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Pareto Optimal Solution for PID Controller by Multi-Objective GA

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Abstract— PID controllers designing is reaching to its optimal tuning state and there are so many hybrid system present for tuning and optimizing of the PID controller parameters. In this paper we are going to propose a dominant pole placement techniques for the state space system. By using the Genetic algorithm we can find the value of the feedback gain directly with the information of the transient response unlike in traditional approach where we finds the pole location at first place. In this paper we tested Genetic algorithm with the traditional parameters for the transient response like MSE, ITAE and also two objective and tree objective Fitness functions. The multi-objective fitness function is actually designed to give the Pareto optimal solution between the contradicting Parameters. We found much more satisfactory pole location and feedback gain with three objective fitness function as compared to the single objective and two objective fitness function.

Keywords—PID controller, Genetic Algorithm, Optimization, PID controller ,MATLAB.

I. INTRODUCTION

Proportional Integral and Derivative controller mean the PID controller are the simplest controller to design and also it provides best controlling of many real time control problem. PID controllers are now available with the great features like auto tuning, high stability and etc. Today's many real-world control problems depend upon the PID controller. This makes researcher to optimize the response of the PID controllers. After developing the new nature inspired algorithms there are drastically improvement in the research of optimization problems. Whenever the traditional methods uses the assumptions for formulating any problem then the limitation of the solution starts and then traditional methods become no more accurate. In that case the Nature Inspired Algorithm gives better result as compared to the traditional formula based methods [1-2]. These methods the based on the stochastic searching of solution.

Taking Integral of error is actually finds the area under the curve. And area covered by the step response cannot be unique, so there will be not always the optimal solutions. There are many nature inspired algorithms available for solution of these type of problem. T. Chaiyatham used ABC for the PID controller optimization [1]. There are many work is going in this area for optimize the PID control parameters. Many researcher used ITE, ITAE, ISE, ITSE and MSE as a fitness function for genetic algorithm. These methods provides better results than the traditional PID controller tuning but those are not actually the optimal result. Basic problem with those fitness function is that they do not take care overshoot and settling time. They let this parameter to be controller by the ITAE, MSE and etc. As a matter of fact that fitness function gives a middle solution but not optimal solution and we found there is need to improvise that fitness function.

In this paper we are going to propose a new multi-objective fitness function in which we considered the steady state error, Settling time and Peak Overshoot for optimization. Unlike the other multivariable system which consider the multi objective system in the form of vectored fitness function, we consider the all objectives separately. Here we have the Pareto Optimal solution instead of the best solution. The settling time and the Peak overshoot are contradictory in nature so the best result will be found by the Pareto front of GA and on this paper we will show that Pareto solution is better than the single objective or vectored objective.

II. METHOD

A. The PID controller and Multi-objective Genetic Algorithm

The PID controller consist of the three variable Kp, Ki and Kd (proportional gain, Integral Gain and Derivative Gain). System can be forced to perform desirably by adjusting these three Gain value. The standard PID controller transfer function is given as:

$$u(t) = Kp + Ki \times \int e(t)dt + Kd \times \frac{de(t)}{dt} \qquad (1)$$

Where s is standard Laplacian operator. The time domain equation of the PID controller is given as:

$$Gc(s) = Kp + {}^{Ki}/_{s} + Kd \times s \qquad (2)$$

Where u(t) is the PID controller output to the plant and the e(t) is the error between the output and the input of the output of the plant. The block diagram representation of the system in given in figure 1. Block diagrams represents the basic control strategy with the PID controller parameter and Genetic Algorithm.

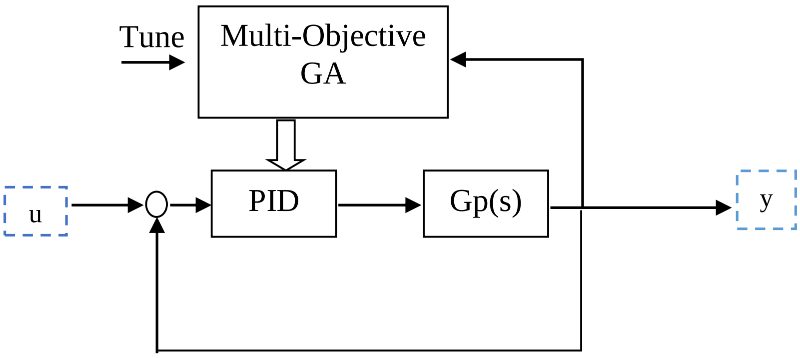

Fig 1: Block Diagram of Multi-Objective GA PID

Basic concept of genetic algorithm is contains three main process Evaluation, Selection, Crossover and Mutation. In the Genetic Algorithm the first step is to generate a random expected solution called population. The Population is then tested on the fitness function called evaluation. The according to their fitness the population for the next generation is been created by the crossover between the parents. The parents selected by the random or by some process. Finally after mutation we have the next generation. The same process is repeated until stopping criteria achieved. Hence by the stochastic search we will reach to the final solution which may be optimum. The solution accuracy is totally depends upon the population size and fitness function formulation [3].

Genetic algorithm test the fitness of each population as already explained. In this case the fitness function is the plant's transient characteristics (settling time and peak overshoot). The population is generated for the PID controller's Gain. When Tune signal is high then the 'Multi Objective GA' block start tuning the PID controller according to the output (y) and one its find the optimal value then the PID controller lock for the optimal value and plants starts working. When operator need to retune the system then he will make the 'Tune' signal high by mechanical switch or by the digital signal via Microcontroller or microprocessor.

B. The Fitness Function Formulation

We had designed a fitness function which contains three objective for Pareto optimal solution. We used MATLAB software environment for design and testing the system. MATLAB is a very powerful tool which contains some predefined control system function by which we can easily measure all transient response characteristics. If we designed a transfer function by 'tf' function then there is a 'stepinfo' inbuilt function in the MATLAB which measures all transient response characteristics.

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We fist design the PID controller with the Population and connect to the original plant which is to be control. The ‘stepinfo’ command giver the settling time and peak overshoot for the plant with PID controller and hence it’s set to the first objective. The ‘stepinfo’ command can be used for a MATLAB transfer function model ‘sys’ as:

$$h=stepinfo(sys); \quad (3)$$

$$T_s=h.SettlingTime; \quad (4)$$

$$M_p=h.Overshoot; \quad (5)$$

And hence we can represent first objective function as:

$$J_1=T_s \quad (6)$$

Where T_s calculated by the ‘stepinfo’ command and similarly the M_p also calculated by the same command. And the second Objective function will be given as:

$$J_2=Mp \quad (7)$$

The M_p (Peak Overshoot) and T_s (Settling time) can never be negative so there is no problem to use M_p and T_s as fitness function and also we want both parameter as minimum as possible. The third objective function steady state error is be set as following in MATLAB:

$$J_3=-1/\ (1-y(end)) \quad (8)$$

Where y is the output of the plant and y(end) is the final value of the output. The equation (6), (7), (8) is used as the fitness function objectives.

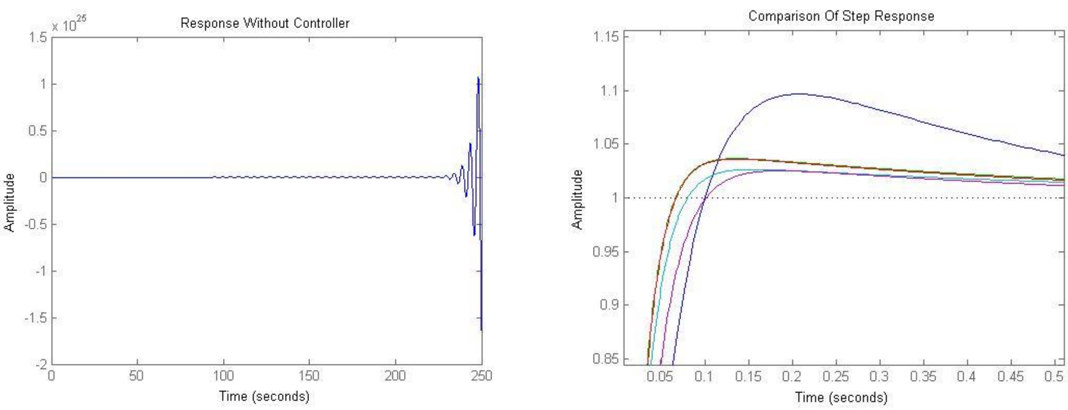
III. RESULTS

We tested results with the parameter ISE, ITSE and MSE and proposed method on following plan whose open loop transfer function is given as:

$$Gp = \frac{s+2}{s^3+0.8s^2+0.3s+0.4} \quad (9)$$

The response of the uncompensated system is given in figure 2(a).

The uncompensated system is unstable as shown in figure 2(a). Then we applied the PID controller as given in figure 1 and optimize it with the different Fitness functions. The table 1 represents the optimized gain value and corresponding transient response detail. Figure 2(b),(c) represent the step response with all optimize controller gain values.



(a) (b)

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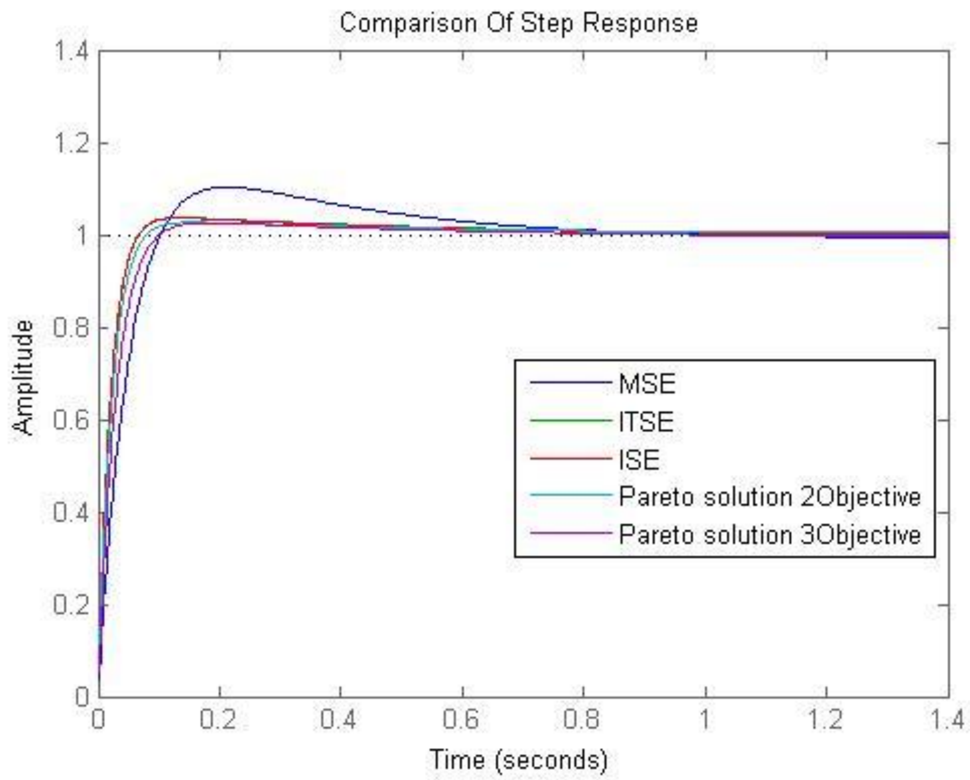

(c)

Fig 2: Response of (a) Uncompensated system (b),(c) GA PID controller

The table shows that single objective fitness function gives satisfactory results but not the optimal. When we use the 2 objective fitness function which J_1 and J_2 then the response is much better than the other topologies. Pareto Optimal solution with the three objective gives best result then the other because in this fitness function we considered the settling time, Peak overshoot and steady state error. The all optimal response is plotted in the figure 2.

There are 2 plot in the figure 3 one plot represents the controller performance optimized by the different techniques and second figure is zoomed figure to give the better view and comparison between deferent techniques. We can see in the figure that the Pareto optimal solution gives better result than the other single objective techniques

TABLE I. PID COMPARISON WITH DIFFERENT FITNESS FUNCTION

S.No.	**PID Controller Gain**				**Transient Response**	
	Method	***Kp***	***Ki***	***Kd***	T_s	M_p
1	MSE	49.9	24.4	22.9	0.6715	9.6436
2	ITSE	49.9	35.6	49.9	0.4487	3.6605
3	ISE	48.4	21.9	49.5	0.4253	3.6106
4	Pareto 2Obj	12.2	19.6	44.8	0.3345	2.6555
5	Pareto 3Obj	1.28	35.3	43.2	0.3079	2.5211

VI. CONCLUSION

In this paper we showed an indigenous approach for optimizing the PID controllers. As compared to the previous research in which they used the Integral time error or integrate time absolute error is which is partially related to the settling time Peak overshoot and steady state error. In the present works by using the Matlab tool we showed that we can directly use the transient response parameter as a fitness function instead of the ITSE or ITAE etc. which gives desired response as compared to the other single objective GA technique. We found the Pareto optimal solution which minimizes the all there objective which we describes (Table-1). We also showed the use of the 2 objective Pareto solution and three objective Pareto solution. Pareto solution do not give the optimum value for every objective but instead it gives the solution which satisfy all objective. The one objectives can be found minimum at other value but other may the not satisfactory so in dilemma of choosing the value for satisfying two or more contradicting parameter we can use the Multi-objective GA for the Pareto optimal Solution.

REFERENCES

[1] Taher, S.A., Hemati, R., Abdolalipour, A., Tabie, S.H., "Optimal Decentralized Load Frequency Control Using HPSO Algorithms in Deregulated Power Systems", *American Journal of Applied Sciences* **5**. 1167-1174, 2008-09.

[2] H. Bevrani, V. Mitani, K. Tsuji, "Robust Decentralized AGC in a Restructured Power System Energy Conversion and Management" **45** (2004), 2297–2312.

[3] Kim Dong Hwa and Park Jin Ill, "Intelligent PID Controller Tuning of AVR system using GA and PSO" Springer-Verlag Berlin Heidelberg: ICIC 2005, Part II, LNCS 3645, pp 366-375.(2005).

[4] Ziegler, G. and Nichols, N. B,"Optimum settings for automatic controllers", Trans. ASME-1942, 64,759-768.

[5] K.RamaSudha,V.S.Vakula, R.VijayaShanthi, "PSO based Design of Robust Controller for Two Area Load Frequency Control with Non linarites", *International Journal of Engineering Science and Technology*, Vol. 2(5), 2010, 1311-1324

[6] G.H Cohen and G.A Coon: "Theoretical Consideration of Retarded Control" , Trans ASME 75,pp.827/834,(1953).

[7] G. Raj Goutham,Dr. B. Subramanyam, "IMC Tuning of PID Load Frequency Controllerand Comparing Different Configurations for Two Area Power System",*Internationa lJournal of Engineering Research and Applications*, Vol. 2, Issue 3, May-Jun 2012,pp.1144-1150.

[8] Unbehauen, H., Keuchel, U., Kocaarslan, I.," Real-Time Adaptive Control of Electrical Power and Enthalpy for a 750 MW Once-Through Boiler", Proceedings of IEE International Control Conference 91, Edinburg, Scotland, Vol. **1**, pp. 42-47, 25-28 March 1991.

[9] P. Sooraksa, G. Chen "Fuzzy (Pl+D)2 Control for flexible robot arms", Proc. IEEE Int. Conf. on Control Appl., Deerborn, MI, Sept. 15-18, pp. 536-541, 1996.