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Review Paper

Performance analysis of AVR without controller and with particle swarm optimization (PSO)-PID tuned controller

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Abstract

This paper presents the study and comparison of controller applied for stabilization of an automatic voltage regulator (AVR) system. The AVR without any controller does not ensure robust stability of the system. To ensure this characteristic, PID controller is used in conjunction with voltage regulator and PSO algorithm is used to tune the parameters of PID to get the better outputs. MATLAB turned out to be a useful tool and it is used for the optimization process. The paper also shows us the comparison of AVR output without controller and with PSO tuned PID controller.

Keywords: Robust Stability, AVR, PSO optimization technique.

Introduction

A voltage regulator is defined as any electronic or electrical device that maintains the voltage of a system within an acceptable limit. It is designed such as to maintain a constant voltage level spontaneously. An AVR (Automatic Voltage Regulator) system can simply be a “feed-forward” design or may comprise negative feedback control loop. Relying upon the different designs it can be used to control one or more than one AC voltages or DC voltages. A basic AVR consists of following components: i. Amplifier, ii. Exciter, iii. Generator and iv. Sensor.

PSO or Particle Swarm Optimization technique is grown rapidly. There are 3 parameters for PID controller namely proportional, integral and differential which are optimized using PSO techniques. Similarly for Hybrid controllers the selection of weighting function parameters is done using the PSO technique.

In past decades, many processes are suggested to tune the PID parameters. The PSO technique which was first introduced by Kennedy and Eberhart, is an interesting algorithm. This algorithm is found robust in resolving continuous non-linear optimization problems.

This technique can produce a high-quality with stable convergence characteristics and shorter calculation time than other methods. This algorithm has a lot of applications in the engineering fields. This has many useful applications in engineering fields also. Controllers are designed by using IAE (Integral Absolute Error) criteria by using MATLAB simulation and comparison is done for the AVR output.

Modelling of AVR

AVR is a voltage regulator, which keeps the output voltage at a constant value. This is used with a system to keep the terminal voltage at the specified level i.e. constant magnitude. In an AVR by mathematical modelling and transfer function of the components specified above must be linearized, in which the saturation or other non- linearity has been ignored and major time constant is considered. The transfer function of these components may be modelled, and is shown in Figure-3 with transfer functions[1].

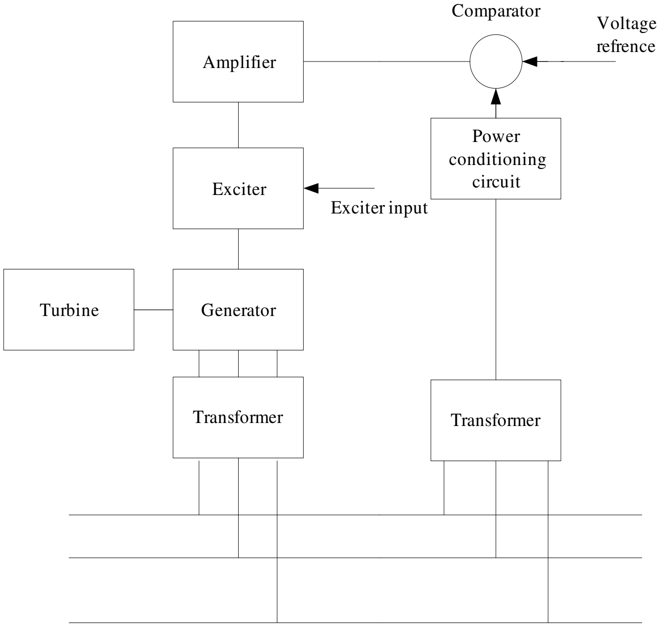

Figure-1: Simple model of an AVR.

The excitation system of the generator maintains the generator voltage and also regulates the reactive power flow by means of an AVR[2]. As the work of the AVR is to maintain the synchronous generator voltage. Hence, the change in AVR system stability may severely affect the power system and its security. Following analysis shows, a practical AVR with PID controller, and with Hybrid controller are adopted for testing the performance of an AVR and the results are compared.

Methodology for PID controller tuning

For tuning of PID controller for AVR, Out of the various optimization technique PSO with IAE criterion has been employed[11].It is a population based optimization technique and is encouraged through the societal behavior of fish schooling and bird flocking. The basic algorithm of PSO is as follows:

Step-1 State the upper and lower boundaries of the three controller parameters and initialize arbitrarily the individuals of the population including velocities p_{best} , searching points and g_{best} .

Step-2 Compute the fitness value of every individual in the population by means of the evaluation function.

Step-3 Compare every individual‘s evaluation value with its p_{best} The best evaluation value out of all p_{best} is denoted as g_{best} .

Step-4 Alter the member velocity **v** of every individual k .

$$v_{j,g}^{(t+1)} = \omega \times v_j^{(t)} + c_1^* \, rand() \times \left(p_{best_{j.g}} - k_{j,g}^{(t)} \right)$$
$$+ c_2^* \, rand() \times \left(g_{best_g} - k_{j,g}^{(t)} \right) \quad (1)$$

Where: $j = 1, 2, 3......n$, $g = 1, 2, 3......n$ here the value of ω is set. When g is1 $v_{j,g}$ signifies the alteration in velocity of $\boldsymbol{k_p}$ controller parameter. When g is 2, signifies the alteration in the velocity of K_p controller parameter. When g is 3, signifies the alteration in velocity of K_d controller parameter.

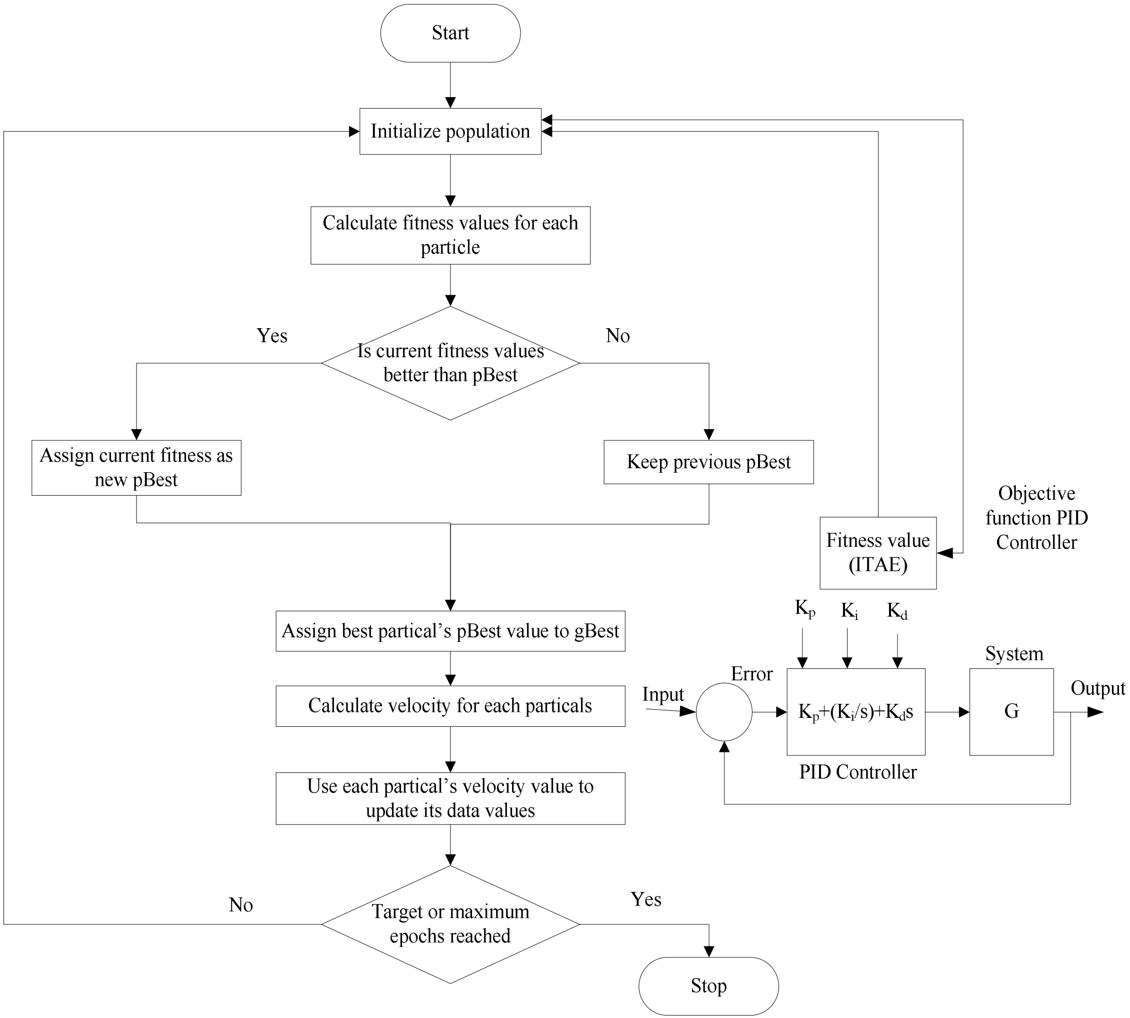

Figure-2: Flowchart of parameter optimizing procedure using PSO[12]**.**

Step-5If $v_{j,g}^{(t+1)} > V_g^{\max}$,then $v_{j,g}^{(t+1)} = V_g^{\max}$ (2)

If $v_{j,g}^{(t+1)} > V_g^{\min}$ then $v_{j,g}^{(t+1)} = V_g^{\min}$ (3)

Step-6 Modified the member of every individual k .

$$k_{j,g}^{(t+1)} = k_{j,g}^{(t)} + v_{j,g}^{(t+1)} \quad (4)$$

$$k_g^{\min} \le k_{j,g}^{(t+1)} \le k_g^{\max} \quad (5)$$

Where: $k_g^{\min}$ and $k_g^{\max}$ signifies the lower and upper boundaries, respectively, of member g of the individual. When value of g is 1, the upperand lower bounds of the K_p controller parameter are $K_p^{\max}$ and $K_p^{\min}$ respectively. When value of g is 2, the upper and lower bounds of the K_i controller parameter are $K_i^{\max}$ and $K_i^{\min}$ respectively. When the value of g is 3, the upper and lower bounds of the K_d controller parameter are $K_d^{\max}$ and $K_d^{\min}$

Step- 7 If the number of iterations reaches the peak value then go to Step 8. Else, go to Step 2.

Step-8every individual produces the latest is an optimal controller parameter.[10]

Figure-2 shows the flow chart of PSO tuned controller, first of all, the population is initialized and fitness value of each particle is calculated[4-5]. Individual p_{best} and the global best values are calculated.

Model of an AVR with Pid controller

A PID controller is used to reduce or eliminate the steady state error along with to improve the dynamic response of the overall system.[7] PID stands for proportional integral and derivative control, the proportional term amplifies the gain, and integral controller increases the type of the system by adding a pole at the origin and reduces the steady state error. And the derivative controller helps to improve the transient response by adding a finite zero to the open loop plant transfer function[9]. The transfer function of a PID controller is given as

$$G_{pid}(s) = K_p + \frac{K_i}{s} + K_d s \quad (6)$$

Therefore the alteration in terminal voltage $\Delta V_t(s)$ of the system respect to a alteration in input reference voltage $\Delta V_{ref}(s)$ is given as

$$\Delta V_t(s) = \left[\Delta V_{ref}(s) - \left(\frac{K_a}{1+T_a s}\right)\Delta V_t(s)\right] \times \left[\left(\frac{K_a}{1+T_a s}\right)\left(\frac{K_e}{1+T_e s}\right)\left(\frac{K_g}{1+T_g s}\right)\left(K_p + \frac{K_i}{s} + K_d s\right)\right] \quad (7)$$

The simulation result under matlab

The various step responses are simulated in MATLAB and there comparative study has been tabulated, using characteristic parameters of the step response of AVR without PID, AVR with PID in Figure-4 step response shows oscillatory behavior for quite a time and the peak is even high with respect to other controlled AVR.

Figure-5 shows the step response of AVR with PID control having parameters set to $K_p = 0.26$, $K_i = 1$ and $K_d = 0.25$. Thus, there is an improvement in the system response.

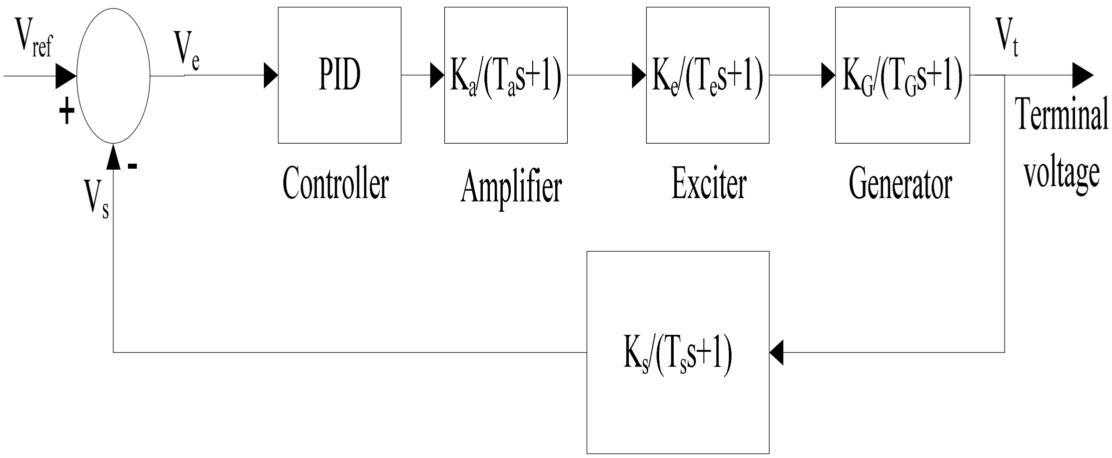

Figure-3: Complete Block diagram of AVR-PID controller.

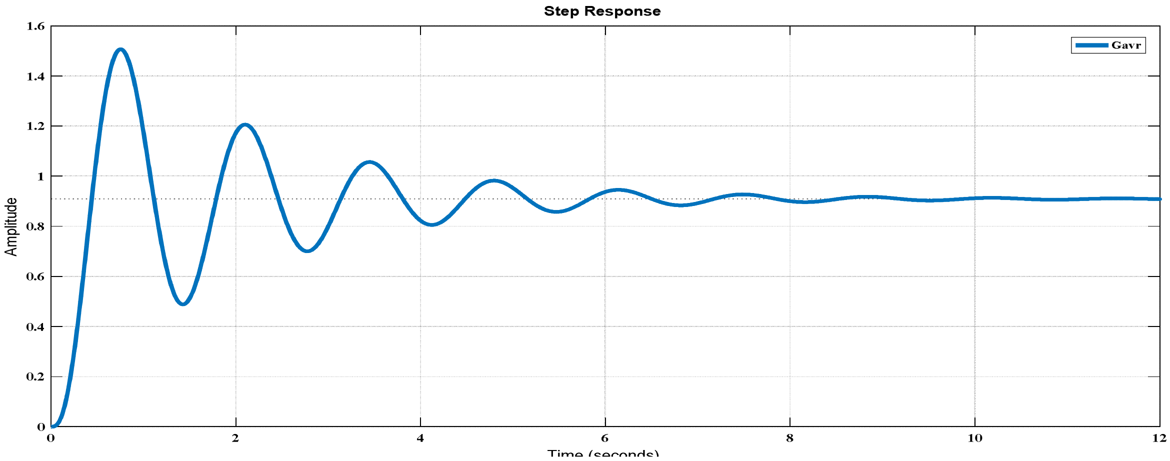

Figure-4: AVR without PID controller step output.

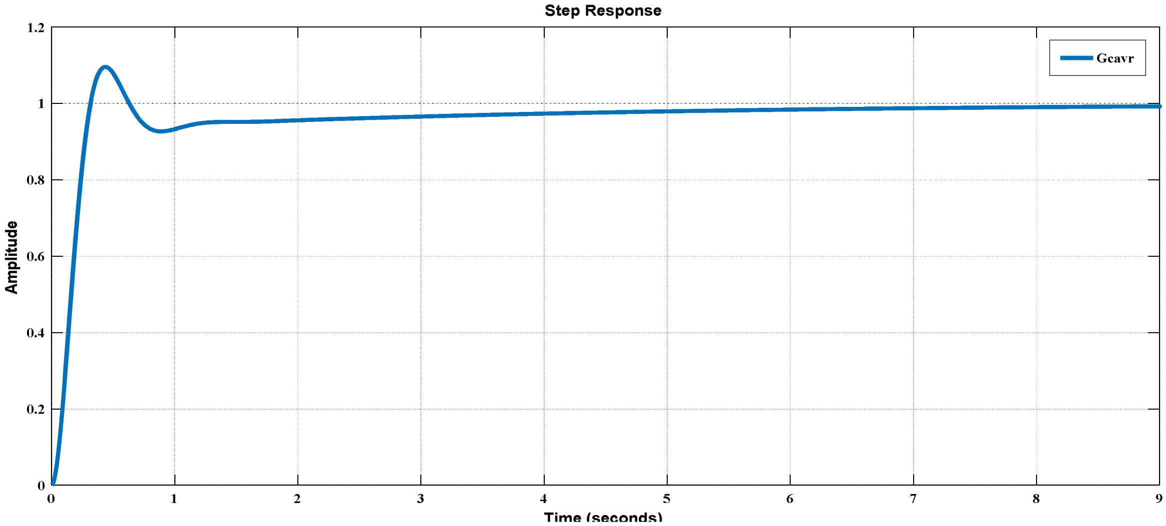

Figure-5: AVR with PID controller step response.

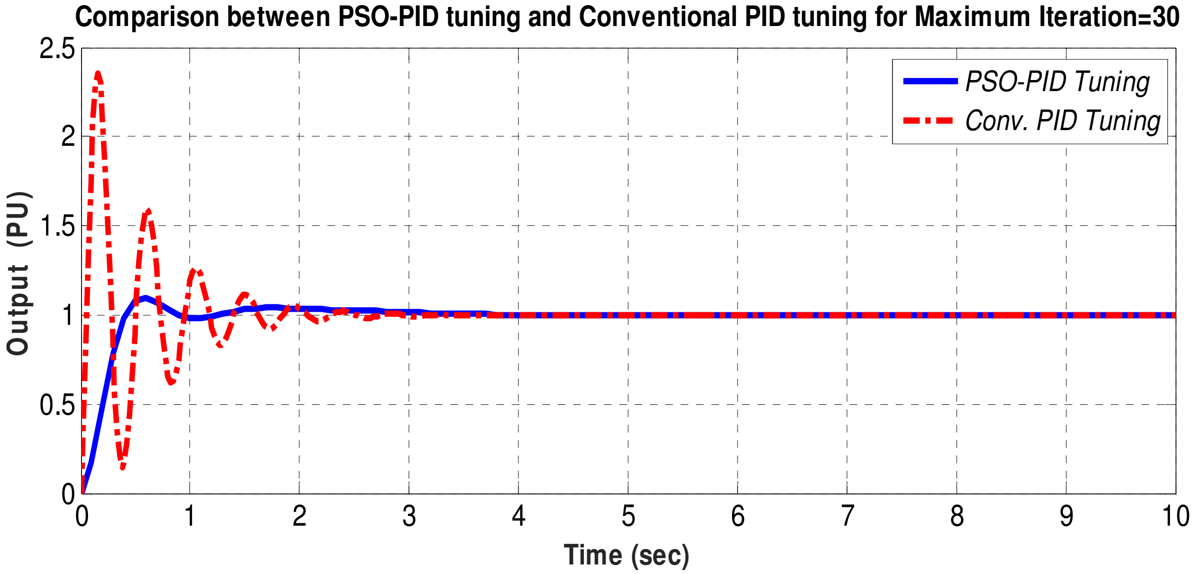

Figure-6: Comparison of step response of PSO-PID tuned AVR and a conventional PID tuned AVR for 30 iterations.

Figure-6 shows the comparison of the PSO-PID tuned AVR and AVR without controller. The optimum value obtained are, $K_p = 0.3911$, $K_i = 0.4232$ and $K_d = 0.2036$ from the above step response it is clear that on employing PSO techniques to hybrid controller it will result in better outputs.

Table-1: Comparison of various parameters for different controllers.

Method	Overshoot	T_s	T_r	T_p
Conventional AVR without PID	137.88	2.217	0.0399	0.1625
AVR with PSO-PID	4.99	3.2932	0.2867	0.5590

Table-1 indicates the PID tuned AVR also compensate on overshoot whereas it doesn't reduces the peak time, settling time as PSO-PID tuned controller.

Conclusion

The analysis is done on the AVR with and without controller in this paper. The AVR with PID controller tuned by PSO is much better than the AVR without controller. There are less oscillations in the output with controller and it also reduces the maximum peak overshoot of the system but it does not affect significantly on the settling time, rise time and peak time. According to the above analysis the automatic voltage regulator with PSO-PID controller is comparatively more relevant and accurate.

Acknowledgement

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