2012 IEEE International Conference on Power Electronics, Drives and Energy Systems
December16-19, 2012, Bengaluru, India

DECENTRALIZED CONTROL OF MULTI-AREA POWER SYSTEM RESTRUCTURING FOR LFC OPTIMIZATION

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Abstract—**Power systems restructuring is one of the trending technologies which help in Energy Management Systems worldwide. Decentralized Interconnected Power Systems in use in recent times have issues like load perturbations affecting output frequencies, issues with nonlinearity, randomness in time delay, delayed settling time, large peak overshoot and large frequency deviation. Therefore to maintain effective Load Frequency Control (LFC) and to maintain optimum performance we propose a new paradigm of AGC system. A One-Area System has been applied with Pole placement and LQR methodologies. Also it has been studied with AGC and Fuzzy controllers, and the simulation results have been obtained. For a Two-Area Power system, AGC has been applied and the concept of deregulation introduced. Simulation works are presented for two area power systems incorporating the concept of two way interactions between DISCO and GENCO systems with DPM matrix.**

I. NOMENCLATURE

AGC- Automatic Gain Control
ACE_i- Area Control Error of area i
DISCO- Distribution Co
GENCO- Generation Co
LQR- Linear Quadratic Regulator
CPF- Contract Participation Factor

II. INTRODUCTION

The main objective is to study how effective decentralized load frequency control is when it is an implemented using different type of controllers in a multi area power system.

In case of an interconnected power system having two or more areas connected through tie lines, each area supplies its control area and tie lines allow electric power to flow among the areas. However, a load perturbation in any of the areas affects output frequencies of all the areas as well as the power flow on tie lines. Hence the control system of each area needs information about transient situation in all the other areas to restore the nominal values of area frequencies and tie line powers. The information about each area is found in its output frequency and the information about other areas is in the deviation of tie line powers.

We use load frequency control to maintain voltage and frequency within permissible limits, minimize frequency fluctuations, to regulate tie- line power in case of interconnected systems.

The concept of decentralization is that the controller of each subsystem operates independently of the other subsystems. The main objective is to find a decentralized feedback law for an interconnected system in order to attain a sufficiently small performance index.

III. SINGLE-AREA POWER SYSTEM ANALYSIS

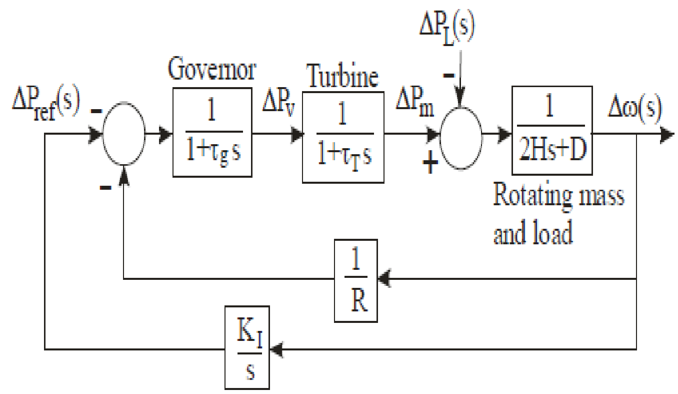

Figure 1. Block Diagram of One-Area Power System

The diagram shown above in Fig.1 is that of a single-area power system. Different methodologies are used here for the analysis namely Pole placement and linear quadratic regulator (LQR).

The pole placement design allows all roots of the system's characteristic equation to be placed in desired locations resulting in constant gain vector K. The design objective is to find the gain matrix K such that the characteristic equation for the control system is identical to the desired characteristic equation.

For LQR analytical design [1], the performance criterion such as steady state, reliability, cost, energy consumption, etc. must be mathematically related to the designed parameters. For this a popular index that involves the integral sum of squares of several system variables is implemented. Such indices are called quadratic performance criteria.

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An isolated power station has the following parameters for a single area system [2]:

Turbine time constant T_T = 0.6 sec
Governor time constant T_g = 0.3 sec
Governor inertia constant H = 5 sec
Governor speed regulation R = 0.065 pu
D = 0.8

The matrix for the state space equation has been taken from a standard formula (SAADAT) [3].

$$\begin{bmatrix} \Delta\dot{P}_V \\ \Delta\dot{P}_m \\ \Delta\dot{\omega} \end{bmatrix} = \begin{bmatrix} \frac{-1}{\tau_g} & 0 & \frac{-1}{R\tau_g} \\ \frac{1}{\tau_T} & \frac{-1}{\tau_T} & 0 \\ 0 & \frac{1}{2H} & \frac{-D}{2H} \end{bmatrix} \begin{bmatrix} \Delta P_V \\ \Delta P_m \\ \Delta\omega \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{-1}{2H} \end{bmatrix} \Delta P_L$$

Thus we can get the values of matrices A, B, C, D of the state space equation from the above formulas as follows:

$$\mathbf{A} = \begin{bmatrix} 3.33 & 0 & 51.28 \\ 1.6 & -1.6 & 0 \\ 0 & 0.1 & -0.08 \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} 0 \\ 0 \\ -0.1 \end{bmatrix}$$

$$\mathbf{C} = [0 \quad 0 \quad 1] \qquad \mathbf{D} = [0]$$

The simulation results are shown below in Fig. 2

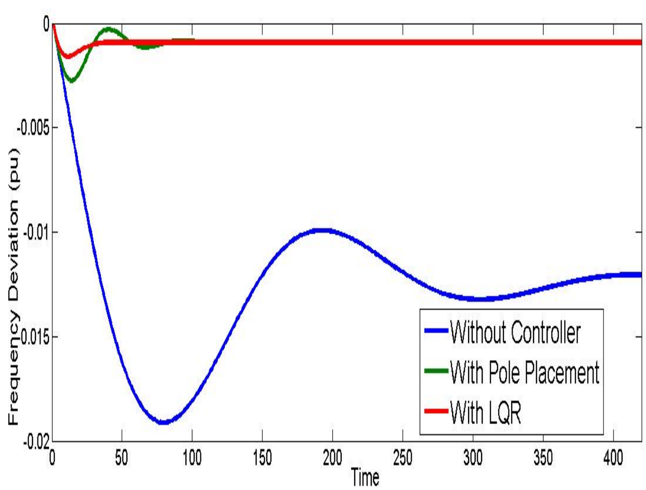

Figure 2. Simulation Response for Pole Placement, LQR

The results above shows that the oscillations and steady state decreases as we use pole placement and LQR (optimal control) respectively. Thus we can conclude that the effect of frequency deviation is the least in LQR than compared to pole placement technique and normal controllers.

IV. ONE-AREA POWER SYSTEM WITH FUZZY LOGIC CONTROLLER

The fuzzy logic controller has a number of distinguished advantages over the conventional controllers. It is not so sensitive to the variation of system structure, parameters and operation points and can be easily implemented in a large scale nonlinear system. Furthermore, the fuzzy logic controller is a sophisticated technique that is easy to design and implement.

The fuzzy logic controller is comprised of four main components: the fuzzifier, the inference engine, the rule base, and the defuzzifier, as shown in Fig. 3 [4].

The fuzzifier transforms the numeric into fuzzy sets, so that, this operation is called fuzzification. The main purpose of the fuzzy logic controller is the inference engine, which performs all logic manipulations in a fuzzy logic controller. The rule base consists of membership functions and control rules. Last, the results of the inference process is an output represented by a fuzzy set, however, the output of the fuzzy logic controller should be a numeric value. Therefore, fuzzy set is transformed into a numeric value by using the defuzzifier, so that, this operation is called defuzzification.

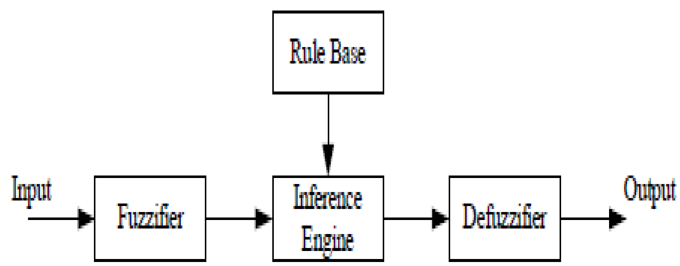

Figure 3. Components of Fuzzy Logic Controller

The control rules for Fuzzy Logic Controller are shown in Figure 6. Results for the model shown in Fig 5 have been obtained and shown in Fig 8.

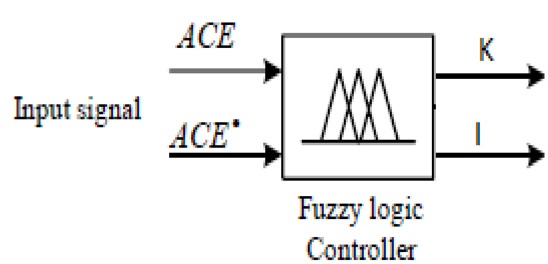

Figure 4. Structure of FL Controller

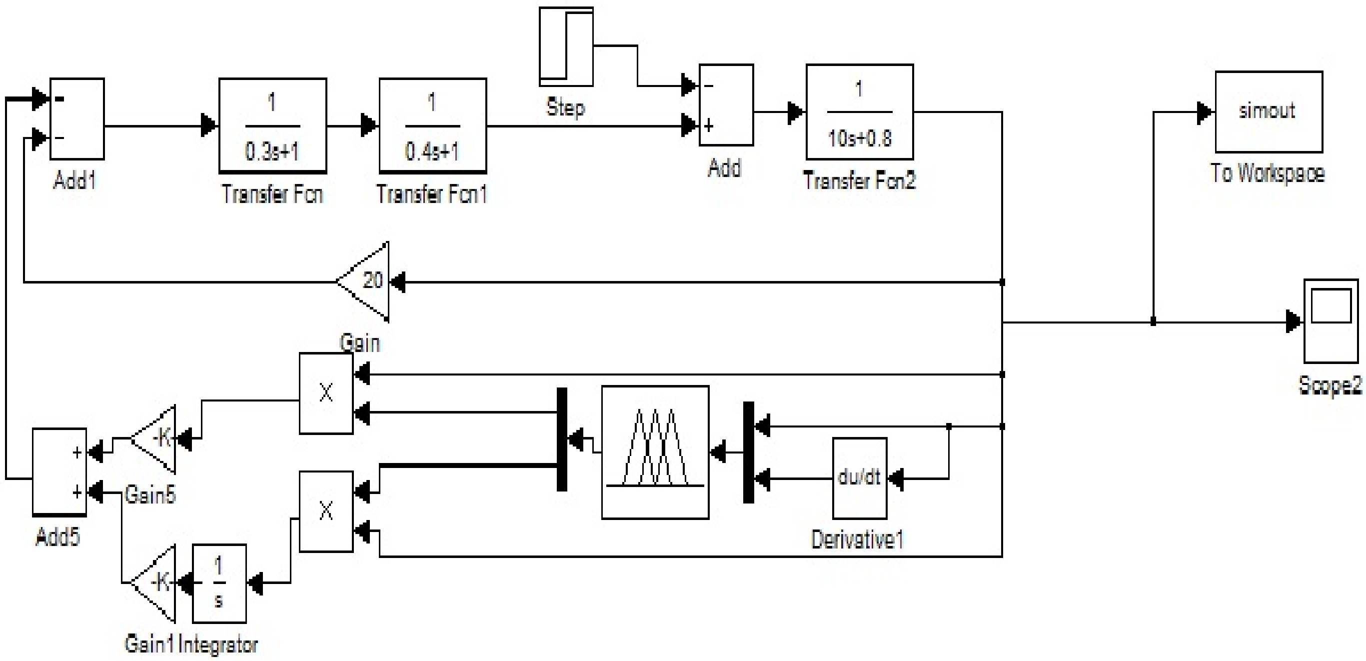

Figure 5. Model of One-Area Power System with Fuzzy Logic PI Controller

				ACE*		
		NB	NS	Z	PS	PB
	NB	S	M	B	B	VB
ACE	NS	M	B	B	VB	VB
	Z	B	B	VB	VB	VVB
	PS	B	VB	VB	VVB	VVB
	PB	VB	VB	VVB	VVB	VVB

Figure 6. Control Rules

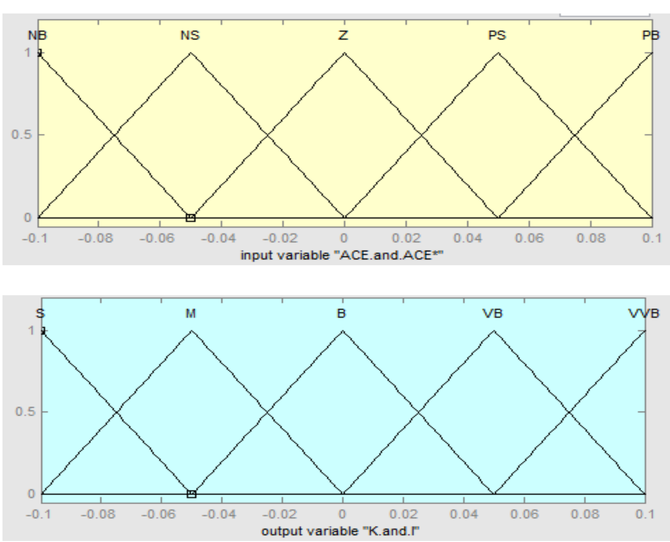

Figure 7. Membership functions for FGPI controller

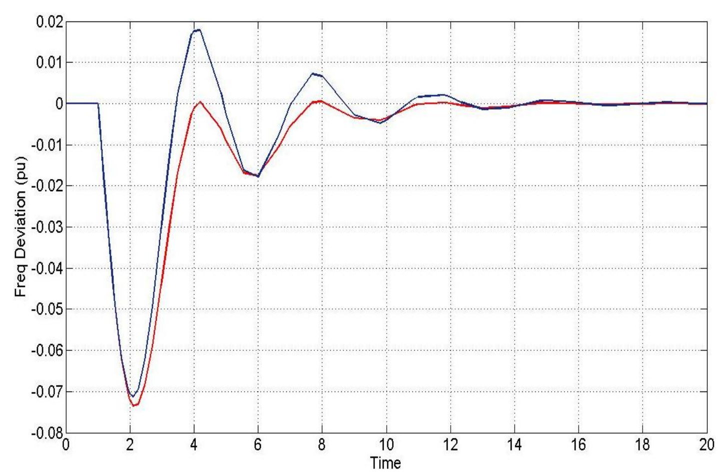

Figure 8. Simulation result with and without FL controller

The fuzzy logic controller is given to standard block diagram for one area system. The membership functions and rules table are framed so as to obtain better results when compared to other controllers.

The response curves are obtained when the fuzzy controller along with membership functions are simulated using MATALB.

Thus after the application of the fuzzy gain proportional integral (FGPI) controller the response is faster. It achieves steady state quickly, the oscillations have reduced considerably.

V. TWO-AREA POWER SYSTEM WITH AGC

The model shown in Figure 9 is that of a two-area power system with AGC (Automatic Gain Control) applied to the system.

The main objectives of AGC are:

- To maintain the desired megawatt output and the nominal frequency in an interconnected power system.
- To maintain the net interchange of power between control areas at predetermined values.

The dynamic performance depends upon the values of control parameters, which are obviously the group of loads connected, the speed and the frequency changes in accordance with the load change. In case of interconnection, the complexity of the system is increased due to the possibility of sharing of load of the two machines, the power outages of the two areas and the amount of load picked up by each.

Practically all power systems nowadays are interconnected with the neighboring areas which are interconnected by a number of tie lines. So the tie line bias control plays a vital role in the control of multi area systems.

Thus, an AGC scheme for an interconnected power system basically incorporates suitable control system, which can bring the area frequencies and tie line powers back to nominal or very close to nominal values effectively after the load perturbations.

Simulation will show that if system is unstable, damper winding contributions are neglected. In a situation like this the tie-line impedance will make the damper windings somewhat ineffective and additional damping by control system compensation or Power System Stabilizers will be needed. But in practice this additional damping has to come from supplementary damping schemes and will not come from damper windings.

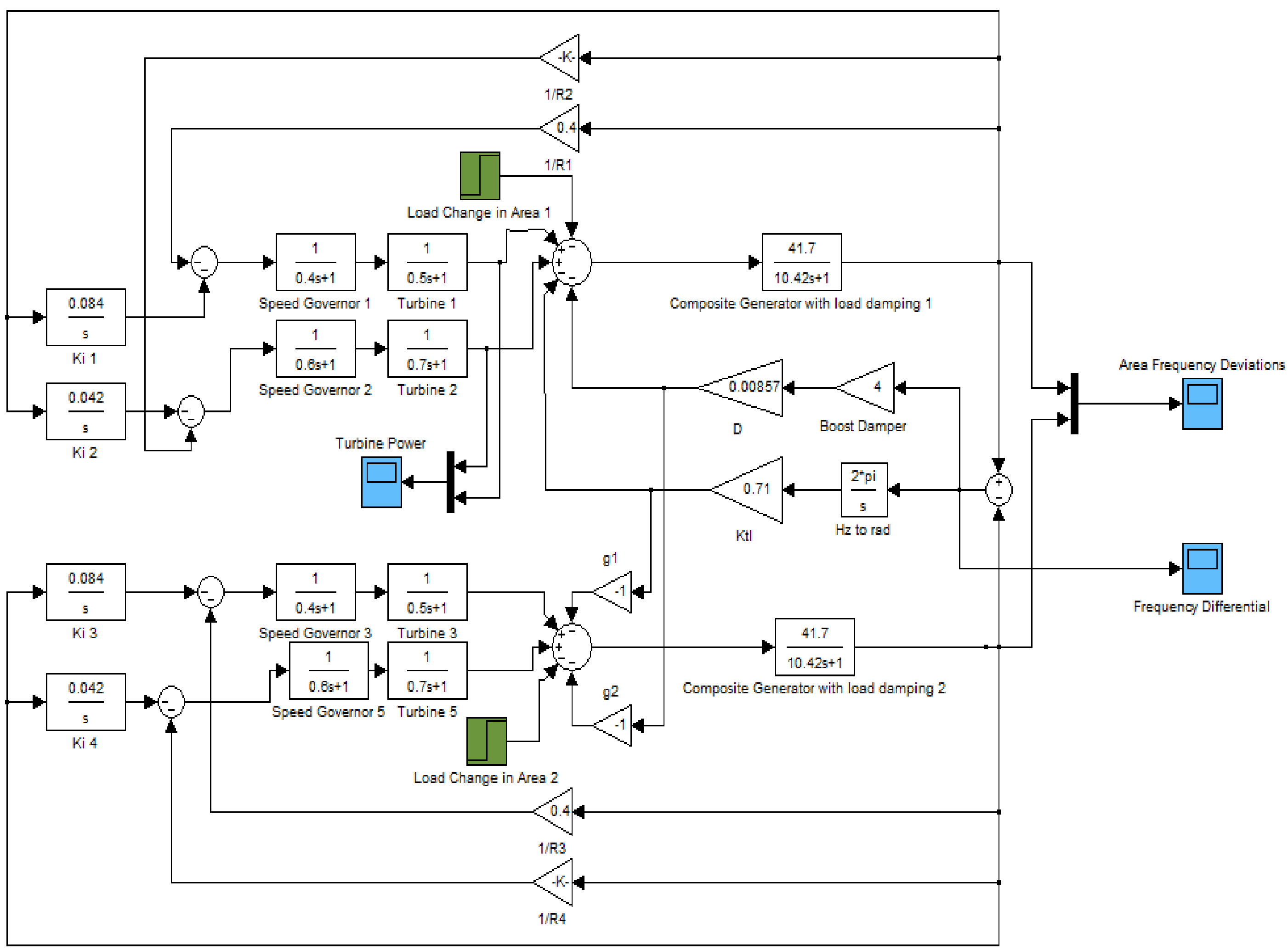

Figure 9. Model of two area power system with AGC

The simulation results for MATLAB Model indicating Area Frequencies, Frequency Differential and Turbine Powers are as simulated below:

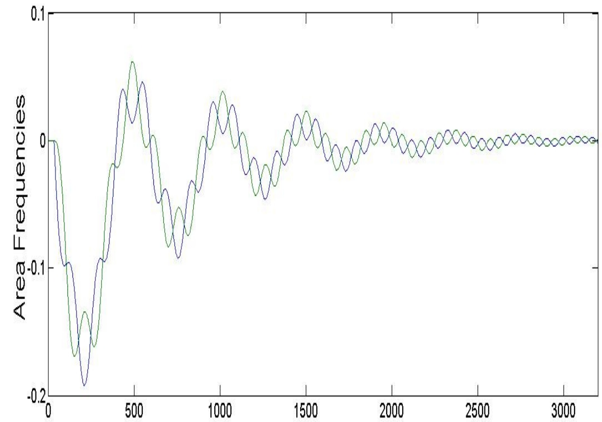

Figure 10. Area Frequencies for 2 Area System.

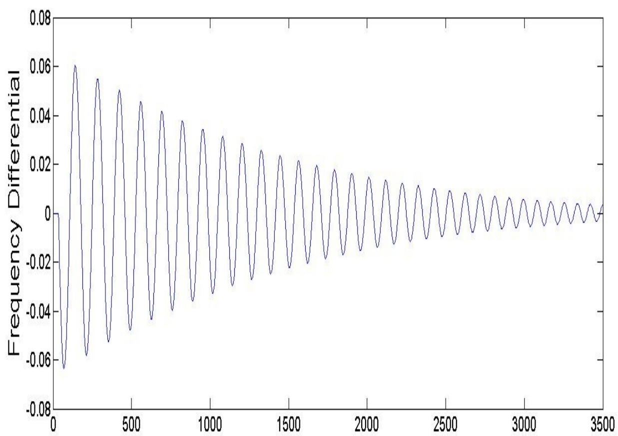

Figure 11. Frequency Differential for 2 Area System.

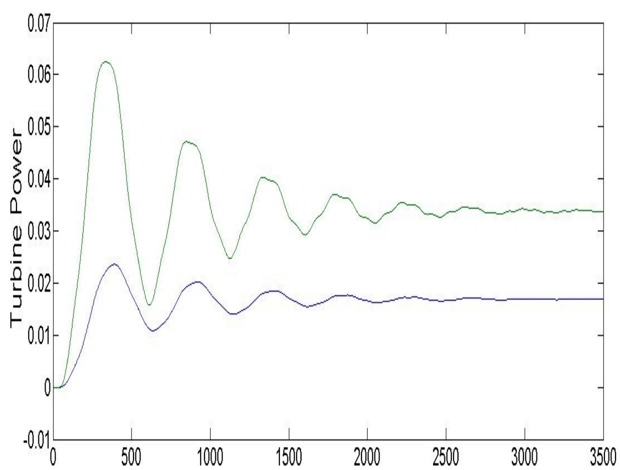

Figure 12. Turbine Power for 2 Area System.

VI. TWO-AREA POWER SYSTEM IN A DE-REGULATED ENVIRONMENT

With the evolution of concept like DISCO (Distribution unit), GENCO (Generation unit), ISO (Independent system operator) systems, the two area power supply system in Fig 9 is modified to provide better results.

Consider a two area network in which each area have 2 DISCOs and 2 GENCOs as shown in Fig 13 and Fig 16. The disco of any area can interact with the GENCO of other area resulting in a two way interaction. All the interactions are cleared by an entity called ISO. Since any DISCO-GENCO pair is possible, we create a matrix called disco participation matrix (DISCO-column and GENCO-row).

Each value in the matrix is a part of the total load exerted by a disco system. The sum of all entries in the column must be equal to unity.

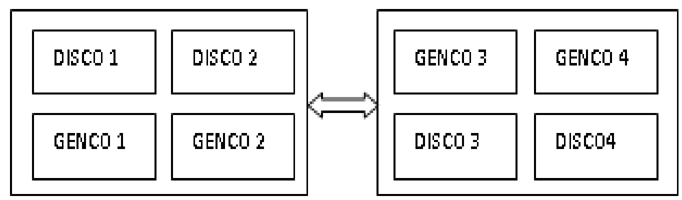

Figure 13. Structure of De-Regulated Power System [5]

$$\mathrm{DPM} = \left[\begin{array}{cc:cc} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ \hdashline cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{array}\right]$$

Figure 14. DPM Matrix indicating Contract Participation Factor

Simulation Result:

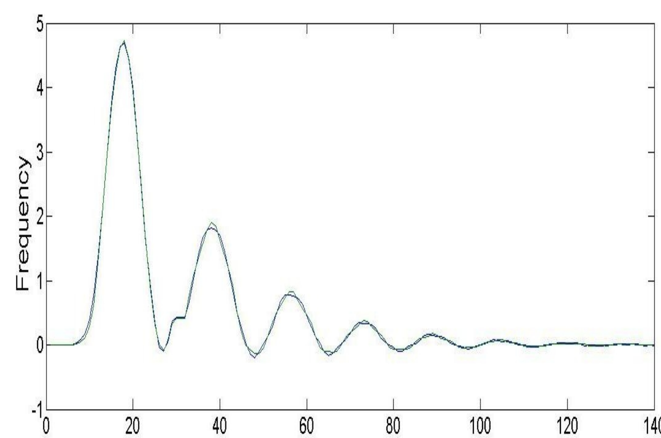

Figure 15. Simulation Result for Deregulated Two-Area System

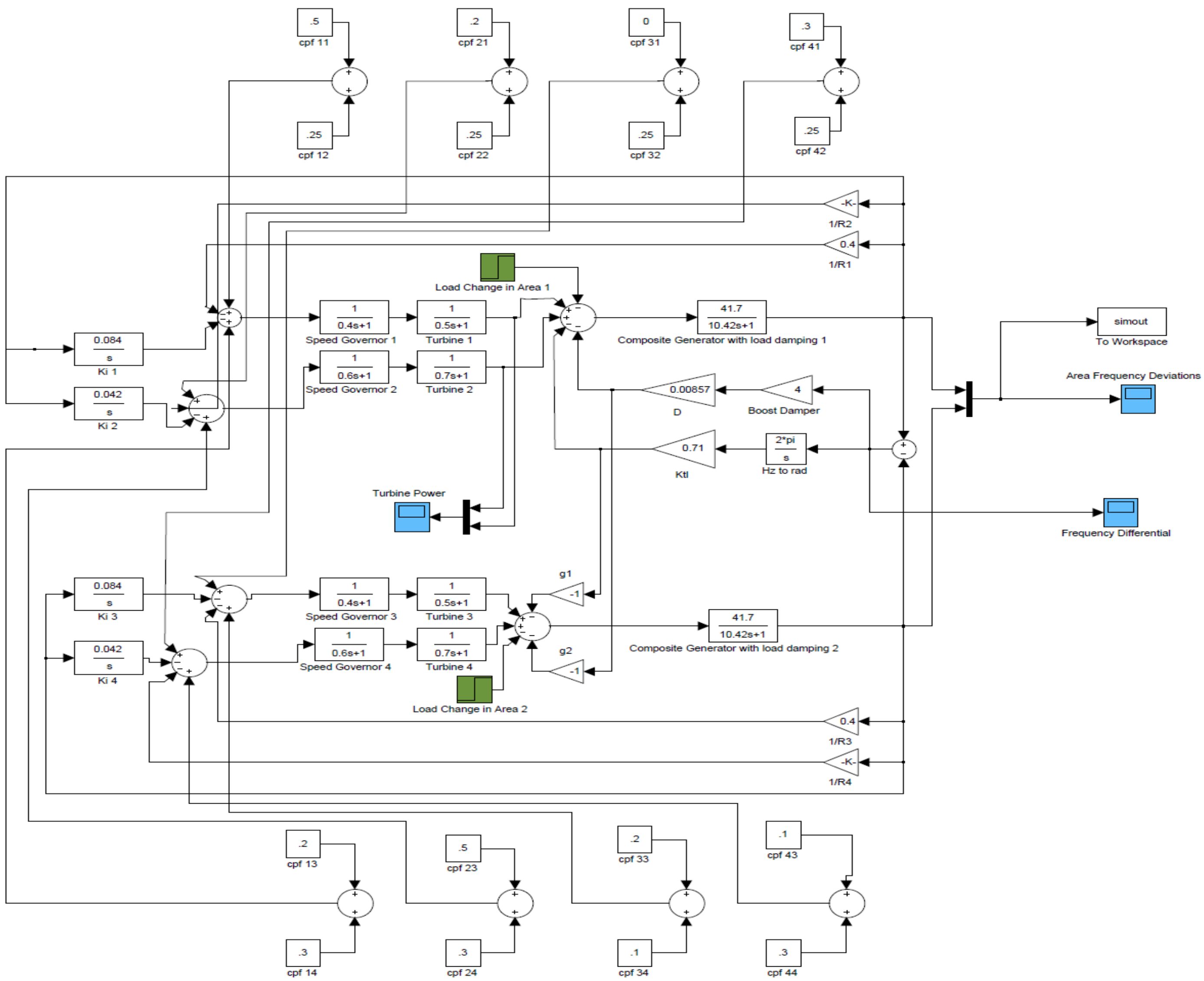

Figure 16. Restructured De-regulated environment for a Two-Area Power System.

VII. CONCLUSION

In the current scenario it is increasingly difficult to monitor, control and optimize the performance of generation and transmission system, so there raises a need for a control strategy that manages the energy systems across the country effectively. There is a major power restructuring in many developing countries with the help of decentralization and deregulation. The analysis of single area power systems was done using pole placement, LQR methodologies, Fuzzy Logic used for better improvement to obtain results for peak overshoot, settling time and steady state. Then the AGC for two-area power network is evaluated and also the concept of deregulation implemented and simulation results obtained.

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