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A Comparison of Optimal Control of AGC for Hydrothermal System using Local Optimization

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***Abstract*—This work is mainly focused on Automatic Generation Control (AGC) of an interconnected hydrothermal system in continuous and discrete mode. Initially, the conventional controllers such as Proportional Integral Derivative (PID) of linear controllers were tuned with different tuning approaches such as direct search algorithm. Finally, those results are compared with the PI controllers. Optimal control strategies have been taken as Integral Square Error (ISE), Integral Time-Absolute Error (IATE) and Integral Time Square Error (ISTE). The simulation results indicate that better control performance regarding overshoot, settling time can be obtained by a direct search algorithm. For the given plant's appropriate generation rate constraints (GRC) has been considered both for the thermal and hydro plants. System performance is examined considering 1% step load performance (SLP) in both thermal and hydro area with 1 second sampling period. Investigations reveal that the performance of the direct search for tuning the controller parameters, at the same time the performance of the PID controller is better than the conventional controller of PI.**

***Index Terms*— AGC, hydrothermal system, optimal control, PI control, PID control and Optimization.**

I. INTRODUCTION

An interconnected power system consists of control areas which are connected by tie lines. In a control area, all the generators speed up or slow down together to maintain the frequency and relative power angles to registered values in static as well as changing conditions. In an interconnected power system, any unexpected small load disturbances in any of the interrelated areas cause the deviation of frequencies of all the regions and also of the tie line powers. The perturbation like adding a block of the load in a single area power system performing at the nominal value of frequency effects the power mismatch in generation. This mismatch is initially compensated by the uprooting of kinetic energy from the system, which causes a declining system frequency. As the rate goes on decreasing, the power was taken by the old load also goes on diminishing.

In large power systems, the stability may be accomplished essentially by themselves at a point when the extra amount is compensated by the diminution in power taken by old load plus the power corresponding to kinetic energy extracted from the system. This equilibrium is obtained at the cost of a drop in frequency. This stability is self-managed by the system, and it does not need any governor action. The frequency deterioration under such a condition is quite significant. However, if the mismatch is large enough, the governors come

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into, and the output of generators is increased. Now the equilibrium is achieved at a point when the new load is compensated with the reduction in the power exercised by old weight plus the increased generation due to governor action. Thus, the amount of kinetic energy extorted from the system is reduced to a greater extent, although not completely. Hence for this type of equilibrium, the decline in frequency still exists, but in this case, it is quite smaller than the fact discussed above. Such stability is obtained within 10-12 seconds after the extension of load. The action of governors is thus a primary control.The AGC problem has been dealt with broadly for more than three decades. The major part of the work described so far has been accomplished by estimating linearised models of two/multi-area power systems.
They explained that the problem in reaching the traditional approach for such operations was overcome by assuming that all areas to operate at the same frequency. They obtained the model by ignoring the frequency difference between the control areas [1]. The formulation of AGC of interconnected systems and investigations via linear control theory was presented in [2]. They compared three relatives to their capacity to influence the transient response of essential system variables. Later on, the effect of generation rate constraint (GRC) was incorporated in these types of studies, examining both continuous and discrete power system models [3-7]. The small signal analysis is justified for studying the system acknowledgement for small perturbations [8]. However, the implementation of AGC approach based on a linearized model on an inherently nonlinear system does not necessarily ensure the stability of the system. Considerable consideration has been given by researchers to consider the system nonlinearities. The studies were done to estimate the effect of performing a non- linear tie line bias component discussed in [9-11].

II. PID Controller, Optimal Control Systems and Search Algorithms

The basic PID controller output of PID controller is given by equation (1) as,

$$u(t) = Kpe(t) + Ki\int e(t)dt + Kd\frac{d}{dt}e(t) \qquad (1)$$

Where, error $e(t)$= set point-plant output. $u(t)$= input to the plant or output of the controller, K_p is proportional gain, K_i is integral gain and K_d is derivative gain. The following are the suggested control system specifications. The control loop must be characterized by a sufficient degree of Stability. Following a step load change, the frequency error should return to zero. The integral of the frequency error should be minimized.

III. Optimal Control Systems

A control system is optimum when the chosen performance index is minimized. The optimum value of the system parameters depends undeviatingly on the characterization of optimality. Mostly these are involving with zero steady state step error systems; The primary function of a feedback control system is to diminish the error, e(t), between any variable and its reference value to zero as instantly as possible. Therefore, any criterion applied to measure the quality of system response must take into account the deviation of error over the whole range of time. Equation (2) gives the current form of the optimum criterion.

$$J = \int_0^\infty t^n e(\theta,t)^2 dt \qquad (2)$$

Where, e(θ, t) is the error signal which starts the PI controller, where θ is the system parameters, and J is known as the performance index which should be optimised according to the control designation. In particular, for different values of n, for example, n = 0, 1, 2 three different criteria have to be satisfied. These cases correspond, to three different optimum criteria, i.e., Integral squared error (ISE) criterion, Integral squared time-weighted error (ISTE) criterion, and the Integral squared time-squared weighted error (IST 2E) criterion respectively. Generally, four basic principles are in everyday use, i.e. Integral Time Absolute Error (IATE). Integral Square Error (ISE). Integral Time Square Error (ITSE). This work has taken the first three criterion discussed above and correlates their appearance to conclude which one is better for the system produced into consideration.

IV. MODELLING OF POWER SYSTEM FOR AGC WITH OPTIMAL CONTROL

In starting, the performance of PID has been tested for a disturbance of 1% step change in load in a single area thermal system. The models of interconnected power systems with the integral and proportional control scheme, state space modelling of these power systems to design optimal controllers and stability studies of these power system models have been dealt with in this paper. The block diagram of multi-area interconnected system is given in figure 1.

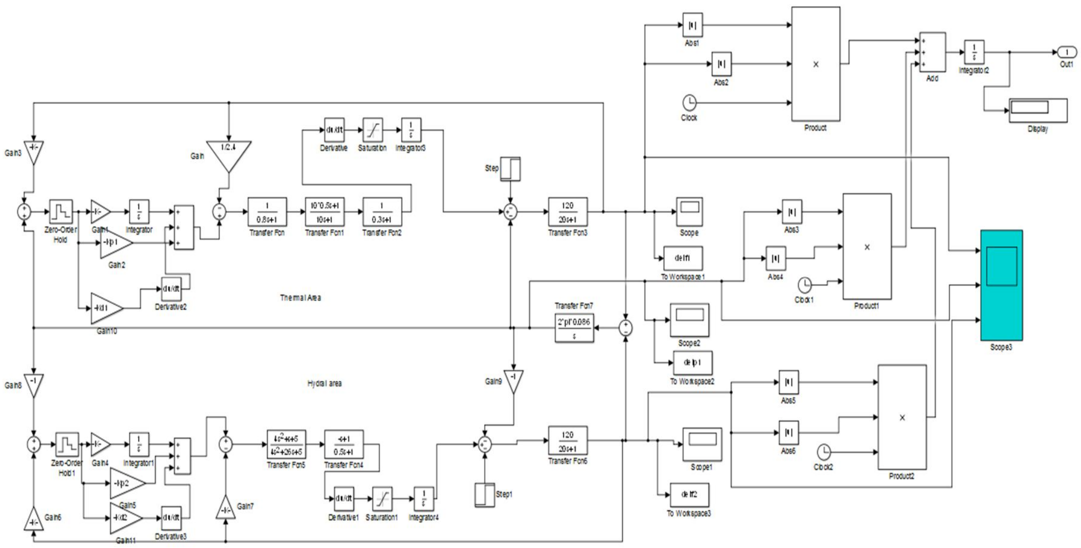


Figure1: Block diagram of Thermal-Hydro (Reheat) Power System with PID controller of ISTE technique

V. RESULTS AND DISCUSSION

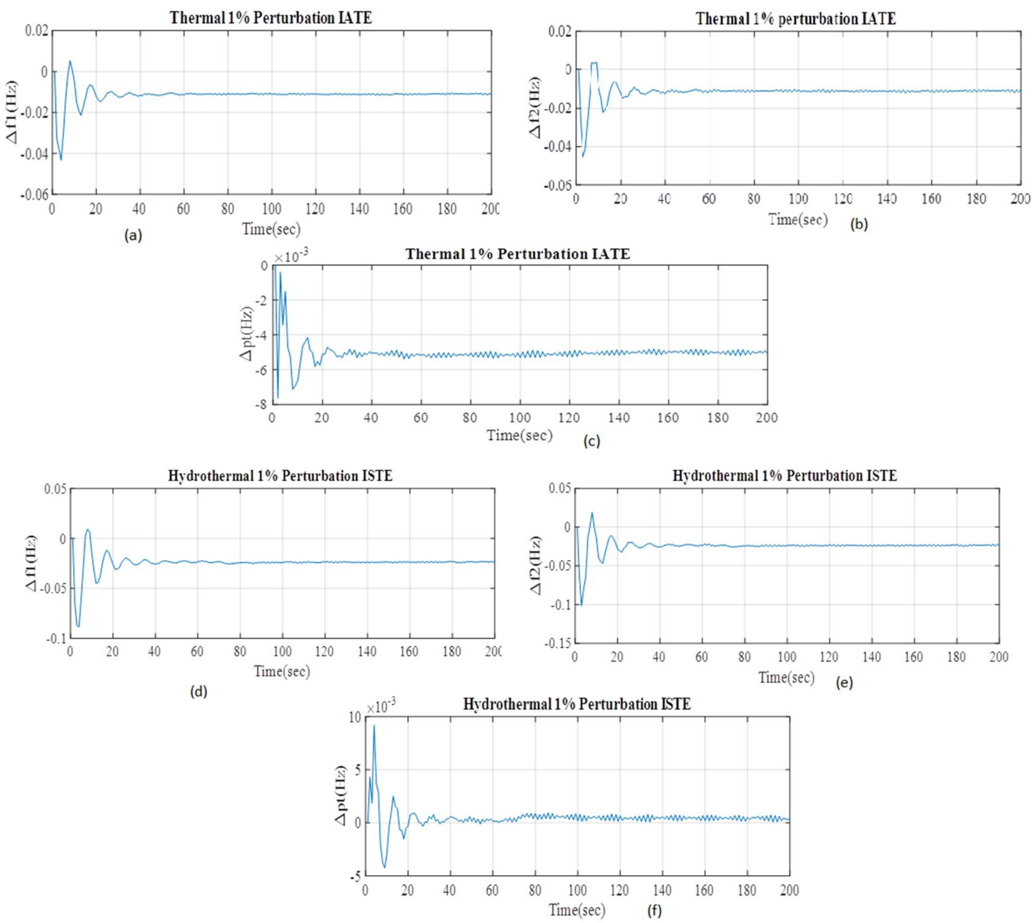
Initially, the Simulation has been done by using the system under consideration as shown in Figure. For this type of control areas, the Optimal Criterion is taken as IATE, ISE and ISTE. The Simulation outcomes for the frequency variation in both areas (i.e., $\Delta f1$ and $\Delta f2$) and tie line power ($\Delta Ptie$) for all the 3-cases of Optimal Criterion with the conventional controller is properly analysed. For the traditional controller (i.e. PID and PI Fminsearch) is taken as Optimization algorithm for all the problems of Optimal Criterion. Table 1 shows the value of the objective function (J) for all an interconnected area consisting reheat turbine model in the thermal region. From Table 1, it is clear that the actual function value for is IATE and ISTE much less than the other Optimal Criterion (i.e. ISE). Table 2 shows the tuned control parameters for various optimal criterions. Figure 2 shows the composite performance of all the individual performances for the hydrothermal system. Figure 2 (a), (b), (c) demonstrates the responses for 1% disturbance in the only thermal area. Figure 2 (d), (e), (f) shows the performance responses for 1% perturbation in the thermal and hydro area. From these responses, it is observed that with the proper controller, the stable operation can be achieved in the appearance of various operating situations.

TABLE I: OBJECTIVE FUNCTION VALUES (J) OF PID CONTROLLER, AT 1%, 3%, 5%, 7%, 9% PERTURBATIONS FOR THERMAL AREA OF VARIOUS OPTIMUM METHODS FOR AN INTER CONNECTED AREA

	Objective function value (J)				
Optimum Techniques	1%	3%	5%	7%	9%
ISTE	4.9237	43.8823	120.0039	228.4961	438.3171
ISE	0.06099	0.4493	1.4843	2.1919	5.4752
IATE	528.8701	1502.3366	2613.0482	361.12998	4947.4458

TABLE II: PI AND PID CONTROL PARAMETERS FROM FMINSEARCH FOR INTERCONNECTED AREA

Controlling parameters	IATE		ISE		ISTE	
	PI	PID	PI	PID	PI	PID
Kp1	0.0000219	0.00005	-0.000175	-0.000063	0.00099	-0.000058
Kp2	-0.0000599	-0.00019	0.000023	-0.00019	-0.00011	-0.000193
Ki1	0.000254	0.000131	0.000348	0.000147	-0.000527	0.000137
Ki2	-0.0000360	0.000139	0.000418	0.000148	0.00025	0.000145
Kd1	0	0.000134	0	0.000138	0	0.000131
Kd2	0	-0.000049	0	-0.000057	0	-0.000054



Figures 2: PID controller with 1% step load perturbation in thermal area and hydro-thermal area. The ISTE criteria using FminSearch is considered for the tuning the control parameters

VI. CONCLUSION

Among all the responses collected, it is observed that PID is the traditional controller rather than I & PI controllers whose performance features is better concerning rising time, settling time, oscillations & overshoot for both frequency and tie-line power. Tuning of the controller is also vital for obtaining good acknowledgement and stability with minimum error or disturbance. It is also observed that the different area thermal power system yields better frequency and tie-line power response as correlated to the equal area thermal power system. PID theory is more accurate and faster than the conventional PI control scheme even for the complex dynamical system. It is evident that responses obtained reveal that PID better-settling performance than PI. Therefore, the intelligent control approach using PID concept is more accurate and faster than the conventional PI control scheme even for the complicated dynamical system.

APENDIX

Parameters used in simulation studies for hydrothermal system and Fminsearch parameters.

Nominal Parameters of Hydrothermal System	
f=50Hz	D1=D2=8. 33∗10−3p.u.MW/Hz
Tg = 0.08sec	R1 = R2 = 2.4Hz/p.u.MW
Tr = 10.0sec	Tt = 0.3sec
H1 = H2 = 5sec	Kp = 1.0
P1 = P2 = 2000MW	Kd = 4.0
Ptie,max = 2000MW	Ki = 5.0
Kr = 0.5	Tw = 1.0sec
KP1=KP2=120Hz/p.u.MW	TP 1 = TP 2 = 20sec
a12 = −1	T12 = 0.086p.u.MW/rad

Fminsearch	
Max iterations	200∗No of variables
Max evaluations	200∗No of variables
X tolerance	1 ∗ e−4
Function tolerance	1 ∗ e−4
Fitness Function	IATE,ISE,ISTE
Elitism	2
Crossover Probability	0.8

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