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Load Frequency Control of Two Area Power System using PID Controller

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***Abstract*--Recently, PID controller is widely used for different applications. In this project a particle swarm optimization tuned Proportional Integral Derivative (PSO-PID) controller has been proposed. The performance of the proposed controller has been compared with the other classical controllers under different loading conditions. It is shown the performance PID controller tuned with Particle swarm algorithm was better than classical controller in terms of transient stability**

Keywords: LFC, proportional integral controller, PSO-PID controller- transient stability of LFC.

I. INTRODUCTION

Modern days of the electrical power system are interconnected to neighboring power plants. Each power plant to generate own electrical power generation, during maximum load conditions all plants share electrical power through Tie-line control. Because, if load demand of the plant increases [1-2]. This can be effect on the power angle delta, delta angle decreases due to speed of the generator decreases; speed is directly proportional to the frequency. Hence the load demand is increase frequency of the system is decreases. Once frequency exceeds the within the limits i.e. 50±5% HZ, the entire power system goes to blackout conditions and alternators comes to rest position.

The power systems, frequency are dependent on active power and voltage dependence on reactive power limit. The control power system is separated into two independent problems. The control of frequency by active power is called as load frequency control (LFC) [3-4]. An important task of LFC is to maintain the frequency deviation constant against due to continuous variation of loads, which is also referred as un- known external load disturbance. Power exchange error is an important task of LFC. Generally a power system consists of several generating units connected together; these generating units are inter-connected through tie-lines to become fault tolerant. This use of tie-line power creates a new error in the control problem, which is the tie-line power exchange error. Area controller error (ACE) is play major role in interconnected power system and also minimizing error functions of the given system. In this paper particle swarm optimization tuned PID controller is proposed and performance of the load frequency control on the two area power system and also performance of the proposed PSO-PID controller as compared to conventional PI and PID controller.

II. MATHEMATICAL MODELING OF LFC

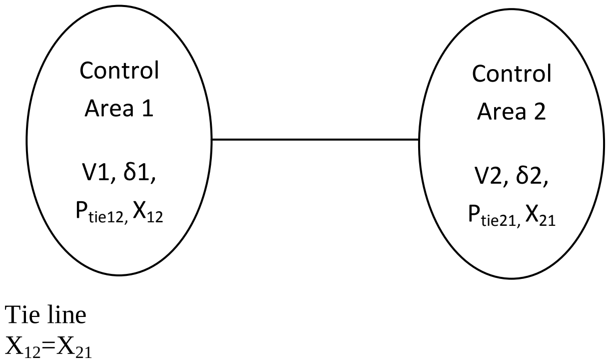

Fig 1: Two Area power system Control block diagram

The power transfers from area 1 to area 2 are

$$p_{tie12} = \frac{|V1||V2|}{X_{12}} \sin(\delta 1-\delta 2) \text{ ---------- } (1)$$

If the change in load demands of two areas there will be incremental change in power angle.Δδ1 and Δδ2 be the incremental changes in δ 1 and δ 2 the Change in power is

$$p_{tie12} + \Delta p_{tie12} = \frac{|V1||V2|}{X_{12}} \sin[(\delta 1 + \Delta\delta 1) - (\delta 2 + \Delta\delta 2)]$$

-- (2)

$$p_{tie12} = \frac{|V1||V2|}{X_{12}} \cos(\delta 1 - \delta 2)(\Delta\delta 1 - \Delta\delta 2) \text{ ---- (3)}$$

$$T_{12} = \frac{|V1||V2|}{X_{12} * P1} \cos(\delta 1 - \delta 2) \text{ --- (4)}$$

$$\Delta P_{tie12}(p.u) = T_{12}(\Delta\delta 1 - \Delta\delta 2) \text{ --- (5)}$$

$$P_{max12} = \frac{|V1||V2|}{X_{12}} (\Delta\delta_1 - \Delta\delta_2) \text{ ---- (6)}$$

$$T_{12} = \frac{P_{max12}}{P1} \cos(\delta 1 - \delta 2) \text{ --- (7)}$$

$$2\pi\Delta f = \frac{d\delta}{dt} \text{ ----- (8)}$$

Incremental tie line power output of area1

$$\Delta P_{tie12}(P.U) = 2\Pi T_{12}\left(\frac{\Delta f1}{s} - \frac{\Delta f2}{s}\right) \text{ -------- (9)}$$

On taking Laplace transform on both side, then

$$\Delta P_{tie21}(s) = \frac{2\Pi T_{12}}{s}(\Delta f\ 2(s) - \Delta f\ 1(s)) \text{ --- (10)}$$

$T_{21} = a_{12} T_{12}$ Then

$$\Delta P_{tie21}(s) = \frac{-2\Pi T_{21}}{s}(\Delta f1(s) - \Delta f2(s)) \text{ --- (11)}$$

According to swing equation [5].Let ΔP_D is increases in load at area 1 the power balance is

$$\Delta P_G - \Delta P_D = \frac{2H}{f^0}\frac{d}{dt}\Delta f + B\Delta f \text{ ---- (12)}$$

Where

H- Inertia constant, f^0 – Nominal frequency,

Δf- change in frequency, B- Area parameter

Area control error plays a major role in interconnected power system, because controller input is Area control error.

For the two Area power systems is

$$\Delta P_G - \Delta P_D = \frac{2H}{f^0}\frac{d}{dt}\Delta f + B\Delta f + \Delta P_{tie12}$$

$$\Delta P_G(s) - \Delta P_D(s) = \frac{2Hs}{f^0}\frac{d}{dt}\Delta f(s) + B\Delta f(s) + \Delta P_{tie12}(s)$$

$$\Delta f1(s) = \frac{\Delta P_{G1}(s) - \Delta P_{D1}(s) - \Delta P_{Tie12}(s)}{B1\left(\frac{2H1s}{f^0 B1} + 1\right)} \text{ ----13)}$$

$$\Delta f1(s) = [\Delta P_{G1}(s) - \Delta P_{D1}(s) - \Delta P_{Tie12}(s)]\left[\frac{k_{ps}}{1 + sT_{ps}}\right] \text{ - (14)}$$

Where $K_ps=1/B1$ and $T_ps= 2H/B_1f^0$
Similarly

$$\Delta f2(s) = [\Delta P_{G2}(s) - \Delta P_{D2}(s) - \Delta P_{Tie21}(s)]\left[\frac{k_{ps}}{1 + sT_{ps}}\right] \text{ ------ (15)}$$

A power system can be divided into various areas each area connected into its neighboring areas through tie-lines.[7] Load frequency control means to control the Active power and frequency kept constant while any load deviations occurring on the power system

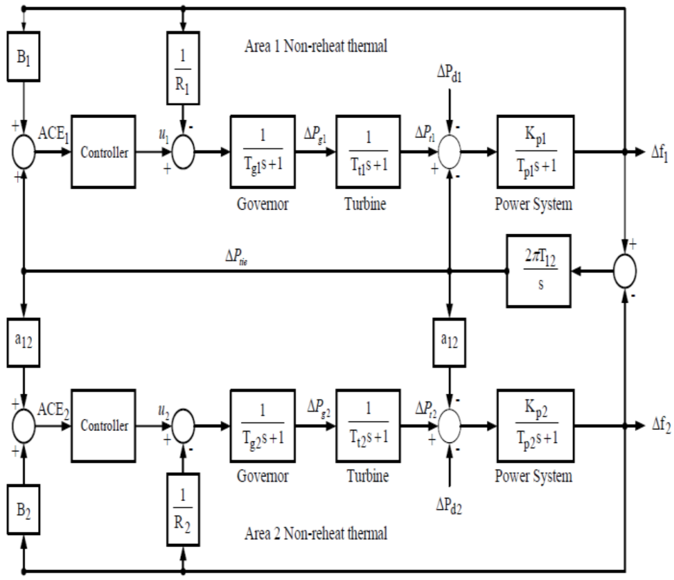

Fig 2: Block diagram of two area interconnected power system with controller

$$ACE_i = \sum_{j=1}^{N} \Delta P_{ij} + B_i\Delta\omega_i \text{ -------------------- (16)}$$

Where

N is number of areas interconnected areas *i*,

P_{ij} is the power deviation between areas i and j from the scheduled values.

III. PARTICLE SWARM OPTIMIZATION

James Kennedy an American Social Therapist alongside Russell C.Eberhart developed another evolutionary computational strategy termed as Molecule Swarm Advancement in 1995.The methodology is suitable for taking care of nonlinear issue. The methodology is focused around the swarm conduct, for example, flying creatures discovering sustenance by rushing. An essential variety of the PSO calculation satisfies desires by having a masses (called a swarm) of candidate result (called particles). These particles are moved around in the interest space according to a few essential formulae. The advancements of the particles are guided by their own particular specific best known position in the request space and furthermore the entire swarm's best known position. Modeling of $\Delta f1$ and $\Delta f2$ applied on partial swarm optimization algorithm.

$$\Delta f1 = \frac{\begin{array}{l} -1.2S^5-(1.072S^4Kd-1.2S^4Kp)+(-2.06S^3Kd \\ -10.72KpS^3-1.2S^3Ki)+(-0.12S^2Kd-2.06S^2Kp \\ -1.072KiS^2)-0.12KpS-2.06KiS-0.12Ki \end{array}}{\begin{array}{l} (60-35.28Kd)S^5-S^4(22.08Kd+24.72Kp \\ -54.8)-S^3(42.43Kd+22.08Kp+24.72Ki \\ -102.09)-S^2(2.472Kd+42.43Kp+24.08Ki- \\ 80.6)-S(2.47Kp+42.43KI+0.12)-2.472Ki \end{array}}$$

Δω is the speed deviation

$$B_i = \frac{1}{R_i} + D_i \text{----------------------------------} (17)$$

B_i is frequency bias factor.

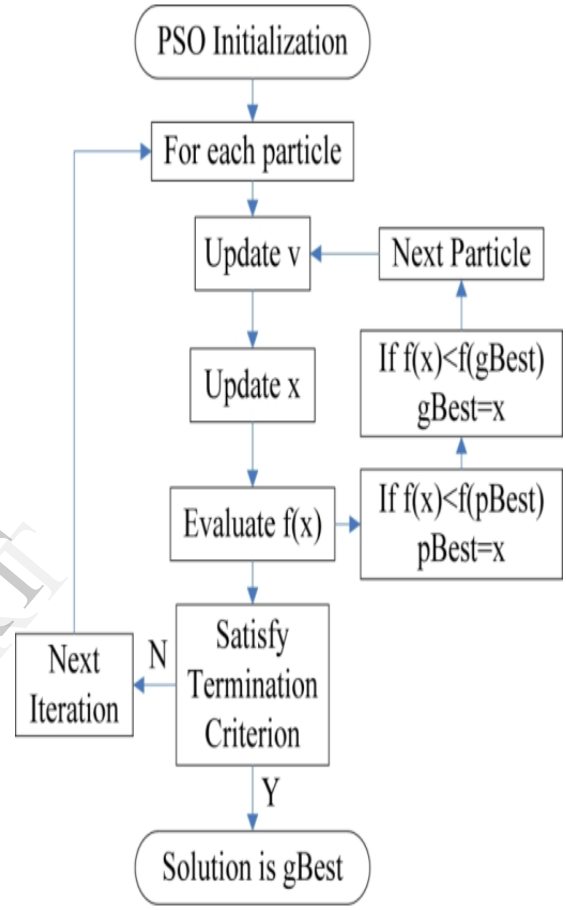

Fig 3: Flow chart of PSO algorithm

IV. SIMULATION AND RESULTS

The practical swam optimization tuned in proportional integral derivative controller using design of LFC in two area power system, the controller plays regulating power flow between different areas while holding frequency is constant. The performance of the proposed controller has less peak value and quick settling time and improves the stability of the system .

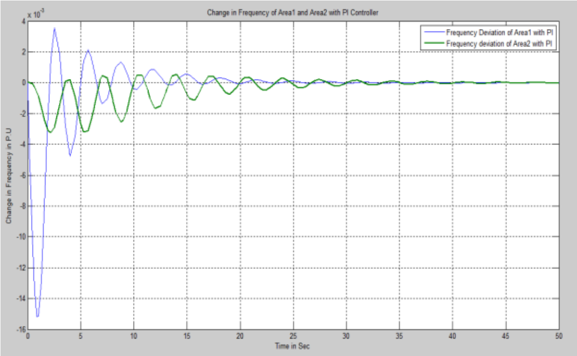

Fig 4: Frequency deviations of Area1 and Area2 with PI controller

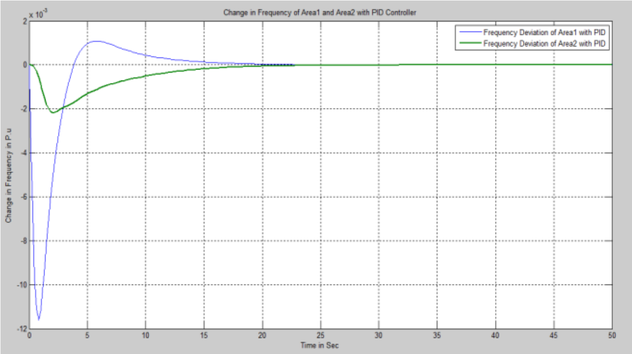

Fig 5: Frequency deviations of Area1 and Area2 with PID controller

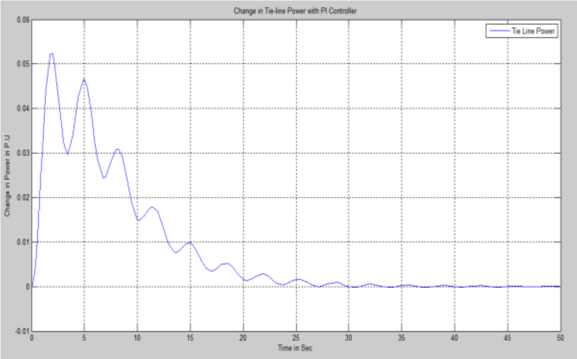

Fig 6: Tie-line power deviation of PI controller

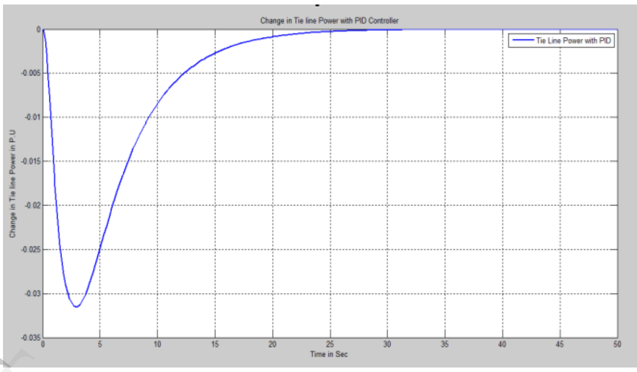

Fig 7: Tie-line power deviation of PID controller

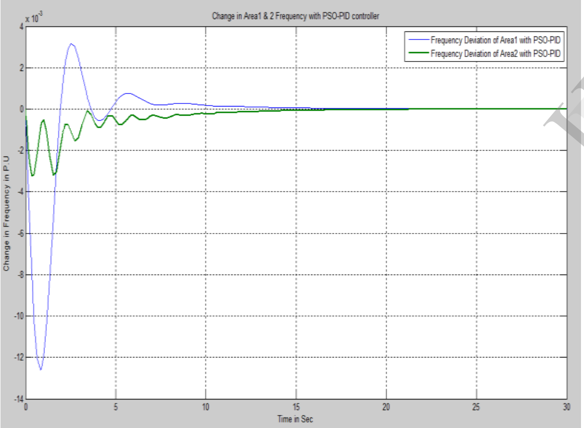

Fig 8: Frequency deviations of Area1 and Area2 with PSO-PID controller

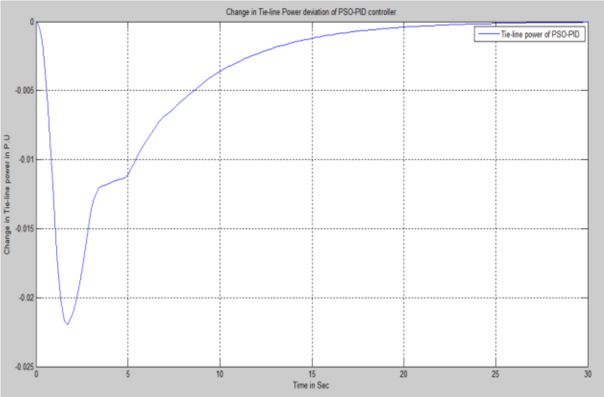

Fig 9: Tie-line power deviation of PSO-PID controller

From Fig 8 and 9 shows, PSO-PID controller using LFC on the power system at change in power of Area1 is 25% and change power of Area2 is 10% of the base load. The performances of PSO tuned proportional derivative controller tuned in LFC as quick settling time [9] i.e. area1 settling time is 18 sec and area2 settling time is 16 sec respectively. Peak overshoots of the area1 and area2 has very less then compared to the PI and PID controllers as shown in fig 4 and 5 as PI controller applied to LFC and fig 6 and 7 shows to the PID controller applied to the LFC. Hence, the performances of PSO-PID controller using LFC of the power system, reduces the error and improve the dynamic response of the system.

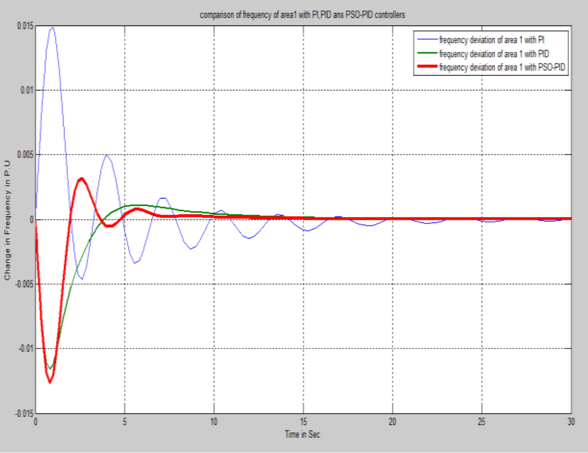

Fig 10: Comparison of Frequency in Area1 with PI, PID and PSO-PID controllers

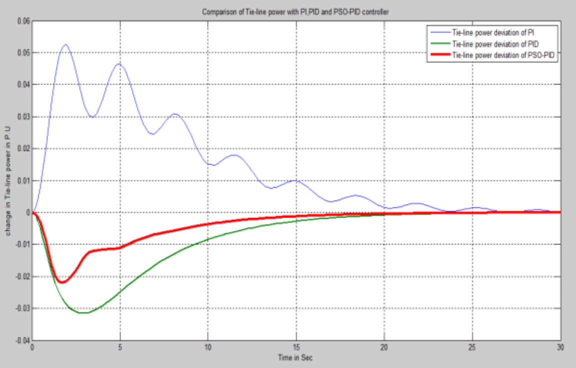

Fig 12: Comparison of Tie-line power with PI, PID and PSO-PID controllers

Table 1: summarized Area1 frequency deviation

Controller	*Rise time (s)*	*Peak overshoot*	*Settling time(S)*
PI	0.0075	0.015	35
PID	0.006	0.012	20
PSO-PID	0.0055	0.011	16

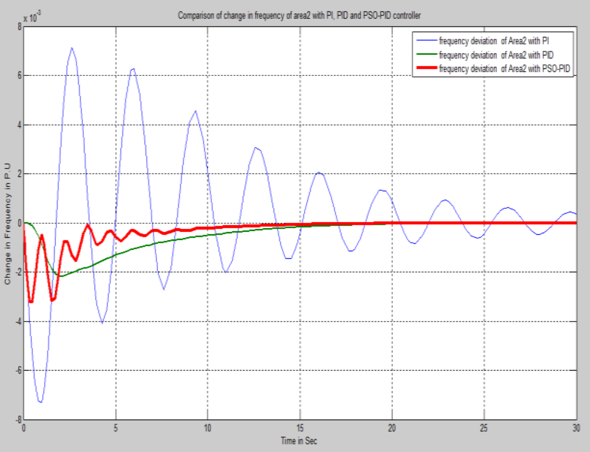

Fig 11: Comparison of Frequency in Area2 with PI, PID and PSO-PID controllers

From fig 10 and 11 shows, comparison of LFC of two area power systems with proportional integral, proportional integral derivative and practical swarm optimization tuned PID controller at area1 25% of change in load and Area2 is 10% of change in Load. By observing the wave forms of the following figures PSO tuned proportional integral derivative controller has better performance than that of the conventional PI and Conventional PID controller. The performance of the Rise time, peak time and settling time of the given system summarized different types of controllers.

Table 2: summarized Area2 frequency deviations

Controller	*Rise time (s)*	*Peak oversho*	*Settling Time(s)*
PI	0.0035	0.007	40
PID	0.0015	0.003	25
PSO-PID	0.001	0.002	20

Case Study:

Case 1: Change in Active power of Area1 is 10% and Area2 is 0% with PSO-PID controller

Table 3: Valid proportional, integral and Derivative constants are shown below

% Change in Load	*Area*	K_p	K_i	K_d
10%	Area1	0.1458	0.6458	1.5468
0%	Area2	0.4121	0.5027	0.863

Case 2: Change in Active power of Area1 is 25% and Area2 is 10% with PSO-PID controller

Table 4: Valid proportional, integral and Derivative constants are shown below

% Change in Lo	*Area*	K_p	K_i	K_d
25%	Area1	0.2816	0.8179	0.2610
10%	Area2	2.5306	2.5026	2.5475

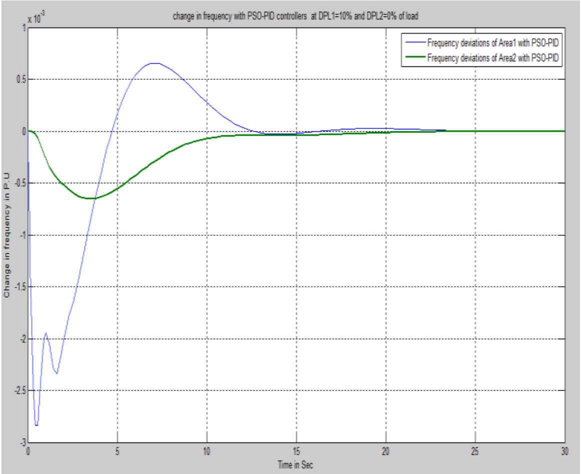

Fig 13: LFC on power system with PSO-PID controller at ΔP_{L1}=10% and ΔP_{L2}=0% of change in Active power.

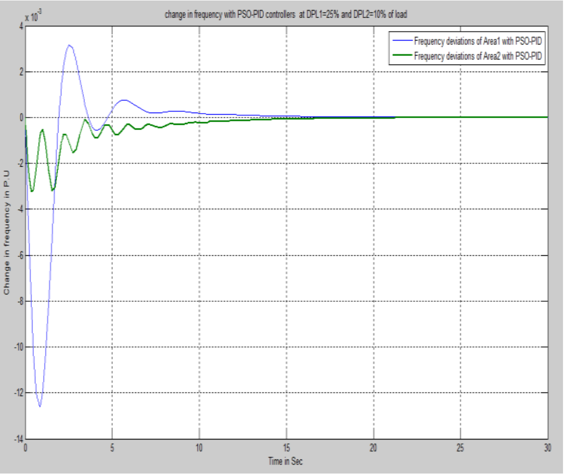

Fig 14: LFC on power system with PSO-PID controller at ΔP_{L1}=25% and ΔP_{L2}=10% of change in Active power.

By comparing Fig 14 and Fig 15 shows, if change in Active power of both areas+ 25% and +10% of the base load, the response of the frequency deviation curves to increases peak overshoot, more no of oscillations and Fast settling time compare to change in Active power of 10% and 0% of the base load.

V. CONCLUSION:

In this paper, it can be concluded that practical swarm optimization tuned proportional integral derivative controller give optimal value for load frequency control on the two area power system. The performance of the given proposed controller has more accurate than that of the other conventional PI and PID controller under different load conditions.

Therefore the proposed controller of two area power systems, the transient response was improved with less peak overshoot and settling time .The performance and robustness of proposed controller was analyzed for different change in load disturbance.

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