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Load Frequency Control of Hydro-Hydro Power System with Proportional-Integral-Derivative (PID) Controller

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Abstract: In this work Automatic Generation Control (AGC) of hydro power system is investigated. The investigated power system is equipped with two equal hydro power system with PID controller. Each hydro power system incorporates appropriate hydro turbine, hydro governor unit. The gain values of PID controller are tuned by using Ant Colony Optimization (ACO) technique with one percent Step Load Perturbation (1% SLP) in area1. The Integral Square Error objective function is considered for the optimization of controller gain values.

Key words: Ant Colony Optimization (ACO) · Automatic Generation control · Objective function · PID controller

INTRODUCTION

Generally power system or plant converts one form of energy into electrical energy with help of appropriate technique. For example, in thermal power plant heat energy, hydro power plant kinetic energy in water, solar power plant sun light and wind power plant kinetic energy in wind, etc. In this work, hydro power plant is considered for the investigation. With help of hydro power plant kinetic energy stored in the water in converted into useful mechanical energy with help of hydro turbine. From the literature, it is found that few works has been carried out related to hydro power system and PID controller. Load frequency control of interconnected hydro power system is investigated by considering fuzzy proportional-integral (PI) controller in [1]. LFC of hydro power system is studied by implementing fuzzy PID controller in [2]. LFC crisis in four area interconnected hydro power system is discussed in [3] and performance of the system is improved by implementing Superconducting Magnetic Energy Storage (SMES) unit. PI controller is designed for AGC of hydro power system in [4] and LFC of two area interconnected power system is discussed with SMES unit in [5].

Fuzzy based PID controller is designed and implemented in AGC of multi-area power system in [6] and controller gain values are optimized by using Teaching Learning Based Optimization (TLBO) technique. PID controller is implemented for LFC o power system and gain values are optimized by using Imperialist Competitive Algorithm (ICA) [7]. Ant colony optimization technique based PID controller is implemented in hydro thermal power system [8-9].

The remainder of this work is organized as follows: Section 2 " Hydro-hydro power system with PID controller" gives the details about the investigated power system and control strategy, simulation results of the investigated power system and results are discussed in the section 3 " Simulation results and discussions", finally, conclusion about the present work given in the section 4 " Conclusion".

Hydro-Hydro Power system with PID Controller: The transfer function model of investigated two area hydro-hydro power system is given in Figure 1 [5]. The investigated power systems are equal size and equipped with suitable hydro governor, hydro turbine and generator and PID controller as a secondary controller. The transfer functions of each component in hydro power system given in Table 1 [5].

In the interconnected power system two equal hydro power plants are interconnected through tie-line. During normal or scheduled value each power system carries its own load and maintains system parameters within the limit and stability. When sudden load occurs in any one of interconnected power system it affects system stability

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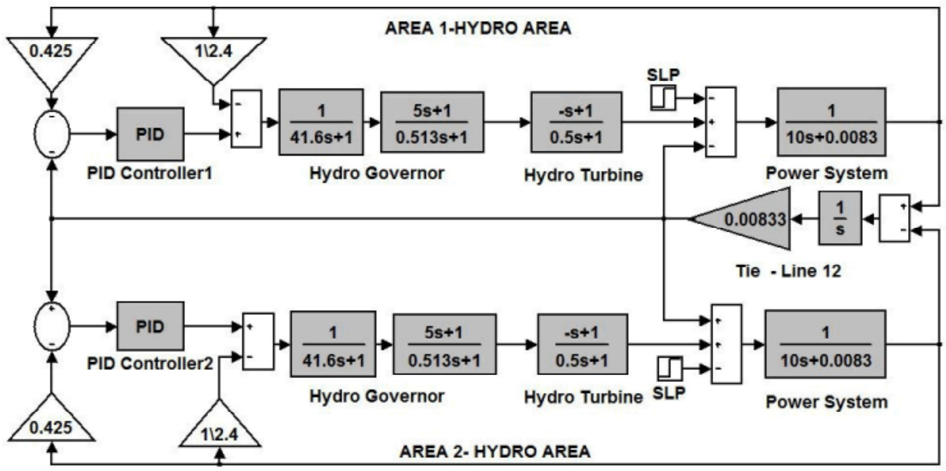

Fig. 1: Transfer function model of two area hydro-hydro power system

Table 1: Transfer function and nominal parameters of the power system component

Component	Transfer function	Nominal parameters
Hydro governor	$\frac{1}{1+sT_1} \cdot \frac{1+sT_R}{1+sT_2}$	$\frac{1}{1+41.6s} \cdot \frac{1+5_S}{1+0.513s}$
Hydro turbine	$\frac{1-sT_w}{1-0.5sT_w}$	$\frac{1-s}{1-0.5s}$
Power system	$\frac{1}{D+s2H}$	$\frac{1}{0.0083+10s}$
Tie-line	$\frac{2\Pi T_{12}}{S}$	$\frac{0.00833}{s}$

Table 2: Optimal gain values of PID controller

Proportional	Kp1	9.1
Gain (Kp)	Kp2	7.9
Integral Gain	Ki1	0.2
(Ki)	Ki2	0.3
Derivative Gain	Kd1	9.3
(Kd)	Kd2	5.1

and system response yield more damping oscillations with large over and undershoot with steady state error. In order to overcome this afore mentioned issue is solved by introduced by proper secondary controller. In the power system primary control loop is speed regulator unit. The PID controller is introduced as a secondary controller in the power system [6-9]. The transfer function of PID controller is given by:

$$U(S) = K_p\ E(S) + \frac{K_p}{Ti_S}E(S) + K_d\ E(S)$$

Where, Kp-Proportional gain, Ki-Integral gain, Kd-Derivative gain, Ti-Integral time, Td-Derivative time and s-Laplace function, e(s)-error signal

For better controller performance of ay power system is based on the proper selection controller gain values. In this work controller gain values are optimized by using Ant Colony Optimization technique with Integral Time Square Error (ISE) objective function [8-11]. The expression of ISE objective function is as follows:

$$J = \int_0^t e^2(t)dt$$

Where, J-Performance index, t-Simulation time and e(t)-error signal.

Based on the ACO optimized controller gain values are given in the Table 2 and values are implemented into investigated power system and compared with open loop performance of the same power system given in the Section 3.

RESULTS AND DISCUSSION

The investigated two area hydro- hydro power system is designed under MATLAB/ SIMULINK environment with PID controller. The open loop performance of the system is obtained by considering one percent Step Load Perturbation (1% SLP) in compared and shown in Figures 2-4.area 1 for the simulation time of 300s. The controller gain values are optimized using ACO technique and gain values are given in the Table 2. The performance comparisons of open loop response and response with PID controller are

Figure 2 shows, frequency deviation in the performance of open loop response and response with PID in the same investigated power system. Where dotted line shows the open loop response of system and solid

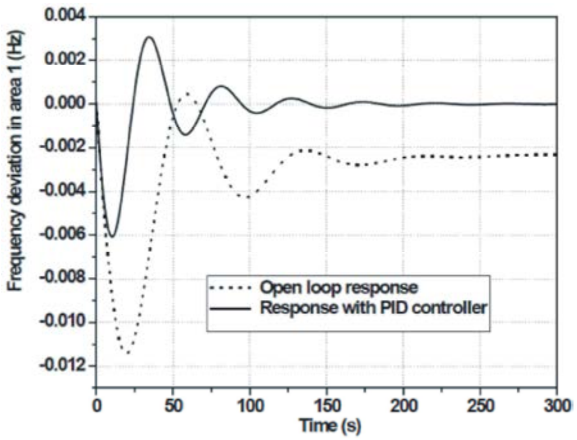

Fig. 2: Frequency deviation comparisons in area 1

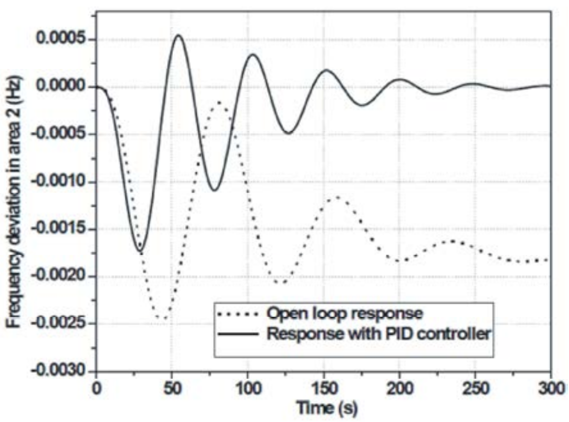

Fig. 3: Frequency deviation comparisons in area 2

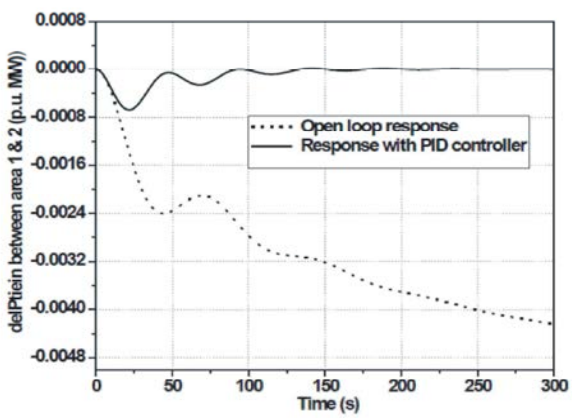

Fig. 4: Tie-line power flow deviations in between area 1 and 2

bold line shows the response of the system with PID controller in the investigated power system. From the above the response it is clearly shows that, controller effectively reduces the damping oscillations with minimal damping oscillations and zero steady state error. Figure 3 shows the frequency deviation comparisons in area 2, it is clearly shows that response with PID controller is guarantee for better dynamic controlled response and it improve the performance of the system during sudden loading conditions. Figure 4 shows the response comparisons of tie-line power flow deviations between area 1 and area 2 [10,11].

From the Figures 2-4, it clearly shows that dynamic performance of the power system effectively improves the performance of the power system during normal or sudden loading conditions. The performance of the power system is measured in terms of time domain specification (Settling time, peak over shoot, under shoot and settling time).

CONCLUSION

In this work AGC of two are hydro-hydro power system is investigated with PID controller. The PID controller gain values are optimized by using Ant Colony Optimization (ACO) technique with ISE objective function. The performance of the proposed algorithm based controller performance is compared with open loop performance of the same investigated power system. Finally simulation result clearly shows that, during sudden loading condition performance of the system is improved by implementing PID controller compared to open loop response of the system.

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