An Approach for Real Power Scheduling to Improve System Stability Margins under Normal and Network Contingencies

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Abstract

In the present day power system planning and operation, considerable interest is being shown in system security and stability analysis. Pattern of load sharing / generation scheduling that results in heavy flows tend to incur greater losses, threaten stability, security and ultimately making certain generation patterns undesirable. Generation schedules mainly based on economic criteria may lead to lower reserve margins and therefore diminished reliability is a serious concern for the systems. With increased loading of existing power transmission systems, the problem of voltage stability and voltage collapse has also become a major concern in power system planning and operation. While the voltage stability is more dependent on the reactive power sources/voltage profile in the system, it is also a function of real power flows. In this paper, network sensitivity between load voltages and source voltages to compute voltage stability index (L), is used as the basis to evaluate desirable load sharing for improving stability margins. The proposed method has been tested on typical sample systems and also on a practical 24-bus equivalent power system, and results are presented to illustrate the proposed approach.

Keywords: planning and operation, system security, stability analysis.

1. Introduction

The present day power systems have evolved as large interconnected power grids to take advantages of integrated operation both technical and economical. Earlier, the individual power systems developed as self sufficient islands to match its generation to its load with system-wide planning for reserve margins, expected load growth, available generation sites and adequate transmission and reactive power capabilities. Interconnection of these island systems has great advantages to each individual system during normal operation and also during emergency conditions.

The goal of the Interconnected power grid operator is to achieve the best possible security for the network with available facilities. This requires tools for assessing the vulnerability of the grid to possible contingencies, implementing protection and controls that are responsible to the prevailing system conditions, and minimizing the likelihood of blackouts resulting from various forms of instabilities [1].

The ability to maintain voltage stability in an interconnected power grid has become a growing concern in present day stressed power systems. The monitoring and analysis of power system security has also become an integral part of modern energy management systems.

In this paper, network sensitivity between load voltages and source voltages to compute voltage stability index (L) is used as the basis to develop an approach for load sharing/generation scheduling for improving stability margins. The proposed approach gives the most desirable generation scheduling for a given network under normal and network contingency condition for improving voltage stability in addition to improving the system angular stability.

2. Voltage Stability Index (L-Index)

Consider a system where n is the total number of buses with $1, 2, \dots, g$, g number of generator buses, and $g+1, \dots, n$, remaining $(n-g)$ buses. For a given system operating condition, using the load flow (state estimation) results, the voltage stability L-index is computed as [2],

$$L_j = \left| 1 - \sum_{i=1}^g F_{ji} \frac{V_i}{V_j} \right| \quad (1)$$

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Where $j = g+1 \dots n$ and all the terms within the sigma on the RHS of equation (1) are complex quantities. The values of

F_{ji} are obtained from the network Y -bus matrix. For a given operating condition

$$\begin{bmatrix} I_G \\ I_L \end{bmatrix} = \begin{bmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix} \quad (2)$$

Where I_G, I_L and V_G, V_L represent complex current and voltage vectors at the generator nodes and load nodes.

$[I_G] = [I_1, \dots, I_n]^t$ Injected currents of generator buses

$[I_L] = [I_{g+1}, \dots, I_n]^t$ Injected currents of load buses

$[V_G] = [V_1, \dots, V_g]^t$ Complex generator bus voltages

$[V_L] = [V_{g+1}, \dots, V_n]^t$ Complex load bus voltages

$[Y_{GG}], [Y_{GL}], [Y_{LL}]$ and $[Y_{LG}]$ are corresponding partitioned portions of network Y -bus matrix. Rearranging the above equation (2) we get,

$$\begin{bmatrix} V_L \\ I_G \end{bmatrix} = \begin{bmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} I_L \\ V_G \end{bmatrix} \quad (3)$$

Where $[F_{LG}] = -[Y_{LL}]^{-1} [Y_{LG}]$. F_{ji} are the complex

elements of $[F_{LG}]$ matrix. This matrix gives the relation between load bus voltages and source bus voltages, which is used as basis for the desirable best load sharing/generation scheduling.

It can be shown that the stability limit is reached for $L_j=1$, when two conditions are met [2]. The first requires that all generator voltages remain unchanged, amplitude and phase wise. The second calls for nodal currents, which respond

directly to the current I_j and are indirectly proportional to

the voltage V_j at the node j under consideration. The stability margin in this case is obtained as the distance of L from a unit value i.e., $(1-L)$.

While the different methods give a general picture of the proximity of the system voltage collapse, the L -index gives a scalar number to each load bus. Among the various indices for voltage stability and voltage collapse prediction, the L -index gives fairly consistent results. The advantage of this method lies in the simplicity of the numerical calculation and expressiveness of the results. The L -indices for given load conditions are computed for all load buses and the maximum of the L -indices gives the proximity of the system to voltage collapse. An L -index value away from

1(unity) and close to 0(zero) indicates an improved voltage stability margin [3,4,5,6].

3. Approach for Load Sharing/Generation Scheduling

This paper concentrates on real power scheduling for achieving improved margin of stability. The L -index is used as the basis for evaluating the most suitable real-power generation scheduling.

The L -index is function of F_{ji} elements derived from the transmission network parameters and generator/load bus complex voltages (voltage magnitudes and angles). Considering an unloaded network with nominal voltage profile, it can be seen that the L -indices for the load buses are close to 0(zero). For a given load distribution in the system, we can have many possible combinations of generation schedules. Reactive power controls such as, generator excitations, transformer taps and switchable VAR compensators can change the reactive power flows in the network and voltage profile (voltage magnitudes) and have influence on the voltage stability index. Different possible combinations of real power generation schedules to meet a given load demand give different real power flows in the network and voltage angles which also influence the voltage stability indices. The best load sharing is obtained by using the relative proportions of generation, which are evaluated, from the F_{LG} matrix.

4. Evaluation of Relative Proportions of Generation (RPG)

To illustrate the proposed method of load sharing/generation scheduling the following five-bus sample radial system-1 shown in Fig.1 is considered.

Fig. 1. Sample Radial System -1

4.1. Case 1: Equal Line Lengths

In this case it is assumed that the lines $L1$ and $L2$ are of 220 kV lines of equal length of 200kms each. The generators considered are two units of 250 MVA with step up transformers of 250 MVA each at both buses 1 and 2. The 220 kV line parameters in p.u. Per 100 kms are $r=0.0166, x=0.0826$ and $b/2=0.0694$. The generator X_d is

considered 0.2 p.u. on its own base. The $[F_{LG}]$ matrix corresponding to the load/generator bus for the network is given by

$$[F_{LG}] = \begin{bmatrix} .9516 - 0.0072i & .0540 + 0.0069i \\ .0540 + 0.0069i & .9516 - 0.0072i \\ .5146 - 0.0026i & .5146 - 0.0026i \end{bmatrix}$$

4.2. Case 2: Unequal Line Lengths

In this case the lines L1, L2 are considered of 220 kV of unequal lengths of 100kms and 300kms respectively with the same generating units as in case 1. The F_{LG} matrix for this system is given by,

$$[F_{LG}] = \begin{bmatrix} .9519 - 0.0073i & .0537 + 0.0070i \\ .0537 + 0.0070i & .9518 - 0.0072i \\ .7400 - 0.0064i & .2831 + 0.0025i \end{bmatrix}$$

The elements of $[F_{LG}]$ matrix are complex and its columns correspond to the generator bus numbers 1, 2 and rows correspond to the load bus numbers 3, 4 and 5. It can be observed that the sums of the each row elements of the $[F_{LG}]$ matrix are close to (1.0,0.0). For an unloaded system with generator /load buses voltages $1.0\angle 0$, the L-indices for load buses are close to 0(zero), indicating that the system has maximum stability margin. For a given network as the load/generation increases the voltage magnitude and angles change and for near maximum power transfer condition the voltage stability index L_j values for load buses tend to close 1(unity), indicating that the system is close to voltage collapse.

4.3 Relative Proportions of Generation (RPG) for the Sample System -1

The relative proportions of generation to meet each load demand for the given network are obtained by taking the absolute values of the elements of $[F_{LG}]$ matrix. The Relative Proportions of Generation (RPG) for the systems above case 1 and case 2 are given in Table 1.

Table 1
Relative Proportions of Generation

Load Bus No.	Relative Proportions of Generation (RPG)			
	Case1		Case2	
	G1	G2	G1	G2
3	.9516	.0544	.9519	.0542
4	.0544	.9516	.0542	.9518
5	.5146	.5146	.7400	.2831

The relative proportions of generation (RPG) values are used as the basis for the best load sharing, which can also be

said as optimum load sharing, as far as the system stability performance is concerned. If the generators share the load according to these relative proportions it improves the angular stability of the systems in addition to improving voltage stability.

In case 1, since the load bus 5 is at equal distance from both the generators, the corresponding elements

of $[F_{LG}]$ matrix magnitudes with respect to generators 1 and 2 are same i.e., 0.5146 and 0.5146 as given in Table 1. These values, which are also called as relative proportions of generation, are used for load sharing/generation scheduling.

For example, if load at bus 5 is 100MW, then 51.46MW of load should be shared by generator 2 and partial remaining load (including losses) should be shared by generator 1. In case 2, similarly, if the load at bus 5 is 100MW, then 28.31MW of load should be shared by generator 2 and partial remaining load (including losses) should be shared by generator 1. It means the load sharing/generation scheduling according to the relative proportions of generation improve stability margins with respect to voltage profile and angles.

From the above studies considered, also by intuition, we can say that, in case1, maximum load can be met by equal sharing of the load by each generator buses situated at equal distance from the load node. In case 2, the desirable load sharing has to be approximately in proportion of 0.25 and 0.75 from generators 1 and 2 respectively. Power flow analysis is carried out for the system and in case 1 and it is found that the system reaches unstable condition at a load of 325 MW, 142 MVAR (load power factor is assumed 0.9). The summary of power flow results is given in Table 2, 3 and 4. The generator terminal voltages are $1\angle 0^\circ$, $1\angle -0.5^\circ$ and their internal angles behind X_d , are $1.777\angle 7.576^\circ$, $1.176\angle 6.93^\circ$ giving separation of generators by a minimum angle 0.646° , when the load sharing is according to the relative proportions of generation. Any other combinations of generation scheduling leads lower maximum power transfer condition and also lower margin of angular stability as shown in Tables 3 and 4. Table 3 shows the variation of voltage profile (V) in pu, voltage stability index (L) and bus angles (δ), in degrees, for the sample radial system 1.

Table 2
System Grid Totals

Case 1		Without RPG	With RPG
Maximum Load (MW)		325	325
%Power Loss		16.0	15.4
Power Loss (MW)		60.29	57.74
Generation (MW)	G1	217	194
	G2	170	190
Case 2			
Maximum Load (MW)		370	370
% Power Loss		19.4	9.9
Power Loss (MW)		85.85	40.4
Generation (MW)	G1	229	305
	G2	230	105

Table 3
System Profiles

Case 1						
Bus No.	Without RPG			With RPG		
	V	L	δ	V	L	δ
1	1.000	-	0.0	1.000	-	0.0
2	1.000	-	-8.5	1.000	-	-0.5
3	0.955	0.064	-2.5	0.957	0.063	-2.2
4	0.958	0.064	-10.4	0.958	0.063	-2.7
5	0.585	0.984	-32.1	0.595	0.955	-27.7

Case 2						
1	1.000	0.000	0.0	1.000	0.000	0.0
2	1.000	0.000	41.1	1.000	0.000	-3.0
3	0.920	0.110	-2.6	0.945	0.088	-3.5
4	0.959	0.041	38.5	0.983	0.032	-4.2
5	0.572	0.922	-16.1	0.716	0.604	-21.6

Table 4
Internal Angle of Generators

Case 1	Without RPG		With RPG	
	G1	G2	G1	G2
P (MW)	217	170	194	190
Q (Mvar)	222	208	209	208
δ (deg.)	0	-8.5	0	-0.5
E (pu)	1.190	1.174	1.177	1.176
δ_{int} (deg.)	8.38	-1.85	7.58	6.93

Case 2				
P (MW)	229	190	305	105
Q (Mvar)	397	208	268	81
δ (deg)	0	41	0	-3.0
E (pu)	1.331	1.174	1.239	1.068
δ_{int} (deg.)	7.92	50.12	11.37	1.51

From the Tables 2, 3 and 4 it can be seen that the percentage power loss, power loss in MW and the angle separation between the generators is less when the load sharing is according to the relative proportions of generation and they are more if the load sharing is not according to the relative proportions of generation. It means that the system angular stability is also improved.

5. Relative Proportions of Generation (RPG) for System with Multiple Generators and Loads

A sample six-bus system (system-2) shown in Fig.2 is considered.

Fig. 2 Sample Radial System -2

5.1. Case 1: Equal amount of Loads

In this case it is assumed that the lines L1, L2 and L3 are of 200, 300 and 100kms length respectively and each of 400kV line. The generators considered are two units of 250 MVA with step up transformers of 250 MVA each at both buses 1 and 2. The 400 kV line parameters in p.u. Per 100 kms are $r=0.0166, x=0.0206$ and $b/2=0.2692$. The generator X_d is

considered 0.2 p.u. on its own base. The $[F_{LG}]$ matrix corresponding to the load/generator bus for the network is given by

$$[F_{LG}] = \begin{bmatrix} .8999 - 0.0040i & .1343 + 0.0021i \\ .1343 + 0.0021i & .8997 - 0.0040i \\ .6717 - 0.0043i & .4106 - 0.0017i \\ .5464 - 0.0035i & .5419 - 0.0030i \end{bmatrix}$$

The relative proportions of generation (RPG) to meet each load demand for the given network are shown in Table 5. The system grid total for maximum power transfer is shown in Table 6.

Table 5
Relative Proportions of Generation

Load Bus No.	Generators	
	G1	G2
3	.8999	.1343
4	.1343	.8997
5	.6717	.4106
6	.5464	.5419

Table 6
System Grid Totals for Case 1

		Without RPG	With RPG
Maximum Load (MW)	Load 1	493	493
	Load 2	493	493
%Power Loss		3.45	3.01
Power Loss (MW)		62.97	61.60
Generation (MW)	G1	560	581
	G2	493	470

Table 7
System Profiles for Case 1

Bus No.	Without RPG			With RPG		
	V	L	δ	V	L	δ
1	1.000	-	0.0	1.000	-	0.0
2	1.000	-	5.3	1.000	-	1.5
3	0.877	0.228	-6.9	0.877	0.226	-7.1
4	0.903	0.173	-0.6	0.907	0.171	-4.1
5	0.653	0.929	-28.0	0.657	0.917	-29.1
6	0.639	0.990	-28.8	0.647	0.970	-30.4

From the Tables 5, 6 and 7 it can be seen that the percentage power loss, power loss in MW and the angle separation between the generators is less when the load sharing is according to the relative proportions of generation.

5.2. Case 2: Unequal amount of Loads

In this case it is assumed that the loads at buses 5 and 6 are unequal in magnitude. The system grid totals for maximum power transfer are shown in Table 8.

Table 8
System Grid Totals for Case 2

		Without RPG	With RPG
Maximum	Load 1	593	593
Load (MW)	Load 2	393	393
%Power Loss		3.57	2.73
Power Loss (MW)		64.33	60.85
Generation (MW)	G1	661	594
	G2	393	456

Table 9
System Profiles for Case 2

Bus No.	Without RPG			With RPG		
	V	L	δ	V	L	δ
1	1.000	-	0.0	1.000	-	0.0
2	1.000	-	-9.8	1.000	-	1.2
3	0.861	0.240	-8.3	0.874	0.231	-7.3
4	0.915	0.167	-14.4	0.912	0.164	-4.2
5	0.632	0.988	-34.8	0.652	0.940	-30.0
6	0.651	0.948	-35.6	0.660	0.920	-29.1

Table 9 shows the variation of voltage profile (V), voltage stability index (L) and bus angles (δ) for the sample radial system 2. From the Tables 7, 8 and 9 it can be seen that the percentage power loss, power loss in MW and the angle separation between the generators is less when the load sharing is according to the relative proportions of generation and they are more if the load sharing is not according to the relative proportions of generation.

6. 24- Bus Equivalent EHV Power System

The proposed approach has been tested on large interconnected networks. The results for a practical system of 24-bus equivalent EHV power system network shown in Fig.3 are presented in this section. The system has 4 generator buses and 20 other buses. The load is represented at 220 kV side of 400 kV / 220 kV nodes at 8 number of buses.

Fig 3. 24-Bus Equivalent Practical Power System

6.1. Case1: base case condition

The Relative Proportions of Generation (RPG) for the 24-bus system, which are obtained from the F_{LG} matrix, are shown in the Table 10.

Table 10.
Relative Proportions of Generation

Load Bus No.	RPG values of Loads from Generators			
	G1	G2	G3	G4
5	.5534	.0789	.3335	.0855
6	.1342	.0834	.1761	.6735
7	.1712	.0788	.2247	.5954
8	.2164	.2237	.2840	.3997
9	.2767	.1155	.3632	.3481
10	.2943	.1321	.3863	.2903
13	.2191	.1818	.2876	.4282
15	.8413	.0286	.1209	.0310

Table 11
Generation Scheduling With RPG Values

Load Bus No.	Generators Load Sharing (MW)				Load at the bus (MW)
	G1	G2	G3	G4	
5	237.97	33.91	143.39	36.75	430
6	37.58	23.34	49.32	188.58	280
7	54.78	25.22	71.89	190.53	320
8	38.95	40.27	51.12	71.95	180
9	33.21	13.86	43.58	41.77	120
10	17.66	7.92	23.18	17.42	60
13	98.60	81.80	129.41	192.69	450
15	656.18	22.29	94.27	24.16	780
Gen. Sum	1175	248.6	606	764	

The system generation scheduling is obtained by the corresponding load sharing by the generators according to the Relative Proportions of Generation (RPG) values for a peak load condition of 2620 MW, 980 MVAR and is shown in Table 11. Power flow results are obtained for the peak load condition with and without Relative Proportions of Generation (RPG) values and results are summarized in Table 12 and 13.

Table 12
System Grid Totals

	% Power loss	Power Loss (MW)	Generation (in MW)			
			G1	G2	G3	G4
Without RPG	2.42	64.94	1655	160	350	520
With RPG	1.89	50.47	1052	249	606	764

Table 13
Internal Angle of Generators

With RPG	Gen. No.	P MW	Q Mvar	E Pu	$\delta_{int.}$ (deg.)
	1	1051	373	1.547	32.93
	2	249	21	1.036	13.48
	3	606	148	1.219	25.24
	4	764	341	1.411	29.57
Without RPG	1	1655	518	1.937	43.12
	2	160	36	1.036	-5.50
	3	350	193	1.188	2.73
	4	520	300	1.308	-4.59

From the above Tables 12 and 13 it can be seen that the percentage power loss and the angle separation between the generators are minimum when the load sharing is according to the relative proportions of generation and they are more if the load sharing is not according to the relative proportions of generation. Also the improvement of Voltage Stability Indices for the 24- bus system is shown in Table 14.

The voltage stability indices at all the 20 load buses and the maximum value of voltage stability index is reduced from 0.542 to 0.529 at bus number 13 when the load sharing / generation scheduling is according to the relative proportions of generation as given in the above Table 14. The improvement of voltage profiles and bus angles for the 24-bus system are shown in Fig 4 and 5 respectively.

From the Figs. 4 and 5 we can see that the minimum voltage profile has been increased from 0.847 to 0.858 and the maximum bus angle is decreased from -35° to -20° when the load sharing is according to the relative proportions of generation giving reduction of bus angle by 15° . It means the system has more angle stability when the load sharing /generation scheduling is according to the relative proportions of generation.

Fig. 4. Voltage profile Improvement

Fig 5. Bus angle Improvement

Table 14
Voltage Stability Indices

Load Bus No.	Voltage Stability Indices (L)	
	Without RPG	With RPG
5	0.360	0.350
6	0.412	0.411
7	0.453	0.449
8	0.542	0.529
9	0.371	0.362
10	0.350	0.341
11	0.201	0.198
12	0.267	0.262
13	0.540	0.528
14	0.464	0.454
15	0.093	0.093
16	0.226	0.221
17	0.122	0.120
18	0.316	0.309
19	0.325	0.324
20	0.348	0.345
21	0.198	0.197
22	0.437	0.429
23	0.302	0.296
24	0.150	0.148
20	0.348	0.345
21	0.198	0.197
22	0.437	0.429
23	0.302	0.296
24	0.150	0.148

6.2. Case2: line 22-23 outage contingency

The Relative Proportions of Generation (RPG) for the 24-bus system under contingency, which are obtained from the

F_{LG} matrix, are shown in the Table 15. The system generation scheduling is obtained by the corresponding load sharing by the generators according to the Relative Proportions of Generation (RPG) values for a peak load condition of 2620 MW, 980 MVAR and is shown in Table 16.

Table 15
Relative Proportions of Generation

Load Bus No.	RPG values of Loads from Generators			
	G1	G2	G3	G4
5	.5546	.0766	.3350	.0785
6	.1140	.0908	.1496	.6966
7	.1761	.0715	.2311	.5731
8	.1766	.2401	.2318	.4506
9	.2980	.0965	.3911	.2896
10	.2719	.1402	.3568	.3155
13	.1759	.1997	.2309	.4838
15	.8417	.0278	.1214	.0284

Table 16
Generation Scheduling With RPG Values

Load Bus No.	Generators Load Sharing (MW)				Load at the bus (MW)
	G1	G2	G3	G4	
5	238.49	32.93	144.11	33.74	430
6	31.92	25.43	41.91	195.04	280
7	56.36	22.89	73.96	183.38	320
8	31.79	43.22	41.72	81.11	180
9	35.76	11.58	46.93	34.76	120
10	16.31	8.41	21.41	18.93	60
13	79.17	89.88	103.91	217.72	450
15	656.52	21.65	94.72	22.18	780
Gen. Sum	1146	256	569	787	

Power flow results are obtained for the peak load condition with and without Relative Proportions of Generation (RPG) values and results are summarized in Tables 17 and 18.

Table 17
System Grid Totals

	% Power loss	Power Loss (MW)	Generation (in MW)			
			G1	G2	G3	G4
Without RPG	2.14	89.90	1679	160	350	520
With RPG	1.56	72.24	1091	256	569	787

Table 18
Internal Angle of Generators

With RPG	Gen. No.	P MW	Q Mvar	E Pu	δ_{int} (deg.)
	1	1091	478	1.117	11.26
	2	256	125	1.119	11.85
	3	569	276	1.084	8.95
	4	787	489	1.150	14.23
Without RPG	1	1679	665	1.080	8.95
	2	160	155	1.131	-8.81
	3	350	361	1.153	-4.83
	4	520	383	1.172	-14.38

From the above Tables 17 and 18 it can be seen that the percentage power loss and the angle separation between the generators are minimum when the load sharing is according to the relative proportions of generation and they are more if the load sharing is not according to the relative proportions of generation. Also the improvement of Voltage Stability Indices for the 24-bus system is shown in Table 19.

The voltage stability indices at all the 20 load buses and the maximum value of voltage stability index is reduced from 0.925 to 0.915 at bus number 13 when the load sharing / generation scheduling is according to the relative proportions of generation as given in the above Table 19. The improvement of voltage profiles and bus angles for the 24-bus system are shown in Fig 6 and 7 respectively.

Table 19
Voltage Stability Indices

Load Bus No.	Voltage Stability Indices (L)	
	Without RPG	With RPG
5	0.378	0.366
6	0.612	0.612
7	0.527	0.514
8	0.912	0.900
9	0.352	0.338
10	0.514	0.493
11	0.280	0.273
12	0.395	0.384
13	0.925	0.915
14	0.764	0.747
15	0.096	0.095
16	0.237	0.230
17	0.153	0.150
18	0.468	0.450
19	0.488	0.486
20	0.401	0.390
21	0.267	0.264
22	0.760	0.750
23	0.279	0.268
24	0.160	0.156

Fig. 6. Voltage profile Improvement

Fig. 7. Bus angle Improvement

From the Figs. 6 and 7 we can see that the minimum voltage profile has been increased from 0.642 to 0.664 and the maximum bus angle is decreased from -47.8° to -30.1° when the load sharing is according to the relative proportions of generation giving reduction of bus angle by 17.7° . It means the system has more angle stability when the load sharing /generation scheduling is according to the relative proportions of generation

7. Conclusions

In this paper a new concept, called relative proportion of generation (RPG), is used to load sharing /generation scheduling for improving angular stability in addition to improving voltage stability. The proposed approach gives a better way of improving stability margins using the existing generation facilities. It can also be used more effectively under contingency condition for optimal load sharing to improve stability margins. The results on the equivalent practical system illustrate the application of the approach for large power systems. The proposed method has been tested on typical sample systems and also a practical 24-bus power system and results are presented to illustrate efficiency of the proposed approach.

8. References

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