Fuzzy Based composition Control of Distillation Column

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***ABSTRACT*-This paper proposed a control scheme based on fuzzy logic for a methanol - water system of bubble cap distillation column. Fuzzy rule base and Inference System of fuzzy (FIS) is planned to regulate the reflux ratio (manipulated variable) to obtain the preferred product composition (methanol) for a distillation column. Comparisons are made with conventional controller and the results confirmed the potentials of the proposed strategy of fuzzy control**.

Keywords: Distillation column, Fuzzy logic controller, PID

I. INTRODUCTION

The purpose of the distillation column is separation and purification of liquids in industries. Most significant key element in the process plant is the distillation system. Distillation column or fraction column is the procedure of distinguishing more than two miscible liquids based on the liquids boiling point. lately, fuzzy logic control (FLC) scheme is mostly preferred close to formal organize techniques [1] [2] and more of its efficient appoints are instanced [3] [4] [5].A conventional classic design and FLC implementation can be demonstrated in literature [6] [7] [8].Experimental comparison results FLC is perfume improve then the PID controller and has formulated a fuzzy gain programming scheme to find out PID parameters [9] [10]. Mamdani type model [11] [12] has its firm in its familiarity to fuzzy reasoning Zadeh's method and a human being like internal representation of policy.

This paper proposed a fuzzy based composition control of fractional column by varying reflex ratio. The process of distillation is highly non-linear. Any critical change in process PID does not maintain composition accuracy. So that in this critical situation FLC maintains the accuracy of methanol composition.

II. PROCESS DISCRIPTION AND MODELING

The distillation column feed tank is carrying methanol and water mixtures. During the process the methanol water mixture can be heated at 95^{o}c. The light weight molecules rise to the top of the column and weighty components moves downstairs to the column. The vapor increases towards the top of the tower are enhanced to condense. The condensed the fumes into fluid and it flows into the recipient or accumulator, which its reservoir for fluids. A component of the fluid from the recipient and sent back to the tower is called reflux. The reflux and upcoming vapors contact with plates. Few of the components withdrawn to the top of a column are called distillate.

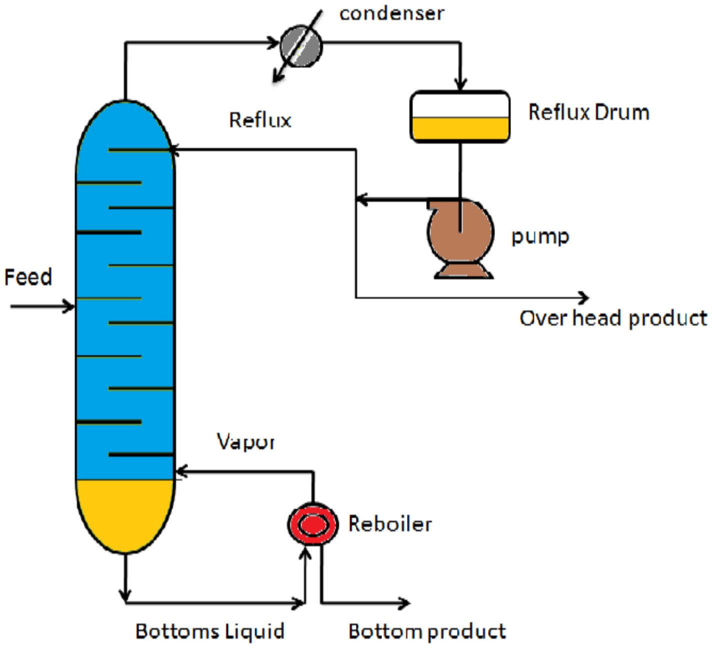

Fig. 1 .Distillation column structure

In this process, reflex ratio is manipulated and composition of methanol is controlled while temperature parameter is kept constant and the composition of the overhead product can be traced out. The model of the process is obtained by applying step response method, the response of composition in terms of mole fraction is obtained and from the response shown in Fig 2, the parameters required for finding the model are obtained. The models are found out by the sunderesan and kumaraswamy method are close to the real time response [13] and the model is identified as first order plus delay time (FOPDT) process and it is given as,

$$G(S) = \frac{Ke^{-\theta s}}{\tau s+1} \tag{1}$$

The model is validated by giving a step input and the simulated curves are obtained. The comparison of real time and simulation response curve for the model is shown inFig.3. From the graphs, it is clear that the model response curve obtained is closer to that of the real time response curve for the four model.

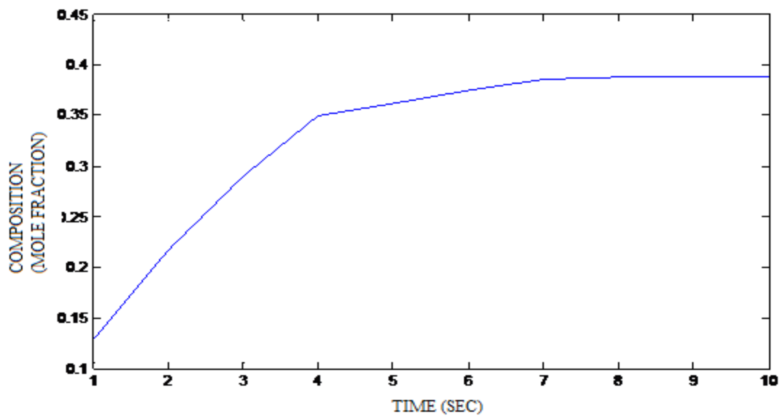

Fig2. Process reaction curve

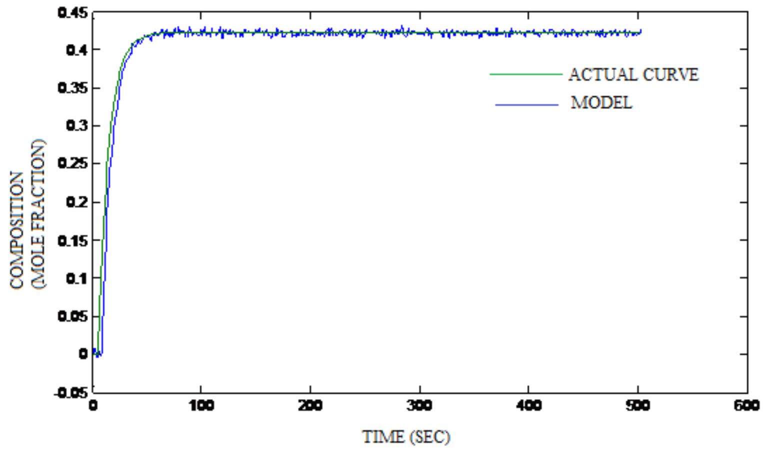

Fig 3.Model validation

TABLE: I.PID TUNING VALUES

KP	0.6
□i	0.9
□d	0.001

III. FUZZY CONTROLLER DESIGN

The schematic diagram of a fuzzy based control system as depicted in Fig.4.It consists of fuzzification, knowledge base, defuzzification, Inference system. The following procedure is followed for design of fuzzy controller.

- Inputs of fuzzification process are taken as change in error and error.
- Rule base is formed using Five linguistic variables
- Rules are manipulated from the rule base.

The knowledge based fuzzy system contains IF-THEN rules [10], [11] 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 components, fuzzy rule and membership function. Fuzzy rules primarily contingent on the consequential arrangement straightly impacted through the outputs. Aggregation of being a linguistic IF-THEN rule in the Mamdani type as follows;

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

$\tilde{A}_1^{m}$ and $\tilde{A}_2^{m}$ Are fuzzy sets constituted the m^{th}Antecedent pairs,B^{m} is the fuzzy set m^{th}Consequentt. Where, y and ai being the linguistic output and input variables, with $\tilde{A}_i$ and B the linguistic label linked with fuzzy set defining their denotation. The fuzzy set is defined in several general of discourse $U_1, \ldots \ldots, U_m, V$, are qualified membership functions:

$$\mu U_m(B):\ \mu U_m(V)\ \ \rightarrow [0,1]\,, \qquad m = 1, \ldots\ldots\ldots r \tag{3}$$

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

$$\mu(a_1) = \delta\big(a_1 - input(i)\big) = \begin{cases} 1, & a_{1=}\ input(i) \\ 0\,, & otherwise \end{cases} \tag{4}$$

$$\mu(a_2) = \delta\big(a_2 - input(i)\big) = \begin{cases} 1, & a_{2=}\ input(j) \\ 0, & otherwise \end{cases} \tag{5}$$

Mamdani implication inference method is

$$\mu_R\,(x,y) = \min\left[\mu_{\tilde{A}_1}(x), \mu_{\tilde{A}_2}\,(y)\right] \tag{6}$$

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

$$\mu^{m}(y) = {}^{max}_{\ \ m}[\ \min\,[\mu_{\tilde{A}_1^{m}}\big(\text{input(i)}\big), \mu\tilde{A}_2^{m}\,(input(j))]] \qquad m = 1, 2, \ldots\ldots, r \tag{7}$$

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

$$\mu^{m}(y) = \max_{m} [\mu_{\tilde{A}_1^m}(\text{input(i)}) \,.\, \mu\tilde{A}_2^{m}(input(j))] \qquad m = 1, 2, \ldots\ldots, r \tag{8}$$

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

The simulink diagram for the process controlled by the fuzzy controller is indicated in Fig.5 and matching membership functions are expressed in Fig.6 - 8.

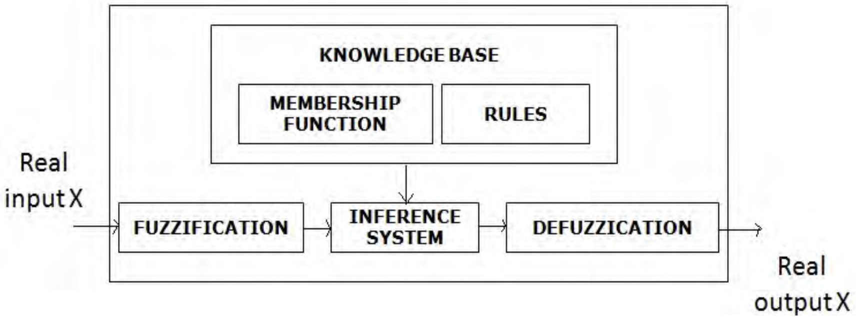

Fig. 4.fuzzy rule based system Mamdani-type general structure

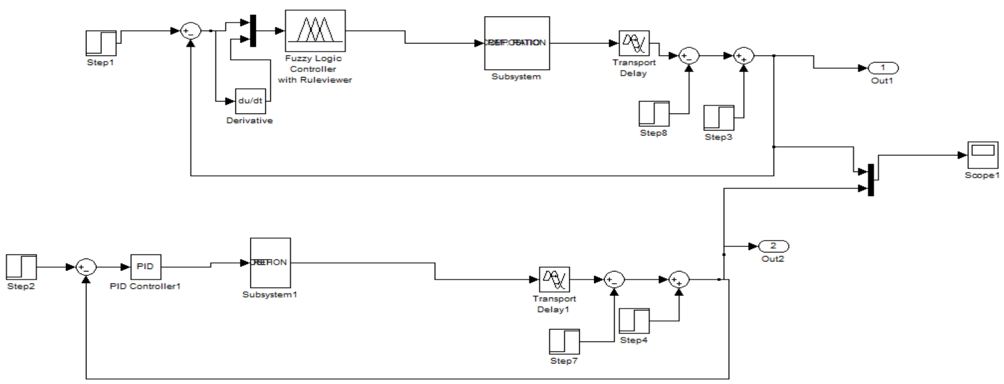

Fig.5.simulationdiagram of FLC and PID controllers

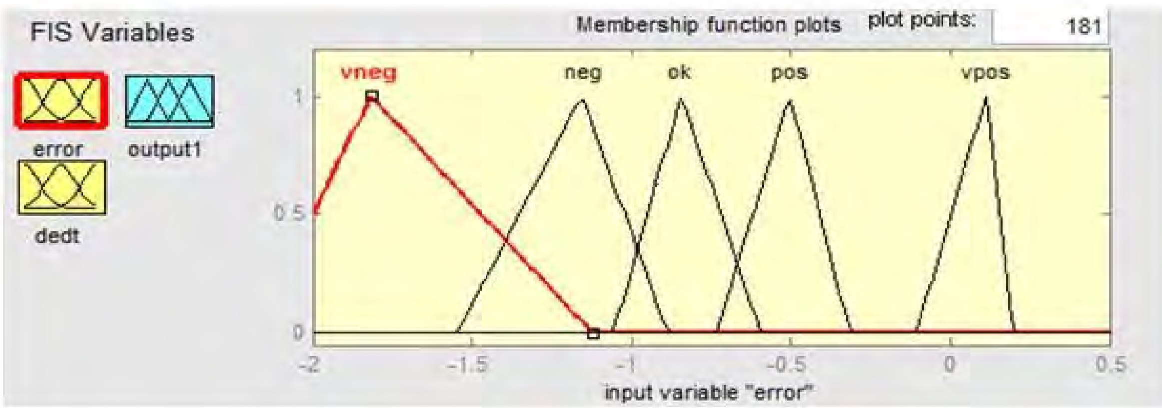

Fig. 6. ERROR MEMBERSHIP FUNCTIONS

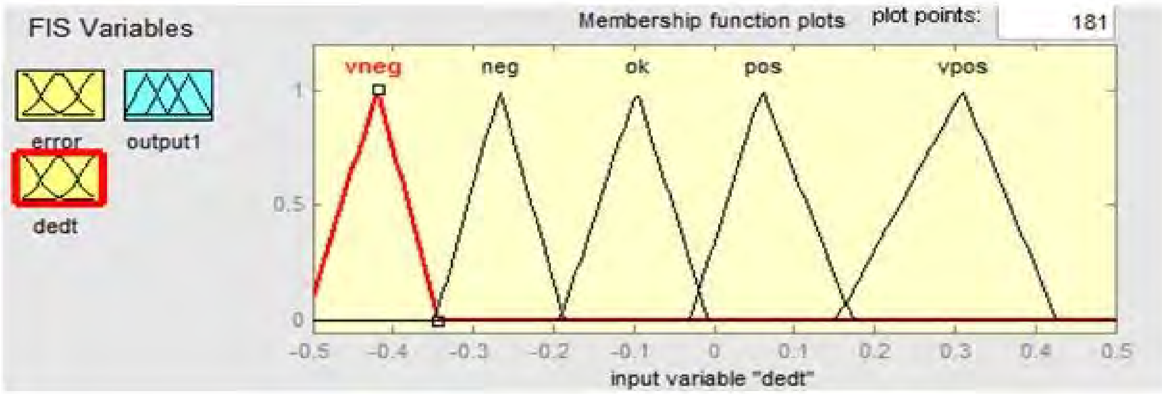

Fig.7.CHANGE IN ERROR MEMBERSHIP FUNCTION

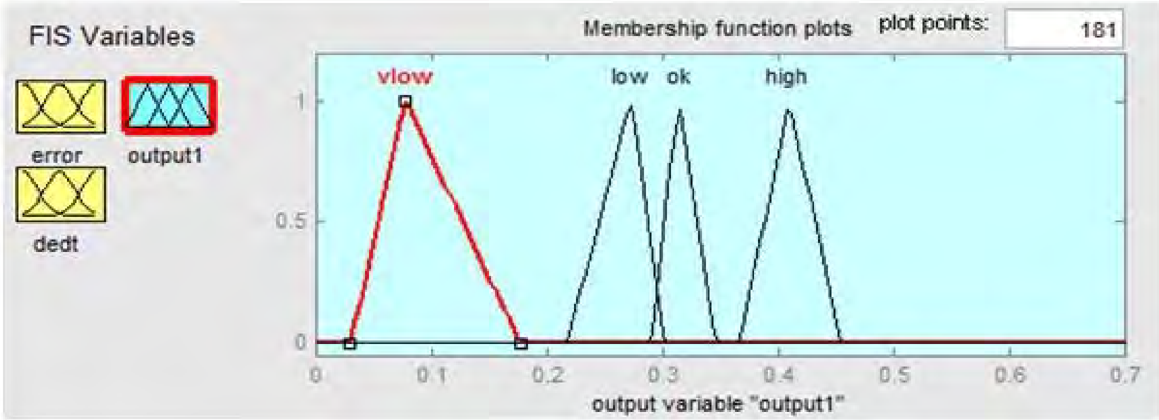

Fig.8.OUTPUT MEMBERSHIP FUNCTION

IV. RESULT AND DISCUSSION

Performance of the above said controllers are observed by implementing the same in MATLAB simulation. The response of the controllers proves the effectiveness of fuzzy controller over other controllers. The response of the controllers for are different configurations are shown in Fig 9-11.It can be seen that the execution of the PID is sluggish and carries more time to respond whereas fuzzy controller has faster response. The controller based on fuzzy had a better control when it comes to the analysis in terms of settling time and over shoot which are tabulated in Table II and III.

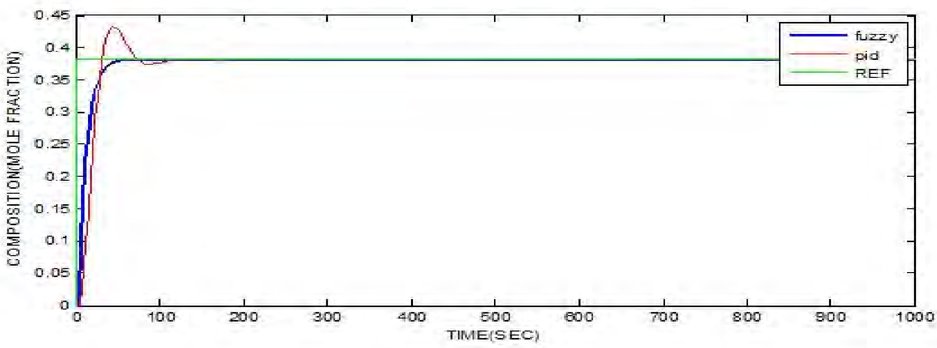

Fig (9) PID and FLC response graph

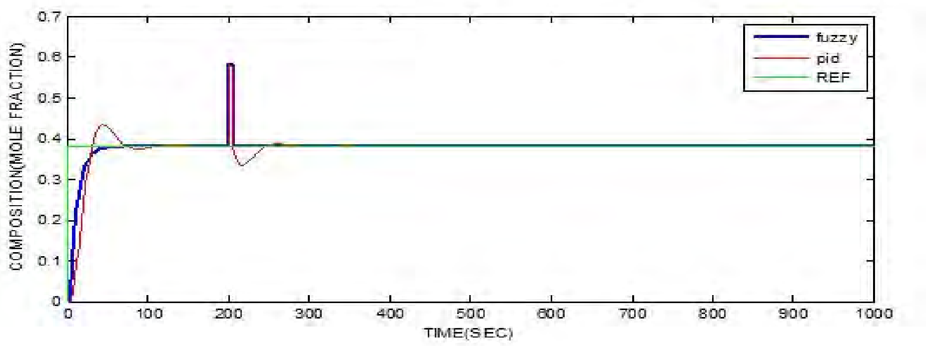

Fig (10).Positive step response

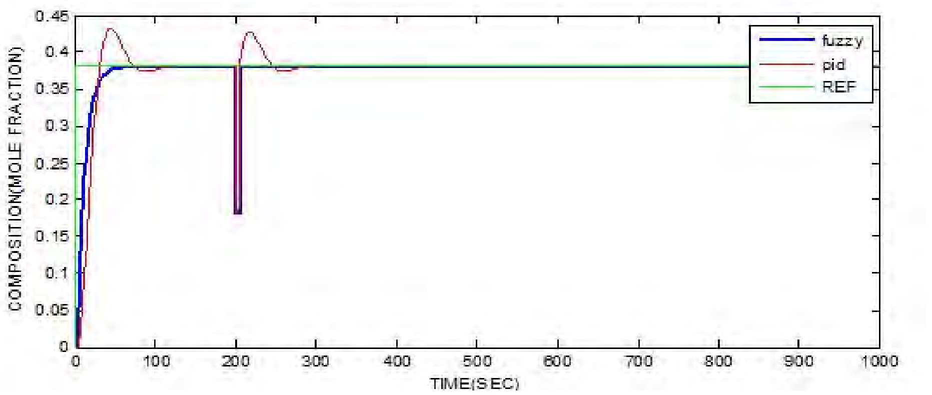

Fig (11).Negative step response

TABLEII: Performance Indices

Controller	IAE	ISE	ITAE
Fuzzy logic	3.5713	0.9274	86.0990
PID	5.0211	1.3671	108.4377

TABLE III: Time domain specification

Controller	Settling Time	Overshoot
Fuzzy logic	101	0
PID	199	0.0515

V.CONCLUSION

Composition control of bubble cap distillation column using fuzzy logic controller is designed.The main advantage of implementing the fuzzy scheme is that it can address the nonlinear problem incorporated with the process control. Triangular membership functions are used to represent the input and output variables. When compared with conventional PID controller, the fuzzy logic controller contributes lower IAE, ISE and ITAE then the PID controller. Then the response of the performance can be equated, the FLC scheme gives better performance and works efficiently in terms of reduced settling time and overshoot.

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