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Automatic Generation Control of interconnected Hydro Thermal system by using APSO scheme

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Abstract: *This article deals with automatic generation control of a multi area interconnected hydro thermal system in different modes using intelligent integral and proportional-integral controllers and provides the comparative analysis of electrical and mechanical governors. Appropriate generation rate constraint has been considered for the hydro thermal generation plants. These cumulated thermal areas are considered with reheat turbines. Performances of reheat turbine mechanical governor and hydro turbine electrical governor dynamic responses have been investigated. Further, selection of suitable integral and proportional-integral controllers has been investigated with an Accelerated particle swarm optimization. Cumulative System performance is examined considering with different load perturbation in both cumulative thermal areas. Further, System is investigated with different frequency bias values and results are explored.*

Keywords: *Accelerated particle swarm optimization;Power System modeling;Advance control techniques;Two area system control.*

I. Introduction

Several researches are going in the field of automatic generation control of interconnected power systems since few decades. Due to continuous changes of loads, automatic generation control is becoming key criteria. Whenever the load demand increases it poses serious threats on reliable operation of power systems. Whenever the load demand increases, leading to reduction of turbine speed (Ns) and therefore reduction of generator frequency (f). It is desirable feature to achieve a better frequency constancy, which is obtained by speed governor alone. The power system which are connected, it is desirable to maintain the tie line power at a given level irrespective of load changes in any area .To accomplish this, it is become necessary to automatically manipulate the operation of steam valve in accordance with the suitable control strategy which in turn controls real power output of electric generators. The way controlling error in active power output of electric generators is termed as Automatic Generation Control (AGC).

In view of Cohn discussion the following qualitative specifications must be considered for the design purpose.

1. The steady state frequency error following a step load change should go away provided area in which load change occurred can adjust its generation fully to accommodate this change.
2. The static change in tie power following a step load change in area must be zero provided the area in which step load change occurred can adjust its generation.
3. The frequency and tie power errors should be small. Time error and inadvertent interchange should be small.
4. Automatic generation controller providing a slow monotonic kind of response should be preferred in order to reduce the wear and tear of the equipment.

These investigation deals with how to select a frequency bias, selection of controller parameters and selection of speed regulator parameter of speed governor. Investigation regarding to the AGC of interconnected thermal system is limited to the selection of controller parameter and effect of generation rate constraints (GRC). Intelligent control scheme for interconnected thermal system is examined here. Nanda et al considered the problem of AGC in interconnected thermal generated power system in discrete-continuous mode using conventional integral and PI controllers. They have considered the appropriate GRC for the thermal plants. Nanda and Kothari have extensively studied the AGC problem of a two-area thermal system. It has studied the effect of generator rate constraints and governor dead band. Concordia and Kirchmayer [1] and Kirchmayer [2] have studied the AGC of a hydrothermal system considering non reheat turbine and mechanical governor in hydro system, neglecting generation rate constraints. Kothari *et al.* [3] are possibly the first to consider GRC to investigate the AGC problem of a hydrothermal system with conventional integral controllers. They have discussed about finding the optimum integral controller settings and their sensitivity to GRC, speed regulation parameter, water starting time constant, base load condition etc. Kothari *et al.* [4] have also studied the AGC problem of hydrothermal system, considering GRC where their main contribution is to explore the best value of speed regulation parameter (R). All the above research works discussed consider the system & controllers in the continuous mode strategy. Nanda, Kothari, and Satsangi [5] have explained the AGC problem in continuous- discrete mode with classical integral controllers and differentiated the responses. Their main finding shows that the optimum integral controller gains achieved in the continuous mode are totally unacceptable in the discrete mode for sampling time period used in practice. In the interconnected hydrothermal system, thermal power system uses reheat turbine and the hydropower system uses a mechanical governor. Many of the existing hydro power stations are equipped with mechanical governors. Modern hydropower system units are generally equipped with electric governors in which the electronic apparatus is used to perform low power actions are associated with speed sensing and droop compensation [8].A literature survey shows that no comparison has been made for the performances of mechanical and electric governor to critically appreciate their operation. It would be of practical significance to explore the system performance if a mechanical governor is replaced by an electric governor. Kothari *et al.* [6] have investigated the effect of variation in sampling period on the performance of AGC of an interconnected two area thermal system considering GRC and reheat turbines. Their investigations reveal that a relatively large sampling time period to a tune of 20 s is permissible to provide more or less best system performance instead of small sampling period of 2 to 4 s used in practice. Such finding about sampling period in a thermal-thermal system may not hold well in a hydrothermal system which needs further investigations. Hari*et al.* [9] investigate proper selection R for interconnected reheat thermal-thermal system in continuous-discrete mode considering appropriate GRC. Their findings reveal that there is no necessity for going for a low value of R, since a large value R with corresponding optimum integral controller gain settings can be preferred to provide better dynamic response of AGC. They advocate very strongly that for the governor design consideration, it is better to adopt as large value of R as permissible without jeopardizing the dynamic responses. Higher value of R makes the realization of the governor simpler and reduces its cost [10] such finding about R in a thermal-thermal system may not hold well in a hydrothermal system which needs further investigations. In reheat turbines, the reheating may be in a single stage or in multistage [7].A transfer function model for single stage reheat turbine has been given by Kundur [7].

II. System Investigation

The AGC system investigated consists of two generating areas of same size, area 1 is said to be a reheat thermal power system and area 2 is said to be a hydropower system. Gain Rate Constraints of the order of 3%min for thermal power generated area and 270% per minute for raising and 360%per minute for downing generation in hydropower generated area has been considered. The AGC model as shown in Fig.1 shows with single stage reheat turbine in thermal area and electric governor in hydro area. A bias setting of Bi = βi is considered in both hydro and thermal areas. Matlab version 6.1 has been used, to obtain dynamic responses for Δf1, Δf2, ΔPtie for 1% step load perturbation in either area. The system data has been taken from [11] and [12] and given in Appendix. The optimum values of derivative, proportional and integral gains for the electric governor have been taken from the work of Nanda *et al.* [3] and given in the Appendix. For the system analysis, 1% step load perturbation has been considered either in thermal or hydro area. Controllers in

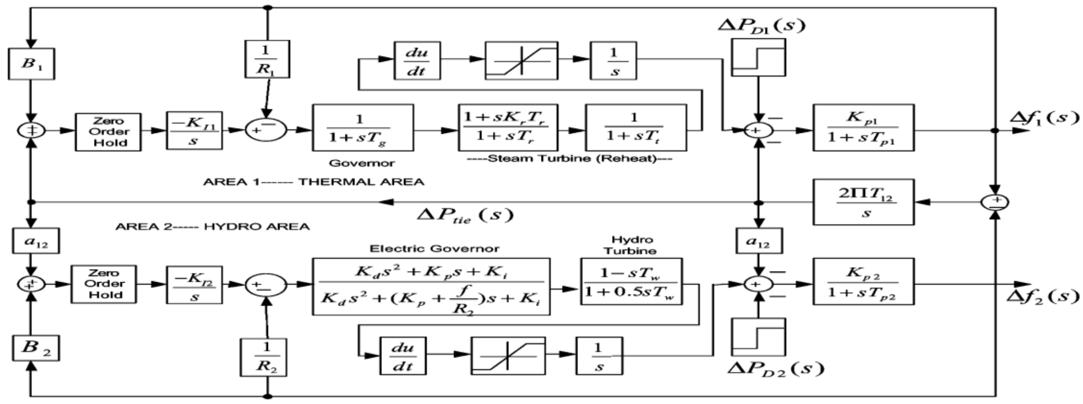


Fig.1. Transfer function model of an interconnected two-area hydrothermal system.

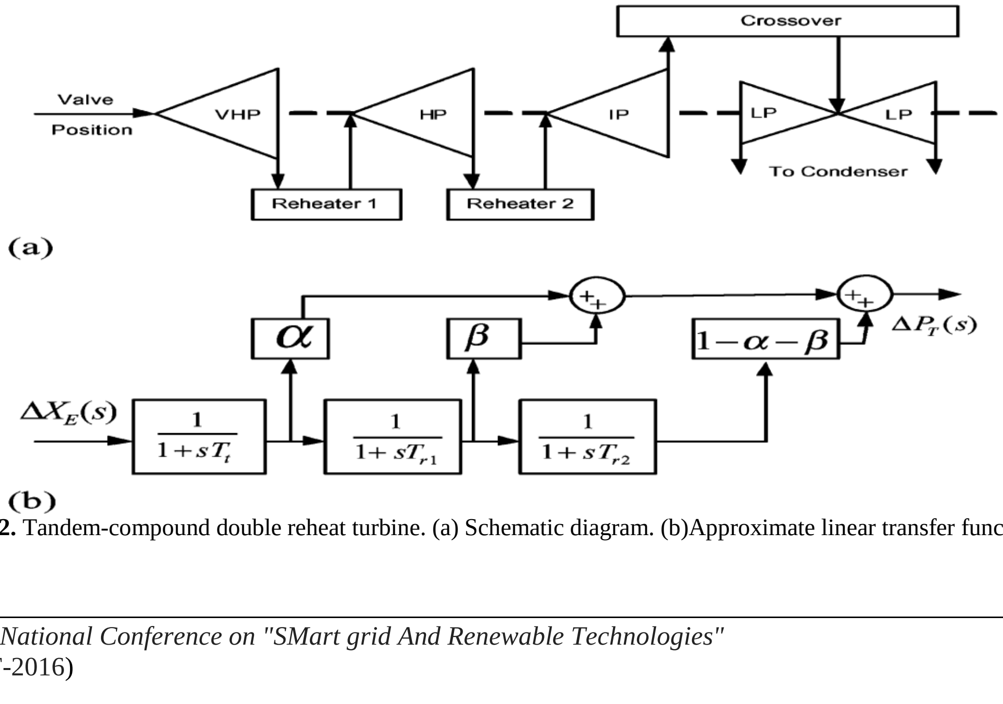


Fig.2. Tandem-compound double reheat turbine. (a) Schematic diagram. (b)Approximate linear transfer function.

III. Particle Swarm Optimization

Particle Swarm Optimization (PSO) refers to a relatively new family of algorithms that may be used to find the optimal solutions to numerical and qualitative problems. It was introduced by Russell Eberhart and James Kennedy in 1995. It is easily implemented and has proven to be both very fast and effective. In PSO particles are flown through where the problem in space following the current optimum particles. Each Particle save the point of its coordinates where the problem in space, which are combine with the best solution that had been achieved so far. This implies that each particle has memory, which allows it to remember the best position on the feasible search space that it had ever visited. This value is commonly calledP_{best}. Another best value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the neighborhood of the particle. This location is commonly called asG_{best}. The basic concept behind the PSO technique consists of change in the velocity of each particle towards its P_{best} and G_{best} positions at each step. This means that each particle tries to modify its current position and velocity according to the distance between its current position and velocity according to the distance between its current position andP_{best}, and distance between its current position andG_{best}. The position and velocity vectors of the i_{th} particle of a N-dimensional search space can be represented asX_i=X_{i1},X_{i2}…………....X_{id}andV_i=V_{i1},V_{i2}…………………V_{id}respectively. In PSO, each potential solution to the problem is called *particle* and the population of particles is called *swarm*. In this algorithm, each particle position *xi* is updated each generation *t* by means of the next equation.

$$X_i(t) = X_i(t-1) + V_i(t) \quad (1)$$

$V_i(t)$ is the velocity and is given by

$$V_i(t) = V_i(t-1) * w + C1 * r1(X_{pbesti} - X_i) + C2 * r2(X_{gbesti} - X_i) \quad (2)$$

X_{pbesti} is the best solution, X_{gbesti} is the best particle , w is the inertia weight of the particle, r1 and r2 are two uniformly distributed random numbers in the range [0, 1], and C1 and C2 are specific parameters which control the relative effect of the individual and global best particles. Individual Coefficient Factor C1 = 1.4, Social Coefficient Factor C2 = 1.4, Max Inertia Weigh W_{max} = 0.4, Min Inertia Weigh W_{min} = 0.2 .After finding the two best values, the particle updates its velocity and positions with following equation (3) and (4).

V[t]=V[t]+c1*rand*($P_{best}(t) - present(t)$)+rand*$G_{best}(t)$-present(t) (3)

Present (t) = present (t) + V(t) (4)

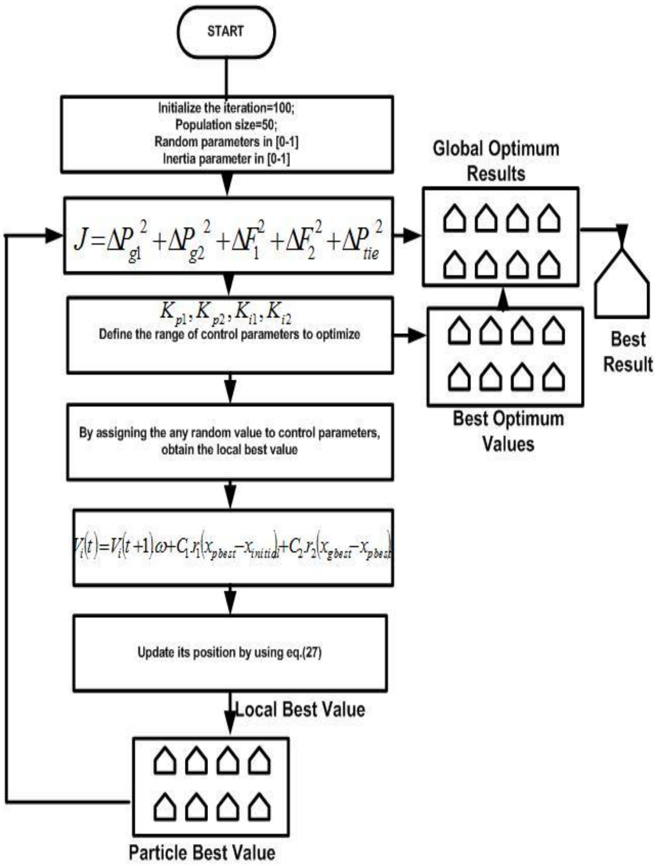


Fig.3. Flow chart of particle swarm optimization

IV. Accelerated Particle Swarm Optimization

There are many variants of PSO which extend the standard PSO algorithm, and the most noticeable improvement is probably to use inertia function $w_i(t)$. So that $V_i(t)$ is replaced by $w_i(t) * V_i(t)$ in (2).

Where w (t) takes the values between 0 and 1. In the general case, the inertia function is a constant, probably 0.3 ~ 0.8. This is equivalent to a duplicate mass to stabilize the motion of the particles, and thus the APSO algorithm is expected to converge more fast. The standard particle swarm optimization uses both the current global best g_{best} and the individual best p_{best}. The main reason of using the individual best is to increase the diversity in the quality solutions, but, this diversity can be simulated using some randomness. In APSO initially a random value is selected and this is used to find the G_{best} solution. This G_{best} is taken as the initial value and one more G_{best} is calculated. Thus there is no particular reason for using the individual best. Thus, in this algorithm, the velocity component is generated by a simple formula. Another advantage is to reduce the randomness as lesser number of iterations is required, while the algorithm is processing. The solutions are reached like a monotonically exponential decay. These parameters are fine-tuned to suit the current optimization problem. The implementation of the APSO has been carried in MATLAB. In APSO the convergence to the solution is faster than standard PSO.

In this article, the solution methodology by using APSO has given and complete information about of APSO is given in [12]. $V_i(t)$ is the velocity of swarm at current position, $V_i(t+1)$ is the velocity of swarm in next position, ω is the inertia function, C_1, C_2 are the individual social co-efficient factor, x_{pbest} is the particle best position, $x_{initial}$ is the initial position of the particle, r_1 and r_2 are the random numbers of the particle. Primarily, all the particles have been initialized with their respective parameters and then the objective function with their variables has to be checked with their constraints. With the help of APSO technique the accurate velocity of particle has be found with the following position and velocity updates.

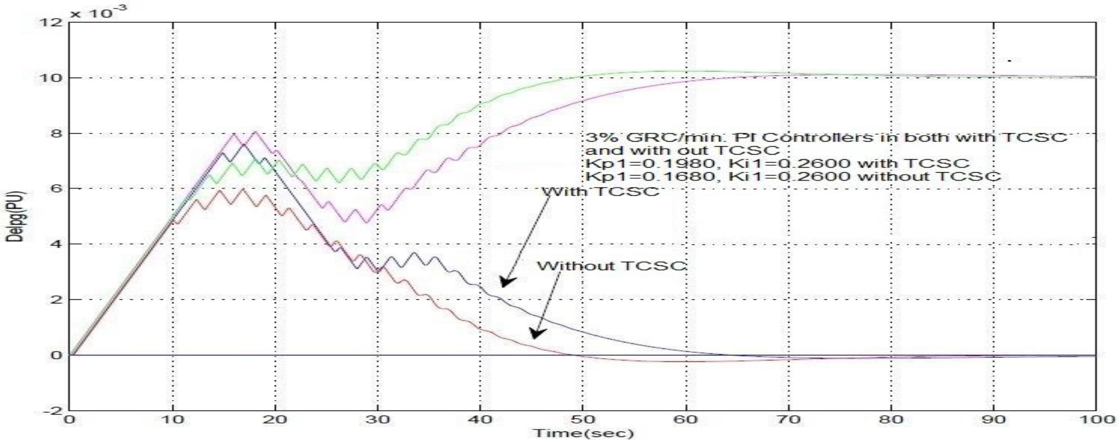
$$x_i(t) = x_i(t-1) + v_i(t).\omega \quad (5)$$

$$v_i(t) = v_i(t-1) + x_i(t).\omega \quad (6)$$

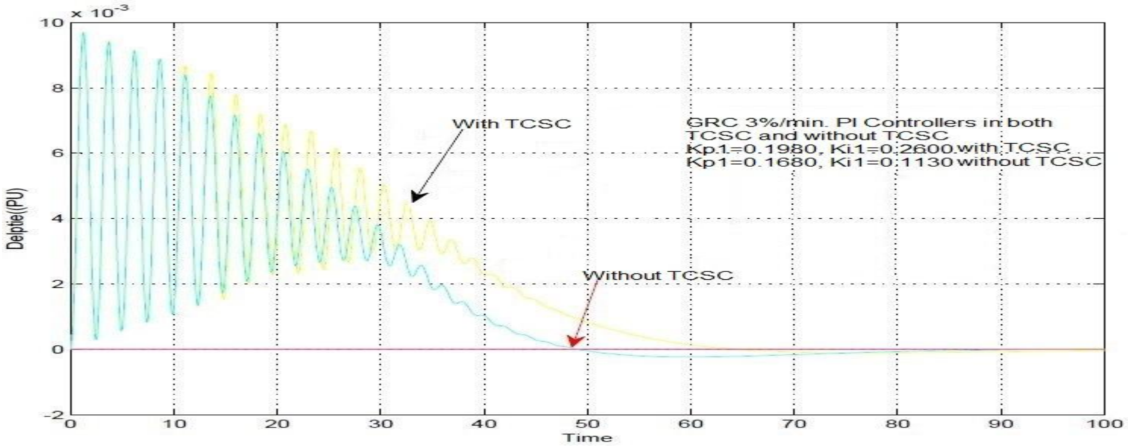
V. Implementation And Results

CASE 1:

In this case, GRC 3%/min proportional-integral controller is taken in the system. Both with and without compensation responses are plotted in Figure 4.



(a)



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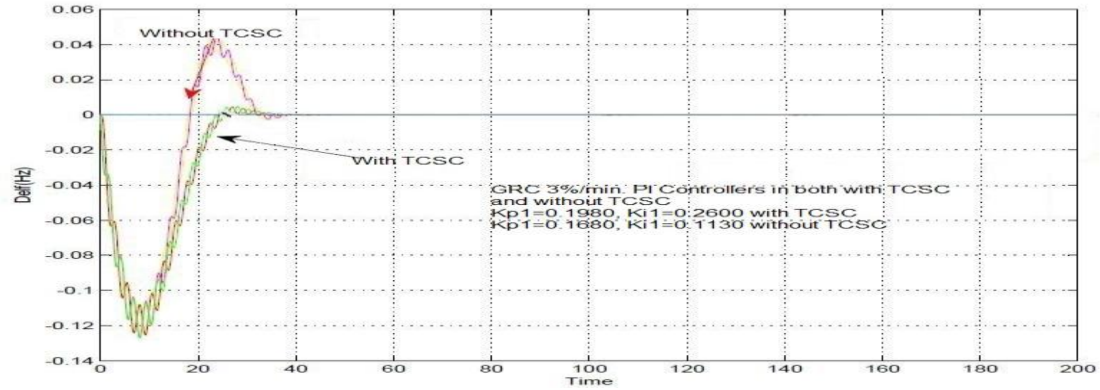
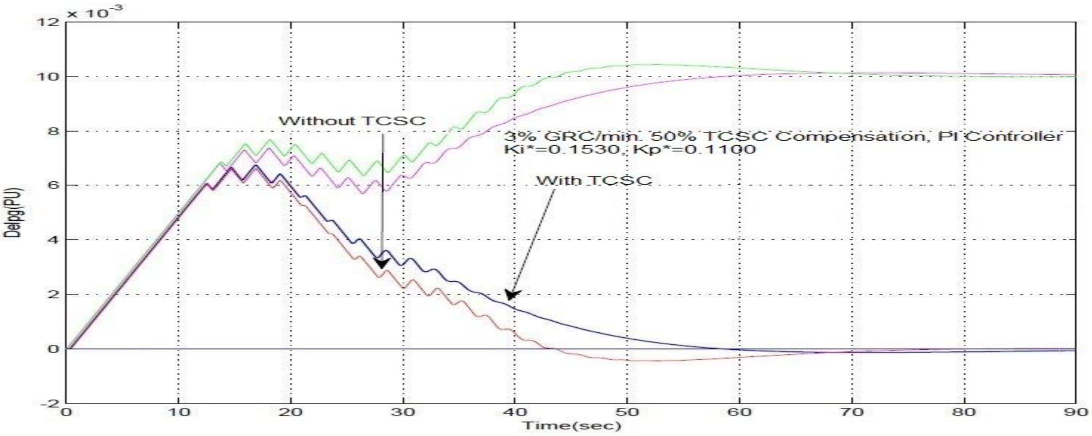


(c)

Fig4: GRC 3%/min proportional-integral controller is taken in the system with and without compensation.

CASE 2:
Here, 3% min GRC is taken in the system with proportional-integral controller in both the areas. Responses with and without compensation are plotted in Figure 5.



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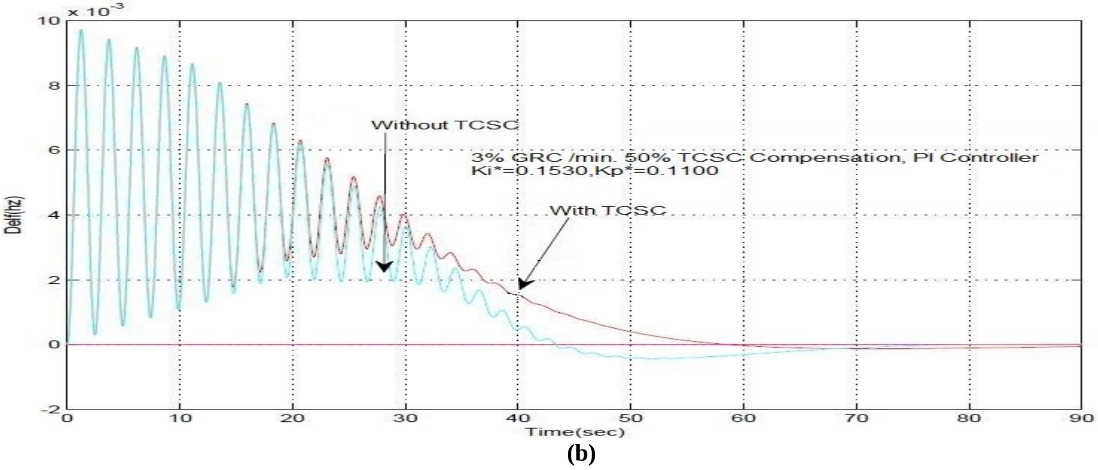

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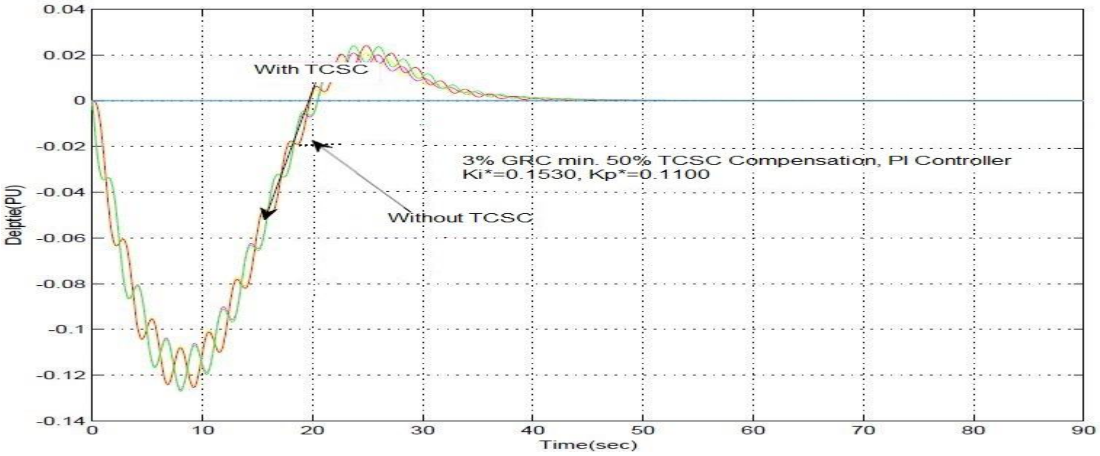

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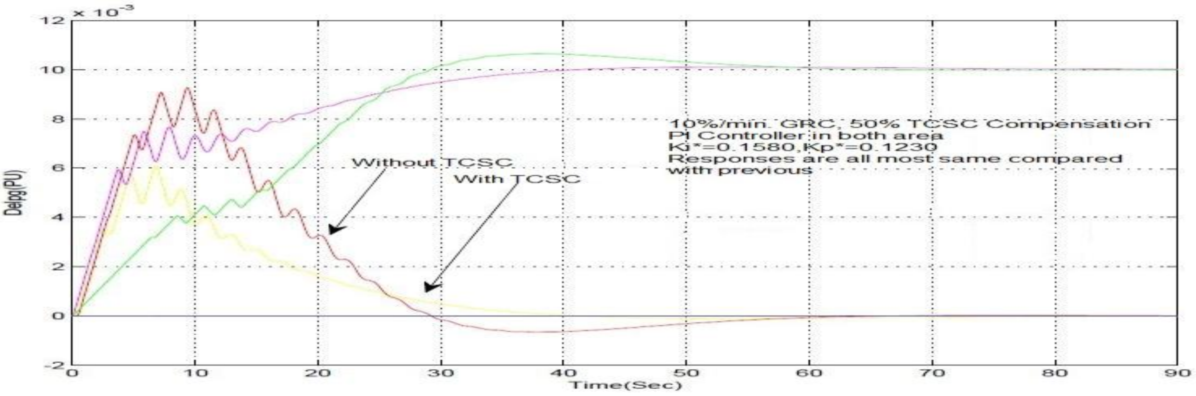
Fig 5: 3% min GRC is taken in the system with proportional-integral controller in both the areas with and without compensation.

CASE 3:

In this case, 10%/min GRC and 50% of TCSC compensation are considered in the system. PI controllers are provided in both the areas. Responses with and without compensation are plotted in Figure 6.



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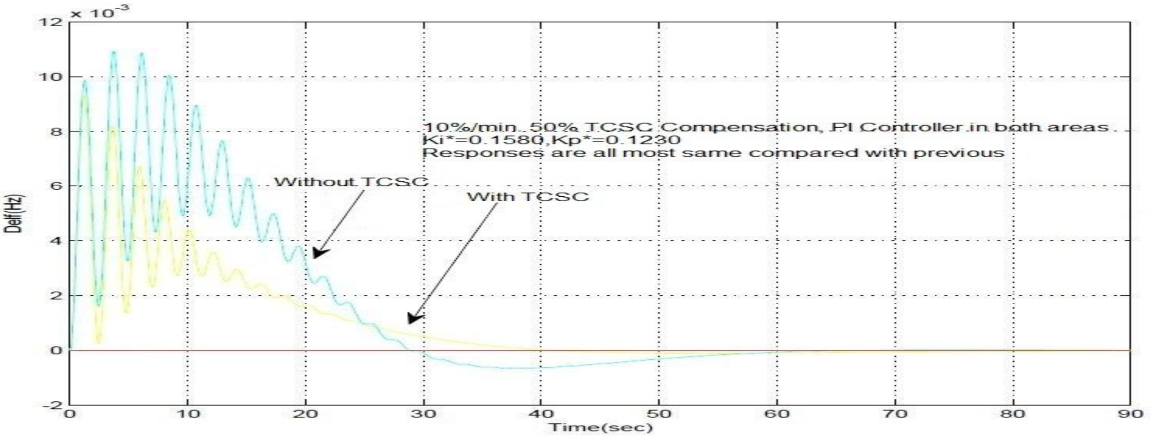

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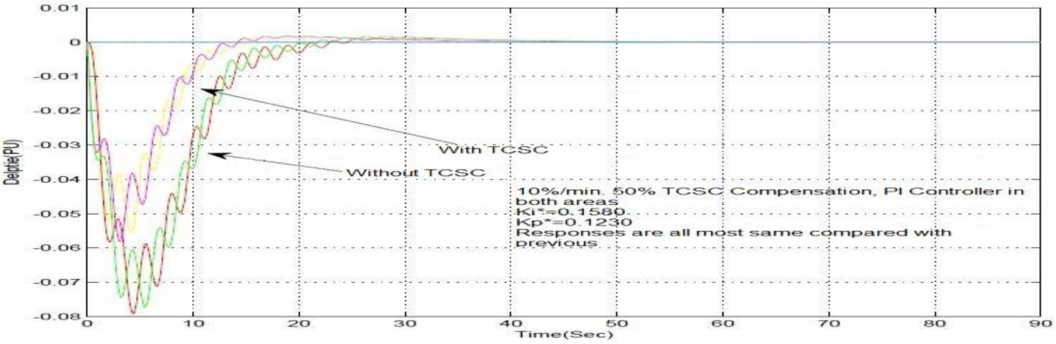
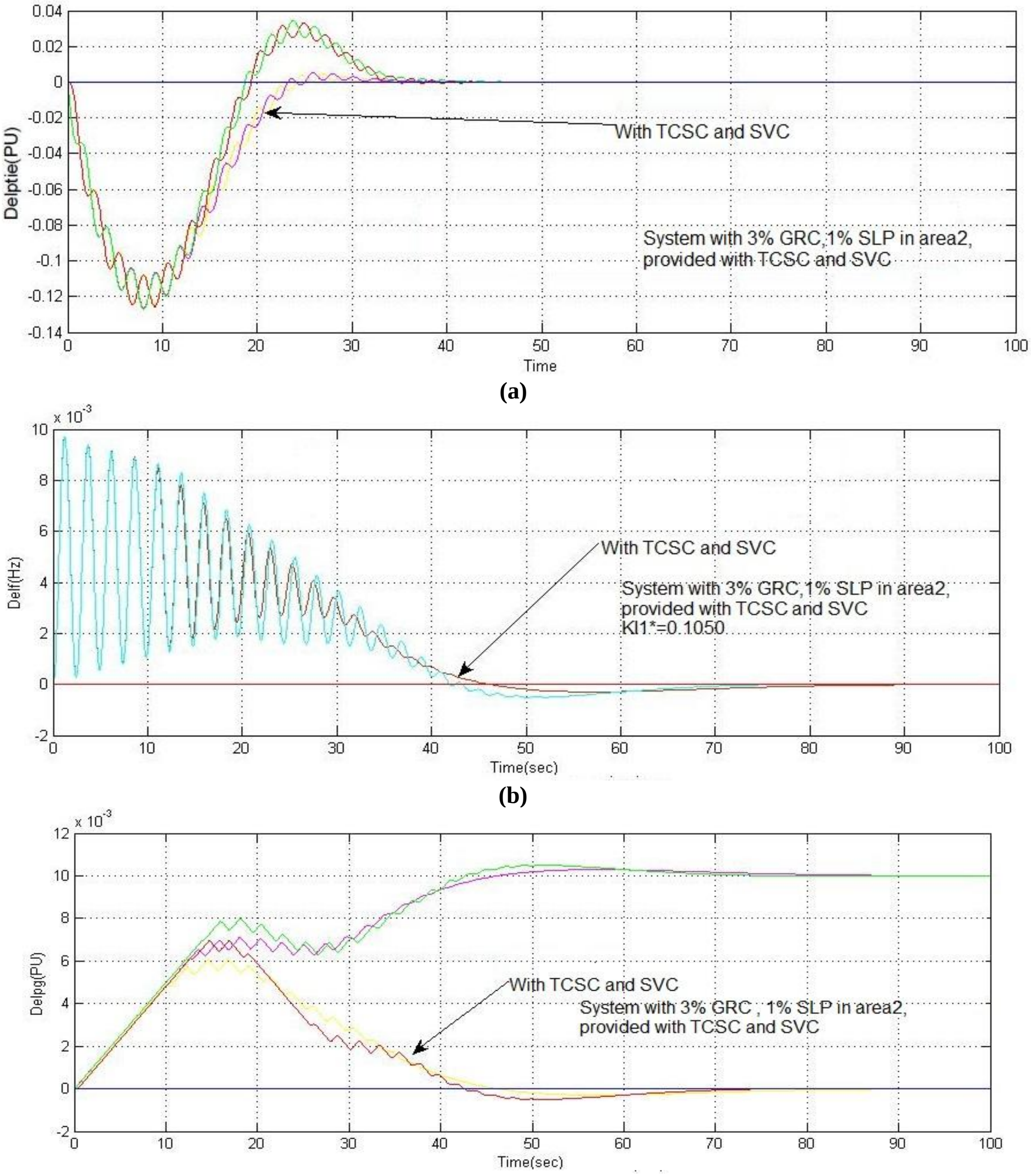


(c)

Fig 6: 10%/min GRC is taken in the system with proportional-integral controller in both the areas with and without compensation.

CASE 4:

The system is provided with 10% SVC and 30% TCSC compensation. The value of the integral controller is found to be 0.1050. After comparison, it can be concluded that system with TCSC gives better result than system with both (SVC and TCSC). Responses are plotted in Figure 7.



(a)

(b)

(c)

Fig 7: The system with 10% SVC and 30% TCSC compensation.

VI. Conclusion

The following are the significant contributions.

i. Higher the GRC, better is the response, lesser is the peak deviation and lesser is the settling time.
ii. The system with the optimum ID controller gives better results than integral controller.
iii. The system can be concluded that it is better not to use controllers in the initial 10–12 s. Consequently, it reduces the wear and tear of the controller and also increases the life span of the system.
iv. It is advisable not to use a controller in the initial 10–12 s. Instead, a delayed integral controller can be used.
v. Investigations reveal that the system with PI controller reaches steady state faster as compared to I controller.
vi. Investigations reveal that in a reheat thermal system, it is permissible to choose a much higher sampling period than that used in practice.
vii. Frequency response reveals that peak overshoot is decreased, transient response is improved and oscillations are decreased. Settling time is found to be 34 s and 40 s with TCSC and without TCSC, respectively.

Appendix

f=60 Hz; R_1=R_2=2.4 Hz/per unit MW

T_{g2}=0.08 s; Ptie, max=2000 MW

T_{r1}=10.0 s; K_{r1}=0.5

H_1=H_2=2 s; P_{r1} =P_{r2} =3,000 MW

T_{t1}=0.3 s; K_{P1}=1.0

K_{d1}=4.0; K_{i1}=5.0

T_{w1}=1.0 s; D_1=D_2=8.33*10^{-3} p.u. MW/Hz

a_{12}=-1 T_{12}=0.066 p.u. MW/Hz

T_R =3 s; K_{P1}=K_{P2}=120 Hz/p.u. MW

T_{P1}=T_{P2}=10 s; T_1=49.30 s; T_2=0.120 s.

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