Generation Rescheduling for Congestion Management Using Relative Electrical Distance

[1] KAUSHIK K PATEL, [2] NILESH K PATEL

[1, 2] Department of Electrical Engineering ,

Sankalchand Patel College of Engineering, Visnagar,

Ta- Visnagar, Di-Mehsana, Gujarat

kaushikp98@yahoo.com , nkpatel.ee@spcevng.ac.in

ABSTRACT: *After Electricity Act 2003, power system trend is to replace the previous regulated public utilities with competitive power markets. However, the development of the restructured power systems has been accompanied by many problems, such as capacity storage, transmission congestion, wholesale electricity price volatility and reduced system reliability. In a competitive electricity market, congestion occurs when the transmission network is unable to accommodate all of the desired transactions due to a violation of system operating limits.In this paper, Relative Electrical Distance (RED) concept is used to optimize rescheduling of generators in order to relieve congestion in transmissions lines. In Relative Electrical Distance (RED) concept, relative location of the load nodes is found with respect to the generator nodes. Also contribution of each generator for overloading to the loads and line flows and tried to reschedule with the minimum losses in the system for relieving congestion in transmission system. Simple radial network is considered as initial test system and then six bus test system is used to demonstrate the rescheduling of generators and relieve congestion with the use of Relative Electrical Distance. Newton-Raphson A.C.Load flow method is applied for 6-Bus sample test system and results are carried out using m.file in MATLAB software.*

KEYWORDS: Generation rescheduling, Unbundled system, Congestion Management, Relative Electrical Distance,

1. INTRODUCTION

S. A. Khaparde [1], focused on the Electricity Bill 2003,its aim is reforms the power sector of the India. As per Electricity Act 2003 currently power industries are undergoing restructuring and trend is to replace the previous regulated public utilities with competitive power markets. However, the development of the restructured power systems has been many problems, such as capacity storage, transmission congestion, and wholesale electricity price volatility and reduced system reliability.

For the healthy system to maintain its loading level within the limit. Overloading of the system may occur due to the line outage and under going to violet its limit and security level. Network overloading can be relieved by different controls as below. [2]

- Real power generation rescheduling
- Phase shifting transformers
- Flow control through HVDC link
- Line switching
- Load shedding.

For the congestion management A. Kumar et. al [3], author proposed zonal based congestion management method L.J de Vries [4], discussed about the different congestion methods based on the power market. S.N. Singh and A.K. David [5], focused on the FACTS device used at optimal level for to manage the power flow for congestion in the transmission line. Sudipta Dutta and S. P. Singh [6], author developed appropriate solution technique for congestion management problem. S. K. Joshi and K. S. Pandya [7], proposed sensitivity based method and select number of generator participating in rescheduling process and minimize the cost. D.Thukaram and G. Yesuratnam [2], focused on the RED concept improve the voltage stability. In this paper author proposed approach for rescheduling the power for for transmission congestion management. B. V. Manikandan et al. [8], compare two different concepts for the congestion management.

In this paper presents Relative Electrical Distance (RED) concept for rescheduling the power for congestion management in the transmission line.

Also give the algorithm for the approach for the rescheduling power for the congestion management.

2 RELATIVE ELECTRICAL DISTANCE

A. Relative Electrical Distances (RED) Concept

Relative Electrical Distances (RED) Concept means that maximum generation supplied to the load which is nearest to that generator. Because of that length of the line and losses are reduced and improve the voltage drop.

This method gives the information about the relative locations of load points with respect to the generator points.

B. Approach for desired Generation / Load scheduling

Consider a system where n is the total number of buses with 1, 2... g, g number of generator buses, and g +1,..., n, remaining (n -g) buses. For a given system we can write

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

Where I_G, I_L represent complex current vectors and V_G, V_L represent complex voltage vectors at the generator nodes and load nodes. $[Y_{GG}]$, $[Y_{GL}]$, $[Y_{LL}]$ and $[Y_{LG}]$ are portions of network Y-bus matrix. From that equation we get

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

From that

$$F_{LG} = -[Y_{LL}]^{-1} [Y_{LG}]$$

The elements of $[F_{LG}]$ matrix are complex and its columns represent to the generator bus numbers and rows represents to the load bus numbers. This matrix gives the relation between load bus voltages and source bus voltages. It also gives information about the location of load nodes with respect to generator nodes this concept call as a relative electrical distance between load nodes and generator nodes. [2]

The relative electrical distances, i.e., the relative locations of load nodes with respect to the generator nodes are obtained from the $[F_{LG}]$ matrix and is given by

$$[R_{LG}] = [A] - \text{abs}\{[F_{LG}]\}$$

Where, [A] is the matrix with (n -g) rows and g number of columns of all elements equal to '1'or unity.

The desired load sharing/generation scheduling is also obtained from the $[F_{LG}]$ matrix and we can say in other words it is the absolute value of the $[F_{LG}]$ matrix given by

$$[D_{LG}] = \text{abs}\{[F_{LG}]\}$$

C. Case study for Radial System

For make desired load /generation scheduling we take case simple radial system. This system has two generators at Bus no.1 and Bus no.2 and three loads are connected at bus no.3, 4and 5.

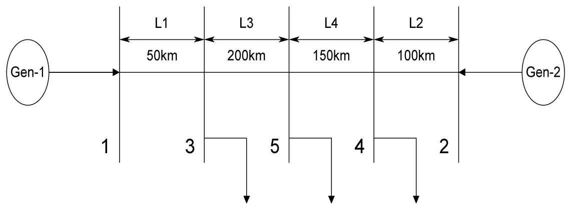

Fig.1 Sample system [2]

Here we take the assumption the lines L_1 has 50 Km, L2 has 100 Km, L_3 has 200 Km and L_4 has 150 Km length, respectively. The line parameters in per unit per 100 Km are R = 0.00165 and X = 0.02059.

The $[F_{LG}]$ matrix for the load/generator buses for the network is given by

$$FLG = \begin{bmatrix} 0.9000 + 0.000i & 0.1000 + 0.000i \\ 0.2000 + 0.000i & 0.8000 + 0.000i \\ 0.5000 + 0.000i & 0.5000 + 0.000i \end{bmatrix}$$

The elements of $[F_{LG}]$ matrix are complex and its columns represents to the generator bus numbers 1, 2 and rows represents to the load bus numbers 3, 4, 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 the sample system the relative electrical distance matrix $[R_{LG}]$ is given by

$$[RLG] = \begin{bmatrix} 0.10 & 0.90 \\ 0.80 & 0.20 \\ 0.50 & 0.50 \end{bmatrix}$$

Sample system D_{LG} is given by

$$[D_{LG}] = \begin{bmatrix} 0.90 & 0.10 \\ 0.20 & 0.80 \\ 0.50 & 0.50 \end{bmatrix}$$

The load at bus 3 is 200 MW then it should take 0.90 × 200 = 180 MW of load from generator 1 and the partial remaining load of 0.10 × 200 = 20 MW from generator 2. Same as the load at bus 4 is 150

MW then it should take 0.20 × 150 = 30 MW of load from generator 1 and the partial remaining load of 0.80 × 150 = 120 MW from generator 2. Same as at load no -5 is 300 MW so it should take150MW and 150 MW load from generator 1 and generator 2 respectively. The desired load sharing / generation scheduling for the radial sample system given in table-1.

Table-1 Desired load sharing/generation scheduling for the sample system

3. Approach for Generation Rescheduling for CM

For make that concept efficient we take sample six bus test system as shown in Fig.2 it has two sources and four loads at buses 1 and 2 and 3–6, respectively.

Load Bus No	Power taken from Generator (MW)		Load at Bus(MW)
	G_1	G_2	
3	180	20	200
4	30	120	150
5	150	150	300
Gen.Sum	360	290	650

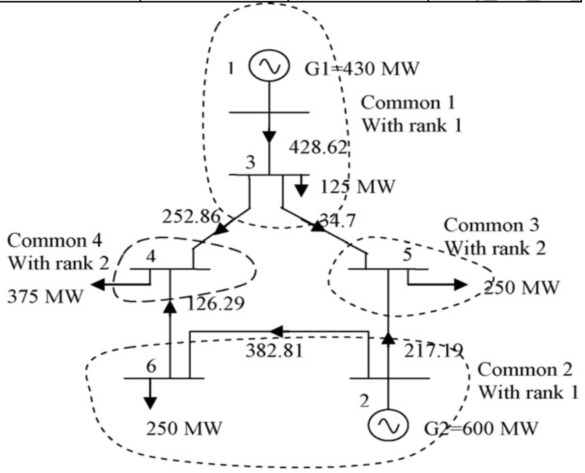

Fig.2 Six bus test system [2]

The system line data is given in Table-2.

Table-2 Line parameters of the sample six bus system [2]

From Bus	To bus	Line Resistance (pu)	Line Reactance (pu)
1	3	0.008	0.096
3	4	0.005	0.060
3	5	0.006	0.072
4	6	0.002	0.024
2	5	0.003	0.036
2	6	0.004	0.048

Computational Steps [2]

Fig.3 shows the major computational blocks in the proposed approach for congestion management suitable for an unbundled power system.

Step 1: Perform the initial operational load flow and check for any overload present. If any over load presents go to next step otherwise stop.

Step 2: Form the F_{LG} and D_{LG} matrices, and then estimate the desired generation

Step 3: For the given operating condition identify the over loaded and fully loaded lines and then find the contribution of each generator for all these lines

Step 4: Split up the generators into two groups (GD and GI) with their actual contribution values to the congested lines.

Step 5: From the steps 2 and 4, estimate the margin available on each generator of both the generator groups GD and GI.

Step 6: Estimate the required generation change to relieve congestion of the mostly congested line using the actual contribution of generators through the congested line.

Step 7: Distribute the required generation change among the generators of GD group based on the margins available from step 5

Step 8: Distribute the required generation change among the generators of GI group based on the margins available from step 5.

Step 9: Perform the operational load flow with the new generation scheduling. If congestion still occurs for any line go to step 2, otherwise stop.

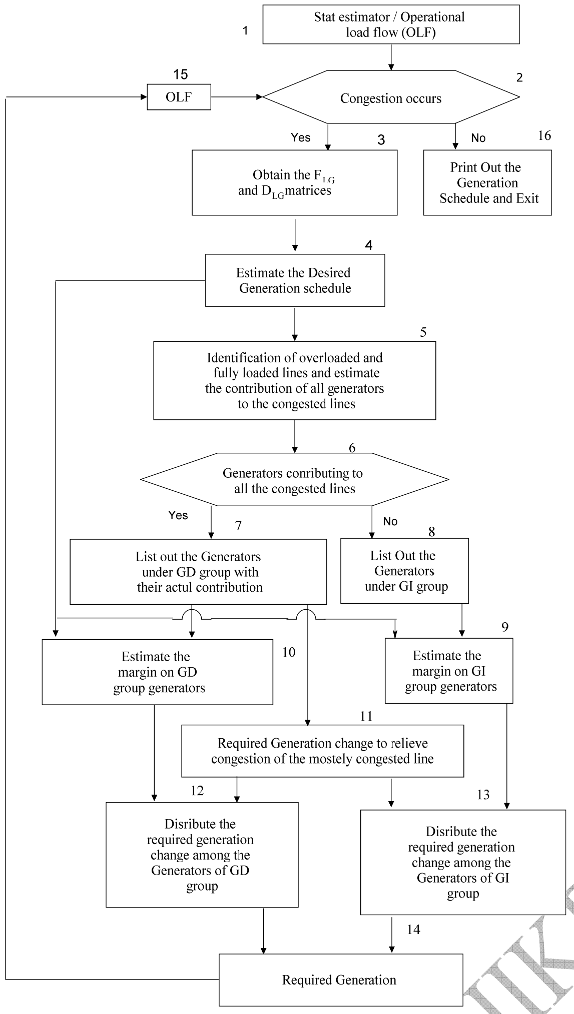

Fig. 3 Approach for Generation Rescheduling For Congestion Management [2]

The F_{LG} and D_{LG} matrices for the network are given by

$$FLG = \begin{bmatrix} 0.2085 + 0.0000i & 0.7915 + 0.0000i \\ 0.1274 + 0.0000i & 0.8726 + 0.0000i \\ 0.1390 + 0.0000i & 0.8610 + 0.0000i \\ 0.3822 + 0.0000i & 0.6178 + 0.0000i \end{bmatrix}$$

$$D_{LG} = \begin{bmatrix} 0.2085 & 0.7915 \\ 0.1274 & 0.8726 \\ 0.1390 & 0.8610 \\ 0.3822 & 0.6178 \end{bmatrix}$$

The desired load sharing/generation scheduling for the sample system using the $[D_{LG}]$ matrix is given in Table 3. From this for a load of 125 MW at bus 3, it should take 26.0618 MW from the generator at bus 1 (G1) and 98.9382 MW from the generator at bus 2 (G2). Similarly for the load at bus 4, it should take 47.7799 MW from the generator G1 and 327.2201 MW from the generator G2.

Table-3 Desired load sharing/generation scheduling (MW)

Load bus no.	**Power taken from Gen.in MW**		**Load at the Bus**	**Total Power Loss**
	G_1	**G_2**		
3	26.0618	98.9382	125	
4	47.7799	327.2201	375	
5	34.7490	215.2510	250	19.79
6	95.5598	154.4402	250	
Gen.sum	204.1506	795.8494	1000	

From that we make desired load sharing/generation scheduling at constant load and take four combination with different ratio and conclude that for this case 1:4 ratio gives the optimal results with the minimum loses shown in Table-4.

Table-4 Different combinations of load sharing/generation scheduling

Case no.	**Power taken from Gen.in MW**		**Total load**	**Power loss (MW)**
	G_1	**G_2**		
1	428.8	600	1000	28.82
2	322.3	700	1000	22.30
3	**208**	**811.8**	**1000**	**19.79**
4	120.7	900	1000	20.66

Generators contribution

Based on the active or reactive branch flows obtained from on-line power flow/state estimator results the actual contribution of generators to loads and line flows can be estimated. Here we used two generators so find out how much power contributed by which generator for that we used power tracing algorithm or propos anal sharing principle. [9] For the contribution of the power towards loads and line flows also find out by below concepts.

Domain of a generator

The domain of a generator is defined as the set of buses which are reached by power produced by this generator. Power from a generator reaches a particular bus if it is possible to find a path through the network from the generator to the bus for which the direction of travel is always consistent with the direction of the flow as computed by a power flow program or a state estimator. [2, 10]

Commons

A common is defined as a set of contiguous buses supplied by the same generators. Unconnected sets of buses supplied by the same generators are treated as separate commons. A bus therefore belongs to one and only one common. The rank of a common is defined as the number of generators supplying power to the buses comprising this common. [2, 10]

Links

Having divided the buses into commons, each branch is either internal to a common or external. One or more external branches connecting the same commons form what will be called a link. [2, 10]

From the fig.-2 we can say the system contains four commons and two rank of generator as shown in below table-5.

Table 5 Information of common number, rank and its group buses

Common no	1	2	3	4
Rank	1	1	2	2
Buses	1,3	2,6	5	4
Gen. no.	G1	G2	G1,G2	G1,G2
Contribution (%)	100	100	13.79 and 86.21	66.69 and 33.31

Contributions to the loads

The loads at the buses 3 and 6 are fully supplied by the generators G1 is 125.0 MW and G2 is 250.0 MW. For the load at bus 4, 66.69% of 375 MW means 250.09 MW is supplied by G1 and 33.31% means124.91 MW is supplied by G2. Similarly 13.79% of 250 MW means 34.48 MW of the load at bus 5 is supplied by G1 and 86.21% of that load 215.52 MW is supplied by G2 as shown in Table 6.

Table 6 Actual contributions to the loads

Load bus no.	Load (MW)	Contribution of G1		Contribution of G2	
		%	MW	%	MW
3	125	100	125	0	0.0
4	375	66.69	250.09	33.31	124.91
5	250	13.79	34.48	86.21	215.52
6	250	0	0.0	100	250

Case study [2]

To check the effectiveness of the proposed method the line- loading limit of line 3–4 has been set to 200.0 MW. To bring down the loading on this line from 252.86 MW the following procedure is adopted. From the contributions it has been observed that this line is completely contributed by G1 only. There is no contribution from the generator G2; hence generator G1 belongs to GD group and the generator G2 belongs to GI group. So generation decrease is recommended at G1 and the equal amount of generation increase is recommended at G2 to avoid load shedding.

Amount of over loading on the congested line 3–4 is **252.86 - 200 = 52.86 MW.**

As per desired generation schedule according to D_{LG} matrix the flow recommended through the line 3–4 is 163.08 MW.

Flow margin available on the line 3–4 is

= Flow suggested as per D_{LG} matrix - Actual flow

= 163.08−252.86 =−89.78 MW

Here negative sign indicates that the flow magnitude of 89.78 MW can be reduced as per desired generation schedule. Sufficient margin is available on this congested line, so 52.86 MW flow can be reduced on the congested line by suggesting the required generation change on the generator G1. To avoid load shedding at the bus 4, a load of 52.86 MW must be met from the generators in GI group (G2). Consequently the loading on the line 6–4 is increased by 52.86 MW. So before suggesting the rescheduling, margin available on the line 6–4 is to be checked.

As indicated in Table 7 according to D_{LG} matrix the flow recommended through the line 6–4 is 214.42 MW.

Flow margin available on the line 6–4

= Flow suggested as per DLG matrix - Actual flow

= 214.42 - 126.29 = 88.13 MW

Sufficient margin is also available on this line 6–4, so 52.86 MW flow can be increased on this line by suggesting the required generation increase on the generator G2. Magnitude of generation increase suggested at G2 to increase the flow of 52.86 MW on the line 6–4 (to relieve the congestion on the line 3–4).

4. RESULTS

Table 7 Summary of Results

	Gen. from G1	Gen. from G2	Flow from 3–4	Flow from 6-4	Flow from 2–6	Power loss
Before	428.757	600.0	252.865	126.29	382.805	28.822
After	261.738	758.70	185.565	192.176	450.904	20.442
Desired	207.988	811.80	163.078	214.424	474.048	19.791

5. CONCLUSION

In this work to relieve transmission congestion a Relative Electrical distance concept is used which is reliable and fast to determine congested lines. There are many types of congestion management schemes such as Zonal –cluster, Sensitivity/Distribution Factors Based Methods, Price Based Methods, etc. the best method among them is Relative Electrical distance.

In Relative Electrical Distance based congestion management scheme we can find the relative location of the load nodes with respect to the generator nodes and make desired scheduling. Also find contribution of each generator for overloading to the loads and line flows and tried to reschedule with the minimum losses in the system for relieve congestion.

6. REFERENCES

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