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MODELING AND ANALYSIS OF THREE AREA THERMAL POWER SYSTEM USING CONVENTIONAL CONTROLLERS

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ABSTRACT

This paper describes the automatic load frequency control of interconnected multi area power system with conventional controllers. The study has been designed for a interconnected three area thermal system considering reheat turbine thermal system in each area. The comparison between a conventional Proportional Integral(PI) controller , Proportional Derivative (PD) controller and Proportional Integral Derivative (PID) controller with a step load change given in all the three areas shows that the PID Controller can generate best dynamic performance in terms of peak over shoot, peak undershoot and settling time. The system simulation is realized by using MATLAB/SIMULINK software.

Index Terms—Automatic Load Frequency Control, Area Control Error, Frequency deviation, Tie–Line Power deviation, Proportional Integral Derivative Controller.

I. INTRODUCTION

Load frequency control is a very important topic in power system operation and control. The power system is affected with sudden load change and severe fault conditions. This leads to system frequency deviations and scheduled Tie line power interchange between the interconnected areas. So Automatic Load Frequency Control (ALFC) is needed in the interconnected power system design to regulate the system frequency and Tie-line power interchange within the scheduled values. If these values deviate from their limits, they cause unwanted disturbances in the power system [1]-[6]. For example, the frequency deviation will affect the power system operation, security, reliability, efficiency, degrading load performance, over loading of transmission lines and triggering of protection devices.

The turbine mechanical power output depends on the steam injection into the turbine blades, which will then be converted to electrical power by synchronous generator. Therefore, the frequency of current and voltage waveforms at the generator output mainly depends on steam injection to the turbine blades. So the frequency can be varied by varying the steam injection, which involves the adjustment of control valve at the steam flow pipe. Two types of control loops are available in the power system are the Automatic Load Frequency Control

(ALFC) and the Automatic Voltage Regulator (AVR). The ALFC which maintains the system frequency and tie line power interchange within the limits. ALFC also has two control loops which are primary control and secondary control. Under normal operating conditions, the small frequency deviation can be corrected by primary control which includes the fly ball governor and speed governing mechanism. The sudden load changes initially managed by the stored the kinetic energy in the flywheel. Then the speed governing mechanism with secondary control is responsible for the fine tuning of frequency deviation [7]-[8].

Conventional PI, PD, PID controllers can be used as secondary control [9]. By tuning the proportional, Integral and derivative gains, the desired dynamic response of the power system can be achieved with minimum Area Control Error.

II. MODELING OF THERMAL PLANT AND CONVENTIONAL CONTROLLERS

A. Modeling of a thermal power plant

The steam input to the turbine is controlled using the speed governor, when there is an imbalance occurs between the generation and demand. This imbalance is sensed by the governor in terms of change in frequency (Δf). Based on the change in frequency, the speed governor controls the position of the control valve, and increases or decreases the steam injection to the turbine blades. The steam input can also be controlled using reference power setting ($\Delta Pref$) of the governor. The speed governor output (ΔPg) is given by equation (1).

$$\Delta P_g = \Delta P_{ref} - \Delta f \frac{1}{R} \quad (1)$$

$$\Delta P_g(S) = \Delta P_{ref}(S) - \Delta F(S)\frac{1}{R} \quad (2)$$

The governor is assumed to have a time constant of T_g then the governor output equation is

$$\Delta P_v(S) = \frac{1}{1+sT_g}\Delta P_g(S) \quad (3)$$

The turbine is assumed to have a time constant of T_t then the turbine output equation is

$$\Delta P_t(S) = \frac{1}{1+sT_t}\Delta P_v(S) \quad (4)$$

The reheat turbine is considered in this paper, whose output (ΔP_T) is furnished in equation (5).

$$\Delta P_T(S) = \frac{1+K_rT_rs}{1+sT_r}\Delta P_t(S) \quad (5)$$

B. Modeling of conventional controllers

The Proportional Integral controller, Proportional Derivative controller and Proportional Integral Derivative controller are used in many control system are called as conventional controllers. The PD controller produces the control signal consisting of two terms one is proportinal to the error signal and the other is proportinal to the derivative of the error signal. The PD controller could add damping and but it maintains a constant steady state error all over the time. When a PI controller is added with a system the type and order number of the system is increaesd by one. Thus the steady state error is improved by one order and it can reduced to zero, if the system input is constant. But at the same time the rise time is decreased. To overcome these problems many systems are controlled with PID controller which has the best features of PI and PD controllers.

The control signal produced in PD controller is

$$U = (K_p + K_dS)\,\mathrm{E(s)} \quad (6)$$

The control signal produced in PI controller is

$$U = (K_p + \frac{K_i}{S})\,\mathrm{E(s)} \quad (7)$$

The control signal produced in PID controller is

$$U = (K_p + \frac{K_i}{S} + K_dS)\,\mathrm{E(s)} \quad (8)$$

III. AUTOMATIC LOAD FREQUENCY CONTROL OF THREE AREA SYSTEM

The power system with three control area interconnected by tie line as shown in fig.1 is considered. Each area supplies its user pool and the tie line allows electric power to flow between areas. Therefore, the load distribution in one of the areas affects the frequencies of other areas, as well as the power flows on tie line. Due to this a control system is needed in each area to bring the system frequency and tie line power to its steady state values. Fig. 2 shows the Simulink diagram of interconnected three area system.The area control error of i^{th} area in a multi area system is given in equation (9).

$$ACE_i = \sum_{j=1}^{n} \Delta P_{ij} + K_i \Delta_w. \quad (9)$$

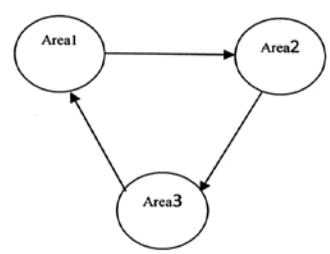

Fig. 1 Interconnected three area power system.

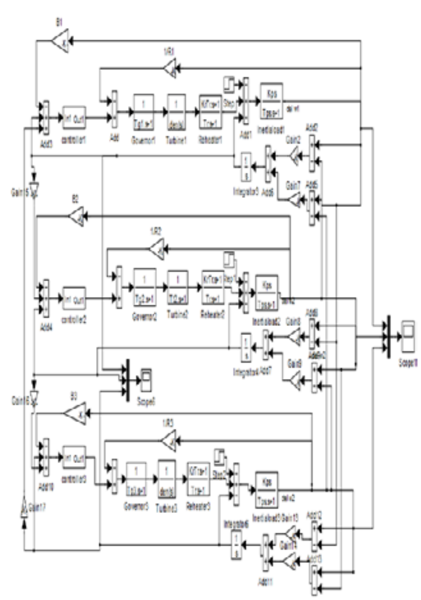

Fig. 2 Simulink model for three area interconnected thermal power system.

To obtain the optimum gain values of PD, PI and PID controllers Integral Of Squared Error Multiplied With Time (ITSE) parameter optimisation method is used. The performance index J is to be minimised to get the optimum gain value is given in equation (10). The performance index curve for PD, PI and PID controllers are shown in figure 3a,3b and 3c respectively.The optimal gain values is shown in table1.

Performance Index $J = \int (\Delta f1^2 + \Delta f2^2 + \Delta f3^2) t.dt$ (10)

TABLE I
OPTIMAL GAIN VALUES

	Performance Index J	Proportional Gain Kp	Integral Gain Ki	Derivative Gain Kd
PI controller	0.0023	0.2163	0.206	-
PD controller	1.791	3.15	-	2.4
PID controller	0.003	0.2184	0.0208	0.104

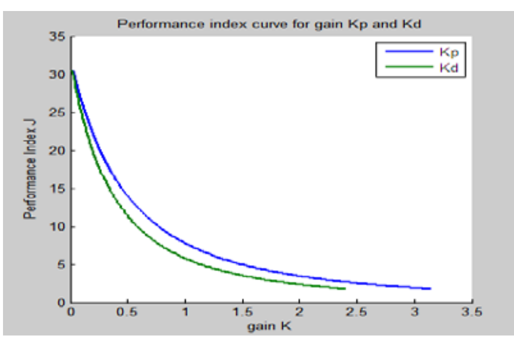

Fig.3a. Performance Index curve for PD controller.

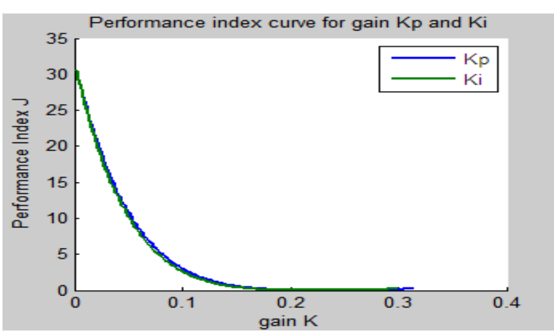

Fig. 3b Performance Index curve for PI controller.

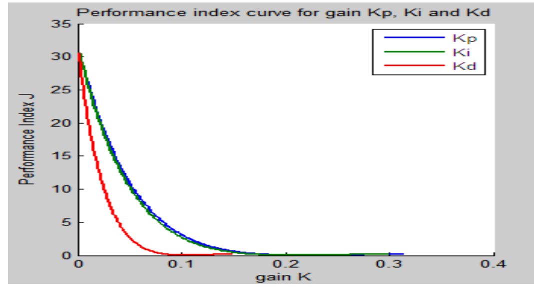

Fig. 3c Performance Index curve for PID controller

V.SIMULATION RESULTS

Frequency deviation of three area sytem with PD, PI and PID controller in area1, area2 and area3 following a step load disturbance is shown in Fig 4a, 4b and 4c respectively. Tie line power deviation of area 12 ,area23 and area31 using PD, PI and PID controller is shown in figures 5a,5b and 5c respectively. The peak overshoot values, undershoot values, steady state error and settling time values of the frequency deviation curve area1, area2 and area3 of interconnected three area system determines the system stability. The simulation results shows that the PID Controller can generate best dynamic performance.

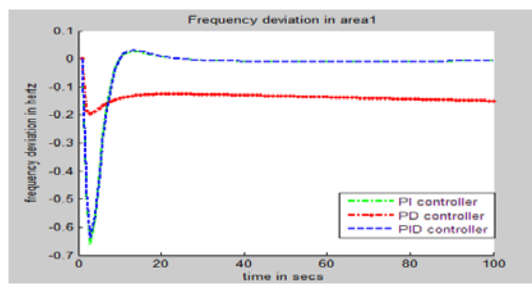

Fig.4aFrequency deviation of area1 with PI,PD,PID controller with step load disturbance given in all the areas.

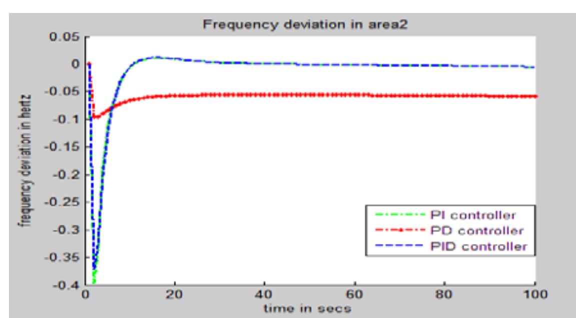

Fig. 4bFrequency deviation of area2 with PI,PD,PID controller with step load disturbance given in all the areas.

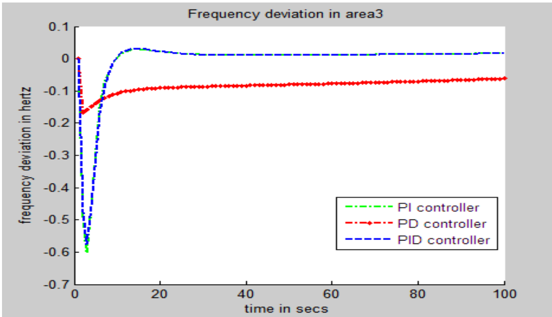

Fig. 4cFrequency deviation of area3 with PI,PD,PID controller with step load disturbance given in all the areas.

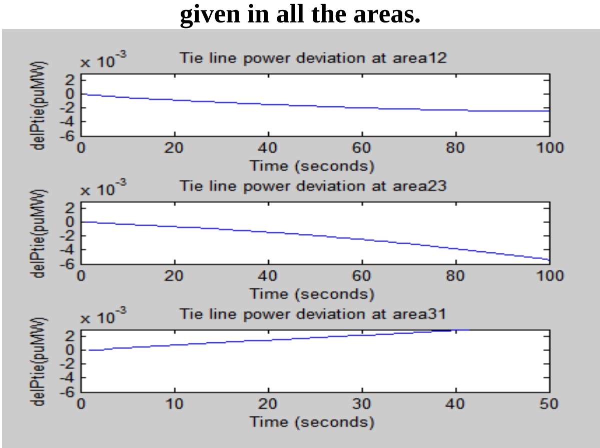

Fig. 5a Tie line power deviation of three area system using PD controller with step load disturbance given in all the areas.

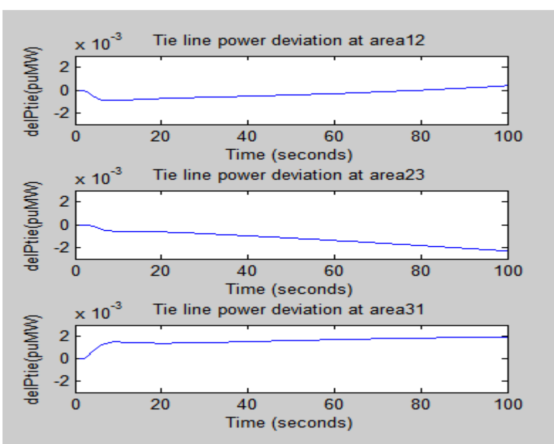

Fig. 5b Tie line power deviation of three area system using PI controller with step load disturbance given in all the areas.

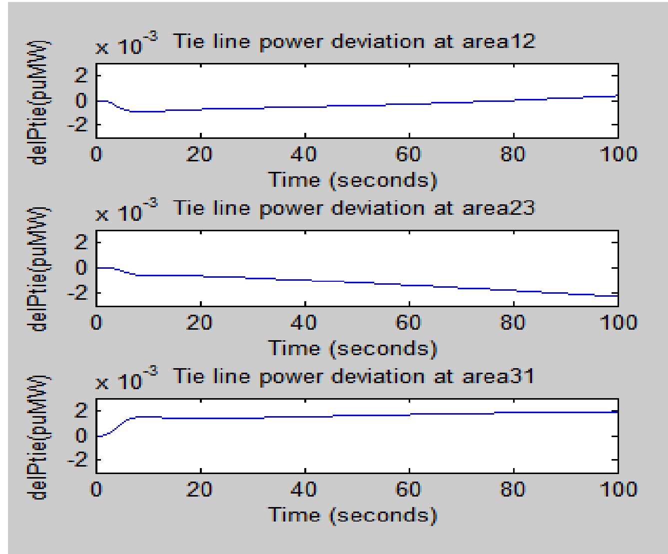

Fig. 5c Tie line power deviation of three area system using PID controller with step load disturbance given in all the areas.

VI. CONCLUSION

In this study, Automatic Load Frequency Control of three area interconnected power system with reheat turbine in each area is employed. The performance of PD controller, PI controller and PID controller is shown in the simulation results in terms of Peak overshoot, Peak undershoot and settling time. From the results, it is observed that the PID controller has less settling time and less steady state for frequency deviation as compared to conventional PD and PI controller. Even though the PD controller has less peak overshoot and peak undershoot the steady state error is not minimized. Here the generator rate constraints and governor non linearity's are not taken for simplicity.

Appendix

System Parameters:

T_{g1}=0.2sec, T_{t1}=0.3sec, K_{ps1}=120, T_{ps1}= 20 sec, K_{r1}=0.5, T_{r1}=10sec , R_1=5Hz/puMW, B_1 =0.2083puMW/Hz.

T_{g2}=0.1sec, T_{t2}=0.4sec, K_{ps2}=100, T_{ps2}= 18 sec, K_{r2}= 0.5 , T_{r2}=10sec , R_2=2.4Hz/puMW, B_2 =0.425 puMW/Hz.

T_{g3}=0.1sec, T_{t3}=0.5sec, K_{ps3}=120, T_{ps3}= 20 sec, K_{r3}= 0.5 , T_{r3}=10sec , R_3=4 Hz/puMW, B_3 =0.2583 puMW/Hz.

T_g :Governor time constant, T_t: Turbine time constant, K_{ps}: Power system Gain , T_{ps} : Power system gain constant ,K_r: Reheater gain,T_r:Reheater time constant,R: Regulation paameter, B: Frequency bias factor.

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