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Two Regional Power System PSO PID Control Research

Jingfang Wang
School of Information Science & Engineering, Hunan International Economics University,
Changsha, China, postcode:410205
email: matlab_bysj@126.com

Abstract

In this paper, we propose a PID parameter tuning of particle swarm optimization for multi-objective optimization characteristics of two regional power system PID controller design. By defining a comprehensive consideration of system output overshoot, rise time and the fitness function term steady-state error indicators, such as the ITAE, and in accordance with the performance requirements of the actual control system, appropriate weighting of each index item. Use with base and improved particle swarm algorithm for multi-objective optimization PID. PSO optimization algorithm has good global search ability and high convergence rate. You can respond to the PID controller tuning parameters directly from the output of the PID control system easily balance between speed and stability control systems. After using PSO-PID control in two regional power system，the amount of overshoot in the step total response downs from 65% to 5%. Adjust time downs from 12 seconds to 3 seconds.

Keywords*: two regional power system, PID, particle swarm optimization (PSO), power system control*

1. Introduction

The active changes mainly impact the frequency of systems (voltage phase), reactive changes have little effect on the system frequency, which mainly affect the voltage amplitude of the system. The active and reactive power control can be considered separately. Load frequency control (LFC-load frequency control) controls frequency and active, automatic voltage regulation (AVR-automatic voltage regulator) adjusts the reactive power and voltage amplitude. LFC has been applied to large interconnected power system. Today, it is still the basis for many new control principle.

Automatic Generation Control (AGC-automatic generation control) play a role in the operation of the power system, which controls the contact line active of interconnected system. [1]. The purpose of control is when the system voltage and frequency are within the normal range, to ensure the system as much as possible to achieve better economy and reliability [2-4].

In the automatic generation system, when the load suddenly increases, before the speed control system changes into the steam of the steam engine, the turbine speed has dropped. Flywheel detected frequency error signal is small, turbine speed can be maintained in such a steady state, it is constant, the speed is lower than the rated speed, there is a frequency deviation (ie, frequency adjustment is governor droop). There is a way to accumulate such a frequency deviation, or it is the frequency deviation integral unit with integral frequency offset monitoring period, the frequency is back to the nominal valuebased on the integral value. When the system load changes continuously, the frequency of the generator is adjusted to the rating, which is called the Automatic Generation Control (AGC). In the interconnected system, which is composed of several regions, AGC distributes load between regions, between the power plant and between the generators in order to achieve maximum economic benefits. It also controls the tie-line power at the planned value, and to ensure the system's frequency rating. Of course, the system must be stable premise. Under the case of large disturbances and accidents, AGC will exit, and the accident control program is used.

In today's society, accompanied with the continuous improvement of science and industry, it becomes more important for the requirements of technical. Consequently people pay more and more concern on the increase of advanced technology for the past years. In the field of industrial, difficulty in controlling, target and a rising complexity provide a push to the industrial control technology just as the new expectations. Previous experience such as ZN law

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[5] can no longer meet the latest control requirements, and in the genetic algorithm has been put forward for several decades, the accuracy and efficiency have been not able to satisfy the need. A variety of improved algorithms based on genetic algorithms[6-9] were brought forward frequently, but none of them could be generally applicable. Particle swarm optimization (PSO) is an evolutionary computation technique, put forward by Dr. Eberhart and Dr. Kennedy[10]. Imitating from the behavior of birds, PSO algorithm suppose a group of birds random search for food, which is the single or several best. In the particle simulation of birds searching for food, according to the individual's location, speed, fitness and other individual variables we can obtain the two polar value-particle optimum and global optimum. The PSO algorithm has been proven to be evolutionary optimization algorithm with a huge potential. In this article, PID controller is designed based on PSO algorithm, it is used to two regional power system, the experiment shows its advantages through the simulation results.

2. Particle Swarm Optimization PID Design

2.1. PID Summary Description

In actual industrial process, there will be an error of variable, it is the regulator for controlling according to the proportional, integral and differential of the deviation, it is known PID regulator (also known as PID controller), the system diagram is shown in Figure 1. PID control algorithm is simple and easy to achieve, there are good control performance and high stability, it is widely used in industrial process control. The current industrial control loop are using PID control thought at 90 percent. The actual process will inevitably exist nonlinear, uncertainties and other complicating factors, there will be the following difficulties: it is difficult to establish the precise control of the system model; tuning method is too dependent on traditional parameters, PID controller parameter tuning often be poor, poor performance, poor adaptability to the operating environment. In response to these problems, for a long time, people have been improved PID controller parameters of self-tuning technology to meet the control requirements of complex conditions and high indicators.

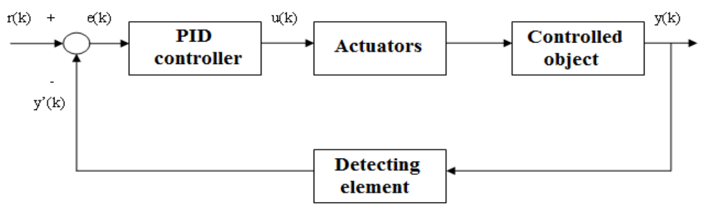

Figure 1. Control System Block Diagram

When the system is continuously controlled, the relationship between the proportional, integral, differential will exist in Formula (1) from the input e (t) to the output u (t) of the PID controller.

$$u(t) = K_p[e(t) + \frac{1}{T_i}\int_0^{\infty} e(t)dt + T_d \frac{de(t)}{dt}] \quad (1)$$

e (t) = r (t) -y (t), Kp is the proportional gain, Ti is the integral time, Td is the derivative time.

In different industrial processes, control purposes will be different, therefore, when PID controller parameters are tuned, performance indicators are often chosen according to specific requirements. There are two common performance index, which is based on individual performance indicators of the closed-loop response characteristics, such as the attenuation ratio, the maximum dynamic deviation, the adjusting time or the oscillation period, and the other one is the error performance from the start time point to a stable time until the entire response curve shape. Individual performance indicators are intuitive, simple and clear meaning, but it is difficult to accurately measure, error performance is more accurate compared to use yet more trouble. In this paper, the integral of time and absolute error product (ITAE)of the step response curve on the closed-loop control system is selected as a fitness function of PSO. The error performance indicator is shown in Equation (2).

$$ITAE = \int_0^\infty t\,|\,e(t)\,|\,dt \tag{2}$$

2.2. PSO PID Design

PSO get inspiration from this model and is used to solve optimization problems. In PSO, each individual solution of the optimization problem is a bird in the search space. We call it "particle". All the particles have an adaptative values which is determined by function to be optimized, fitness value is determined by the performance index (2), each particle has a speed which determines the direction and distance of their flight. Then the particles are to follow the current optimal particle search in the solution space. PSO is initialized to a group of random particles (random solution), and then find the optimal solution by iteration. In each iteration, the particles by tracking two "extremes" to update their own: the first "extreme value" is the optimal solution which is found by the particle itself, this solution is called the individual extreme point_Best, other extreme is. the entire population to find the optimal solution, it is namely global extreme group_Best. Alternatively, you can not have global extreme, but according to the actual situation, the use of local optimum, so it is not selected for the entire population but only as part of a collection of particles, then the extremes particle collection is not global minimum, while is a local extreme. PSO algorithm is iterative in (3).

$$\begin{aligned} &v_{id}^{k+1} = w \bullet v_{id}^{k} + c_1 \bullet rand_{gd} \bullet (p_{gd}^{k} - x_{id}^{k}) + c_2 \bullet rand_{id} \bullet (p_{id}^{k} - x_{id}^{k}) \\ &x_{id}^{k+1} = x_{id}^{k} + \mu \bullet v_{id}^{k+1} \\ &|\,v_{id}^{k}\,| \le V_{mm} \\ &|\,x_{id}^{k}\,| \le X_{mm} \end{aligned} \tag{3}$$

In the formula, v_{id}^{k} represents the k-th generation, the i-th particle, the d-dimensional velocity v. x_{id}^{k} represents the k-th generation, the i-th particle, the d-dimensional location x. w is inertia factor. μ is constraint factor of speed ratio. p_{id}^{k} is the optimal value for the position of the individual particles. p_{gd}^{k} is optimal value for the group location. c_1 , c_2 is accelerating factor. $rand_{gd}$, $rand_{id}$ is random number between [0,1].

Vmm is speed range, and it is the boundaries of the speed size of the individual movement, it appears as a change in the individual trend. Xmm is range for the population, and it is the scope which population individuals can activity, That is range of parameters, and it is K_p, T_i and T_d threshold amount in PID [11, 12].

PSO with a similar genetic algorithm is based on an iterative optimization tools. But it did not use the crossover(crossover) and variation (mutation) of genetic algorithm. The particles only search in the solution space as birds follow the optimal particle simulation. Comparison with Genetic algorithm, the advantages of PSO is simple and easy to achieve without many parameters need to be adjusted, with better robustness and feasibility, and more important is that PSO algorithm is easier to implement and understand.

3. Two Regional Power System Model
3.1. Basic Generator Control Loops and L FC-Load Frequency Control

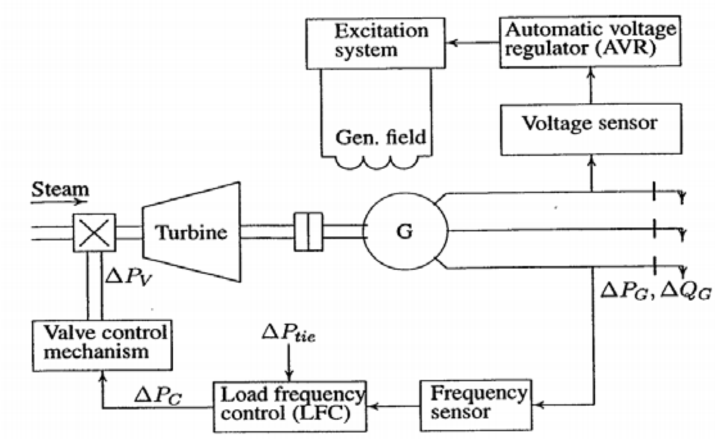

Figure 2. Schematic diagram of a synchronous generator's LFC and AVR

In interconnected systems, load frequency control (LFC) and automatic voltage regulation (AVR) are installed on each generator, load frequency control (LFC) rings and automatic voltage regulation (AVR) ring are shown in schematic diagram of the Figure 2. The controller is set to run a particular state, it detects small changes in load, maintaining the frequency and amplitude of the voltage of the generator within an allowable range. Active changes are mainly detected in the angle of the generator rotor, ie frequency changes are achieved, changes in reactive power are mainly achieveed by generator voltage amplitude detection. Excitation system time constant is much smaller than the original motivation for the time constant, so it's much faster in transient decay, and it will not affect the dynamic characteristics of LFC, and therefore, LFC control loop and AVR control loop can be viewed independently of each other.

LFC's goal is to keep that the system frequency is the nominal frequency, load is distributed between the generators, control tie line power is for the planned value. It detects the frequency and tie-line power changes, such as by detecting a frequency error signal Δf and tie-line power error signal ΔP_{tie}, the error signal is amplified, mixed and transformed into the active control signal ΔP_V, and it i sent to the prime mover to get torque increment.

Prime mover brings generator output power change ΔP_g, it will change the Δf and ΔP_{tie}, so that it remains within the allowable range. The first step in the analysis and design of control systems is to establish a mathematical model of the system, and the most popular model of the two methods are the transfer function method and the state variable method. State variable method can be applied to linear and nonlinear systems, and in order to use the transfer function method and linear equation of state, the system must first be linearized, ie, with reasonable assumptions and approximations, the mathematical equations are linearized to obtain transfer function of a generator model, load model, prime mover model and the speed control system model. These models are in References [1].

3.2 AGC-Automatic Generation Control in the Two Area System

When the load suddenly increases, before the speed control system changes the amount of steam into the steam engine, the speed of the turbine has been dropped.Eerror signal of flywheel detected frequency is small, turbine can be maintained in such a steady state, its speed is constant, the speed is lower than the rated speed, there is a frequency deviation (ie, adjustment frequency of governor is droop). There is a way to accumulate such a frequency deviation, or it is the frequency deviation integral, the frequency offset is monitored for period with integral unit, the frequency is back to the nominal value based on the integral value. When the system load changes continuously, the frequency of the generator is adjusted to the rating, which is called the Automatic Generation Control (AGC). In the interconnected system composed of several regions, AGC between regions distribute loads between the power plant and between the generators in order to achieve maximum economic benefits. It also controls the tie-line power at the planned value, and the system's frequency is ensured in rating. Of course, the system must be stable. In the case of large disturbances and accidents, AGC will exit, and it is applied to accident control program [1].

A group of closely generators, speed unity, generator rotor has the same response characteristics, such as turbine are called as relatedgenerators which is a representative by LFC ring, it is called the control area. AGC in two regions is used to understand multi-zone system AGC, consider two equivalent generators are on behalf of two regional systems. AGC model of two-zone system is in Figure 3 [1]. Area control error (ACEs) is use to establish two areas of the system simulation diagram. And the frequency response of the power is determined in each region. Figure 4 shows the SIMULINK simulation diagram [1].

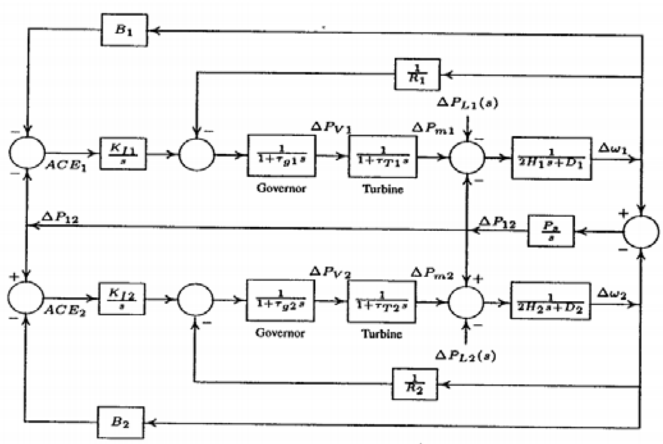

Figure 3. AGC block diagram of a two-zone system [1]

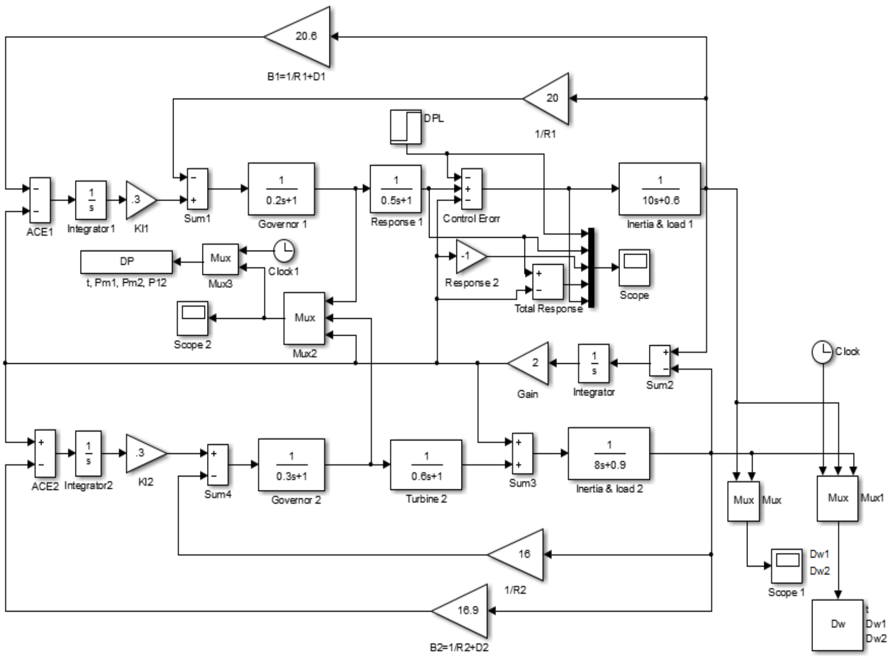

Figure 4. Example simulation block diagram [1]

4. Simulation of PSO-PID Experimental Tests

Based on two regions turbine model in Figure 4, PSO-PID control is designed, and matlab simulation is in Figure 5. PSO-PID control simulation work flowchart diagram is in Figure 6. Step tracking and key response indicators before using PSO-PID control are in Figure 7. And step tracking and key response indicators by using PSO-PID control are in Figure 8.

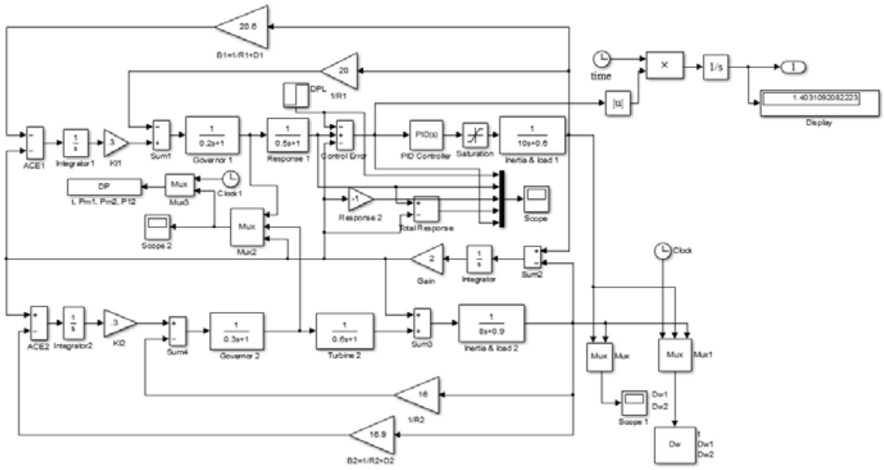

Figure 5. PSO-PID control simulation block diagram

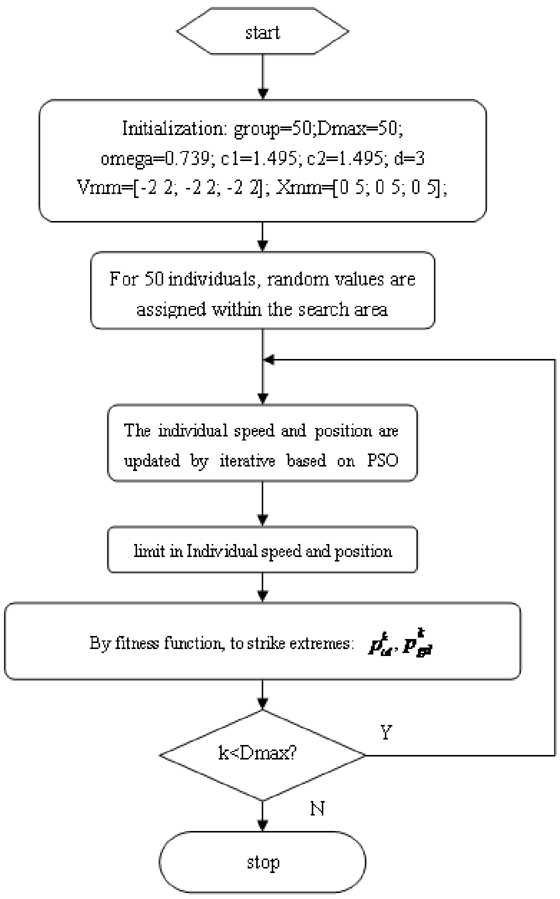

Figure 6. PSO-PID control simulation work flowchart diagram

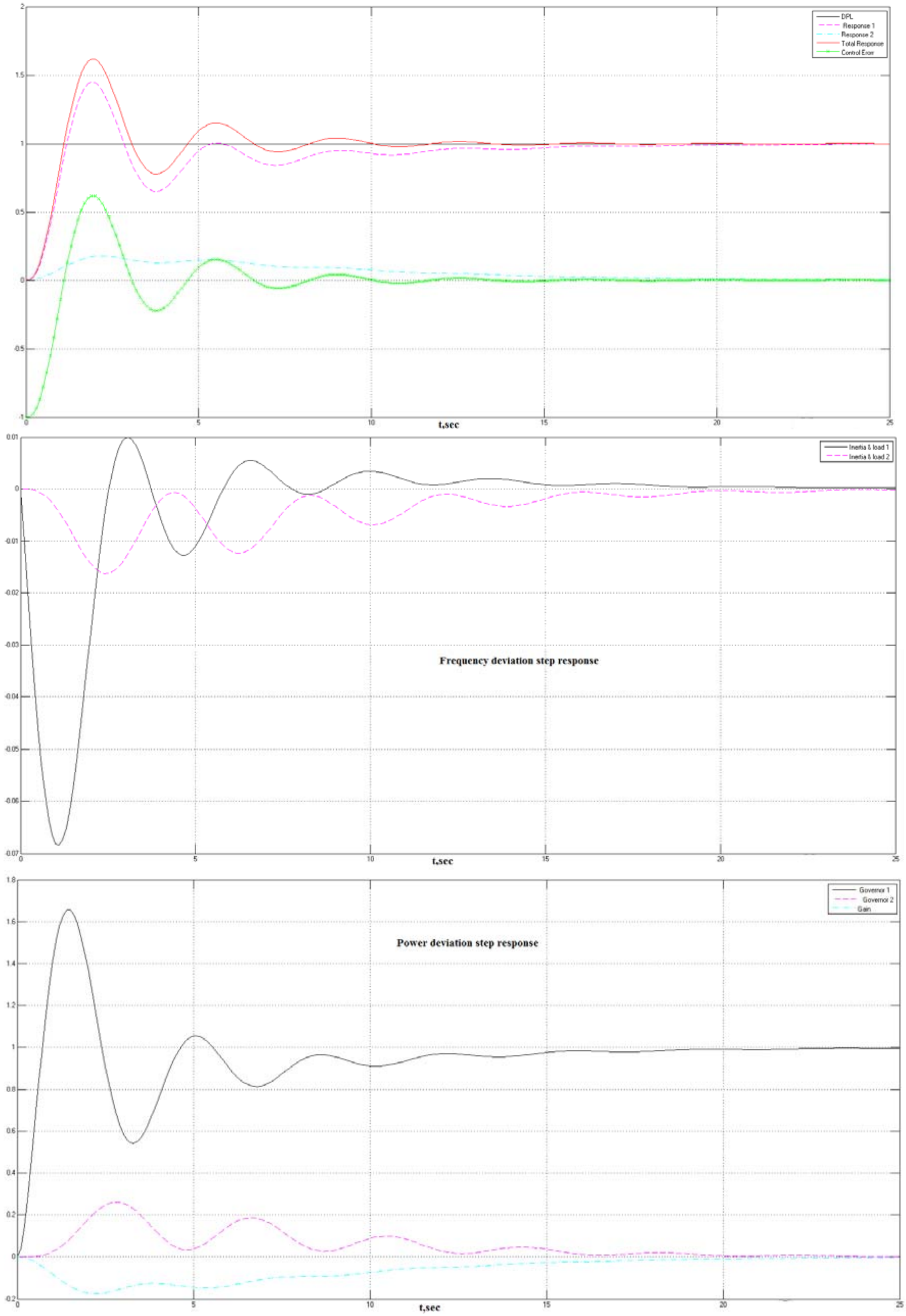

Figure 7. Step tracking and key response indicators in no PID control

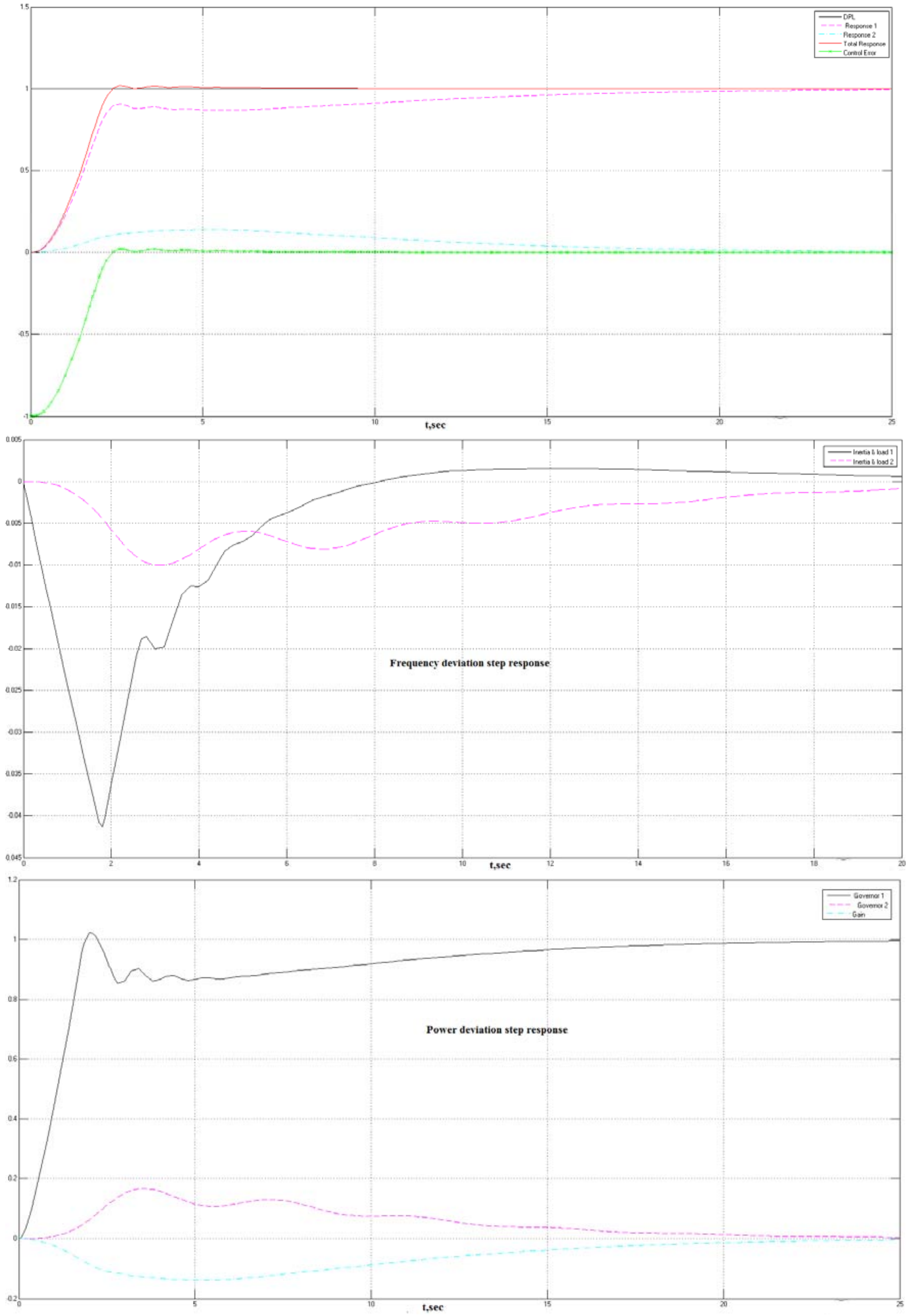

Figure 8. Step tracking and key response indicators by using PSO-PID control

By comparing the simulation results before and after using PSO-PID control, 1) the amount of overshoot in the step total response downs from 65% to 5%. 2) Adjust time downs from 12 seconds to 3 seconds. 3) The main parameters: Frequency deviation step response and power deviation step response are improved significantly.

5. Conclusion and Outlook

In this paper, for multi-objective optimization characteristics of two regional power system PID controller design, we propose a PID parameter tuning of particle swarm optimization. First, by defining a comprehensive consideration of system output overshoot, rise time and the fitness function term steady-state error indicators, such as the ITAE, and in accordance with the performance requirements of the actual control system, appropriate weighting of each index item. After that, the tape-based and improved particle swarm algorithm are used for multi-objective optimization PID. PSO optimization algorithm has good global search ability and high convergence rate. The PID controller tuning parameters can be responded directly from the output of the PID control system, it is easily balance between speed and stability control systems. Implementation of the algorithm does not depend on the actual controlled object model, it is with a wide range of practicality.

Particle swarm algorithm is used to optimize the parameters of PID control system design, through simulation experiments can be seen, PSO algorithm has good robustness and dynamic quality. Optimize performance and efficiency of the algorithm than the genetic algorithm has improved to some extent. When the transfer function with large lags, PSO algorithm is able to meet the system requirements for the adaptive PID parameters. Therefore, the use of particle swarm optimization algorithm PID parameter optimization method is a kind of good practical value.In the power control system, frequency deviation step response and power deviation step response are improved significantly

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