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Load Frequency Control in Power System

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Abstract

This research presents decentralized control scheme for Load Frequency Control in a multi-area Power System by appreciating the performance of the methods in a single area power system. A number of modern control techniques are adopted to implement a reliable stabilizing controller. An attempt has been undertaken aiming at investigating the load frequency control problem in a power system consisting of two power generation unit and the dynamic performance of Load Frequency Control (LFC) in three-area interconnected hydrothermal reheat power system by the use of Artificial Intelligent. In this propose scheme, control methodology developed using conventional controller, for three-area interconnected hydro-thermal reheat power system. In this research, area-1 and area-2 consists of thermal reheat power plant whereas area-3 consists of hydro power plant. Further in this scheme, the combination of most complicated system like hydro plant and thermal plant with reheat turbine are interconnected. The performances of the controllers are simulated using MATLAB/SIMULINK package. The robustness and reliability of the various control schemes is examined through simulations.

Keywords: *Load Frequency Control (LFC), Area Control Error (ACE), Multiple generators, Load control in interconnected systems, Tie-line power, Automatic Generation Control (AGC).*

I. Introduction

In an electric power system, Load Frequency Control (LFC) is a system to maintain reasonably uniform frequency, to divide the load between the generators and to control the tie-line interchange schedules. Load Frequency Control badly needed for power system because if the normal frequency is 50 Hertz and the system frequency falls below 47.5 Hertz or goes up above 52.5 Hertz then the blades of the turbine are likely to get damaged so as to prevent the stalling of the generator. Here given some model that how to control load frequency in power system. Two main variables that change during transient power load are- area frequency and tie line power inter change (Load Frequency Control (LFC), 2013). The concept of Load Frequency Control (LFC) is directly related to the aforementioned variables since the task is to minimize this variation (Load Frequency Control (LFC), 2013). The key thing is to maintain the steady state at null position. In this vein, effective measures like Active Disturbance Rejection Control (ADRC) have been developed that allow practical control (Load Frequency Control (LFC), 2013). The main bifurcation between frequency and voltage in power system is on the account of active and reactive power. The dependency of frequency is on active power whereas that of voltage is on the reactive power(Load Frequency Control (LFC), 2013). The combination of active power and frequency control is generally known as Load Frequency Control (Load Frequency Control (LFC), 2013). Modern day power systems are divided into various areas. For example in Bangladesh, there are many plants, e.g., Ashugonj Power Plant, Bheramara Power Plant etc. Each of these areas is generally interconnected to its neighboring areas. The transmission lines that connect an area to its neighboring area are called tie-lines. Power sharing between two areas occurs through these tie-lines. Load frequency control, as the name signifies regulates the power flow between different areas while holding the frequency constant.

The remainder of this paper is organized as follows: Section II presents, the Problem Formulation in contrast with single and multi-area. In Section III presents, illustrate the technical performance of proposed AGC scheme through computer simulations on single and multi-area interconnected test system. Finally in Section IV presents, discussions and the conclusions with future work

II. Problem Formulation

If a change in load is taken care by two generating stations running parallel then the complex nature of the system increases. The ways of sharing the load by two

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machines are as follow; two generating stations that are connected to each other by tie line. If the change in load is either at A or at B and the generation of A is regulated so as to have constant frequency then this kind of regulation is called as Flat Frequency Regulation. The other way of sharing the load is that both A and B would regulate their generations to maintain the frequency constant. This is called parallel frequency regulation. The third possibility is that the change in the frequency of a particular area is taken care of by the generator of that area thereby maintain the tie-line loading. This method is known as flat tie-line loading control. In Selective Frequency control each system in a group is taken care of the load changes on its own system and does not help the other systems, the group for changes outside its own limits. In Tie-line Load-bias control, all the power systems in the interconnection aid in regulating frequency regardless of where the frequency changes originates.

A. Single area power systems

The Load Frequency Control (LFC) problem for single area thermal power systems is including Generation Rate Constraint (GRC) is presented in (A P Battebury *et al.* 1974). The LFC scheme of one-area thermal system with single time delay is presented in (Pan CT *et al.* 1989). The LFC with multi-source (Thermal–Hydro) as single area is proposed in (Wang Y *et al.* 1994). The LFC problem for single area hydro-power system is presented in (Jiang en L *et al.* 2012). The transient speed response of a single, isolated, governed hydro-generator operating at, or near full load is discussed in. The automatic generation control of hydro- plant is presented in (Jiang en L *et al.* 2012). The LFC of an isolated small- hydro-power system with reduced dump load is described in (TS, 2006). This power plant for LFC design consists of governor G_g(s) non-reheated turbine G_t(s), load and machine G_p(s), and 1/R is the droop characteristics, a kind of feedback gain to improve the damping properties of the power system. The dynamics of these subsystems are-

$$G_g(s) = \frac{1}{T_G s + 1},\ G_g(s) = \frac{1}{T_G s + 1}$$

$$G_t(s) = \frac{1}{T_T s+1},\ G_p(s) = \frac{K_P}{T_P s+1}$$

The whole system model can be illustrated by,

$$\Delta f(s) = G(s)u(s) + G_d(s)\Delta P_d(s) = \frac{K_P}{T_T T_P T_G s^2 + (T_p T_T + T_T T_G + T_P T_G)s^2 + (T_P + T_T + T_G)s + (1 + \frac{K_p}{R})}$$

$$G_d(s) = \frac{G_p(s)}{1 + G_g(s)G_t(s)G_p(s)/R}$$

Previous in this system have some problems such as disturbance, fluctuation and LFC is not sufficient enough but in this model most of problems are solved.

B. Two area power systems

The Load Frequency Control (LFC) problem for two area power systems is presented in (Singh *et al.* 2012). Due to non-linearity in the connected load and governor dead bands, the actual system response characteristic is non- linear. Therefore, a linear tie-line bias characteristic does not match the actual system response characteristic (Fosha C *et al.* 1970). This mismatch causes unnecessary fuel consumption and increased wear and tear on generators. The LFC of two-area hydro–hydro-power system with Proportional Integral Derivative (PID) controller based on maximum peak resonance specification that is graphically supported by the Nichols chart is discussed in (Sudha KR *et al.* 2012). The automatic generation of three types of interconnected two-area multi-unit all-hydropower system, all-thermal and thermal-hydro mixed have been investigated in (K Khshian *et al.* 2010). There heat thermal power system with governor dead zone is discussed in (Bahtti P 2010), while reheat thermal power system with GRC is presented in (T. Sou, 2011). The LFC of two-area thermal–thermal power system with time delay is considered in (Shuda KR, 2012). The two-area interconnected thermal reheat power system with Inter- line Power Flow Controller (IPFC) and Redox Flow Batteries (RFB) units for LFC is proposed in (IA Chidambaram et al 2012). The two-area power system consisting of identical reheat turbines interconnected via AC link and AC/DC links are presented for LFC in (Ibraheem *et al.* 2012).

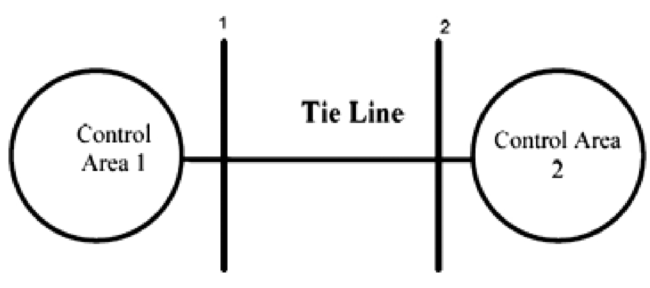


Figure 1: Two-area with Tie-Line Connection.

The control objective is now to regulate the frequency of each area and to simultaneously regulate the tie-line power as per inter-area power contracts.

$\Delta F(s) = [\Delta P_{G1}(s) - \Delta P_{D1}(s) - \Delta P_{tie,1}(s)]$

Let,

$K_{ps,1} = \frac{1}{B_1}$ And $T_{ps,1} = \frac{2H_1}{B_1 f^0}$

Also,

$\Delta P_{tie,1}(s) = \frac{2\prod T_{12}}{s}[\Delta F_1(s)\ \Delta F_2(s)]$

$\Delta P_{tie,2}(s) = -\frac{2\prod a_{12} T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)]$

In two-area power system, in order that the steady state tie line power error be made zero, another integral control loop must be introduced to integrate the incremental tie-line power signal and feed it back to the speed changer. This is accomplished by defining ACE as a linear combination of incremental frequency and tie-line power.

Thus, for control area 1,

$ACE_1(s) = \Delta P_{tie,1}(s) + b_1 \Delta F_1(s)$

$ACE_2(s) = \Delta P_{tie,2}(s) + b_2 \Delta F_2(s)$

There are some problems such as disturbance, accuracy shortage and LFC is not sufficient enough but in this model most of problems are solved.

C. Three area power systems

The Load Frequency Control (LFC) challenges in three area power systems are presented in (Milan, 1972). Those three-area are interconnected (D Rerkpreedapong *et al.* 2003) consists one steam plus one hydro unit, which forms area 1, while one steam plus one hydro unit of area 2 and area 3 with one steam. The thermal power system interconnected as three areas is presented in (SP, 2003). The three interconnected areas that consist of two thermal and one hydro unit in each area is considered in (SP, 2005). Three thermal generating units in each area of three-area interconnected power system are considered in (H Bevrani *et al.* 2009). Two different interconnections (a) Radial type and (b) Ring type with thermal unit in three area power systems have been considered in (F Daneshfar *et al.* 2010). The LFC problem for three-area thermal power system with communication delays is discussed in (W. Jiang L *et al.* 2012). In order to consider AGC, the area-1is modeled by two generators while the other two areas have single generator equivalents of four and three generators in area-2 and area-3, respectively (X.Alrifai MT *et al.* 2011). The LFC for three area power system with time delays has been also discussed in (J Uang CF *et al.* 2006). The load frequency controller for a three area thermal power system is proposed in (F Daneshfar *et al.* 2012). The LFC for three-area power system with different turbine units, such as non-reheat, reheat and hydraulic is considered in (Dong L *et al.* 2012).The transfer of power between two areas is done through tie lines.

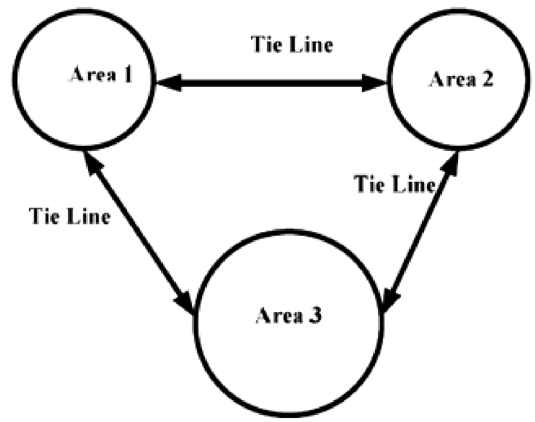


Figure 2: Three-Area inters Connection.

The Transfer Functions of different blocks used in power system model are given below:

Transfer function (T/F) of hydraulic Turbine is,

$$\frac{-T_w.\ S+1}{0.5\ T_{w\ .\ S+1}}$$

T/F of hydraulic Governor is, $\frac{Kd.\ s^2 + Kp\ .\ s + Ki}{Kd\ .\ s^2 + \left(Kp + \frac{f}{R_2}\right)s + Ki}$

T/F of governor (thermal plant) is, $\frac{1}{T_g.\ s+1}$

T/F of steam turbine is, $\frac{K_r T_r.\ s+1}{T_r.\ s+1}$

T/F of Re-heater is, $\frac{1}{T_t.\ s+1}$

And transfer function of Generator is, $\frac{K_p}{T_p.\ s+1}$

Previous in this system have some problems such as accuracy shortage, disturbance, fluctuation and LFC is not sufficient enough but in this model most of problems are solved.

III. Simulation Results

A. Uncontrolled Single-Area

In an uncontrolled single area power system has governor, turbine and inertia load. By changing of value its output looks much better than others and reliable.

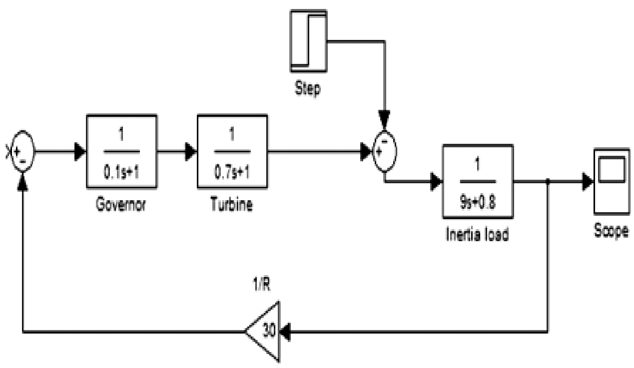


Figure 3: MATLAB Model of an uncontrolled single area power system.

From Fig 4, showing the disturbance Y-axis change of frequency looks stable at point 0-1s with respect to time of X-axis at time 1s it decreasing with respect to time. Afterwards disturbance at point -0.065dB and time scale 1.9s it increasing and oscillating.

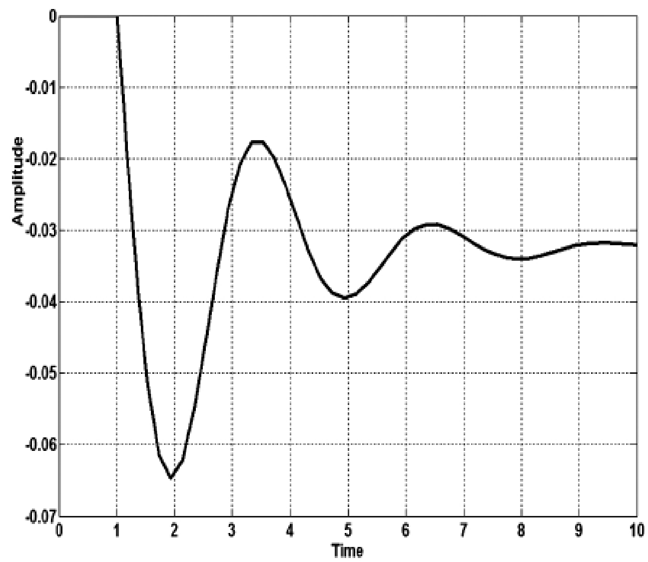


Figure 4: Output of an uncontrolled single area power system.

B. Thermal and Hydro Power Plant

There have a thermal area where the main technique has been applied in generator side where need to have a generator with a tie-line but in this scheme applied two generator parallel in thermal area but another area of hydro there has been used a generator and a tie-line part that's why this scheme is much better than others (Fig-5). By using of two generators in thermal area, the output result looks much more reliable.

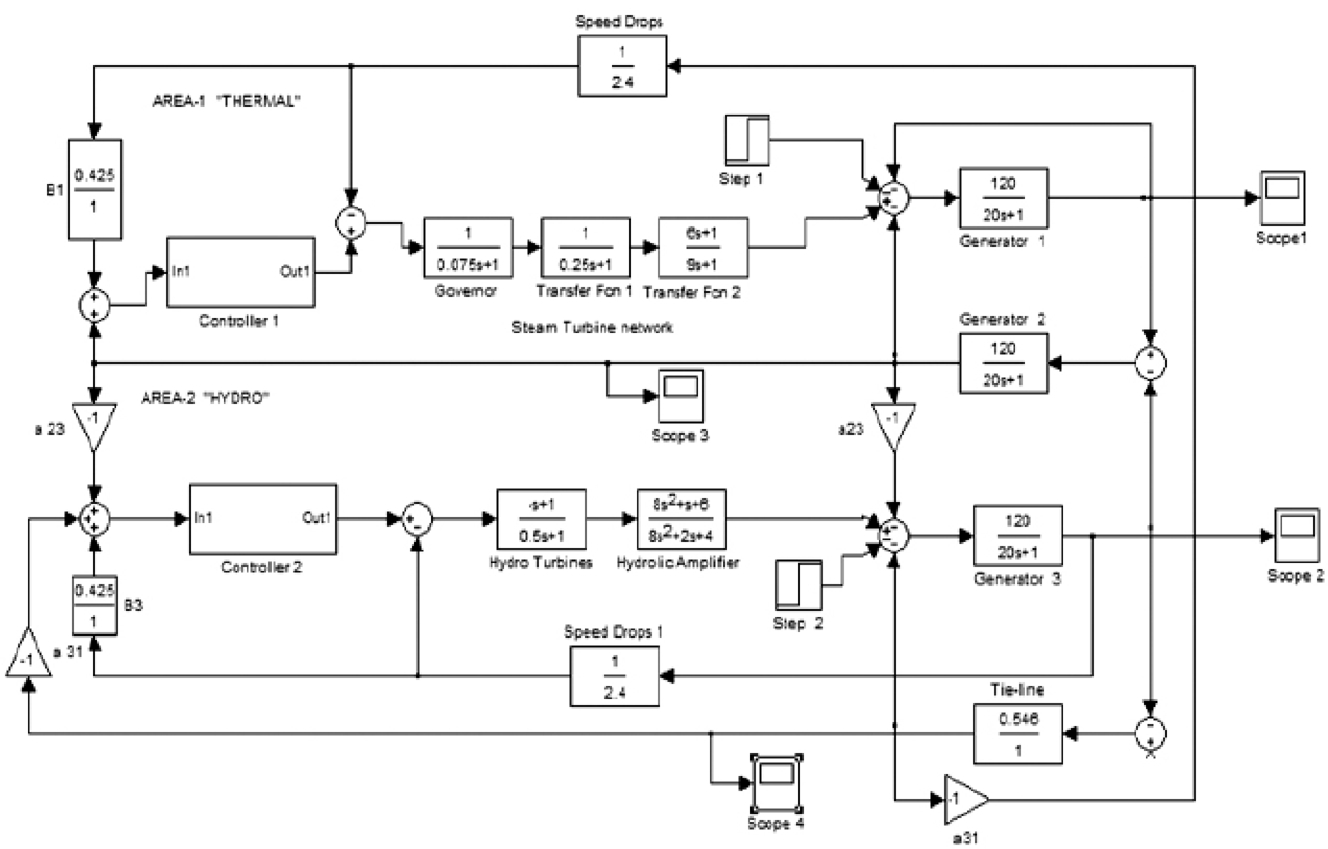


Figure 5: MATLAB Model of two-area Hydro-thermal reheats power system.

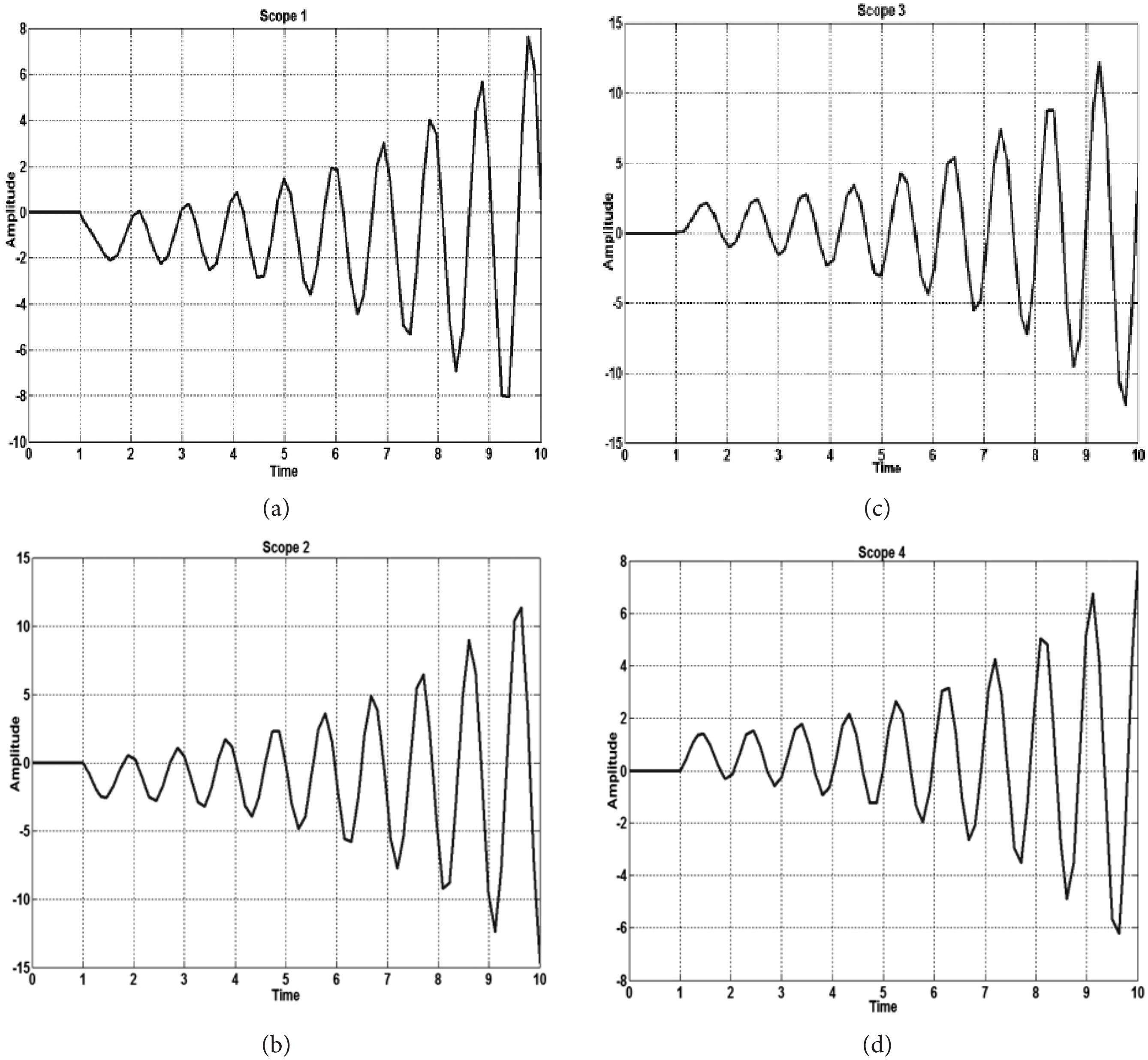


Figure 6: Output of two area hydro-thermal reheats power system.

In Fig 6, there have scopes (a), (b), (c), (d) at time 0-1s change of frequency looks stable then the frequency in scope (a) and (b) start to decreasing from 1-1.5s then increasing with respect to time oscillate and change of frequency fluctuating on the other hand in scope (c) and (d) change of frequency increasing 1-1.5s then decreasing with respect to time oscillate and change of frequency fluctuating.

C. TWO THERMAL AND A HYDRO POWER PLANT

There have three areas where the main technique has been applied in two thermal areas showing that in Fig7. In two thermal area has been used saturation, integrator parts and generator side of second thermal area has been used two generator in parallel but another thermal area and hydro area side have a generator and tie-line parallel that's why this scheme is much better than others. By using of saturation, integrator and two generators in parallel in second thermal area, the output result looks much more reliable.

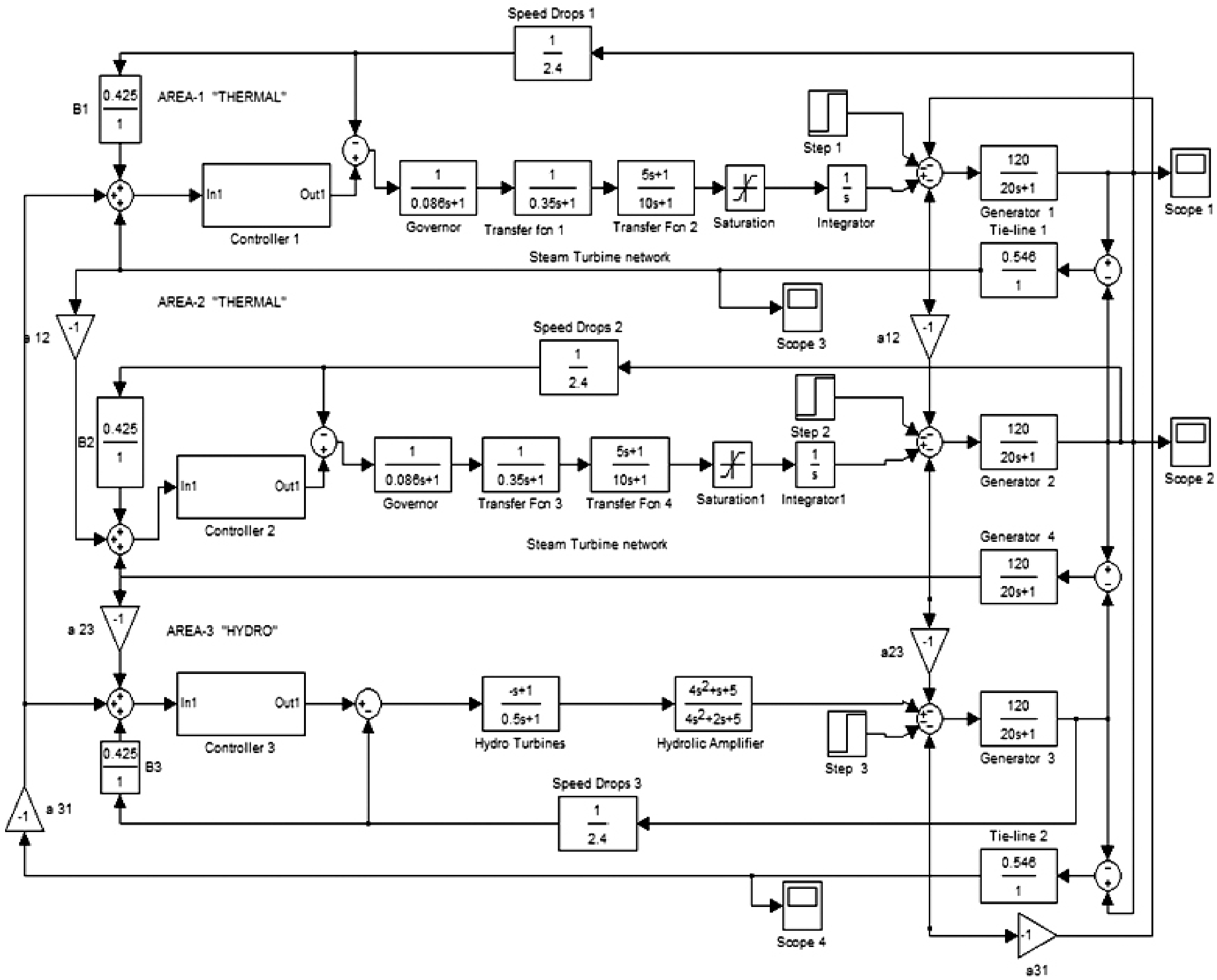
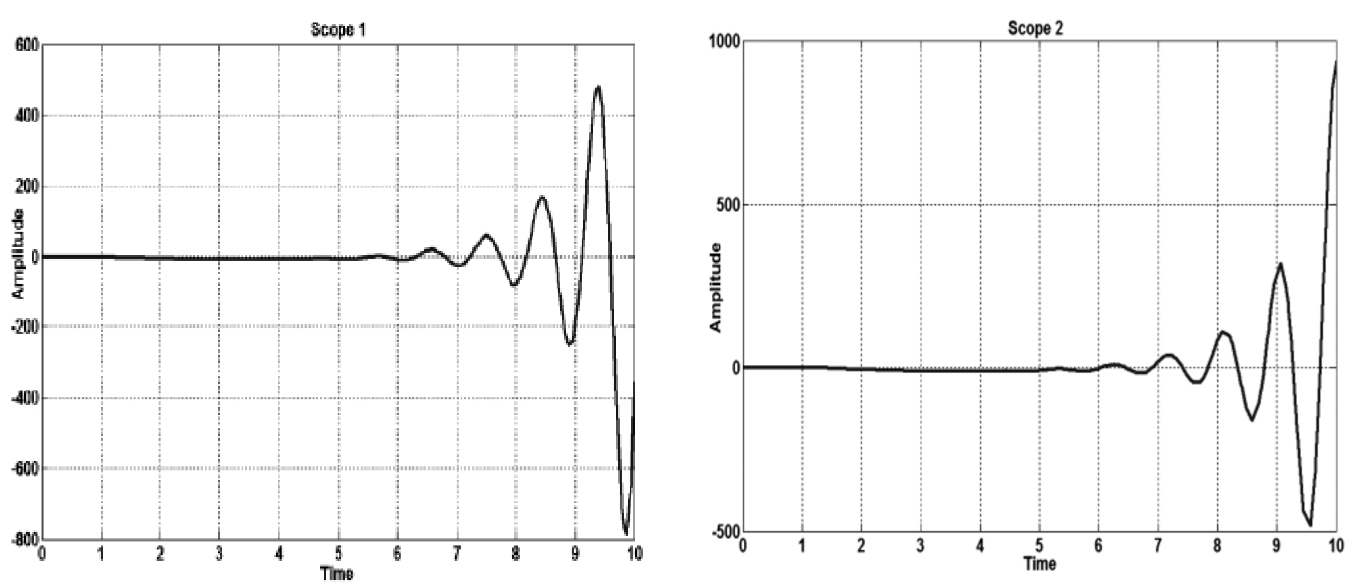
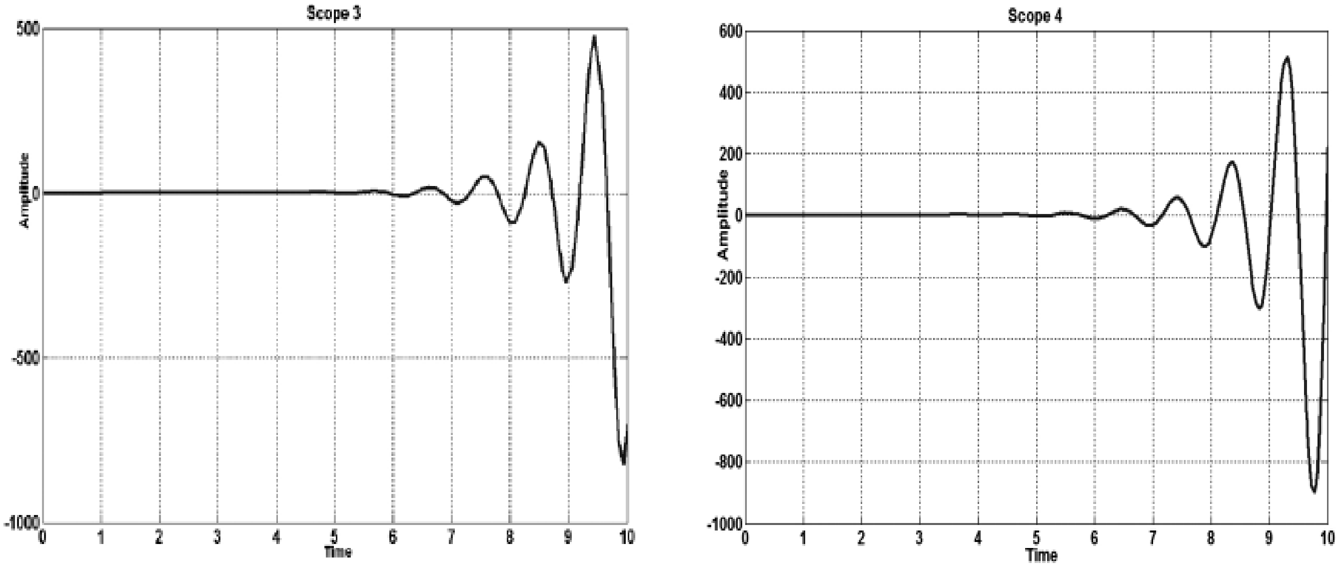


Figure 7: MATLAB Model of three-area Hydro-thermal reheats power system.



(a) (b)



(c) (d)

Figure 8: Output of three-area hydro-thermal reheats power system.

In Fig 8, there have scopes (a), (b), (c), (d) time 0-5.5s change of frequency looks stable after that frequency smoothly increase. All of those scopes it showing same but with respect to time change of frequency fluctuating different to each other.

IV. Conclusions

In this paper a Load frequency control (LFC) of interconnected multi-area power system is studied. The impact of LFC control method on the fluctuations caused by step load disturbance is examined. Therefore, power utilities consider the frequency and active power balance throughout their networks to sustain the inter connection. In interconnection between national/ continental networks, providing the constant frequency between areas is a serious operational problem. Hence fast and no delay decision-making mechanism have to be installed in network control units namely the LFC. The load frequency control is achieved within three levels, considering many issues from maintaining constant frequency and the minimization of the losses for taking saturation, integrator through tie lines to the optimal dispatch of generation between units or even areas. The simulation techniques are very useful in studying and predicting the response of control systems, giving the opportunity to optimize the response and so the behavior of the system under study.

References

Load Frequency Control (LFC). (2013, March 06). Retrieved November 01, 2016, from Electrical installation & energy efficiency: http://engineering.electrical-equipment.org/power-quality/load-frequency-control-lfc.html

Ashmoe PH Battebury DR, B. R. (1974). Frequency disturbances. Power-system model for large frequency disturbances proceedings of IEEE, 601-8.

Bahtti P, Ghoshal SP, Roy R. (2010). Load frequency stabilization. Load frequency stabilization by coordinated control of Thyristor controlled phase shifters and super conducting magnetic energy storage for three types of interconnected two-area power systems., 1111-24.

Bevrani H, Hiyama T. (2009). On load–frequency regulation with time delays. On load–frequency regulation with time delays: design and real-time implementation., 292-300.

Chidambaram IA, Raramasivam B. (2012). Control performance standards based load-frequency controller. Control performance standards based load-frequency controller considering Redox flow batteries coordinate with interline power flow controller, 292-304.

Daneshfar F, Bevrani H. (2010). LFC of a GA-based multi-agent reins. Load frequency control: a GA-based multi-agent reins for cement learning, 13-26.

Daneshfar F, Bevrani H. (2012). Multi-objective design of LFC. Multi-objective design of load frequency control using genetic algorithms. , 257-63.

Dong L, Zhang Y. (2012). A robust decentralized LFC. A robust decentralized load frequency controller for interconnected power systems., 410-9.

K. G. (1988). Automatic generation control. Automatic generation control for hydro systems, 33-9.

Fosha C, Elgerd OI. (1970). Mega-watt-frequency. The mega-watt-frequency control problem: a new approach via optimal control , 566-70.

Ibraheem, Kumar P, H Nazimuddin. (2012). Sub-optimal automatic generation control of interconnected power system. Sub-optimal automatic generation control of interconnected power system using output vector feedback control strategy, 977-94.

J Uang CF, LU CF. (2006). LFC by hybrid devolutionary fuzzy PI controller. Load–frequency control by hybrid devolutionary fuzzy PI controller, 196-204.

Jiang en L, Yao W, Wu QH, Cheng SJ. (2012). Delay-dependent stability. Delay-dependent stability for load frequency control with constant and time-varying delays, 932-41.

Khodaba Khshian A, Hooshmand R. (2010). PID Controller design for AGC. A new PID controller design for automatic generation control of hydro power systems., 375-82.

Milan, C. (1972). Linear regulator design. Linear regulator design for a load and frequency control, 2271-85.

Pan CT, Liaw CM. (1989). Adaptive controller for power system. An adaptive controller for power system load–frequency control IEEE Transactions on Power Systems., 122-8.

Rerkpreedapong D, Hasanovic A, Feliachi A. (2003). Robust load frequency control. Robust load frequency control using genetic algorithms and linear matrix inequalities., 855-61.

Shuda KR, Raju YB, Sekhar AC. (2012). Robust decentralized load frequency control of interconnected power system. Fuzzy C-Means clustering for robust decentralized load frequency control of interconnected power system with generation rate constraint, 58-66.

Singh Parmer KP, Majhi S, Kothari DP. (2012). LFC of multi-source power generation. Load frequency control of a realistic power system with multi-source power generation, 426-33.

SP, G. (2003). Multi-are frequency and tie-line power flow control . Multi-are frequency and tie-line power flow control with fuzzy logic based integral in scheduling., 135-41.

SP, G. (2005). GA-fuzzy based fast acting adaptive active PFC. GA-fuzzy based fast acting adaptive active power-frequency control of interconnected multiple thermal generating areas. , 209-15.

Sudha KR, Santhi RV. (2012). LFC of an interconnected reheat thermal system. Load frequency control of an interconnected reheat thermal system using type-2 fuzzy system including SME Sunits. , 1383-92.

Tain-Sou, T. (2011). LFC of interconnected power system. .Load–frequency control of interconnected power system with governor back lash on linarites., 1542-9.

TR, F. (1978). Governor hydro- generator. Step response of a governed hydro- generator, 125 (11).

TS, D. S. (2006). LFC of an isolated small hydro power plant. Load frequency control of an isolated small –hydro power plant with reduced dumped load, 1912-9.

W. Jiang L, Yao W, Wu QH, Wen JY, Cheng SJ. (2012). Delay-dependent stability for LFC. Delay-dependent stability for load frequency control with constant and time-varying delays., 932-41.

Wang Y, Zhou R, Wen C. (1994). New robust adaptive LFC. New robust adaptive load-frequency control with system parametric uncertainties., 141.

X.Alrifai MT, Hassan MF, Zribi M. (2011). Decentralized load frequency controller for a multi-area. Decentralized load frequency controller for a multi-area interconnected power system., 198-209.