Design and Application of PID-PID Dual Loop Controller for Load Frequency Control

Manjit Bahadur Singh, Manoj Kumar Debnath, Shreeram Choudhury, Sanjeeb Kumar kar

Abstract*: *Spider Monkey Optimization (SMO) tuned PID-PID dual loop controller is proposed for Load Frequency Control (LFC) for dual area power systems in this paper. Dual area based thermal (reheat type) system is employed and the gains of the PID-PID dual loop controller are tuned by SMO with 1% sudden load disturbance in control area 1. The dominance of the suggested PID-PID dual loop controller was compared with the previous journal outcomes like Artificial Bee Colony (ABC) Optimization based PID controllers for the same power system. Further, sensitivity analysis is carried out by intensifying the loading of the system by 5% which demonstrates the ability of the proposed approach to manage frequency oscillations.

Index Terms*: *Spider Monkey Optimization, PID-PID dual loop controller, Load Frequency Control, Optimal Controller.

I. INTRODUCTION

Power system is growing with complexity with growth demand for energy requirements. Expansion of power industry is uncontrollable. The biggest challenge is to bring the deviations of power parameters (voltage, frequency) to the limited value. Each Power system commits to supply the power with legitimacy and stability. The necessary conditions are to maintain the frequency and voltage profile [1]. Each control zone encounters some sort of unsettling influences because of multifaceted nature and uncertainty of load demand. When the demand changes the system, parameters deviate from prescribed limits. Hence the system state changes is assigned to detect changes and it is equipped with certain control techniques to minimize the deviations [2]. Synchronous generators are the mass power sources, are the most important means of system control. When there is a disturbance of reactive power demand, Voltage departs from the prescribed value. Balance Between net generation (PG-(PD+PL)) and resultant loads with losses is essential[3]. Zero error is always desired after getting a disturbance. In other words, zero steady state error is coveted. AGC of Alternator consists of two major loops called “Automatic Voltage Regulator”, and “Load frequency Control”. Immensity of load voltage is controlled by AVR. Similarly (A.L.F.C) loop control the frequency and active power.

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Voltage collapse occurs, if voltage departs excessively from the rated value. The intention of AGC is that, frequency aberrations as well as steady state error must be nullified. Area Control Error is a function of power differences and frequency deviations For accomplishing the power equilibrium in interconnected control region, ACE can be used as an effective means in LFC studies. The singular objective is to retain the power and frequency close to the nominal value. In ACE signal, frequency bias factor is taken into account which makes it a great tool for Automatic generation Control method [4].

Some approaches for AGC of inter connected power system network is anticipated by many scientist & researchers in the past eras. The primary effort on AGC was devised in paper [5].

In Paper [6], authors have used a P-Controller along with feedback action to AGC of a power framework. An intermittent nonlinear control technique [7] called VSC (variable-structure -controller) was realized to Automatic Generation Control in a multi-area power framework. New methods, for example, fuzzy logic[8] and ANN(Artificial neural network)is implemented for improving the performance of AGC controllers. Analysis with classical PID controller was studied in [9]. Sahu et.al has presented a controller named Two DOF-PID. ACE (Area Control Error) determines whether the Power generated is more than demand or vice versa. MPC is a method of computer control which uses a process model [10].

Squirrel search algorithm (SSA) is a recently progressed optimization method introduced by Mohit et.al [11]. This method emulates the food searching actions with its hovering elements with its competent movement recognized as gliding technique, which is basically utilized by the animals for food collection in a large area. A PD-Fuzzy-PID controller with PD controller in outer loop and PID controller in inner loop was employed in paper[12].The implemented SSA(Squirrel Search Algorithm) is applied to tune the parameters of PD-Fuzzy-PID series controller. AGC Problem was resolved by a combined stage fuzzy PID controller in a deregulated power framework dependent on the two sided approach conspire [13].A relative scrutiny of different fuzzy enabled Proportional, Proportional-Integral for different power converter along with the similitude between sliding mode converters and FLC was proposed [14].

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In paper [15] the scaling factor is adjusted by the controller itself i.e. self-tuning relative to derivative coefficient factor. The control prompt is a function of fuzzy knowledge base and inference. Fuzzy -PID controller was applied to a nuclear power plant and genetic algorithm was utilized

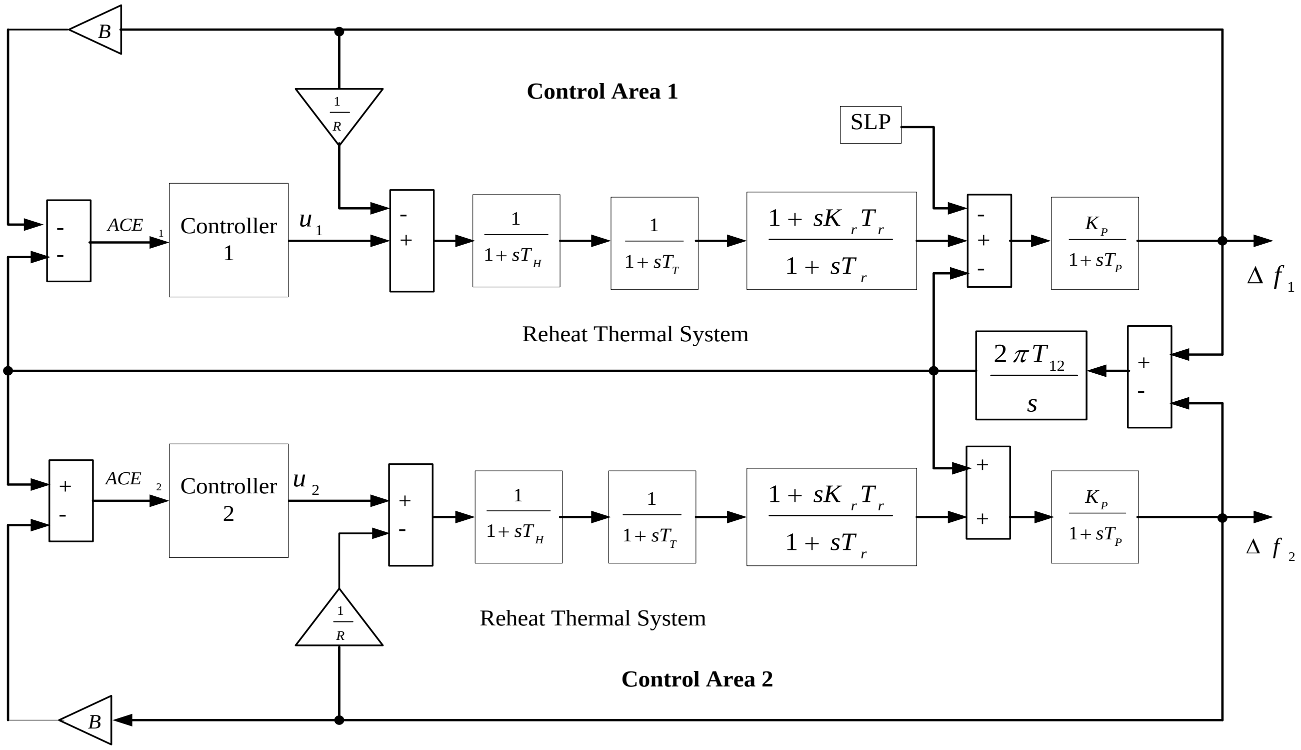

Fig.1. Dual area unified system with thermal generating units.

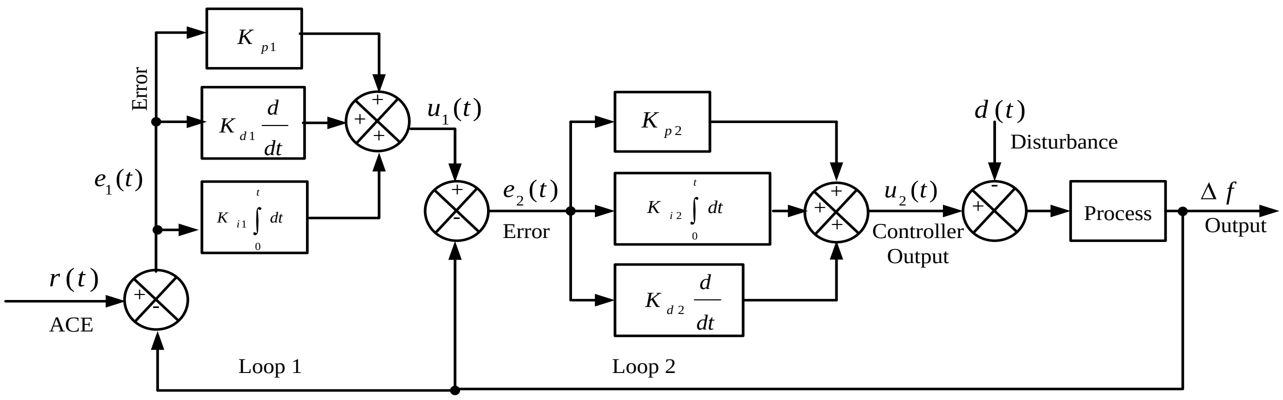

Fig.2. Framework of PID-PID dual loop controller.

to tune the gains of the controller [16].Similarly in paper [17] PSO method was utilized to obtain the solutions of LFC problem in a deregulated power framework. Article [18] has used Fire Fly Algorithm upgraded Fuzzy-PID for AGC of a multi generation control framework with ITAE criteria. Performance, accuracy of single input FLC was compared against the traditional FLC in [19].In [20] the author have used a bilinear transform to quantize the traditional controller.

Here we implemented the thermal power system (reheat type) for LFC using a very superior optimization technique called as Spider Monkey Optimization which is used to optimize the PID-PID dual loop controller.

II. SCRUTINIZED MODEL

Our framework is incorporated with thermal power plants equipped with two reheat type steam turbine which is presented in Fig.1. PID-PID dual loop controller is responsible to handle the deviations in nominal frequency. Parameters such as frequency biased constant ß, Regulation Constant R, time constants of the various units such as Hydraulic amplifier, steam turbine etc. are extracted from article [9]. Area control error (ACE) acts as an input signal to PID-PID dual loop controller. u1 and u2 are nominated to be the outputs of the controllers. ACE employs to accomplish the primary targets of AGC i.e. maintaining the tie-line power and frequency to their ostensible values. For the given framework the Area control Error Signal can be communicated as:

$$ACE1 = \Delta P_{12} + B_1 \Delta f_1 \quad \& \quad ACE2 = \Delta P_{21} + B_1 \Delta f_2 \qquad (1)$$

The parameters ΔP12, ΔP21 are called "line power differences". Whereas B1, B2

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are called frequency bias constants. Δf1 and Δf2 are frequency divergence in both areas. When a little disturbance are applied to the given system, ACE creates an activating error signal affirming that Δf and ΔP12 is made zero ideally. PID-PID dual loop controller specified gain parameters should be allocated properly to improve the time response of the proposed system.

III. RECOMMENDED METHOD

A.Design of Controller

We use PID-PID dual loop controller tuned by SMO, so as to decrease or reduce the Area Control Error. But using the individual controller won’t be a good decision because it has its own pros and cons and when they are combined they perform a little better. In addition to this, this paper recommends two PID controllers connected in cascade form to develop PID-PID dual loop controller. The framework of the projected PID-PID dual loop controller is depicted in Fig.2. PID-PID dual loop controller works in a very efficient way so as to give a desired output, here the inner loop regulates the input disturbances and then the outer loop regulates the final response. PID-PID dual loop controller doesn`t have any steady state error and also gives robustness from the variations occurring in the phase crossover frequency and high frequency noise. The only thing which makes PID-PID dual loop controller to be different than the PID is that it has two control loop that helps in managing smooth control action. A single PID-PID dual loop controller has six control factors as specified in Fig.2.

B. Spider monkey Optimization Algorithm

Dated back in 2014 Bansal introduced a nature stirred spider monkey optimization technique. Generally, spider monkeys inhabit in a pack of 40-50 individuals. A female leader named as the global leader helps other group members to find sufficient food for themselves. The group divided into local groups by global leader having 3-6 spider monkeys along with a female leader. During the daytime, all of them searched their food in altered directions. Lastly, they recombine and share their experiences and foods. Various stages of SMO has been briefly described below.

1. Initialization of population

At first, a population having dimension $[n \times d]$ have been initialized by following the below equation

$$M_{pq} = M_{\min q} + (M_{\max q} - M_{\min q}) \times U(0,1) \quad (2)$$

Above mentioned $n, d, M_{\min y}, M_{\max y}$ represents the size of the population, number of the control variable, upper and lower bounds in yth direction respectively.

2. Local leader level:

In this level, the location of each monkey is restructured with the help of the expertise local female leader and other experienced group members by using the equation (3).

$$M_{newpq} = M_{PQ} + (LL_{lq} - M_{pq}) \times U(0,1) + (M_{mq} - M_{pq}) \times U(-1,1)$$

(3)

In this pth local group, Xth and qth monkey try to update their location with a perturbation rate (pr) within a range of (-1,1).

3. Global leader level:

In this exploitation level, the location of all the members updated by the experiences of global leader and other local members by following equation (4).

$$M_{newpq} = M_{pq} + (GL_{pq} - M_{pq}) \times U(0,1) + (M_{lq} - M_{pq}) \times U(-1,1)$$

(4)

Based upon the probability factor (prb_x), the xth monkey update their locations.

$$prb_x = 0.1 + \left(\frac{fit_x}{\max\_ fit} \right) \times 0.9 \quad (5)$$

fit_x *and* $\max\_ fit$ are known as the fitness of xth monkey and maximum fitness of the pack respectively. The monkeys having better fitness have the more chance to update their locations.

4. The learning level of Local leader :

The location of the local leader is updated by following the location of the monkey having the best fitness value in that pack. In case the local female leader does not update her location, that local limit is increased by one.

5. The learning level of Global leader :

The location of the global leader is updated by comparing the old location of herself with the help of greedy selection. If not so, then the global limit is increased by one.

6. Decision-making level of Local leader :

In this stage, every member in the pack reinitialized by gathering information from the local and global leader by following equation (6)

$$M_{newpq} = M_{pq} + (GL_q - M_{pq}) \times U(0,1) + (M_{pq} - LL_{mq}) \times U(0,1)$$

(6)

In this phase, the monkey gets diverted from the local leader and get attracted towards the global leader.

7. Global leader decision phase:

If the location of global leader remains unchanged till the maximum limitation, then all the members recombined into one pack and again divided into small groups and so on.

IV. RESULT AND ANALYSIS

The PID-PID dual loop controllers which are optimized by using SMO algorithm contained in an organized structure is analyzed using the MATLAB Simulink software. All the controllers containing gains within them are simulated by considering the values within [0.01, 3.0] and the adjusted values of the controller are given below in the Table 1. In the algorithm of optimization

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the number of particles and the number of iterations are considered to be 100. The tuning of controller factors are carried out considering ITAE or integral time absolute error (eq.7) as evaluative function. The unified system, which is designed in Simulink was verified under the load disturbances of 1% in control area 1. When the system was put to certain load disturbances of around 0.1 p.u,

Table 1. The tuned values of controller gains obtained by SMO.

PID-PID Dual Loop Controller											
Control Area 1						Control Area 2					
K_{P1}	K_{I1}	K_{D1}	K_{P2}	K_{I2}	K_{D2}	K_{P1}	K_{I1}	K_{D1}	K_{P2}	K_{I2}	K_{D2}
2.998	0.01	2.974	2.896	2.718	0.010	2.989	2.76	1.243	1.272	2.905	0.010

PID Controller [9]					
K_P	K_I	K_D	K_P	K_I	K_D
1.966	9.5902	3.9320	0.710	0.6827	0.7419

the certain deviations in frequency of both the areas and also the tie-line power exchange are being represented in Fig. 3-5. The simulated outcome is compared to the outcome of published article [9]. The Table 2 contains the response indices for the proposed proposed method (PID-PID dual loop controller) and conventional method of published article [9] (PID controller). For all the response PID-PID dual loop controllers holds the superior indices as compared to PID controller [9].

$$ITAE = \int \left(|\Delta f_1| + |\Delta f_2| + |\Delta P_{tie}| \right) t.dt \qquad (7)$$

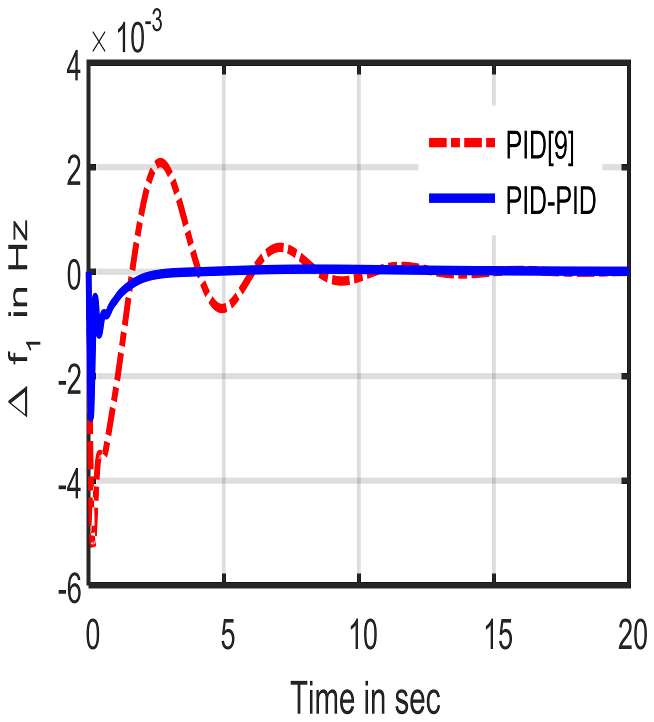

Fig.3. Frequency swinging in area 1.

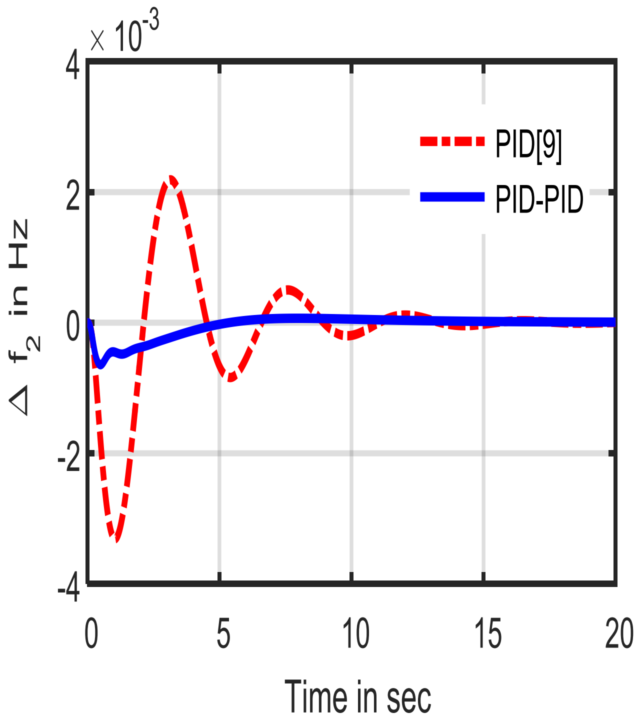

Fig.4. Frequency swinging in area 2.

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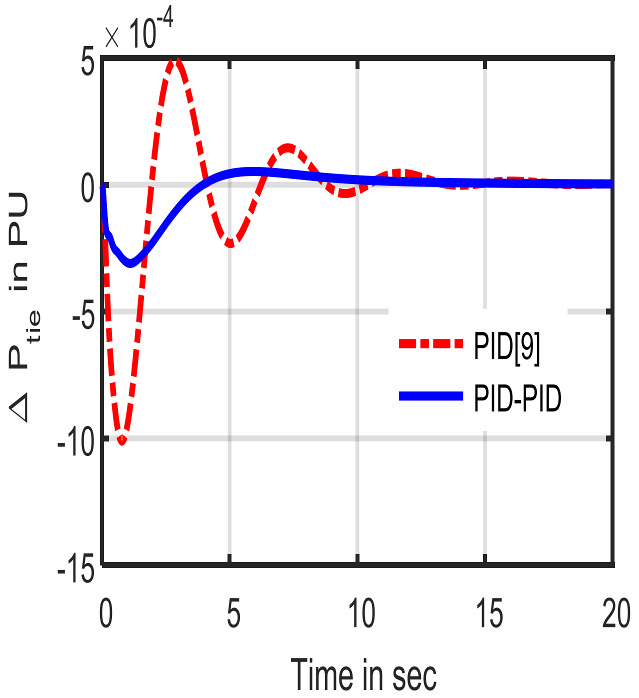

Fig.5. Tie-line power swinging.

Table 2. Response evaluative factors of different methods.

Deviances	Performance Indices	PID[9]	PID-PID
Δf_1	T_s in sec	5.4600	1.0500
	Undershoot	-0.0052	-0.0028
	$O_{sh} \times 10^{-3}$	2.100	0.0492
Δf_2	T_s in sec	7.6400	0.7600
	Undershoot	-0.0033	-0.0006
	$O_{sh} \times 10^{-3}$	2.200	0.0678
ΔP_{tie}	T_s in sec	1.4800	NIL
	Undershoot	-0.0010	-0.0003
	$O_{sh} \times 10^{-3}$	0.500	0.0522

In the later case, load in area 1 is amplified by 5% to verify the robustness of the proposed methodology. An abrupt loading of 0.06 p.u. in applied in control area 1 to investigate the system response with existing controller parameters. The deviations such as , and are depicted in Fig.6-8 respectively. From these figures it can be judged that PID-PID dual loop controller shows superior performance as compared to existing classical PID controller and proves its robustness.

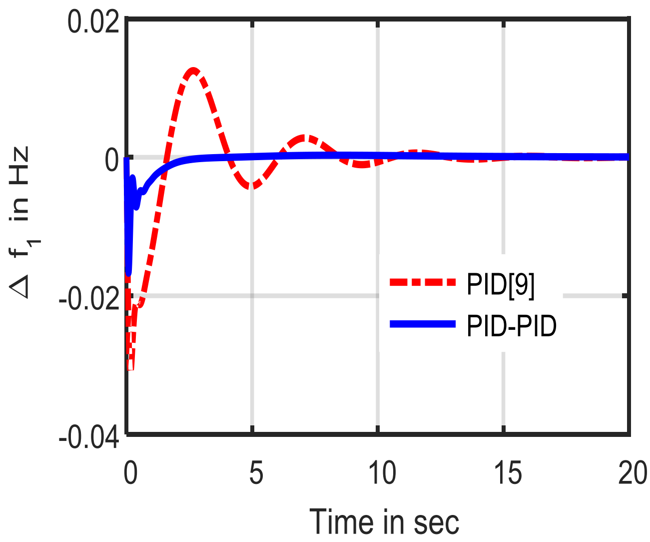

Fig.6. Frequency swinging in area 1 with load increment.

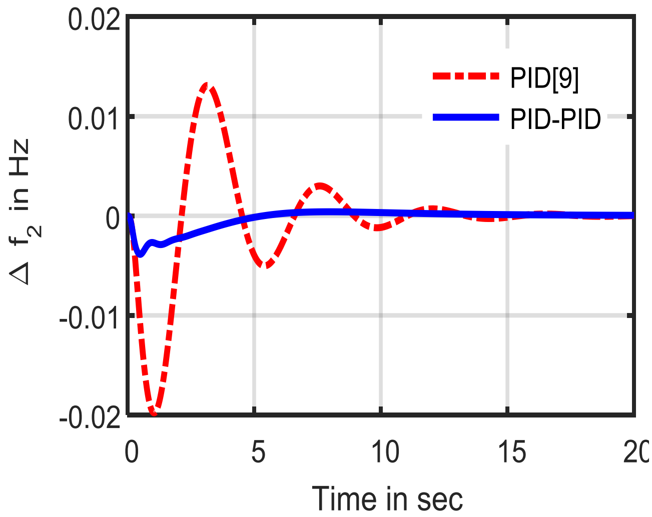

Fig.7. Frequency swinging in area 2 with load increment.

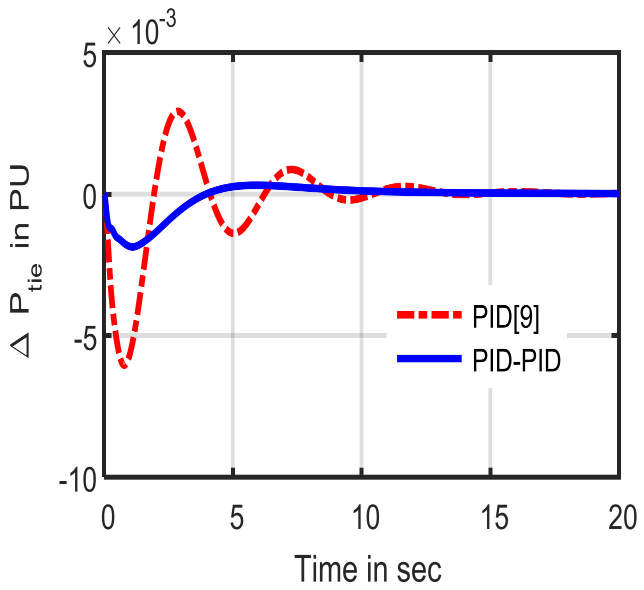

Fig.8. Tie-line power swinging with load increment.

V.CONCLUSION

When all the topics and

research work were analyzed time-to-time, it was found that, the spider monkey optimization technique tuned PID-PID dual loop controllers in comparison to conventional PID controller, regulates the oscillations in frequency and inter-line power in a faster manner. The research work is carried on by giving a load perturbation of about 1% in the area 1 for the dual area thermal system. All the results obtained are compared with the results of a published journal, to prove this project method's dominance over it. This research paper actually considered some of the conventional sources so as to generate power, and it is an assurance that it can be extended further to renewable type power generation even in the presence of multi-area interconnected system.

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