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OPTIMAL DESIGN OF GA BASED PID BOILER DRUM LEVEL CONTROLLER USING MATLAB

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Abstract- This paper proposes a GA based PID controller for boiler drum level control. It is an important parameter that ensures the safety in production. To design an effective PID controller, Genetic Algorithm is applied to control boiler water level with a reasonable objective function and weighted coefficients are designed according to the control requirements. The results of the proposed controller are compared with conventional controller and these controllers are optimized under different population sizes of GA using MATLAB/Simulink. Simulation investigation indicates that, compared to the parameter-fixed PID, GA-PID is able to reject endogenous and exogenous disturbances more effectively and rapidly.

Keywords- Genetic Algorithm, PID Control, Boiler Drum Level, MATLAB

I. INTRODUCTION

Boiler is a closed vessel where steam is produced by the interaction of water in water tubes with hot gases by conversion of stored chemical energy of fuel to heat energy of steam. Steam generation system is a complicated industrial process with disturbance, uncertainty and nonlinearity [1]. The steam system is a part of process of generating electric power or heating building. Accurate modelling and controlling of the steam generation system are vital and important scopes to increase the efficiency and performance in the power plants, especially while fuel costs keep rising [2]. There are many studies about the modeling and control strategies of the steam system is available in the literature [1].

The boiler model was designed in terms of experiments, nonlinear distributed parameter equations, artificial intelligence, neural network, neurofuzzy, stochastic fuzzy, etc. [3, 4]. In order to provide stable and efficient operation of the boiler, water level is considered one of the main control objectives.

Several control techniques exist to control the drum level of the boiler.Pole placement control was employed in high order steam generation model and a cascade control topology with predictive aspect was used for system variables. In addition to these, multistage approach with PI controller, sliding mode control, predictive control, H2/H∞ control, combination PID controller and fuzzy logic control and also PID-controller. Recently the thrust is given to soft computing methods like GA, PSO to design the controller for the steam generation systems[3,4,6-10]. In this paper, GA based PID controller is designed to control the drum level of the boiler. PID control is one of the earlier control strategies. Performance analysis of GA-PID and conventional PID controller has been done by the use of MATLAB and Simulink. Comparison of various time domain parameters is done to prove that the GA-PID has no overshoot and lesser settling as compared to Conventional PID controller.

II. BOILER –TURBINE MODEL

The boiler-turbine model used in this paper was first developed by Bell and htrom [7]. The model is a 3rd order, non-linear MIMO system with hard constraints and rate limits imposed on the actuators. It has fuel flow, control valve position, and feed water flow as control inputs, and drum pressure, power output, and drum water level deviation as outputs. Although the model is of low order, it is capable of illustrating some of the complex dynamics associated with the real plant.

At a load level of 66.65 MW, pressure of 108 kg/cm^2, and fluid density of 428 kg/m^3, the nominal inputs are found to be $u^0 = [\,0.34 \quad 0.69 \quad 0.436]^T$. From theses nominal values, a linearized model is obtained from a truncated Taylor series expansion of the non-linear equations:

$$\frac{d\bar{x}}{dt} = A\bar{x} + B\bar{u} \qquad (1)$$

$$\bar{y} = C\bar{x} + D\bar{u} \qquad (2)$$

Where $\bar{x} = x - x^0$, $\bar{y} = y - y^0$ and $\bar{u} = u - u^0$. The linear system matrices can be found to be

$$A = \begin{bmatrix} -2.509X10^{-3} & 0 & 0 \\ 6.94X10^{-2} & -0.1 & 0 \\ -6.69X10^{-3} & 0 & 0 \end{bmatrix} \qquad (3)$$

$$B = \begin{bmatrix} 0.9 & -0.349 & -0.15 \\ 0 & 14.155 & 0 \\ 0 & -1.389 & 1.659 \end{bmatrix} \qquad (4)$$

$$C = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 6.34X10^{-3} & 0 & 4.71X10^{-3} \end{bmatrix} \quad (5)$$

$$D = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0.253 & 0.512 & -0.014 \end{bmatrix} \quad (6)$$

The transfer function of the boiler model is derived using the above matrices using MATLAB function toperform the simulation.

III. DESIGN OF PID CONTROLLER

PID (proportional integral derivative) control is one of the earlier control strategies. Its early implementation was in pneumatic devices, followed by vacuum and solid state analog electronics, before arriving at today's digital implementation of microprocessors. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. Since many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control. It has been found possible to set satisfactory controller parameters from less plant information than a complete mathematical model [Hameed].

A. Conventional PID Controller

In this paper, conventional PID controller is designed using Ziegler –Nichols method.In 1942 Ziegler and Nichols, both employees of Taylor Instruments, described simple mathematicalprocedures, the first and second methods respectively, for tuning PID controllers. These procedures arenow accepted as standard in control systems practice. Both techniques make a priori assumptions onthe system model, but do not require that these models be specifically known. Ziegler-Nicholsformulae for specifying the controllers are based on plant step responses.

Fig1. Shows the block diagram of boiler with controller. The transfer function obtained from the state space matrices discussed in section II, is incorporated in the Simulink transfer function block.

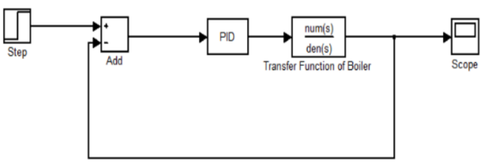

Fig.1. Block diagram of boiler with PID controller

To design a conventional controller, initially the open loop response of the boiler without controller is obtained as shown in Fig.2. From Fig2., it is evident that for a given step disturbance the boiler level starts to increase rapidly and steady state is not reached. The response is characterized by two constants L and T.These are found by drawing a tangent to the step response at its point of inflection and noting its intersections with the time axis and the steady state value. Table 1 is used to determine the PID parameters and the simulation is carried out with the CPID controller [reference]. Fig 3. Shows the response the system with controller. It is observed that the steady state response is obtained with overshoot and increased settling time.

PID Type	Kp	Ti= Kp/Ki	Td= Kd/Kp
P	T/L	∞	0
PI	0.9 (T/L)	L/0.3	0
PID	1.2 (T/L	2L	0.5L

Table 1. Zeigler –Nichols Recipe

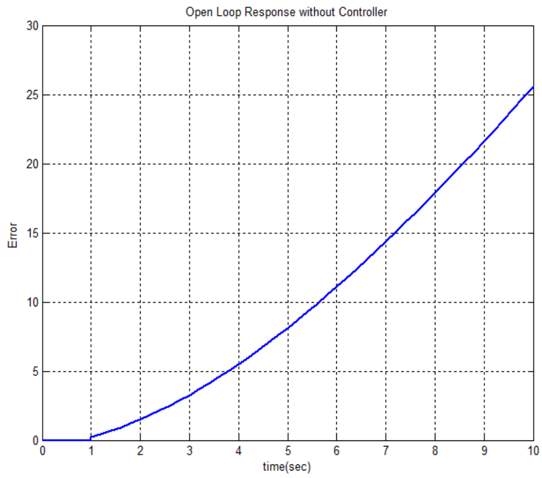

Fig.2. Open loop response of boiler without controller

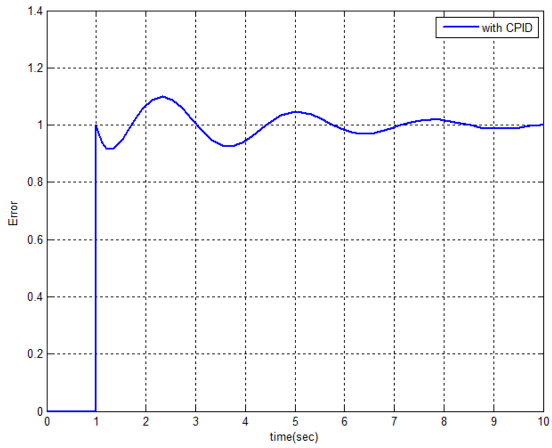

Fig.3. Closed loopresponse with CPID controller

B. GA basedPID Controller

Genetic algorithm(GA) is a parallel random search optimization method proposed by Professor Holland at the University of Michigan in 1962 which formed by simulating the biological genetic mechanisms in nature and the biological evolutionism [14]. The steps of GA are used to find the optimal parameters (Kp, Ki, Kd) for PID controller. An objective function carefully selected will determine the fitness of the population and the search will be terminated if the fitness level is reached.

1. Fitness Function Formulation

In order to design a PID controller which guarantees stability ofsystem in a wide range of operating conditions, the objective function isdefined such that the resultant time response is restricted to lie within specificbounds as well as limiting the amount of overshooting of systemresponse when subjected to disturbances. To obtain the optimum parameters with a step disturbance the fitness function represented in Eq (7) is minimized using GA

$$F = \frac{1}{(1+\boldsymbol{\Delta\omega p})(\mathbf{1}+\boldsymbol{ts})} \qquad (7)$$

The settling time (ts) and peak overshoot ($\boldsymbol{\Delta\omega p}$) are evaluated foreach iteration and the performance index F is minimized through iterative program written in MATLAB programming language.

2. GA parameters

These parameters were selected on the basis of system experience and main criteria for selection were taken as [14]:

1. Accuracy in the solution,
2. Convergence
3. Small changes in these parameters should not significantly affect the GA performance.

Number of variables 3; Population size 100; Chromosome Length 24Selection 0.5; Probability 0.7; Mutation probability 0.15; Termination criterion 200.

IV. SIMULATION RESULTS AND DISCUSSION

Dedicated program is written in MATLAB to find the optimal parameters of PID controller. Steps of GA with a carefully selected objective function are transformed in to a MATLAB-M file and iterative simulation is carried out. A comparative analysis is made between the conventional and GA based PID based on the time domain specifications like % overshoot and settling time. From Table 2, it is seen that, the proposed controller reduces the oscillations with reduced overshoot and settling time.

Controller	PID parameters	%Overshoot	Settling time (ts) Sec
CPID	Kp= 0.15 Ki=32 Kd=4.8	1.1	9.5
GAPID	Kp=85.8965 Ki=28.3071 Kd=32.6165	0.1	2.3

Table 2. System performance with Controllers

Fig.4 shows the convergence of objective function with GA as a sample. The population size selected here is 50. From Fig 4, It is observed that the objective function starts to converge after 120 iterations and provides optimal results after it. If the population size increased to 200 it will start to converge faster than the present sample.

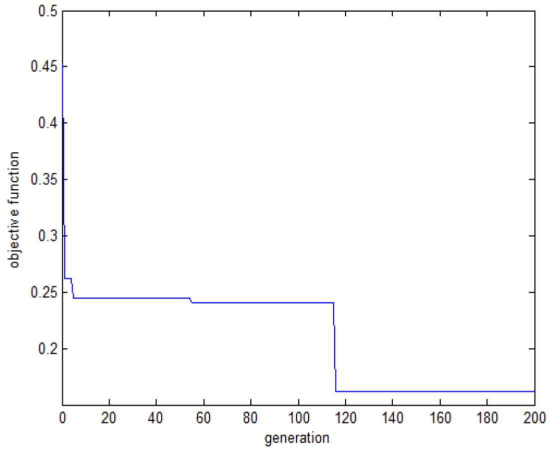

Fig.4. Convergence of objective function with GA

The optimal values of PID controller obtained using GA are incorporated in the Simulink model and the simulation result is as shown in Fig 5. For comparative analysis the conventional PID responseis also included in the plot. From Fig.5, it is evident that the proposed controller reduces the oscillations in the system and stability of the system is maintained.

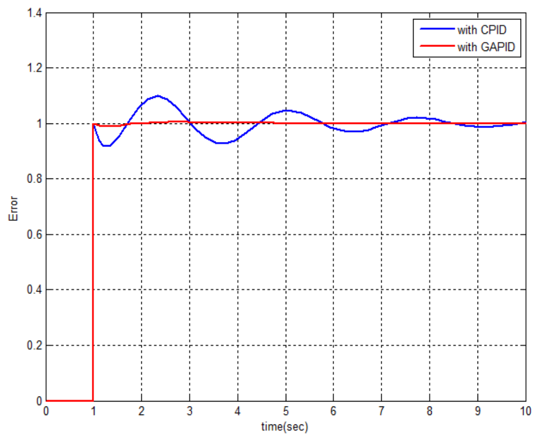

Fig.4. Comparison of CPID with GAPID controller

A comparative study has been made to check the effect of population size of GA in finding the optimal parameters. The population size increased from 50 to 200 with regular intervals of 50. The PID parameters obtained are incorporated in the Simulink model and the responses are plotted as shown in Fig.6. It is seen that there is no much effect on the population size on optimal parameters. The response of different population size looks almost similar and possesses reduced undershoot for maximum population size ie.,200.

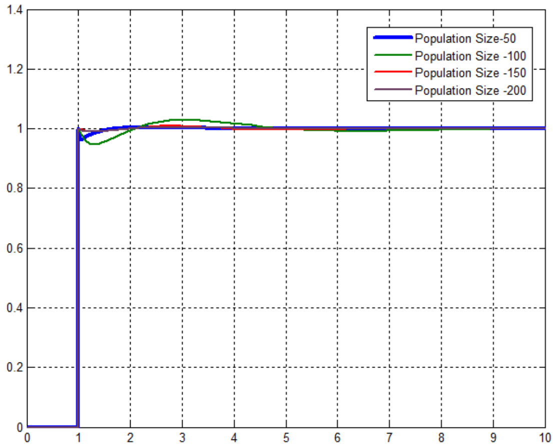

Fig 6. Response with Different Population Size

V. CONCLUSION

The GA based PID controller is proposed here to control the steam boiler drum water level, which can reduce the blindness and subjectivity of conventional manual method based on experience of engineers, reduces the work load of designers and improves the design efficiency. The results of the proposed controller and conventional controller were presented. It was found that the GAP1D control system achieved good steady-state tracking with reduced oscillations and improves the system response in a better way.

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