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Load Following Under Different Market Models in a Restructured Power System

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Load following is one of the major components which ensures the secured operation of power systems. The complexity of the load following control strategy increases when the system operates under deregulated environment. A load following system has to control not only the frequency and tie line power but also the power generation as per the contract. The contract is decided by any one of the three market model namely single buyer, bilateral and poolco model. This paper develops load following system operating under different models. The generalized factors based on which the load following satisfies the scheduled and violated power are computed for all market models. Finally the system is simulated under different models with contract violation to justify the performance of load follower. The developed generalized market participation factors and violation participation factors make the load follower to yield desired secured power system.

Keywords: Bilateral market; load following; poolco market; restructured power system; single buyer market.

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1. Introduction

Security of an interconnected power system relies on the balance between total generation and total load demand plus associated system losses. Disturbances due to load or generation losses results in imbalance between electrical load and power supplied by connected generators. This directly causes lowering of turbine speed and thus, deviation in system frequency. Sequentially, the contracted power exchange between control areas deviate from their nominal values. This poses serious threat to reliable operation of power system [1]. It is necessary to have a system that automatically manipulates the operation of fuel valve which in turn adjusts real power output of electric generators to match with the demand. This is accomplished with the help of load following system [2-3], one of many ancillary services.

The load follower regulates the system frequency and tie line power. The natural self-governing response, called primary frequency control attenuates frequency deviations that are greater than the speed governor tolerance. The secondary frequency control can be used to re-establish area frequency to the nominal value. This is accomplished with the incorporation of integral controller as the secondary frequency control. The input to the secondary controller, called the area control error (ACE), includes system frequency deviation and tie line power change. With this input to the secondary controller, load following system monitors the system frequency and tie line power deviations as a result of change in demand, determines the net change in generation required and changes the set operation of the generators within the area, so as to keep the ACE within limits. As the

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ACE is adjusted within limits, both frequency and tie line power deviations become within allowable band.

Very early works in attaining the objectives of load following with secondary controllers have been done in [4, 5]. These works are based on tie-line bias control strategy that satisfies the NERC requirement.

With the key interest in social welfare, the electric power system has been reformulated from vertical structure to horizontal. The new structure having independent entities such as GENerating COmpanies (GENCOs), DIStribution COmpanies (DISCOs), TRANSmission COmpanies (TRANSCOs) and System Operator (SO) [6], creates a competitive electricity market. With many technical issues for changing system from vertical to horizontal structure [7], it is necessary for the SO to provide a number of ancillary services for secure operation of power system. The primary objective of the load following system is to engender the GENCOs and TRANSCOs to operate based on the contract [8]. The load following system in deregulated electricity market should be designed to consider the contracted and violation power in different market models. The market models include single buyer, bilateral and poolco model. The operation of the load following under new environment introduces many technical challenges. A detailed discussion on load following issues in deregulated power system is reported in [9]. A framework for price based operation to understand load following system under the market environment is presented in [10]. Based on [10], a load following simulator for price based operation is developed in [11]. A competitive way to provide load following ancillary service under bilateral market has been presented by [12]. [13] has proposed a frame work for load following service under single buyer and poolco operation. The literatures [14-21] have not treated poolco and bilateral market transaction as per the standard definition listed in [10-13, 22-26]. This paper is intended to give a clear understanding on the different markets and develops appropriate model for load following system under these markets. The performance of the system under different market models is analysed for contracted condition and during violation.

Section 2 explains the market clearing procedure adopted in different market models. The mathematical modelling of considered two area system is presented in Section 3. The mathematical model of contracted power of each GENCO based on the participation factors for different market models is also developed. Section 4 analyses the proposed model under different markets with and without violation, for the effective operation. The findings are summarized in section 5.

2. Different market models in a restructured power system

In restructured power system, the power flows from the GENCOs to DISCOs based on the contract. The power trading is done in a platform called as ‘market’. It is the SO who clears the market, decides the market power and price and announce the winning players. Different market models exist in restructured power system. Each model has its own unique market clearing procedure. This section analyses the operation and market clearance procedure adopted by SO in different market model.

2.1. Single buyer model

In the single buyer model, SO collects the offered power and price from all GENCOs for a prescribed period. The total demand in an area for the corresponding period is predicted. The supply curve is then plotted in ascending order of offer price to determine the Market Clearing Price (MCP). MCP is obtained at the intersection between the supply curve and the vertical line corresponding to predicted total demand as shown in Fig. 1.

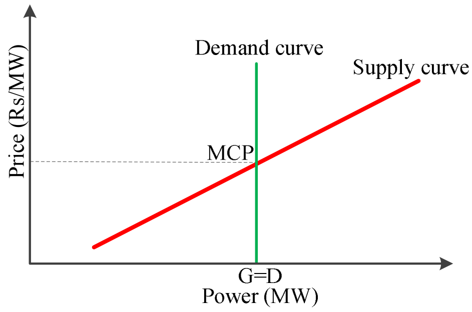

Fig. 1 Market clearing in a single buyer model

At MCP in Fig. 1, the total offered power is equal to the predicted demand. The GENCOs to the left of intersection point are the winning players. The winning GENCOs are paid with the price greater than the bid price. The winning DISCOs are benefited with low price than their bid price. However, the offer price of GENCOs to the right of the equilibrium point is less than MCP. Similarly, bid price of all DISCOs to the right of equilibrium point is greater than MCP. These players are not benefitted and hence are announced as loosing players. The power requirement for the prescribed period is met by the winning GENCOs.

2.2. Bilateral model

In the bilateral market, the GENCOs and DISCOs enter into negotiations and finally come to an agreement for the contracted power. Each GENCO makes contract with the DISCOs either within or outside the area [27]. If the contract is made between GENCOs and DISCOs within area, the TRANSCO power is zero. The TRANSCO power flow occurs when GENCOs contract with DISCOs outside the area. The bilateral power trading is done among any GENCOs and DISCOs. These GENCOs and DISCOs contract for any amount of power and price. The contract information must be informed to SO before power trading is done.

2.3. Pooclo model

In the poolco market, SO collects the offers and bids from the GENCOs and DISCOs respectively for a specific period [28]. The supply and demand curves are sketched in the ascending and descending order of offer and bid price respectively. From the intersection between two curves, MCP is determined as shown in Fig. 2.

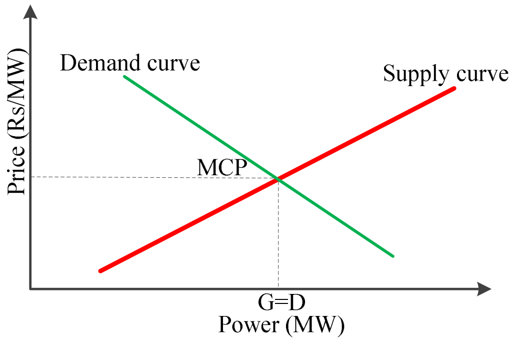

Fig. 2 Market clearing in a poolco model

As shown in Fig. 2, the total offered power is equal to the total bid power at MCP. Till MCP, the offered price of GENCOs is less than MCP and the bid price of DISCOs are greater than MCP. Hence, these players are benefitted and are the winning players. However, the players to the right of MCP are not benefited, since the offer price and bid price is lesser and greater than market price respectively. The power trading is done between the winning GENCOs and DISCOs.

3. Modelling of load following system under different market models

The GENCOs those are allowed to do power trading with the winning DISCOs, generate the contracted and violation power demand with the help of load following system. A two area system shown in Fig. 3 is selected to illustrate the operation of load following system without and with contract violation under deregulated environment.

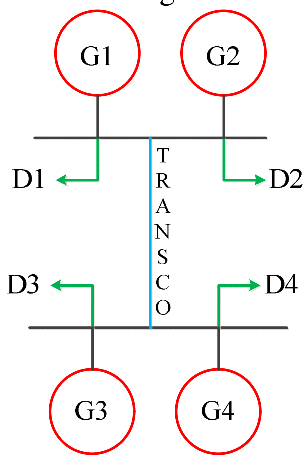

Fig. 3 Schematic of two area restructured power system

The two area system in Fig. 3 has two GENCOs and DISCOs in each area. The areas are connected by a TRANSCO. Contracted power flows from GENCOs to DISCOs and even through TRANSCO.

To analyse the performance of two area deregulated load following system, it is required to develop a mathematical model. The transfer function model of two area thermal system without the contracted power model is shown in Fig. 4.

Fig. 4 represents the transfer function model of two area thermal system with non-reheat turbine. The two areas are connected by a TRANSCO. Fluctuation in load causes frequency variation in system from the nominal value. The feedback parameter R represents static increase in turbine power output with static frequency drop. A detailed description regarding the modelling of thermal system under vertical system is given by [1]. The model is modified by [10] in order to accommodate the power transactions under deregulated environment. In deregulated power system, each GENCO meets the contracted power demand of DISCO based on the participation factor. During contract violation, each GENCO contribute for the un-scheduled power depending on the economic participation factor (*epf*). Thus, for models explained in section 2, each GENCO has its participation on market sharing and violation sharing. The contribution of each GENCO to fulfill the contracted and violation demand of a DISCO is explained in section 3.1 and 3.2 respectively.

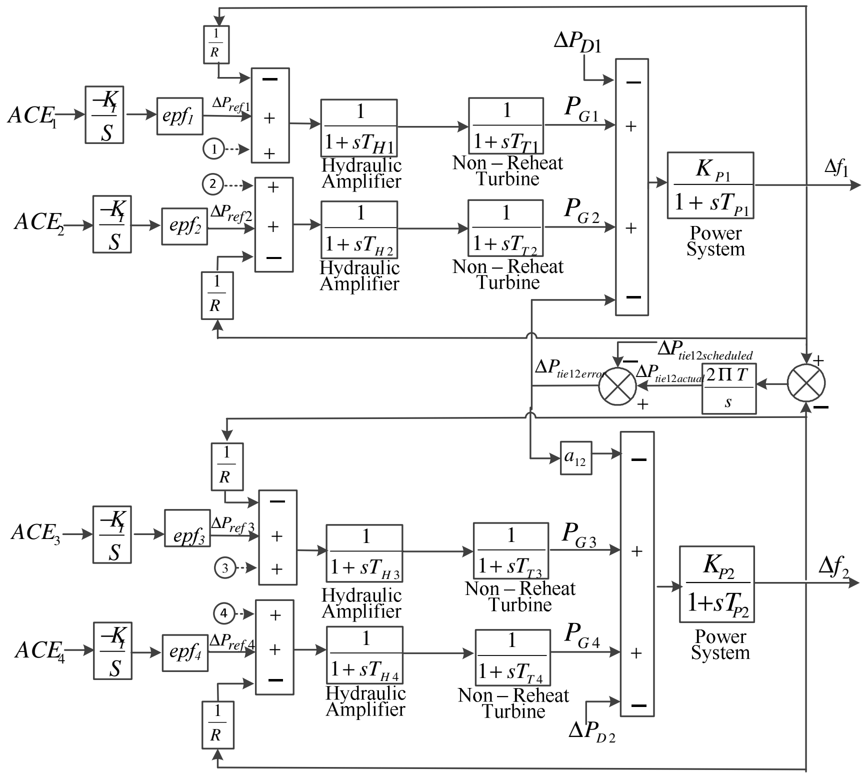

Fig. 4 Mathematical model of two area restructured power system

3.1. Market participation

The contribution of each GENCO to meet the contracted power is based on the market model.

3.1.1. Single buyer model

As explained in section 2.1, total predicted demand is met by GENCOs using Fig. 1. The contribution of i^th GENCO of j^th area, to meet the total demand (P_L) is represented as GENCO participation factor (gpf_{ij}).

The *gpf* values of all GENCOs in j^th area are represented by GENCO participation matrix (*GPM*) as given in equations (1).

$$GPM_j = \begin{bmatrix} gpf_{1j} \\ \cdot \\ gpf_{ij} \\ \cdot \\ gpf_{Gj} \end{bmatrix} \quad (1)$$

Since, all GENCOs contribute to the total demand; the sum of GPM elements is unity.

$$\sum_{i=1}^{G} gpf_{ij} = 1 \quad (2)$$

Where,

G is the GENCOs in area ‘j’.

Based on *gpf*, the power output of each GENCO is calculated using equation (3).

$$P_{Gi-contract} = gpf_{ij} \times P_{Lj} \quad (3)$$

GPM for two areas shown in Fig. 3 becomes as given in equations (4) and (5).

$$GPM_1 = \begin{bmatrix} gpf_{11} \\ gpf_{21} \end{bmatrix} \quad (4)$$

$$GPM_2 = \begin{bmatrix} gpf_{32} \\ gpf_{42} \end{bmatrix} \quad (5)$$

The *gpf* values satisfy the condition given in equation (2). The GENCOs of the system shown in Fig. 3 generates contracted power based on these *gpf* values, using equation (3) – (5). This is represented in Fig. 5.

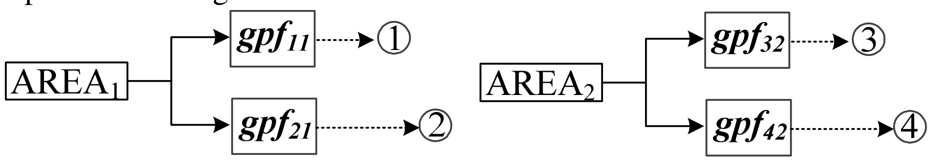

Fig. 5 Market contracted power of GENCOs under single buyer model

The transfer function model of system given in Fig. 3, operating under single buyer model explained in section 2.1, is obtained by combining Fig. 4 and Fig. 5. The power demand in each area is met by same area GENCOs and therefore, TRANSCO power is zero.

3.1.2. Bilateral model

For the bilateral model explained in section 2. 2 using Fig. 3, the demand of a DISCO is met by each GENCO based on contract participation factor (*cpf*). The *cpf* makes the elements of *DPM* matrix as shown in equation (6).

$$DPM = \begin{bmatrix} cpf_{11} & cpf_{12} & \cdot & cpf_{1D} \\ \cdot & \cdot & \cdot & \cdot \\ cpf_{i1} & cpf_{i2} & cpf_{ij} & cpf_{iD} \\ \cdot & \cdot & \cdot & \cdot \\ cpf_{G1} & cpf_{G2} & \cdot & cpf_{GD} \end{bmatrix} \quad (6)$$

Where,

G is the number of GENCOs

D is the number of DISCOs

cpf_{ij} represents participation factor of ith GENCO to meet demand of jth DISCO.

The *cpf* values are such that, for each column, the sum of elements is unity as given in equation (7).

$$\sum_{i=1}^{G} cpf_{ij} = 1 \quad (7)$$

Using the *cpf* values, the power output of ith GENCO is as given by equation (8).

$$P_{Gi-contract} = \sum_{j=1}^{D} cpf_{ij} \times P_{Lj} \quad (8)$$

The power export ($P_{exp\,i}$) and import ($P_{imp\,i}$) from and to area ‘i’ is given in equation (9) and (10) respectively.

$$P_{exp\,i} = \sum_{d=R+1}^{S} \sum_{k=1}^{P} cpf_{kd} \times P_{Ld} \quad (9)$$

$$P_{imp\,i} = \sum_{d=1}^{R}\sum_{l=1}^{Q} cpf_{ld} \times P_{Ld} \qquad (10)$$

Where,

P is the number of GENCOs in area 'i'

R is the number of DISCOs in area 'i'

Q is the number of GENCOs in area 'j'

S is the number of DISCOs in area 'j'

The scheduled power deviation is given in equation (11).

$$\Delta P_{tieij\ scheduled} = P_{exp\ i} - P_{imp\ i} \qquad (11)$$

The error in the TRANSCO power deviation is the difference between scheduled and actual power as given in equation (12).

$$\Delta P_{tieij\ error} = \Delta P_{tieij\ actual} - \Delta P_{tieij\ scheduled} \qquad (12)$$

DPM for the system shown in Fig. 3 is as given in equation (13).

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

The *cpf* values are such that it satisfies the condition given in equation (7). Under bilateral model, the contracted power of GENCOs is based on these *cpf* values and is obtained using equation (8). This is represented in Fig. 6.

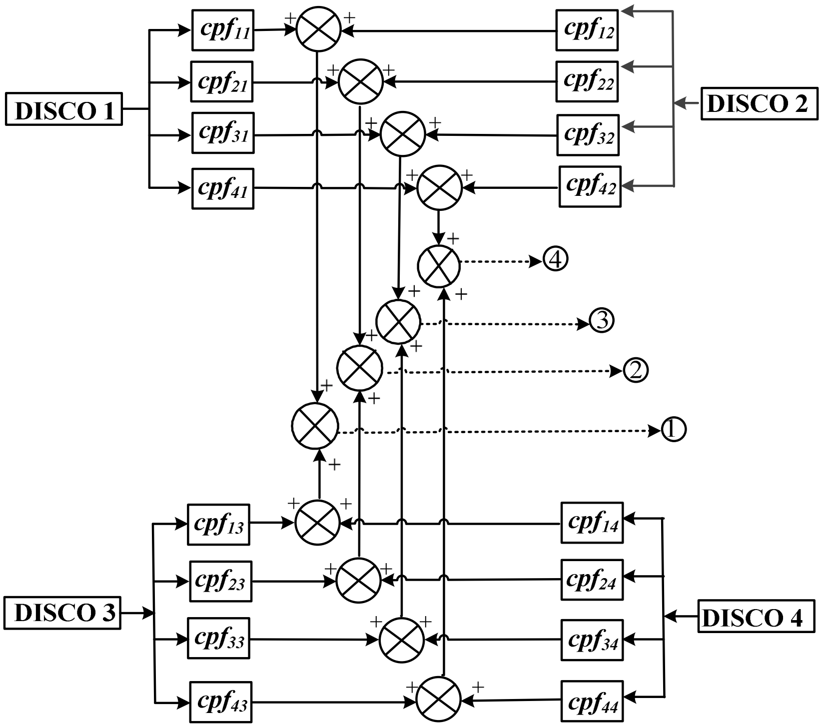

Fig. 6 Market contracted power of GENCOs under bilateral model

The transfer function model of system given in Fig. 3 under bilateral model explained in section 2.2, is obtained by combining Fig. 4 with Fig. 6.

3.1.3. Poolco model

The contracted power of GENCOs in Fig. 3 under poolco model explained in section 2.3 is based on area participation factor (*apf*). The *apf* values are represented using Area Participation Matrix (*APM*). The *APM* for jth area is formulated as per equation (14).

$$APM_j = \begin{bmatrix} apf_{11} & apf_{12} & apf_{1j} & apf_{1A} \\ apf_{21} & apf_{12} & apf_{2j} & apf_{2A} \\ apf_{i1} & apf_{i2} & apf_{ij} & apf_{iA} \\ . & . & . & . \\ apf_{P_j1} & apf_{P_j2} & apf_{P_jj} & apf_{P_jA} \end{bmatrix} \quad (14)$$

Where,

P_j is the GENCOs in the j^{th} area

A is the total number of area

In equation (14), apf_{i2} corresponds to the participation of i^{th} GENCO of j^{th} area, to meet the demand in area 2.

For the system shown in Fig. 3, connected by a TRANSCO, the criterion of *apf* depends on the direction of power flow through TRANSCO and is given in equation (15) – (17).

When the TRANSCO power flow is zero:

$$\left.\begin{aligned} \textstyle\sum_{k=1}^{P} apf_{ki} &= \textstyle\sum_{l=P+1}^{Q} apf_{lj} = 1 \\ apf_{li} &= apf_{kj} = 0 \end{aligned}\right\} \quad (15)$$

When the TRANSCO power flow is positive:

$$\left.\begin{aligned} \textstyle\sum_{k=1}^{P} apf_{ki} &= \textstyle\sum_{l=P+1}^{Q} apf_{lj} + \textstyle\sum_{l=P+1}^{Q} apf_{li} \\ &= \textstyle\sum_{m=1}^{G} apf_{mj} = 1 \\ apf_{li} &= 0 \end{aligned}\right\} \quad (16)$$

When the TRANSCO power flow is negative:

$$\left.\begin{aligned} \textstyle\sum_{k=1}^{P} apf_{ki} + \textstyle\sum_{l=P+1}^{Q} apf_{li} &= \textstyle\sum_{m=1}^{G} apf_{mi} \\ = \textstyle\sum_{l=P+1}^{Q} apf_{lj} &= 1 \\ apf_{kj} &= 0 \end{aligned}\right\} \quad (17)$$

Where,

apf_{ki} is *apf* of k^{th} GENCO in area i to meet demand in area 'i'

apf_{kj} is *apf* of k^{th} GENCO in area i to meet demand in area 'j'

apf_{li} is *apf* of l^{th} GENCO in area j to meet demand in area 'i'

apf_{lj} is *apf* of l^{th} GENCO in area j to meet demand in area 'j'

P is the number of GENCOs in area 'i'

Q is the number of GENCOs in area 'j'

G is the total number of winning GENCOs

The power output of i^{th} GENCO to meet the demand of j^{th} area is calculated as per equation (18).

$$P_{Gi-contract} = \textstyle\sum_{j=1}^{A} apf_{ij} \times P_{Lj} \quad (18)$$

Where,

A is the number of areas

P_{Lj} is the demand in j^{th} area

For a poolco model, the power export ($P_{exp\,i}$) and import ($P_{imp\,i}$) from and to area i is given in equation (19) and (20).

$$P_{exp\,i} = \textstyle\sum_{k=1}^{P} apf_{kj} \times P_{Lj} \quad (19)$$

$$P_{imp\,i} = \textstyle\sum_{l=P+1}^{Q} apf_{li} \times P_{Li} \quad (20)$$

The scheduled TRANSCO power deviation $\Delta P_{tieij\,scheduled}$ is given in equation (21).

$$\Delta P_{tieij\,scheduled} = P_{exp\,i} - P_{imp\,i} \quad (21)$$

The error in the TRANSCO power deviation is the difference between scheduled and actual power as given in equation (22).

$$\Delta P_{tieij\ error} = \Delta P_{tieij\ actual} - \Delta P_{tieij\ scheduled} \tag{22}$$

APM_1 and APM_2 for the system shown in Fig. 3 based on equation (14), is given in equation (23) and (24).

$$APM_1 = \begin{bmatrix} apf_{11} & apf_{12} \\ apf_{21} & apf_{22} \end{bmatrix} \tag{23}$$

$$APM_2 = \begin{bmatrix} apf_{31} & apf_{32} \\ apf_{41} & apf_{42} \end{bmatrix} \tag{24}$$

The *apf* values are such that it satisfies the equation (15), (16) or (17).

The contracted output power of each GENCO, based on equations (23) – (24) is represented in Fig. 7.

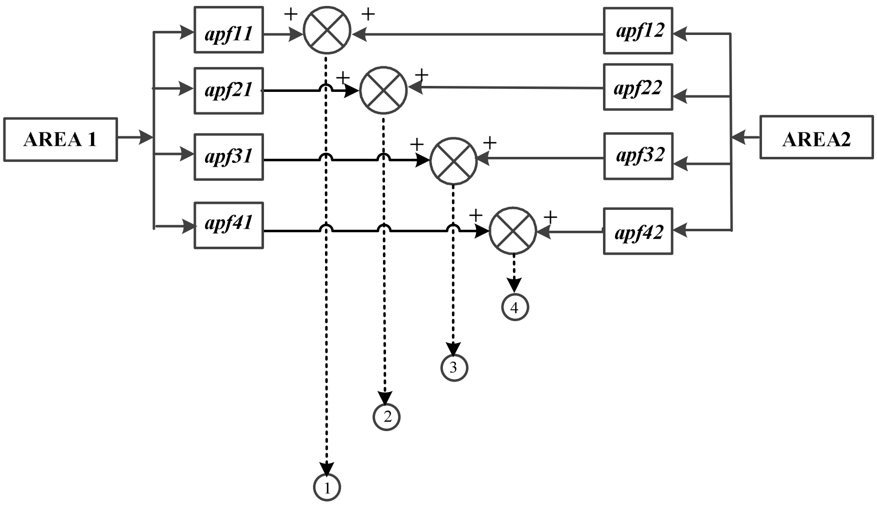

Fig. 7 Market contracted power of GENCOs under poolco model

Combining Fig. 4 with Fig. 7 yields the complete transfer function of the system operating under poolco model.

3.2. Violation participation

During contract violation, with Cohn's control strategy, the same area GENCOs of violation participate to meet the un-scheduled power. Each GENCO meet the un-contracted demand based on *epf*. The economic participation matrix for the GENCOs in j^{th} area is given in equation (25).

$$EPM_j = \begin{bmatrix} epf_{1j} \\ epf_{2j} \\ . \\ . \\ epf_{P_j j} \end{bmatrix} \tag{25}$$

Where,

P_j is the GENCOs in j^{th} area

The output power of GENCO during contract violation is given in equation (26).

$$P_{Gi-new} = P_{Gi-contract} + (epf_i \times P_{D-violation}) \tag{26}$$

This research adopts Cohn's strategy of tie line bias control for all the market models where the system frequency and TRANSCO power is maintained at nominal value. Since, only the same area GENCOs of violation meet for the un-contracted demand, the TRANSCO power remains unchanged.

4. Simulation results

In order to study the performance load following in two area deregulated system given in Fig. 3, the complete transfer function model presented in section 3 is to be simulated under all market models. This section furnishes the performance of load following system on different market without and with contract violation.

4.1. Single buyer model

To obtain the power response of GENCOs and TRANSCO in Fig. 3 under single buyer model, the complete transfer function model obtained from Fig. 4 and Fig. 5 is to be simulated.

The predicted demand in area 1 and area 2 are considered to be 0.15 p.u. and 0.3 p.u. respectively. Based on equations (4) and (5), the participation matrixes of two areas are as given in equation (27) and (28).

$$GPM_1 = \begin{bmatrix} 0.7 \\ 0.3 \end{bmatrix} \tag{27}$$

$$GPM_2 = \begin{bmatrix} 0.4 \\ 0.6 \end{bmatrix} \tag{28}$$

Using equations (3), (27) and (28), the GENCOs output power is calculated and is shown in Table 1. Under contract violation of 0.01 p.u. in area 1, GENCOs in same area (GENCO 1 and GENCO 2) is made to compensate for the violated demand based on *epf* values. The *EPM* for GENCOs in area 1 and area 2 are given in equation (29) and (30) respectively.

$$EPM_1 = \begin{bmatrix} 0.6 \\ 0.4 \end{bmatrix} \tag{29}$$

$$EPM_2 = \begin{bmatrix} 0.3 \\ 0.7 \end{bmatrix} \tag{30}$$

With *epf* of GENCO 1 and GENCO 2 given in equation (29), the output of GENCOs is calculated using equation (26) and is furnished in Table 1.

Table 1: GENCOs output power under single buyer model (p.u.)

	Without contract violation	With contract violation in area 1
G1	0.105	0.111
G2	0.045	0.049
G3	0.12	0.12
G4	0.18	0.18

The complete mathematical model of the system is simulated and the GENCOs and TRANSCO responses during contract violation in area 1 is shown in Fig. 8.

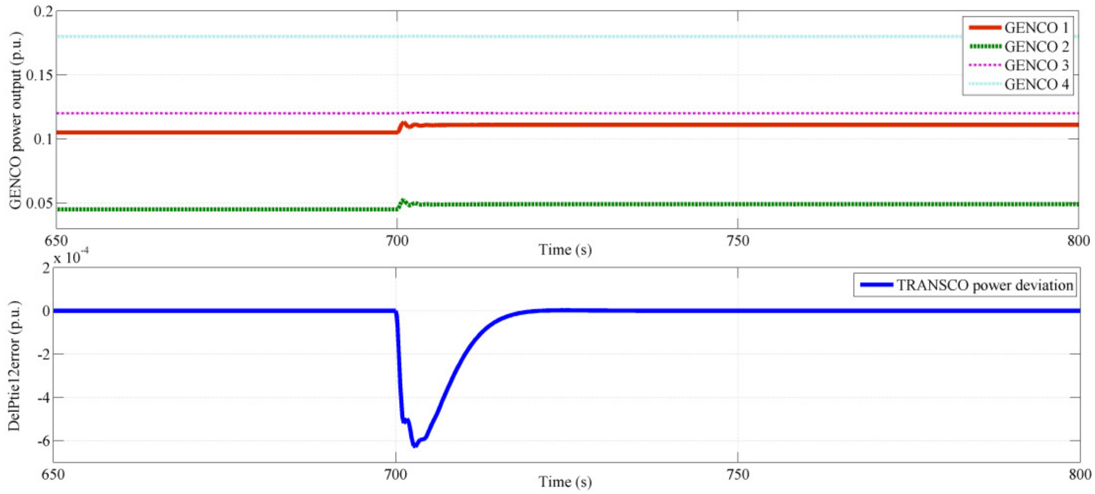

Fig. 8 GENCOs and TRANSCO responses during contract violation in area 1 under single buyer model

From Fig. 8, it is seen that the output power of GENCOs during contracted condition (between 0 and 700s) is in tune with the values given in Table 1. The demand in each area is met by the same area GENCOs and hence, TRANSCO power is zero. During contract violation at 700s in area 1, GENCO 1 and GENCO 2 power output is increased from 0.105 p.u. to 0.111 p.u. and from 0.045 to 0.049 p.u. respectively. This increased power output meets the un-contract demand. The new output power of GENCOs also matches with the values under contract violation given in Table 1. The un-scheduled demand in area1 is met by GENCOs in same area. Thus, TRANSCO power remains unchanged.

4.2. Bilateral model

The transfer function model of the system shown in Fig. 3 operating under bilateral model is obtained by combining the transfer function model of the system shown in Fig. 4 and market model shown in Fig. 6. DISCO 1, DISCO 2, DISCO 3 and DISCO 4 demands a power of 0.1 p.u., 0.05 p.u., 0.2 p.u. and 0.1 p.u. respectively. The *cpf* of each GENCO is represented using *DPM*, and is given in equation (31).

$$DPM = \begin{bmatrix} 0.1 & 0.1 & 0.1 & 0.1 \\ 0.2 & 0.2 & 0.2 & 0.2 \\ 0.3 & 0.3 & 0.3 & 0.3 \\ 0.4 & 0.4 & 0.4 & 0.4 \end{bmatrix} \tag{31}$$

Using equation (8) and (31), the contracted power of GENCOs is calculated and is presented in Table 2.

Table 2: GENCOs contracted power under bilateral model (p.u.)

	Without contract violation							With contract violation in area 1
	D1		D2	D3		D4	Total	Total
G1	0.01		0.005	0.02		0.01	0.045	0.051
		0.045			0.09			
G2	0.02		0.01	0.04		0.02	0.09	0.094
G3	0.03		0.015	0.06		0.03	0.135	0.135
		0.105			**0.21**			
G4	0.04		0.02	0.08		0.04	0.18	0.18

Table 2 shows that a power of **0.045 p.u.** and **0.21 p.u.** of power demand in area 1 and area 2 respectively is met by GENCOs in same area. Similarly, 0.09 p.u. of demand in area 2 is met by GENCOs in area 1 and 0.105 p.u. of area 1 demand is met by GENCOs in area 2. Thus the net power flow through TRANSCO from area 2 to area 1 is 0.015 p.u..

When contract violation of 0.01 p.u. occurs in area 1, GENCO 1 and GENCO 2 are made to contribute for the un-contracted power with *epf* values as given in equation (29). The output power for this condition is calculated and is presented in Table 2.

The complete transfer function model under bilateral model is simulated and the GENCOs and TRANSCO responses with contract violation in area 1 is shown in Fig. 9.

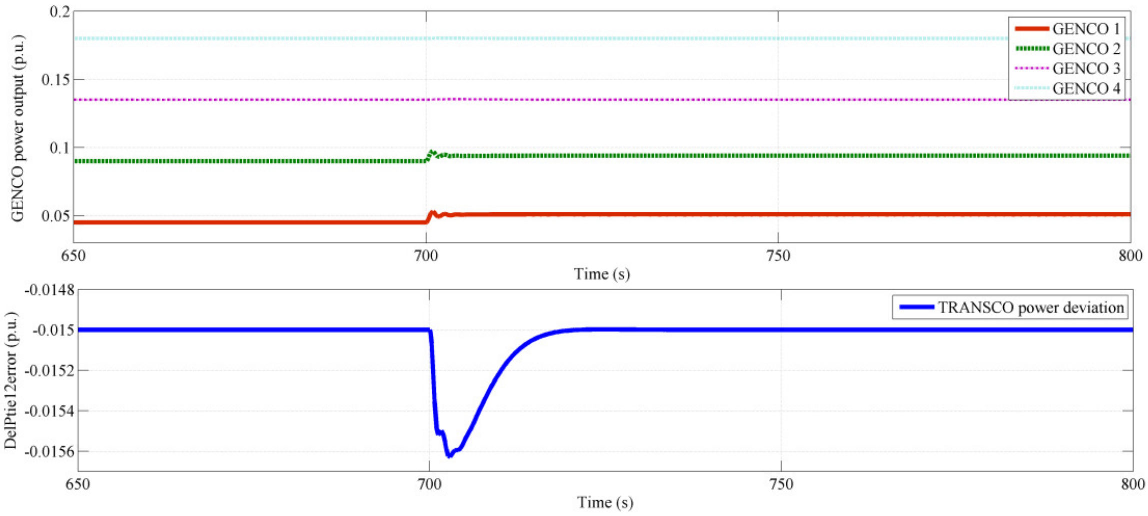

Fig. 9 GENCOs and TRANSCO responses during contract violation in area 1 under bilateral model

The GENCOs and TRANSCO contracted power (from 0 to 700s) in Fig. 9are in tune with the calculated values given in Table 2. At 700s, the GENCO 1 and GENCO 2 power is increased from 0.045 p.u. to 0.051 p.u. and from 0.09 p.u. to 0.094 p.u. respectively. The other area GENCOs do not compensate for the violated demand and hence, the TRANSCO power remains unchanged.

4.3. Poolco model

The system given in Fig. 3, when operating under poolco model, is represented by combining mathematical model of the system given in Fig. 4 and market model given in Fig. 7. In this model, the demand in area 1 and area 2 is considered to be 0.15 p.u. and 0.3 p.u. respectively. The APM for area 1 and area 2 GENCOs are given in equations (32) and (33).

$$APM_1 = \begin{bmatrix} 0.3 & 0 \\ 0.6 & 0 \end{bmatrix} \tag{32}$$

$$APM_2 = \begin{bmatrix} 0.05 & 0.425 \\ 0.05 & 0.575 \end{bmatrix} \tag{33}$$

Using equations (17), (32) and (33), the output of GENCOs is computed and is given in Table 3.

Table 3: GENCOs contracted power under poolco model (p.u.)

	Without contract violation			With contract violation in area 1
	Area 1	Area 2	Total	Total
G1	0.045	0	0.045	0.051
G2	0.09	0	0.09	0.094
G3	0.0075	0.1275	0.135	0.135
G4	0.0075	0.1725	0.18	0.18

Table 3 shows that 0.135 p.u. of demand in area 1 and 0.3 p.u. of demand in area 2 is met by GENCOs in same area. At the same time, 0.015 p.u. flow through TRANSCO from area 2 to area 1.

During contract violation of 0.01 p.u. occurring in area 1, the same area GENCOs are made to compensate with *epf* of GENCO 1 and GENCO 2 as per equation (29). The output power is calculated and is shown in Table 3. The simulation result for the case is presented in Fig. 10.

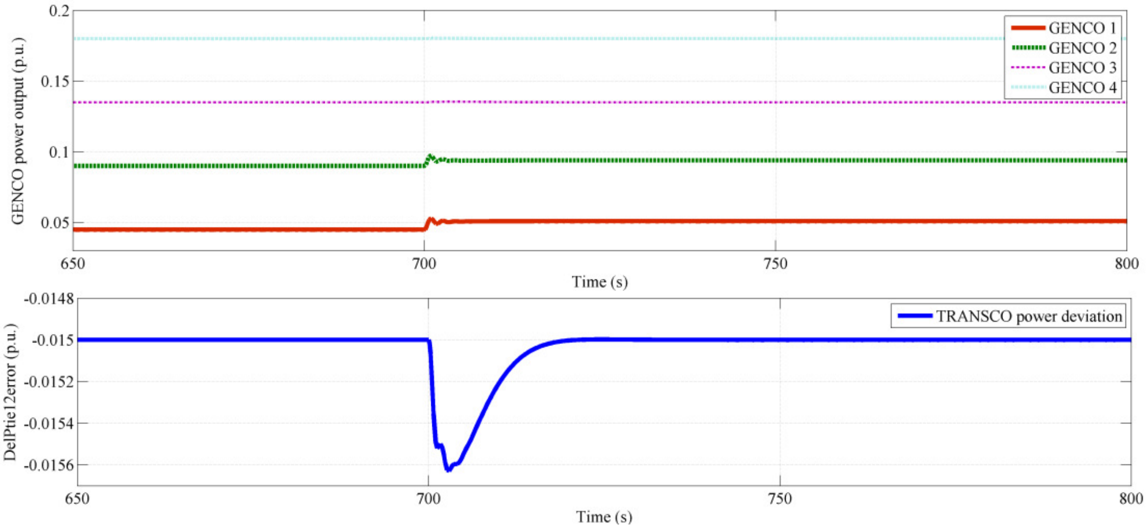

Fig. 10 GENCOs and TRANSCO responses during contract violation in area 1 under poolco model

The GENCOs and TRANSCO responses in Fig. 10 during contract (from 0 to 700s), are in tune with the calculated values given in Table 3. Under contract violation at 700s, the output of GENCO 1 and GENCO 2 is increased from 0.045 p.u. to 0.051 p.u. and from 0.09 p.u. to 0.094 p.u. respectively. Since, the participating GENCOs are in same area of violation, the TRANSCO power remains unchanged.

5. Conclusion

The paper presented a deep perception about the different market models under deregulated environment. An insight about the importance of load following system was provided in this paper. Market participation and violation participation factors for each market model, corresponding to contracted condition and during violation were introduced. These factors were incorporated in the mathematical model of two area deregulated system. The model was tested under tie line bias control strategy and claimed that this model is apt in forcing GENCOs and TRANSCO to have scheduled power (during contracted condition) and willing GENCOs to share un-contracted power (during contract violation).

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