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Genetic Optimization Tuning of an Automatic Voltage Regulator System

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***Abstract*— In this paper, a genetic optimization with a new fitness function method is proposed to design a PID controller for the automatic voltage regulator system (AVR). The proposed fitness function is made by cost function to improve the transient response of the controlled system and optimize the gain. The proposed algorithm applied in the PID controller design for the AVR system. Based on simulation results, author observed that the proposed genetic algorithm with this new fitness function can find a PID control parameter set effectively so that controlled AVR system has a better control performance.**

Keywords- PID controller, genetic algorithm, AVR system

Introduction

In power system stability and consistency are the major problem. In substation grid so many equipment are connected to control stability, an automatic voltage regulator is one of them it controls voltage fluctuation. In power system basically there are two types of power active power and reactive power .In AVR reactive power is control Due to reactive power losses increases in power system so mainly using AVR voltage fluctuation is controlled by controlling the losses in system. For achieving this so many method are available i.e. PI, PD and PID controller. Author chosen PID control tuning due to its robustness and better transient response as well as dynamic response but so many problems like steady state error ,rise time, overshoot are there in PID controller .To overcome these problems author uses genetic algorithm. The real model of such a system is depicted in Figure 1.

In Previous works on AVR system with self tuning control was initiated in the years of 1990s. Sweden bank and coworkers carried out the classical self-tuning control techniques to the AVR system in 1999 [1]. After this study, Finch used a generalized predictive control technique as a self-tuning control algorithm in the same year [2]. Since the conventional self-tuning control methods contains more mathematical calculation a conditions due to the complexity of the power systems such as nonlinear load characteristics and variable operating points. The usage of artificial intelligence based self-tuning controllers was preferred by researchers from the beginning of 2000. In particular, self-tuning PID type controllers which were tuned with the optimization methods based on artificial intelligence have been initiated to carry out to the AVR system since then. Gaing suggested a PSO based self tuning PID controller for AVR system, and compared the results with that of genetic algorithm based methods in 2004 [3].

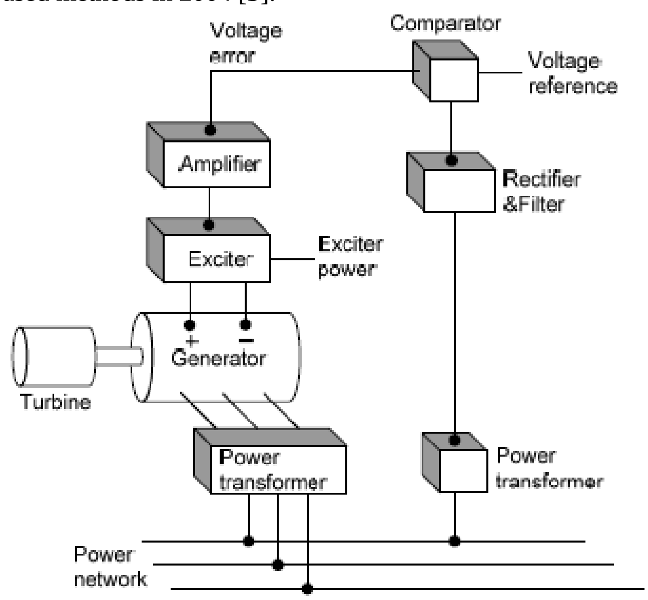

Figure 1. A real model of AVR system

In 2006, Kim and colleagues developed the hybrid method which contains genetic algorithm and bacterial foraging optimization technique in order to improve the performance of self-tuning PID controller in AVR system [4]. In 2007, Mukherjee and Ghoshal reported the Sugeno fuzzy logic self-tuning algorithm based on crazy-PSO for PID controller.

In this paper more recent soft technique is used for tuning of PID controller. Since MATLAB genetic algorithm (cost function) has characteristics of strong robustness and efficient optimization cost function with genetic algorithm optimization solutions is exposed in order to tune the gains of PID controller. Genetic algorithm is applied to achieve better transient response of the system.

I. PROPOSED METHOD AND STARTERGY

A. Fundamentals of PID controller

The PID controller is simple and easy to implement. PID controllers have been used for decades. During this time, many modification have been presented in the literature [5]. The transfer function of PID controller (see representation in Figure 2) is described by the following equation in the continuous s-domain (Laplace operator)

$$Gpid = P + I + D$$

$$\frac{U(s)}{E(s)} = Kp + \frac{Ki}{s} + Kd.s$$

or

$$Gpid(s) = Kp.\left(1 + \frac{1}{Ti.s} + Td.s\right)$$

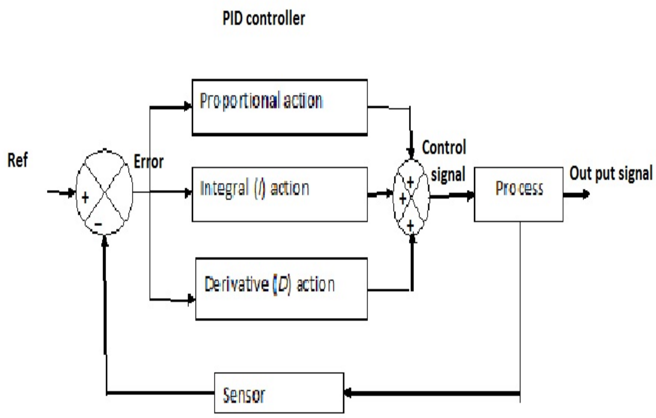

Figure 2. Block diagram representation of a PID controller in a closed loop system.

where U(s) and E(s) are the control (controller output) and tracking error signals in s-domain, respectively; K_p is the proportional gain, K_i is the integration gain, and K_d is the derivative gain. T_i is known as the integral action time or reset time and T_d is referred to as the derivation action time or rate time.
In this context, output of the PID controller in time domain is given by

$$=Kp.e(t) + Ki \int_0^1 e(\tau)$$

Where u(t) and e(t) are the control and tracking error signals in time domain, respectively. The proportional part of the PID controller reduces error responses to disturbances. The integral term of the error eliminates steady-state error and the derivative term of error dampens the dynamic response and thereby improves stability of the system. The parameter settings of a PID controller for optimal control of a plant (process) depend on the plant's behavior To design the PID controller the engineer must choose the tuning way of design parameters to improve the transient response as well as the steady-state error. In the design of a PID controller, the three gains of PID must be selected in such a way that the closed loop system has to give the desired response. The desired response should have minimal settling time with a small or no overshoot in the step response of the closed loop.

Table 1.Transfer function and parameter limits of AVR system

	Transfer function	Parameter limits	Used parameter value
PID controller	$Kp + \frac{Ki}{s} + Kd.s$	$.2 \le kp, ki, kd \le 2.0$	K_p, K_i, K_d =optimum values
Amplifier	$\frac{ka}{1+sTa}$	$10 \le ka \le 40$ $0.02 \le Ta \le .1$	$ka = 10$ $Ta = .1$
Exciter	$\frac{ke}{1+sTe}$	$1 \le ke \le 10$ $0.4 \le Te \le 1.0$	$ke = 1$ $Te = .4$
Generator	$\frac{kg}{1+sTg}$	Kg depends on load (0.7-1.0) $1.0 \le Tg \le 2.0$	Kg=1 $Tg = 1$
sensor	$\frac{ks}{1+sTs}$	$0.001 \le Ts \le 0.06$	$ks = 1$ $Ts = 0.01$

B. Description of an AVR model

The problem of dynamic stability of power system has challenged power system engineers recently. In a synchronous generator, the electromechanical coupling between the rotor and the rest of the system causes it to behave in a manner similar to a spring mass damper system, which exhibits an oscillatory behavior around the equilibrium state, following any disturbance, such as sudden change in loads, change in transmission line parameters, fluctuations in the output of turbine and others.

Synchronous generator excitation control is one of the most important measures to enhance power system stability and to guarantee the quality of electrical power it pro vides. Essentially, an AVR is to hold the terminal voltage magnitude, V t(s), of a synchronous generator at a specified level [6]. In the linear zed model, the transfer function relating the generator terminal voltage to its field voltage can be represented by a gain Kg and a time constant τ_g.the generator transfer function as Kg / (τ_gs + 1), where Kg depends on load (0.7–1.0) and 1.0 s $\le \tau_g \le$ 2.0 s. The same model has been taken in this work.

A simplified AVR system comprises four main components, namely amplifier, exciter, generator, and sensor. In this work, the AVR system is compensated with a PID controller. A block diagram of AVR system using PID control and genetic optimization procedure is shown in Figure3.

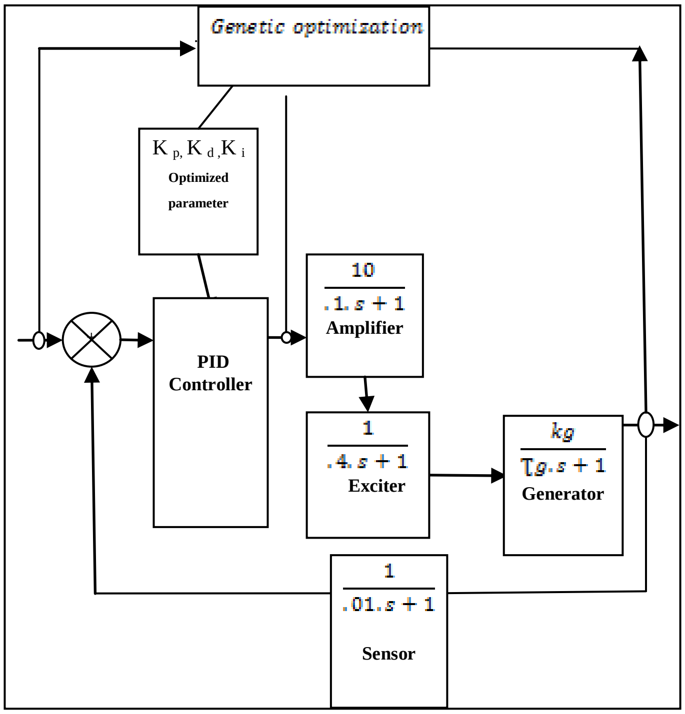

Figure 3. Block diagram representation of an AVR system using a PID controller with genetic optimization

In the terminal voltage step response of the AVR system in closed loop, but without the PID controller (to transfer functions presented in Figure 4) is shown. In this case, the transfer function of system is given by

$$G(s) = \frac{0.07s+7}{.0004s^4+0.0454s^3+0.555s^2+1.51s+8}$$

Where the transfer function has two real poles (-99.9798, -11.9284) and two complex poles (-0.7959 ± 4.0170i). In this case, the transfer function without controller is stable, but it presents oscillatory behavior.[7]

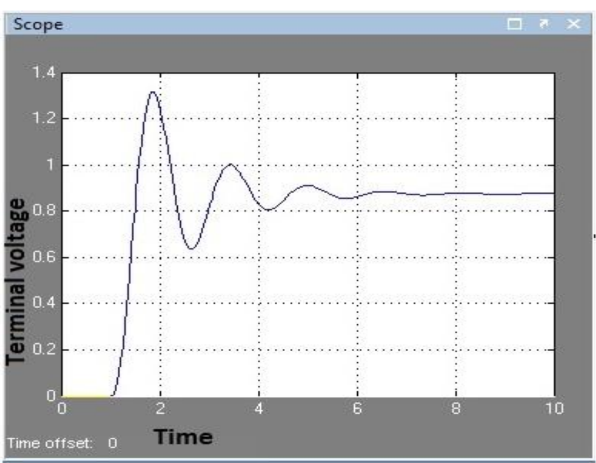

Figure 4.Response in closed loop of AVR system with K_g=.7 and T_g=1.

C. Genetic algorithm

The genetic algorithm is a robust optimization technique based on natural selection. The basic goal of GA is to optimize functions called fitness functions. A possible solution to a specific problem is seen as an individual. A collection of a number of individuals is called a population. The current population reproduces new individuals that are called the new generation. The new individuals of the new generation are supposed to have better performance than the individuals of the previous generation. GA have been successfully implemented in the area of industrial electronics, for instance, parameter and system identification, control robotics, pattern recognition, planning and scheduling and classifier system [8]. For its use in control engineering, GA can be applied to a number of control methodologies for the improvement of the overall system performance.

The GA has the following advantages:

- It is a simple algorithm to understand and implement.
- The algorithm is robust.
- GA is a non-linear process that could be applied to most industrial processes with good results.
- GA searches a population of points instead of a single solution. The GA is therefore not easily sidetracked to obtain a local optimal solution instead of a global optimal solution.
- GA does not need information about the system except for the fitness function.

Due to these considerable advantages of GA, we apply it for optimizing gain coefficients of conventional PID controller.
A tuning Genetic algorithm-PID controller can be implemented as follows.

1) Start
2) Create a population for K_P,K_D,K_I .Initialization of the population of chromosomes for K_p , K_d,K_i (set of randomly generated chromosomes).
3) Evaluation of cost function (fitness)for all chromosomes and run the model.
4) Selection of parent chromosomes, Crossover and mutation all three thing done by automatically using cost function
5) Find the best value.
6) Set iteration and compare the best value to the previous value are equal, optimizations is done then stop.
7) It compare the best value to the previous value is not equal. it replace old population to new population jump to step 2.the loop is continuous run until compare best value to the previous value are equal.

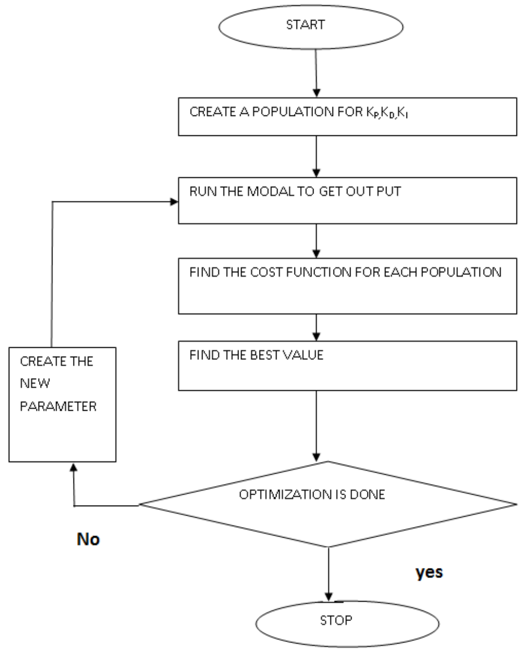

Figure 5. Tuning of PID controller with genetic algorithm

II. RESULT

In this study, three parameters of the PID controller are optimized. Their upper and lower limits are chosen as [0, 1]. In the genetic algorithm, the parameters are settled as the population size is 10 and the number of iterations is 5. The results is obtained by simulation in MATLAB 7.9-b, in order to determine the performances of the proposed AVR system, 5% band of unit step change is made for determining the overshoot. The results of the transient response analysis are represented in Table 2.

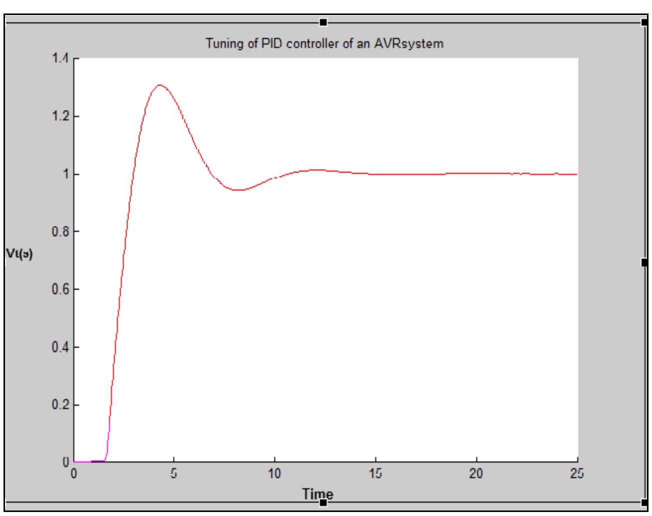

Figure 6. Tuning of PID controller of AVR system without genetic algorithm.

Table2. Result of the transient response analysis of AVR system

	PID CONTROLLER WITHOUT GENETIC ALGORITHM	PID CONTROLLER WITH GENETIC ALGORITHM
Initial value	K_p=1, K_i=1 K_d=1	K_p=1, K_i=1 K_d=1
Optimize value	K_p=1, K_i= 1 K_d=1	K_p=0.81, K_i=0.13 K_d=0.56
Delay time	1.7693	1.7950
Rise time	1.0484	1.8929
Peak time	4.3250	7.8002
Overshoot	0.3056	0.006376

The voltage variation curves which are obtained from the output of these PID controllers of an AVR system are shown in Figure 6, in which overshoot is 0.3056.

The tuned parameters of the PID controller with genetic algorithm and the delay time, rise time, overshoot of the voltage variation curves are measured with transient response analysis as represented as Figure7.

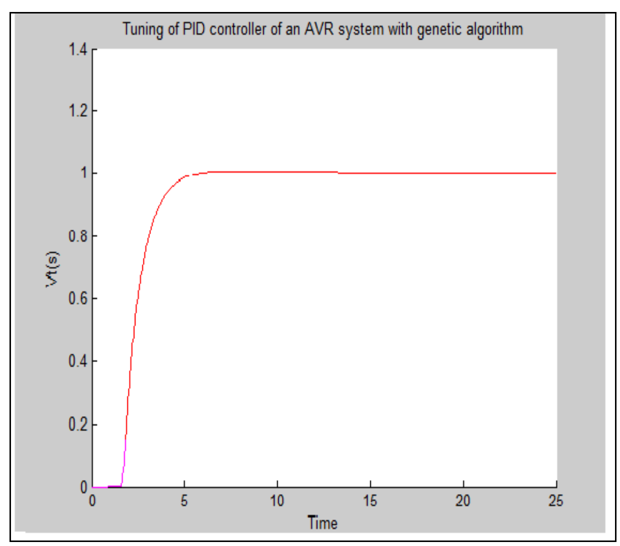

Figure 7. Tuning of PID controller of AVR system with genetic algorithm

It is seen that the overshoot obtained through the tuning of PID controller with genetic algorithm is smaller than the results obtained through the simple PID controller tuning of an AVR system.

It is observed that, genetic algorithm gives better performance than the other optimization method according to the transient response analysis shown in Figure 8.

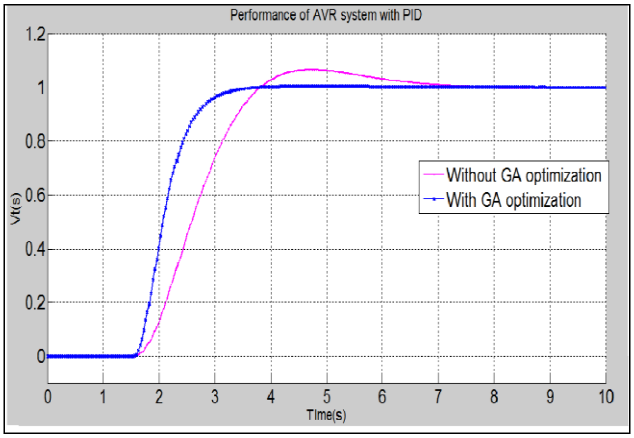

Figure 8. Tuning of PID controller of AVR system Comparison with or without genetic algorithm

III. CONCLUSION

It is observed from the result i.e. Figure 6, 7shows that the performance of genetic algorithm is better than simple PID controller.

In table-2 & Figure 8 the comparison of both the system are shown. It is clear from the table that the overshoot is a decrease from 0.3056 to 0.006376. which is essential parameter for system stabilization. Rise time, delay time, and peak time is increasing in genetic algorithm but it can be considered for better performance. overall performance is better in case of genetic algorithm.

The aim was to improve the control performance using a genetic algorithm for PID controller tuning, the tuning new controller parameters using genetic algorithm was succeeding very good results. The proposed controller parameter settings appear feasible and effective.

IV. REFERENCE

[1] E. Swidenbank., M.D. Brown and D. Flynn, “Self-Tuning Turbine Generator Control for Power Plant”, Mechatronics, Vol. 9, pp. 513-537, 1999.

[2] J.W. Fitch, K.J. Zachariah and M. Farsi, “Turbo generator Self-Tuning Automatic Voltage Regulator”, IEEE Transactions on Energy Conversion, Vol. 14, No. 3, pp. 843-848, 1999

[3] Z.L. Gaing, “A Particle Swarm Optimization Approach for Optimum Design of PID Controller in AVR System”, IEEE Transactions on Energy Conversion, Vol.19, No. 2, pp. 348-391, 2004.

[4] D.H. Kim and J.H. Cho, “A Biologically Inspired Intelligent PID Controller Tuning for AVR Systems”, International Journal of Control Automatic and Systems, Vol. 4, pp. 624-636 , 2006.

[5] A ˚ stro¨m KJ, Ha¨gglund T. PID controllers: theory, design and tuning. USA: Instrument So

[6] Yoshida H, Kawata K, Fukuyama Y, Takayama S, Nakanishi Y. A particle swarm optimization for reactive power and voltage control considering voltage security assessment. IEEE Trans Power System 2000; 15(4):1232–9

[7] Gaing ZL. A particle swarm optimization approach for optimum design of PID controller in AVR system. IEEE Trans Energ Convers 2004; 19(2):384–91

[8] K. F. Man, K. S. Tang, and S. Kwong , “Genetic algorithms: Concepts and applications,” IEEE Trans. Ind. Electron, vol. 43, no. 5, pp. 519-534,May 1996.

[9] O.I. Elgard, “Electric Energy Systems Theory”, Mc Graw-Hill, New York, pp. 299-362, 1982