Artificial Intelligent and meta-heuristic Control Based DFIG model Considered Load Frequency Control for Multi-Area Power System

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Abstract— *The penetration of wind energy conversion system in power system becomes very important because of green energy in recent power system. The incorporation of wind energy conversion system using doubly fed induction generator (DFIG) in load frequency control in multi-area power system is proposed with Area-1 and Area-2 consist of thermal reheat power plant where as area-3 and area-4 as hydro power plant. The performance evaluation is carried out using PI controller, PI-controller tuned with particle swarm optimization technique and fuzzy logic controller is presented. MATLAB software is used for evaluation and comparison of results.*

Key words: DFIG, Control Scheme, Wind penetration, Artificial Intelligence, pi,pi-pso,fuzzy,4-area control.

INTRODUCTION

The load frequency control is mandatory in the field of power system to Improve the controllability of the system. Load frequency control (LFC) is being used for several years as part of the automatic generation control (AGC)scheme in electric power systems [4–7]. A control strategy is needed that not only maintains constancy of frequency and desired tie-power flow but also achieves zero steady state error and inadvertent interchange. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller. The PI and PID controllers are). very simple for implementation and gives better dynamic response, but their performances deteriorate when the complexity in the system increases due to disturbances like load variation boiler dynamics [8,9]. Therefore, there is need of a controller which can overcome this problem. The artificial intelligent controllers like fuzzy and neural control approaches are more suitable in this respect. Fuzzy system has been applied to the load frequency control problems with rather promising results by Nanda [10]. The literature survey says that by the application of conventional controllers such as PI and PID, though the steady state error is minimized to zero but it fails when the system complexity increases due to many interconnections and non-linearity. The performance of fuzzy controllers is much better than the conventional controllers [11–15]. Particle Swarm Optimization is used in few literatures for PI control parameter optimization. In this paper 4-area system with hydro and thermal plants, 4-area system is controlled with PI, fuzzy and PSO tuned PI are used for minimization of settling time.

Intelligent Controls

Selection of controllers is important to make the response faster. Here PI controller, Fuzzy and PSO based tuning of Pi controllers are used and comparative performance analysis is made with setting time.

PI and Fuzzy based Control

In general, PI controllers are used in speed regulation of electrical drives. The output of the conventional speed regulator is expressed in equation (1).

$\mathrm{Out(t)} = \mathrm{K_p(E)} + \mathrm{K_i} \int \mathrm{E\,dt}$ (1)

Where, E is the error which should be minimized by the PI controller. The output (out(t)) is the error minimized proportional signal. Kp is the proportional constant and Ki is integral constant.

The block diagram for fuzzy logic based speed regulation is shown in Fig.1. The fuzzy logic rules are developed by absorbing the characteristic of the PI controller performances.

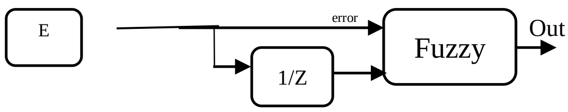

Figure 1. Fuzzy logic control of speed regulation

Table 1. Fuzzy logic rules

Error	Low	Medium	High
Low	Low	High	Medium
Medium	Low	High	High
High	Medium	Low	Medium

The table 1 and figure shows the rules of the Fuzzy logic inference system and developed based on input and output parameters of FLC.

PSO Optimized PI based Controller

The random variation of PI controller parameters with fixed limits shows the change in Error (E) characteristics. So, there is infinite number of possibilities to choose the PI controller parameters. The K_p and K_i are the variables, which should be found with the objective minimization of Settling time.

Minimization of Setting Time

minimize $\sum_{i=1}^{n}(\text{Settling Time})$ (1)

with respect to constraints

$K_{p\,min} \le K_p \le K_{p\,max}$ (2)

$K_{i\,min} \le K_i \le K_{i\,max}$(3)

Where $K_{p\,min}$ and $K_{p\,max}$ are the minimum and the maximum proportional gains, while $K_{i\,min}$ and $K_{i\,max}$ are the minimum and maximum Integral gains obtained by experience while PI controller is used

Particle Swarm Optimization

Particle swarm optimization algorithm works on the behavior of swarm in food searching habit. The number of birds or fishes (Particle) searching for its food and the best particle shares it position to its neighborhood particle (entire population is considered as neighborhood particle) and the information is shared to entire swarm with best position in the search space. Here, food is the objective function, the particles are the population and swarm is the total population in every iteration As PSO is based on the behavior of the food search in a group of fish or bees or birds. The procedure of the algorithm is given as follows

Step 1. Assume the size of the swarm or particle (N). Usually size of 20 to 30 particles are used.

Step 2. Generate the initial population of X in the range X(l) and X(u), randomly as X1, X2, …XN.

Step 3. Evaluate the objective function value.

Step 4. Find the velocities of particles. All velocities are initially assumed as zero. All particles move towards the optimal point.

Step 5. Find the historical best value of the particles, which is known as local best, or particle best (P_{best}) and find the best particles of all the previous iterations called as global best or G_{best}. Find the velocities of the particles j in i^{th} iteration as follows,

$V_j(i) = V_j(i-1) + c_1r_1[P_{best} - X_j(i-1)] + c_2r_2[G_{best}-X_j(i-1)]$ (13)

Where j = 1,2,…N.

c_1, c_2= learning factor assumed as 2

r_1, r_2 = Uniformly distributed random numbers range 0 and 1.

Now find the position or coordination of the j^{th} particle in the i^{th} iteration

$X_j(i) = X_j(i-1) + V_j(i)$ (14)

Now evaluate the objective values of the above X_j.

Step 6. Check the convergence of the current solution, if the positions of all particles converge to the same set of values the method is assumed to have converged else increment the iteration number and evaluate step 5.

Results

Scenario 1 is considered as DFIG-4 area system implementation, scenario 2 is considered as 4-area, where thermal, hydro and DFIG are hybrid.

Then for different controls considered as different cases. Case1 is applied with PI controller, case 2 is applied with PI-PSO controller and case 3 is applied with fuzzy controller.

Fig.2, 5, 7,9,12,14,16,19 and 21 shows the tie line power of three different scenarios and cases. Fig. 3,6,8,10,13,15,17,20 and 22 shows the frequency deviation of three different scenarios and cases. Here it can be seen that all the tie line power and frequency are made as zero which shows the controllability. But the settling time is different for all the scenarios and cases.

Fig. 4,11 and 18 shows the convergence graph of PSO algorithm.

Scenario 1: DFIG, 4-area

Case 1: PI controller

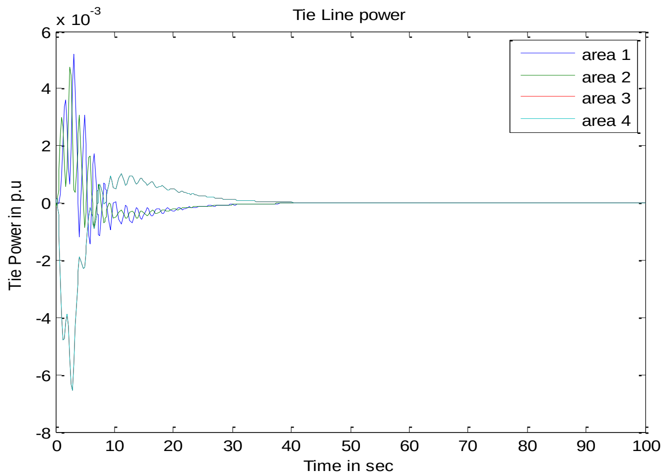

Fig.2 Tie line power in p.u with PI controller

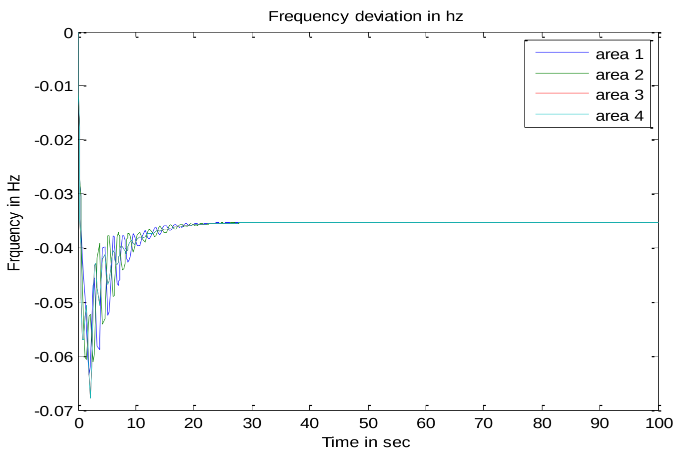

Fig.3 Frequency Deviation in hz with PI Controller

Case 2: PI-PSO

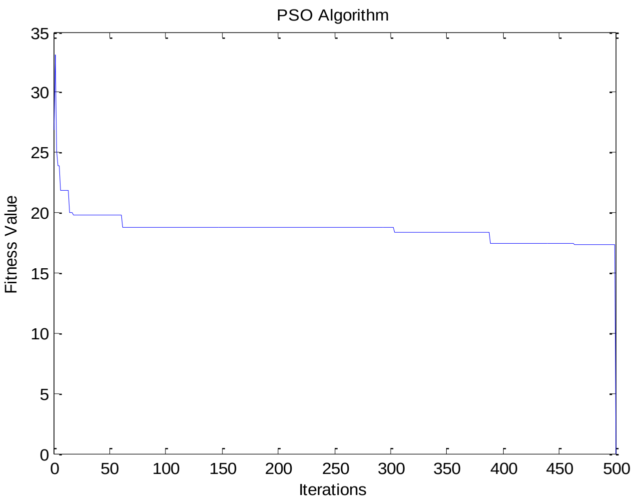

Fig.4 PSO algorithm vs Iteration

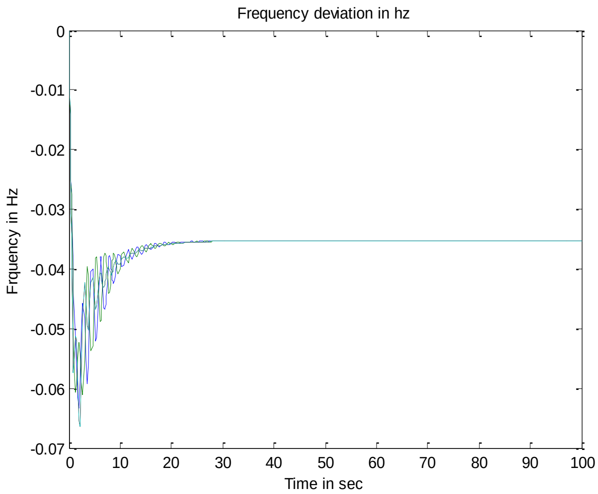

Fig.5 Tie line power in p.u with PI-PSO controller

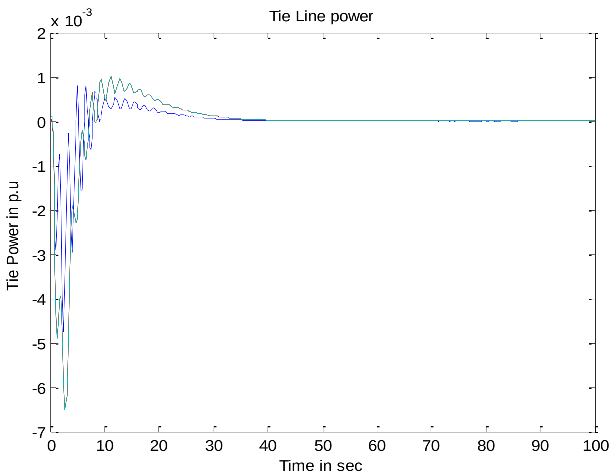

Fig.6 Frequency Deviation in hz with PI-PSO Controller

Case 3: Fuzzy

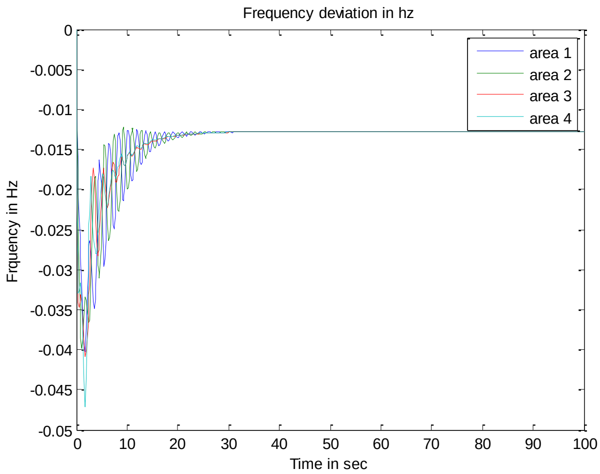

Fig.7 Tie line power in p.u with Fuzzy controller

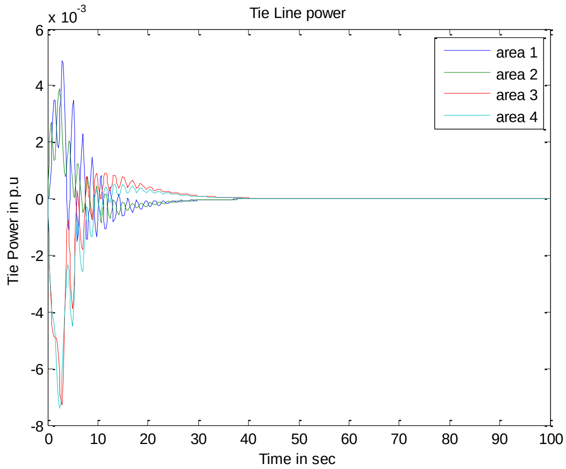

Fig.8 Frequency Deviation in hz with Fuzzy Controller

Scenario 2: : Thermal, hydro 4-area

Case 1: PI controller

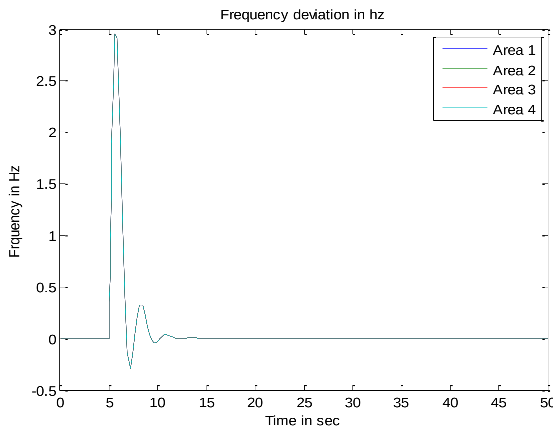

Fig.9 Tie line power in p.u with PI controller

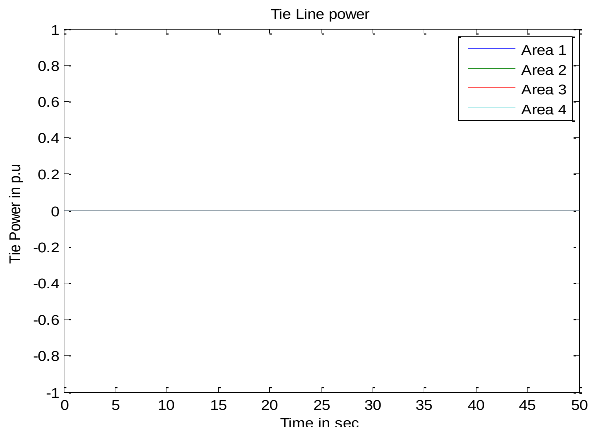

Fig.10 Frequency Deviation in hz with PI Controller

Case 2: PSO

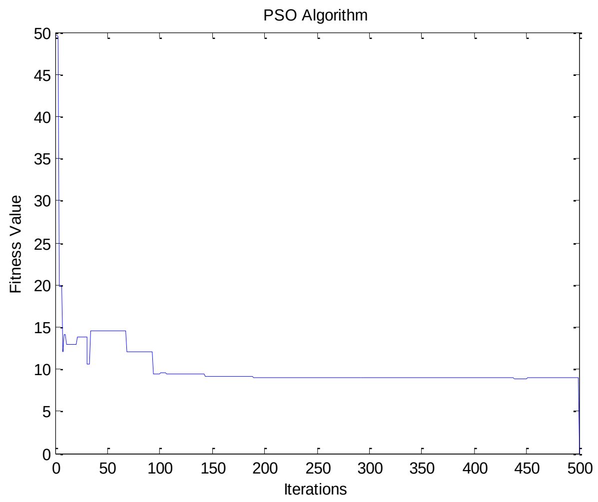

Fig.11 PSO algorithm vs Iteration

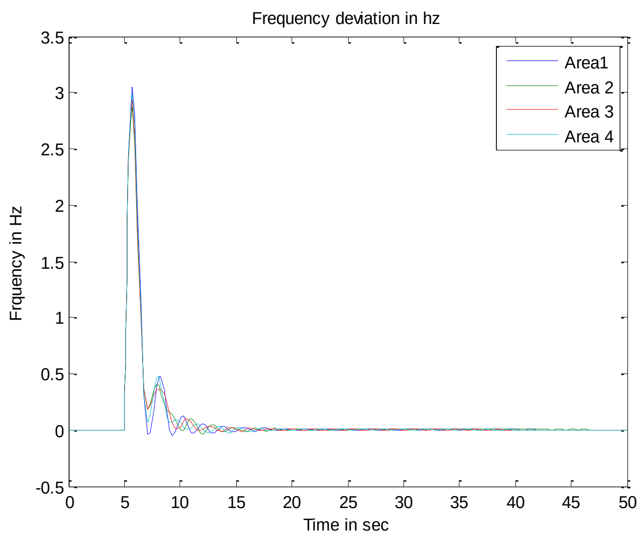

Fig.12 Tie line power in p.u with PI-PSO controller

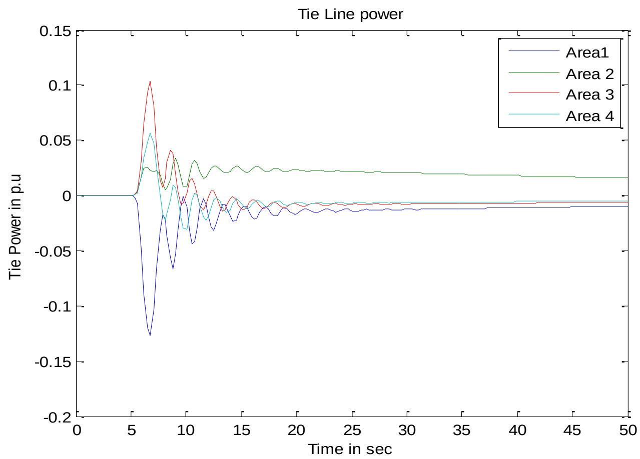

Fig.13 Frequency Deviation in hz with PI-PSO Controller

Case 3: Fuzzy

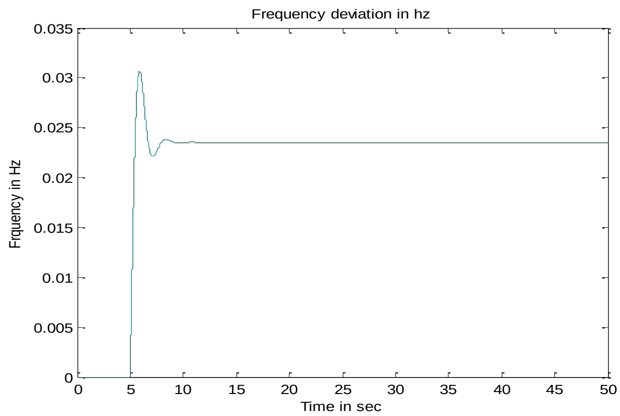

Fig.14 Tie line power in p.u with Fuzzy controller

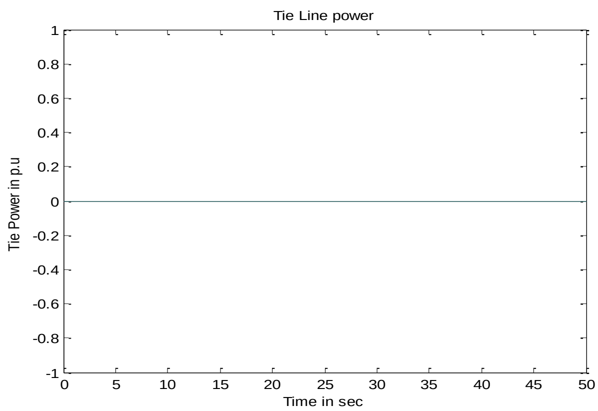

Fig.15 Frequency Deviation in hz with Fuzzy

Controller

Table 2 shows the identified optimal values of kp and ki parameters. Table 3 shows the performance comparison of setting time and other parameters. Here the analysis is made for only settling time.

Table 2- Identification of kp and ki values using PSO algorithm

	kp1	ki1	kp2	ki2	kp3	ki3	kp4	ki4	Iterations Used
Scenario 1	1.0057	1.3527	1.531	1.0095	1.3447	1.7769	1.7169	1.4238	500
Scenario 2	0.122	0.52315	0.27923	0.61005	0.18447	0.76725	0.16441	0.62216	500

Table 3- Performance comparison table

	Scenario 1			Scenario 2		
All time in secs	**PI**	**PSO-PI**	**Fuzzy**	**PI**	**PSO-PI**	**Fuzzy**
RiseTime	4.2902	2.2254	0.28787	3.41E-05	0.0030782	0.3546
SettlingTime	29.811	**12.085**	14.475	8.885	9.0049	**7.698**
SettlingMin	0.14117	0.14117	0.051171	-0.010046	-3.0543	0.021181
SettlingMax	0.26273	0.25985	0.17738	0.53476	0.051205	0.030697
Overshoot %	86.101	84.058	246.64	76757	116600	30.462
Undershoot	0	0	0	5709700	1956.4	0
Peak	0.26273	0.25985	0.17738	2.71E+00	3.0543	0.030697
PeakTime	6.5547	3.0436	1.36	3.8072	4.0817	5.8927

From the above tabular column, it can be noted that the PSO is performing better in scenario 1 and in scenario -2 fuzzy is working better. So, the fuzzy makes the system response faster.

Conclusion

The load frequency control is made with three different controllers, PI, PI-PSO and fuzzy for 4-area. The performance is compared with high speed response after fault assurance. In this paper comparison of Setting time is made and with the fuzzy it is better in higher area system and PI-PSO is better is lower area system. So the choice can be made according to the number of area of power system.

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