membership functions used by the fuzzy controller for inputs and outputs are depicted in Fig. 5, 6, 7 and 8

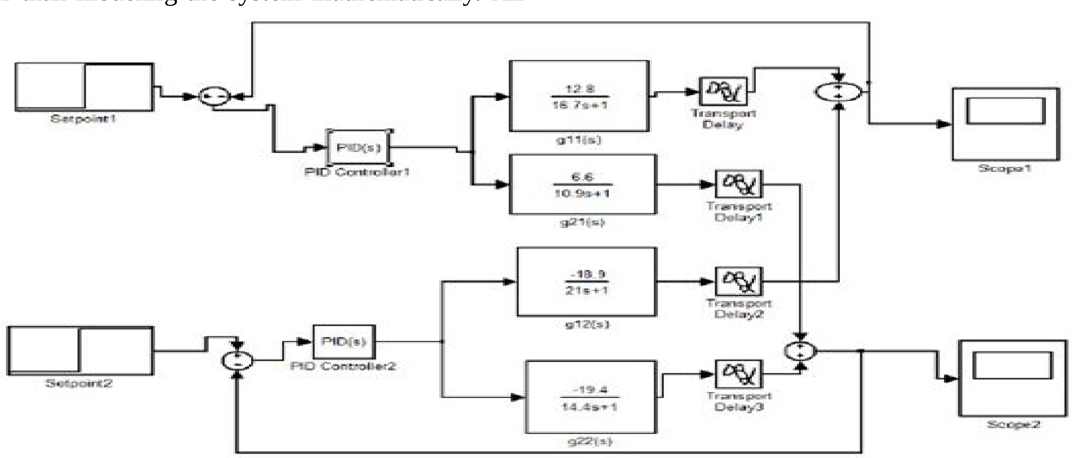

Fig.1 PID controller for distillation colum

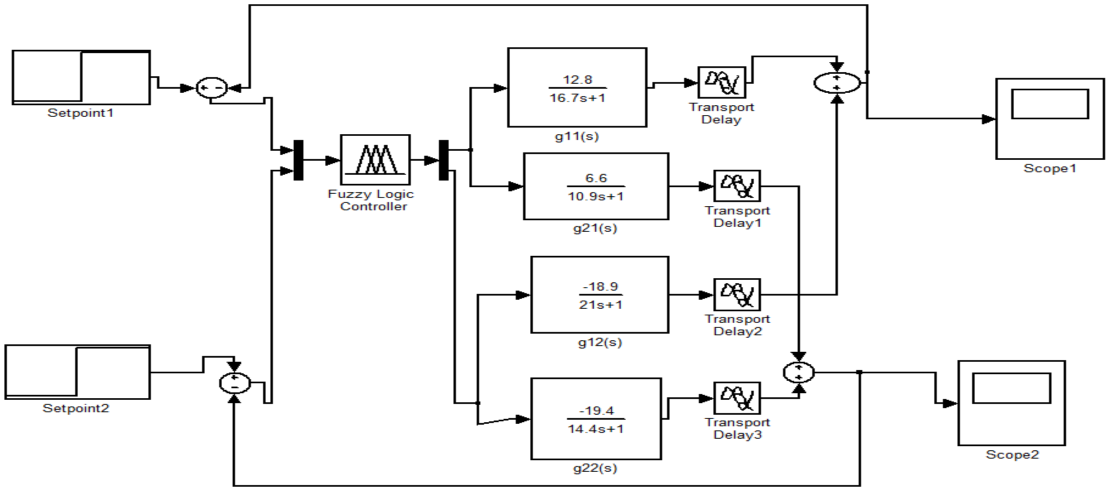

Fig.2 Fuzzy controller for distillation column

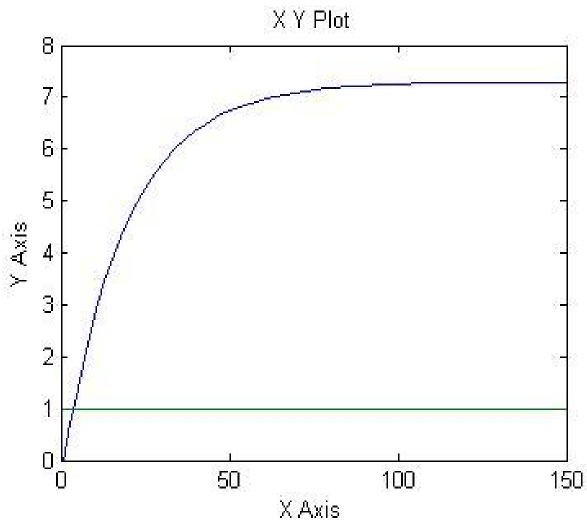

Fig.3 Step response of PID controller for x_D

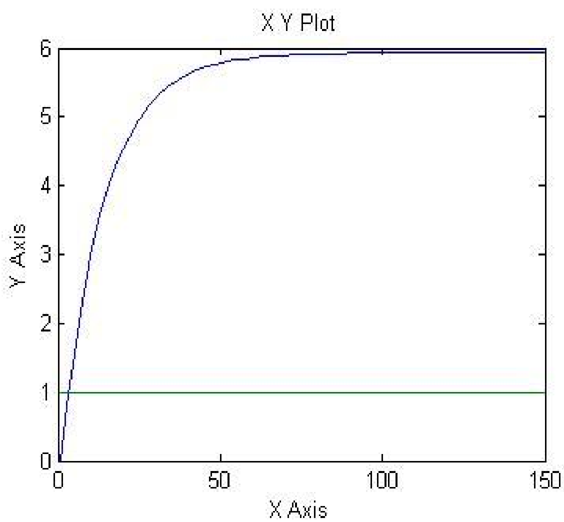

Fig.4 Step response of PID controller for x_B

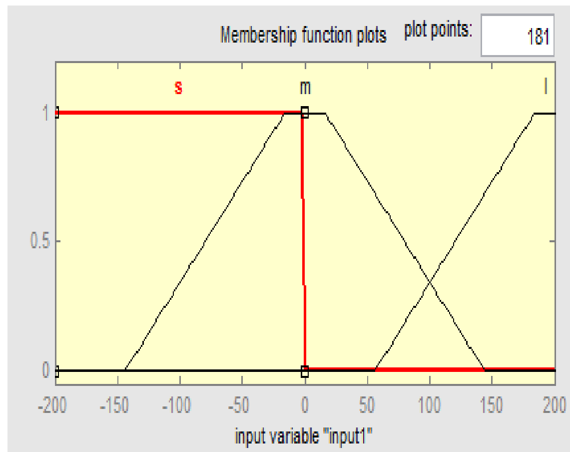

Fig 5 Membership functions for x_D error

In these plots of membership functions ‘s’ stands for small.’m’ for medium and ‘l’ for large.These functions have been optimized by error and trial method.

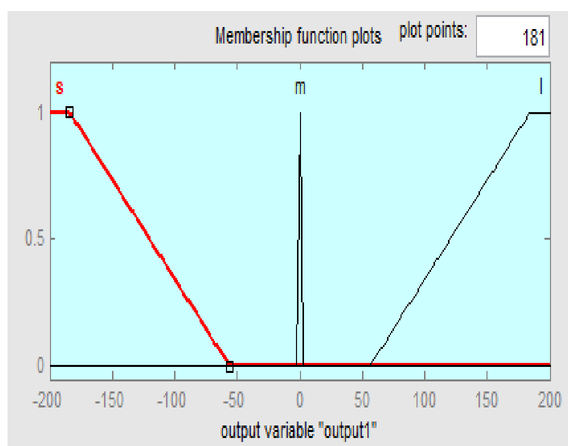

Fig 6 Membership functions for reflux R

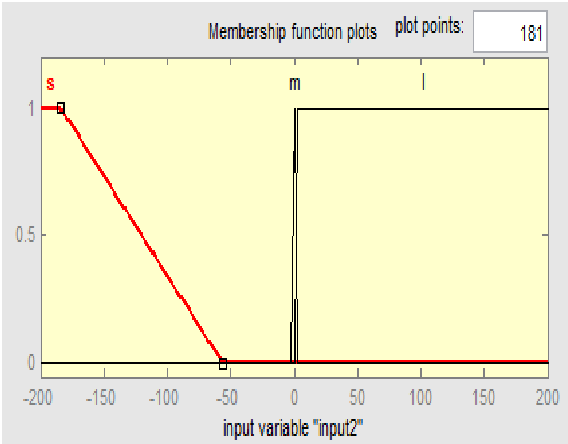

Fig 7 Membership functions for x_B error

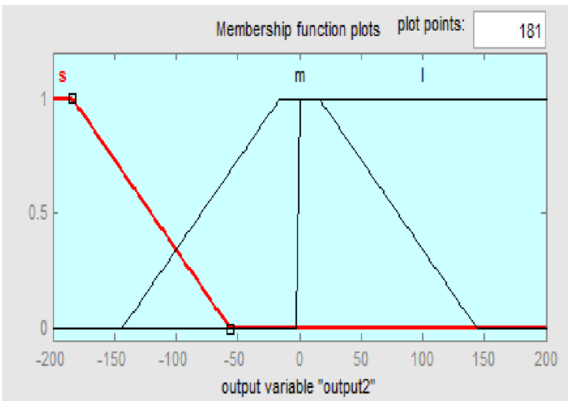

Fig 8 Membership functions of vapour boilup V

Now,the 9 rules which have been fed in the knowledge base of the fuzzy inference system are as follows:

(i) If x_D error is small and x_B error is small then reflux R is small and vapour boilup V is large.

(ii) If x_D error is small and x_B error is medium then reflux R is small and vapour boilup V is medium.

(iii) If x_D error is small and x_B error is large then reflux R is small and vapour boilup V is small.

(iv) If x_D error is medium and x_B error small is then reflux R is medium and vapour boilup V is large.

(v) If x_D error is medium and x_B error is medium then reflux R is medium and vapour boilup V is medium.

(vi) If x_D error is medium and x_B error is large then reflux R is medium and vapour boilup V is small.

(vii) If x_D error is large and x_B error is small then reflux R is large and vapour boilup V is large.

(viii) If x_D error is large and x_B error is medium then reflux R is large and vapour boilup V is medium.

(ix) If x_D error is large and x_B error is large then reflux R is large and vapour boilup V is small.

The step responses of this controller for x_D and x_B are depicted in Fig. 9 and 10 showing excellent setpoint tracking as compared with PID controllers.

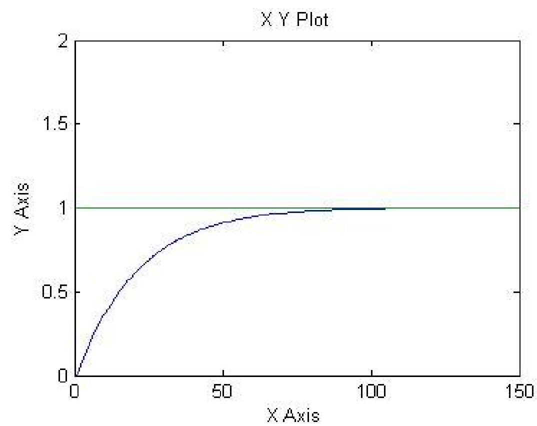

Fig. 9 Step response of fuzzy controller for x_D

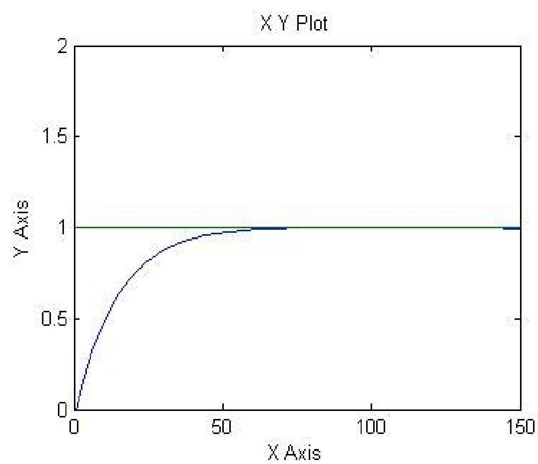

Fig.10 Step response of fuzzy controller for x_B

III. CONCLUSION

Soft computing techniques are much more effective as compared to conventional techniques. Mamdani fuzzy logic approach can be easily applied to the multiple inputs multiple outputs fuzzy distillation composition controller and it gives very effective results then PID controllers.

REFERENCES

[1] M. Bazregar, F. Piltan, A. Nabaee and M. M Ebrahimi," Parallel Soft Computing Control Optimization Algorithm for Uncertainty Dynamic

System", International Journal of Advanced Science and Technology vol. 51, February, 2013.

[2] P.Melin and O. Castillo," Soft Computing for Intelligent Control of Nonlinear Dynamical Systems", International Journal of Computational Cognition vol. 2, no. 1, March 2004, pp. 45–78.

[3] D.Kelde, D.Nagde ,R.Patel and P. Pawar ," Information Forensic Application using Soft Computing Techniques", International Journal of Computer Science and Information Technologies, vol. 4 (1) , 2013,pp. 69 – 72.

[4] R.Misra, A.Patel and R.Singh,"Highway Entrance Ramp Monitoring and Control Using Soft Computing Techniques", International Journal on Recent and Innovation Trends in Computing and Communication ,vol.1, issue -4 ,pp. 332 – 334.

[5] S. N. Singh, V. N. Tigga and S. Mishra," Rural Home Energy Management by Soft Computing Fuzzy Control Models for a Photovoltaic System in India", vol. 2 (3) , March 2010.

[6] K.Tsagkaris, P.Demestichas, A.Vasilakos and M.Theologou, "Power Control in CDMA networks based on soft computing methods", Springer, February 2005, vol. 9, issue- 2, pp 81- 87.

[7] P.P.Bonissone and K.Goebel,"When will it break? A Hybrid Soft Computing Model to Predict Time-to-Break Margins in Paper Machines" Proceedings of SPIE 47th Annual Meeting, International Symposium on Optical Science and Technology, vol. 4787, 2002, pp. 53-64.

[8] K.Owa1, S.Sharma and R.Sutton, " Nonlinear Model Predictive Control Strategy Based on Soft Computing Approaches and Real Time Implementation on a Coupled-Tank System", International Journal of Advanced Research in Computer Science and Software Engineering vol.3, issue -5, May 2013.

[9] F.Baig et al.,"Design and Simulation of Fuzzy Logic Based Elid Grinding Control System", International Journal of Advanced Technology & Engineering Research.

[10] J. Zhao, F. Yao ,H.Wang, Y.Mi and Y.Wang, "Research on Application of Genetic Algorithm in Optimization Design of Transformer",Electric Utility Deregulation and Restructuring and PowerTechnologies,4th International Conference (IEEE),2011,pp. 955 -958.

[11] M. Abbas, M. Saleem Khan and N. Ali,"Fuzzy Logic Based Hydro-Electric Power Dam Control System", International Journal of Scientific & Engineering Research ,vol. 2, issue- 6, June- 2011.

[12] D. A. Ahmad, V. Redhu and U. Gupta,"Liquid Level Control by Using Fuzzy Logic Controller", International Journal of Advances in Engineering & Technology, July 2012.