International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.6, No.1, pp 800-806, Jan-March 2014

FLC Based Bubble Cap Distillation Column Composition Control

Guru.R, Arumugam.A*, Balaji.V.S, Balasubramanian.G, Ramkumar.K

School of Electrical and electronics, SASTRA University, Thanjavur, India.

***School of Chemical & Biotechnology, SASTRA University, Thanjavur, India.**

***Corres.author: aruchemxl@scbt.sastra.edu**

Abstract: This paper projected fuzzy logic control based intention has been protruded for a methanol water arrangement of bubble cap distillation column. In this distillation column is extremely non- linear and conventional control is controlling the composition is a difficult task. Fuzzy inference system (FIS) and fuzzy rule based system (FRBS) is designed to govern the manipulate variable (reflux ratio) to get the favored methanol (product composition) for a distillation column.

Keywords: Distillation column, least square algorithm, Fuzzy logic control.

Introduction

The principle of distillation column is partition and purification of liquid in industries. Most major key factor in the process plant is the distillation system. Distillation or fraction column is the practice of discerning more than two mixable liquids based on the liquids boiling point. Invariable product composition is essential to the political economy production columns[4]. Continuing an invariant efficiency in a column is really significant and that goal of key for the more beneficial control[5].

Fuzzy logic, neural network and fuzzy- neuro are mostly employed to construct the database[1]. Database can be contain rules set, a pattern, topological figures, associating input and output of the system[2]. The database was considerably demonstrated ANN model and it can be described and represent the system operation (input) and product quality (output) relations[3].A comprehensive classic design and FLC implementation can be established in literature[6-8]. An Essam Natsheh[11] experimental comparisons result FLC performance is good compare to the PID. Zhen-Yu Zhao[12] has formulated a fuzzy gain programming scheme to find out PID parameters. Mamdani type model[13] has its firm in its familiarity to fuzzy reasoning Zadeh’s method and human being like internal representation of policy.

This paper optional to fuzzy based composition control of fractional column by varying reflex ratio (R) .The process of distillation is highly non-linear. Any critical changes in process PID do not maintain composition accuracy. Those in this critical situation FLC maintain methanol composition accuracy.

Process Discription and Modeling

A distillation column comprises perpendicular column(fig1) where trays are used the component separations, a Reboiler used to supply heat energy for the necessity evaporation from the Stripping Section and condenser condensate methanol vapors, reflex drum carried the liquid and reflex can be enter back to the top of the column and distillate methanol collect to column top.

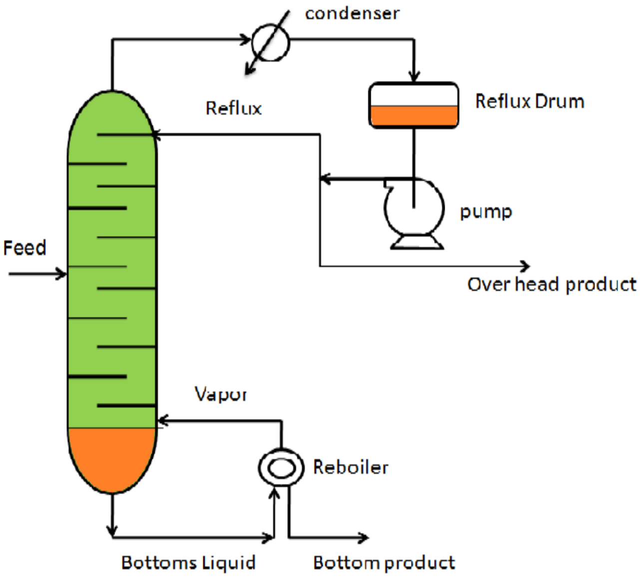

Fig.1. distillation structure

Least square method is used for altering and generalizing the data using a smoothed and linear representation of the natural data. In this least square method is used to the normalizing the practical non-linear data in to linear data. In this method is widely used to calculate numerical data's of the parameters to set a data for fit a function. Consider the set of data graphical representation below fig.2.

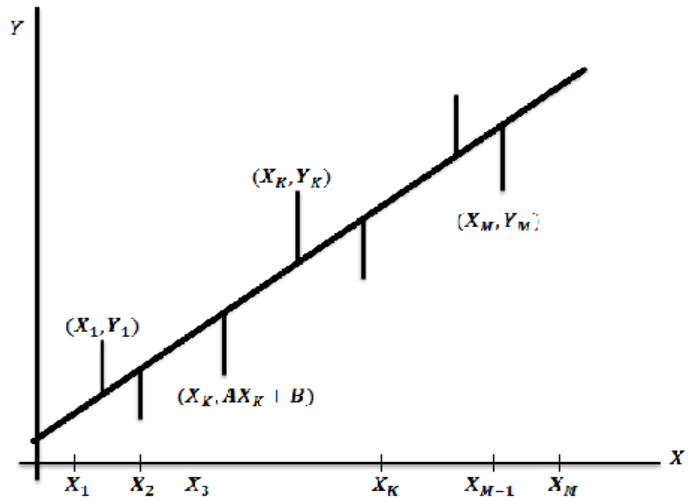

Fig.2.grapical representation of least square

In this graphical representation (X_1, Y_1) to (X_M, Y_M) be the input and output data, Xk and Yk are the general co-ordinates and it is desired to make these data in this form of straight-line equation. There are many straight lines are drawn through the practical data. Best straight line or linear line is nothing to the total of the squares of the differences is minimized. In this sum of the squares of the differences is minimize in this criterion is known as least squares criterion (E), and more specificity in this case, linear least square criterion. For all n points

$$E = \sum_{i=1}^{i=n} (a_0 + a_1 x_i - y_i)^2$$

In this least square algorithm,

$$y(k) + a_1\, y(k-1) + a_2\, y(k-2) = b_1 u(k) + b_2\, u(k-1)$$

Input and output sequences are u (-1), u (0), u (1)… y (0), y (1), y (2) …

Estimate to find the system parameters a1, a2, b1 and b2 and the initial condition is y (-1) and (N+1) measurement. That is k=0, 1, 2…N

$$y(0) + a_1\, y(-1) + a_2 y(-2) = b_1\, u(-1) + b_2\, u(0)$$

$$y(1) + a_1\, y(0) + a_2\, y(-1) = b_1 u(0) + b_2\, u(1)$$

$$y(N) + a_1\, y(N-1) + a_2 y(N-2) = b_1\, u(N-1) + b_2\, u(N)$$

$$\Theta = \begin{pmatrix} a_1 \\ a_2 \\ b_1 \\ b_2 \end{pmatrix} \quad y = \begin{pmatrix} y_1 \\ \vdots \\ y(n) \end{pmatrix}$$

$$\phi = \begin{pmatrix} \phi^T(0) \\ \phi^T(1) \\ \vdots \\ \phi^T(N-1) \end{pmatrix} = \begin{pmatrix} -y(0) & u(0) \\ -y(1) & u(1) \\ \vdots & \vdots \\ -y(N-1) & u(N-1) \end{pmatrix}$$

$$Y = \phi\Theta$$

Inputs and outputs sequence necessitate error due to measured noise then for all input and output pair $\{u(k)\,,\ \ y(k)\}$ exists an error e (k).

$$y(k) + a_1 y(k-1) = b_1 u(k-1) + e(k)$$

Where k varies from 0 to N

$$y = \Phi\Theta + e$$

Where e is the N-dimensional error vectors

Performance measure (J) of the system is

$$J = e^T e = \sum_{k=1}^{N} e^2\,(k)$$

$$J = (y - \phi\Theta)^2 (y - \phi\Theta)$$

Differentiate equation

$$\phi^T \phi\Theta = \phi^T y$$

$$\Theta = (\phi^T \Phi)^{-1} \Phi^T Y$$

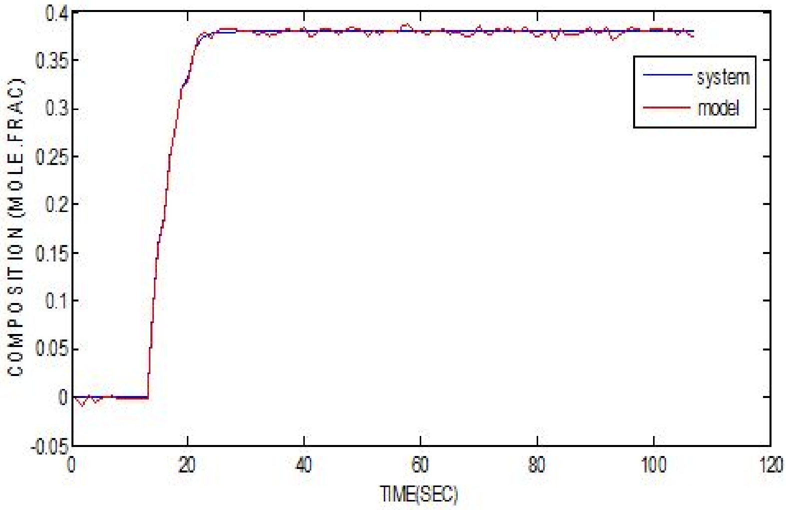

Fig.3.model validation

Controller

Mamdani-type fuzzy control system consider as two important elements :(1) fuzzy inference method, which is the system inputs are scalar values, its implement the procedure to be utilized to the system inputs and to acquire the output. (2) Fuzzy knowledge base system method. It constitutes the knowledge around the problem being solved as shown in fig. 3.

The knowledge based fuzzy system (KBFS) contains IF-THEN rules[9, 10] compiled of linguistic variables. The fuzzy set is defined semantics linguistic labels; all rules are included in the knowledge base, thus easily read the system for humanity. The basic fuzzy structure consists of two dissimilar component, fuzzy rule and membership function. Fuzzy rules primarily depending on the sequent structure instantly impacted through the output. Aggregation of r linguistic IF-THEN rule in the Mamdani type as follows;

$$IF\ \ a_1 \text{ is } \tilde{A}_1^m \text{ and } a_2 \text{ is } \tilde{A}_2^m \text{ THEN } y^m \text{ is } B^m \qquad \text{for } m = 1,2, \dots \dots r$$

$\tilde{A}_1^m$ and $\tilde{A}_2^m$ Are fuzzy sets constituting the m^{th} antecedent pairs, B^m is the fuzzy set m^{th} consequent. Where, ai and y let to the linguistic input and output variables, and with $\tilde{A}_i$ and B the linguistic variables linked with fuzzy sets defining their meaning. The fuzzy sets are defined in several general of discourse

$U_1, \dots \dots, U_m, V$, and are qualified membership function:

$$\mu U_m(B):\ \mu U_m(V)\ \rightarrow [0\ ,\ 1]\ , \qquad m = 1, \dots \dots \dots r$$

Triangular shaped fuzzy membership strong fuzzy partition (SFP) consider fig (4).

Dual input single output fuzzy inference max-min method contains the scalar values of inputs a1 and a2 are crisp values that is delta functions. The rule based fuzzy system is membership function for the inputs a1and a2 respectively. It will described by

$$\mu(a_1) = \delta(a_1 - input(i)) = \begin{cases} 1, & a_1 = input(i) \\ 0\ , & otherwise \end{cases}$$

$$\mu(a_2) = \delta(a_2 - input(i)) = \begin{cases} 1, & a_2 = input(j) \\ 0, & otherwise \end{cases}$$

Mamdani implication inference method is

$$\mu_R\ (x,y) = \min\left[\mu_{\tilde{A}_1}(x), \mu_{\tilde{A}_2}(y)\right]$$

Disjunctive rules set, the aggregated output for the r rules given by

$$\mu B^{m}(y) = {}^{max}_{m}[\min[\mu_{\tilde{A}_1^m}(\text{input}(i)), \mu\tilde{A}_2^m(\mathit{input}(j))]] \qquad m = 1, 2, \ldots, r$$

Dual input single output max-product or correlation-product implication method for rules of disjunctive, the aggregated output for the r rules given by

$$\mu B^{m}(y) = {}^{max}_{m}[\mu_{\tilde{A}_1^m}(\text{input}(i)) \,.\, \mu\tilde{A}_2^m(\mathit{input}(j))]] \qquad m = 1, 2, \ldots\ldots, r$$

The aggregated consequent for the disjunctive rules set and a defuzzified value of y.

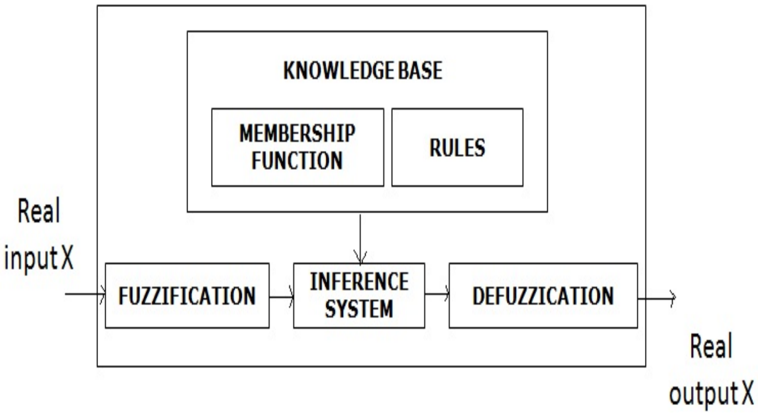

Fig.3.fuzzy rule based system Mamdani-type general structure

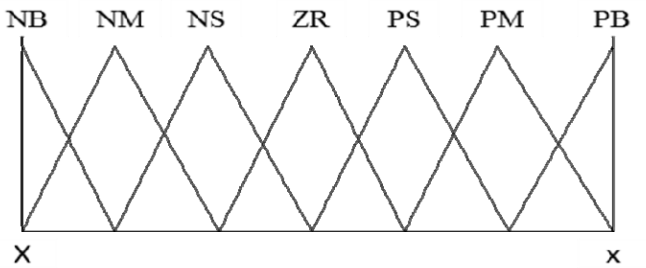

Fig.4.seven linguistic triangular membership function

Result and Discussion

The fuzzy logic control is containing fuzzy rule base and fuzzification, inference system and defuzzification.This FRBS (fuzzy rule based system) using maxima method. Tuning the PID controller using Ziegler- Nichols (Z-N). Simultaneously the PID and FLC (Fuzzy Logic Controller) controllers for the column documented using MATLAB and receiving the result. The fig (5) is the PID and FLC response graph and the fig (6), fig (7) is different step disturbance response.

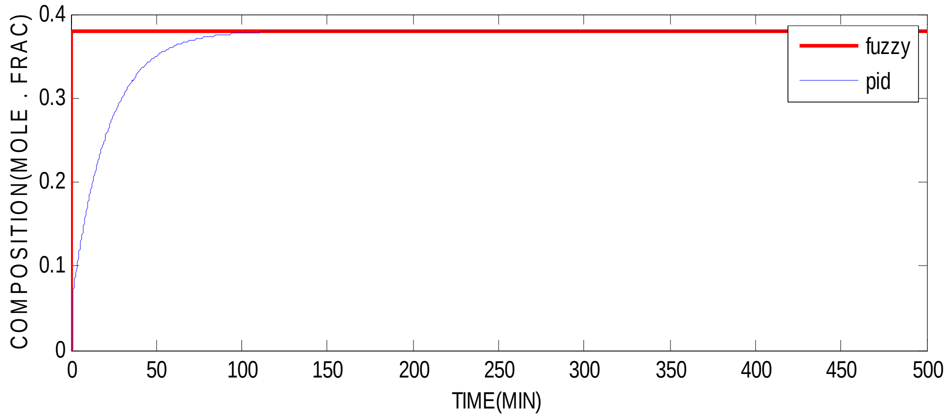

Fig.5. PID and FLC response

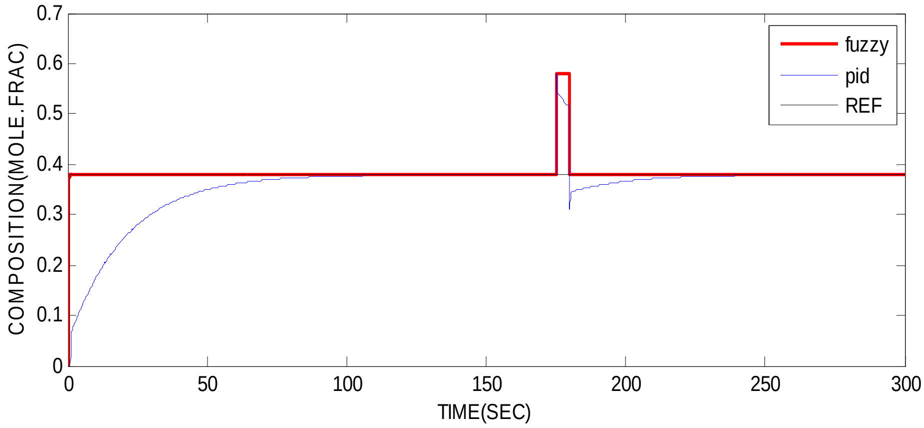

Fig.6.ositive step disturbance response

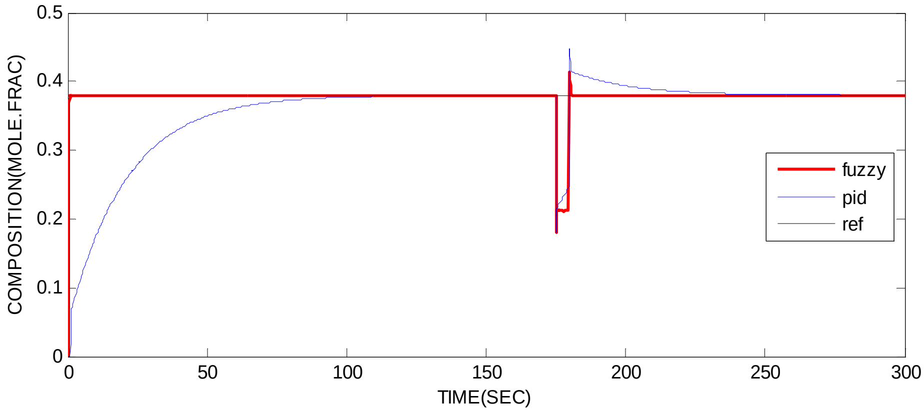

Fig. 7.negative step disturbance response

Table I: IAE, ISE, ITAE, Error Comparision Table

	IAE	ISE	ITAE
FUZZY Controller	3.1967	1.0232	2.5135e^+03
PID Controller	27.1071	4.8032	79.1085

Table II: Settling Time Comparision Table

	Settling Time
FUZZY Controller	82.26
PID Controller	179.52

Conclusion

Methanol Composition control of bubble cap distillation column using fuzzy logic control(FLC) are procurable.comparision of conventional PID and fuzzy logic controller(FLC), most beneficial part its supremacy. The fuzzy logic control leads lower ISE, IAE and ITAE then the PID controller. Then the response of the functioning can be equated, the FLC gives well performance compared to PID and it's used for several non-linear processes, as a controller itself or an enrichment of conventional control.

References

1. Lababidi, H.M.S. & Christopher, G.J.B (2003). Web-based expert system for food dryer selection. Computer and chemical engineering, 27.997-1009.
2. Jackson. (1999). Introduction to expert system. England: Addison Wesley Longman
3. An expert system design for a crude oil distillation column with neural networks model and the process optimization using genetic algorithm framework. S.Motlaghi,F.Jalali, M. Nili Ahmadabadi Expert system with Applications 35 (2008) 1540-1545
4. Fuzzy Rule- Based controller for Binary Distillation Column , Amit Kumar Sing , Barjeev Tyagi ,Vishal Kumar
5. Ryskamp, C.J., "New strategy improves dual composition column control", hydro.Proc.59, 51 (1980)
6. J.Jantzen, "Design of Fuzzy Controllers", Technical University of Denmark: Department of Automation, Technical report number 98-E864, 19 Aug 1988, URL: http//WWW.iau.dtu.dk/
7. C.C. Lee, "Fuzzy Logic in Control System: Fuzzy LOGIC Controller-Part 1", IEEE Transaction on System, Man, and Cybernetics, Vol.20, No.2, pp.404-418, 1990.
8. R.Isermann, "On Fuzzy Logic Application for Automatic Control, Supervision, and Fault Diagnosis", IEEE Transaction on System, Man, and Cybernetics. Part A: System and Humans, Vol. SMC-28, No.2, pp.221-235, 1988
9. Comparison between conventional and Fuzzy Logic PID Controller for Controlling DC Motors. Essam Natsheh and Khalid A.Buragga
10. Mcayoy, T.J. and L.Hsie," Comparison of Single –Loop and QDMC Based Control of crude Oil Distillation Towers", University of Maryland, MD (1990)
11. Mamdani, E.H.Application of fuzzy algorithm for control of simple dynamic plant. Proc. IEE, 1974, 121(12), 1585-1588
12. Fantasize, C.Bases of fuzzy control. In Proceedings of International Summer School on FLC Advances in Methodology, Ferrara 1, 1988, pp. 1-34
13. R. R. Yager and D. P. Filev, "Essentials of Fuzzy Modeling and Control", John Wiley & Sons, 1994.

*****