PERFORMANCE ANALYSIS OF DOUBLE REHEAT TURBINE IN MULTI -AREA AGC SYSTEM USING CONVENTIONAL AND ANT COLONY OPTIMIZATION TECHNIQUE

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Abstract: *The responsibility of power system is to ensure that adequate power generation with good quality and more economic power delivery to all consumers. Hence, proper control strategy is required to maintain a continuous power balance between power generation and surplus. So it is necessary to implement Automatic Generation control for more efficient control performance. In this paper , three area reheat thermal power is considered for the investigation and each generating unit equipped with either Single Reheat Turbine (SRT) or Double Reheat Turbine (DRH) with Proportional-Integral-Derivative(PID) controller. Optimal controller gain values are obtained using both conventional and Artificial Intelligence (AI) optimization technique. Finally, performances of AI-PID controller are compared with conventional optimized PID controller. Simulation result shows that contribution of AGC with AI PID controller more superior to conventional controller.*

Keywords: *Automatic Generation contro, Cost function; Doule reheat turbine;Performance Index; Proportional-Integral-Derivative controller.*

1. Introduction

Healthy and effective operation of all electronic components are depends on the good quality of power supply. The term quality is measured by consistency in frequency, voltage and level of reliability. In order to achieve above said condition, power balance plays very vital role. But practically, big energy gap exist between power generation and surplus. Load is a device which taps energy from power system and tapped energy is wasted in the form heat, illuminations, etc,. It varies randomly, due to enormous augmentation in industries and technology, which causes effects in real and reactive power of the system. The changes in real and reactive power affect system frequency and voltage magnitude respectively. The process of maintaining frequency and voltage magnitude of power system within the specified value is called “Automatic Generation Control (AGC)” [14-16].

There has been considerable research work attempting to offer better load frequency control scheme based on modern control and optimization techniques. Particle Swarm Optimization (PSO) [8], Bacterial Foraging (BF) [2,7], Cuckoo search [13]. Artificial Bee Colony (ABC) [3], Ant Colony Optimization (ACO) [5, 10], Fuzzy logic Controller [4], Genetic Algorithm (GA) [1, 9], Artificial Neural Network (ANN) [11], Imperialist competitive Algorithm (ICA) [12], Classical controllers [11].

In this paper two types of controller have been applied for solving AGC problem in multi-area power system. The first type is conventional PID controller and gain values have been tuned by conventional tuning technique with Integral Time Absolute Error (ITAE) cost function. The second controller technique is Artificial Intelligence (AI) technique which has been applied for same power system. The performances have been applied on the same graph for easily comparisons between two techniques.

For clear interpretation, the investigated system is presented in system in section 2. The simulation performance of system and robustness analysis for double reheat turbine and single reheat turbine with conventional and AI based systems are given in section 3 & 4, followed by the conclusion in section 4.

2. System Studied

In this work, a three area reheat thermal power system model is considered for the assessing the impact of AI technique and double reheat turbine on the AGC problem [15]. The three area transfer function model of thermal power system is shown in figure1. All the three areas are thermal power plant and equipped with regular governor,

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turbine (either single or double reheat turbine), and generator and PID controller.

2.1. Single Reheat Turbine

The tandem-compound type single stage reheat turbine comprises three cylinders High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP).The transfer function of tandem-compound type single stage reheat turbine is given by [15]

$$G_T(S) = \frac{1}{1+ST_t}\left(\frac{1+\alpha ST_r}{1+ST_r}\right) \quad (1)$$

2.2. Double Reheat Turbine

The transfer function model of two stage tandem-compound reheat turbine discussed here. It comprises four cylinders Very High Pressure (VHP), High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP) P.U MW ratings of each cylinder α, β, γ and μ respectively [15-16]. So that α + β + γ+ μ=1. The overall turbine transfer function for a two stage tandem-compound reheat turbine is given by

$$G_T(S) = \frac{\left(S^2T_{r1}T_{r2} + \beta ST_{r2} + \alpha S(T_{r2}+T_{r1}) + 1\right)}{(1+ST_{r1})(1+ST_{r2})(1+ST_t)} \quad (2)$$

2.3. PID Controller

The control signal generated by PID controller is given by [5, 8]

$$u(t) = K_p(ACE + \frac{1}{ST_i}ACE + ST_d ACE) \quad (3)$$

Proportional-Integral-Derivative (PID) controller gain values are obtained by using conventional tuning technique. Integral Time Absolute Time error (ITAE) objective function is considered for tuning of controller gain (Proportional gain (Kp), integral gain (Ki) and derivative gain (Kd)) values. Performance indices curve is shown in fig.2.

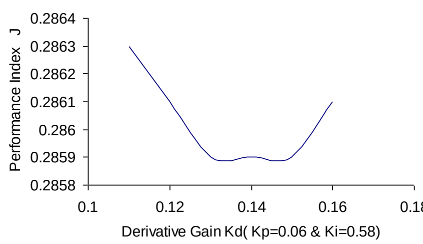

Figure 2. Performance index curve for single reheat turbine

The above indices curve shows optimum gain values of conventional PID controller of single reheat turbine based system. It is clear that the gain values are Kd=0.13 for KI=0.58 and Kp=0.06.

2.4. Ant Colony Optimization Technique

Ant colony optimization technique was introduced by M.Dorigo and colleagues in early 1900s as a novel nature inspired metaheuristic for the solution of combinatorial optimization problem [5, 10]. In nature, ants wander randomly to finding food source return to their colony while laying down a pheromone material. The behavior of real ant in searching the source of food, it evident that shortest path having large pheromone concentrations, so more ants tends to choose and travel in the path.

There are there major phase in Ant Colony Algorithm namely [5, 10]

- Initialization
- Constructing ant solution
- Updating pheromone

3. Simulation Results and Discussion

In the three area interconnected power system, three single areas are interconnected via tie-line. The development of interconnection improves overall system reliability. If any one of connected area fails, the other generating units compensate sudden load demand and keep the system stability. The matlab simulink model of investigated system with PID controller is shown in fig.1.
A small step load perturbation of 1% SLP is applied to thermal area 1. The frequency deviation, interline power exchange and area control errors are shown in fig.

3.1. Case 1: Conventional PID Controller

The gain values of PID controller parameters are optimized by conventional tuning technique with ITAE cost function. The frequency deviation, interline power exchange and area control error changes for each area shown in fig.3-11 PID controller parameters and system performance is recorded and shown in table I & II.

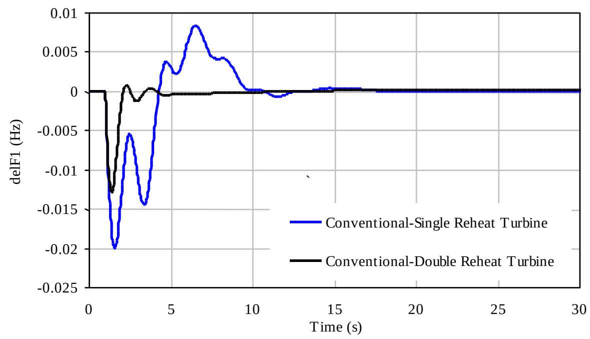

Figure 3. Frequency deviation in area 1 vs. time

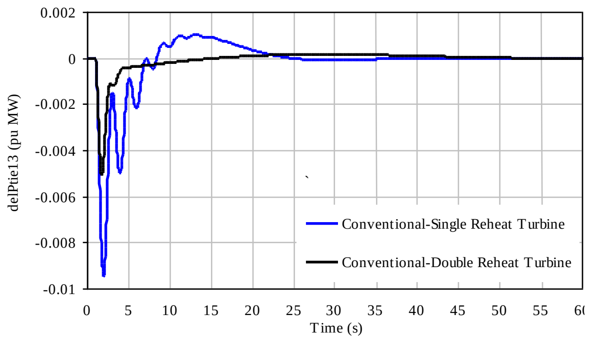

Figure 4. Power deviation between area 1 and area 3 vs. time

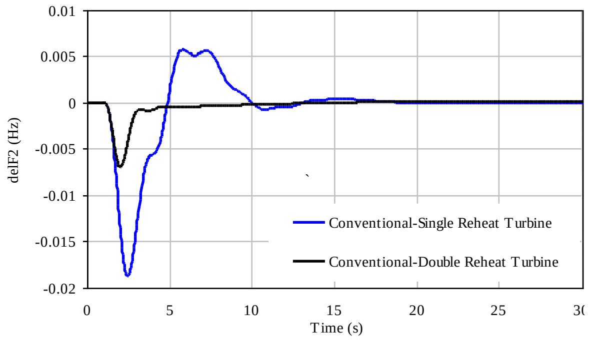

Figure 5. Frequency deviation in area 2 vs. time

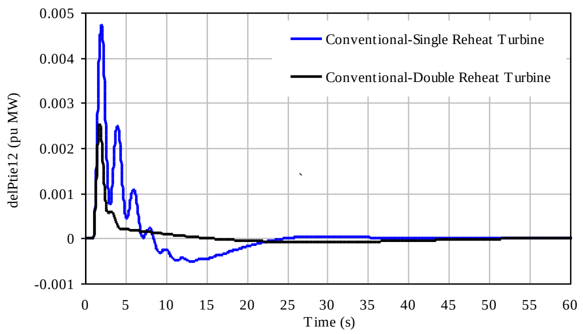

Figure 6. Power deviation between area 1 and area 2 vs. time

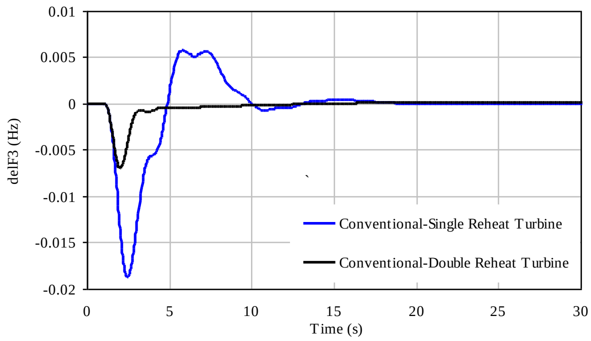

Figure 7. Frequency deviation in area 3 vs. time

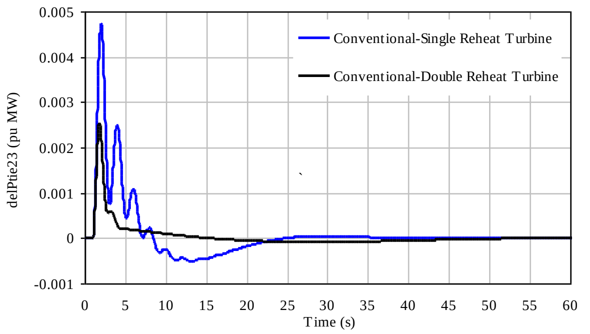

Figure 8. Power deviation between area 2 and area 3 vs. time

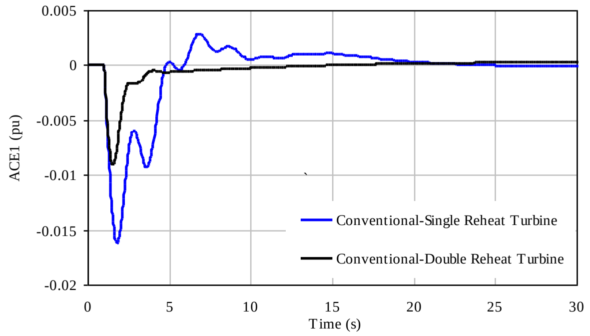

Figure 9. Area control error in area 1 vs. time

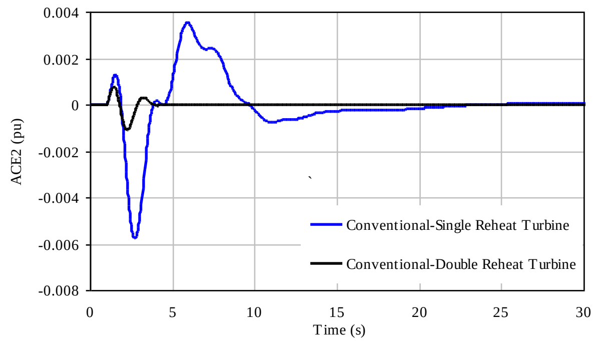

Figure 10. Area control error in area 2 vs. time

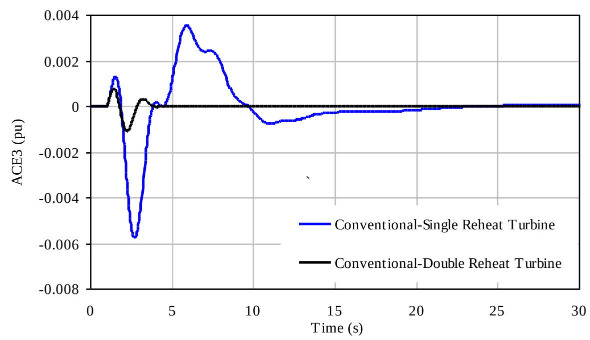

Figure 11. Area control error in area 3 vs. time

The simulation result shows that the double reheat turbine associate with power system improves both the system stability and performance. However, it can be observed that double reheat turbine, a perceptible amount of oscillations and overshoot are reduced in the system response. Controller gain values and system performance are given in the table 1 & 2.

Table 1. Optimal conventional PID controller parameters

Turbine	Optimal PID parameters		
	Proportional gain(Kp)	Integral Gain (Ki)	Derivative Gain (Kd)
Single reheat	0.06	0.6	0.15
Double reheat	0.27	1.16	0.14

Table 2. System performance with single and double rehaet turbine

Turbine	**Response**	**System Performance**	
		Settling time (s)	***Overshoot***
Single reheat	delF1	20.49	-0.0194
	delPtie13	23.65	-0.0092
	ACE1	21.07	-0.0158
Double reheat	delF1	8.36	-0.0126
	delPtie13	13.7	-0.00499
	ACE1	11.98	-0.0088

3.2. ACO PID Controller

In this case, same previous system has to be considered for the analysis. PID controller parameters are optimized using new AI technique with ITAE cost function. Fig. 12-20 shows the investigated system dynamic control performance (defF, delPtie and ACE). Table III & IV shows the optimal PID gain values and performance of the system

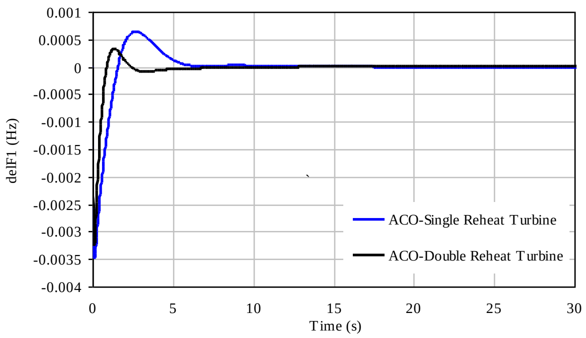

Figure 12. Frequency deviation in area 1 vs. time

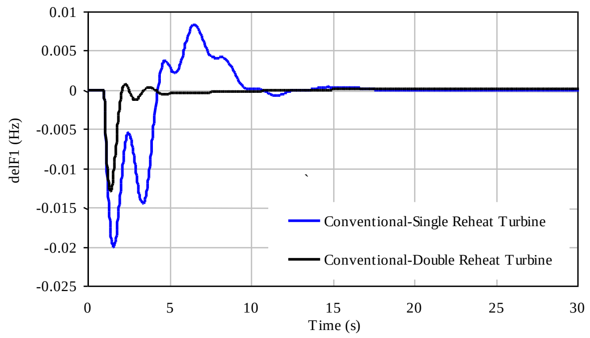

Figure 13. Power deviation between area 1 and area 3 vs. time

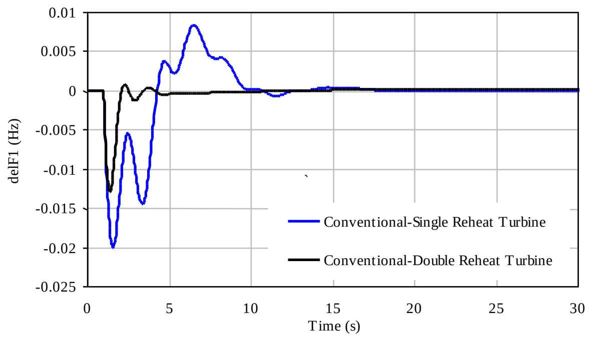

Figure 14. Frequency deviation in area 2 vs. time

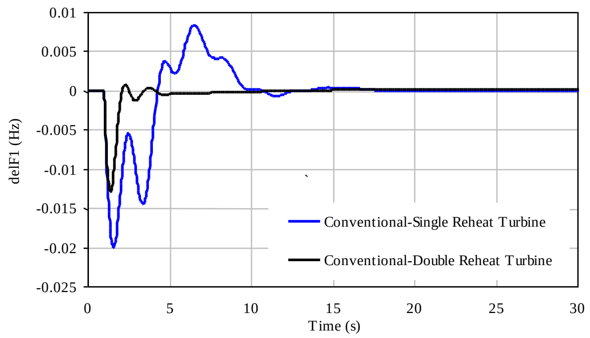

Figure 15. Power deviation between area 1 and area 2 vs. time

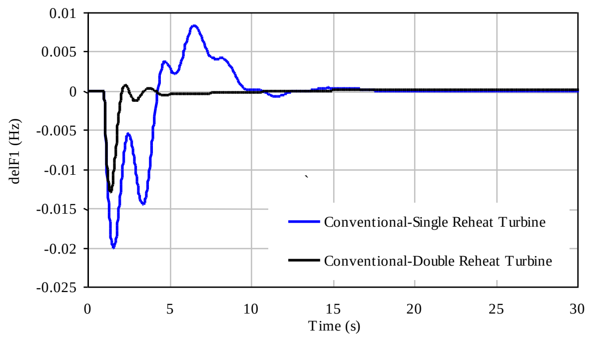

Figure 16. Frequency deviation in area 3 vs. time

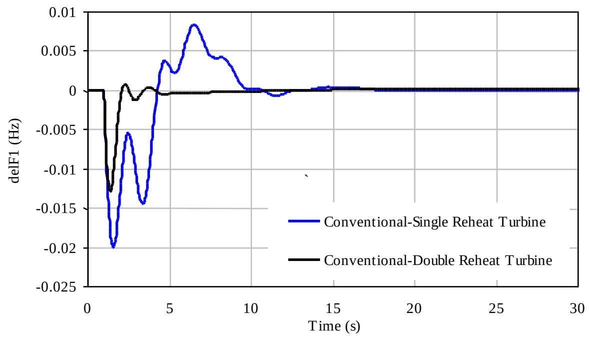

Figure 17. Power deviation between area 2 and area 3 vs. time

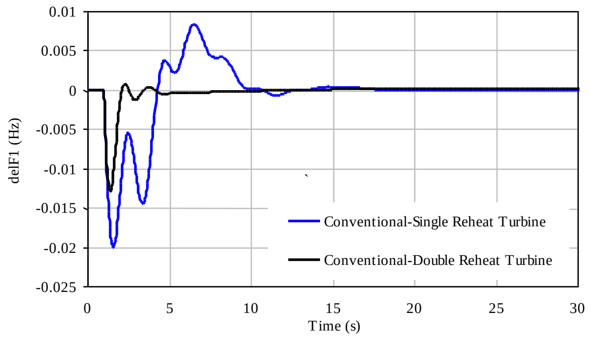

Figure 18. Area control error in area 1 vs. time

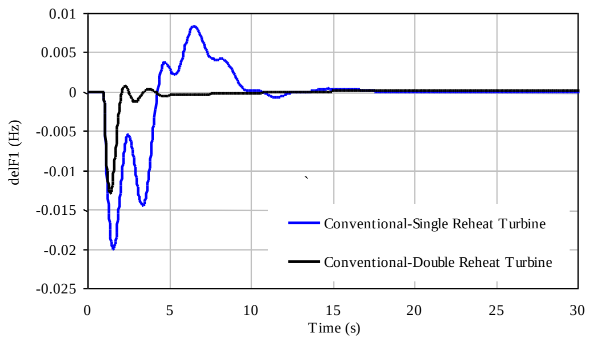

Figure 19. Area control error in area 2 vs. time

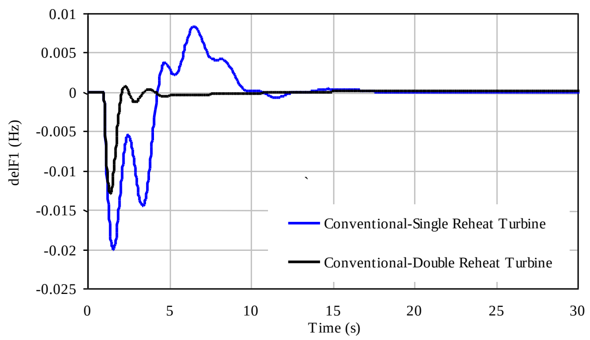

Figure 20. Area control error in area 3 vs. time

The simulation result shows that the double reheat turbine associate with power system improves both the system stability and performance. However, it can be observed that double reheat turbine, a perceptible amount of oscillations and overshoot are reduced in the system response. The optimal gain values of ACO PID controller and performance comparisions of single reheat turbine and Double reheat turbine are given in the Table 3 & 4 respectively.

Table 3. Optimal AI-PID controller parameters

Turbine	Optimal PID parameters								
	Proportional gain (Kp)			Integral Gain (Ki)			Derivative Gain (Kd)		
	Kp1	Kp2	Kp3	Ki1	Ki2	Ki3	Kd1	Kd2	Kd3
Single reheat	8.1	8.7	7.3	9.9	9.4	8.9	5.5	1.8	7.3
Double reheat	5	1.6	0.3	9.9	3.9	3.3	1.9	7.5	9

Table 4. System performance with single and double rehaet turbine

Turbine	Response	System Performance	
		Settling time (s)	Overshoot
Single reheat	delF1	6.26	-0.0034
	delPtie13	13.6	-0.001
	ACE1	11.64	-0.008
Double reheat	delF1	4.7	-0.0032
	delPtie13	10.77	-0.0007
	ACE1	8.7	-0.0015

4. Conclusions

In this work, the performance of double reheat turbine in AGC system for interconnected three area equal reheat thermal power system is investigated. Two different investigations were carried to highlight and analyze the objectives of this investigation. In the first case, system equipped with both single and double reheat turbine with PID controller. Controller gain values for both turbines are tuned using conventional method. In the second case same system has been considered and their gain values are optimized by new AI optimization technique. In both investigations ITAE objective function is considered. The tabulated results and simulation response show that double reheat turbine give superior control performance over single reheat turbine.

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