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# Optimization of Automatic Generation Control Scheme with Pso Tuned Fuzzy Pid Controller And Comparision With Conventional Pso Pid Controller

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***Abstract :*** *Automatic generation control or AGC system is substantial control process that operates perpetually to balance the generation and load in power system at minimum cost. If any kind of mismatch occurs between generation and demand causes the variation in the system frequency from its nominal value. This high frequency deviation may cause system breakdown. In order to maintain the stability, a very fast, reliable and accurate controller is needed to maintain the system frequency within the range. This paper presents the particle swarm optimization (PSO) technique to tune the Fuzzy based PID controller gains for the automatic generation control (AGC) of the interconnected two area power system. Each control area includes the dynamics response of the power systems. The results reported in this paper present the potency of the particle swarm optimizer in the tuning of the Fuzzy based PID controller parameter for two area power system. The improvement in the dynamic response of the power system is verified. The output response of the proposed work is compared with PSO-PID controller.*
***Keywords:*** *Automatic Generation Control, Particle Swarm Optimization, Fuzzy PID controller*

## I. Introduction

The main purpose of power system operation and control is to provide continuous supply of power with an acceptable range, for all the consumers in the system. The system will be in equilibrium, when there is symmetry between the power generation and the demand. There are two types of control methods used to attain reactive power balance i.e. acceptable frequency values and real power balance acceptable voltage profile. The former is called the automatic load frequency control or automatic generation control [1] and the latter is called automatic voltage regulator.

The requirement of parallel operation of multi area power systems is that to fulfill requirement with the increase in size of electrical power system, controlling the frequency of interconnected power system has becoming the quite challenging[3]. The frequency deviation and tie-line power arise because of unpredictable load variations, which occur due to a difference between the generated and the demanding power [1].The main objective of providing an Automatic Generation Control is to maintain system frequency at nominal value.

### A. Automatic Generation Control: Fundamentals

The main aim of AGC is to regulate the frequency using for both primary and supplementary controls. The Automatic Load Frequency Control is used to control the frequency variation by controlling the real power balance in the power system. The ALFC loop shown in Fig, is known as primary ALFC loop. It achieves the primary goal of real power balance by adjusting the turbine output to match change in load demand. The restoration of the frequency to the nominal value requires an additional control loop known as the supplementary loop. This purpose is to met by using integral controller so that the frequency variation zero [2]. The ALFC with the supplementary or additional loop is generally called the Automatic Generation control.

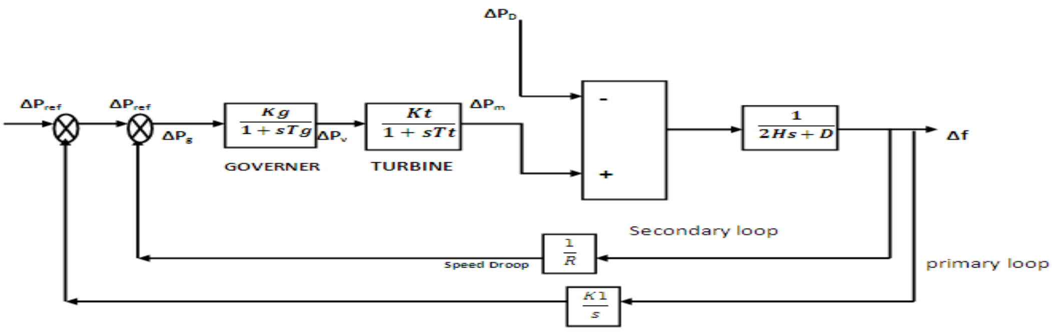


**Fig1: Block diagram representation of AGC unit**

In a single area system, there is no tie-line schedule to be maintained. Thus the function of the AGC is only to bring the frequency to the nominal value [2].This will be achieved using the supplementary loop which uses the integral controller to change the reference power setting so as to change the speed set points.

**B. Fuzzy Logic**

A fuzzy logic system **(FLS)** is unique system which is able to simultaneously handle numerical data and linguistic knowledge. It is a kind of nonlinear mapping of an input data (feature) vector into a scalar output, i.e. it maps numbers into numbers. Fuzzy set theory and fuzzy logic establish the specifics of the nonlinear mapping [11]. Fuzzy logic, which is the logic on which fuzzy control is based, is much closer in spirit to human thinking and natural language than the traditional logical systems. Basically, it provides an effective means of capturing the approximate, inexact nature of the real world. Viewed in this perspective, the essential part of the fuzzy logic controller (FLC) is a set of linguistic control rules related by the dual concepts of fuzzy implication and the compositional rule of inference. In essence, then, the FLC provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy.

Generally, a FLS is a nonlinear mapping of an input data vector into a scalar output (the vector output case decomposes into a collection of multi input single output systems). The benefit of FL is that there are many numbers of possibilities that leads to lots of different mappings. This requires a understanding of FL and the elements that comprise a FLS.

**C. Particle Swarm Optimization (PSO)**

Particle Swarm Optimization is a procedure used to explore the search space of a given problem to find the settings or parameters needs to maximize a particular objective. PSO belongs to the broad class of stochastic optimization algorithms. PSO is a population based algorithm which exploits a population of individuals to probe promising regions of the search space. In this process, the population is called a swarm and the individuals are called particles. Each particle moves with an adaptable velocity for finding space and holds in its memory it ever considered.

In the *global* version of PSO the best position ever attained by all individuals of the swarm is communicated to all the particles. In the *local* version, each particle is assigned to a neighbour comprising of a prespecified number of particles. In this case, the best position ever achieved by the particles that comprise the neighborhood is communicated between them. Finally, because of the PSO algorithm the best fitness value achieved between all particles in the swarm, called the global best fitness, and the candidate solution that achieved this fitness, known as the global best position or global best candidate solution. PSO also retains the track of the all the best values that the particles have achieved so far.

## II. System Modeling

**A. Linearised model of two area system using SMES**

In this paper we have considered a two area system with SMES. The Fuzzy-PID controller used in this system is being optimized by using PSO. For the dynamic response of the test system 10% load change is considered.

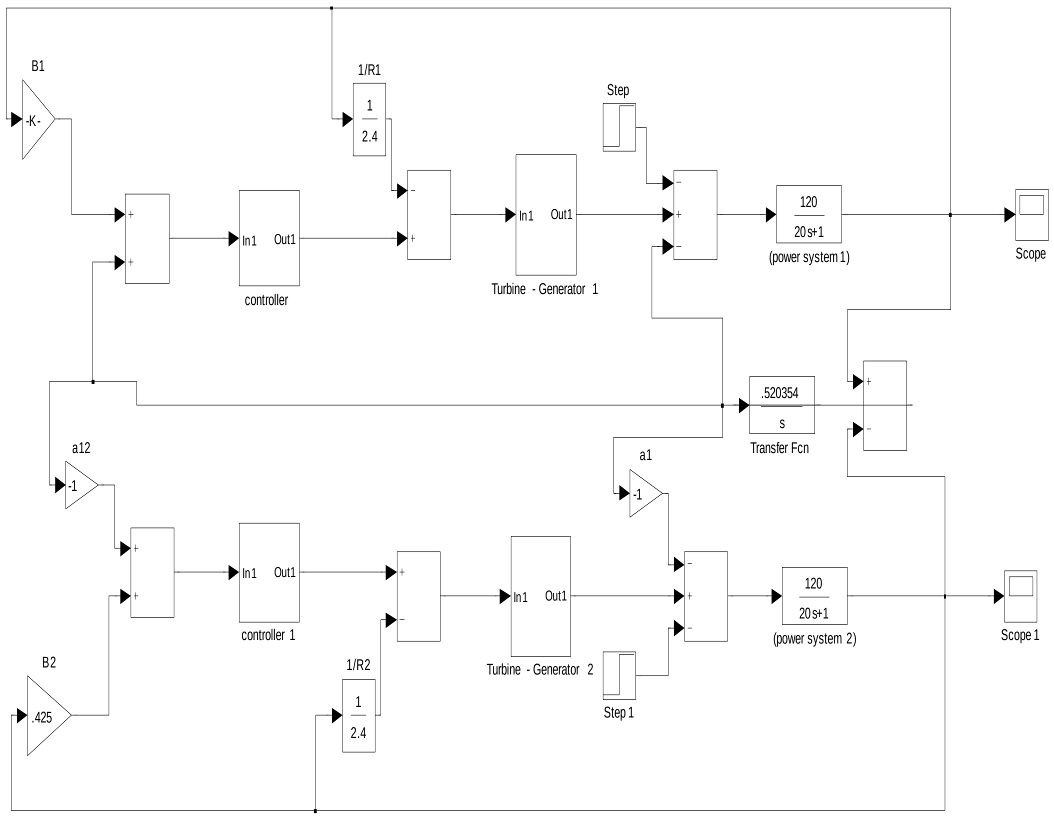


**Fig2: linearised model of two area AGC system**

**B. Fuzzy controller**

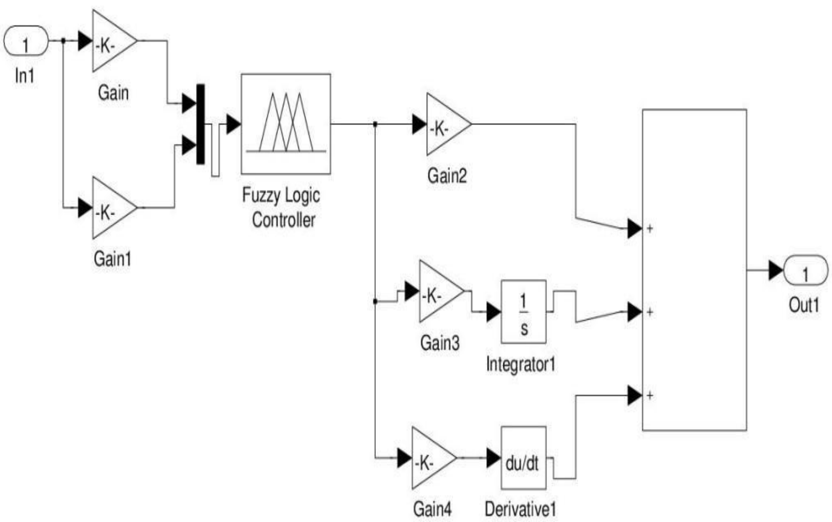


**Fig 3: Fuzzy PID controller**

**C.Calculation of Area control error**

In the control approach each area of an interconnected system tries to regulate its area control error (**ACE**) to zero [2].This error signal can be used to generate the Area Control Error (ACE) signal as

$$ACE_i = B_i \Delta f_i + \Delta P_{tie-i-error} \qquad (1)$$

Where, $B_i$ is the frequency bias factor and $\Delta f_i$ is the frequency deviation in area-i.

**D.PSO Tuned Fuzzy PID Controller**

The choice of the tolerable values for the scaling factors of each PID-type Fuzzy Controller structure is often done by a trials-errors hard practice. This optimizing problem becomes difficult and weak without a

systematic design method. To deal with these problems, the optimization of these scaling factors is projected like a promising result. This tuning problem can be formulated as the subsequent guarded optimization problem:
{ minimize f ($x$)
$x$ €**D**
$g_l(x) \leq 0; \forall\, l = 1, \ldots, n$ **}**
Where $f$: $\mathbf{R}^m \rightarrow \mathbf{R}$ the cost function, $\mathbf{D} = \{ x$ €$\mathbf{D}^m$; $x$ min $\leq x \leq x$ max$\}$ the initial search space, which is supposed containing the desired design parameters, and $g_l : \mathbf{R}^m \rightarrow \mathbf{R}$ the problem's constraints.
The optimization-based tuning problem consists the finest decision variables x* = (x*1, x*2, x*3, x*4, x*5....... x*m) representing the scaling factors of a PID-type FC structure, which minimizes the defined cost function, chosen as the IAE and ISE performance criteria. These cost functions are minimized, using the proposed constrained PSO algorithm, under various time-domain control constraints like overshoot D, steady state error $E_{ss}$, rise time $t_r$ and settling time $t_s$ of the system's step response, as shown in the equations (9),.Hence, in the case of the PID-type Fuzzy Controller structure without self-tuning method, the scaling factors to be minimised as Ke,Kp,$K_d$,α and β.The formulated optimization difficulties is defined as follows:
{minimize $f(x)$
$x= (K_e,K_p,K_d,\alpha,\beta)^T$ € $\mathrm{R}^4_+$
Subject to
$D \leq D^{\max}$; $t_s \leq t_s^{max}$ ; $t_r \leq t_r^{\max}$; $Ess \leq E_{ss}^{\max}$}
Where $D_{\max}$, $E_{ss\max}$,$t_{r\max}$,$t_{s\max}$ are the specified overshoot, steady state, rise and settling times respectively, that constraint the step response of the PSO-tuned PID-type Fuzzy logic controlled system, and can define some time-domain templates.

## III. PSO Working

The PSO algorithm works simultaneously by maintaining several candidate solutions in search space. In each iteration of the algorithm, each candidate solution is evaluated with objective function being optimized, determining the fitness of that solution. Individually candidate solution can be assumed as a particle flying through the fitness landscape finding the minimum or maximum of objective function. Originally, the PSO algorithm selects candidate solutions randomly within the search space. Figure below shows the initial state of a four particle PSO algorithm seeking the global maximum in a one dimensional search space. The PSO algorithm simply makes usage of the objective function to calculate its candidate solutions and operates upon the resultant fitness values.

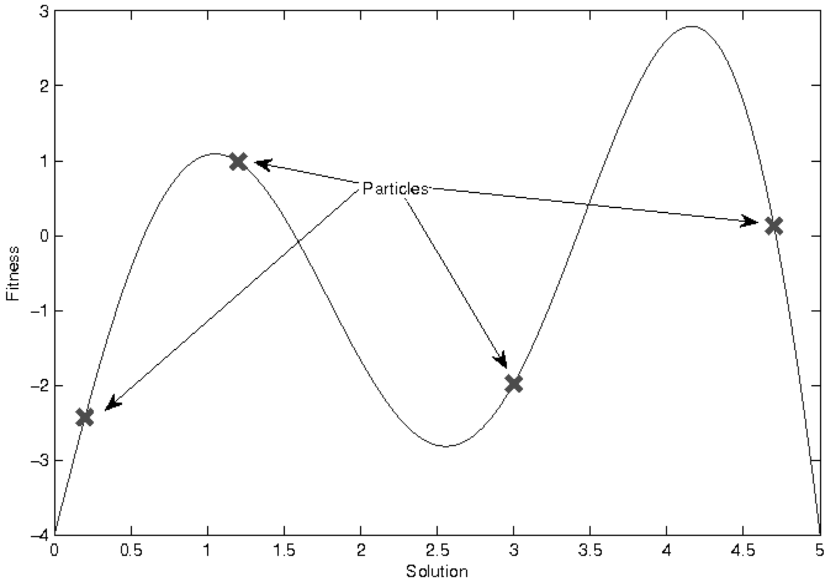


**Fig4: Initial PSO State**

Every particle maintains its position, composed of the candidate solution and its evaluated fitness, and its velocity. Additionally, it remembers the best fitness value that it has achieved, referred to as the individual best position and individual best solution. The PSO procedure consist just three steps to find out the results, which are repeated until some stopping condition is not obtained.

1. Calculate the fitness of each particle
2. Update individual and positions and goble best fitnesses
3. Update position and velocity of each particle

First two steps are fairly unimportant [7].

The velocity & position of each particle in the swarm is updated using the following equation [8]:

$$\mathbf{v_i\,(t+1) = w\ v_i\,(t) + c_1\ r_1\ [x_i\,(t) - x_i\,(t)] + c_2\ r_2\ [g\ (t) - x_i\,(t)]}$$

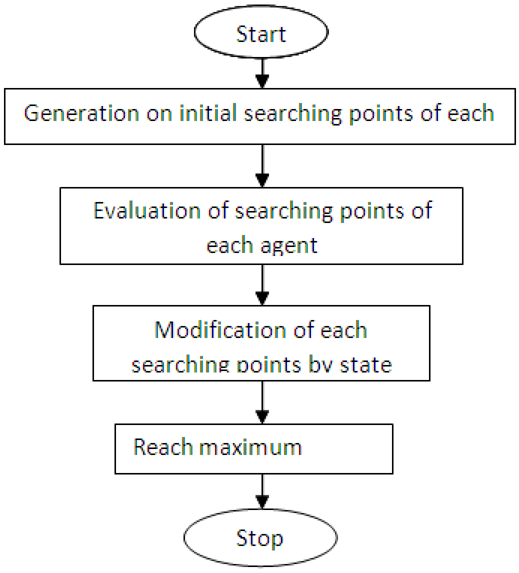


**Fig5: Flow Chart of particle swarm optimization**

## Iv. Fuzzy Logic Working

The working of the Fuzzy Logic controller can be divided into three parts namely; allocation of the area inputs, rules associated with the inputs & defuzzifying of the output.

### A. Allocation of the Area inputs

Here frequency deviation and error are the two inputs for the fuzzy logic controller. Both the frequency deviation and error were divided into three control areas based on magnitude and sign. These are Negative (N), zero (Z), Positive (P) .Here fig 6(a) & 6(b) represents the input functions for the fuzzy logic controller.

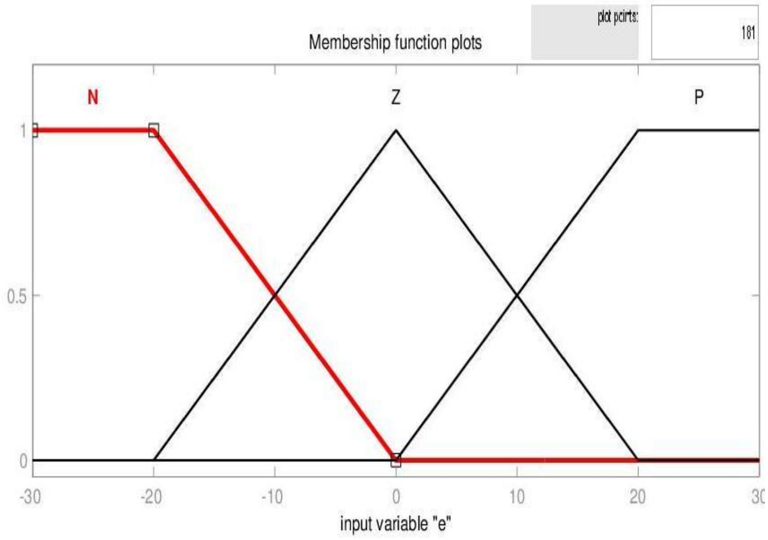


**Fig6 (a): Membership function plot for input 1**

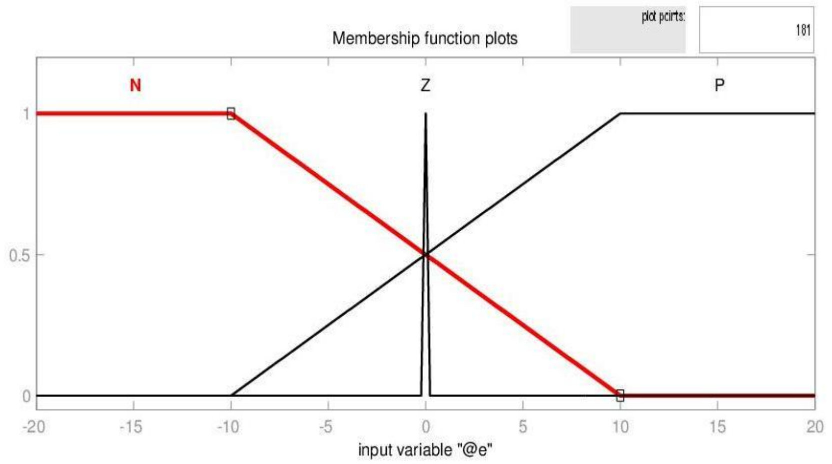


**Fig6 (b): Membership function plot for input 2**

**B. Rules Associated with Inputs**

The rules used for the fuzzy controller are described in the fuzzy rule table shown in Fig. 8. The mathematical formula applied is the “minmax” rule for “and’ and “or” respectively. This was to reduce the calculation complexity and time.

| S.No | INPUT 1 | INPUT 2 | OUTPUT |
|---|---|---|---|
| 1 | N | N | P |
| 2 | N | P | P |
| 3 | Z | N | Z |
| 4 | Z | P | Z |
| 5 | P | N | N |
| 6 | P | P | N |

**Fig7 (a): Rules Table**

Here: - N= Negative, P=Positive, Z=Zero

**C. Defuzzifying of the Output Value**

The output function of the fuzzy logic is shown in fig 8(b). Here we used 'centroid' method for defuzzification. In this method of defuzzification we use the centre of the two inputs.

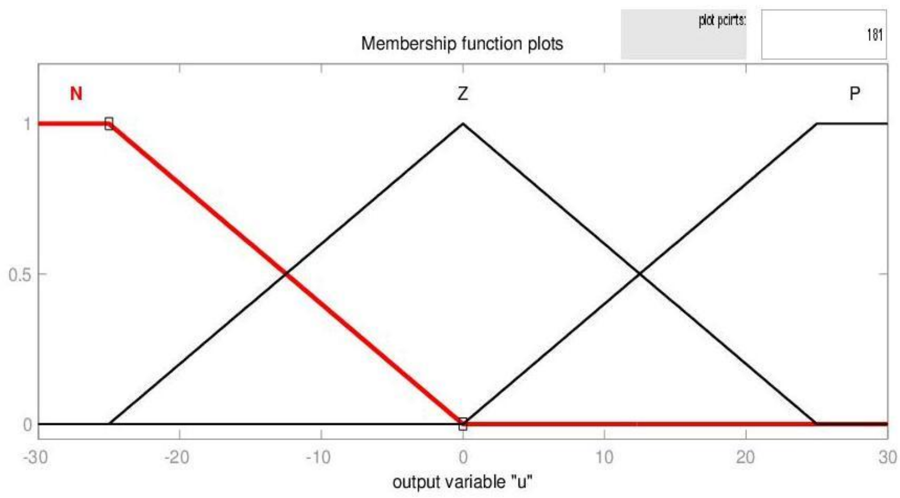


**Fig7 (b): Membership function plot for output**

## V. Simulation Results

Here we compare PSO-PID based system with PSO tuned Fuzzy PID based system

**A. Comparison between PSO-PID & PSO tuned Fuzzy PID system**
**PSO-PID based Test system:**

Firstly simulation is done on a two area power system. Control parameters of Fuzzy PID controller are tuned by using PSO technique. Result so obtained is shown below:

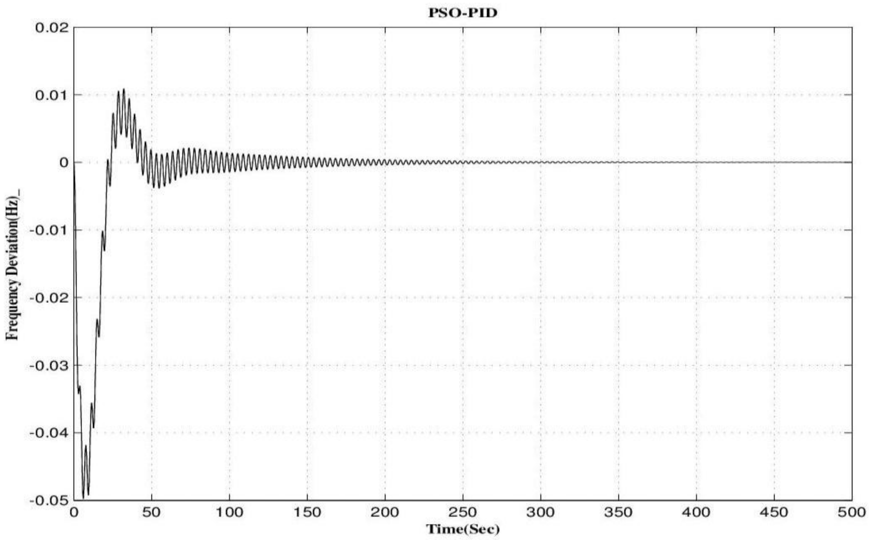


**Fig8: Transient response of PSO based PID controller for a two area unit**

**PSO tuned Fuzzy PID based Test system:**

Optimization was performed on a two area system with PSO tuned Fuzzy PID controller the simulation result is show below.

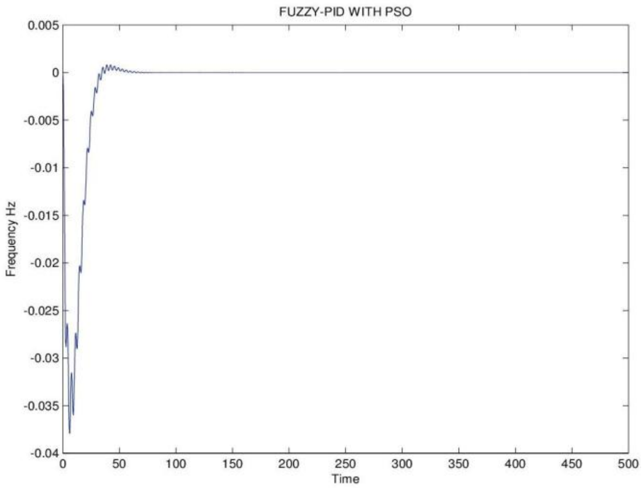


**Fig9: Transient response of a PSO tuned Fuzzy PID controller**

From the above two plots it can be seen that the PSO tuned Fuzzy PID controller has low value for error and a better settling time as compared to PSO PID controller.

**B. Comparison of Tie line power devotion in two area system:**
**PSO-PID based Test system:**

The Tie-line power deviation for PSO-PID Based test system has been shown below.

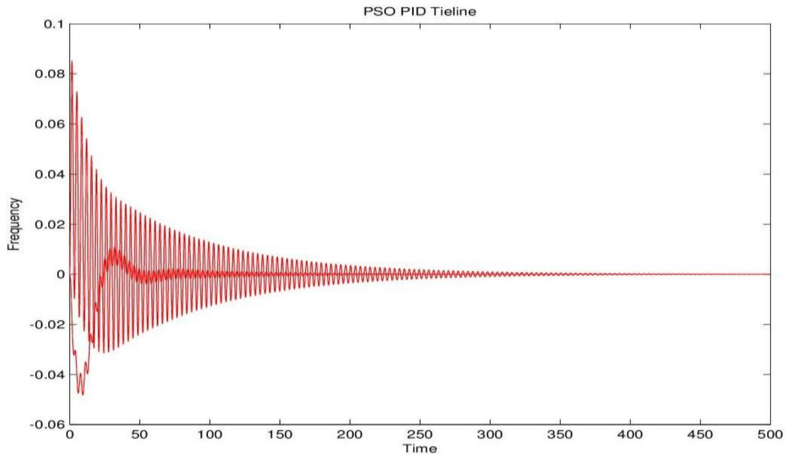


**Fig10: Tie line deviation response of a PSO based Test system**

**Fuzzy Logic Based Test system:**

Tie line deviation of a PSO tuned Fuzzy PID based test system is shown below:

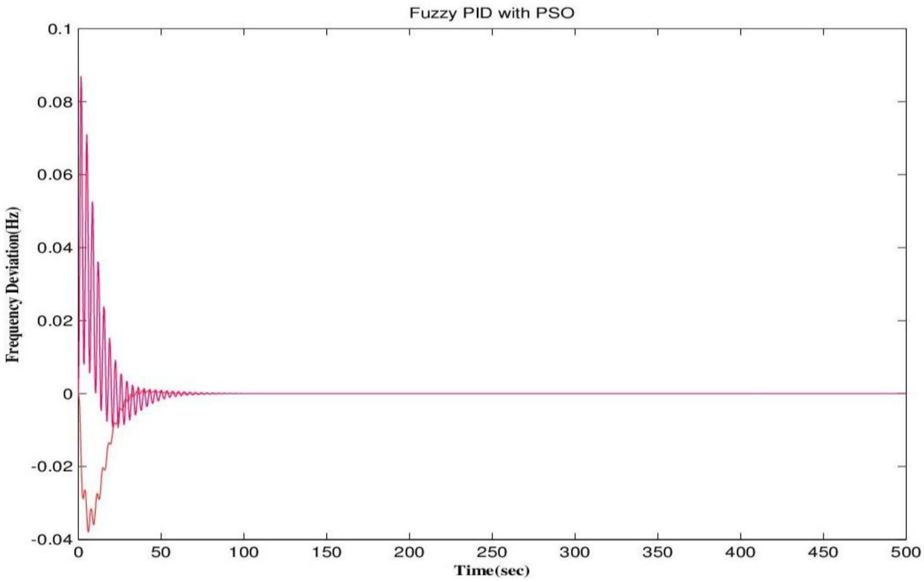


**Fig11: Tie-line deviation for a PSO tuned Fuzzy PID based test system**

From Fig 10 & 11 it can be seen that the settling time for the Tie line deviation for PSO tuned Fuzzy PID based test system is much better as compared to PSO-PID based test system.

## III. Conclusion

Significant conclusion of this paper is as follows:

(a)This paper presents design method for determining the Fuzzy PID controller parameters using the PSO Algorithm.

(b) A comparative study is made between PSO based PID controller and PSO tuned Fuzzy PID based PID controller. The results show that the proposed approach had superior features, including easy execution, stable convergence characteristic, and good computational efficiency. Fast tuning of optimum PID controller parameters yields high-quality solution.

(c) Compared with the PSO-PID, the proposed method was indeed more efficient and robust in improving the step response of an AGC system.

(d)PSO tuned Fuzzy PID based optimization technique have yielded good results.

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## Appendix

Table: The system data (capacity of each area is 1000MW)

| | |
|---|---|
| **Pr1=Pr2** | 1000 MW |
| **Kp1=Kp2** | 120Hz/Pu.MW |
| **R1=R2** | 2.4Hz/Pu.MW |
| **B1=B2** | 0.425 |
| **D1=D2** | 0.0083 |
| **Tp1=Tp2** | 20S |
| **T12** | 0.0707 |
| **Tg1=Tg2** | 0.2 |
| **$T_{T1}=T_{T2}$** | 0.3 |

| s.no | INPUT 1 | INPUT 2 | OUTPUT |
|---|---|---|---|
| 1 | N | N | P |
| 2 | N | P | P |
| 3 | Z | N | Z |
| 4 | Z | P | Z |
| 5 | P | N | N |
| 6 | P | P | N |

Here: - N= Negative, P=Positive, Z=Zero