Optimum Design of PSO based tuning using PID controller for an Automatic Voltage Regulator system

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Abstract - *In this paper, an endeavour is made to apply the Optimization procedure to tune the parameters of a PID controller for a viable Automatic Voltage Regulator (AVR). Existing metaheuristic tuning strategies have been turned out to be very fruitful yet there were detectable territories that require upgrades particularly as far as the framework's gain overshoot and steady state mistakes. Utilizing the improved algorithm where every area in the crowd is a hopeful answer for the Proportional-Integral-Derivative parameters was extremely useful. The empowering results acquired from the reproduction of the PID Controller parameters-tuning utilizing the PSO when contrasted and the execution of formal PID, and (Enhanced Particle-Swarm Optimization PID (PSO-PID), and creates enhanced-PID a good addition to solving PID Controller tuning problems using metaheuristics. This optimization done with the help MATLAB 2018a*.

Keywords- AVR system, optimal control, particle swarm optimization, PID controller.

1. INTRODUCTION

The main function of AVR loop is to control the generator terminal voltage. This implies keeping regulated voltage inside endorsed restrains as conceivable as could be Increasing or diminishing terminal voltage is performed by relative process for excitation voltage/current. This directly increases or reduces the reactive power output of the generator. This procedure is confined by two cutoff points; AVR loop impediments and generator capacity.

Electricity must be expended at a similar moment it is created. Therefore, the total generation must meet the total load requirement of both active and reactive power. The heap dynamic interest is voltage and recurrence freque [1]. It is for the most part increments as voltage or frequency dependent (inside the safe operational breaking points). The electrical burdens are not steady always but rather lamentably, a large portion of the heaps fluctuate frequently or arbitrarily everywhere throughout the time In request to enhance the execution of the AVR frameworks, the PID controller is ordinarily utilized since it has basic structure. Likewise, it is strong to varieties of the framework parameters. The reason of this acceptability is for its simple structure which can be easily understood and implemented [5]. Easy implementation of hardware and software has helped to gain its popularity. A few methodologies have been reported in literary works for deciding the PID controller parameters. Most well known techniques are Ziegler Nichols tuning, as given in Ziegler JG, and Nichols NB (1942), neural system, as given in Q.H. Wu, B.W. Hogg, and G.W. Irwin, (1992), fluffy based methodology as given in A. Visioli (2001), and Genetic Algorithm as given in R.A. Krohling, and J.P. Rey (2001). Particle swarm optimization (PSO) method is utilized in tuning the parameters of the proposed (PID) controller of a synchronous generator.

This PSO system is exceptionally effective in taking care of persistent non-linear optimization issues [11]. The performance index used for tuning the controller considers both the set point and disturbance responses. Next to the strong dependability of the closed loop framework is ensured by determining limited bound on the greatest affectability work. The results of the simulation show that when the PSO method is used the performance of the tuned PID controller is significantly more efficient and the response is better in quality.

In general, the responsive power deviations influence the terminal voltage of the framework and the job of AVR is to hold the voltage extent of synchronous generator at a predetermined dimension and furthermore to improve the framework steadiness [17]. The essential methods for generator responsive power control in AVR circle is finished with the excitation control and the valuable control activity is furnished with customary controllers like Proportional (P), Integral (I), Proportional Integral (PI) and PID controller or with an intelligent controllers. The fundamental choice criteria of these controllers are assessed by its legitimate control exhibitions, quick reaction and its robustness towards the non linearity, time fluctuating elements, unsettling influences and different variables. The PID controller has been prescribed as a presumed controller in this understanding and can be utilized as an advantageous controller for AVR framework. Normally, the gain parameters PID controllers are computed through trial and error or conventional Ziegler–Nichols methods (Katsuhiko Ogata, 2008).

There is so many optimization techniques are developed now a days for optimal tuning of these gain parameters

(Indranil Pan and Saptarshi Das, 2013; Seyed Abbas Taher, 2014). Among them the Swarm Intelligent (SI) techniques are very popular only because of, providing good quality of solutions within a short duration of time for mixed integer nonlinear optimization problems (Anil Kumar and Rajeev Gupta, 2013). Although, these techniques have been used in almost all fields of engineering (Noureddine Bouarroudj et al., 2015), the effectiveness is dreadfully confirmed in control and stability domain. The SI methods for the most part comprise of a populace of regular or counterfeit swarms, communicating locally with each other and furthermore with their condition. This phenomenon aids to find an optimal solution in any field of optimization problems.

The earlier research work proves that both the transient performances and the stability of an AVR system can be improved with PID controller compared to Particle Swarm Optimization (PSO) algorithm (Haluk and Cengiz, 2011). For the same system configurations.

Focusing only two of the transient measuring parameters called maximum peak and settling time. However, the rise time of the system, which is one of the main transient measures to be considered for analyzing the transient performances. When, the system is having high rise time characteristics, the settling time of the system also increased drastically in most of the cases. This can be clearly demonstrated when the system is subjected to any kind of uncertainties/ disturbances. Correspondingly, in enhanced PSO based tuning the system exhibits rapid variations in settling time and peak time during the robustness performance analysis with parameter variations. Proved its effectiveness over ultimate algorithms like previous PSO Algorithm and enhanced PSO. The objective function plays a major role in optimization problems. Normally, minimization of integrated absolute error (IAE), or integrated time absolute error (ITAE), or the integral of squared-error (ISE), or the integrated of time weighted-squared-error (ITSE) are used as an objective function for optimal tuning of PID controller. In contrast to others a new objective function with fundamental time domain specifications such as maximum peak, rise time, settling time, and steady-state error is used in this paper to enhance the transient performances of the AVR system. The results of the proposed approach are analyzed in three different ways such as transient analysis, stability analysis and robustness analysis to prove its superiority over other algorithms. At first, the output response of the system with proposed approach is analyzed with the essential transient measuring parameters like Maximum Peak, Settling time, Rise Time and Peak Time. Further, the stability of the system is demonstrated with necessary stability margins such as peak gain, phase margin, gain margin and delay margin. At the point when a designer plans a control framework, the structure is normally founded on some mathematical model for the framework to be controlled. However, the system model is only an approximation. In reality the system may behave differently than the model indicates, or the system parameters may vary with time. So as to acquire palatable control design, it is required that the control framework performs well, on the embraced ostensible model, as well as on the genuine physical process. This leads directly to that agreeable execution is accomplished for the unverifiable model and the class of possible perturbations. In this way this manuscript did the various types of robustness analysis to ensure the proper design of the controller.

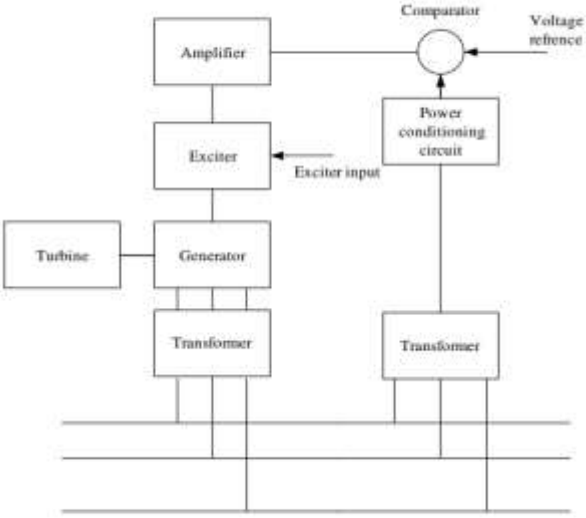

Fig.1. Block Diagram of AVR system

2. PID CONTROLLER DESIGN FOR AVR SYSTEM

It is a critical issue for the stable electrical power service to build up the AVR of the synchronous generator with a high productivity and a quick reaction. As of not long ago, the similarity PID controller is commonly utilized for the AVR as a result of its effortlessness and ease.

However, these parameters of PID controller are not easy to tune Gaining [17] proposed a method to search these parameters by using a particle swarm optimization (PSO) algorithm. The AVR system model controlled by the PID controller can be expressed by Figure 1. Where is the output voltage of sensor model, *e* is the error voltage between the *s* and reference input voltage *ref* (*S*), *R* is an amplify voltage by amplifier model, *F* is a output voltage by exciter model, and *t* is a output voltage by generator. There are 5 models: (a) PID Controller Model, (b) Amplifier Model, (c) Exciter Model, (d) Generator Model, and (e) Sensor Model. Their exchange capacities are described as pursues:

(a) PID Controller Model The transfer function of PID controller is

$$G_c(s) = k_p + k_d s + \frac{k_i}{s} \qquad \text{..........(1)}$$

Where k_p, k_d, and k_i are

the proportion coefficient, differential coefficient, and integral coefficient, respectively.

(b) Amplifier Model The transfer function of amplifier model is

$$\frac{V_R(s)}{V_e(s)} = \frac{K_A}{1+\tau_A s} \qquad \text{..........(2)}$$

Where KA is a gain and A is a time constant.

(c) Exciter Model The transfer function (TF) of exciter model is

$$\frac{V_F(s)}{V_R(s)} = \frac{K_E}{1+\tau_E s} \qquad \text{...............(3)}$$

Where KE is a gain and E is a time constant.

(d) Generator Model the TF of generator model is

$$\frac{V_t(s)}{V_F(s)} = \frac{K_G}{1+\tau_G s} \qquad \text{.................(4)}$$

Where KG is a gain and G is a time constant.

(e) Sensor Model the TF of sensor model is

$$\frac{V_S(s)}{V_t(s)} = \frac{K_R}{1+\tau_R s} \qquad \text{...................(5)}$$

Where K_R is a gain and R is a time constant. In this paper, the PSO algorithm is applied to search best PID parameters so that the controlled system has a good control performance. In [17], a perform

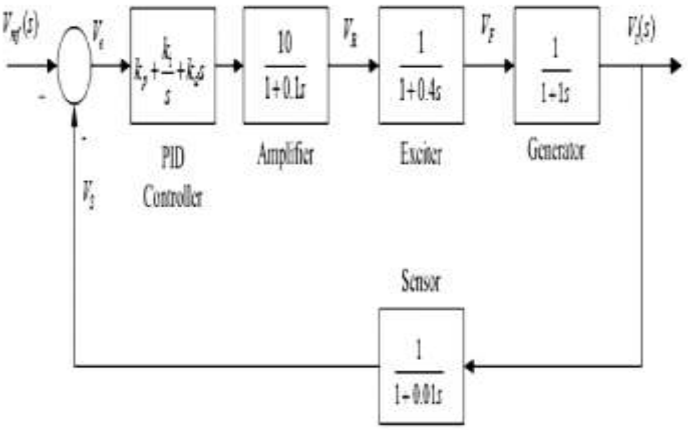

Fig.2.A practical high-order AVR system controlled by a PID controller.

Table 1. Parameter limits in AVR system

Model Name	Parameter limits	Used Parameter values
PID controller	0.2 ≤ Kp ≤ 2 0.2 ≤ Ki ≤ 2 0.2 ≤ Kd ≤ 2	Optimum values
Amplifier	10 ≤ Ka ≤ 40 0.02 ≤ Ta ≤ 0.1	Ka = 10 Ta = 0.1
Exciter	1 ≤ Ke ≤ 10 0.4 ≤ Te ≤ 1	Ke = 1 Te = 0.4
Generator	Kg depends on load (0.7-1) 1 ≤ Tg ≤ 2	Kg = 1 Tg = 1
Sensor	0.001 ≤ Ts ≤ 0.06	Ks = 1 Kg = 0.01

Table 2. Effect of PID controller on time domain specifications

Controller	Rise-time	Overshoot	Settling time	Steady state error
K p	Decreases	Increases	Small Change	Decreases
Ki	Decreases	Increases	Increases	Eliminates
Kd	Small Change	Decreases	Decreases	Small Change

3. PROBLEM FORMULATION

In huge interconnected frameworks soundness issues like low recurrence motions are normal. Electro-mechanical oscillations must be damped out as fast as would be prudent. To do so, a simple way is to play with the performance indices of the system such as maximum peak overshoot (*Mp*), settling time (*ts*), rise time (*tr*).Therefore in order to improve the damping performance of power systems we go for coordinated tuning of PID parameters for an AVR system with PSS. Choosing good control parameters *K p*, *Ki* and *Kd* gives rise to good step response and better stability performance to a system. The simultaneous tuning of over three control parameters is defined as an improvement issue.

$$F(K)=\alpha Mp+\beta(tr+ts)$$

Where α and β are the weights the above objective function is known as weighted objective function. We try to control the values of M_p, t_r and t_s by associating each with proper weights. The allocation of weights varies with different problem descriptions. In this paper, the main aim is to increase the damping performance of a AVR-PSS system. Therefore, more weight age is allocated to settling time and rise time i.e. > . But this does not mean that maximum peak overshoot has no effect on the damping performance, it does have a significant and considerable effect but in this paper, we have worked based on the following case. The above optimization problem is subjected to following inequality constraints.

$$Kp\ min < Kp < Kp\ max,$$
$$Ki\ min < Ki < Kimax \text{ and}$$
$$Kd\ min < Kd < Kd \text{ max}$$

Where K_p min, K_i min and K_d min are the minimum limits of proportional, integral and derivative gains individually and K_p max, K_i max and K_d max are the base furthest reaches of corresponding, essential and subordinate gains separately.

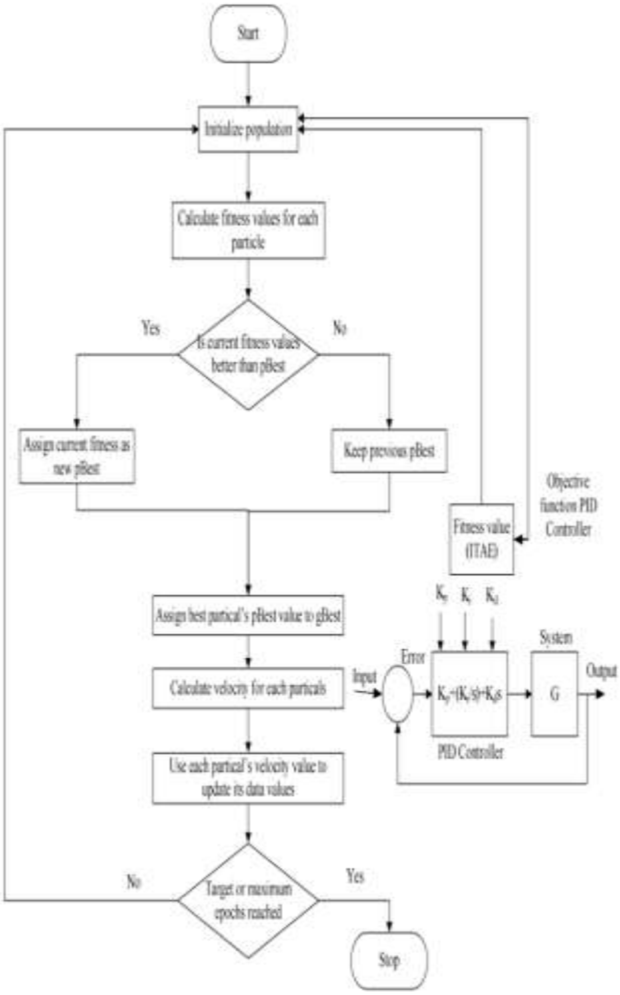

Figure-3: Flowchart of parameter optimizing procedure using PSO

4. SIMULATION RESULTS

To verify the efficiency of the proposed fitness function in the PSO algorithm, a practical high order AVR system [19] as shown in Figure 2 is tested. The AVR system has the following parameters.

Fig.4. Effects without PID Controller

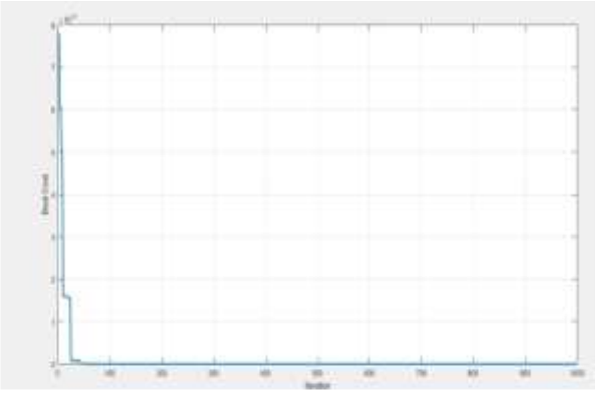

Fig.5. Iteration behaviour of the System

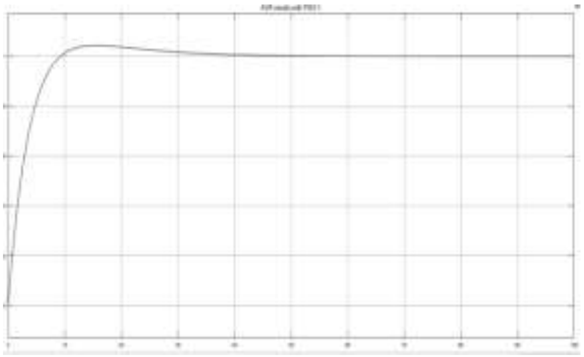

Fig.6. Normal PSO-1 Effect with AVR System

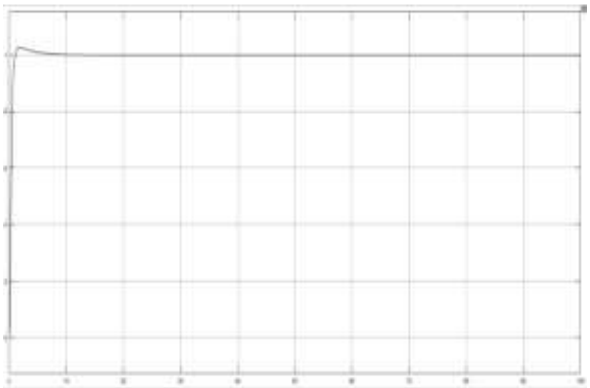

Fig.7. Enhanced PID Effect for AVR System

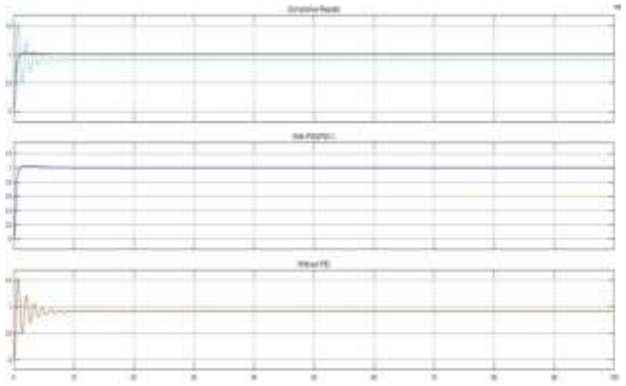

Fig.8. Comparative Results AVR System

5. CONCLUSION

The amenity of using PSO-PID to enhance the control and stability of AVR system is discussed in this paper. In AVR, the steady and quick reaction of the controller is hard to accomplish because of the high inductance of the generator field windings and load variety. Henceforth, different control structures have been proposed for the AVR framework, be that as it may, among these controllers the relative in plus integral plus derivative (PID) is recommended as the most ideal controller in this paper. The gain parameters of PID controller in AVR system are, effectively tuned with applied optimization approach and the improvement in closed loop performances are clearly established in point in this paper. Minimization of voltage deviations in output response is considered as a main objective of AVR and a new fitness function with all the essential time domain specifications is introduced in this paper to satisfy this objective. The potency of the proposed algorithm is confirmed by comparing the output responses, stability and robustness of the system with the recently reported modern heuristic algorithms such as PSO and improved PSO. The transient response analysis assures that, the maximum peak, settling time, rise time and peak time of the system is considerably reduced with the applied approach. All these analysis certainly assures that effective tuning of controllers, better control performances, enhancement in system stability and robustness can be obtained through the applied optimization for tune PID controller.

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