Melioration of Dynamic Performance of LFC System of Multi Area Power System using Allochronic Parallel Tie-lines

A. Suresh Babu

Abstract— **In an interconnected power system, as a power load demand varies randomly, both area frequency and tie-line power interchange also vary. The objectives of LFC are to minimize the transient deviations in area frequencies and tie-line power interchange, and to ensure their steady state errors to be zeros. In this paper an analysis of improvement of dynamic performance of multi area load frequency control system (LFC) system interconnected via allochronic parallel tie-lines when subjected to parametric uncertainties is presented. In the present work we have chosen three generators i.e. hydro, thermal and gas turbo generators in each area. The high voltage DC (HVDC) link is connected in parallel with AC line to interconnect and this HVDC link is considered to be operating in constant current control mode. The power flow deviation through dc link is modeled based on frequency deviation at rectifier end. The effectiveness of asynchronous parallel tie lines in improving the dynamic performance of LFC system is demonstrated through MATLAB/Simulink. Automatic Generation control (AGC) and LFC are used in this report interchangeably.**

Index Terms— Load Frequency control, Automatic generation control, allochronic parallel tie-line, HVDC link.

I. INTRODUCTION

As the power industry all over the world is increasing with very much rapid speed, it is the responsibility of the electrical engineers to deliver economical, adequate, reliable and quality power to the consumers. The main aim of LFC is to govern the output powers of power plants so as to keep the frequency of power system and tie-line powers within prescribed limits. Many control strategies have been proposed and investigated by many researchers over the past several years on LFC of power system. D.P. Kothari and K.P.Singh [1] have extensively studied the improvement of dynamic performance of LFC of the two area power system. Vikas choudhary, Abdul Kadir and Prathibha Gupta [2] discussed the advantage of parallel ac-dc power transmission for the improvement of transient and dynamic stability and damp out oscillations have been established. The main object is to emphasize the possibility of simultaneous ac-dc transmission with its inherent advantage of power flow control. Tolumoye J. Ajoko and Emmanuel M.Adigio [3] have presented mathematical modeling of gas turbine and diagnosis. S.Ramesh and A.Krishnan [4] have presented about the frequency stabilization using AC-DC parallel tie-lines is been studied. Aidin Sakshavathi, Gevork B.Gharehpetian and Seyed Hossein [5] have provided a detail study investigating the problem of load-frequency control in the interconnected power systems in order to obtain robustness against uncertainties. Sathan and Akhilesh Swarup [6] provide detail information about AGC in interconnected two area system. This study includes the operation of the two areas AGC. V.Hicks [7] gives the information regarding to Automatic Generation Control. He has been explaining the mismatch in the load changes and frequency deviations in the two area interconnected systems. Umashankar [8] have presented a paper on the operation and improvement of dynamic performance of generating systems. L.Shanmukarao and N.Venkata ramana [9] presented a critical review of AGC of hydro thermal system in deregulated environment. It has paid particular attention to categorize various AGC strategies in the literature that highlights its salient features. P.Kundur [10] has defined the details of automatic generation control, mathematical modeling and analysis of generating systems.

The operation and control of power system becoming highly complex due to many number of interconnection where the disturbance due to load variations in one area leads to change in frequency and tie-line power in the neighboring areas, which causes a serious problem of LFC. To overcome the problem of LFC this paper takes the advantage of power modulation control offered by HVDC link to enhance the system damping, but also extends to stabilize frequency oscillations in an AC power system. By utilizing the interconnections between AC power systems as control channels of power modulation of HVDC link, this creates a new application of the HVDC link to stabilize frequency

Manuscript received July 27, 2014
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oscillations. The proposed control can also be coordinated with conventional governor control for greater efficiency.

The main contributions of the present work are:

a) Simulation of a realistic power system using MATLAB/Simulink tool.

b) Improving the dynamic response of LFC system in a realistic two area interconnected power system considering parallel AC-HVDC tie lines.

c) Comparing the dynamic responses of the LFC of the power system considering AC tie lines and parallel AC-HVDC tie lines.

d) Examining the effect of Load disturbance by varying the Step load perturbation from 1% to 4%.

II. Dynamic Mathematical Model

Electric power systems are complex, nonlinear dynamic system. The Load Frequency controller controls the control valves associated with High Pressure (HP) turbine at very small load variations. The system under investigation has tandem-compound single reheat type thermal system. Each element (Governor, turbine and power system) of the system is represented by first order transfer function at small load variations in according to the IEEE committee report. Figure 1 shows the transfer function block diagram of a two area interconnected power system. Each area comprises reheat thermal, hydro and gas generating units and the two areas are interconnected by AC-HVDC parallel tie-lines.

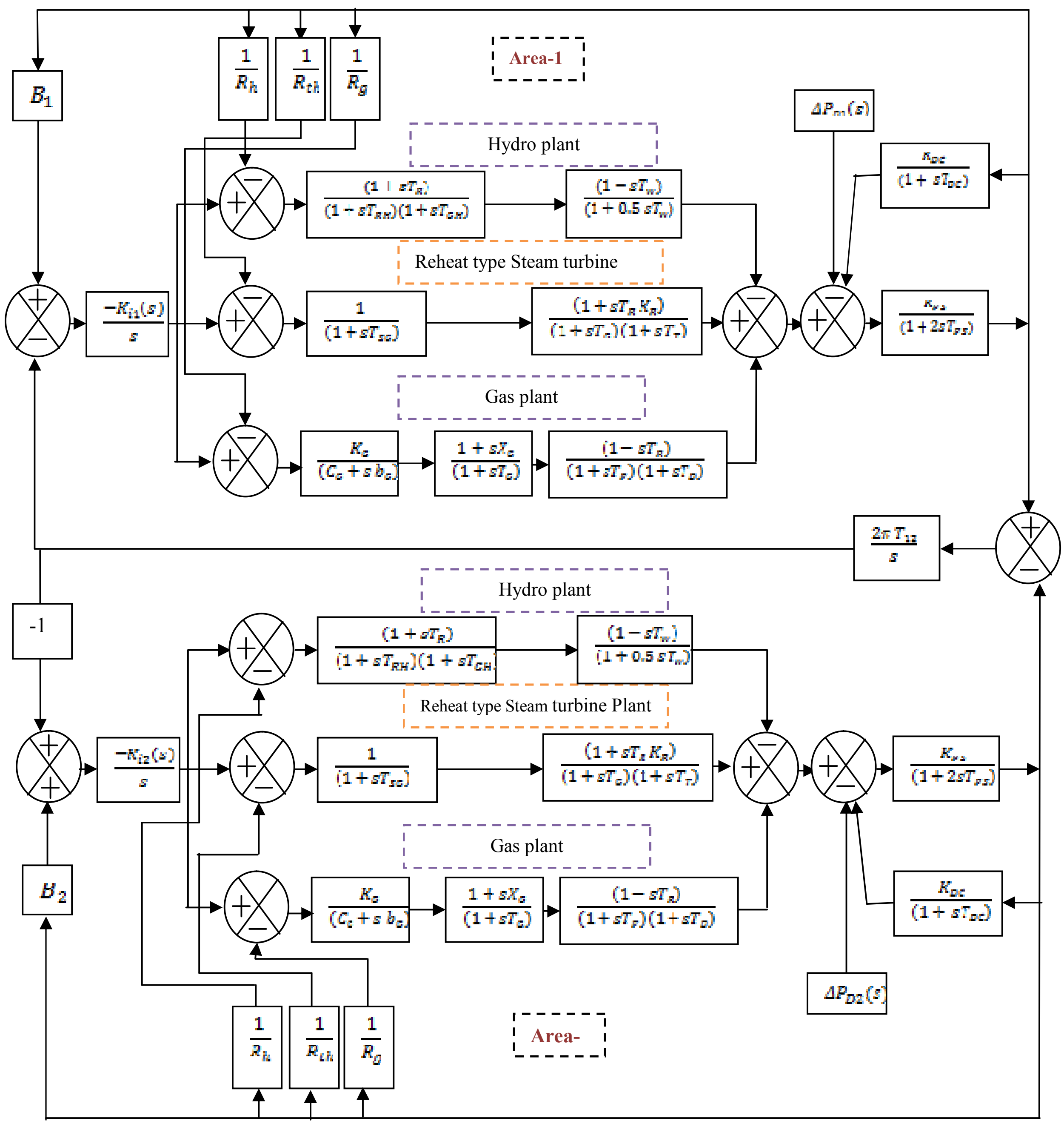

Fig. 1. Two Area load following Hydro thermal system with parallel HVDC link

III. Modeling of HVDC link

One of the major applications of HVDC transmission is operating a HVDC link in parallel with an EHVAC link interconnecting two control areas. With these developments, the power utilities are capable to fulfill the requirements of good quality of electric power supply to consumers to some extent but on the other hand the operational and control aspects of these systems are subjected for their review.

The two area interconnected power system model with AC-HVDC parallel tie-line is shown in figure 2. Parallel operation of A.C. link with HVDC link to interconnect the two or more AC power system areas increases the stability limit of the system. Here the HVDC line is an asynchronous link between two rigid (frequency constant) systems Where otherwise slight transfer control in a small capacitive link. Each area comprises reheat thermal, Hydro and Gas generating units and the equal areas are interconnected by AC-DC tie-lines.

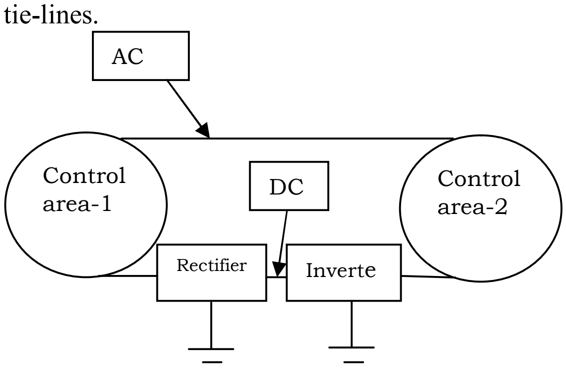

Fig.2. *Two area power system interconnected through AC-DC parallel tie-lines*

The simulation of this interconnected power system in a new power system environment is based on concepts of considering variety of generators with their corresponding participation rates in each area and parallel AC-DC Tie-lines.

The transfer function of HVDC link is shown figure 3.

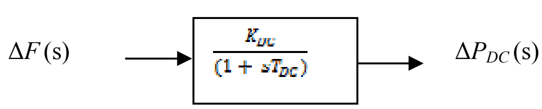

Fig.3. *Transfer function of HVDC link*

IV. Results analysis

In this paper, a two-area interconnected system contains reheat type steam, hydro and gas turbines in each area are considered to design and validate the effectiveness of the HVDC link in improving the dynamic performance of LFC system. System data are given in an appendix. The simulation study is carried out by using MATLAB/ Simulink.

A) Frequency deviation responses with AC line

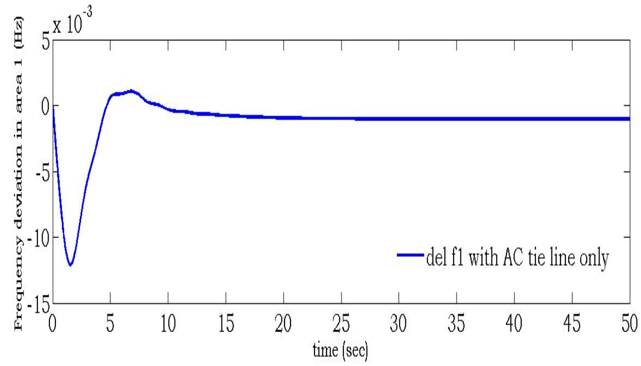

Fig.4*: Frequency deviation in area-1 with AC tie-line*

The frequency variation in area-1 is starts from 0Hz and it comes to steady state at 0.002 Hz, the system frequency contains some dampings at initial, the settling time for area-1 is 15sec.

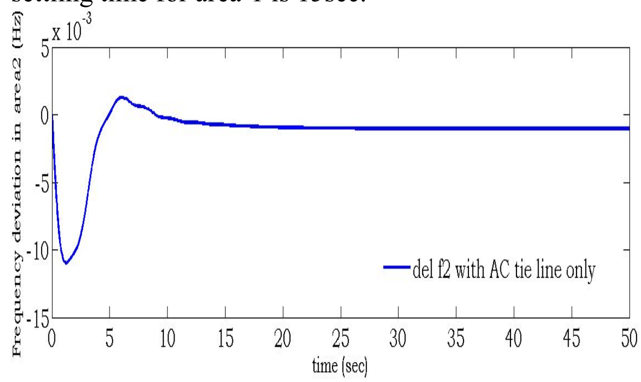

Fig.5*: Frequency deviation of area-2 with AC tie-line*

In area-2 frequency variation starts from 0Hz and comes to steady state at 0.002Hz. The settling time for area-2 is 15 sec.

B) Tie-line power deviation responses with AC line

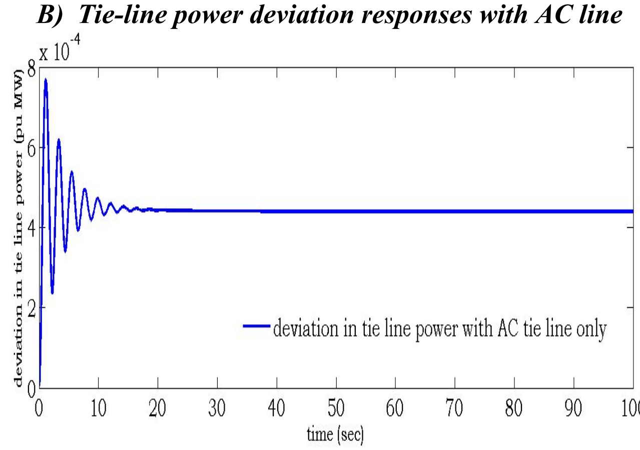

Fig.6*: Tie-line power deviation response with AC tie-line*

The AC tie-line contains distortions at time of initialization, these dampings are sinusoidally varying and at a particular period of time the tie-line power deviations will become stable. The settling time for tie-line power deviations is 15sec.

C) Frequency deviation responses with AC-DC line

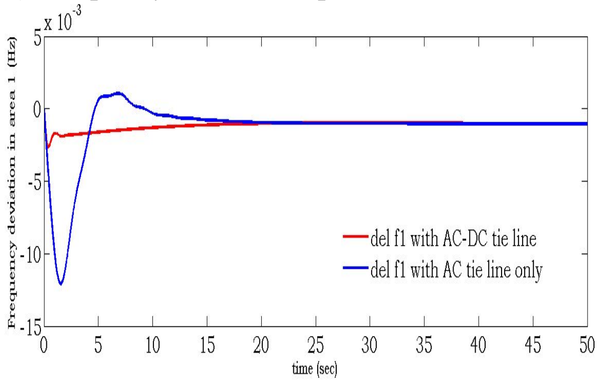

***Fig.7**. Frequency deviation response in area-1*

The frequency deviation in area-1with AC tie line taking 15sec of time to become stable and area-1 with AC-DC tie-line comes to stable in less than 25sec of time.Though the settling time for both the systems is same, but the dampings and frequency deviations are been reduced in AC-DC parallel tie-lines.

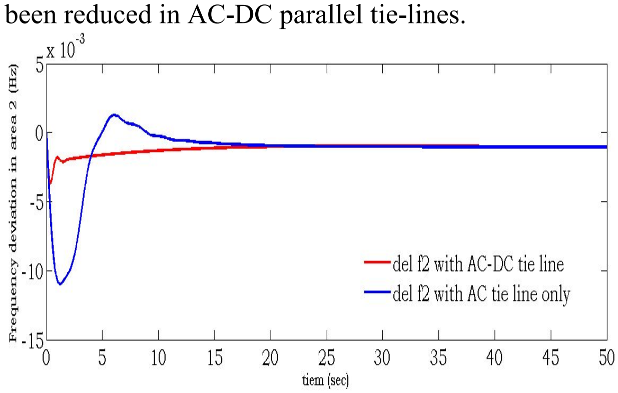

***Fig.8**. Frequency deviation response in area-2*

The frequency deviation in area-2 with AC tie line taking 15sec of time to become stable and area-2 with AC-DC tie-line comes to stable in less than 25sec of time. The frequency dampings will be absent after reaching stable point.

D) Tie-line power deviation responses with AC line

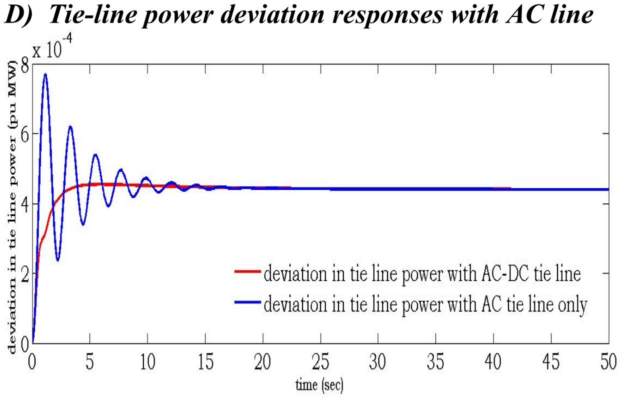

***Fig.9**. Tie-line power deviation response with AC tie -line and AC-DC parallel tie line*

The tie-line is interconnecting cable, which is connecting two areas in a power system. Here a AC-DC parallel tie line is used in order improve the dynamic performance of the system, the tie-line power deviation in AC tie-line has more number of dampings compared to AC-DC parallel tie-line and the settling time is comparatively less than AC tie line.

E) Frequency deviation responses with AC-DC line with different SLPs

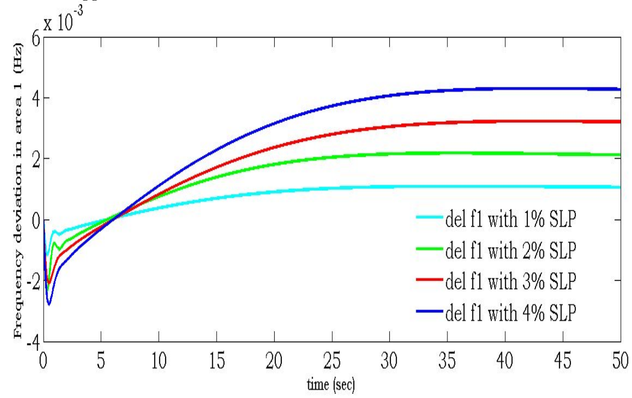

***Fig.10**. Frequency deviations in area-1 with different SLPs*

In area-1 the frequency deviations are been varying with the increase in step load perturbations, different SLPs are considered to analyze the frequency deviations.

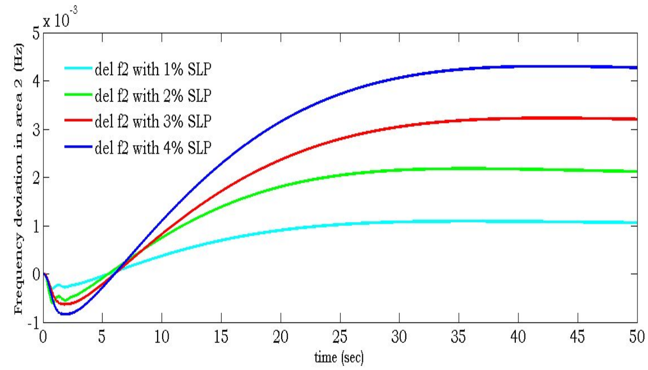

***Fig.11**. Frequency deviations in area-2 with different SLP's*

Similarly the frequency deviations in area-2 are varying with the step load perturbations.

F) Tie-line power deviation responses with AC-DC line with different SLPs

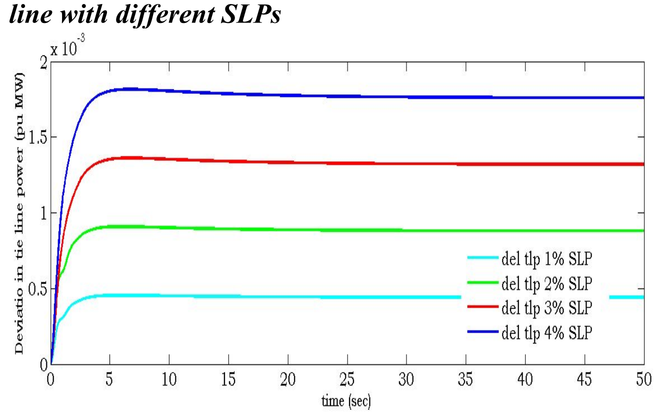

***Fig.12**. Tie-line power deviation responses with different SLPs*

As the step load perturbations percentage is increasing the tie-line power deviation is increasing, the settling time for tie-line bias control is less for less step load perturbations. As SLP increase from 1% to 4% the tie-line power deviations also increasing.

Fig.10, Fig.11 and Fig.12 shows the Dynamic responses for step load perturbations varying from 1% - 4%. By observing all the results we can see that the dynamic performance of the system could be improved.

Conclusions

An attempt is made in this paper to improve the dynamic performance of LFC of the two area interconnected power system by considering HVDC parallel tie line. To improve the dynamic response of LFC system in a realistic power system environment considering HVDC tie line in parallel with AC tie line. Dynamic responses are obtained for wide range of variation in load disturbance from 1% to 4% which satisfy the LFC requirements. The simulation results show that proposed control strategy considering parallel AC-HVDC tie line is very effective and guarantees good performance.

Appendix

P_r=2000 MW (Rated capacity of each area)
P_L=1740 MW (Nominal load of each area)

f=50 Hz;	H=5 MWsec/MVA;
D=0.0145 pu MW/Hz;	K_{PS}=68.9655 Hz/pu MW;
T_{PS}=11.49sec;	T_{SG}=0.06sec;
T_T=0.3sec;	T_{12}=0.043;
R_{TH}=R_H=R_G=2.4 Hz/puMW	
B_1=B_2=0.43112;	K_R=0.3sec;
T_R=10.2sec;	T_W=1.1sec;
T_{RS}=4.9sec;	T_{RH}=28.749sec;
T_{GH}=0.2sec;	X_G=0.6sec;
Y_G=1.1sec;	C_g=1;
b_g=0.049sec;	T_F=0.239sec;

HVDC link parameters
K_{DC}=1,T_{DC}=0.2sec

References

[1]K.P. sing parmar, S.Maji, D.P. Kothari. "Improvement of dynamic Performance of the LFC of the two area power system: An analysis using Mat lab". International journal of computer applications (0975-8887), Volume 440-No10 February 2012.

[2]Visas Choudary, Abdul Khadir, Prathiba Gupta "A novel idea: simultaneous ac-dc power transmission" international journal of advanced engineering technology.

[3]Toulmoye J.Ajoko and emmanule M. Adigio "mathematical modeling of gas turbine diagnosis" journal of petroleum and gas exploration research(ISSN 2276-6510) vol. 2(9) pp. 161-167, October,2012.

[4]S. Ramesh and A. Krishnan "stabilization of frequency deviation in AC-DC interconnected power systems using supervisory fuzzy controller". Tamkang journal of science and engineering, vol.14, no. 4, pp. 341-349(2011).

[5]Adini Sakhavati, Gevork B.Gharehpetian, Seyed Hossein "Decentalized robust load frequency control of power system based on quantative feed back theory". Turk J Elec & comp sci, vol.19, No.4, 2011.

[6]Sathans, Akhilesesh Swarup "Automatic generation control of two area system with and without SMES: from conventional to modern and intelligent control" International journal of engineering science and technology.

[7]Glenn V. Hicks, B.Eng "An investigation of automatic generation control of an isolated power system". Has been proposed to say about automatic generation control.

[8]Umashankar "Modeling of Automatic Generation Control of Thermal Unit". Which has been presented the working and its related information.

[9]L. Shanmukha rao N. Venkata Ramana "Recent philosophies of AGC of a hydro-thermal system in a de-regulated environment" Intrenational journal of advances in engineering & technology, Jan 2012 ISSN: 2231-1963.

[10] R.Francis, Dr.I.A.Chidambaram "automatic generation control for an interconnected reheat thermal power system using wavelet neural network controller" international journal of emerging technology and advanced engineering (ISSN 2250-2459, volume 2, Issue4, April 2012).

[11] D.P. Kothari and I.J. Nagrath. Modern Power System Analysis. 4th ed.New Delhi: McGraw Hill; 2011.

[12] P. Kundur. Power System Stability and Control. Fifth reprint. New Delhi: Tata McGraw Hill; 2008.

[13] IEEE power engineering systems committee report. Hydraulic turbine and turbine control models for system dynamics. IEEE Trans. Power. Syst. vol.PWRS-7, 1992.

[14] K.S.S.Ramakrishna, Pawan Sharma, T.S.Bhatti. "Automatic Generation Control of interconnected power system with diverse source of power generation".

[15] A.Suresh Babu, Ch.Saibabu, Sivanagaraju."Implementation of load following in multi area hydrothermal system under restructured environment".

[16] Sivanagaraju."power system operation and control". Load frequency control, Modeling of turbines and governing systems.

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