Comparison of automatic load frequency control in two area power systems using pso algorithm based pid controller and conventional pid controller

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Abstract: In this paper, Simulink model of Two Area power systems is developed and system dynamic response has been studied. Also the load frequency control of the system is improved by the application of PID Controller. The settling time, overshoot and frequency error are considered while doing simulation of the Model with PID Controller. Also with the application of Particle Swarm Optimization (PSO) technique, the values of PID controller are obtained which brings the frequency error of the system to zero in quick time. Simulink model is prepare and analyzed using MATLAB.

Keywords: ACE, AGC, ALFC, PID Controller, Particle Swarm Optimization (PSO).

1. Introduction

Load Frequency Control plays an important role in interconnected power system. It helps to retain the frequency of each area and the tie-line power flow within the specified limit or range. The property of a reliable power supply needs the balance of frequency and voltage in the permissible limits, i.e to provide a match between the generation and the load. If the two Areas are interconnected through a Tie-line, then performance level of the overall power system is increased [4]. If the load changes in any one area in interconnected power system, then it affects the remaining areas, and there will be deliberate change in frequency (real power), and voltage (reactive power).

ACE is change in area frequency which when used with tuned PID Controllers helped in bringing system frequency error to zero [1].

AGC helps in keeping the balance between the generation and demand of a particular power system [2].

Load frequency Control (LFC) helps to improve the Regulation of the real power whereas Automatic
Voltage Regulator (AVR) helps to improve the regulation of the reactive power. In this work, as we are considering the real power output of the generating unit (or frequency). The LFC helps in maintaining the output frequency and the tie-line power flow.

2. Terminology

LFC - Load Frequency Control
ACE - Area Control Error
ISE - Integral Square Error
R - Speed Regulation of Governor
TG – Governor Time Constant
TP - Time constant of power system
KP - Gain constant of power system
ΔPtie - Tie line power flow
Δf - Change in frequency
ΔPG - Change in turbine output

3. Particle Swarm Optimization

PSO was first developed in 1995 by Kennedy and Eberhart. This Algorithm is based on Swarm Technology. The concept of social interaction in this technique is used for problem solving.

In this algorithm, each particle is considered as a point moving in space which adjusts its position by referring its own moving experience as well as the moving experience of other particles based on the flying direction and the distance. This value is called the best value of the individual (pbest).

The next best value which will be found by the PSO will be the best value obtained around that particle. This value is known as global best value of the individual (gbest). Figure 1 shows the concept of searching the particles.
3.1. Velocity Updating
Each particle updates its velocity by using Equation 1. The acceleration constants $c_1$ and $c_2$ keeps the right equilibrium between the personal identification and the sociality of the particles.

$$V_{i+1}^{m} = V_i^{m} + c_1 r_1 * (P_{best} - x_i^{m}) + c_2 r_2 * (g_{best} - x_i^{m})$$

\[ (1) \]

3.2. Position Updating
Particles update its position at each interval

$$X_i^{m+1} = X_i^{m} + V_i^{m+1}$$

\[ (2) \]

Where, $V_m$ the modified velocity of the particle ‘i’ at mth iteration. By incorporating these parameters in Equation 1, we achieve the velocity updating given in Equation 3.

$$V_i^{m+1} = W * V_i^{m} + c_1 r_1 * (P_{best} - x_i^{m}) + c_2 r_2 * (g_{best} - x_i^{m})$$

\[ (3) \]

4. Design of the PSO-PID Controller
Equation 4 gives the performance index used to optimize (minimization of the error).

$$ISE = \int e^2(t) dt$$

\[ (4) \]

The PSO algorithm used here is to give the new updated values of PID Controller.

Step 1: The frequency error is given as the input to the PSO algorithm, was achieved from the output of various corresponding simulation.

Step 2: Particles with random positions and velocities are defined on the N Dimensional search space.

Step 3: Define the loop and each particle.

Step 4: Calculate and compare the value of fitness with its best position.

Step 5: Check the velocity $V$ of each particle according to Equation 5.

$$V_i^{m+1} \geq V_{max}, then \ V_i^{m+1} = V_{max}$$

\[ (5) \]

Step 6: Check the particle in the surrounding

with the best value so far and allocate the coordinates which is gbest.

Step 7: The velocity of each particle is updated using Equation 2.

Step 8: Each particle updates its position using Equation 3.

Step 9: After the maximum iterations are achieved, we have to move to the next step otherwise we have to go to step 4.
Step 10: The gbest values obtained are the ideal values of the performance index (optimal values of KP, KD and KI of the controller).

Step 11: Stop the evaluation procedure.

5. PID Controller

It is a proportional–integral–derivative controller which is used to give the optimal values of KP, Ki and Kd [5].

The performance characteristics of the systems such as rise time, overshoot, settling time, steady state error can be improved by tuning value of parameters (KP, Ki and Kd) of PID Controller. Mathematically PID is represented as:

\[ y(t) = K_p e(t) + \frac{1}{T_i} \int_0^t e(t) dt \]  

\[ Y(t) = [K_p e(t) + K_d \frac{d e(t)}{d t} + K_i \int_0^t e(t) dt] \]  

Controller must be sensitive against changes in frequency and load. Intelligent controllers have been used in place of conventional controllers to get fast and better system response in large interconnected power systems [3].

6. Circuit Description

Figure 2 shows the Simulink Model of two Area power systems. The Integral Square Errors (ISE 1 & 2) for both the areas are calculated. The Simulink time is taken as 100 seconds and the system frequency error is shown in simulink graphs where it is seen that the time required for minimizing the error is 9 seconds.

But with the application of PSO-PID, the system model is again simulated. Now the frequency error time is reduced to 2 seconds.

So it is seen that the time required to minimize the frequency error by the PID Controller is more than the PSO-PID controller.

7. ALFC

Automatic Load Frequency Control (ALFC): is being applied in power system which helps an area to fulfill its load demand changes and helps in bringing the steady state frequency of the system \( f \) to zero.

The frequency and power in case of turbine governor can be related as

\[ \Delta P_m = (\Delta P_{ref} - 1/R* \Delta f) \]

Where

\( \Delta P_m \) = change in turbine mechanical power output.
\( \Delta P_{ref} \) = change in reference power setting
\( \Delta f \) = change in frequency
R = Regulation constant which identifies the sensitivity of the generator to a change in frequency.

8. SYSTEM EQUATIONS

The system equations for both the areas have been developed and shown below:

\[
\Delta f(s) = G_P(s)[\Delta P_f(s) - \Delta P_D(s)] \quad \text{---------(8)}
\]

\[
\Delta f_1 = \Delta P_{T1} - \Delta P_{D1} - \Delta P_{I2} \quad \text{---------(9)}
\]

\[
\Delta f_2 = \Delta P_{T2} - \Delta P_{D2} - \Delta P_{I2} \quad \text{---------(10)}
\]

\[
ACE_1 = \Delta P_{I2} + B_1 \Delta f_1 \quad \text{---------(11)}
\]

\[
ACE_2 = \Delta P_{I2} + B_2 \Delta f_2 \quad \text{---------(12)}
\]
Table 1, Comparison of Results of PID & PSO-PID Controllers

| Sl No. | Controller | Layout | Settling Time (secs) | Overshoot (Hz) |
|--------|------------|--------|----------------------|----------------|
| (a)    | PID        | Area 1 | 9.0                  | 0.9            |
|        |            | Area 2 | 9.0                  | 0.9            |
| (b)    | PSO-PID    | Area 1 | 2.0                  | 0.55           |
|        |            | Area 2 | 2.0                  | 0.55           |
Table 1
Shows the Comparison of the frequency responses and overshoots for the PID controller and the PSO tuned PID controller. It is clear from the Table that the magnitude of overshoot is minimized from (0.9 Hz to 0.55 Hz) in PSO-PID Controller and as well as error settling time in both the areas are reduced in PSO-PID Controller from (9 secs to 2 secs).

9. Simulink Graphs

‘Figure 3’, ACE for Area 1
(with PSO- PID)

‘Figure 4’, ACE for Area 2
(with PSO- PID)
10. CONCLUSION

The dynamic response of the system is improved by minimizing the Integral Square Error (ISE) in both the Areas. The response of the PSO tuned PID controller is compared with the response of the conventional PID controller for the system considered. It is found that, the response of the proposed PSO tuned PID controller gives better output results than the normal PID controller. The error is minimized in almost 2 seconds as shown in the Figure 3 & 4. But the error minimization time in case of PID Controller is 9 seconds as shown in Figure 5 & 6.

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