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Performance Enhancement of Gas Plants by PSO Optimized Temperature Controller

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ABSTRACT: In most of the industrial plant processes heat exchangers are very significant part of production quality. There is a very large range of temperature and pressure values for maintaining the desired plant response. Control of the temperature of various fluids at a desired value against all kinds of deviations is required to achieve desired performance of the plant. In this paper we have investigated different types of control techniques that are used presently to eliminate the various drawbacks of conventional control techniques. We have compared latest control techniques like PSO tuning based PID controllers and fuzzy logic controllers with the conventional advanced 2DOF PID controllers tuned by popular conventional tuning techniques. We have developed simulink models using 3,7 and 9 MF fuzzy rules and PSO tuned PID controller values and finally demonstrated our results in terms of improvement in peak overshoot and settling time of the plant by a comparative analysis of results of these system responses.

INDEX TERMS: Fuzzy Logic Controller (FLC), Gas Process Plant, Particle Swarm Optimization (PSO), PID Controller, Z-N method.

I. INTRODUCTION

In the last decade, approaches based on PSO have received increased attention from the academic and industrial communities for dealing with optimization problems that have been intractable using conventional problem solving techniques.A novel hierarchical fuzzy-PSO information fusion technique was proposed [1] representing a combined reasoning that takes place by means of fuzzy aggregation functions, capable of combining information by compensatory connectives that better mimic the human reasoning process than union and intersection, employed in traditional set theories. The parameters of the connectives are found by PSO. An approach [2] evaluated the use of different methods from the fuzzy modelling field for classification tasks and the potential of their integration in producing better results. The methods considered approximate in nature, study the integration of techniques with an initial rule generation step and a following rule tuning approach using different evolutionary algorithms.To discover classification rules Carvalho and Freitas, a decision tree/PSO method [3]. The central idea of this hybrid method involves the concept of small disjunctions in data mining.

The authors developed two PSO specifically designed for discovering rules in examples belonging to small disjunctions, whereas a conventional decision tree algorithm is used to produce rules covering examples belonging to large disjunctions [4]-[6]. This work focuses on the development of a heat exchanger temperature control process that would be used for investigating of the effectiveness of several PID tuning strategies for effective control.

Due to its general application in most process industries, the process chosen for this paper is a gas process. There are various process variables that could be addressed but in this work the process model is on temperature.

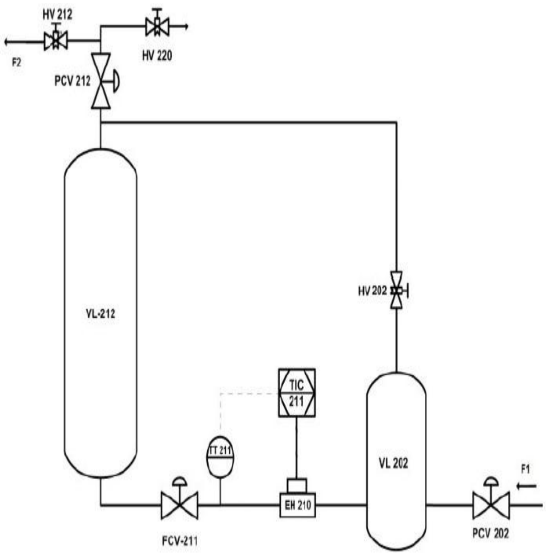

Fig. 1: Gas pilot plant with a controller to control temperature of gas.

One of the important parameter of industrial process control is the temperature of the feed. Our proposed work fulfils the objective of maintaining temperature at an optimum value and kept within the limits at all times for a

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gas pilot plant with a controller to regulate temperature of gas (Fig. 1). This ensures the safety and reliability of the process, determines the quality of the products produced and most importantly determines the efficiency of the plant. In this way we can say that temperature control has a major impact on the profitability of a company and it is considered very seriously.

II. PSO METHODOLOGY

In PSO algorithm, each particle in the swarm represents a solution to the problem, and it is defined with its position and velocity. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating the particles in each generation. In every iteration, each particle is updated by two "best" values. The first one is the best solution (fitness) achieved so far (the fitness value is also stored) called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called gbest. After finding the two best values, the particle updates its velocity and positions.

The above mentioned overview of PSO is depicted as shown in Fig. 2. The variables which are used in PSO algorithm and their definitions are given in Table 2.

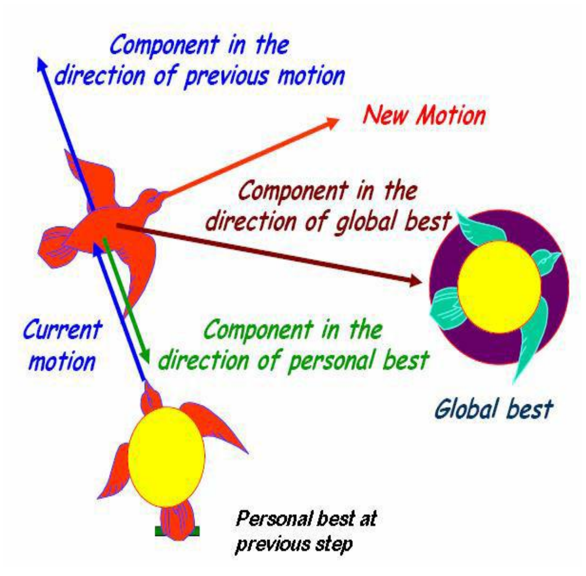

Fig. 2: Representation of PSO

Table 2: Variables and their Definitions used in PSO Algorithm

Variable	Definition
$Iter_{max}$	Maximum number of iterations
X	Position of the particle
X_i	Position of i^{th} particle
V	Velocity of the particle
V_i	Velocity of i^{th} particle
P	Best position of the particle
P_i	Best position previously visited by i^{th} particle
P_g	Best position visited by a particle
W	Inertia weight
W_{max}	Maximum value of inertia weight
W_{min}	Minimum value of inertia weight
C_1	Cognitive coefficient
C_2	Social coefficient
R	Random number between 0 and 1

In D-dimensional search space, the position of the ith particle can be represented by a D-dimensional vector, $X_i = (X_{i1}, \ldots, X_{id}, \ldots, X_{iD})$. The velocity of the particle vi can be represented by another D-dimensional vector $V_i = (V_{i1}, \ldots, V_{id}, \ldots, V_{iD})$. The best position visited by the ith particle is denoted as $P_i=(P_{i1},\ldots,P_{id},\ldots,P_{iD})$, and Pg as the index of the particle visited the best position in the swarm, then Pg becomes the best solution found so far and the velocity of the particle and its new position will be determined according to the (2.1) and (2.2).

$$V_{id} = W*V_{id}+C1*R(P_{id}-X_{id})+c2*R(P_{gd}-X_{id}) \quad (2.1)$$
$$X_{id}=X_{id}+V_{id} \quad (2.2)$$

The parameter 'W' in (2.1) is inertia weight that increases the overall performance of PSO. It is reported that a larger value of 'W' can favour higher ability for global search while lower value of W implies a higher ability for local re-search. To achieve a higher performance, we linearly decrease the value of inertia weight W over the generations to favour global re-search in initial generations and local re-search in the later generations. The linearly decreasing value of inertia weight is expressed in (2.3).

$$W=W_{max} - iter*(W_{max}- W_{min})/iter_{max} \quad (2.3)$$

Where $iter_{max}$ is the maximum of iteration in evolution process, W_{max} is maximum value of inertia weight, W_{min} is the minimum value of inertia weight, and iter is current value of iteration.

III. PSO FOR PID CONTROLLER

The basic idea of PSO is based on food searching of a swarm of animals, such as fish flocking or birds swarm. PSO is a computational intelligence-based technique that is not largely affected by the size and nonlinearity of the problem, and can converge to the optimal solution in problems where most analytical methods fail to converge [7]. The PSO algorithm incorporates both individual and social experiences in the search (Emara and Abdel Fattah 2004) since the group members share information about the best positions found during their search for food. Much research is still in progress for proving the potential of the

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PSO which was developed through simulation of a simplified social system and has been found to be robust in solving continuous nonlinear optimization problems [8]-[11].

In this work the aim of using PID controller is to increase the stability of the system by improving control since it has an ability to predict the future error of the system response. In order to avoid effects of the sudden change in the value of the error signal, the derivative is taken from the output response of the system variable instead of the error signal. Therefore, D mode is designed to be proportional to the change of the output variable to prevent the sudden changes occurring in the control output resulting from sudden changes in the error signal. In addition D directly amplifies process noise therefore D-only control is not used.

In the current technology, a PSO technique is used to search an optimum value that can satisfies the objective of getting a best trade off between minimum overshoot and steady state errors. It improves the operation of a process control system and the knowledge of an important system parameter.

2-D.O.F PID controller, also known as ISA-PID controller gives good performance for both reference tracking and disturbance rejection. It contains a standard PID controller in the feedback loop and adds a pre-filter to the reference signal. The pre-filter helps produce a smoother transient response to set-point changes [12].

IV. FUZZY LOGIC CONTROLLER (FLC)

The designed FLC attempts to model the human decision making and reasoning processes thus allowing further handling of imprecise information and vagueness. Modern control theory has made modest inroad into practice FLC i.e. fuzzy logic control has been quickly gaining recognition among working engineers. This increased recognition can be recognized to the fact that fuzzy logic provides a powerful vehicle that allows engineers to incorporate human reasoning in the control algorithm.

As opposed to the modern control theory, fuzzy logic design is not based on the mathematical model of the process. The controller designed using fuzzy logic implements human reasoning that can be programmed into fuzzy logic language (Membership Functions (MF), rules and the rule interpretation).

V. SIMULATION RESULTS

Both the controlling methodologies that are discussed above are used to design simulink models of different design analysis. The model diagram is described in Fig. 5a using Fuzzy Logic Controller with 3M.F, 7M.F, 9M.F.
This model was determined by making small changes in the input variable about a nominal operating condition [12-13].

The control process parameters are taken with the norms that change in voltage is 20% in MV, change in ultimate value is 7.25 with 28% and 63% process time of 1.46 and 9.07 minutes. The control process parameters obtained shows for a first order model with dead time model are calculated as Process gain, K_P =0.3685degree C/% open, time constant tau=11.42 mins and time delay theta=2.35 mins. Based on these parameters the first order with dead time transfer function for the plant is as follow:

$$G(s) = \frac{0.3685e^{-2.35s}}{11.42s+1} \quad (5.1)$$

The fuzzy rules of 9M.F are described in table 5.1; the results of FLC are shown in table 5.2.
We have taken the population size of 15 and bird step size of 50 iteration to search optimum value of Kp, Ki and Kd by PSO.

The algorithm is run several times and best results are sorted out on the basis of minimum fitness the value. The step responses are shown in Fig. 5b and Fig. 5c. The results are shown in table 5.3

TABLE 5.1: 9 MF rule table

I/P↓ →		Δe →								
		NXH	NH	NM	NL	Zo	PL	PM	PH	PXH
	NXH	NXH	NXH	NXH	NXH	NXH	NXH	NXH	NXH	NXH
	NH	NH	NH	NH	NH	NH	NH	NH	NH	NH
	NM	NM	NM	NM	NM	NM	NM	NL	NL	NL
e↓	NL			NL	NL	NL	NL	NL		

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	Z	NH	NM	NL	NL	Z	PL	PL	NM	NH
	PL			PL	PL	PL	PL	PL		
	PM	PL	PL	PL	PM	PM	PM	PM	PM	PM
	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH
	PXH	PXH	PXH	PXH	PXH	PXH	PXH	PXH	PXH	PXH

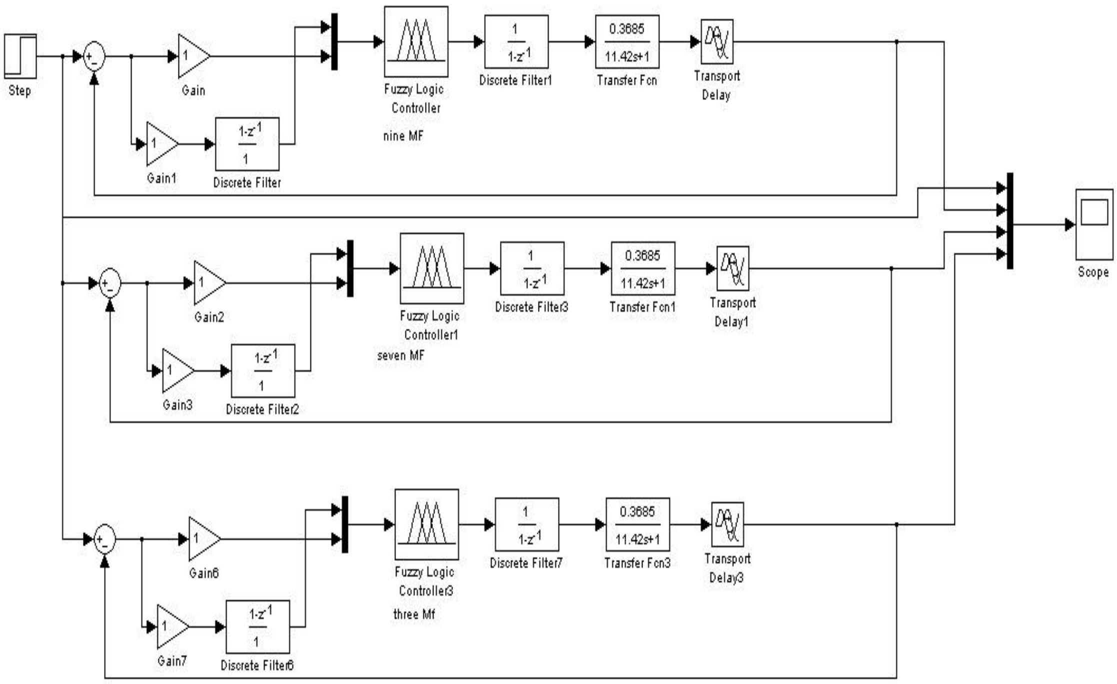

Fig. 5a: Simulink model for temperature controller using FLC.

Specification	**9MF**	**7 MF**	**3MF**	**2DOF**
Rise Time(min)	13.36	8.01	28.89	1.8
Settling Time(min)	79.93	76.84	74.45	36.7
% OS	16.49	31.08	nil	36.4

Table 5.2: Results of FLC.

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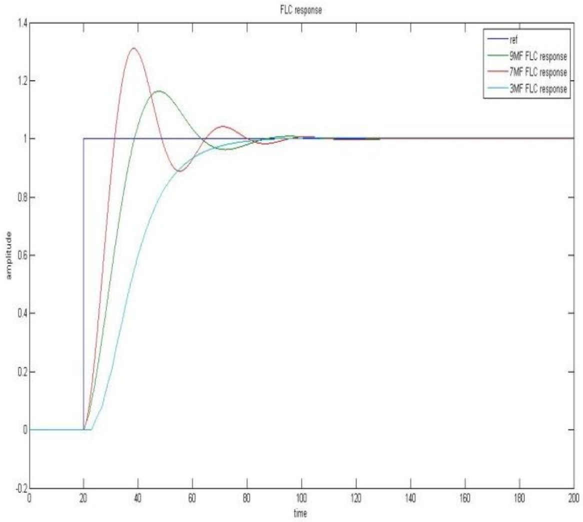

Fig. 5b: Step response of FLC temp Controller.

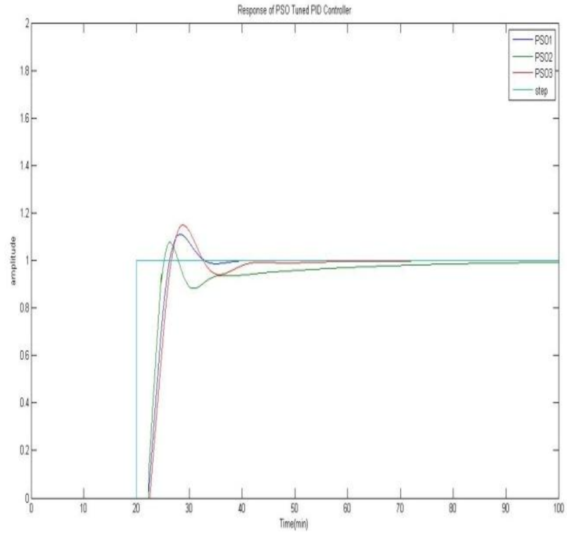

Fig. 5c: Step response of PSO tuned PID Controller.

Table 5.3: Results of PSO tuned PID controller.

Specifications	**Kp=8.9 Ki=0.7 Kd=2.1**	**Kp=11.6 Ki=0.4 Kd=5.9**	**Kp=8.3 Ki=0.6 Kd=1.6**
Rise Time(min)	3.5729	3.1784	3.1177
Settling Time(min)	32.565	60.999	39.954
% OS	11.367	6.4964	15.338

VI. CONCLUSION

We have generated the step response for our five different types of simulink models representing three FLC controllers one 2D-O-F and PSO based optimized PID controller. We have tabulated the values of rise time, settling time and peak overshoot for different controllers. It has been found that 7M.F FLC has highest overshoot while gives PSO tuned PID gives lowest overshoot. PSO tuned PID has the fastest response. The step responses are shown in Fig. 5b, 5c Hence we see the controller has become faster along with the reduction of peak overshoot. It has been found that PSO tuned PID controller gives better response in terms of time domain specification as compared to conventionally tuned PID controller. This result can further be extended to a higher order transfer function of any other industrial process control.

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BIOGRAPHIES

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