

# Optimum Design Parameter Estimation of PID Controller in AVR System using Artificial Bee Colony Algorithm

Arvind Pande<sup>1</sup>, B.S Patil<sup>2</sup>, Dr. S.B Patil<sup>3</sup>

Assistant Professor, Department of Information Technology, PVPIT Engineering College, Sangli, MS, India<sup>1</sup>

Associate Professor, Department of Information Technology, PVPIT Engineering College, Sangli, MS, India<sup>2</sup>

Professor, Department of Electronics Engineering, Dr. JJMCOE, Kolhapur, MS, India<sup>3</sup>

**ABSTRACT:** In this paper, an artificial intelligence method, artificial bee colony Optimization (ABC) algorithm is presented for determining the optimal parameter for proportional-integral-derivative (PID) controller. Proportional-Integral-Derivative (PID) controllers are widely used in industry because of their remarkable efficiency, simple structure and robust performance for a wide range of applications. Parameters tuning (  $K_p$ ,  $K_i$ ,  $K_d$  ) of PID controller is necessary to satisfy the operation of the system. But many tuning methods such as Ziegler-Nichols methods do not work as perfectly as it is expected. Such methods have many disadvantages such as lack of precision, long run time and lack of stability. Therefore, artificial bee colony Optimization (ABC) algorithm is applied to system in order to optimize the PID controller parameters and improve the performance of PID controller system. The simulation results show that the ABC method is more effective in improving the step response characteristics such as: overshoot, rise time and settling time.

**KEYWORDS:** ABC, AVR, step response, PID Controller, PSO

## I. INTRODUCTION

The proportional-integral-derivative derivative (PID) controller has been chosen over other controller because it is simple and having a wide range of robust performance. Proportional Integral Derivative (PID) controllers are widely used in industrial applications even though many new control techniques have been proposed [1]. The reason is that it has a simple structure which is easy to be understood by the engineers, and under practical conditions, it has been performing more reliably compared to more advanced and complex controllers [3-4]. The main propose of designing a PID controller is to determine the three gains and they are proportional gain ( $k_p$ ), integral gain ( $k_i$ ) and derivative gain ( $k_d$ ) of the controller [2]. However, the three adjustable PID controller parameters should be tuned appropriately [1].

The Ziegler-Nichols (ZN) method [4] is the most commonly used methodology but this method is hard or difficult to for finding accurate PID parameters such as lack of precision, long run time and lack of stability. Other method is Swarm Intelligence which has two based methods, first is Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO). Particle Swarm Optimization (PSO) originally was introduced by Kennedy and Eberhart in 1995 [8] and it has been applied to a wide variety of applications and because of it is simplicity, easy implementation, it has been found to continuous in solving of continuous nonlinear optimization problem. PSO is a stochastic population optimization algorithm [5], [6]. It is a concept for optimizing nonlinear functions using particle swarm methodology. The advantage of PSO technique is that it is simple in concept, easy to implement and found to be computationally efficient compare to other methods. These methods show premature convergence, slow speed convergence and reduction in diversity. In order to overcome such disadvantages, we proposed ABC algorithm to tune parameters of PID controller.

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Figure 1 shows design of automatic voltage regulator (AVR) using PID (proportional integration derivative) Controller. Here PID controller parameters are obtained by Artificial Bee Colony optimization algorithm [2].

## II. AVR SYSTEM DESIGN USING PID CONTROLLER

The basic function of power system stabilizer is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal(s). In order to provide damping, the stabilizer will produce electrical torque which minimized the rotor speed deviations. The excitation system is controlled by an automatic voltage regulator (AVR) and a power system stabilizer (PSS).

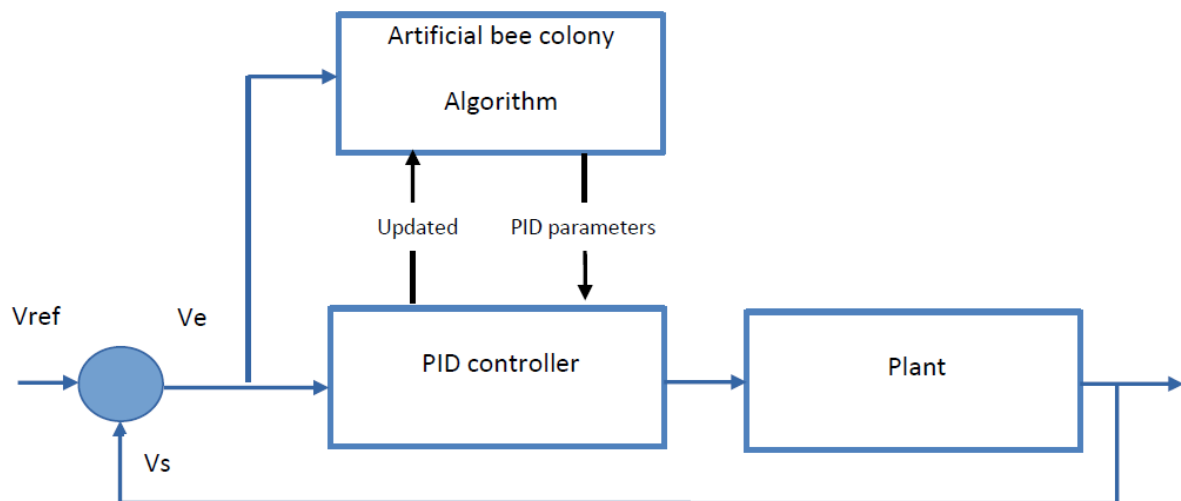


Figure 1. Block diagram of PID Controller tuning

## III. PID CONTROLLER DESIGN FOR AVR SYSTEM

The stable electrical power service to develop the automatic voltage regulator (AVR) of the synchronous generator with a high efficiency and a fast response. Until now, the analog PID controller is generally used for the AVR because of its simplicity and low cost. However, these parameters of PID controller are not easy to tune. Optimum parameters are designed by artificial bee colony optimization algorithm. The AVR system model controlled by the PID controller can be expressed by Figure 2. where  $V_s$  is the output voltage of sensor model,  $V_e$  is the error voltage between the  $V_s$  and reference input voltage  $V_{ref}(S)$ ,  $V_R$  is an amplify voltage by amplifier model,  $V_F$  is a output voltage by exciter model, and  $V_t$  is a output voltage by generator. Following table shows the transfer functions of each model.

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Sr.no	Name of model	Transfer function	Parameter description
1	PID Controller Model	$G_c(s) = K_p + \frac{K_i}{s} + K_d s$	$k_p$ is proportion coefficient, $k_d$ is differential coefficient, and $k_i$ integral coefficient
2	Amplifier Model	$\frac{V_R(s)}{V_e(s)} = \frac{K_A}{1 + \tau_A S}$	$K_A$ is a gain and $\tau_A$ is a time constant
3	Exciter Model	$\frac{V_F(s)}{V_R(s)} = \frac{K_E}{1 + \tau_E S}$	$K_E$ is a gain and $\tau_E$ is a time constant
4	Generator Model	$\frac{V_I(s)}{V_F(s)} = \frac{K_G}{1 + \tau_G S}$	$K_G$ is a gain and $\tau_G$ is a time constant
5	Sensor Model	$\frac{V_S(s)}{V_I(s)} = \frac{K_R}{1 + \tau_R S}$	$K_R$ is a gain and $\tau_R$ is a time constant

In this paper, the GA and PSO algorithm are applied to search best PID parameters so that the controlled system has a good control performance. The AVR system model controlled by the PID controller can be expressed by Figure 2.

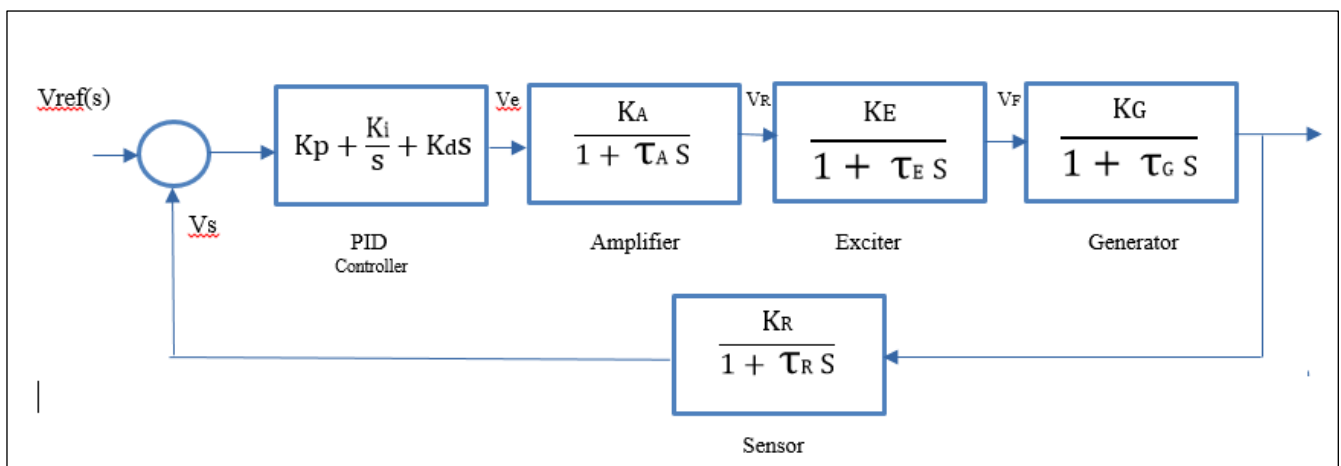


Figure 2: Closed loop block diagram AVR system

In [17] a performance criterion  $W(K)$  is defined by

$$\text{Min } k: \text{stabilizing } W(K) = (1 - e^{-\beta}) (M_p + e_{ss}) + e^{-\beta}(t_s - t_r)$$

Where  $\beta$  is weighting factor,  $M_p$  is overshoot time,  $t_r$  is rise time, settling time  $t_s$ , and  $e_{ss}$  is steady state error in the time domain.  $M_p$  and  $e_{ss}$  are positive values. Here fitness function is proposed as

$$f_G(k) = \frac{1}{W(k) \times ITAE}$$

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This fitness function  $f_G$  is used in an over-damping system and  $ITAE$  is an integral of time multiplied by absolute-error value.

$$ITAE = \sum_{i=0}^{\text{end time}} t_i | e_i |$$

Where  $I \{0, 1, 2, \dots, \text{end time}\}$  is an index,  $t_i$  is the  $i$ -th sampling time, and  $e_i$  is the absolute-error value in the  $i$ -th sampling time.

## IV. ARTIFICIAL BEE COLONY ALGORITHM

Artificial bee colony (ABC) is a new population-based stochastic algorithm which has shown good search abilities on many optimization problems. Here this algorithm is used to get the values of  $k_p$ ,  $k_i$ ,  $k_d$ . This triplet is passed to PID controller which controls AVR. This simulation finds optimized values for  $k_p$ ,  $k_i$ ,  $k_d$  after multiple feedback iteration from system. The optimized value of above parameter tunes significantly well and suppresses the oscillations in the system and provides good damping characteristics to low frequency oscillations. Hence it stabilizes the system much faster.

In the ABC algorithm, the colony consists of three groups of bees: employed bees, onlookers and scouts. It is assumed that there is only one artificial employed bee for each food source. The number of employed bees in the colony is equal to the number of food sources around the hive. Employed bees go to their food source and come back to hive and dance on this area. The employed bee whose food source has been abandoned becomes a scout and starts to search for finding a new food source. Onlookers watch the dances of employed bees and choose food sources depending on dances.

The main steps of the ABC algorithm are as below.

Initial food sources are produced for all employed bees

- REPEAT
  - Each employed bee goes to a food source in her memory and determines a neighbor source, then evaluates its nectar amount and dances in the hive
  - Each onlooker watches the dance of employed bees and chooses one of their sources depending on the dances, and then goes to that source. After choosing a neighbor around that, she evaluates its nectar amount.
  - Abandoned food sources are determined and are replaced with the new food sources discovered by scouts.
  - The best food source found so far is registered.
- UNTIL (requirements are met)

## V. SIMULATION RESULTS AND DISCUSSION

Generally, traditional method of tuning doesn't guarantee optimal parameters and in most cases the tuned parameters needs improvement through trial and error. To evaluate the effectiveness of the ABC method on PID to improve the stability of the power system, the dynamic performance of the ABC was examined under different loading conditions

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The transfer function of the system is:

$$G(s) = \frac{14.33 s^2 + 67.44 s + 12.48}{0.000105 s^5 + 0.02478 s^4 + 0.7667 s^3 + 1.935 s^2 + s}$$

Figure 3 Shows the sample step response of obtained from ABC tuning method for above system transfer function. A PID controller has to be designed such that it improves the following time response parameters.

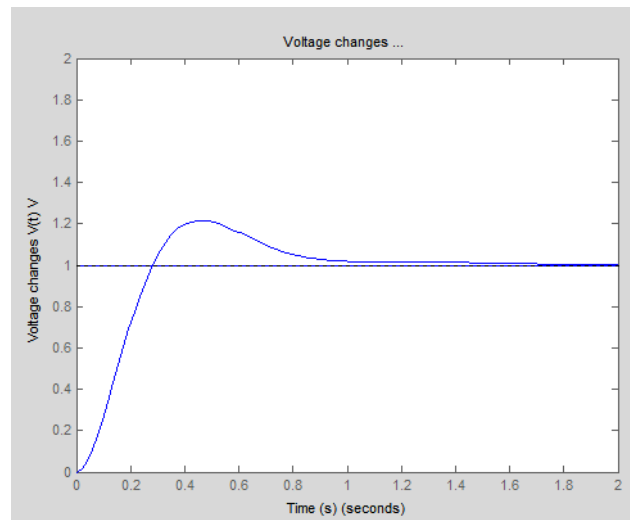


Figure 3: Step Response using ABC tuning method.

Figure 4 shows bode diagram. It is a combination of a Bode magnitude plot, expressing the magnitude (usually in decibels) of the frequency response, and a Bode phase plot, expressing the phase shift. Both quantities are plotted against a horizontal axis proportional to the logarithm of frequency

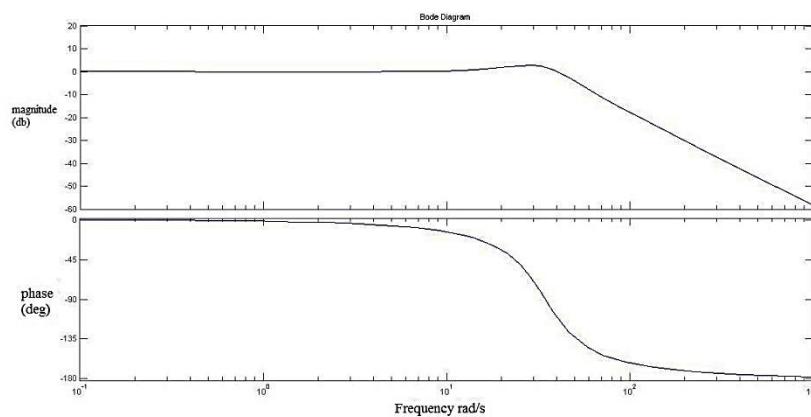


Figure 4 : bode diagram

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The obtained results has been compared with the conventional Ziegler- Nichols tuning technique & PSO (Particle swarm optimization algorithm) on performance metrics on overshoot (Mp) in%, settling time (Ts), rise time (Tr) and peak time (Tp). Through the simulation results, it is clearly shown that the ABC controller can perform an efficiently and obtain optimal PID controller parameter that can achieve better performance criterion. Following table shows Time response parameters comparisons of obtained using various tuning method. Following table 1 shows searching range for each parameters used in simulation work.

Parameters	Min	Max
Kp , Ki ,Kd	0.2	2
Ka	10	40
Ke	1	10
Kg	0.7	1
Ks	1	1
Ta	0.02	1
Te	0.4	1
Tg	1	2
Ts	0.001	0.6

Table 1: Range of parameters.

Table 2 shows the results of time response parameter Ts, Tr & Tp for 100 iterations of tuning algorithm. The tuning parameters given by ABC algorithm is  $K_p = 1.9267$ ,  $K_i = 0.3564$ ,  $K_d = 0.4094$

Sr.no	Tuning method	Settling time (Ts)	Rise Time ( Tr)	Peak Time (Tp)
1	Ziegler- Nichols	10.410	0.5110	0.094
2	PSO	5.620	0.4212	0.182
3	ABC	0.268	0.0635	0.150

Table 2: Time response comparisons for 100 iterations.

Table 3 shows the results of time response parameter Ts, Tr & Tp for 200 iterations of tuning algorithm. The tuning parameters given by ABC algorithm is  $K_p = 1.5779$ ,  $K_i = 0.8408$ ,  $K_d = 0.7342$

Sr.no	Tuning method	Settling time (Ts)	Rise Time ( Tr)	Peak Time (Tp)
1	Ziegler- Nichols	6.410	0.5910	0.084
2	PSO	0.2813	0.4021	0.196
3	ABC	0.2501	0.0425	0.095

Table 3: Time response comparisons for 200 iterations.

Table 4 shows the results of time response parameter Ts, Tr & Tp for 300 iterations of tuning algorithm. The tuning parameters given by ABC algorithm is  $K_p = 1.6521$ ,  $K_i = 0.3896$ ,  $K_d = 0.5634$

Sr.no	Tuning method	Settling time (Ts)	Rise Time ( Tr)	Peak Time (Tp)
1	Ziegler- Nichols	8.410	0.6310	0.034
2	PSO	3.740	0.9212	0.292
3	ABC	0.668	0.0235	0.137

Table 4: Time response comparisons for 300 iterations.

## VI. CONCLUSION

In this paper, an ABC algorithm is proposed for predicating PID control parameters  $K_p$ ,  $K_i$ ,  $K_d$  to set for AVR system. From the simulation and comparison results, we can see that the ABC algorithm find a high-quality PID control parameter set effectively so that the controlled AVR system has a better control performance than the other methods.

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Simulation results have shown that the control parameters obtained from ABC method gives stable time response parameters which provides more stability and efficiency for AVR. Results also show that searching PID controller parameters is easier and quicker than PSO & Ziegler- Nichols method.

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