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Power Loss Distribution to the Generators in Restructuring Power System using Loss Balancing Factor

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Abstract:
Regulated power system is one in which electrical power flow from generation to transmission and to distribution. With this some of consumers has to pay much compared with others and some cases the consumer may not get the power from the generator. As rules and regulations are involved in the regulated power system, and in order to provide the healthy competition among the generating companies, deregulated power systems are introduced. In such system, the customer may get the power from generating stations directly or any other sources provided by the private provider. As many sources involved in the deregulated power system, the losses are increased and the generators are not generating the power based on their cost characteristics. In this paper, by introducing the Loss Balancing Factor (LBF) the losses are assigned to the generators and constrained load flow is also presented for the deregulated power system. The total analysis is tested on IEEE-14 bus system and analytical observations are presented.

Keywords: *Constrained load flow; Generator power balancing*

I. INTRODUCTION

The analysis of power flow is the first step to the research for electrical engineers i.e related to power system. It is observed that there are limitations in the analysis of power flow. Those are, in entire system we assumed only one voltage delta bus (V,δ). Generally it is not occurred in the real time power system power flow. And another limitation is same price characteristic generators do not generate the same amount of power. As we know, the power industry is deregulating day by day, some generating companies disappointed with the selection of voltage delta bus. When generating company is considered as voltage delta bus, then the total losses are thrown at respective generating company. Hence it is required to balance such generating station. The loss on the voltage delta bus is removed by distributing the all power losses to the all participated generators [1].

In [1], the burden on voltage delta bus is removed by introducing the loss balancing factor (LBF) but still we can reduce the nonlinearity of the power system and hence the loss by taking the constrained load flow analysis.

While assigning the losses to the generators the frequency variations also taken into account [7,8]. It is also observed the analysis of power loss modification effect on the power system from [9].

The generation fuel cost is taken as cubic equation instead of quadratic equation. The main aim to consider like this is to take realistic fuel cost of the generator. It is observed many methods that gives the approximations and hence not fair while assigning the loss to the generators [2-6].

In this paper, the electrical power loss is balancing by other member called P_B in the 'Economic Load Dispatch' problem. Hence

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electrical output of alternator is represented by P_B. With this introduction, all generators generation again calculated with P_B.

This paper also presented that the LBF defined and used in [10-11] is summarized in the proposed procedure while the price function at the generator is given by cubic equation. The losses are reduced and hence the burden on the generator also reduced.

II. THE VOLTAGE DELTA BUS

In regular power flow analysis there are two explications of voltage delta bus. Those are first one is phase mark bus, and another one is which makes unequal power generations among the generators. If such bus is not chosen in the power flow problem which is solved by Newton Raphson procedure, the Jacobian matrix may not be fair which results the problem to whom the power losses has to assign. Hence the voltage delta bus is required while we are calculating the power flow.

III. CONSTRAINED LOAD FLOW

In regular power flow, as the loads are not constant the voltage magnitude at the load bus is not maintained constant. As power system industry is changing day by day for fair and quality power distribution to the consumers, some amount of loss is reduced if we maintain the voltage magnitude at the load bus by using [4]

IV. FORMULATION OF GENERATION BALANCING PROCEDURE

The main aim of this paper is to reduce the cost of generation by taking the new quantity P_B. That is

$$\min \sum_{j=1}^{N} C_j\left(P_{Gj}\right) \quad \text{such that}$$

$$\sum_{j=1}^{N} P_{Gj} - P_D - \Delta P_B = 0 \tag{1}$$

Where, $C_j\left(P_{Gj}\right)$ is the cost of j[th] generator, N is the total number of generators in the system. P_D is the total load, C_j is the cost function of the generator which is given by

$$C_j = a_j P_{Gj}^3 + b_j P_{Gj}^2 + c_j P_{Gj} + d_j \tag{2}$$

Incremental fuel cost of the generator is given by

$$\frac{dC_j}{dP_{Gj}} = 3a_j P_{Gj}^{\ 2} + 2b_j P_{Gj} + c_j \tag{3}$$

But we know that,

$$\frac{dC_j}{dP_{Gj}} = \lambda \tag{4}$$

Hence from equations (2) and (3)

$$3a_j P_{Gj}^{\ 2} + 2b_j P_{Gj} + c_j = \lambda$$

$$\text{or, } 3a_j P_{Gj}^{\ 2} + 2b_j P_{Gj} + c_j - \lambda = 0 \tag{5}$$

The roots of equation (4) given by,

$$P_{Gj} = \frac{-2b_j \pm \sqrt{(2b_j)^2 - 4(3a_j)(c_j - \lambda)}}{2(3a_j)} \tag{6}$$

For positive and real value of P_{Gi} equation (5) is considered as

$$P_{Gj} = \frac{-2b_j + \sqrt{(2b_j)^2 - 4(3a_j)(c_j - \lambda)}}{2(3a_j)}$$

$$P_{Gj} = \frac{-b_j}{3a_j} + \frac{b_j}{3a_j}\left(1 - \frac{(c_j - \lambda)}{(b_j)^2}(3a_j)\right)^{\frac{1}{2}} \tag{7}$$

Equation (7) is approximated as

$$P_{Gj} = \frac{-b_j}{3a_j} + \frac{b_j}{3a_j}\left(1 - \frac{1}{2}\frac{(c_j - \lambda)}{(b_j)^2}(3a_j)\right)^{\frac{1}{2}}$$

$$P_{Gj} = \frac{-b_j}{3a_j} + \frac{b_j}{3a_j} - \frac{1}{2}\frac{(c_j - \lambda)}{(b_j)} \qquad \text{or}$$

$$P_{Gj} = \frac{\lambda - c_j}{2b_j}$$

Where P_{Gj} is the power to be generated by the generator, which is connected to the j^{th} bus, hence

$$P_{Gjnew} = \frac{\lambda - c_j}{2b_j} \tag{8}$$

We know that,

$$P_{Gj} = \frac{-b_j}{3a_j} + \frac{\sqrt{\left(b_j^{\,2} - 3a_j(c_j - \lambda)\right)}}{3a_j}$$

Then,

$$\sum_{i=1}^{N} P_{Gi} = \sum_{i=1}^{N}\frac{-b_i}{3a_i} + \sum_{i=1}^{N}\frac{\sqrt{\left(b_i^{\,2} - 3a_i(c_i - \lambda)\right)}}{3a_i}$$

$$\sum_{i=1}^{N} P_{Gi} = \sum_{i=1}^{N}\frac{-b_i}{3a_i} + \frac{\sum_{i=1}^{N}\sqrt{\left(b_i^{\,2} - 3a_i(c_i - \lambda)\right)}}{\sum_{i=1}^{N} 3a_i}$$

$$\sum_{i=1}^{N} P_{Gi} = \sum_{i=1}^{N}\frac{-b_i}{3a_i} + \frac{\sum_{i=1}^{N}\left(b_i^{\,2} - 3a_i(c_i - \lambda)\right)^{\frac{1}{2}}}{\sum_{i=1}^{N} 3a_i}$$

$$\sum_{i=1}^{N} P_{Gi} = \sum_{i=1}^{N}\frac{-b_i}{3a_i} + \frac{\left(\sum_{i=1}^{N} b_j\left(1 - \frac{3a_i(c_i - \lambda)}{b_i^{\,2}}\right)^{\frac{1}{2}}\right)}{\sum_{i=1}^{N} 3a_i} \tag{9}$$

Now equation (9) is simplified as

$$\sum_{i=1}^{N} P_{Gi} = \sum_{i=1}^{N}\frac{-b_i}{3a_i} + \frac{\left(\sum_{i=1}^{N} b_i\left(1 - \frac{3a_i(c_i - \lambda)}{2b_i^{\,2}}\right)\right)}{\sum_{i=1}^{N} 3a_i}$$

$$\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N}\frac{b_i}{3a_i} = \frac{\left(\sum_{i=1}^{N} b_i\left(1 - \frac{3a_i(c_i - \lambda)}{2b_i^{\,2}}\right)\right)}{\sum_{i=1}^{N} 3a_i}$$

$$\frac{\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N}\frac{b_i}{3a_i}}{\sum_{i=1}^{N}\frac{1}{3a_i}} = \sum_{i=1}^{N} b_i\left(1 - \frac{3a_i(c_i - \lambda)}{2b_i^{\,2}}\right)$$

$$\frac{\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N}\frac{b_i}{3a_i}}{\sum_{i=1}^{N}\frac{1}{3a_i}} = \sum_{i=1}^{N} b_i - \sum_{i=1}^{N}\frac{3a_i(c_i - \lambda)}{2b_i}$$

$$\frac{\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N}\frac{b_i}{3a_i}}{\sum_{i=1}^{N}\frac{1}{3a_i}} - \sum_{i=1}^{N} b_i + \sum_{i=1}^{N}\frac{3a_i(c_i)}{2b_i} = \sum_{i=1}^{N} 3a_i\lambda$$

Hence

$$\lambda = \frac{\frac{\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N}\frac{b_i}{3a_i}}{\sum_{i=1}^{N}\frac{1}{3a_i}} - \sum_{i=1}^{N} b_i + \sum_{i=1}^{N}\frac{3a_i(c_i)}{2b_i}}{\sum_{i=1}^{N} 3a_i} \tag{10}$$

From equations (7) and (9)

$$P_{Gjnew} = \frac{\dfrac{\dfrac{\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N} \frac{b_i}{3a_i}}{\sum_{i=1}^{N} \frac{1}{3a_i}} - \sum_{i=1}^{N} b_i + \sum_{i=1}^{N} \frac{3a_i(c_i)}{2b_i}}{\sum_{i=1}^{N} 3a_i} - c_j}{2b_j}$$

We know that, $\sum_{i=1}^{N} P_{Gj} = P_D + P_L$, Where P_L is the power Loss

$$P_{Gjnew} = \frac{\sum_{i=1}^{N} \frac{b_i}{3a_i} + P_D + P_L}{2b_j\left(\sum_{i=1}^{N} 3a_i\right)\left(\sum_{i=1}^{N} \frac{1}{3a_i}\right)} - \frac{\sum_{i=1}^{N} b_i}{2b_j \sum_{i=1}^{N} 3a_i} + \frac{\sum_{i=1}^{N} \frac{3a_i c_i}{2b_i}}{2b_j \sum_{i=1}^{N} 3a_i} - \frac{c_i}{2b_j}$$

Where P_D is the power scheduled at generator 'j' that is P_{Gjsch}

$$P_D = P_{Gjsch}$$

$$P_{Gjnew} = \frac{P_{Gjsch}}{2b_j\left(\sum_{i=1}^{N} 3a_i\right)\left(\sum_{i=1}^{N} \frac{1}{3a_i}\right)} + \frac{P_L}{2b_j\left(\sum_{i=1}^{N} 3a_i\right)\left(\sum_{i=1}^{N} \frac{1}{3a_i}\right)} + \frac{\sum_{i=1}^{N}}{2b_j\left(\sum_{i=1}^{N} 3a\right.} \quad (11)$$

4. LOSS BALANCING FACTOR

From equation (12) loss balancing factor is given by

$$LBF = \frac{1}{2b_j\left(\sum_{i=1}^{N} 3a_i\right)\left(\sum_{i=1}^{N} \frac{1}{3a_i}\right)} \quad (12)$$

V. IMPLIMENTATION METHODOLOGY

For regular load power flow analysis

Step1. Economic Load Dispatch problem is solved without considering the losses

Step2. From the loss found in step1 run the load flow

Step3. Find loss balancing factor for each generator

Step4. Update the generation of the generator i.e. $P_{gnew}=P_{gschedule}+P_{loss}*LBF$

Step5. Run the load flow with the above generations

Step6. Repeat the above for 24 hours

VI. RESULTS AND ANALYSIS

The above procedure is tested in IEEE 14 bus system. The results are as follows Load flow curve for IEEE-14 bus system. Figure 1 and Figure 2 indicates the IEEE-14 bus system and variation of load for day in MW.

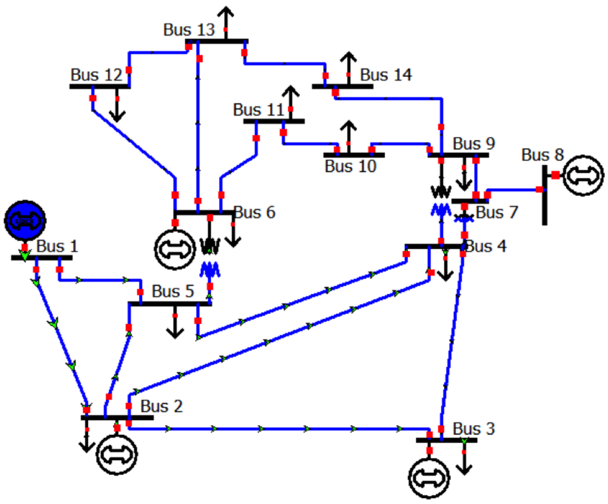

Figure 1: IEEE 14 bus system

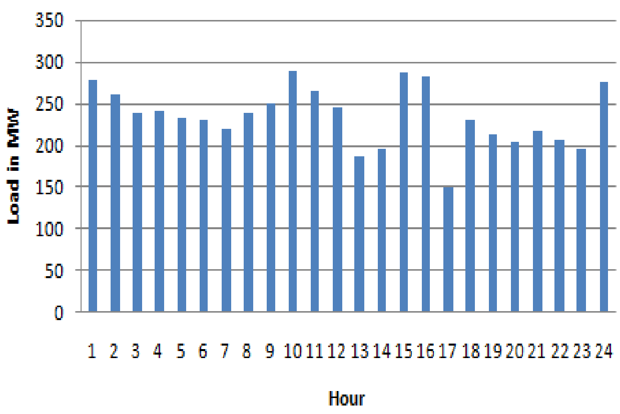

Figure 2: IEEE 14 bus Load profile

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The Table 1 gives the results of load flow solution with losses. From this we observed that, the total loss is assigned to generator 1 which is considered as voltage magnitude and phase angle bus. Even the price coefficients of generator 1 and generator 3 are same, but unable to generate the same amount of power. The same procedure is run for a day i.e 24 hours.

Table 1: Power generation of the generators over the 24 hours

Hour	Power generation by the generators in MW					Total Generation in MW
	Pg1	Pg2	Pg3	Pg6	Pg8	
1	69.86858	46.01326	55.00244	46.01326	75.9751	292.8726
2	63.84681	43.13684	51.54296	43.13684	71.14489	272.8083
3	56.45053	39.40688	47.05693	39.40688	64.88137	247.2026
4	57.65581	39.99887	47.76891	39.99887	65.87545	251.2979
5	54.76899	38.35371	45.79027	38.35371	63.11283	240.3795
6	54.19324	38.02505	45.39499	38.02505	62.56093	238.1993
7	51.44094	36.23369	43.24052	36.23369	59.5528	226.7016
8	56.09526	39.4058	47.05562	39.4058	64.87955	246.842
9	58.77691	41.18063	49.19021	41.18063	67.85992	258.1883
10	70.77614	47.60696	56.91918	47.60696	78.65131	301.5606
11	59.23176	43.81064	52.35333	43.81064	72.27635	271.4827
12	54.45763	40.7374	48.65714	40.7374	67.11563	251.7052
13	49.13879	31.04059	36.99476	31.04059	50.83231	199.047
14	44.24683	32.3392	38.5566	32.3392	53.01299	200.4948
15	68.28012	47.32787	56.58351	47.32787	78.18264	297.702
16	63.22361	46.63805	55.75387	46.63805	77.02427	289.2778
17	31.83384	24.89496	29.6034	24.89496	40.51229	151.7394
18	63.62814	38.14943	45.54458	38.14943	62.76979	248.2414
19	51.3648	35.02014	41.78098	35.02014	57.51495	220.701
20	44.83449	33.91881	40.45641	33.91881	55.66555	208.7941
21	51.00014	36.09448	43.0731	36.09448	59.31904	225.5812
22	43.40334	33.99898	40.55283	33.99898	55.80018	207.7543
23	45.43175	32.42081	38.65476	32.42081	53.15005	202.0782
24	66.40745	45.45361	54.32934	45.45361	75.0353	286.6793
Total generation over the day (MW)	1330.356	931.2067	1111.857	931.2067	1532.706	5837.331

Table 2 describes the list loss balancing factors of each generator when calculated by using equation (12). As the price coefficients of generator 1, generators 3 are same hence can observe the same factors. As the price coefficients of generator 2, generators 6 are same hence can observe the same factors

Table 2: Loss balancing factors

S.No.	Generator	Loss balancing factor
1	Pg1	0.1977

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2	Pg2	0.1643
3	Pg3	0.1977
4	Pg6	0.1643
5	Pg8	0.276

Table 3 indicates the result of loss generated by the system over the operation of 24 hours. During the 18th hour the loss is more and during the 17th hour the loss is low. The total loss over the day is calculated and represented in Table 3 as 218.4992 MW.

Table 3: Total loss

Hour	LOSS in MW
1	14.86615
2	12.30385
3	9.393604
4	9.886903
5	8.978722
6	8.798251
7	8.200428
8	9.039631
9	9.586695
10	13.85696
11	6.878421
12	5.800487
13	12.14403
14	5.690222
15	11.6966
16	7.469737
17	2.230441
18	18.08356
19	9.583814
20	4.378078
21	7.927046
22	2.850509
23	6.776988
24	12.07811
Total loss over the day	218.4992

The updating of generator generation with loss balancing factor according to step 4 of implementation methodology is presented in Table 4. Generator 2 and generator 6 are updated with same amount of electrical power but generator 1 and generator 3 are not because of loss. The Table 4 represents the list of updated generations of generators with loss balancing factors over the day i.e 24 hours.

Table 4: New generations with loss balancing factor

HOUR	Pg1	pg2	pg3	pg6	pg8
1	72.80762	48.45577	57.94147	48.45577	80.07816
2	66.27928	45.15837	53.97543	45.15837	74.54075
3	58.30765	40.95025	48.91404	40.95025	67.47401
4	59.61045	41.62328	49.72355	41.62328	68.60424
5	56.54409	39.82891	47.56537	39.82891	65.59096
6	55.93265	39.4706	47.1344	39.4706	64.98925
7	53.06217	37.58102	44.86174	37.58102	61.81611
8	57.88239	40.89101	48.84276	40.89101	67.37449
9	60.6722	42.75572	51.0855	42.75572	70.50585

10	73.51566	49.88366	59.6587	49.88366	82.47583
11	60.59162	44.94076	53.7132	44.94076	74.1748
12	55.60438	41.69042	49.8039	41.69042	68.71656
13	51.53966	33.03585	39.39563	33.03585	54.18406
14	45.37178	33.2741	39.68156	33.2741	54.5835
15	70.59254	49.24962	58.89593	49.24962	81.4109
16	64.70037	47.86533	57.23064	47.86533	79.08592
17	32.2748	25.26142	30.04435	25.26142	41.12789
18	67.20326	41.12055	49.1197	41.12055	67.76085
19	53.25952	36.59476	43.6757	36.59476	60.16009
20	45.70003	34.63813	41.32196	34.63813	56.8739
21	52.56732	37.3969	44.64027	37.3969	61.5069
22	43.96688	34.46732	41.11638	34.46732	56.58692
23	46.77156	33.53427	39.99457	33.53427	55.02049
24	68.79529	47.43804	56.71718	47.43804	78.36886

The Table 5 gives the power generated by the generators after balancing the loss and solving the load flow issue by introducing the LBF. The main observation is equal price coefficient generators generate the same amount of powers and still the loss is more. The same calculation is repeated for 24 hours and presented in Table 5. The Table 6 gives the loss generated by the system after balancing the loss.

Table 5: Power generations by the generators after balancing the losses over the day

Hour	Pg1 in MW	Pg2 in MW	Pg3 in MW	Pg6 in MW	Pg8 in MW	TotGen in MW
1	57.9415	48.4558	57.9415	48.4558	80.0782	292.873
2	53.9754	45.1584	53.9754	45.1584	74.5408	272.808
3	48.914	40.9503	48.914	40.9503	67.474	247.203
4	49.7236	41.6233	49.7236	41.6233	68.6042	251.298
5	47.5654	39.8289	47.5654	39.8289	65.591	240.38
6	47.1344	39.4706	47.1344	39.4706	64.9893	238.199
7	44.8617	37.581	44.8617	37.581	61.8161	226.702
8	48.8428	40.891	48.8428	40.891	67.3745	246.842
9	51.0855	42.7557	51.0855	42.7557	70.5059	258.188

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10	59.6587	49.8837	59.6587	49.8837	82.4758	301.561
11	53.7132	44.9408	53.7132	44.9408	74.1748	271.483
12	49.8039	41.6904	49.8039	41.6904	68.7166	251.705
13	39.3956	33.0359	39.3956	33.0359	54.1841	199.047
14	39.6816	33.2741	39.6816	33.2741	54.5835	200.495
15	58.8959	49.2496	58.8959	49.2496	81.4109	297.702
16	57.2306	47.8653	57.2306	47.8653	79.0859	289.278
17	30.0444	25.2614	30.0444	25.2614	41.1279	151.739
18	49.1197	41.1206	49.1197	41.1206	67.7609	248.241
19	43.6757	36.5948	43.6757	36.5948	60.1601	220.701
20	41.322	34.6381	41.322	34.6381	56.8739	208.794
21	44.6403	37.3969	44.6403	37.3969	61.5069	225.581
22	41.1164	34.4673	41.1164	34.4673	56.5869	207.754
23	39.9946	33.5343	39.9946	33.5343	55.0205	202.078
24	56.7172	47.438	56.7172	47.438	78.3689	286.679
Total generation over the day (MW)	1155.054	967.1061	1155.054	967.1061	1593.011	5832.989

Table 6: Loss generated by the system after balancing the loss

HOUR	LOSS in MW
1	14.40784
2	12.03079
3	9.222017
4	9.700506
5	8.821157
6	8.645633
7	8.066629
8	8.875782
9	9.403136
10	13.37871
11	6.754073
12	5.707222
13	11.95282
14	5.620721
15	11.4409
16	7.330645
17	2.210543
18	17.6787
19	9.443355
20	4.324015

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21	7.819106
22	2.816951
23	6.686476
24	11.81915
Total loss over the day in MW	214.1569

The load flow issue is solved under the constrained load flow analysis. The results are listed in Table 7. Here all the load bus maintains the voltage magnitudes. Hence the burden on the generators also decreased. It is calculated for 24 hours. The Table 8 represents the generation of loss by IEEE-14 bus system under constrained load flow.

Table 7: Power generation of the generators over the 24 hours under constrained load flow

our	Power generation by the generators in MW					Total Generation in MW
	Pg1	Pg2	Pg3	Pg6	Pg8	
1	67.81134	46.01326	55.00244	46.01326	75.9751	290.8154
2	62.37845	43.13684	51.54296	43.13684	71.14489	271.34
3	55.47663	39.40688	47.05693	39.40688	64.88137	246.2287
4	56.61118	39.99887	47.76891	39.99887	65.87545	250.2533
5	53.86083	38.35371	45.79027	38.35371	63.11283	239.4714
6	53.30607	38.02505	45.39499	38.02505	62.56093	237.3121
7	50.64021	36.23369	43.24052	36.23369	59.5528	225.9009
8	55.15323	39.4058	47.05562	39.4058	64.87955	245.9
9	57.74775	41.18063	49.19021	41.18063	67.85992	257.1591
10	68.83263	47.60696	56.91918	47.60696	78.65131	299.6171
11	58.5575	43.81064	52.35333	43.81064	72.27635	270.8085
12	53.92972	40.7374	48.65714	40.7374	67.11563	251.1773
13	47.92044	31.04059	36.99476	31.04059	50.83231	197.8287
14	43.89596	32.3392	38.5566	32.3392	53.01299	200.144
15	66.97157	47.32787	56.58351	47.32787	78.18264	296.3935
16	62.52527	46.63805	55.75387	46.63805	77.02427	288.5795
17	31.65603	24.89496	29.6034	24.89496	40.51229	151.5616
18	61.2765	38.14943	45.54458	38.14943	62.76979	245.8897
19	50.56069	35.02014	41.78098	35.02014	57.51495	219.8969
20	44.56535	33.91881	40.45641	33.91881	55.66555	208.5249
21	50.48163	36.09448	43.0731	36.09448	59.31904	225.0627
22	43.18967	33.99898	40.55283	33.99898	55.80018	207.5406
23	44.99826	32.42081	38.65476	32.42081	53.15005	201.6447
24	65.06001	45.45361	54.32934	45.45361	75.0353	285.3319
Total generation over the day (MW)	1307.407	931.2067	1111.857	931.2067	1532.706	5814.382

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Table 8: Total loss under constrained load flow

Hour	LOSS in MW
1	12.8089
2	10.83549
3	8.419701
4	8.842275
5	8.070559
6	7.911076
7	7.399694
8	8.09761
9	8.55754
10	11.91345
11	6.20417
12	5.272579
13	10.92568
14	5.339355
15	10.38805
16	6.771403
17	2.052634
18	15.73192
19	8.779704
20	4.108942
21	7.408536
22	2.63684
23	6.3435
24	10.73067
Total loss over the day	195.5503

The updating of generator generation with loss balancing factor according to step 4 of implementation methodology under constrained load flow is presented in Table 9. Generator 2 and generator 6 are updated with same amount of electrical power but generator 1 and generator 3 are not because of loss. The Table 9 represents the list of updated generations of generators with loss balancing factors over the day i.e 24 hours

Table 9: New generations with loss balancing factor under constrained load flow

HOUR	Pg1 in MW	pg2 in MW	pg3 in MW	pg6 in MW	pg8 in MW
1	70.34366	48.11777	57.53476	48.11777	79.51036
2	64.52063	44.91712	53.68514	44.91712	74.13548
3	57.14121	40.79024	48.7215	40.79024	67.20521
4	58.3593	41.45165	49.51702	41.45165	68.31592
5	55.45638	39.6797	47.38582	39.6797	65.34031
6	54.87008	39.32484	46.95901	39.32484	64.74439
7	52.10313	37.44946	44.70343	37.44946	61.59511
8	56.75413	40.73624	48.65652	40.73624	67.11449
9	59.43958	42.58663	50.88204	42.58663	70.2218
10	71.18792	49.56434	59.27447	49.56434	81.93942
11	59.78407	44.82998	53.5799	44.82998	73.98871
12	54.97211	41.60368	49.69953	41.60368	68.57086
13	50.08045	32.83568	39.15477	32.83568	53.84779
14	44.95155	33.21645	39.61219	33.21645	54.48666
15	69.02529	49.03462	58.63723	49.03462	81.04974
16	63.86398	47.75059	57.09257	47.75059	78.89318
17	32.06184	25.23221	30.0092	25.23221	41.07882
18	64.3867	40.73418	48.65478	40.73418	67.1118
19	52.29643	36.46265	43.51673	36.46265	59.93815

20	45.37769	34.59391	41.26875	34.59391	56.79962
21	51.9463	37.31171	44.53776	37.31171	61.3638
22	43.71097	34.43221	41.07413	34.43221	56.52794
23	46.25237	33.46305	39.90887	33.46305	54.90085
24	67.18146	47.21666	56.45079	47.21666	77.99697

The load flow issue is solved under the constrained load flow analysis after introducing the LBF. The results are listed in Table 10. Hence the burden on the generators also decreased. It is calculated for 24 hours. The Table 11 represents the generation of loss by IEEE-14 bus system under constrained load flow after balancing the loss.

Table 10: Power generations by the generators after balancing the losses over the day under constrained load flow

Hour	Pg1 in MW	Pg2 in MW	Pg3 in MW	Pg6 in MW	Pg8 in MW	Total Gen in MW
1	57.5348	48.1178	57.5348	48.1178	79.5104	290.815
2	53.6851	44.9171	53.6851	44.9171	74.1355	271.34
3	48.7215	40.7902	48.7215	40.7902	67.2052	246.229
4	49.517	41.4517	49.517	41.4517	68.3159	250.253
5	47.3858	39.6797	47.3858	39.6797	65.3403	239.471
6	46.959	39.3248	46.959	39.3248	64.7444	237.312
7	44.7034	37.4495	44.7034	37.4495	61.5951	225.901
8	48.6565	40.7362	48.6565	40.7362	67.1145	245.9
9	50.882	42.5866	50.882	42.5866	70.2218	257.159
10	59.2745	49.5643	59.2745	49.5643	81.9394	299.617
11	53.5799	44.83	53.5799	44.83	73.9887	270.808
12	49.6995	41.6037	49.6995	41.6037	68.5709	251.177
13	39.1548	32.8357	39.1548	32.8357	53.8478	197.829
14	39.6122	33.2165	39.6122	33.2165	54.4867	200.144
15	58.6372	49.0346	58.6372	49.0346	81.0497	296.393
16	57.0926	47.7506	57.0926	47.7506	78.8932	288.58
17	30.0092	25.2322	30.0092	25.2322	41.0788	151.562
18	48.6548	40.7342	48.6548	40.7342	67.1118	245.89
19	43.5167	36.4627	43.5167	36.4627	59.9382	219.897
20	41.2688	34.5939	41.2688	34.5939	56.7996	208.525
21	44.5378	37.3117	44.5378	37.3117	61.3638	225.063
22	41.0741	34.4322	41.0741	34.4322	56.5279	207.541
23	39.9089	33.4631	39.9089	33.4631	54.9009	201.645
24	56.4508	47.2167	56.4508	47.2167	77.997	285.332
Total generation over the day (MW)	1150.52	963.336	1150.52	963.336	1586.68	5814.38

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Table 11: Loss generated by the system after balancing the loss under constrained load flow

HOUR	LOSS in MW
1	12.50912
2	10.61056
3	8.273297
4	8.683906
5	7.935498
6	7.780206
7	7.28439
8	7.957906
9	8.401738
10	11.63523
11	6.095327
12	5.189957
13	10.7208
14	5.276824
15	10.17086
16	6.647919
17	2.034188
18	15.41645
19	8.656817
20	4.058788
21	7.310545
22	2.605265
23	6.263708
24	10.51151
Total loss over the day in MW	192.0308

Figure 3 to Figure 7 represents the variations of powers generated by the generators 1,2,3,6 and 8 under regular load flow and constrained load flow. And it is observed that burden on generator is less during constrained load flow compared with regular load flow.

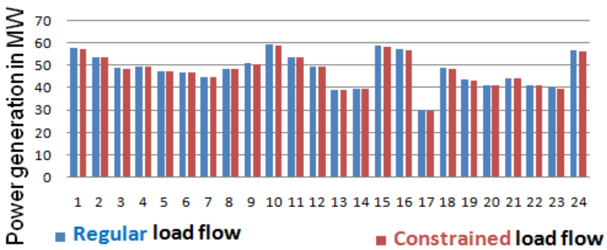

Figure 3: Variation of power generation of generator 1

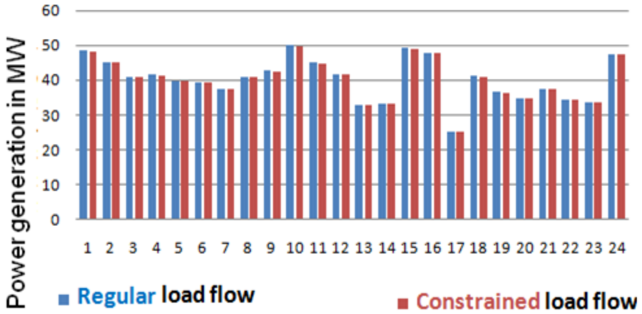

Figure 4:Variation of power generation of generator 2

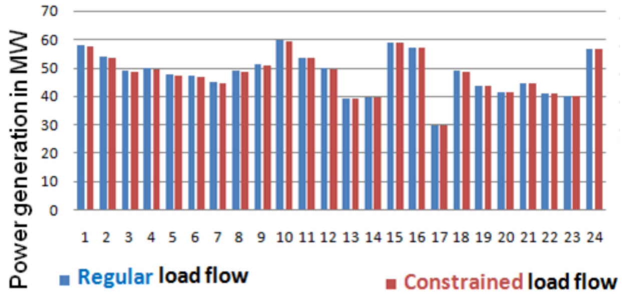

Figure 5: Variation of power generation of generator 3

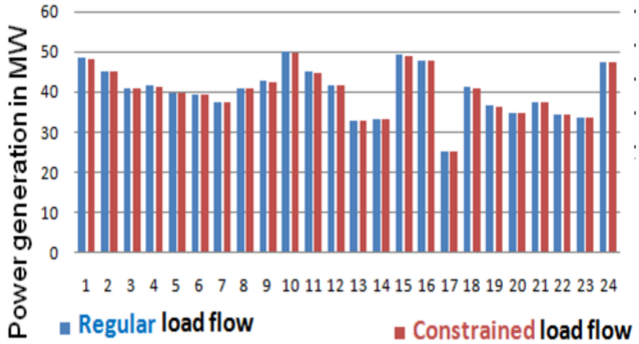

Figure 6: Variation of power generation of generator 6

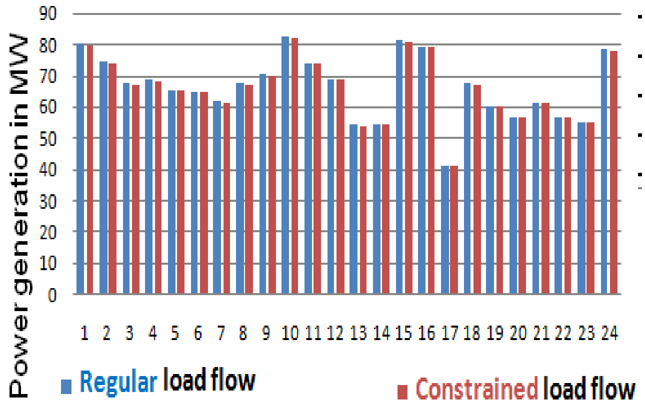

Figure 7: Variation of power generation of generator 8

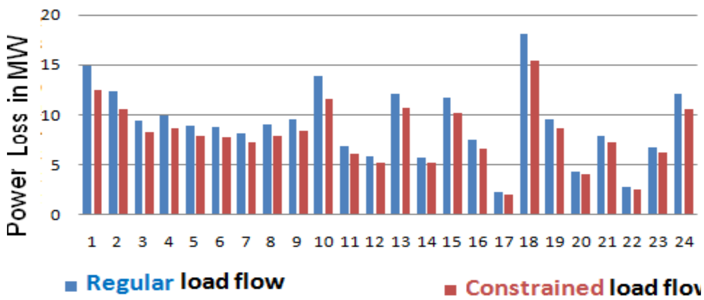

Figure 8: Variation of power loss for a day

From the results the following observations are made as follows

a. The same fuel cost characteristics generators generates the same power.
b. The total loss of the system is decreased by 214.1569-192.0308=22.1261MW.
c. The burden on each generator also decreased as follows

i. At generator1 the burden is decreased by 1330.356-1146.997=183.359 MW
ii. At generator 2 the burden is decreased by 967.1061-963.3356=3.7705 MW
iii. At generator 3 the burden is decreased by 1330.356-1146.997=183.359 MW
iv. At generator 6 the burden is decreased by 967.1061-963.3356=3.7705 MW
v. At generator 8 the burden is decreased by 1593.011-1586.677=6.334 MW

VII. CONCLUSIONS

In this paper, the power system is considered as restructured power system. The meaning of restructured power system for this case is the maintaining the voltage magnitude at real power and reactive power bus. Such system is considered as constrained system in this paper. When regular power system is constrained, then the analysis of constrained load flow is done by comparing with the regular power flow. In proposed method, the system is benefited as reduction of burden on generator and majorly the same price coefficients generators generate same amount of power. When constrained power system is compared with regular power system, the total loss in the system also decreased.

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