GA Based Fuzzy Logic Controller For A Pressure Process Station

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Abstract- In this paper, a genetic algorithm based optimization mechanism is involved in order to optimize the mid-points of the membership functions of PD-Fuzzy logic controller. An optimization methodology for the PD-FLC is designed using the GA Tool, which can automatically optimize the mid points of the membership functions. The proposed approach is applied to a pressure process station whose simulation results are presented.

Keywords – PD-FLC, GA Tool, PD-Fuzzy,

I.INTRODUCTION

Pressure is the crucial process control parameter, controlling which has several constraints (such as valve characteristics, pipeline fouling and so on). In certain plants involving boilers, maintaining appropriate pressure is very essential otherwise it may lead even to hazardous effects such as bursting of the boiler.Convectional controller such as the PID controller need often tuning and provides less stringent action towards disturbance to the system. More over due to dynamic behavior of pressure (in industrial process control), an expert based control behavior is required. In order to this so we go for a fuzzy based controlling technique where the experts ideas are depicted using linguistic variables. Zadeh used the concepts of fuzzy set and systems in 1965 [3]. After ten years the first fuzzy logic controller for process control application was developed by Mamdani[2]. Following which fuzzy logic controllers where widely used in all control domains. Yueh-Ru Young implemented brightness control of LED lamps using fuzzy logic controller.In order to update the FLC, self organizing Fuzzy controllers were developed for self tuning and self adapting of fuzzy control rules by Procyk and Mamdani [4]. The fuzzy controllers can be broadly divided into two types, namely the simple fuzzy controller and advanced fuzzy controller. As the name suggests, simple fuzzy controllers are made of some fixed fuzzy inference system which depicts experts idea and they are usually not altered. Wherein, advanced fuzzy controllers are composed of not only the fuzzy inference system, but also an online or offline self improving schemes for adjusting the fuzzy inference system. Till on dated, research on simple fuzzy controllers are focused on PD or PI control rules and scarcely on Fuzzy-PID [7]. While performing closed loop simulations or experiments, it is required to to refine the Fuzzy response, either online or offline. Unfortunately, the classical optimization techniques such as gradient point method cannot be easily applied for this problem. The advancement of GA and its flexibility provides an alternative solution and better results that can replace the convectional optimization techniques. The GA based algorithm came in existence in the year 1962 and it is based on Darwin's theory 'Survival of the Fittest', one such application of automatic control using GA-FLC is provided in . RP Huang presents a practical approach in design of an adaptive fuzzy control system for a three phased inference engine [8].

This paper presents a simple but efficient GA based optimization mechanism involved for a Fuzzy logic controller for optimizing the mid points of the fuzzy inference system on a pressure process station.

II.EXPERIMENTAL SETUP

The pressure process station is interfaced with a personal computer using VD-104 module. The laboratory setup consists of two pressure tanks, a pneumatic control valve, a pressure regulator, an air muffler, a differential transmitter, release valve setup, compressor and several hand valves. The schematic of the pressure process station is as shown in Fig. 2 below.

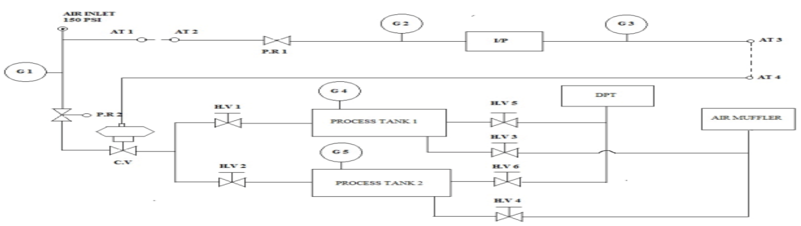


Fig 2: Schematic of the experimental set up for pressure process station

The compressor gives the air pressure at 150 psi which is then regulated using a pressure regulator to the operable 3-15 psi. The pneumatic control valve opens or closes according to the control signal given by the PC through the interfacing module (VD-104). According to the control action, pressure is filled in the tank system and the differential pressure between the two tanks is sensed through a DPT. The main use of air muffler is to avoid the moisture content and dust prevailing in the tank system and in the pneumatic line.

III.SYSTEM IDENTIFICATION &MODEL VALIDATION OF PRESSURE PROCESS STATION

The mathematical model of the pressure process station is obtained by reaction curve method, where a step change in input is given to the system and from the output response the behavioral model is obtained. In order to obtain the model, we involve two techniques namely Sundaresan-Krishnaswamy method (SK) and Two-Point method. By these methods, the obtained model will be a First Order Plus Dead Time (FOPDT) model which is as shown below.

$$\mathbf{Gp(s)}=\frac{K_p}{1+\tau s}e^{-\theta_d s}$$

SK method:

Time delay: θ= (1.3*t1)-(0.29*t2) Time constant: τ=0.69(t2-t1)

Where

t1=35.3% of final value t2 = 85.3% of final value

Similarly using two point method, the model is obtained

Two point method

Time constant: τ=1.5(t1-t2) Time delay: θ=t2-τ

Where

t1=28.3%of final value t2=63.2% of final value

For the present case, the above two system models and the corresponding curves are as given in Fig 3.

SK METHOD TRANSFER FUNCTION: $Gp(s)=\frac{0.6153*e^{-(0.9405*s)}}{1+(6.20242*s)}$

2PT METHOD TRANSFER FUNCTION: $Gp(s)=\frac{0.6153*e^{-(0.3950*s)}}{1+(7.185*s)}$

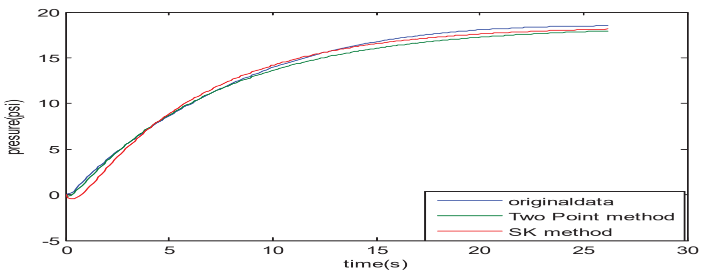


Fig 3: Model validation

Depending on the error calculation **(ITAE, ISE, IAE)**, the best model is chosen for controller implementation**.** Table # indicates that out of the two models, the SK method is having the minimum error. So further work in this paper is based on SK method's model (model validation).

Error	**S-K Method**	**Two Point Method**
ITAE	40.54557785	59.68163514
ISE	74.6476556	92.79817272
IAE	908.5598792	1586.619706

IV.FUZZY LOGIC CONTROLLER AND GA BASED FUZZY LOGIC CONTROLLER DESIGN

Fuzzy logic controllers are those controllers that works on the fuzzy implication, that is "if this : if that : then that" (nothing but AND logic). Design of fuzzy logic controllers mainly involves three steps, namely Fuzzification, Fuzzy rule base, Defuzzification. Fuzzification is a process in which the input's are fuzzified between a range of 0 to 1. Rule base is formed by the experts knowledge and depending on the inputs, the rule base generates the corresponding linguistic variable output. This output is once again defuzzified from 0 to 1 to a global value.

In the present case, the designed FLC has two inputs, error (e) and rate of change of error (de), and a controller output (co). The linguistic variables used are Low, Medium and High. Their corresponding membership functions are as shown in fig 4.

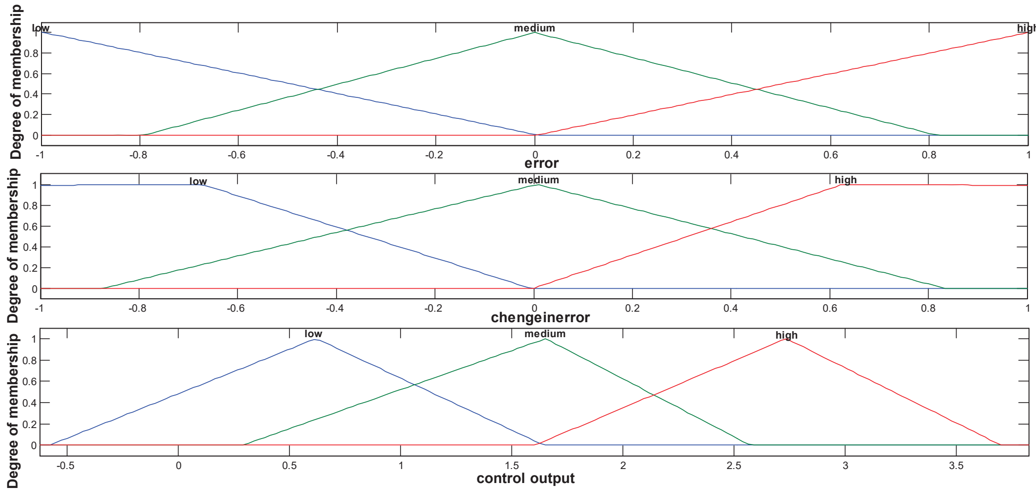


Fig 4: Membership functions for FLC

Genetic Algorithm is a powerful optimizing tool that is based on the mechanism of natural selection and natural genetics. Genetic algorithm has 3 main operations, namely REPRODUCTION, CROSSOVER and MUTATION. A simple diagrammatic representation of GA is as shown in fig 5.

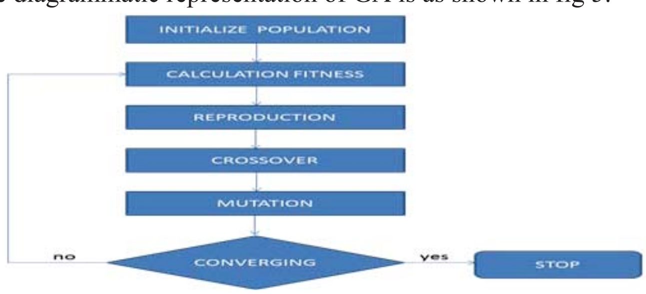


Fig 5: Flow chart for GA

In general, Genetic Algorithm can be used to optimize the fuzzy rules, membership functions and mid points of the membership function. In the present case, we are using the GA to optimize the mid points of the membership function of the FLC. As seen from the previous section, the designed FLC has 3 membership functions that is in total 9 mid points. These 9 mid points are taken in several combinations so as to obtain the best combination that is resulting in minimum ITAE. The several mid point combinations of the 3 membership functions (e, de, co) are as shown below.

COMBINATION 1: e, de, co (9 mid points),COMBINATION 2: e, de (6 mid points),COMBINATION 3: de, co (6 mid points),COMBINATION 4: co, e (6 mid points),COMBINATION 5: e (3 mid points),COMBINATION 6: de (3 mid points), COMBINATION 7: co (3 mid points)

For all the above seven combinations, the GA parameters, namely the population size, optimizing technique and so on are unchanged but then number of optimizing parameters (mid points) are only altered.

V.OBJECTIVE FUNCTION

The optimization using GA revolves around an optimizing function called as the objective function, which guides the GA whether the obtained solution is good or bad. So the role of objective function in the GA search space is very crucial and proper selection of which improves the efficiency as well as reduces the search time of GA. In the present case, the objective function chosen is ITAE which is as shown below.

ITAE FUNCTION: **F(ITAE)**= $\int_{0}^{\infty} t\left|e\right|dt$

- The lower and upper bound for each 7 combinations of the ITAE function is as depicted below. lb=[-20.49, -0.791, 0.006475,(e)
  -34.33, -0.8712, 0.0006733,(de)
  -0.5779, 0.2907, 1.607(co)];
- ub=[0.005291, 0.8121, 18.76,(e)
  -0.007976, 0.8322, 34.33,(de)
  1.643, 2.572, 3.701(co)];

VI. RESULT AND COMPARISON

As discussed in the previous sections, the mid points of membership functions are altered according to GA satisfying the objective function. The unaltered midpoints for membership functions of simple FLC is as shown in fig 7. So the altered midpoints for all 7 combinations are given below.

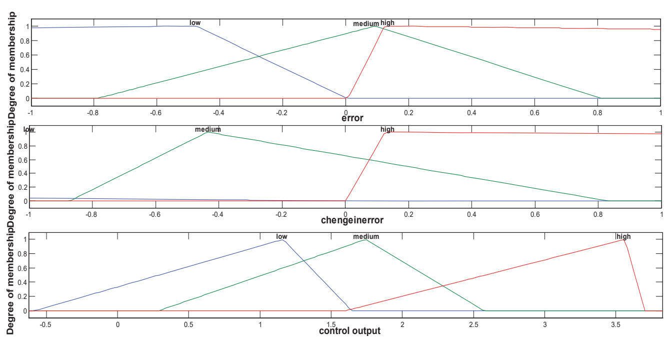


Fig 7: Change in mid points of e, de and co

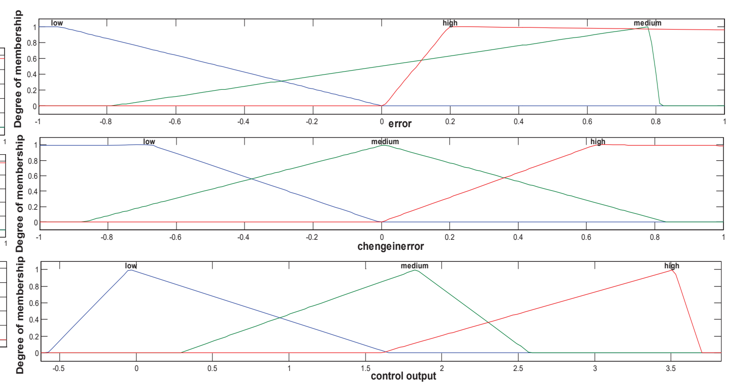


Fig 8: Change in mid points of e and co

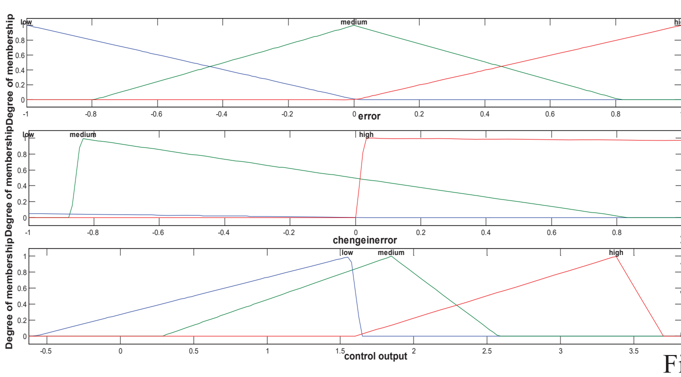


Fig 9: Change in mid points of de and co

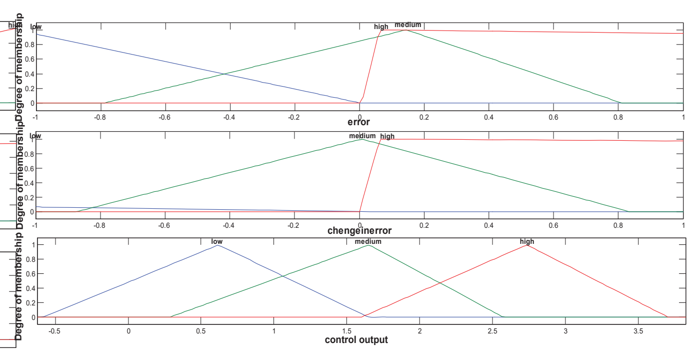


Fig 10: Change in mid points of e and de

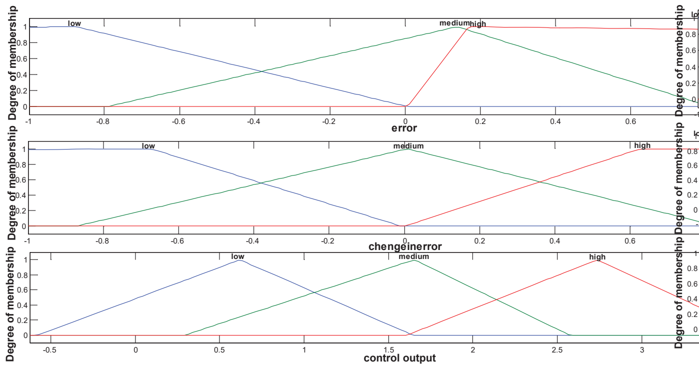


Fig 11: Change in mid points of e

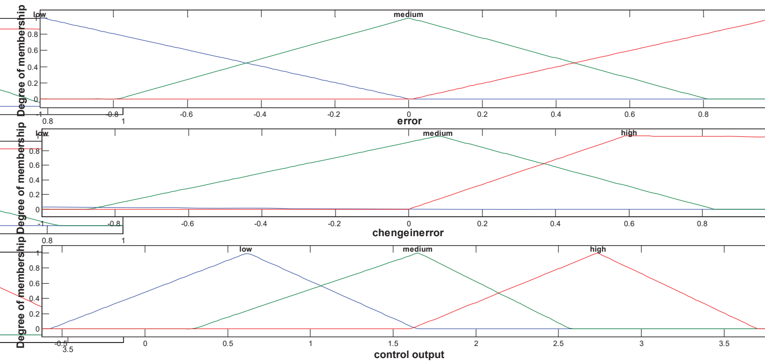


Fig 12: Change in mid points of de

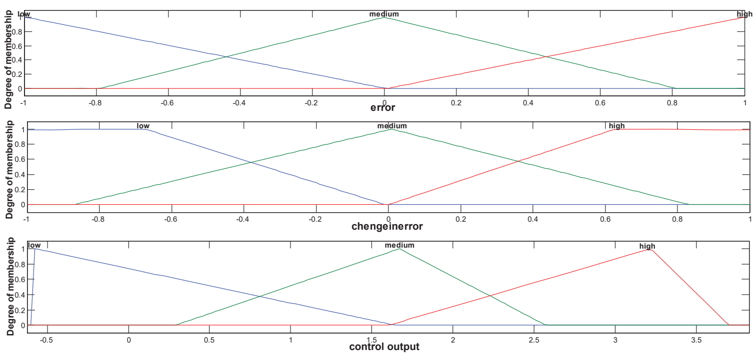


Fig 13: Change in mid points of co

The servo output for the different combinations along with the comparison of simple FLC are as depicted in fig 14 (for 9mid points), fig15 (for 6mid points) and fig16(for 3mid points).

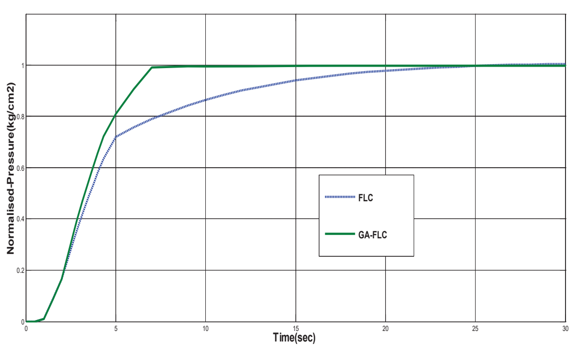


Fig 14: Comparison of FLC with 9 mid points GA-FLC

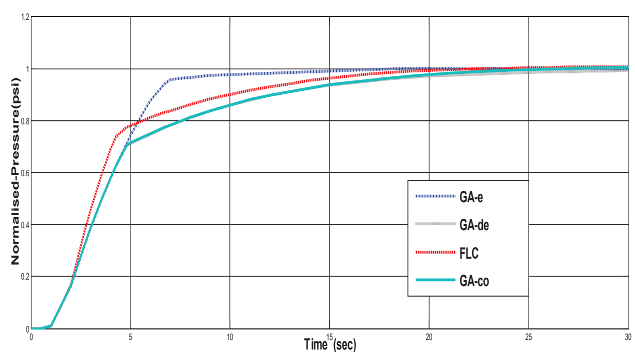


Fig 15: Comparison of FLC with 6 mid points GA FLC for different MF combinations

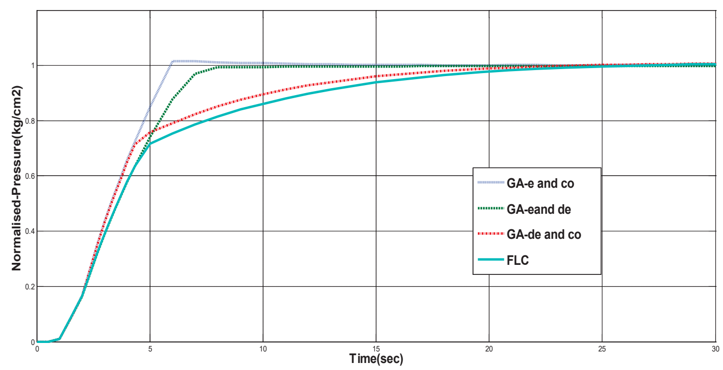


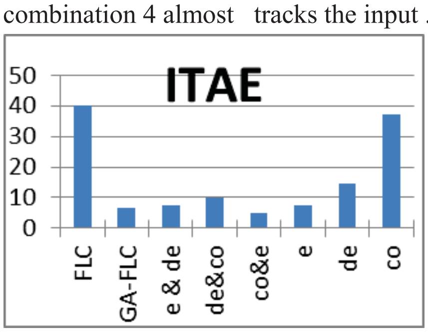
Fig 16: Comparison of FLC with 3 mid points GA-FLC for different MF

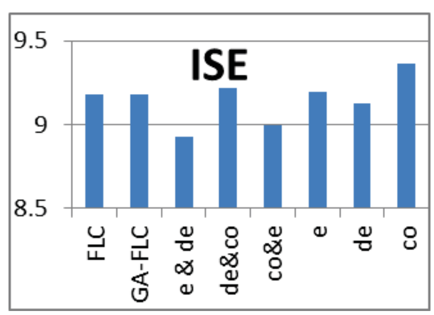
The performance indices for all 7 combinations of the membership function for the fuzzy logic controller designed to the pressure process system is as shown in the table.

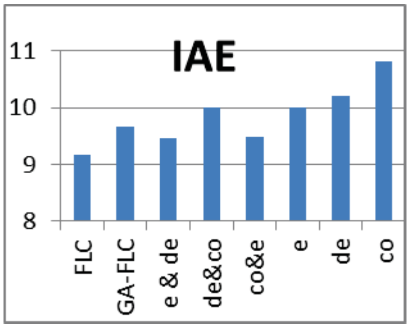
Combination	ITAE	ISE	IAE	RISE TIME	SETTLING TIME	OVERSHOOT
FLC	40	9.1786	9.1786	10.6	20.5	0
GA-FLC	6.8052	9.176	9.674	3.37	5.61	1.4
GA-FLC12	7.5233	8.9289	9.4667	4.25	7.10	0
GA-FLC23	9.9776	9.2168	10.0022	4.09	15.1	0
GA-FLC31	4.9869	8.9965	9.4923	3.19	10.6	4.2
GA-FLC1	7.3854	9.1957	10.0086	5.13	6.9	1
GA-FLC2	14.7241	9.1284	10.2154	9.8	20.2	0
GA-FLC3	37.064	9.3654	10.8101	7.4	15.8	0

VII.CONCLUSION

Based on servo output and performance indices it is avident that GA based FLC is better than simple FLC. Out of all the 7 combination the combination 4(co,e) has a minimum ITAE of 4.44 and better performance indices . Also combination 4 almost tracks the input .







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