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Comparative Study of Load Frequency Control for Interconnected Three Area Power System Using PID and FOPID Controller

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Abstract:- This paper examines the Fractional order PID (FOPID)controller of Automatic Load Frequency Control (ALFC) for three area interrelated power system is designed and analyzed with two steam turbines and one hydro turbine. In any area of the interconnected power system if there is alteration in load demand, it will affect the performance of the system. The frequency and tie-line power also deviate. In order to lessen the frequency and tie-line power deviation, system should be provided by introducing traditional controllers such as I, PI, PID and Artificial Intelligence technique like Artificial Neural Network (ANN). Non-linearities present in the power system components and its behavior, these controllers cannot decrease the oscillations in frequency deviation, tie-line power deviation and also does not provide extra two-degree freedom. The Fractional order PID controller can alleviate this difficulty. FOPID is fast upcoming modified conventional controller used for the designing of controllers. FOPID is tuned by Imperialist Competitive Algorithm (ICA) and the algorithm is flexible to adjust according to the system conditions. To verify the performance of FOPID controller, three area power system is tested with disturbances in load demand and it is run in MATLAB R2014b software. The obtained waveform of frequency deviation and tie line power interchanges are less oscillatory and reduced settling time compare to other converters. Furthermore, the proposed controller can be verified using real-time simulator to test the adaptability.

Keywords:- *Load Frequency Control, Fractional Order PID Controller, Frequency Deviation, Interconnected Power System.*

I. INTRODUCTION

Generating station, Transmission system, Distribution system and loads are connected called power system. Generations are located at few selected areas depends upon the available resources. Due to load demand changes the real and reactive electrical power demands differ uninterruptedly. Changes in real power disturbs mainly the system frequency, while reactive power is less penetrating to changes in frequency and is mainly dependent on changes in voltage magnitude. The real and reactive powers are maintained distinctly. The important restraint on an interconnected power system is to hold the variation in the system frequency and the terminal voltage kept constant. In an interconnected power system, as load changes arbitrarily, both frequency and tie-line power interchange also change. The Load Frequency Control (LFC) is a very vital problem in power system performance and operation.

The LFC has increased position with the development of interconnected systems and finished the operation of interconnected power systems possible [1].

The problem of frequency deviation and tie line power deviation is solved using conventional and intelligence techniques [2]. The power system components are modelled by transfer function model. It is used for analysis of the system. Now a days, the research is mainly focusing on conventional controllers like FOPID. These controllers helped in reducing the steady state error of the responses and also helps to maintain the tie line deviation within certain limit [3].

In the study, the Fractional Order PID (FOPID) controller is presented to achieve better dynamic performance of the interconnected three area power system.

II. MODELING OF POWER SYSTEM

A. Three Area Interconnected Power System

In an interconnected three area power system, all the generators are closely tied and synchronously connected to each other. The generator turbines be inclined to have the identical stable operation. Such a collection of synchronous generators is supposed to be comprehensible. This is denoted as control area. Two or more areas are usually interconnected using transmission lines called “tie lines” which permit the flow of active power from one area to another area.

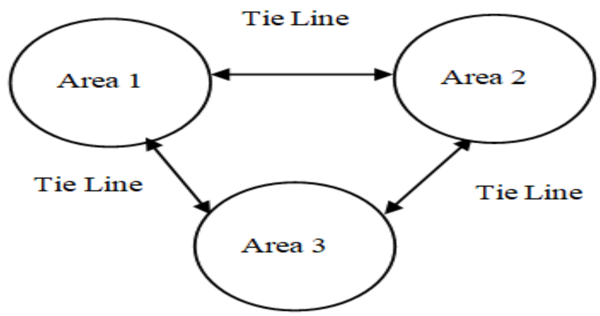

Fig 1:- Typical diagram of interconnected Power System

A simplified three area interconnected power system as shown in Fig. 1. Area 1 and Area 2 are thermal system and Area 3 is a hydro system. Table I shows that the parameters of interconnected three area power systems.

THERMAL UNIT (Area 1)	THERMAL UNIT (Area 2)	HYDRO UNIT (Area 3)
M1(p.u.s) : 10	M2(p.u.s) : 10	M3(p.u.s) : 6
D1 (p.u./Hz) : 1	D2 (p.u./Hz) : 1	D3 (p.u./Hz) : 1
Tch1(s) : 0.3	Tch2(s) : 0.3	Tg3(s) : 0.2
Tg1(s) : 0.1	Fhp : 0.3	Tr(s) : 5
R1(Hz/p.u) : 0.05	Trh(s) : 7	Rt(Hz/p.u) : 0.38
B1(p.u./Hz) : 21	Tg2(s) : 0.2	R3(Hz/p.u) : 0.05
T1(p.u./rad) : 22.6	R2(Hz/p.u) : 0.05	B3(p.u./Hz) : 21
	B2(p.u./Hz) : 21	Tw(s) : 1
	T2(p.u./rad) : 22.6	T3(p.u./rad) : 22.6
Area capacity : 1000 MW	Area capacity: 1000 MW	Area capacity : 1000MW

Table 1:- System Explanation

B. Models of power system

A Power System Model contains the governor, turbine, rotating inertia mass.

1) Thermal Power Unit

A steam turbine changes the energy that is kept in the form of high pressure and high temperature steam into rotating energy, that energy is again converted into electrical energy. Steam turbine may be either reheat type or non-reheat type [4].

Transfer Function for Non-Reheat Turbine:

$$\frac{1}{1+sT_{ch1}}$$

Transfer Function for Reheat Turbine:

$$\frac{1+sT_{rh}F_{hp}}{1+s(T_{ch2}+T_{rh)}+T_{ch2}T_{rh}s^2}$$

2) Hydro Power Unit

A Hydraulic turbine translates the energy of flowing water into kinetic energy then into potential energy of water, then it is changed into electrical energy by connecting turbine into the generators. The governor of Hydraulic turbine units need shugemomentary droop compensation for stable speed control operation.

Transfer Function of Hydraulic Unit:

$$\frac{1-T_w s}{1+0.5T_w s}$$

Transfer Function of Transient droop compensation:

$$\frac{1+T_r s}{1+\frac{T_r R_t}{R_3}s}$$

Symbol	Quantity	Units
T_{ch}	Non-reheat turbine time constant	S
T_{rh} F_{hp}	Low pressure reheat time constant High pressure stage	S
T_w	Water starting time	S
R_r	Temporary droop	Hz/p.u
T_r	Reset time of hydraulic unit	S

Table 2:- Nomenclature

III. CONTROL METHODOLOGY

A. Integral controller

An integral controller is usually intended fordropping the steady state error of the power system.

$ACE_1 = \Delta P_{tie1} + B_1 \Delta f_1$ (1)
$ACE_2 = \Delta P_{tie2} + B_2 \Delta f_2$(2)
$ACE_3 = \Delta P_{tie3} + B_3 \Delta f_3$ (3)
In this paper, the frequencydeviation is represented as area control error (ACE) and is given above [5],
The speed changer ΔP_{e1} $\Delta P_{e2}$and ΔP_{e3} can be repressed as

$\Delta P_{e1} = -K_{I1} \int (ACE_1)\, dt$ (4)
$\Delta P_{e2} = -K_{I2} \int (ACE_2)\, dt$ (5)
$\Delta P_{e3} = -K_{I3} \int (ACE_3)\, dt$ (6)

The constants K_{I1},$K_{I2}$and K_{I3} are integral gain values. The negative sign in the above equation (4), (5) and (6) specifies the synchronous generator in all the areas should increase the generation level either the change in frequency and tie-line power become negative value. For designing the Integral controller, the gain values are K_{I1} = K_{I2} =K_{I3}= -0.9 for simulation study, integral gain values for all three areas are same value.

B. PID Controller

Proportional Integral Derivative control lerused to solve the dynamic problems associated with the frequency responses and also used for getting better performance and operation of the three-area interconnected power system.

Controllers parameters	Kp	Ki	Kd	λ	μ
Area 1	0.4130	-0.8284	0.3298	1	1
Area 2	-0.0463	-0.2745	-0.1973	1	1
Area 3	-1	-1	0.9862	1	1

Table 3

To maintain the dynamic operation of interconnected power system, PID tuning is made, whose values for three area interconnected power system are shown in Table III.

C. FOPID Controller

Fractional order calculus is the part where mathematicians deal with derivatives and integrals in the form of fractional orders. Gamma function is basically the simplification of factorial for all real numbers. The definitions of gamma function are expressed by [7]

$$\Gamma(z) = \int_0^{\infty} t^{z-1} e^{-t} dt$$

Fractional Order PID Controller have been used recently by numerous electrical utilities and also used for reducing oscillations of change in frequency deviation, change in tie-line power in the three-area power system. Fig 4 shows the flowchart for fine tuning the constraints of FOPID controller.

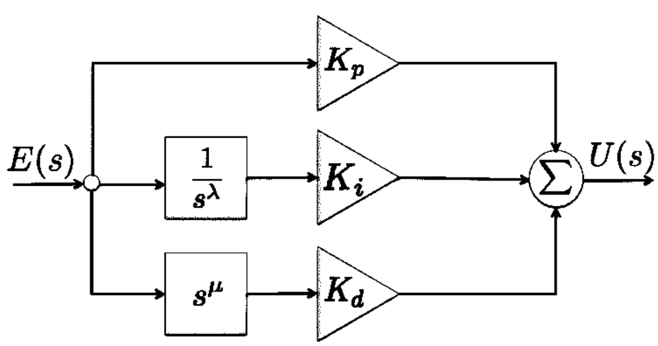

Fig 2:- Block Diagram of FOPID Controller

Controllers parameters	Kp	Ki	Kd	λ	μ
Area-1	0.6700	-0.4006	-0.9910	1	0.654
Area -2	-0.3266	-0.2946	-1	1	0.865
Area -3	-0.984	-1	-0.4888	0.676	0.568

Table 4

For getting better dynamic responses of the multi area interconnected power system proper tuning of proposed FOPID controller is made and the corresponding values of the controller are revealed in table IV. Simulink block of three area interconnected power system with Integral, PID, FOPID is shown in Fig.4.

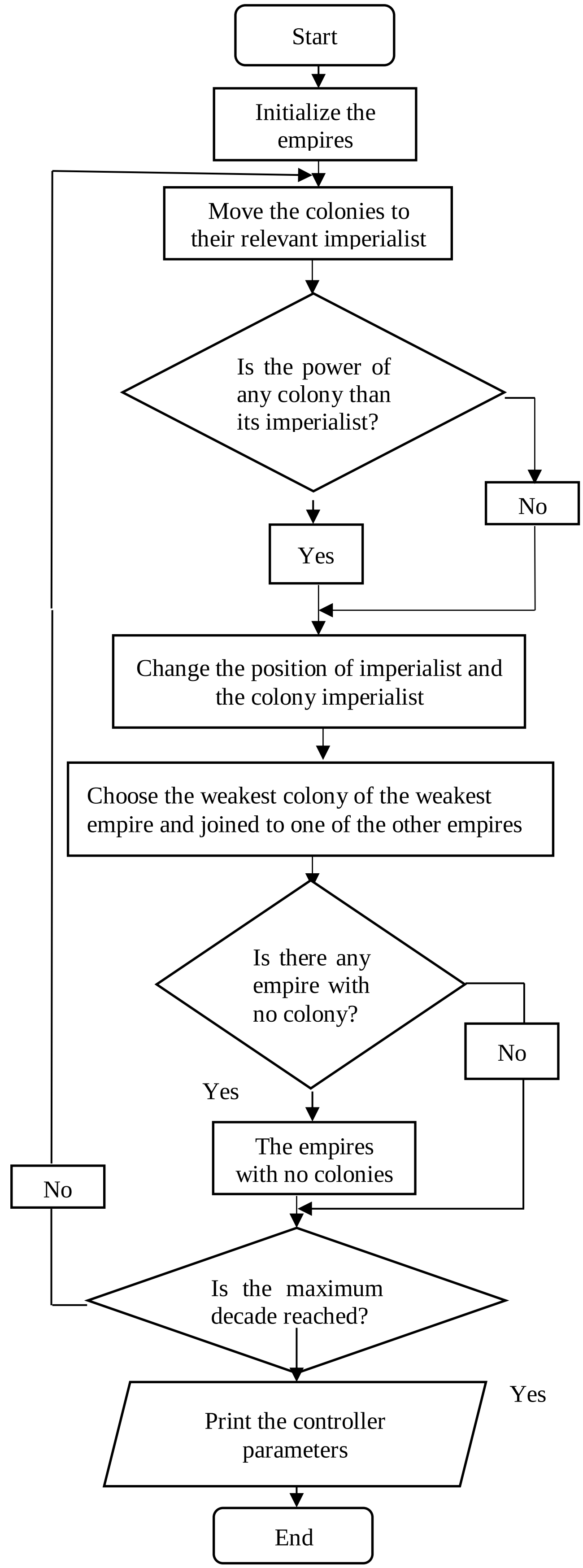

Fig 3:- Flow chart of FOPID Controller

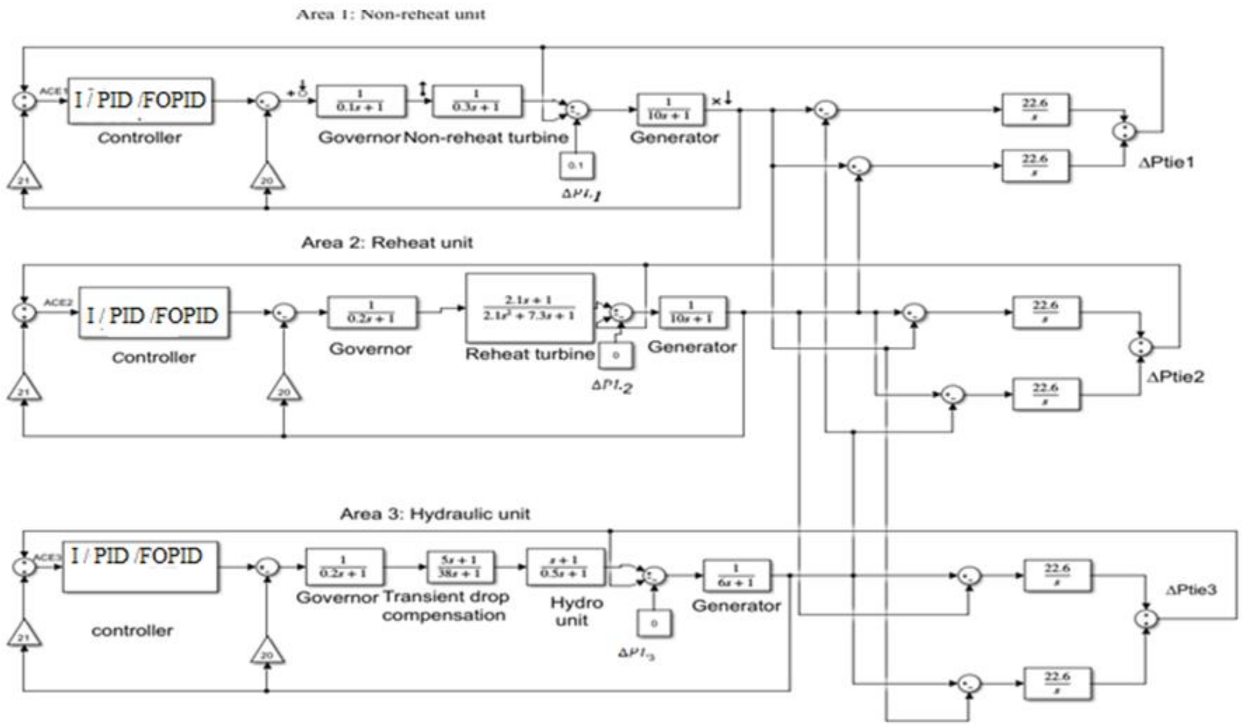

Fig 4:- Simulink Block diagram of interconnected power system

IV. SIMULATION RESULT AND DISCUSSION

Condition I: In this condition, there is a small increase in the load demand of area-1 (ΔPD1) is applied. Area 2 and Area 3 are under unchanged. Fig 5 shows that the variation in system frequency of area 1. The simulation evidence that the presented FOPID controller improves the operation of multi area interconnected power system by reducing the steady state error and oscillations present in the responses. Table V displays the evaluation of settling time for the change in frequency of all areas for 0.1 p.u change in load demand of area-1 with different controller. The settling time and peek overshoot is reduced for the interconnected three area power system with FOPID controller than the PID controller.

Condition II: In this condition, there is a small increase in the load demand of area-2 (ΔPD2) is applied. Area 1 and Area 3 are under unchanged condition. Fig 6 shows that the variation in system frequency of area 2. The simulation proved that the presented FOPID controller improves the operation of multi area interconnected power system by reducing the steady state error and oscillations present in the responses. Table V displays the evaluation of settling time for the change in frequency of all areas, for 0.1 p.u change in load demand of area-2 with different controllers. The settling time and peak overshoot is reduced for the interconnected three area power system with FOPID controller than the PID controller.

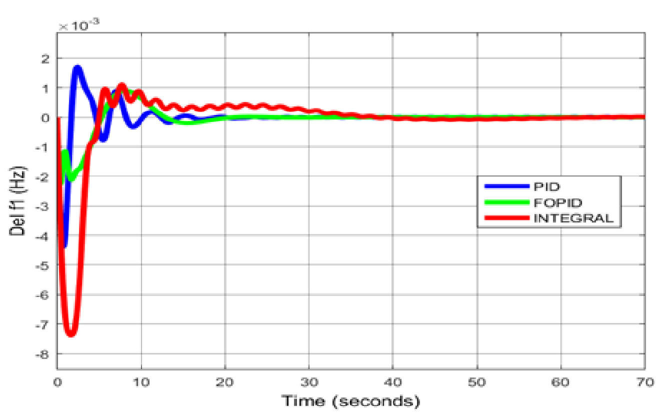

Fig 5:- Frequency deviation in area-1using Integral, PID and FOPID controller

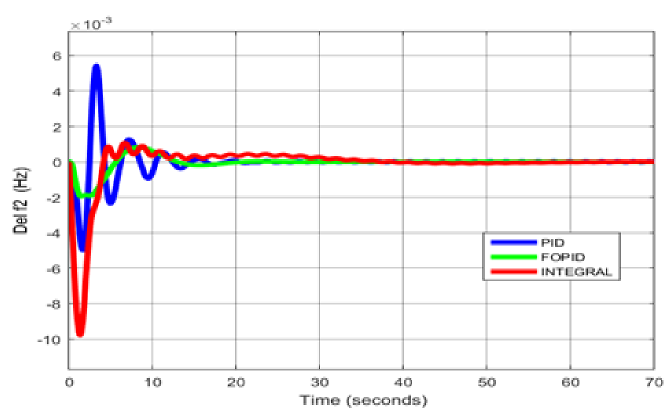

Fig 6:- Frequency variation in area-2 using Integral, PID and FOPID controller

Condition III: In this condition, there is small increases in the load demand of area-3 (ΔP_{D3}) is applied. Area 1 and Area 2 are under unchanged condition. Fig 7 shows that the variation in frequency of area 3. The simulation proved that the presented FOPID controller improves the operation of multi area interconnected power system by reducing the steady state error and oscillations present in the responses. Table V displays the evaluation of settling time for the change in frequency of all area, for 0.1 p.u change in load demand of area-3 with different controllers. The settling time and peek overshoot is reduced for the interconnected three area power system with FOPID controller than the PID controller.

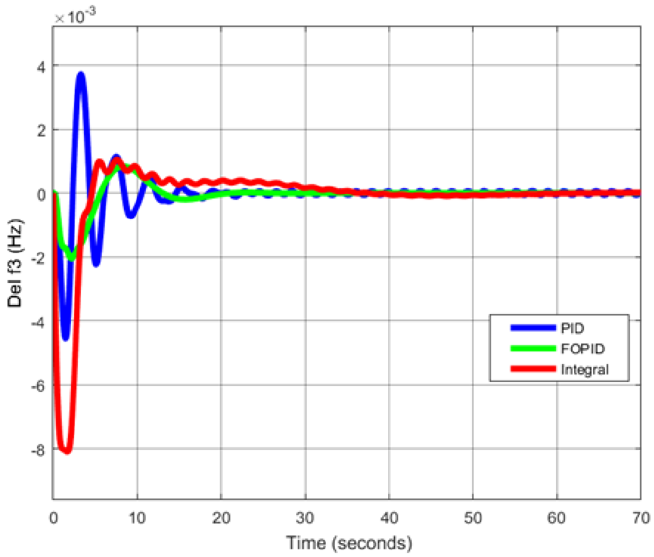

Fig 7:- Frequency variation in area-3using Integral, PID and FOPID controller

Controller	***Settling time (sec)***		
	Δf_1	Δf_2	Δf_3
Integral	*60.52*	*50.04*	*52.65*
PID	*35.36*	*30.48*	*50.03*
FOPID	*28.05*	*26.05*	*24.12*

Table 5

V. CONCLUSION

This paper presents FOPID controller is used in ALFC problem. The results found from simulation initiated that the proposed controller accomplishes the toughness by decreasing the frequency variation of the interconnected multi area power system than the PID controller. The efficiency of the proposed controllers is verified with three cases. Moreover, the concept of FOPID controller can be verified using real time simulator to test the adaptability.

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