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Load Frequency Control of Two Area Interconnected Power System using Modified PID Controller

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***Abstract*:- In this paper, a load frequency control (LFC) of two equal area power system is considered. Initially, a non-reheat thermal system is considered in each area with modified proportional plus integral plus derivative (PID1) controller. In the next step, differential evolution algorithm is employed to tune the optimum gain of the PID1 controller. Then the superiority of the suggested approach is demonstrated by comparing the result with some recently published techniques such as Bacteria Foraging Optimization Algorithm (BFOA), Differential Evolution (DE) based PI controllers for the same interconnected power system. Investigations reveal on comparison that modified proportional integral derivative controller (PID1) provides much better response in terms of ITAE objective function, settling time, peak over shoot and peak under shoot as compared to proportional integral (PI) controllers.**

Keywords: Load frequency control (LFC), Two-area power system, Differential Evolution (DE) algorithm, proportional plus integral (PI), modified proportional plus integral plus derivative (PID1) controller.

1. INTRODUCTION:

An electric energy system must be maintained at a desired operating level characterized by nominal frequency and voltage profile and this is achieved by close control of real and reactive powers generated through the controllable source of the system. Therefore, the control issue in power systems can be decoupled into two independent problems. One is about the active power and reactive power and voltage control [1]. The active power and frequency control is referred to as LFC. A large frequency deviation can damage equipment, degrade load performance, cause the transmission lines to be over loaded and can impede with system protection schemes, ultimately leading to an unstable condition for power system [2]. Thus, the primary job of LFC is to maintain the frequency constant against the arbitrarily varying active power loads, which also referred to unknown external disturbance. Another job of the LFC is to regulate the tie-line power exchange error. A typical large-scale power system is composed of several areas of generating units. To reduce the cost of electricity and to improve reliability of power supply, these generating units are connected via tie lines [1]. The usage of tie-line power imports a new error into the control problem, i.e. tie-line power exchange error. When a sudden active power load exchange occurs to an area, the area will obtain energy via tie-lines from other areas. But eventually, the area that is subject to the load change should balance it without external supports; otherwise there would be economic conflicts between the areas. Hence, each area requires a separate load frequency controller to regulate the tie-line power exchange error so that all the areas in an interconnected power system can set their set-point differently [3]. In [4] Ali and abd-Elazim employed a BFOA to optimize the PI controller parameters and shown its superiority over GA in a two-area non-reheat thermal system. In [5] a modified objective function using integral of time multiplied by absolute value of error(ITAE), damping ratio of dominant eigen values and settling time was proposed, where the PI controller parameters are optimized employed differential evolution (DE) algorithm and the results were compared with the BFOA- and GA- optimized ITAE- based PI controller to show its superiority. In [6] author were employed modified classical controller structure such as structure 1 and 2 of PID controller (PID1) and structure 2(PID2) were applied and their performances were evaluated in automatic generation control (AGC) system. In [7] Saroj et al. had demonstrated the superiority of Firefly Algorithm tuned PI/PID controller of two area interconnected power system for AGC.

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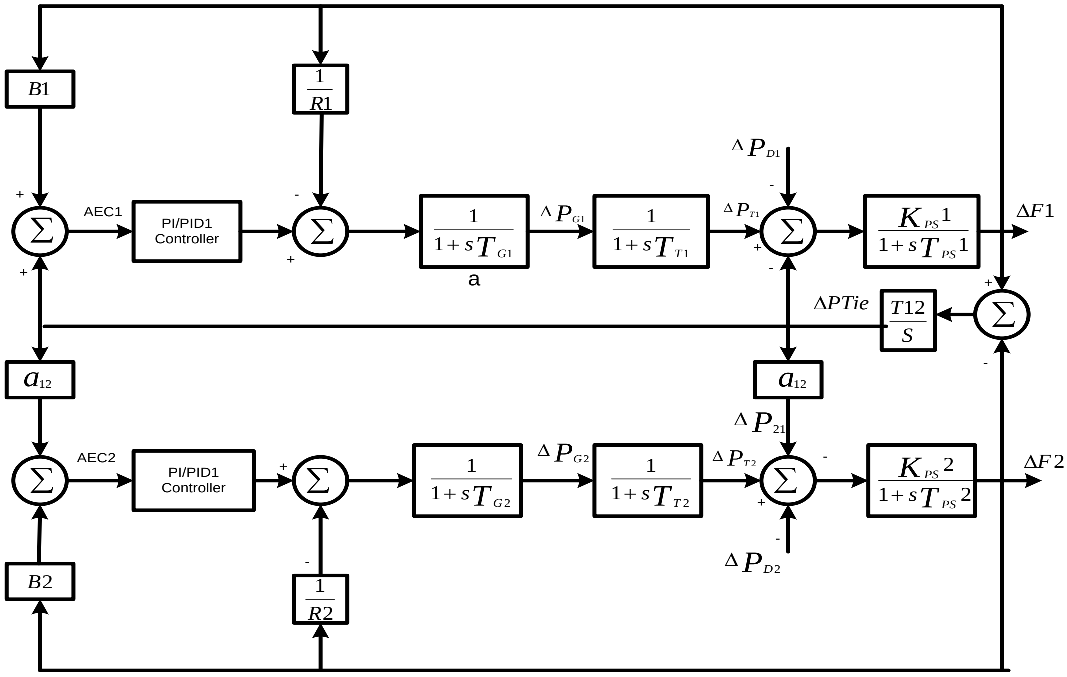


(Fig.1. Block diagram of two area non-reheat thermal power system)

2. POWER SYSTEM MODEL

2.1. LFC model

The Load Frequency Control (LFC) for two-area interconnected non-reheat thermal power system is shown in Figure 1. Each area has two outputs and three inputs. The inputs are the controller input ΔP_{ref}, tie-line power error ΔP_{Tie} and load disturbance ΔP_D .The outputs are the generator frequency Δf and area control error (ACE) given by Eq. (1).

$$AEC = B\,\Delta f + \Delta P_{Tie} \qquad (1)$$

Where B represents the frequency bias parameter.
To simplicity of the frequency-domain analysis, transfer functions are used to model each component of the area. Turbine is represented by the transfer function [2]:

$$G_s(s) = \frac{\Delta P_T(s)}{\Delta P_V(s)} = \frac{1}{1+sT_T} \qquad (2)$$

From [2], the transfer function of a governor is:

$$G_G(s) = \frac{\Delta P_V(s)}{\Delta P_G(s)} = \frac{1}{1+sT_G} \qquad (3)$$

The speed governing system has two inputs ΔP_{ref} and Δf with one output $\Delta P_G(s)$ given by [4]

$$\Delta P_G(s) = \Delta P_{ref}(s) - \frac{1}{R}\Delta f(s) \qquad (4)$$

The generator and load is represented by the transfer function [5]

$$G_p(S) = \frac{kps}{1+sTps} \qquad (5)$$

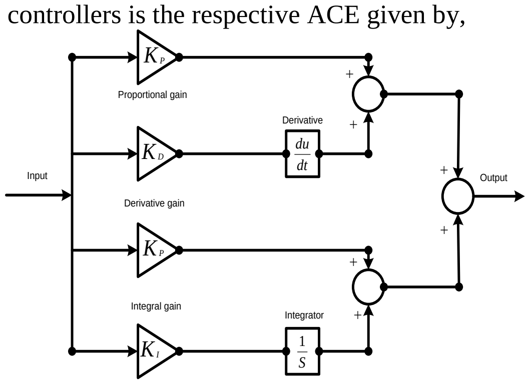
Where, Kps=$\frac{1}{D}$ and Tps = $\frac{2H}{fD}$

The generation load system has two inputs $\Delta P_T(s)$ and $\Delta P_D(s)$ with one output $\Delta f(s)$ given by

$$\Delta F(s) = Gp(s)[\Delta P_T(s) - \Delta P_D(s)] \quad (6)$$

2.2. Controller Structure and Objective Function

To control the frequency PI/PID1 controller are provided in each area. The structure of the PID1 controller is show in figure2 where K_{P1}, K_{P2}, K_{I1}, K_{D1} are the proportional, integral &derivative gains respectively. The error input to the controllers is the respective ACE given by,



(Fig.2. Block diagram of PID1 controller structure)

$$e_1(t) = AEC_1 = B_1\Delta f_1 + \Delta P_{Tie} \qquad (7)$$

$$e_2(t) = AEC_2 = B_2\Delta f_2 - \Delta P_{Tie} \qquad (8)$$

In this paper ITAE is used as objective function to properly design the proposed PI/PD1 controller. The expression for Integral Time Absolute Error (ITAE) objective function is given in equation (9):

$$J = ITAE = \int_0^{t_{sim}} (|\Delta F_m| + |\Delta P_{Tie-m-n}|).t.dt \quad (9)$$

In the above equations, $\Delta F_m$is the incremental change in frequency of area m, $\Delta P_{Tie-m-n}$ is the incremental change in the tie line power connecting between area m and n, and t_{sim} is the time range simulation.
Therefore, the design problem can be formulated as the following optimization problem.

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Minimize J (10)

Subject to

$$K_{p1min} \leq K_{p1} \leq K_{p1max},\ K_{Imin} \leq K_I \leq K_{Imax},\ K_{Dmin} \leq K_D \leq K_{Dmax}, \quad (11)$$
$$K_{p2min} \leq K_{p2} \leq K_{p2max}$$

The minimum and maximum values of PID controller parameters are chosen as -2.0 and 2.0 respectively.

3. SIMULATION RESULT AND DISCUSSION

The load frequency control (LFC) for two-area interconnected non-reheat thermal power system is shown in fig-1. Each area has two output and three inputs the inputs are the controller input ΔP_{refs} tieline power error ΔP_{tie} and load disturbance ΔP_D the output are the generated frequency Δf. The controller parameter values are shown in table 1.

Table 1: PI/PID1 Controller Parameter

Parameter	BFOA:PI [4]	DE:PI [5]	DE:PID1
KP_1	-0.4207	-0.2146	1.5632
KI	0.2795	0.4335	1.9170
KD	-	-	1.0684
KP_2	-	-	1.5632

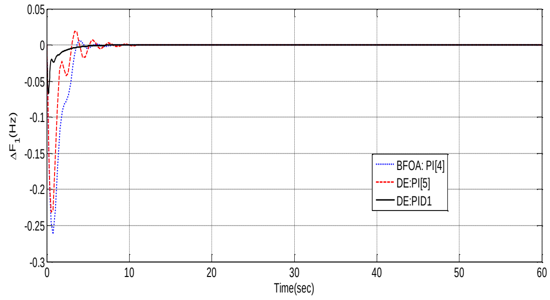
A 10% step increase in load demand is applied in area-1 at t=0 sec and the system performance with the PI/PID1 controller is shown in table 2. It is clear from table 2 that better system performance in terms of settling time in frequency and tie line power deviation with error is achieved with DE PID1 controller compare to Bacteria Foraging Optimization Algorithm PI [4] and Differential Evolution PI [5] approaches as mentioned in table 2.

Table 2: Comparative performance values for 10% step load charge in area-1

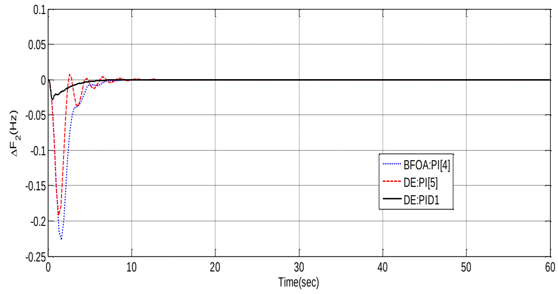
Techniques/ parameters	Settling times(2% band)Ts			ITAE
	ΔF_1	ΔF_2	ΔP_{tie}	
BFOA:PI[4]	5.52	7.09	6.35	1.7975
DE:PI[5]	8.96	8.16	5.75	0.9911
DE:PID1	**0.60**	**0.53**	**0.51**	**0.2817**

Case I: step load change in area-1

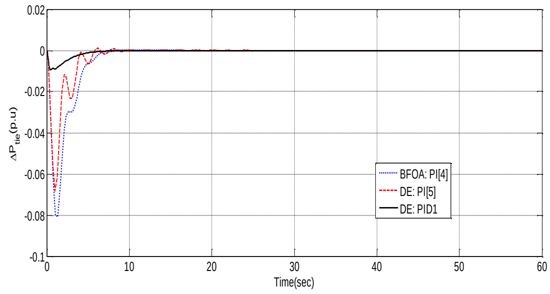
Initially, a step increase in load of 10% in area -1 is considered and system dynamic response i.e. the deviation in frequency of the area-1, area-2 and deviation in tie-line power are shown in figures 3-5. It is clear from figures 3-5 that stability is improved and frequency error, tie-line power deviation and settling time get reduced.



(Fig.3. Change in frequency of area-1 for 10% SLP in area-1)



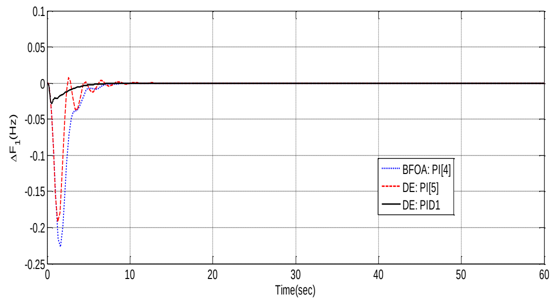
(Fig.4. Change in frequency of area-2 for 10% SLP in area-1)



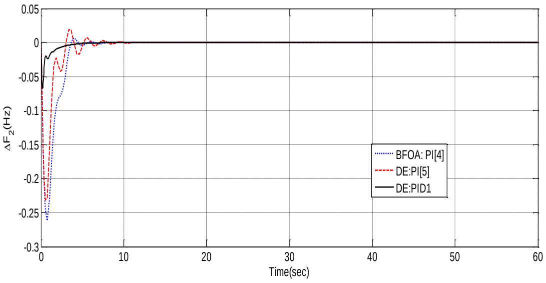
(Fig.5. Change in tie-line power for 10% SLP in area-1)

Case II: Step load change in area-2

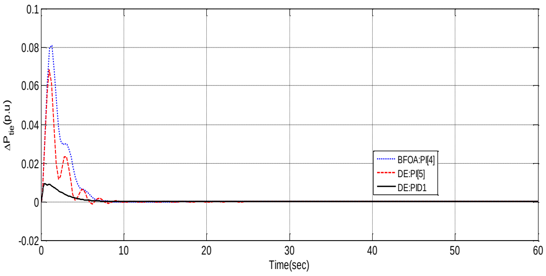
In this case, a step increase in load of 10% in area 2 is considered and the system dynamic response i.e. the deviation in frequency of area-1, area-2 and deviation in tie-line power are shown in figures 6-8. From these figures it can be seen that the maximum under shoot, over shoot are also reduced which improves the stability of the power system.



(Fig.6.Change in frequency of area-1 for 10% SLP in area-2)



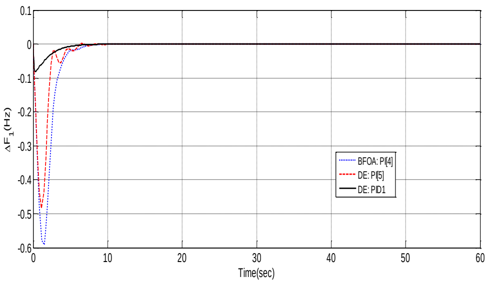
(Fig.7.Change in frequency of area-2 for 10% SLP in area-2)



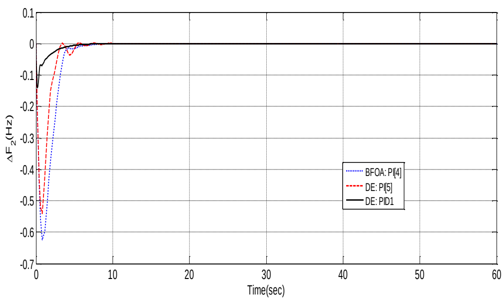
(Fig.8. Change in tie-line power for 10% SLP in area-2)

Case III: Simultaneously step load change of 10% in area-1 and 20% in area-2.

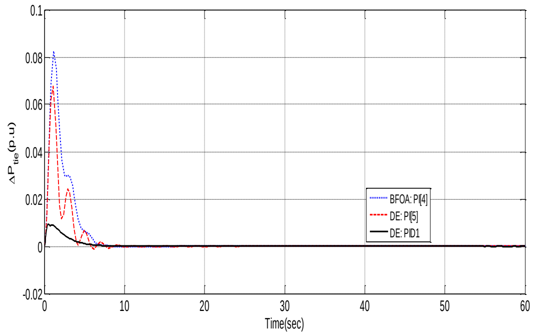
In this case step increase in load of 10% in area-1 and 20% in area-2 simultaneously are considered and system dynamic responses are shown in figure 9-11 that the best dynamic performance is achieved by Differential Evolution tuned PID1 controller compare to the Bacteria foraging optimization algorithm tuned PI and Differential Evolution tuned PI for the similar two area power system.



(Fig.9.Change in frequency of area-1 for 10% SLP in area-1 and 20% SLP in area-2)



(Fig.10. Change in frequency of area-2 for 10% SLP in area-1 and 20% SLP in area-2)



(Fig.11.Change in tie-line power for 10% SLP in area-1 and 20% SLP inarea-2)

CONCLUSION

In this work an attempt has been taken to apply Differential Evolution based modified proportional Integral Derivative controller (PID1) for load frequency control of two area interconnected power system. Simulation result show that better system performances in terms of ITAE objective function minimum setting time in frequency and tie line power deviations is achieved with Differential Evolution optimized modified proportional integral derivative controller (DE PID1) compare to Bacteria foraging optimization algorithm optimized proportional integral controller (BFOA PI) and
Differential Evolution optimized Proportional Integral Controller (DE PI). This concludes that DE PID1 outperform BFOA PI and DE PI.

APPENDIX

Nominal parameters of the two area system investigated are [4]
B1=0.425;B2=0.425;R1=2.4;R2=2.4;Tg1=0.08;Tg2=0.08; Tt1=0.3;Tt2=0.3;
Kps1=120;Kps2=120;Tps1=20;Tps2=20;T12=0.545;a12=-1;

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