Automatic Generation Control and Load Following In a Bilateral Market.

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Abstract - *The conventional Automatic Generation Control (AGC) of two-area interconnected power system is modified to take into account the effect of bilateral contracts between the supplier and customer. And a load following controller on each generator involved in the bilateral contract is considered. A separate control scheme for generators taking part in load-following is proposed to share the uncontracted power demanded by some customers.*

Key Words: **AGC, Deregulation, Load following, Two-area interconnected system, DPM.**

1. INTRODUCTION

Regulation and load following are the frequency related ancillary services in the deregulated system. These two services are required to continuously balance generation and load under normal operating conditions. Instant adjustment of the generation to track the fluctuation between the power supply and demand so that the system is effect balance is called speed regulation or load following. Deviations in load from the scheduled value are normally supplied by some generating units under AGC or participating in manual frequency control. They are substantially the same service except for the time frame. While regulation should follow minute to minute load variations, load following addresses variations that occur over a longer time horizon.

Many researchers have studied the AGC in deregulated environment. Deregulated system is the combination of generation companies (GENCOs), Distribution companies (DISCOs), and Transmission companies (TRANSCOs) and Independent system operators (ISO). In the restructured power system AGC has to be reformulated. In deregulated environment, a DISCO can contract individually with any GENCO for power demand and this transaction is completed under the supervision of ISO.

2. RESTRUCTURED SYSTEM

After deregulation any DISCOs can demand for the power supply from any GENCOs. There is no boundation on the DISCOs for purchasing of electricity from any GENCOs. A DISCO has freedom to make contract with a GENCO in another control area and such transaction are called bilateral transactions. All such transactions are completed under the supervision of independent system operator (ISO). The ISO controls various ancillary services, one of which is AGC.

Let us consider, in area-1, there are two generation company GENCO1 and GENCO2 and two distribution companies DISCO1 and DISCO2. Similarly in area-2, two generation company GENCO3 and GENCO4 and two distribution companies designated by DISCO3 and DISCO4. We define the DISCO Participation Matrix (DPM) as given by

$$DPM = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix} \quad (1)$$

In Eqn. (1), cpfs are the contract participation factors. In DPM, the number of rows is equal to the number of generating units, while, the number of columns is equal to the number of DISCOs. The sum of all the entries in a column in this matrix is unity.

$$\sum_{i=1}^{NGENCO} cpf_{ij} = 1.0; \quad j = 1,2,....NDISCO \quad (2)$$

Where, NGENCO = total number of Gencos and NDISCO = total number of Discos.

The diagonal blocks of the DPM given by the Eqn(1) correspond to local load demands i.e., the demand of Discos in an area from the Gencos in the same area while off-diagonal blocks corresponds to the demand of the Discos in one area from the Gencos in another area. The expression for contracted power of Gencos with Discos is given as

$$\Delta P_{gci} = \sum_{j=1}^{NDISCO} cpf_{ij} \ \Delta P_{Lj}; i = 1,...NGENCO \quad (3)$$

where ΔP_{gci} = contracted power of ith generating unit, ΔP_{Lj} =total demand of $DISCO_j$, cpf_{ij} = contract participation factor. The scheduled steady state power flow on the tie-line is given as: $\Delta P_{tie12,\,scheduled}$ = (Demand of DISCOs in area-2 from the generating units in area-1) – (Demand of DISCOs in area-1 from the generating units in area2)

$$\Delta P_{tie12,scheduled} = \sum_{i=1}^{2}\sum_{j=3}^{4} cpf_{ij}\ \Delta P_{Lj} - \sum_{i=3}^{4}\sum_{j=1}^{2} cpf_{ij}\ \Delta P_{Lj} \quad (4)$$

The tie-line power error is defined as:

$$\Delta P_{tie12,error} = \Delta P_{tie12,actual} - \Delta P_{tie12,scheduled} \quad (5)$$

At the steady state, the tie-line power error, $\Delta P_{tie12,error}$ vanishes as the actual tie-line power flow reaches the scheduled power flow. This error signal is used to generate the respective Area Control Error (ACE) signals as in the traditional scenario,

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie12,error}$$

$$ACE_1 = B_1 \Delta f_1 + a_{12}\, \Delta P_{tie12,error} \quad (6)$$

Where $a_{12} = -(P_{r1}/P_{r2})$ with P_{r1} and P_{r2} being the rated area capacities of area-1 and area-2 respectively. $\Delta P_{tie12,error}$ 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. In the steady state generation of each GENCO matches the demand of Discos in contract with it.

3. BLOCK DIAGRAM REPRESENTATION

Fig. 1 shows the block diagram representation of the two area system shown in Fig. 1. Each area is equipped with an AGC controller. In addition, each unit of the GENCOs is equipped with a load following controller. For example, consider Unit1 in area-1 (Fig. 2). A demand signal ΔP_{gc1} that arrives directly from the load is compared with the power output of Unit$_1$ (ΔP_{g1}) to yield a mismatch and this mismatch is given as an input to a reset controller (load following controller) that will force the mismatch to zero so that the generator follows the load. The inputs $\Delta P_{L1,LOC}$, $\Delta P_{L2,LOC}$ is the total local demand in area-1 and area-2 respectively. There is a possibility that a DISCO violates a contract by demanding more power that the specified in the contract. This excess power is not contracted out to any GENCO. This uncontracted power must be supplied by the GENCO in the same area as the DISCO violates the contract. $\Delta P_{L1,UC}$, $\Delta P_{L2,UC}$ are the uncontracted demand by DISCO in area-1, area-2 respectively. The area participation factor (apfs) decides the distribution of uncontracted power in the steady state among various generating units. And K_{I1}, K_{I2} are integral gain setting for AGC controller and K_1, K_2, K_3, K_4 are integral gain settings of load following controller. The AGC integral control of ith area is given by,

$$u_i = -K_{Ii} \int ACE_i\, dt \quad (7)$$

The integral control law for Load Following for the ith unit is given by

$$V_i = K_j \int (\Delta P_{gcj} - \Delta P_{gi})\, dt \quad (8)$$

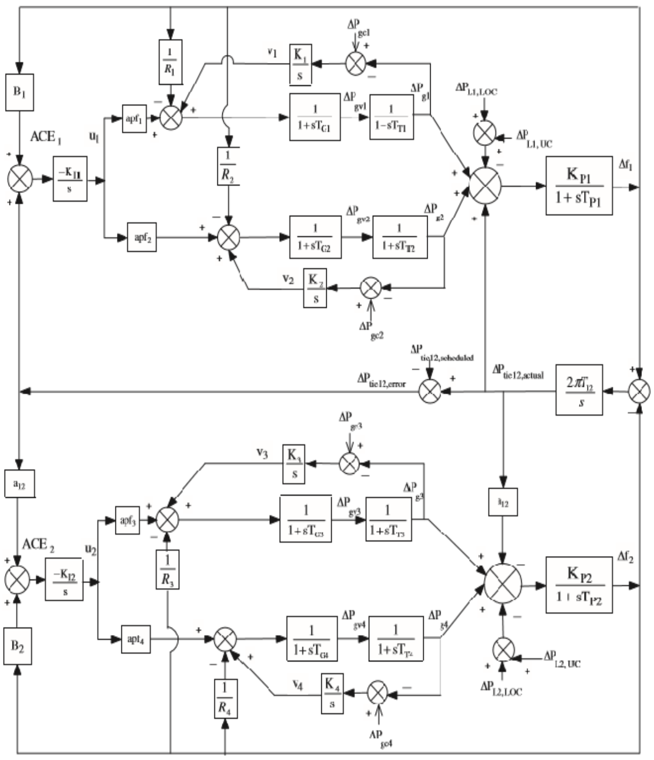


Fig- 1: Two area interconnected system.

4. SIMULATION RESULT AND DISCUSSION

4.1 AGC with Bilateral Contract Only

Transaction between a Disco and a Genco in another area are called bilateral transactions. K_1, K_2, K_3, K_4 are equal to zero, because we are considering AGC only. Consider a case where all the Discos contract with the Gencos as per the following DPM

$$DPM = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix} \quad (9)$$

Let each Disco demand 0.005 pu MW power from the Gencos as defined by the cpfs in the DPM matrix given by Eqn(9) and The desired generation of each Genco, according to Eqn(2), can be expressed as $\Delta P_{gi,ss} = \Delta P_{gci}$ since at steady state, each Genco has to generate the contracted power. Thus in matrix form,

$$\begin{bmatrix} \Delta Pg_1,ss \\ \Delta Pg_2,ss \\ \Delta Pg_3,ss \\ \Delta Pg_4,ss \end{bmatrix} = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix} \begin{bmatrix} \Delta PL_1 \\ \Delta PL_2 \\ \Delta PL_3 \\ \Delta PL_4 \end{bmatrix} \quad (10)$$

Thus, $\Delta P_{L1} = \Delta P_{L2} = \Delta P_{L3} = \Delta P_{L4} = 0.005$ pu MW.
$\Delta P_{L1,LOC} = \Delta P_{L1} + \Delta P_{L2} = 0.01$ pu MW &
$\Delta P_{L2,LOC} = \Delta P_{L3} + \Delta P_{L4} = 0.01$ pu MW.

Since there are no uncontracted power demands in either of the areas, $\Delta P_{L1,UC} = \Delta P_{L2,U} = 0.0$ puMW.

Let each Genco participate in AGC as defined by the following apfs: $apf_{11}= 0.75$, $apf_{12} = 0.25$, $apf_{21} = 0.50$ and $apf_{22}=0.50$. **Fig .1** depicts the deviations in area frequencies when simulations are carried out with the above data. Though the frequencies deviate from their nominal values during the transient condition, the deviations are zero at steady state.

$\Delta P_{tie12,scheduled} =$ (0x0.005 + 0.3x0.005 + 0x0.005 + 0x0.005) - (0x0.005 + 0.25x 0.005 + 0.3x0.005 + 0.25x0.005) = -0.0025 pu MW.

The actual power flow on the tie-line is plotted in **Fig.2**, from which, it can be observed that it settles to -0.0025 pu MW, which is same as the scheduled power on the tie-line in the steady state.

In the steady state, the generation of a Genco must match the demand of the Discos in contract with it. **Fig.3**, the actual generated powers of Gencos have been plotted. Using Eqn.(2), at steady state, $GENCO_1$ has to generate

$\Delta P_{g1,ss}$=(0.5x0.005)+(0.25x0.005)+(0x0.005)+(0.3x0.005) =0.00525 pu MW.

Similarly, $\Delta P_{g2,ss} = 0.00225$ pu MW ;
$\Delta P_{g3,ss} = 0.00975$ pu MW and
$\Delta P_{g4,ss} = 0.00275$ pu MW.

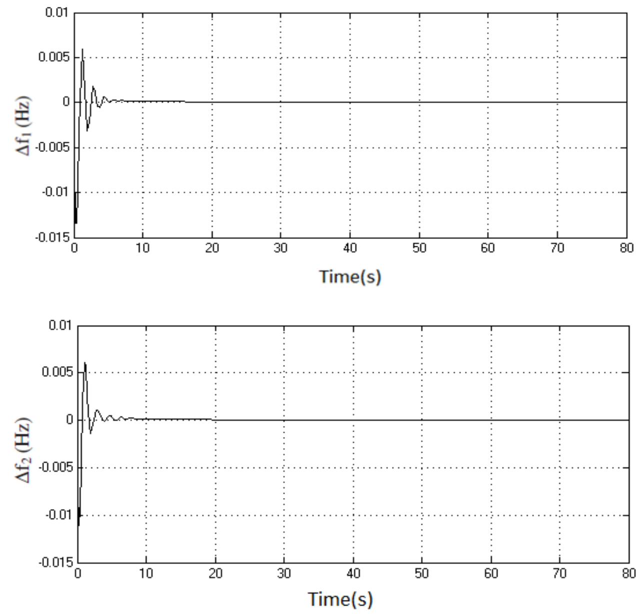


Fig-2: Dynamic responses for deviations in frequency (Δf_1,Δf_2)

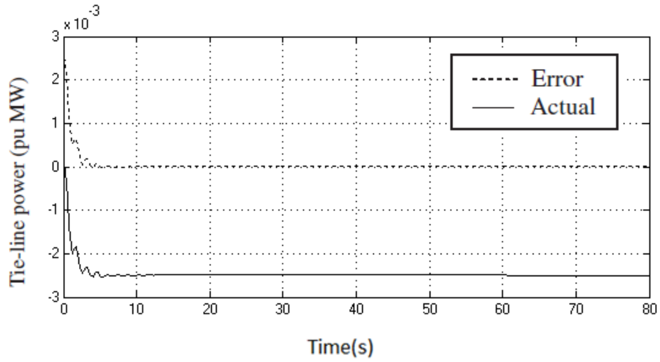


Fig-3: Dynamic responses for the actual tie-line power flow, tie-line power error.

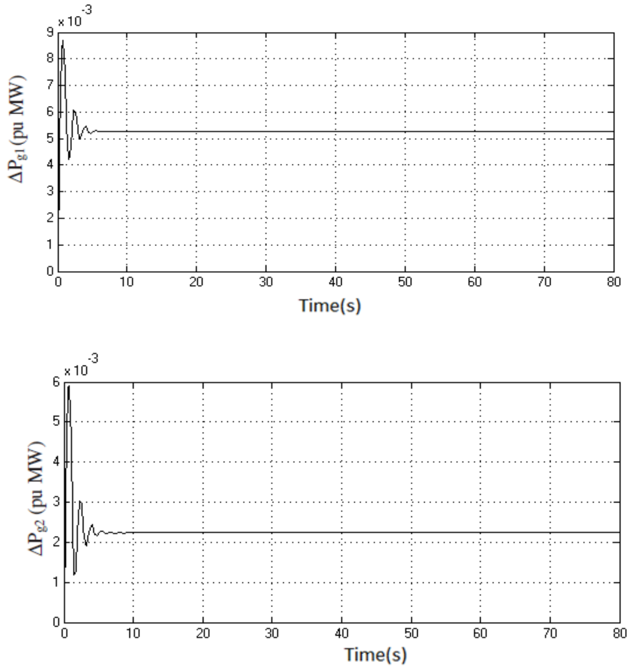


Fig- 4: Generation responses for the Gencos in area-1

4.2 AGC with Contract Violation

A Disco may violate a contract by demanding more than that specified in the contract. This excess power is not contracted out to any Genco and must be supplied by the Gencos in the same area as that of the Disco. Therefore, it must be reflected as an uncontracted local load of that area. Let only $DISCO_1$ of area-1 demands 0.005 puMW of excess power.i.e.,ΔP_{UC1}=0.005 pu MW and DISCO2 of area-2 demands no excess power i.e., ΔP_{UC2}=0 pu MW. Therefore, the total uncontracted load in area-1, $\Delta P_{L1,UC} = \Delta P_{UC1} + \Delta P_{UC2}$ =(0.005+0)=0.005 puMW. Similarly, $DISCO_3$ and $DISCO_4$ of area-2 demand no excess power. i.e., $\Delta P_{UC3} = \Delta P_{UC4}=0$ and hence, $\Delta P_{L2,UC} = \Delta P_{UC3} + \Delta P_{UC4} = 0$ puMW. Considering the same DPM and same ACE participation factors (apfs)and that each Disco has a contracted power of 0.005 pu MW as in section 3.1. we have,$\Delta P_{L1,LOC} = \Delta P_{L1} + \Delta P_{L2}$=(0.005+0.005)=0.01 puMW (contracted load) and $\Delta P_{L2,LOC} = \Delta P_{L3}+$

ΔP_{L4}=(0.005+0.005)=0.01puMW. The frequency deviations are plotted in **Fig.5** and in the steady state, these deviations are zero. Since, the DPM is the same in **section 3.1** and the excess load is taken up by the Gencos in the same area, the tie-line power, in the steady state, is the same as in **section 3.1** as can be seen from **Fig.6** and its error settles down to zero.

The uncontracted load of $DISCO_1$ is reflected in the generations of $GENCO_1$ and $GENCO_2$. When an excess demand occurs, and is not contracted out to any Genco, the change in load appears only in terms of the Area Control Errors and the ACE participation factors decide the distribution of the uncontracted load in the steady state. Hence, the additional demand or shortfall of generation has to be shared by all the GENCOS of the area in which the contract violation occurs and the generation in other area remains unaffected. Thus, at steady state, on the occurrence of an uncontracted demand, the unit generations given by Eqn, (10) gets modified to

$$\begin{bmatrix} \Delta Pg_1, ss \\ \Delta Pg_2, ss \\ \Delta Pg_3, ss \\ \Delta Pg_4, ss \end{bmatrix} = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix} \begin{bmatrix} \Delta PL_1 \\ \Delta PL_2 \\ \Delta PL_3 \\ \Delta PL_4 \end{bmatrix} + \begin{bmatrix} apf_{11} & 0.0 & 0.0 & 0.0 \\ 0.0 & apf_{12} & 0.0 & 0.0 \\ 0.0 & 0.0 & apf_{21} & 0.0 \\ 0.0 & 0.0 & 0.0 & apf_{22} \end{bmatrix} \begin{bmatrix} \Delta PL1, UC \\ \Delta PL1, UC \\ \Delta PL2, UC \\ \Delta PL2, UC \end{bmatrix} \quad (11)$$

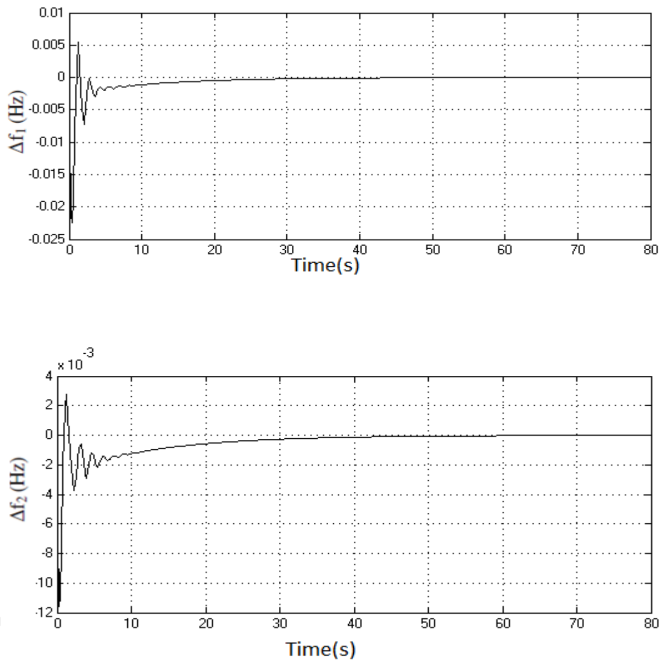


Fig-5: Dynamic responses for deviations in frequency (Δf_1, Δf_2)

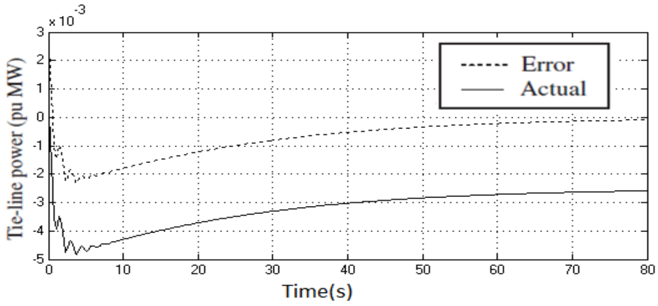
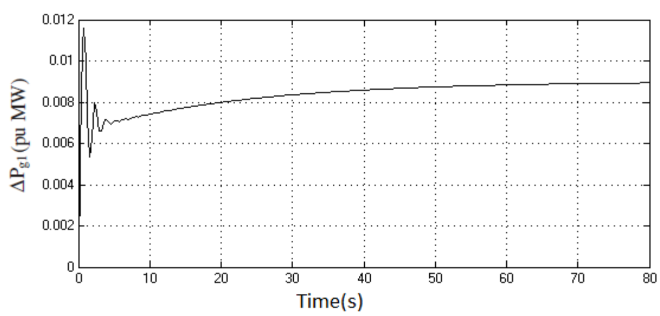


Fig-6: Dynamic responses for the actual tie-line power flow, tie-line power error.

Uncontracted power is demanded by $DISCO_1$ in area-1. $GENCO_1$ and $GENCO_2$ are also in area-1. Therefore, at steady state, this uncontracted power demand must be generated by $GENCO_1$ and $GENCO_2$ of area-1 in proportion to their ACE participation factors plus they will also generate their contracted power demand. Hence,

$\Delta P_{g1,ss}$ = 0.00525 + apf_{11} x 0.005 = .00525+0.75x0.005 = 0.009 pu MW.
$\Delta P_{g2,ss}$ = 0.00225 + apf_{12} x 0.005 = .00225+0.25x0.005 = 0.0035 pu MW.
$\Delta P_{g3,ss}$ = 0.00975 + apf_{21} x 0.005 = .00975+0.50x0.005 = 0.00975 pu MW.
$\Delta P_{g4,ss}$ = 0.00275 + apf_{22} x 0.005 = .00275+0.50x0.005 = 0.00275 pu MW.

Fig.7 shows the dynamic responses for $GENCO_1$ (ΔP_{g1}), GENCO2 (ΔP_{g2}) and GENCO3 (ΔP_{g3}), GENCO4 (ΔP_{g4}). From **Fig.7** it is seen that, at steady state, $GENCO_1$ generates 0.009 pu MW power and GENCO2 generates 0.0035 pu MW power. The generation of GENCO3 and GENCO4 are not affected by the excess load of DISCO1 in area-1, and their respective generations (ΔP_{g3}, ΔP_{g4}), at steady state remain same as that of **section 3.1**.



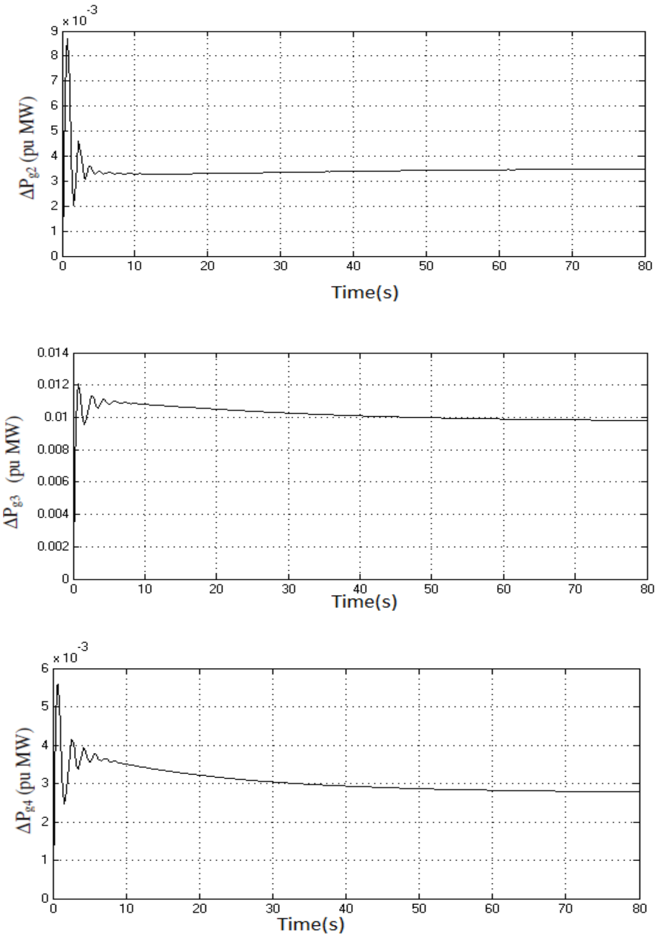


Fig-7: Generation responses for the Gencos in area-1 and area-2

4.3 Load following with Bilateral Contract only

All the Discos have a load demand of 0.005 puMW each i.e., Thus, $\Delta P_{L1} = \Delta P_{L2} = \Delta P_{L3} = \Delta P_{L4} = 0.005$ puMW, which is contracted to the various generating units as per the following DPM.

$$DPM=\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.25 & 0.10 & 0.75 & 0.60 \\ 0 & 0 & 0 & 0 \\ 0.75 & 0.90 & 0.25 & 0.40 \end{bmatrix} \quad (12)$$

$\Delta P_{L1,LOC} = \Delta P_{L1} + \Delta P_{L2} = 0.01$ pu MW & $\Delta P_{L2,LOC} = \Delta P_{L3} + \Delta P_{L4} = 0.01$ pu MW.

It is further assumed that, there are no uncontracted power demands in either of the areas. i.e., $\Delta P_{L1,UC} = \Delta P_{L2,UC} = 0$ pu MW. Since at steady state, each GENCO has to generate the contracted power as given in Eqn(10). Hence, for the case under consideration with given DPM in Eqn.(10) and using Eqn.(12),

$\Delta P_{g1,ss} = (0 \times 0.005) + (0 \times 0.005) + (0 \times 0.005) + (0 \times 0.005) = 0$ pu MW.

$\Delta P_{g2,ss} = (0.25 \times 0.005) + (0.10 \times 0.005) + (0.75 \times 0.005) + (0.60 \times 0.005) = 0.0085$puMW

Similarly, $\Delta P_{g3,ss} = 0$ pu MW, $\Delta P_{g4,ss} = 0.0115$ pu MW

The scheduled tie-line power flow,

$\Delta P_{tie12,scheduled} = [(0.75+0.60)-(0.75+0.90)] \times 0.005 = -0.0015$ pu MW

At the steady state, tie-line power error ($\Delta P_{tie12,error}$) is zero, since actual tie line power equals scheduled tie-line power. The different dynamic responses with local load following controllers are given in **Fig.8, Fig.9** and **Fig.10** .It may be noted that, in this case, the AGC controllers have some effect on the transient behavior of the responses but have no effect on the steady state performance.

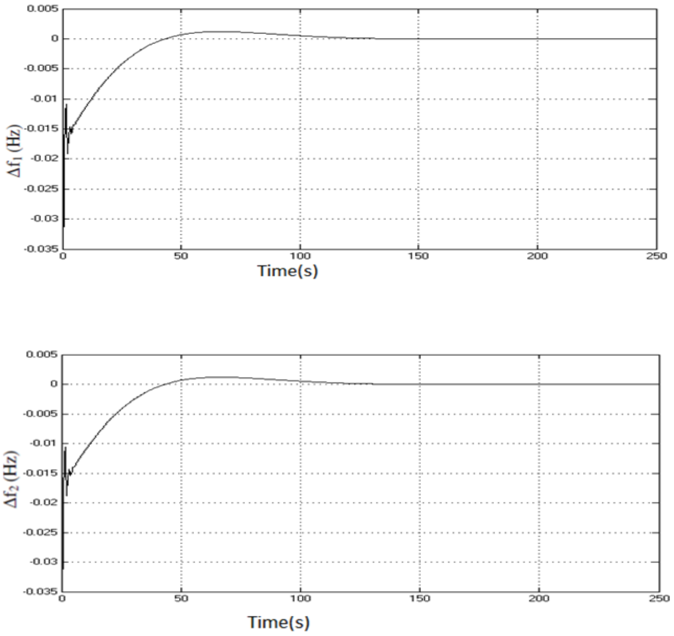


Fig-8: Dynamic responses for deviations in frequency ($\Delta f_1, \Delta f_2$)

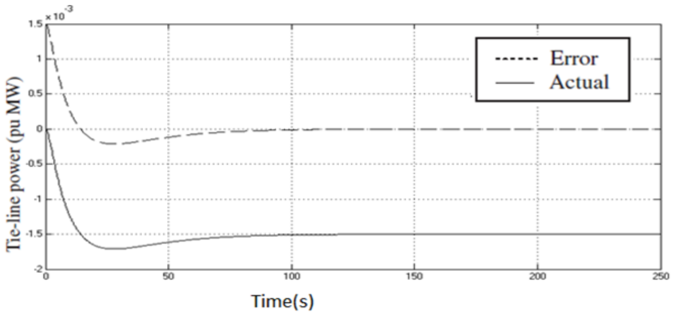


Fig- 9: Dynamic responses for the actual tie-line power flow, tie-line power error

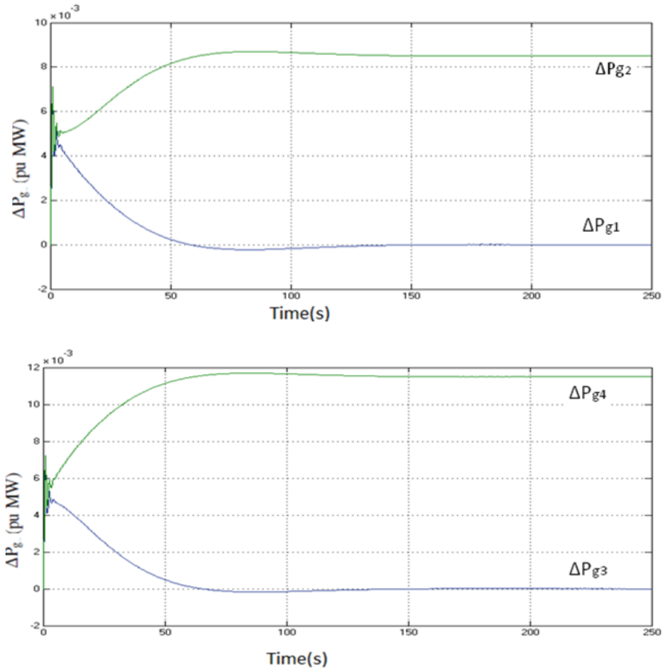


Fig- 10: Generation responses for the Gencos in area-1 and area-2

4.4 Load following with Contract Violation

Let only $DISCO_1$ of area-1 demands 0.005 puMW of excess power.i.e.,ΔP_{UC1}=0.005 pu MW and DISCO2 of area-2 demands no excess power .i.e., ΔP_{UC2}=0 pu MW. Therefore, the total uncontracted load in area-1, $\Delta P_{L1,UC}= \Delta P_{UC1}+ \Delta P_{UC2}$ =(0.005+0)=0.005 puMW. Similarly, i.e., ΔP_{UC3}=0.005 pu MW; ΔP_{UC4}=0 and hence, $\Delta P_{L2,UC}= \Delta P_{UC3}+ \Delta P_{UC4}$= 0.005pu MW. Considering the same DPM and same ACE participation factors (apfs)and that each Disco has a contracted power of 0.005 pu Mw. we have,

$\Delta P_{L1,LOC}= \Delta P_{L1}+ \Delta P_{L2}$=(0.005+0.005)=0.01 puMW (contracted load) and

$\Delta P_{L2,LOC}= \Delta P_{L3}+ \Delta P_{L4}$=(0.005+0.005)=0.01 pu MW (contracted load) .

Uncontracted power is demanded by $DISCO_1$ in area-1. $GENCO_1$ and $GENCO_2$ are also in area-1. Therefore, at steady state, this uncontracted power demand must be generated by $GENCO_1$ and $GENCO_2$ of area-1 in proportion to their ACE participation factors plus they will also generate their contracted power demand.

Hence, $\Delta P_{g1,ss}= 0 + apf_{11}$ x 0.005 = 0+1x0.005 = 0.005pu MW.

$\Delta P_{g2,ss}= 0.0085 + apf_{12}$ x 0.005 = 0.0085+0x0.005 = 0.0085pu MW.

$\Delta P_{g3,ss}= 0 + apf_{21}$ x 0.005= 0+1x0.005 =0.005 pu MW.

$\Delta P_{g4,ss}= 0.0115 + apf_{12}$ x 0.005 = 0.0115+0x0.005 = 0.0115 puMW.

$\Delta P_{tie12,scheduled}$= - 0.0015 pu MW. (same as previous)

The uncontracted load demand of 0.005puMW in area-1 is met by the generating unit under AGC (i.e.,) $GENCO_1$, whereas the generation of other Genco (i.e.,) $GENCO_2$ in area-1 at steady state are same as previous case, similar to area-2. At the steady state, tie-line power error ($\Delta P_{tie12,\ error}$) is zero, since actual tie line power equals scheduled tie-line power. The different dynamic responses with local load following controllers are given in **Fig. 11, 12** and **13**. As expected, at steady state, the excess demand of 0.005 puMW in area-1 is met by $GENCO_1$ which is under AGC. The generation of the other Genco in area-1 remains unaffected. Similarly in area-2, the excess demand is met by GENCO3.

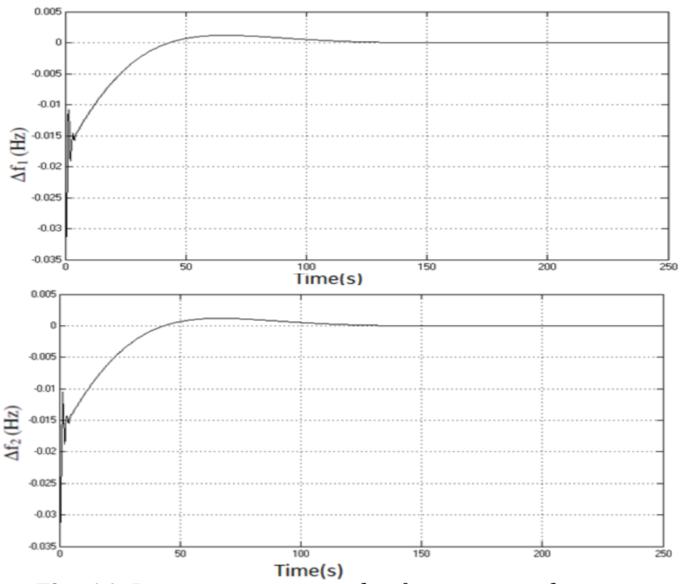


Fig.-11: Dynamic responses for deviations in frequency (Δf_1, Δf_2)

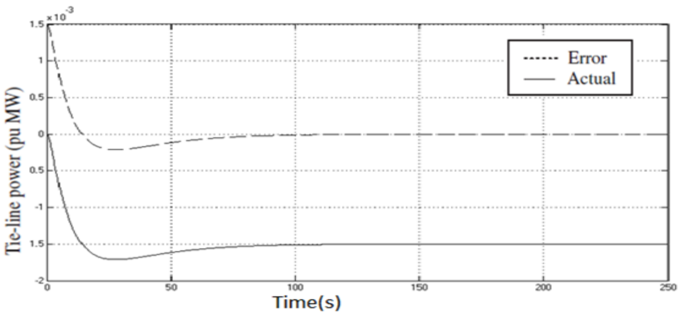


Fig.-12: Dynamic responses for the actual tie-line power flow, tie-line power error

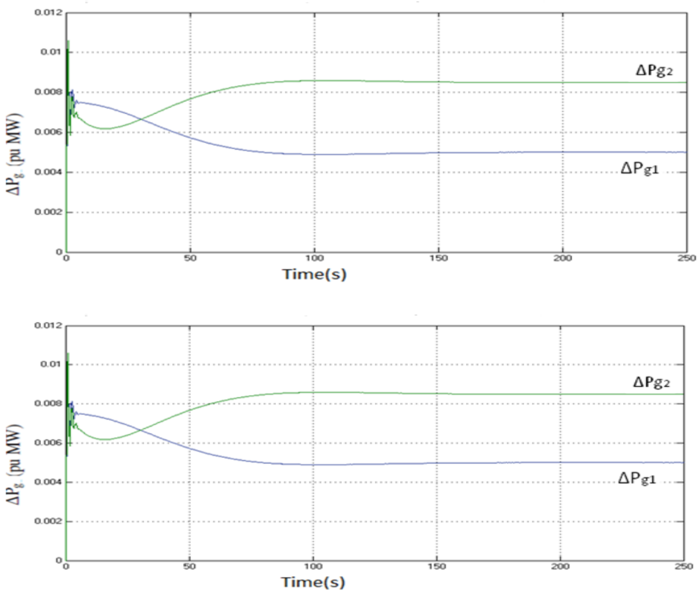


Fig- 13: Generation responses for the Gencos in area-1 and area-2

4.5 Control strategy for a Generating unit with local Load following Controller to meet Uncontracted Load Demand

It was seen (in previous section), that the uncontracted power demand in area-1 and area-2 were met completely by the Gencos under AGC (i.e.,) $GENCO_1$ in area-1 and $GENCO_3$ in area-2. However if it is so desired that some portion of the uncontracted power demands be taken by the other units in area-1& area-2(i.e.,) $GENCO_2$ and $GENCO_4$ are under load following (assuming that the load following Gencos have some reserve capacity), then a different control scheme is required. This is proposed in **Section 4.5** and shown in Fig .14.

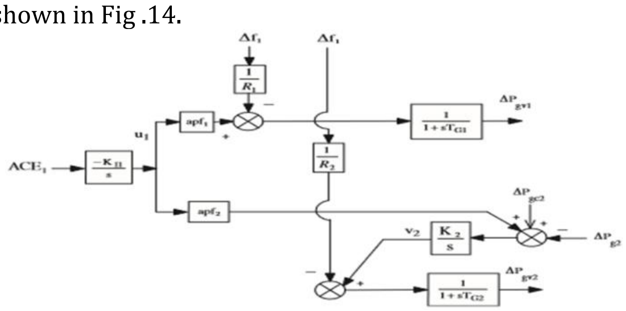


Fig-14: Modified control scheme for area-1

A fraction of the output of the AGC controller in area-1 (apf1u2) is given to the load following controller of Unit2 such that Unit2 generation can chase the contracted power demand + this fraction of uncontracted power demand apf1=0.8;apf2=0.2 & apf3=0.7;apf4=0.3 all other conditions remaining same as in the **Section 4.4**

$\Delta P_{g1,ss}$ = (apf1x ΔPL1,UC)+ ΔPgc1 = (0.8x0.005)+0 = 0.004puMW

$\Delta P_{g2,ss}$=(apf2xΔPL2,UC)+ΔPgc2= (0.2x0.005)+0.0085 = 0.0095puMW

$\Delta P_{g3,ss}$=(apf3xΔPL3,UC)+ΔPgc3=(0.7x0.005)+0.005 = 0.0035puMW

$\Delta P_{g4,ss}$=(apf4xΔPL4,UC)+ΔPgc4= (0.3x0.005)+0.00 = 0.013puMW

$\Delta P_{tie12,scheduled}$ = -0.0015 puMW

At the steady state, tie-line power error ($\Delta P_{tie12,error}$) is zero, since actual tie line power equals scheduled tie-line power. The different dynamic responses with local load following controllers are given in **Fig. 15, 16** and **17.** It may be noted that, $GENCO_2$ in area-1 and $GENCO_4$ in area-2 have taken up a fraction of the excess uncontracted load demand as per the modified control strategy.

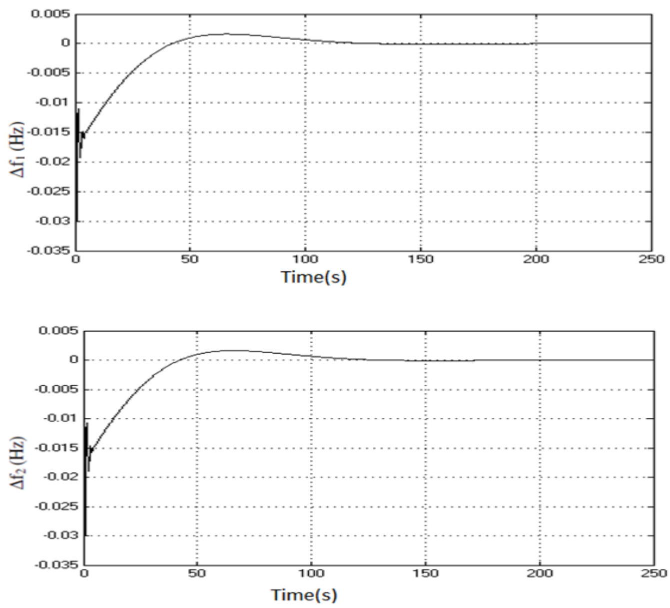


Fig-15: Dynamic responses for deviations in frequency (Δf_1, Δf_2)

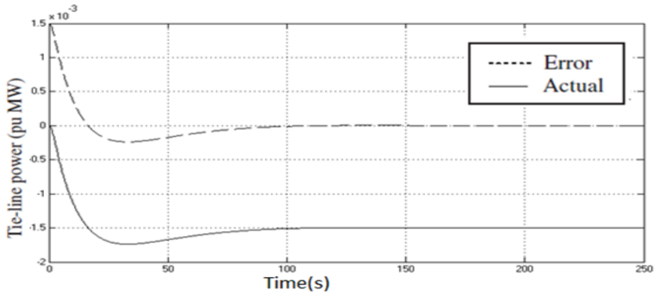


Fig- 16: Dynamic responses for the actual tie-line power flow, tie-line power error

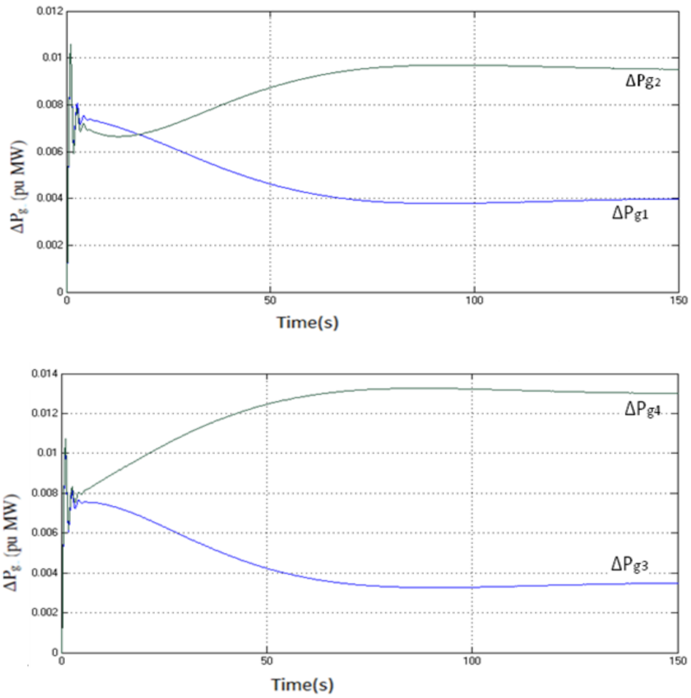


Fig-17: Generation responses for the Gencos in area-1 and area-2

5. CONCLUSION

From the simulation of various cases, it has been observed that ACE participation factors affect only the transient behavior of the system and not the steady state when there is no uncontracted demand. However, if uncontracted power demands are present, the ACE participation factors decide the distribution of uncontracted load in the steady state. Thus, this excess load is taken by the GENCOs in the same areas of that of DISCOs making the excess demand (AGC). And with this new control scheme, units under load following can be made to share any desired portion of an uncontracted power demand in the system, provided sufficient reserve capacity is available. Generally, the units under load following are expected to have less generation reserve and hence given lower ACE participation factors, so that, the major portion of an uncontracted power demand is taken up by those units under AGC only.

APPENDIX A

$P_{R1} = P_{R2} = 1200$ MW.

$T_{P1} = T_{P2} = 20$ s.

$K_{P1} = K_{P2} = 120$ Hz/pu MW.

$T_{T1} = T_{T2} = T_{T3} = T_{T4} = 0.3$ s.

$T_{12} = 0.0866$.

$T_{G1} = T_{G2} = T_{G3} = T_{G4} = 0.08$ s.

$R_1 = R_2 = R_3 = R_4 = 2.4$ Hz/pu MW.

$B_1 = B_2 = 0.425$ pu MW/Hz.

$KI_1 = KI_2 = 0.05$

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