IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Effect of Physical Constraints on the Dynamics of a Multi-Area Interconnected Power System

Dipayan Guha[*1], P.K.Prasad[2]

[*1] Assistant Professor, Kanksa Academy of Technology and Management-TIG, Durgapur, Burdwan, West Bengal, India

[2] Principal, Abacus Institute of Engineering & Management, Mogra, Hooghly, West Bengal, India

guha.dipayan@yahoo.com

Abstract

An attempt is made in this paper to study the dynamic performances of a multi – area interconnected power system considering all possible physical constrains in the power system using conventional integral controllers. Three area with reheat type turbine either single stage or double stage system is considered. Performances of single stage and double stage turbine on the dynamics of power system have been investigated. Since the area control error (ACE) is measured at a fixed interval of time, hence the system is modeled in continuous-discrete mode. Appropriate values of physical constraints are considered. This paper examined the proper values of speed regulation parameter (Ri) and sampling time constant (T) to maintain the system stability. System performances are studied with 10% (sever case) load perturbation in all the areas in MATLAB-SIMULINK environment.

Keywords: Automatic Generation Control, multi-area system, two-stage turbine, effect of speed regulation parameter, MATLAB-SIMULINK

Introduction

Maximum preoccupation and concern of power system engineers was and still to control the MW power since it is the basic governing elements of revenue and requirement. Nowadays, modern power system networks are interlinked through transmission lines, called as tie-line to exchange the power between the neighboring units. For satisfactory and perfect operation of power system, the frequency should remain constant to its nominal value. Modern power system networks comprises long transmission lines, frequent load changes, high load demands etc., which may direct results in variation of frequency from its scheduled value, large deviation may collapse the system completely. Hence load frequency control is one of the most important issues in power systems operation and control. Automatic Generation Control (AGC) plays a vital role in the field of power system operation and control as its main objective to control the frequency and tie-line power to its scheduled values during normal as well as when the system is subjected to small load perturbation. Summation of tie-line power and weighted frequency is used as common variable signal, called as area control error (ACE), in AGC. Since the error is measured at a fixed interval of time, hence the three area system is studied in continuous- discrete form.

Literature survey shows that most of the earlier work considered either two area thermal systems or two area hydro-thermal coordinated systems. But less attention is paid on three area interconnected system. Most of the work in the field of AGC considered simplified model of power system. The aim of the present works is to demonstrate the effect of reheat and non-reheat turbine and some physical constraints on the dynamic performances of three area interconnected system. [1] modeled his system neglecting communication delays. The modeled of power system with GRC is used by [3], [4], [5] and [9] to improved previous studies considering GRC and DB. [7] has presented his paper on three area hydro-thermal system considering only GRC. It should be noted that to get an accurate perception in the field of AGC, it is essential to study the system considering all possible physical constraints of the system. [6] is first who considered all important physical constraints of power system for study of dynamic performances in two area interconnected thermal-thermal system with single stage reheat type turbines.

The main objectives of the present work are as follows-

- To study the dynamic performances of reheat and non-reheat type three area thermal areas considering all possible constraints.

- To compare the performances of single stage and double stage reheat turbine.
- To investigate the proper value of speed regulation parameter (R_i).

To investigate maximum permissible value of sampling time constant without hampering the system stability.

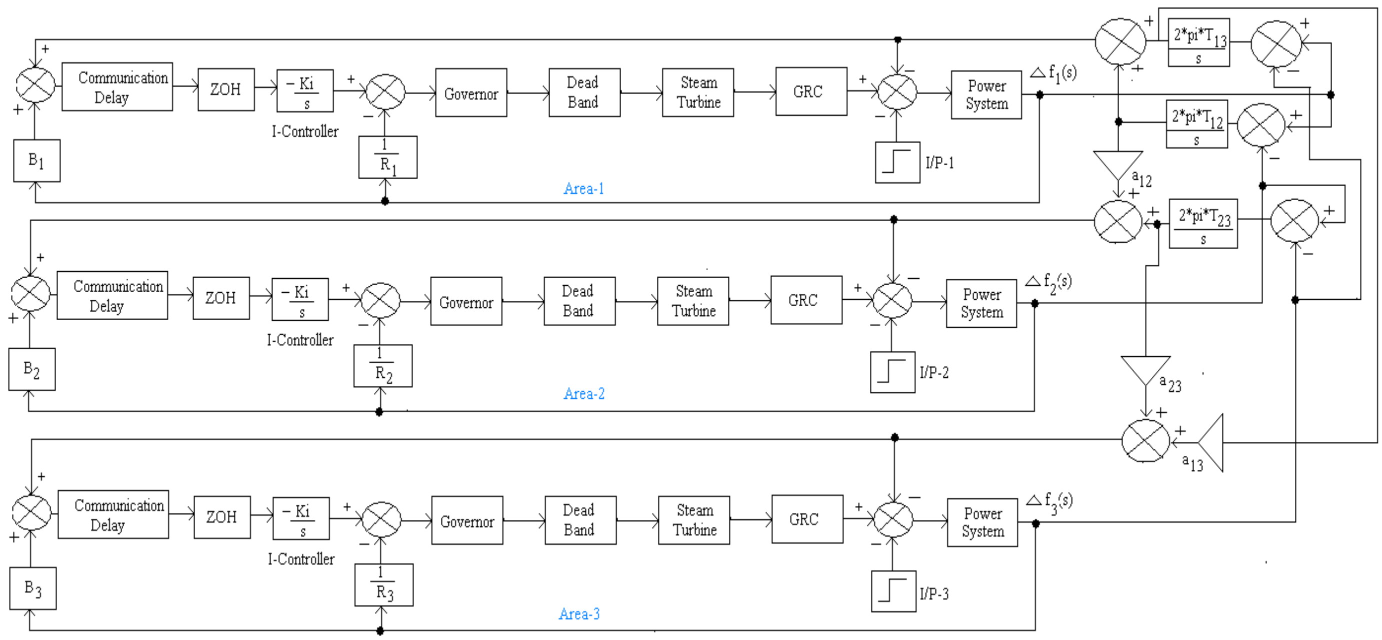

Fig. 1: Block diagram of multi-area system considering all possible constraints

System Investigated

The investigated AGC system consists of three generating thermal units of equal size. The areas are comprise of reheat type thermal units either single stage or double stage turbine operation. For a realistic study of the system, all possible constrains like GRC, DB and delay in communication channel are considered. Bias setting, B_i, is considered for all the three units. *Fig.1* shows the basic block diagram of AGC system in Transfer Function form. *MATLAB R2009a* version has been used to obtain the dynamic responses of the system for 10% load changes in all the three areas. The system data has been taken form [2] and reported in appendix-1.

Model of Two- Stage Reheat Turbine

The approximated Transfer Function (T.F) of two-stage reheat turbine is modeled in [2]. This has been used to demonstrate the effect of small load perturbation in AGC system. *Fig. 2(a)* and *2(b)* shows the T.F representations and schematic of two-stage reheat turbine, respectively. It comprises four main cylinders as very high pressure (VHP), high pressure (HP), intermediate pressure (IP) and low pressure (LP). MW rating of each cylinder is α, β, γ, and δ so that $(\alpha+\beta+\gamma+\delta=1)$.

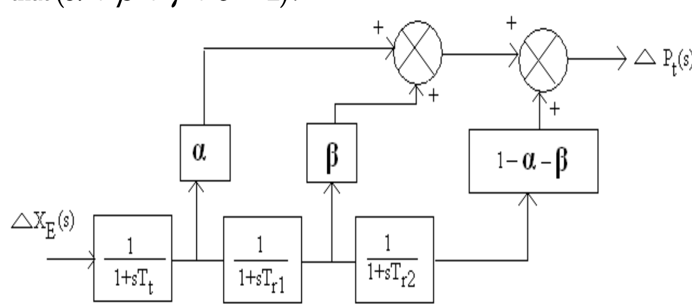

Fig. 2(a): T.F model of two-stage turbine

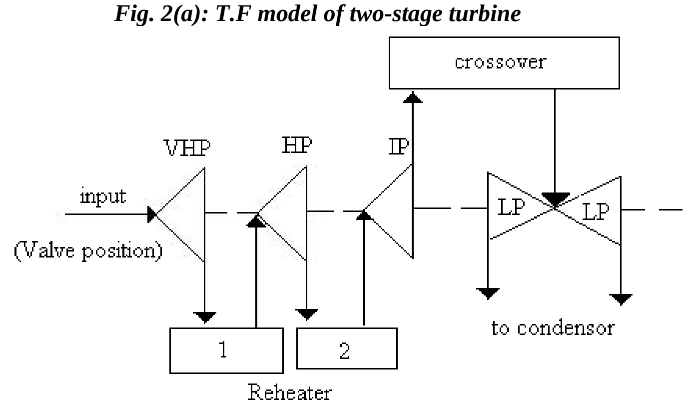

Fig. 2(b): Schematic diagram of two-stage turbine

ISSN: 2277-9655
Impact Factor: 1.852

Linear approximated T.F of two-stage turbine is defined by eq^n: (1).

$$G_T(s) = \frac{1+s\{K_{r1}(T_{r1}+T_{r2})+K_{r2}T_{r2}\}+s^2T_{r1}T_{r2}}{(1+sT_t)(1+sT_{r1})(1+sT_{r2})} \;--(1)$$

Effect of Change of Speed Regulation Parameter

This paper demonstrates the effects of variation of speed regulation constant (R_i) without affecting the dynamic performances of AGC system. 10% load perturbation in all area is considered. Initially R_i of 4% is considered for all the plants and dynamic responses are given in *Fig. 4 and 5*. The value of R_i is increased in steps from 4% to 7% in steps and responses are shown in *Fig. 7*. It is observed that system oscillation increases and system approaches to instability. Further analysis has been made to fix R_i in area-1 and change the same in area-2 and area-3 in steps and responses are given in *Fig. 8 and 9*. It is clearly seen that frequency oscillation and overshoots of the responses increases and it approaches to instability.

Simulink Results

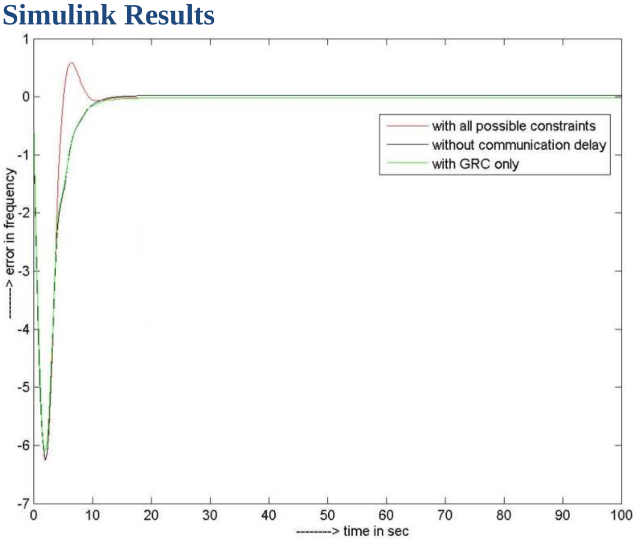

Fig. 3: Frequency error in three area Non-Reheat type system in CT domain

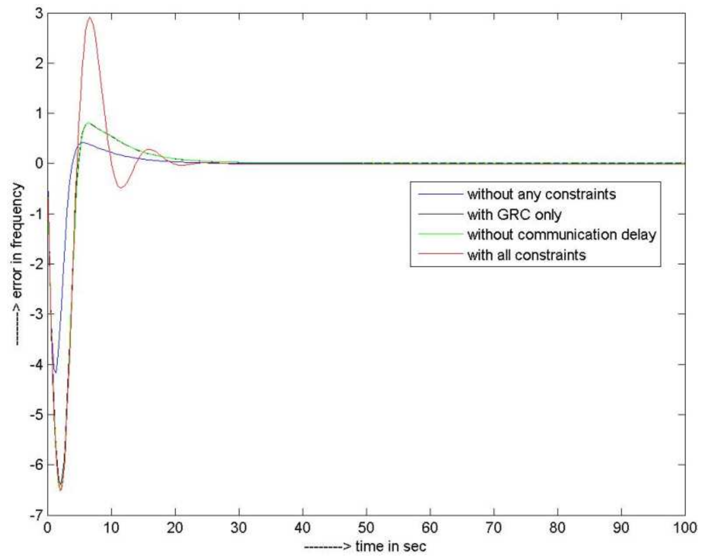

Fig. 4: Frequency error in three area Reheat type system CT domain

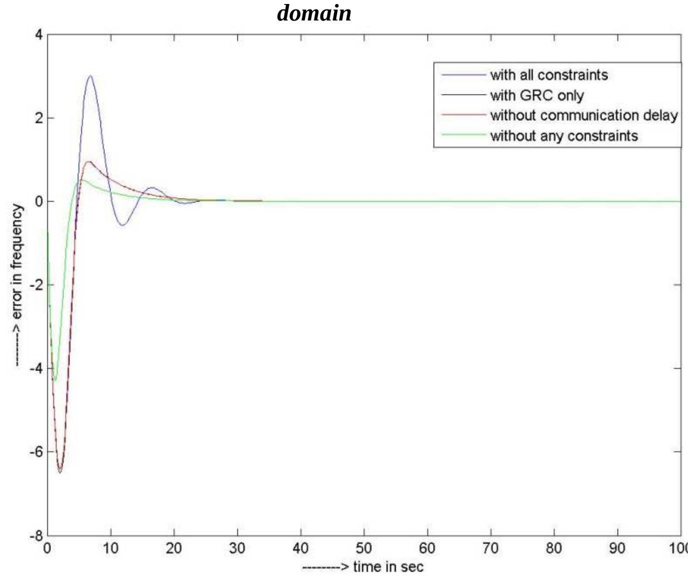

Fig. 5: Frequency error of three area system in DT domain

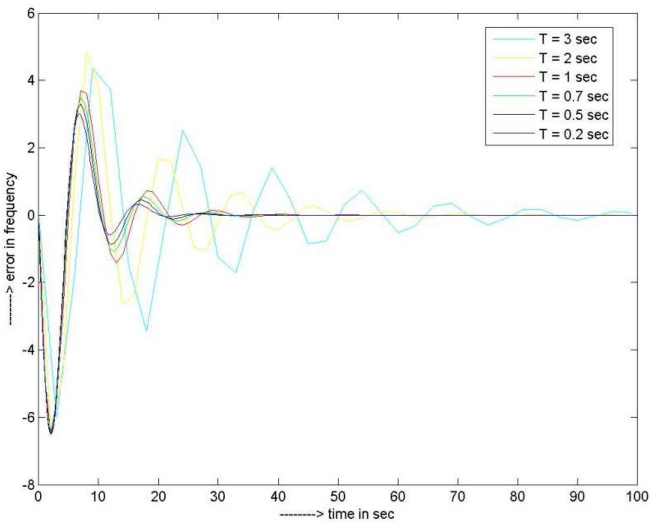

Fig. 6: Frequency error with different values of sampling time

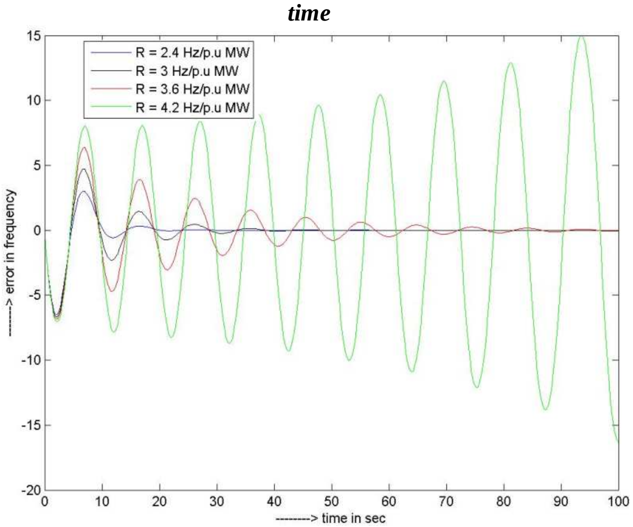

Fig. 7: frequency error in three area system with different values of speed regulation parameter

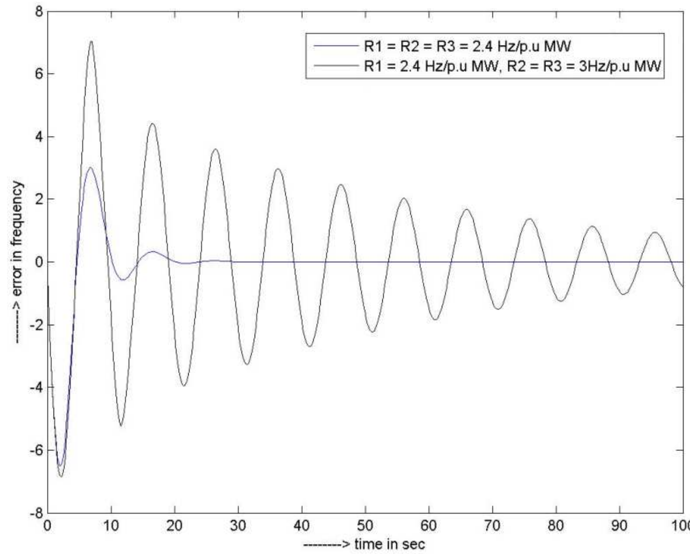

Fig. 8: Frequency error in three area system

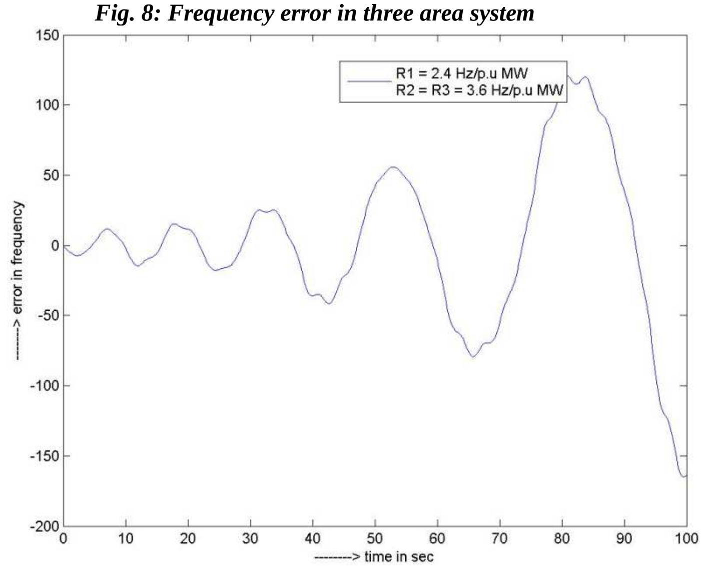

Fig. 9: Frequency error of three area system with R_i is 6% of nominal value of unit 2 & 3

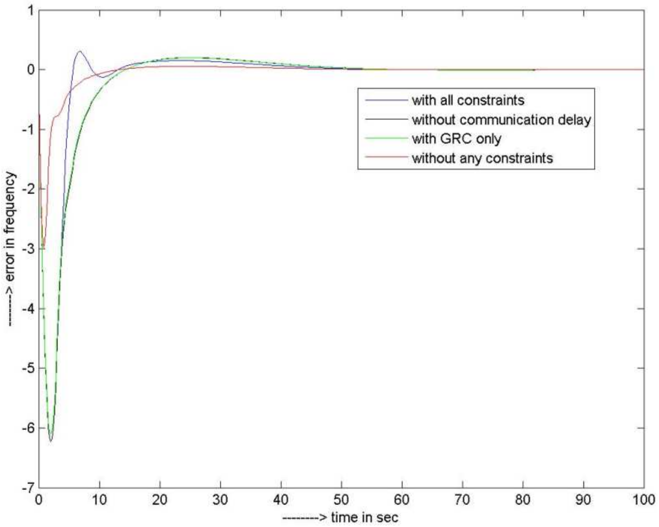

Fig. 10: Frequency error of three area system with two stages reheat turbine

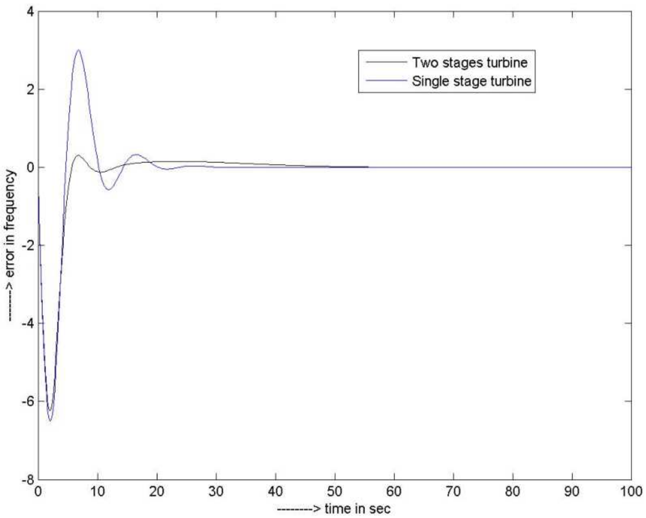

Fig. 11: Frequency error in three area system

Observation

Following points are observed from the SIMULINK results-

- Sluggishness of frequency response is increased in reheat type thermal system compare to non-reheat type unit, *Fig. 3 and 4*.
- System frequency gets steady within 10-12 sec when it studied with all possible constraints, *Fig. 4*.
- Undershoots of the system responses get increased with physical constraints.
- Oscillation of the frequency error is observed with the addition of communication delay in the system, *Fig. 4*.
- *Fig. 6* reveals that system responses get oscillating with increase of sampling time constant, but the observation also reveals the that system retain its stability for higher values of sampling time compare to usual value used in practice.
- System approaches to instability with increase of speed regulation parameter, *Fig. 7*.
- It is observed from *Fig. 10 and 11* that dynamic performances of multi-area system with double stage turbine is far better than the single stage turbine operation.
- It is clear from *Fig. 11* that the settling time of frequency dynamics of power system is about 6-8 sec for two-stage whereas it takes 16-18 sec to settle down for single stage turbine operation.

Conclusion

This paper made an attempt to study of dynamic responses of a multi-area system considering all possible physical constraints present in power system. The system gets non-linear when all constraints are included. System oscillations and undershoot in amplitude both are increased due to the effect of system constraints. It is concluded from the output results that the system response is highly affected by communication delay and other constraints. The oscillations of frequency responses increases with increase of R_i and sampling time constant (T), therefore it is suggested that it must keep at low level to get better dynamic performances of AGC system. The performance of two-stage turbine is quite better that single-stage operation while considering all constraints.

If the system uncertainties, parameters variation and load perturbation are increased then the conventional controllers can be replaced by intelligent controllers.

References

[1] Yang et. al., "*A preliminary study of AGC structure for a regional system considering communication delays*", IEEE trans., vol. 1, June 2005, pp: 618 – 623.
[2] J.Nanda et. al., "*Some New findings on Automatic Generation Control of an Interconnected Hydro-Thermal System with Conventional controllers*", IEEE Trans. on Energy Conversion, Vol. 3, No. 1, 2006
[3] Sheikh et. al., "*Improvement of load frequency control with Fuzzy gain scheduled SMES unit considering governor dead band and GRC*", ICECE 2008, vol. 1, December 2008, pp: 1 – 6
[4] Nanda et. al., "*Maiden application of bacterial foraging based optimization technique in multi-area AGC*", IEEE trans. In power system, vol. 24, May 2009, pp: 602 – 609

[5] Mohamed et. al., "*Decentralized model predictive based load frequency control in an interconnected power system*", Energy conversion and Management, vol. 52, 2011, pp: 1208 – 1214
[6] Hemin Golpira et. al., "*Effect of physical constraints on AGC dynamic behavior in an interconnected power system*", Int. Journal of Advanced Mechartronics Syst., vol. 3, no. 2, 2011, pp: 79 – 87
[7] L.Shanmukha Rao et. al., "*Recent Philosophies of AGC of a Hydro – Thermal System in deregulated environment*", IJAET, vol. 2, Issue 1, Jan 2012, pp: 282 – 288
[8] Naimul Hasan et. al., "*Real Time Simulation of Automatic Generation Control for Interconnected Power system*", International Journal on Electrical Engineering and Informatics, Vol.-4, Number 1, March 2012, pp: 40-51
[9] Sandeep Kumal et. al, "*AGC and AVR of Interconnected Thermal Power System while considering the effect of GRC's*", IJSCE, vol.-2, Issue 1, March 2012.
[10] Sujit Bhat et. al., "*Design and analysis of Fuzzy Logic Controller for Load Frequency Control of Power System*", ICCCE 2012, 12 & 13 April, 2012.
[11] G. Karthikeyan et. al., "*Load Frequency control of three area system with time delays using Fuzzy Logic Controller*", IJESAT, vol. 2, Issue 3, May – June 2012, pp: 612 – 618.
[12] Dr. S. Srinivasa Rao, "*Implementation of load frequency control of Hydro – Thermal System under Restructured Scenario employing Fuzzy Controlled Genetic Algorithm*", IJAREEIE, vol. 1, Issue 1, July 2012, pp: 1- 6
[13] Atul Lkhe et. al., "*Load frequency control using Fuzzy logic controller of Two area thermal – thermal power system*", IJETAE, Vol. 2, Issue 10, October 2012, pp: 425 – 428
[14] Ravi Shankar et. al., "*Optimal Controller design for thermal power system with feedback linearization*", IJECE, vol. 2, Issue 5, October 2012, pp: 672 – 680
[15] Krishna Arora et. al., "*Load frequency control of Interconnected hydro – Thermal system with conventional and expert controllers*", Buletin Teknik Electro dan Informatika, vol. 1, no. 4, December 2012, pp: 255 – 262
[16] J.NANDA ET. AL., "*Automatic Generation Control of a multi area power system with conventional integral controllers*".

APPENDIX – 1

P_r = rated power in two areas = 2000MW
f = nominal frequency of operation = 60Hz
T_{12} = synchronizing time constant = 0.086 sec
B_i = biasing factor = 0.425
K_{ps} = gain of power system = 120
T_{ps} = time constant of power system = 20 sec
T_t = turbine time constant = 0.3 sec
T_{sg} = speed governor time constant = 0.08 sec
K_{sg} = gain of speed governor = 1
K_{r1} = K_{r2} = steam turbine reheat constant = 0.5
T_{r1} = T_{r2} = steam turbine reheat time constant = 10 sec R_i = speed regulation constant = 2.4 Hz/p.u MW
K_I = gain of Integral controller = 0.4sec
GRC = Generation rate constraint = ± 0.5
DB = Dead band = 0.036 sec
Time delay in communication channel = 1 sec