CHAPTER 6

GENCO RESERVE BASED CONTROL STRATEGY FOR TWO AREA DEREGULATED POWER SYSTEM

6.1 INTRODUCTION

The objectives of LFC to schedule and reschedule the generation of GENCOs during contract and violation is achieved with the help of primary and secondary controller. All researchers adopt tie line bias control strategy in accomplishing this objective of LFC under deregulated power system. The tie line bias control strategy, maintains the TRANSCO power at scheduled value by rescheduling power output of GENCOs in the same area of contract violation. However, there may be more economic GENCOs in neighbouring areas willing to compensate for the unscheduled demand. The tie line bias control that gives priority in maintaining TRANSCO power flow at scheduled rather than economics cannot make use of these GENCOs’ reserves. Thus, it is required to make modifications in the widely used tie line bias control strategy so as to make use of economic GENCOs. This chapter modifies the existing tie line bias control strategy to allow willing economic GENCOs in neighbouring areas to compensate for the unscheduled demand. The chapter explains in detail the operation of proposed control strategy in two area deregulated power system. For each mathematical model developed under single buyer, bilateral and poolco market, in chapter 2, the proposed control strategy is then incorporated. These models are then analysed under contract violation to prove for its effective performance.

6.2 PROPOSED GENCO RESERVE BASED CONTROL STRATEGY

The operation of control strategy is purely based on the input to the secondary controller. The secondary controller meets the objective of LFC by making these inputs to zero. The input to the secondary controller under tie line bias control strategy is made as $\beta\Delta f$ and $\Delta P_{\text{TRANSCO12error}}$. These inputs make $ACE$. The secondary controller of LFC makes these inputs to zero. This makes tie line bias control strategy to maintain frequency within limit and TRANSCO power flow at scheduled value, during contract violation. The condition is satisfied only if GENCOs in same area of violation to meet the un-contracted power.
However, there can be GENCOs in neighbouring areas that compensate more economically compared to same area GENCOs. The compensation of un-contracted power must be compensated by GENCOs based on economic factor. The operation of existing tie line bias control strategy that gives priority in maintaining TRANSCO power at scheduled than economics, contradicts with this requirement. Thus it is required to develop a new strategy by modifying the existing tie line bias control strategy that gives priority to economic factor rather than maintaining TRANSCO power at scheduled. The new proposed control strategy allows all economic GENCOs in neighbouring area to compensate for the violated demand. Participation of GENCOs in neighbouring areas make TRANSCO power to increase or decrease. Increase of TRANSCO power implies that TRANSCO reserve is made used. Thus, the new proposed strategy gives priority to economic factor; thereby make use of TRANSCO reserve.

In order to let the new strategy make use of TRANSCO reserve, the power flow through the lines must not be maintained at scheduled. This requires the input to the secondary control to have only $\beta \Delta f$ as given in equation (6.1).

$$ACE_i = \beta \Delta f$$

(6.1)

Where,

$ACE_i$ represents $ACE$ of $i^{th}$ GENCO

$\beta$ represents the bias factor

Since, $\Delta P_{TRANSCO12error}$ is not given as input to the secondary controller, TRANSCO power can be made to vary, allowing economic GENCOs in the neighbouring areas to compensate for the violation. The participating GENCOs compensate for the violated power based on the $epf$ values calculated as per equation (6.2).

$$epf_k = \frac{(1/Price_{off-un \, k})}{\sum_{j=1}^{nwG} (1/Price_{off-un \, j})} \text{ for } k = 1 \text{ to } nwG$$

(6.2)

Where,

$nwG$ represents number of GENCOs participating in second round auction

$Price_{off-un \, k}$ represents the offer price of $k^{th}$ willing GENCO of any area, participating in second phase auction to meet unscheduled power

The change in GENCO’s power is as per equation (6.3).

$$\Delta P_{Gk} = P_{Gk,contract} + (epf_k \times \Delta P_D)$$

(6.3)
The proposed strategy hence makes use of reserve of economic GENCOs in neighbouring areas and also TRANSCO reserve, thus the name ‘GENCO reserve based control strategy’.

The proposed strategy is now to be tested for its performance. This requires the proposed GENCO reserve based strategy to be incorporated in the complete mathematical model of two area system under each market model developed in Chapter 3. The following sections analyse the performance of proposed GENCO reserve based control strategy under single buyer, bilateral and poolco model.

6.3 ANALYSIS OF GENCO RESERVE BASED CONTROL STRATEGY UNDER SINGLE BUYER MODEL

In this section the proposed GENCO reserve based control strategy is analysed under single buyer model for its better performance compared to tie line bias control strategy. The complete mathematical model of single buyer market, developed in chapter 3, is incorporated with the proposed GENCO reserve based control strategy and is analysed during contract violation.

6.3.1 GENCO power incorporating GENCO reserve based control strategy under single buyer model

The proposed GENCO reserve based control strategy is incorporated in the mathematical model of single buyer market developed in Chapter 2. With \( gpf \) value computed in chapter 4, and \( epf \) values as per equation (6.2), the model is then subjected to violation of 0.01 p.u. at 350s in an area. At the instance of violation, the proposed strategy allows all willing GENCOs in same and neighbouring areas to compensate for the violation. However, under single buyer model, each area is treated as separate pool by the pool operator and hence GENCOs in other area cannot compensate for the violated demand.

From Appendix IV, it is clear that for a violation in area 1, GENCO 1\( (G_{11}) \) and GENCO 2\( (G_{21}) \) meet for the violated demand. Similarly, for a violation in area 2, GENCO 4\( (G_{22}) \) meets the violated demand. Using the offer price given in Appendix IV and equation (6.2), the \( epf \) ratios of \( G_{11} \) and \( G_{21} \) is \( 0.462:0.538 \) and is unity for \( G_{22} \).

The GENCOs and TRANSCO powers under single buyer model incorporating GENCO reserve based control strategy using these \( epf \) for violation in area 1 and area 2 is calculated using equation (3.27) and are given in Table 6.1.
Table 6.1: GENCOs and TRANSCO powers during violation of 0.01 p.u. incorporating GENCO reserve based strategy under single buyer model

<table>
<thead>
<tr>
<th>GENCO/TRANSCO</th>
<th>Contracted Power</th>
<th>Violation in Area 1</th>
<th>Violation in Area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG_{11}</td>
<td>0.375</td>
<td>0.3796</td>
<td>0.375</td>
</tr>
<tr>
<td>PG_{21}</td>
<td>0.625</td>
<td>0.6304</td>
<td>0.625</td>
</tr>
<tr>
<td>PG_{12}</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>PG_{22}</td>
<td>0.5</td>
<td>0.5</td>
<td>0.51</td>
</tr>
<tr>
<td>P_{TRANSCO12}</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

It is clear from Table 6.1 that during contract violation in area 1, output power of GENCO 1 (G_{11}) and GENCO 2 (G_{21}) is increased from 0.375 p.u. to 0.3796 p.u. (i.e., 0.375+0.462×0.01) and from 0.625 p.u. to 0.6304 p.u. (i.e., 0.625+0.538×0.01) respectively.

Similarly, for a violation in area 2, power output of GENCO 4 (G_{22}) is increased from 0.5 p.u. to 0.51 p.u. (i.e., 0.5+1×0.01).

As only same area GENCOs under single buyer market model compensate for the uncontracted power, the TRANSCO power remains at zero. The performance of the proposed strategy is same as that with tie line bias control strategy and matches with Table 4.2.

It is now required to simulate the mathematical model of single buyer model with the proposed GENCO reserve based control strategy under contract violation.

6.3.2 Simulation result incorporating GENCO reserve based control strategy under single buyer model

The complete mathematical model of two area system under single buyer model is developed in MATLAB/Simulink. A contract violation of 0.01 p.u. is created at 350s in area 1. The GENCOs and TRANSCO power responses for this contract violation in area 1 are obtained as in Figure 6.1.

Figure 6.1 shows that the output power of GENCO 1 (G_{11}) and GENCO 2 (G_{21}) is increased from 0.375 p.u. to 0.3796 p.u. and 0.625 p.u. to 0.6304 p.u. respectively. Since the violated power is met by the GENCOs in same area, TRANSCO power remains same. The obtained values match with the tabulated values shown in Table 6.1.
Figure 6.1: GENCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 1 incorporating GENCO reserve based strategy under single buyer model.

Again, a contract violation of 0.01 p.u. is created in area 2 at 350s and corresponding power responses of GENCOs and TRANSCO are shown in Figure 6.2.

Figure 6.2: GENCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 2 incorporating GENCO reserve based strategy under single buyer model.

Figure 6.2 shows that the power output of GENCO 4 ($G_{22}$) is increased from 0.5 p.u. to 0.51 p.u., while the power outputs of GENCO 1, GENCO 2 and GENCO 3 remain same. The violated power in area 2 is met by same area GENCO and hence TRANSCO power remains unaltered. The obtained values match with the tabulated values shown in Table 6.1.

A better comparison between the performance of GENCO reserve based and tie line bias control strategy under single buyer model can be made with the help of bar chart.
6.3.3 Performance comparison of GENCO reserve based control strategy with tie line bias control for a violation in area 1 under single buyer model

This section gives the comparison between the performance of GENCO reserve based and tie line bias control strategy for a violation in area 1 under single buyer model with the help of bar chart as shown in Figure 6.3.

Figure 6.3: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 1 under single buyer model

Figure 6.3 shows the GENCOs and TRANSCO power change from the contracted values, during violation in area 1 under single buyer model, incorporating tie line bias and GENCO reserve based control strategies respectively. In Figure 6.3, G1(1) represents GENCO 1 power with tie line bias control, while, G1(2) represents GENCO 2 power output with GENCO reserve based strategy. From Figure 6.3, it is evident that under single buyer model, only same area GENCOs (G1) and GENCO 2 (G2) compensate for the violated power irrespective of the control strategy. This maintains TRANSCO power variations to zero. Thus power output of GENCO 1 (G1(2)) and GENCO 2 (G2(2)) increase.

Now, comparison of performance between the proposed strategy and tie line bias control is made during violation in area 2.

6.3.4 Performance comparison of GENCO reserve based control strategy with tie line bias control for a violation in area 2 under single buyer model

This section gives the bar chart representation showing comparison between the performance of GENCO reserve based and tie line bias control strategy for a violation in area 2 under single buyer model. This is shown in Figure 6.4.
Figure 6.4: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 2 under single buyer model

Figure 6.4 gives change in GENCOs and TRANSCO powers during violation in area 2, incorporating tie line bias and GENCO reserve based control strategies respectively under single buyer model. It is noticeable that during contract violation in area 2, tie line bias control strategy allows only same area willing GENCO - GENCO 4 (G4) to participate so as to meet the un-contracted power. Thus, there is an increase in the power output of this GENCO as clear from Figure 6.4. Since, these GENCOs belong to the same area of violation, TRANSCO (T) power deviation is zero.

The proposed GENCO reserve based control strategy allows all economic GENCOs to take part in LFC during contract violation. However, under single buyer model, each pool is considered separately, and hence, only same area willing GENCOs are made to compensate for the same. Thus, the GENCO participations with GENCO reserve based strategy are similar to that with tie line bias control.

From Figure 6.3 and Figure 6.4, it can be concluded that the desired operation of LFC with the proposed GENCO reserve based control strategy perform similar to tie line bias control, under single buyer model.

6.4 ANALYSIS OF GENCO RESERVE BASED CONTROL STRATEGY UNDER BILATERAL MODEL

In this section the proposed GENCO reserve based control strategy is analysed under bilateral model for its better performance and compared with tie line bias control strategy.
The proposed GENCO reserve based control strategy is incorporated in the complete mathematical model of bilateral market, developed in chapter 3 and is analysed during contract violation.

6.4.1 GENCO power incorporating GENCO reserve based control strategy under bilateral model

The proposed GENCO reserve based control strategy is incorporated in the mathematical model of bilateral market developed in Chapter 3. With $cpf$ and $epf$ computed in chapter 4 and equation (6.2) respectively, the model is subjected to violation of 0.01 p.u. in an area. As explained in section 4.5.1, during a contract violation in any area, the un-contracted power is met by the willing GENCOs that make contract with DISCO based on $epf$. Section 4.5.1 assumes that GENCO 1 ($G_{11}$), GENCO 2 ($G_{21}$), GENCO 3 ($G_{12}$) and GENCO 4 ($G_{22}$) compensate for the violated demand in any DISCO in the ratio $0.3:0.2:0.1:0.4$. Thus or a contract violation each area shares 50% of the violated demand.

The GENCOs and TRANSCO powers incorporating GENCO reserve based control strategy under bilateral model using these $epf$ is tabulated in Table 6.2.

<table>
<thead>
<tr>
<th>GENCO</th>
<th>Contracted power</th>
<th>Violation in area 1</th>
<th>Violation in area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PG_{11}$</td>
<td>0.42</td>
<td>0.423</td>
<td>0.423</td>
</tr>
<tr>
<td>$PG_{21}$</td>
<td>0.34</td>
<td>0.342</td>
<td>0.342</td>
</tr>
<tr>
<td>$PG_{12}$</td>
<td>0.26</td>
<td>0.261</td>
<td>0.261</td>
</tr>
<tr>
<td>$PG_{22}$</td>
<td>0.18</td>
<td>0.184</td>
<td>0.184</td>
</tr>
<tr>
<td>$P_{TRANSCO12}$</td>
<td>0.46</td>
<td>0.455</td>
<td>0.465</td>
</tr>
</tbody>
</table>

It is clear from Table 6.2 that during contract violation in area 1, output power of GENCO 1 ($G_{11}$), GENCO 2 ($G_{21}$), GENCO 3 ($G_{12}$) and GENCO 4 ($G_{22}$) is increased from 0.42 p.u., 0.34 p.u., 0.26 p.u. and 0.18 p.u. to 0.423 (i.e., 0.42+0.3×0.01) p.u., 0.342 (i.e., 0.34+0.2×0.01) p.u., 0.261 (i.e., 0.26+0.1×0.01) p.u. and 0.184 (i.e., 0.18+0.4×0.01) p.u. respectively. GENCOs in area 2 compensate 50% of un-contracted demand in DISCOs in area 1 and thus TRANSCO power decreases to 0.455 (i.e., 0.46–0.5×0.01) p.u..

Similarly, for a violation in area 2, power output of GENCO 1 ($G_{11}$), GENCO 2 ($G_{21}$), GENCO 3 ($G_{12}$) and GENCO 4 ($G_{22}$) is increased from 0.42 p.u., 0.34 p.u., 0.26 p.u. and 0.18 p.u. to 0.423 (i.e., 0.42+0.3×0.01) p.u., 0.342 (i.e., 0.34+0.2×0.01) p.u., 0.261 (i.e., 0.26+0.1×0.01) p.u. and 0.184 (i.e., 0.18+0.4×0.01) p.u. respectively. GENCOs in area 1
compensate 50% of un-contracted demand in DISCOs of area 2 and thus TRANSCO power increases to 0.465 (i.e., 0.46+0.5×0.01) p.u.. This clearly shows that the proposed GENCO based control strategy makes use of TRANSCO reserve.

It is now required to simulate the mathematical model under bilateral model with the proposed GENCO based control strategy during contract violation.

6.4.2 Simulation result incorporating GENCO reserve based control strategy under bilateral model

The complete mathematical model of two area system under bilateral model is developed in MATLAB/Simulink. A contract violation of 0.01 p.u. is created at 350s in area 1 and the GENCOs and TRANSCO power responses are obtained as presented in Figure 6.5.

Figure 6.5: GENCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 1 incorporating GENCO reserve based strategy under bilateral model

Figure 6.5 shows that the output power of GENCO 1 (G₁₁), GENCO 2 (G₂₁), GENCO 3 (G₁₂) and GENCO 4 (G₂₂) is increased from 0.42 p.u., 0.34 p.u., 0.26 p.u. and 0.18 p.u. to 0.423 p.u., 0.342 p.u., 0.261 p.u. and 0.184 p.u. respectively. Compensation of 50% of uncontracted power in area 1 DISCO by GENCOs in area 2 results TRANSCO power to decrease from 0.46 p.u. to 0.455 p.u.. This is clear from Figure 6.5. The obtained GENCOs and TRANSCO values match with the tabulated values shown in Table 6.2.

Again, a contract violation of 0.01 p.u. is created in area 2 at 350s and corresponding power responses of GENCOs and TRANSCO is shown in Figure 6.6.
Figure 6.6: GEnCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 2 incorporating GEnCO reserve based strategy under bilateral model

From Figure 6.6, it is clear that the output power of GEnCO 1 (G11), GEnCO 2 (G21), GEnCO3 (G12) and G 4 (G22) is increased from 0.42 p.u., 0.34 p.u., 0.26 p.u. and 0.18 p.u. to **0.423 p.u., 0.342 p.u., 0.261 p.u. and 0.184 p.u.**. Compensation of 50% of un-contracted power in area 2 DISCO by GEnCOs in area 1 results TRANSCO power to increase from 0.46 p.u. to **0.465 p.u.**. This is clear from Figure 6.6. The obtained GEnCOs and TRANSCO power values match with the tabulated values shown in Table 6.2.

A better comparison between the performance of GEnCO reserve based and tie line bias control strategies under bilateral model can be made with the help of bar chart.

### 6.4.3 Performance comparison of GEnCO reserve based control strategy with tie line bias control for a violation in area 1 under bilateral model

This section gives the comparison between the performance of GEnCO reserve based and tie line bias control strategies for a violation in area 1 under bilateral model with the help of bar chart as shown in Figure 6.7.

Figure 6.7 gives GEnCOs and TRANSCO powers’ change during violation in area 1 under bilateral model, incorporating tie line bias and GEnCO reserve based control strategies respectively. It is visible that during contract violation in area 1, tie line bias control strategy allows only same area willing GEnCOs - GEnCO 1 (G1) and GEnCO 2 (G2) to participate to meet the un-contracted power. Thus, there is an increase in power output of these
GENCOs (G1(1) and G2(1)). Since, these GENCOs belong to the same area of violation, TRANSCO power (T(1)) deviation is zero.

Figure 6.7: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 1 under bilateral model

The proposed GENCO reserve based control strategy allows all economic GENCOs to take part in LFC during contract violation. The GENCOs that are willing to participate for LFC during violations are found to be GENCO 1 (G1), GENCO 2 (G2), GENCO 3 (G3) and GENCO 4 (G4) from chapter 4. Thus, an increase in power of these GENCOs (G1(2), G2(2), G3(2) and G4(2)) are seen in Figure 6.7. A part of the violated demand in area 1 is met by GENCO 3 (G3(2)) and GENCO 4 (G4(2)) in area 2, thus, TRANSCO power that flows from area 1 to area 2 gets reduced. This is clear from Figure 6.7.

For a violation in any DISCO of area 2, the performance comparison is made between GENCO reserve based control strategy and tie line bias control.

6.4.4 Performance comparison of GENCO reserve based control strategy with tie line bias control for a violation in area 2 under bilateral model

This section gives the comparison between the performance of GENCO reserve based and tie line bias control strategies for a violation in area 2 under bilateral model. The bar chart presentation is shown in Figure 6.8.
Figure 6.8: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 2 under bilateral model

Figure 6.8 gives the power variation in GENCOs and TRANSCO under bilateral model, during violation in area 2, incorporating tie line bias and GENCO reserve based control strategies respectively. During contract violation in area 2, tie line bias control strategy allows only same area willing GENCOs - GENCO 3 (G3) and GENCO 4 (G4) to participate to meet the un-contracted power. Thus, the power output of these GENCOs (G1(1) and G2(1)) increases from the contracted value. Since, these GENCOs belong to the same area of violation, TRANSCO power (T(1)) deviation is zero.

GENCO reserve based control strategy allows all economic GENCOs to take part in meeting unscheduled demand. From chapter 4, GENCO 1 (G1), GENCO 2 (G2) GENCO 3 (G3) and GENCO 4 (G4) are found to be the willing GENCOs that participate for unscheduled demand. Thus, an increase in powers for these GENCOs (G1(2), G2(2), G3(2)and G4(2)) are seen in Figure 6.8. GENCO 1 (G1) and GENCO 2 (G2) meet a part of the violated demand in area 2. Thus, there is an increase in TRANSCO power (T(2)). This is also clearly shown in Figure 6.8.

From Figure 6.7 and Figure 6.8, it is concluded that the proposed GENCO reserve based control strategy allows all willing GENCOs to meet the violated demand, thereby making use of its reserve. The strategy also let power from the neighbouring area GENCOs to flow through TRANSCO, thus utilizing the reserve of TRANSCO.
6.5 ANALYSIS OF GENCO RESERVE BASED CONTROL STRATEGY UNDER POOLCO MODEL

In this section the proposed GENCO based control strategy is analysed under poolco model for its performance. The proposed GENCO based control strategy is incorporated in the complete mathematical model of poolco market, developed in Chapter 3 and is analysed during contract violation.

6.5.1 GENCO power incorporating GENCO reserve based control strategy under poolco model

The proposed GENCO based control strategy is incorporated in the mathematical model of poolco market developed in Chapter 3. With \( apf \) computed for poolco model in chapter 4 and \( epf \) calculated using equation (6.2), the model is subjected to violation of 0.01 p.u. in an area. At the instance of violation, the proposed strategy allows willing GENCOs in the same and neighbouring area to compensate for the violation based on their \( epf \) value.

From Appendix IV, it is clear that \( G_{11}, G_{21} \) and \( G_{22} \), are willing to participate in LFC during contract violation. These GENCOs participate based on the \( epf \) calculated from the offer price submitted during second stage auction. Using equation (6.2) and data give in Appendix IV, the participating GENCOs contribute for the violated demand in the ratio 0.32:0.37:0.31. The sum of these values makes unity.

The GENCOs and TRANSCO powers incorporating GENCO reserve based control strategy under poolco model with these \( epf \) is tabulated in Table 6.3.

Table 6.3: GENCOs and TRANSCO powers during violation of 0.01 p.u. incorporating GENCO reserve based strategy under poolco model

<table>
<thead>
<tr>
<th>GENCO</th>
<th>Contracted power</th>
<th>Violation in area 1</th>
<th>Violation in area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( PG_{11} )</td>
<td>0.3003</td>
<td><strong>0.3035</strong></td>
<td><strong>0.3035</strong></td>
</tr>
<tr>
<td>( PG_{21} )</td>
<td>0.4998</td>
<td><strong>0.5035</strong></td>
<td><strong>0.5035</strong></td>
</tr>
<tr>
<td>( PG_{12} )</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>( PG_{22} )</td>
<td>0.333</td>
<td><strong>0.3361</strong></td>
<td><strong>0.3361</strong></td>
</tr>
<tr>
<td>( P_{TRANSCO12} )</td>
<td>0.367</td>
<td><strong>0.3639</strong></td>
<td><strong>0.3739</strong></td>
</tr>
</tbody>
</table>

Table 6.3 clearly shows that for a violation of 0.01 p.u. in area 1, GENCO 1 (\( G_{11} \)), GENCO 2 (\( G_{21} \)) and GENCO 4 (\( G_{22} \)) increase its power output from 0.3003 p.u., 0.4998 p.u., 0.333 p.u. to **0.3035** (i.e.,0.3003+0.32×0.01) p.u., **0.5035** (i.e.,0.4998+0.37×0.01) p.u. and **0.3361** (i.e.,0.333+0.31×0.01) p.u. respectively. Compensation of 0.0031 (i.e., 0.31×0.01)
p.u. of un-contracted power by GENCO 4 (G_{22}), cause TRANSCO power flow from area 2 to area 1, in addition to 0.367 p.u. contracted power flow from area 1 to area 2. Thus, the net TRANSCO power flow becomes, 0.3639 p.u.

Similarly, for a violation of 0.01 p.u. in area 2, GENCO 1 (G_{11}), GENCO 2 (G_{21}) and GENCO 4 (G_{22}) increase its power output from 0.3003 p.u., 0.4998 p.u., 0.333 p.u. to 0.3035 p.u., 0.5035 p.u. and 0.3361 p.u. respectively. Compensation of 0.0069 p.u. of un-contracted power by GENCO 1 (G_{11}) and GENCO 2 (G_{21}) cause TRANSCO power flow from area 1 to area 2, in addition to the flow of 0.367 p.u.. Thus, the net TRANSCO power flow increases to 0.3739 p.u.. Thus from Table 6.3 it is clear that the participation of neighbouring area GENCOs in meeting the un-contracted power in an area cause increase or decrease in TRANSCO power.

It is now required to simulate the mathematical model of poolco model with the proposed GENCO based control strategy under contract violation.

6.5.2 Simulation result incorporating GENCO reserve based control strategy under poolco model

The complete mathematical model of two area system under poolco model is developed in MATLAB/Simulink. A contract violation of 0.01 p.u. is created at 350s in area 1 and the GENCOs and TRANSCO power responses are obtained as presented in Figure 6.9.

![Figure 6.9: GENCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 1 incorporating GENCO reserve based strategy under poolco model](image-url)
Figure 6.9 shows that the output power of GENCO 1 (G_{11}), GENCO 2 (G_{21}), GENCO 3 (G_{12}) and GENCO 4 (G_{22}) is increased from 0.3003 p.u., 0.4998 p.u., 0.3 p.u. and 0.333 p.u. to 0.3035 p.u., 0.5035 p.u. and 0.3361 p.u. Compensation of 31% of un-contracted power in area 1 by GENCOs in area 2 results TRANSCO power to decrease to 0.3639 p.u.. This is clearly shown in Figure 6.9. The obtained GENCOs and TRANSCO power values match with the tabulated values shown in Table 6.3.

Again, a contract violation of 0.01 p.u. is created in area 2 at 350s and corresponding power responses of GENCOs and TRANSCO is shown in Figure 6.10.

Figure 6.10: GENCOs and TRANSCO power responses during violation of 0.01 p.u. at 350s in area 2 incorporating GENCO reserve based strategy under poolco model

From Figure 6.10, it is clear that the output power of GENCO 1 (G_{11}), GENCO 2 (G_{21}), and GENCO 4 (G_{22}) is increased from 0.3003 p.u., 0.4998 p.u., and 0.333 p.u. to 0.3035 p.u., 0.5035 p.u. and 0.3361 p.u. respectively. Compensation of 69.1% of un-contracted power in area 2 by GENCOs in area 1 results TRANSCO power to increase from 0.367 p.u. to 0.3739 p.u.. This is clear from Figure 6.10. The obtained GENCOs and TRANSCO values match with the tabulated values shown in Table 6.3.

A better comparison between the performance of GENCO reserve based and tie line bias control strategy under bilateral model can be presented with the help of bar chart.
6.5.3 Performance comparison of GENCO reserve based control strategy with tie line bias control for a violation in area 1 under poolco model

This section gives the bar chart comparison between the performance of GENCO reserve based and tie line bias control strategies for a violation in area 1 under poolco model. This is shown in Figure 6.11.

Figure 6.11: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 1 under poolco model

Figure 6.11 shows the GENCOs and TRANSCO power changes during violation of 0.01 p.u. in area 1 under poolco model, incorporating tie line bias and GENCO reserve based control strategies respectively. From Figure 6.11, it is apparent that during contract violation in area 1, tie line bias control strategy allows same area willing GENCOs - GENCO 1 (G1) and GENCO 2 (G2) to participate to meet the un-contracted power. Thus, there is an increase in the power output of these GENCOs (G1(1) and G2(1)). Since, these GENCOs belong to the same area of violation, TRANSCO power (T(1)) deviation is zero in Figure 6.11.

The proposed GENCO reserve based control strategy allows all economic GENCOs to participate in LFC during contract violation. The willing GENCOs are found to be GENCO 1 (G1), GENCO 2 (G2) and GENCO 4 (G4) from chapter 4. Thus, an increase in the power for these GENCOs (G1(2), G2(2), G4(2)) are seen in Figure 6.11. A part of the violated demand in area 1 is met by GENCO 4 (in area 2), the TRANSCO power that flows from area 1 to area 2 gets reduced. This is also clear from Figure 6.11.

For a violation in area 2, the performance comparison is now made between GENCO reserve based control strategy and tie line bias control.
6.5.4 Performance comparison of GENCO reserve based control strategy with tie line bias control for a violation in area 2 under poolco model

This section illustrates the comparison between the performance of GENCO reserve based strategy and tie line bias control for a violation in area 2 under poolco model with the help of bar chart as shown in Figure 6.12.

Figure 6.12: Performance comparison of GENCO reserve based and tie line bias control strategies during violation of 0.01 p.u. in area 2 under poolco model

Figure 6.12 presents the GENCOs and TRANSCO power variation during violation of 0.01 p.u. in area 2 under poolco model, incorporating tie line bias control and GENCO reserve based strategy respectively. During contract violation in area 2, tie line bias control strategy allows only same area willing GENCO 4 (G4) to meet the un-contracted power. Thus, there is an increase in the power output of this GENCO (G4(1)). This is clear from Figure 6.11. Since, these GENCOs belong to the same area of violation, TRANSCO power deviation (T(1)) is zero.

Incorporating GENCO reserve based control strategy allows all willing GENCOs to take part in meeting unscheduled demand. From chapter 4, GENCO 1 (G1), GENCO 2 (G2) and GENCO 4 (G4) are found to be the willing GENCOs that participate for unscheduled demand. Thus, an increase in the power for these GENCOs is seen in Figure 6.12. GENCO 1 (G1) and GENCO 2 (G2) meet a part of the violated demand in area 2. Thus, there is an increase in TRANSCO power (T(2)). This is also presented in Figure 6.12.
6.6 CONCLUSIONS

The performance of LFC depends on the adopted control strategy. All literatures make use of Cohn’s strategy of tie line bias control to achieve the objectives of LFC. This strategy maintains TRANSCO power at scheduled values such that GENCOs in same area of contract violation participate for the un-contracted power. However, there can be GENCOs in the neighbouring areas that are willing to meet the violated power more economically. The widely employed tie line bias control fails to make use of the reserve of economic neighbouring area, willing GENCOs. Thus, tie line bias control is modified to allow more economic willing GENCOs in neighbouring areas to compensate for the violated power. The input to the secondary controller under tie line bias control is replaced with change in system frequency.

The performance of the proposed GENCO reserve based control strategy in two area LFC system are analysed under different market models. The epf values are en calculated using offer price of all willing GENCOs submitted in the second stage auction. For each market model, the power generation of GENCOs are calculated. The epf values are included in the mathematical model of two area hydro thermal system under single buyer, bilateral and poolco market, developed in chapter 3, and is incorporated with GENCO reserve based control strategy. The performance of the control strategy is then analysed during contract violation in area 1 and area 2. The power outputs of GENCOs during violation are finally compared with the computed values.

A performance comparison of proposed strategy and tie line bias control for violation in each area under different market models is also presented in the form of bar chart. The observed results prove the effective operation of GENCO reserve based strategy over tie line bias control strategy.