Multi-Area Load Frequency Control Implementation in Deregulated Power System

Isha Garg

***Abstract*—In power system, the main goal of load frequency control (LFC) or automatic generation control (AGC) is to maintain the frequency of each area and tie- line power flow within specified tolerance by adjusting the MW outputs of LFC generators so as to accommodate fluctuating load demands. In this paper, attempt is made to make a scheme for automatic generation control within a restructured environment considering effects of contracts between DISCOs and GENCOs to make power system network in normal state. This scheme is tested on two area system with considering deregulation using MATLAB simulink tool. The results are shown in frequency and power response for two area AGC system in restructured environment.**

***Index Terms*—Automatic generation control, load frequency control, two area control in deregulated power system.**

I. NOMENCLATURE

AGC	Automatic Generation control
ACE	Area Control Error
B	Frequency Bias
Cpf	Contract Participation Factor
DPM	DISCO Participation Matrix
DISCOs	Distribution companies
GENCOs	Generation companies

II. INTRODUCTION

In recent years, power system restructuring has been a worldwide trend with the introduction of competitive market system under deregulation. Also, major changes have been introduced into the structure of electric power utilities all around the world. The reason for this was to improve the efficiency in the operation of power system by means of deregulating the industry and opening it up to private competition. In this new frame work, consumers will have an opportunity to make a choice among competing providers of electric energy. The net effect of such changes will mean that the transmission generation and distribution systems must now adapt to a new set of rules dictated by open markets. In power system, any sudden load perturbations cause the deviation of tie- line exchanges and the frequency fluctuations. So, load frequency control (LFC) or automatic generation control (AGC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. The main goal of AGC of a power system within specified tolerance is to

maintain the frequency of each area and tie- line power flow by adjusting the MW outputs of AGC generators so as to accommodate fluctuating load demands [1]. Automatic generation control (AGC) in a multi-area interconnected power system has four principal objectives when operating in either the so-called normal or preventive operating states:

- Matching total system generation to total system load
- Regulating system electrical frequency error to zero
- Distributing system generation amongst control areas so that net area tie flows match net area tie flow schedules
- Distributing area generation amongst area generation sources so that area operating costs are minimized, subject to appropriate security and environmental constraints. [2].

Power system loads and losses are sensitive to frequency. Data captured right after frequency disturbances indicate that their aggregate initial change is in the same direction as the frequency change. Once a generating unit is tripped or a block of load is added to the system, the power mismatch is initially compensated by an extraction of kinetic energy from system inertial storage which causes a declining system frequency. As frequency decreases, the power taken by load decreases. Equilibrium for large systems is often obtained when the frequency sensitive reduction of loads balances the output power of the tripped unit or that delivered to the added block of load at the resulting (new) frequency. If this effect halts the frequency decline it usually does so in less than 2 seconds. If the mismatch is large enough to cause the frequency to deviate beyond the governor dead band of generating units, their output will be increased by governor action. For such mismatches, equilibrium is obtained when the reduction in the power taken by loads plus the increased generation due to governor action compensates for the mismatch. Such equilibrium is normally obtained within a dozen seconds after the tripping of a unit or connection of the additional load.

III. TWO AREA DEREGULATED POWER SYSTEM FOR LFC

In the competitive environment of power system, the vertically integrated utility (VIU) no longer exists. Deregulated system will consist of GENCOs, DISCOs, and transmission companies (TRANSCOs) and independent system operator (ISO). However, the common AGC goals, i.e. restoring the frequency and the net interchanges to their desired values for each control area, still remain. The power system is assumed to contain two areas and each area includes two GENCOs and also two DISCOs as shown in Fig.1 and the block diagram of the generalized LFC scheme for a two area deregulated power system is shown in Fig. 2. A DISCO can contract individually with any GENCO for power and these transactions are made under the supervision of ISO.

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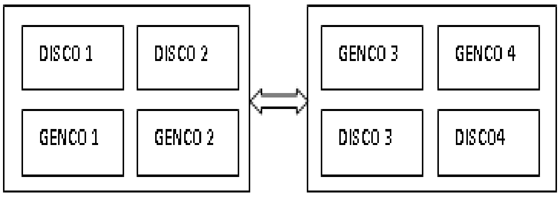
To make the visualization of contracts easier, the concept of a "DISCO participation matrix" (DPM) will be used [2]. DPM is a matrix with the number of rows equal to the number of GENCOs and number of columns equal to number of DISCOs in the system. For the purpose of explanation, consider a two-area system in which each area has two GENCOs and two DISCOs in it. Let GENCO1,

GENCO 2, DISCO 1 and DISCO 2 are in area-1, and GENCO 3, GENCO 4, DISCO 3 and DISCO 4 are in area-2 as shown in fig. 1.



AREA 1 AREA 2

Fig. 1: Two area power system

The DPM of above fig. can be given as:

DPM=

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	cpf 11	cpf 12	cpf 13	cpf 14
GENCO2	cpf 21	cpf 22	Cpf23	cpf 24
GENCO3	cpf 31	cpf 32	cpf 33	cpf 34
GENCO4	cpf 41	cpf 42	cpf 43	cpf 44

It can be thought of as a fraction of a total load contracted by a DISCO (column) toward a GENCO (row). Thus, the ij-th entry corresponds to the fraction of the total load power contracted by DISCO j from GENCO i. The sum of all the entries in a column in this matrix is unity. DPM shows the participation of a DISCO in a contract with a GENCO, and hence the "DISCO participation matrix".

cpf ij refers to "contract participation factor". For the purpose of explanation, suppose that DISCO 2 demands 0.1 Pu MW power, out of which 0.02 pu MW is demanded from GENCO 1, 0.035 pu MW from GENCO 2, 0.025 pu MW demanded from GENCO3 and 0.02 pu MW demanded from GENCO 4.

The column 2 entries can be easily defined as:

cpf 12= (0.02/0.1) = 0.20;

cpf 22=(0.035/0.1) = 0.35;

cpf 32= (0.025/0.1) = 0.25;

cpf 42 = (0.02/0.1) = 0.20;

also cpf 12+ cpf 22+ cpf 32+ cpf 42 = 1.0

other cpfs are defined easily to obtain the entire DPM. In general

$\sum i$ = cpf ij = 1.0

IV. BLOCK DIAGRAM REPRESENTATION

Now formulate the block diagram for a two area AGC system in the deregulated scenario. Whenever a load demanded by a DISCO changes, it is reflected as a local load in the area to which this DISCO belongs. This corresponds to the local loads • PL1 and • PL2 and should be reflected in the deregulated AGC system block diagram at the point of input to the power system block. As there are many GENCOs in each area, ACE signal has to be distributed among them in proportion to their participation in AGC. Coefficients that distribute ACE to several GENCOs are termed as "ACE participation factors".

Note that

$$\sum_{i=1}^{NGENCO_j} \alpha'_{ji} = 1.0$$

Where a'ji = participation factor of i-th GENCO in j-th area. NGENCOj = number of GENCO in j-th area

Unlike the traditional AGC system, a DISCO asks

or demands a particular GENCO or GENCOs for load power. These demands must be reflected in the dynamics of the system. Turbine and governor units must respond to this power demand. Thus, as a particular set of GENCOs are supposed to follow the load demanded by a DISCO to particular GENCO specifying corresponding demands. The demands are specified by cpfs (elements of DPM) and the pu MW load of a DISCO. These signals carry information as to which GENCO has to follow a load demanded by which DISCO.

The scheduled steady state power flow on the tie-line is given as:

Scheduled ΔPtie12 = (Demand of DISCOs in area-2 from GENCOs in area-1) – (Demand of DISCOs in area-1 from GENCOs of area-2)

Scheduled ΔPtie12= ($\sum_{i=1}^{2} 1 \sum_{j=3}^{4} cpfij$ ΔPLj) – ($\sum_{i=3}^{4} 1 \sum_{j=1}^{2} cpfij$ΔPLj)

At any given time, the tie-line power error is defined as:

Error = Actual - Scheduled

ΔPtie12 = ΔPtie12 - ΔPtie12

The tie-line power error vanishes in the steady-state as the actual tie-line power flow reaches the scheduled power flow. This error signal is used to generate the respective ACE signals as in the traditional scenario

ACE1 = B1 Δ F1 + ΔPerror tie12s

ACE2 = B2 Δ F2 + α12ΔPerror tie12

For two area system contracted power supplied by i-th GENCO is given as:

$\Delta Pi = \sum_{j=1}^{NDISCO=4} cpfij \Delta PLj$

For i=1

ΔP1 = cpf11 ΔPL1 + cpf12 ΔPL2 + cpf13 ΔPL3 +cpf14 ΔPL4

Similarly, ΔP2, ΔP3, ΔP4 can easily be calculated.

In this closed loop model above ΔPuc1 and ΔPuc2 are non contracted power demand (if any).

Also from this closed loop model

ΔPL1, LOC= PL1 + Δ PL2

and ΔPL2, LOC = ΔPL3 + ΔPL4

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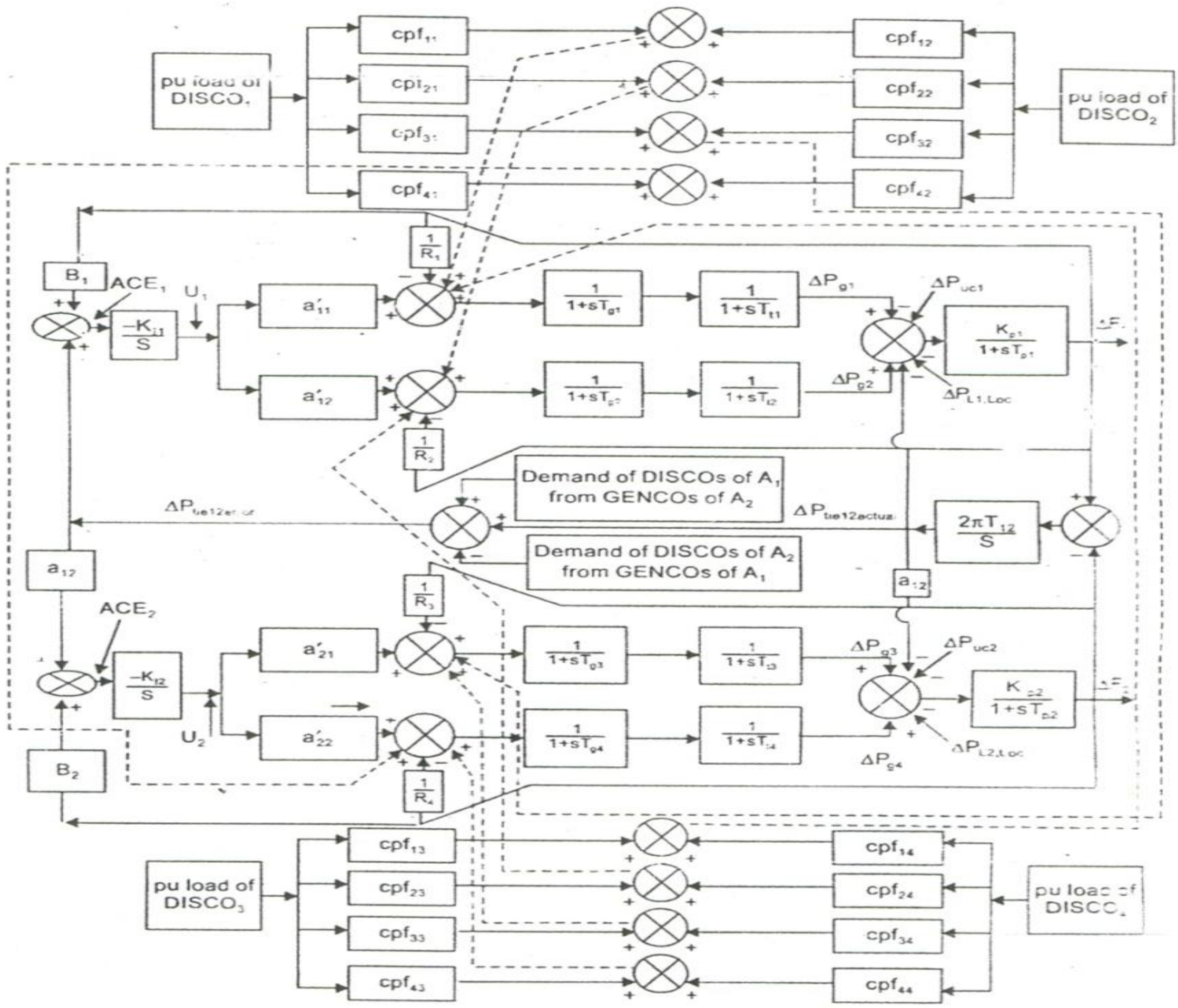

Fig. 2: block diagram of two area deregulated power system

The inputs ΔPL1, LOC and ΔPL2, LOC in the closed loop model are part of the power system model, not part of AGC or LFC i.e. load frequency control. The block diagram of two area AGC system in a deregulated environment is shown in fig. 2

V. SIMULATION RESULT

Extensive testing is involved in the completion of final automatic generation control scheme with deregulation. The testing is completed using the MATLAB simulink tool. Testing is done on two area system with considering deregulation. Each test included in testing the block diagram into Simulink and plugging in the values for each of the parameters. Also involved is the addition of the scopes that would be used to measure the outputs of the system.
The inputs for each of the text are Varied to allow for more data.
The DPM of fig.1 can be given in table 1.

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	0.5	0.5	0	0
GENCO2	0.5	0.5	0	0
GENCO3	0.5	0.5	0	0
GENCO4	0.5	0.5	0	0

Table 1. Disco Participation Matrix

The ACE participation factors for all the units are taken as 0.5.

The simulink diagram for a complete two area AGC system in restructured environment is shown in figure3 below. It can be seen that tie line power flow is zero because no distribution company demands power from generating unit of another area and also the frequency deviation of the system is zero.

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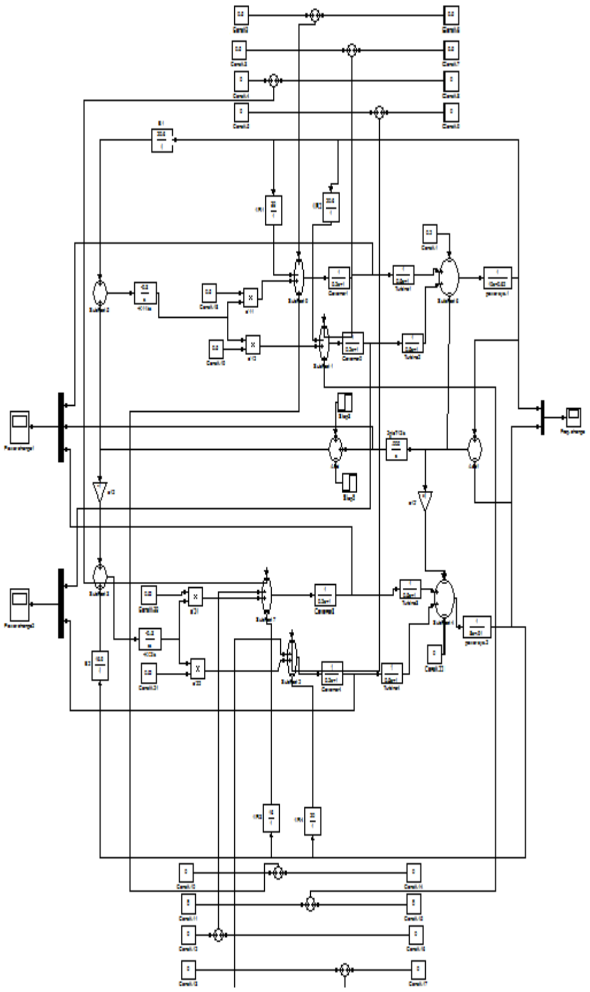

Fig. 3. AGC Model for complete two area system in restructured environment

The frequency response of the system is as shown in fig.4:-

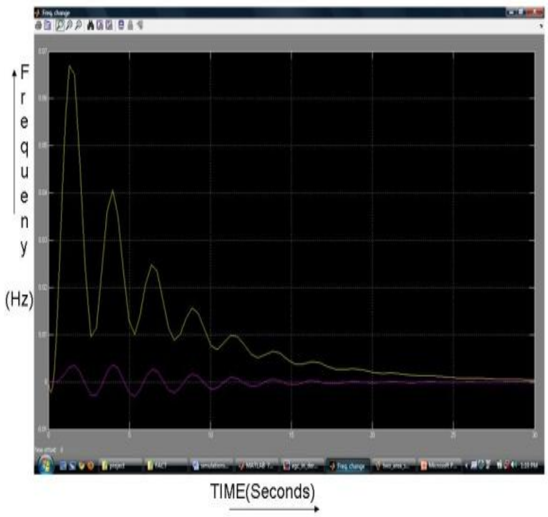

Fig. 4. Frequency Response for complete two area AGC system in restructured environment

The tie line power and power of generating units 1 and 3 is as shown in figure 5:-

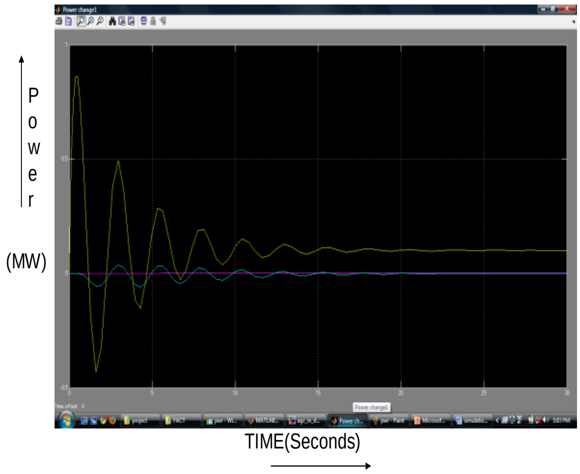

Fig. 5. Power Response for complete two area AGC system in restructured environment

The power curve for generating units 2 and 4 is as shown in fig. 6:-

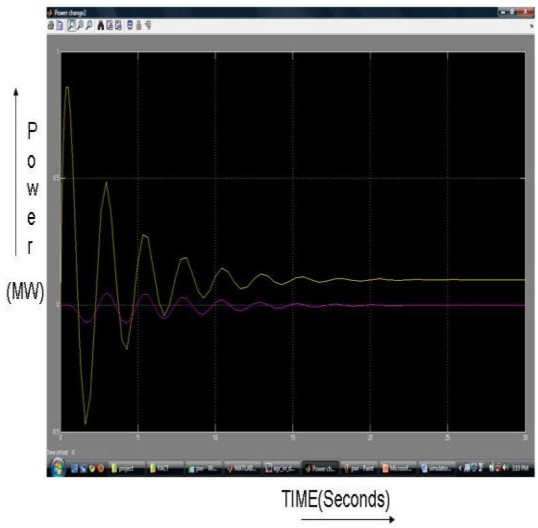

Fig. 6.Power Response for complete two area AGC system in restructured environment

VI. CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

APPENDIX

The following parameter values are assumed and are given in table2:

Table2

Quantity	Area-1	Area-2
Governor Speed Regulation	R1 = 0.051	R2 = 0.065
Frequency Bias Factors	D1 = 0.62	D2= 0.91
Inertia Constant	H1 = 5	H2 = 5
Base Power	1000MVA	1000MVA
Governor Time Constant	T_{g1}= 0.2 sec	T_{g2}= 0.3 sec
Turbine Time Constant	T_{T1}= 0.5 sec	T_{T2}= 0.6 sec
Constant	K= ½*π=0.159	K= ½*π=0.159
Nominal Frequency	F1 = 50 Hz	F1 = 50 Hz
Load Change	ΔPL1 = 180.2 MW	ΔPL1 = 0 MW
Load Disturbance in per unit	(ΔPL1)pu = 0.18	(ΔPL1)pu = 0

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