Optimization Technique Inspired Load Frequency Controller for Multi Area Power System with Renewable Energy Source

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Abstract. Modern day scenario has an increasing power demand due to the growing development which indeed increases the load on the generation which might cause turbulence in the system and may bounce out of stability. The governor itself can’t handle such frequent load changes and adjust the generation amount to keep the frequency between the margins. This paper proposes an approach towards such predicament to incorporate an optimization method in order to ensure stability of the system despite the drastic changes in demand. Load frequency control is a control method for maintaining the frequency of the system during the change in demand. Use of controllers has proven to be effective in controlling the frequency deviations in the power systems and the response of the controller is further improved using optimization technique for better stability. The PID controller tuned by Particle Swarm Optimization is employed in multi-area system which reduces the time response by a considerable amount and the deviation settles much quicker despite the rapid load changes. The proposed controller is executed further for renewable energy sources connected to the individual areas and demonstration proves that the optimized controller is efficient enough in handling the frequency deviations when wind and solar with sunlight penetration is incorporated.

1. Introduction

Power system is termed to be a dynamic one, comprising of numerous control areas with the each individual generation satisfying the demand of that corresponding control area. These control areas are often operated together in unison, interconnected by the tie lines for better performance through scheduled interchange of power between the control areas whenever demand deviates from the estimated margin. The interconnection necessitates the maintenance of frequency & power exchange to standby within the limits for the system to operate synchronously and effectively altogether. The secondary frequency control aka Load Frequency Control is responsible for regulating the above stated control problems in an interconnected power system. The generational uncertainties in active power production has greatly increased as the diffusion of renewable energy resources such as wind and photovoltaic systems have increased, resulting in frequency oscillations. Maintaining the frequency consistently is thus a difficult task. Hence, the effective Load frequency control requires an efficient controller for suppressing the deviations.

LFC frames to be a multi objective control problem with monitoring demand changes, regulating frequency & maintaining tie line power exchange under dynamic conditions. The initial stage LFC controllers in practical power system were adjusted by classical, trial & error approaches. The performance of conventional controller & fuzzy controller for an integrated hydro and steam turbine power systems proved to have better performance [1]. Design and tuning of PID controllers for LFC control in power system as per systematic representation through soft computing, robust, fractional and few other techniques are discussed [2]. PID controllers are still found to be persistent in their place due their complexity less & better use in complex systems. Optimized gains of PID controller through Particle Swarm Intelligence and Fuzzy based inferences for a five area interconnected power system was constructed [3]. Therefore, the uncomplicated nature of PID controllers is to be put in use for better response of LFC in interconnected power system. This paper exhibits a work using PID controller tuned by optimization approach for LFC in multi area system with renewable energy sources interconnected. The paper is organized as follows. Section II explains about the methodology followed by the results and discussions in section III.
2. Methodology

The formulated procedure involves drawing up the control area system for the proposed study through an additional controller which is fine tuned by Particle Swarm Optimization algorithm.

2.1 System Investigated

The generalized LFC model of two area interconnected thermal system comprising of two renewable energy sources depicted in the Figure 1 is formulated and designed for the investigation proposed. A control area is stated to be a combination of one or many power systems. Therefore, Control area one is intended to have a reheat turbine along with Solar Photovoltaic (SPV). Variable effect of sunlight light penetration for the SPV source in an interconnected multi area system [4] is considered for the detailed outcome in this control area. Control area two is planned to consist of a thermal system with wind source assumed under constant criteria. The Control areas are connected to a PID controller which is tuned by both conventional and optimization approach for effective comparative results. The controller parameters are scrutinized by both trial & error as well as by Particle Swarm Optimization (PSO) algorithm.

![Figure 1: Schematic model of two area interconnected power system](image)

2.2 Optimization Algorithm

Particle Swarm Optimization algorithm as declared concept [5] of optimization for non linear problems is utilized for the above proposed tuning of PID controller and the technique’s performance is assessed by using the Integral Square Error as the objective function (ISE) [6] which is given by the following equation,

\[
ISE = \int_0^T \left( Error_1(\Delta f) + Error_2(\Delta f) + Error_3(\Delta P_{tie}) \right)^2 dt
\]  

(1)

Where,

- Error1 = Frequency deviation in area 1 (Hz)
- Error2 = Frequency deviation in area 2 (Hz)
- Error3 = Deviation in tie line power (p.u.MW)

The population based search algorithm updates the velocity and position, thereby reaching out to the best ever solution of finding the optimal parameters for the PID controller in proximity. The process of flowchart is displayed in Figure 2.
3. Results and Discussions

The suitable schematic models of the two area LFC along with the optimization tuning of controllers are worked upon and simulated using MATLAB/SIMULINK toolbox. The analysis is extended for two cases.

3.1 Case 1

This case considers control area 1 is connected to a thermal plant with reheat turbine and SPV with variable sunlight penetration while area 2 connected to wind energy source along with thermal system. A load change of +50MW is assumed in area 1. The plots for the various frequency response & deviations were obtained through MATLAB simulation. Figure 3(a) & 3(b) depicts the comparison of frequency deviation in area 1 and area 2 using the PID controller tuned by classical, trial & error method and PSO tuned PID Controller respectively. Figure 4 shows the overall tie line power deviation response for the same. The convergence of the PSO algorithm towards the objective function is portrayed in figure 5 while the figure 6 shows the plot of sunlight variation. Also, the comparative analyses of the setting time for the mentioned case is represented in Figure 7 & Table 1, whereas the peak overshoot comparisons are displayed in Figure 8 & Table 2.

Figure 3(a): Comparison of frequency deviations in area 1 in case 1
Figure 3(b): Comparison of frequency deviations in area 2 in case 1

Figure 4: Comparison of error in Tie-Line power in case 1
Figure 5: Convergence plot of PSO

Figure 6: Sunlight penetration variation plot for case 1

Figure 7: Comparison of peak overshoots in case 1
Table 1: Comparison of Peak Overshoot in case 1

| Peak Overshoot | Without PSO  | With PSO  |
|----------------|-------------|-----------|
| del F1         | 60.227%     | 34.459%   |
| del F2         | 40.141%     | 5.769%    |
| del Ptie       | 36.301%     | 4.268%    |

Figure 8: Comparison of settling time in case 1

Table 2: Comparison of Settling time in case 1

| Settling Time | Without PSO | With PSO |
|---------------|-------------|----------|
| del F1        | 17.34s      | 4.981s   |
| del F2        | 38.634s     | 33.418s  |
| del Ptie      | 36.212s     | 31.684s  |

3.2 Case 2

This case is stated to have control area 2 with thermal and SPV interconnected with assumption of sunlight variation as well. Control area 1 is said to have a thermal system with constant wind source. Also, a load change of +50MW in area 2 is assumed for the extended analysis. The plots simulated through MATLAB toolbox for the various frequency response & deviations are given below. Figure 9(a) & 9(b) illustrates the frequency deviation comparison in area 1 and area 2 employing the PID controller tuned by traditional, trial & error process and PSO-PID controller respectively. Figure 10 depicts the tie line power deviation graph for the above stated case. Figure 11 shows the variation of sunlight factor followed by the setting time comparative analysis for the respective case is put forth in Figure 12 & Table 3. Also, the proportional peak overshoot comparison are displayed in Figure 13 & Table 4 respectively.
Figure 9(a): Comparison of frequency deviations in area 1 in case 2

Figure 9(b): Comparison of frequency deviations in area 2 in case 2
Figure 10: Comparison of error in Tie-Line power in case 2

Figure 11: Sunlight penetration variation plot for case 2

Figure 12: Comparison of Peak Overshoot values in case 2
4. Conclusions

This paper demonstrates the study of LFC of a two area system which is interlinked with renewable energy sources SPV and wind model. For the further enhanced analysis, the effect of sunlight variation with respect to SPV source was considered as well. PSO algorithm approach for optimizing the PID controller parameters proves to be effective as the settling time as well as the peak overshoot values is reduced and hence, the stability of the system is increased. The above proposed technique proves to be one among the better solution as the response time is also improved even after considering the uncertainty of load changes in both the control areas. Thus, from the above suggested study, it is revealed that the PSO tuned PID controller with ISE function as objective function inclusive of the deviations in the frequency and tie-line shows better results than classical PID controller for the Load Frequency Control of a two-area system.

Appendices

| Specifications          | Area 1       | Area 2       |
|------------------------|--------------|--------------|
| Rated Capacity         | 2000 MW      | 2000 MW      |
| Normal Operating Load  | 1000 MW      | 1000 MW      |
| Nominal Frequency      | 50 Hz        | 50 Hz        |
| Inertia Constant       | 5 s          | 5 s          |
| Speed Regulation       | 2 Hz/p.u.MW  | 2 Hz/p.u.MW  |
| Frequency Constant Bias| 0.51 p.u.MW/Hz | 0.51 p.u.MW/Hz |
| Governor Time Constant | 0.08s        | 0.05s        |
| Turbine Time Constant  | 0.3s         | 0.05s        |
Power System Time Constant | 20s  
Power System Gain Constant | 100  
Solar Gain Constant | 1  
Solar Time Constant | 1.8s  
Wind Gain Constant | 1  
Wind Time Constant | 0.8s

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