Congestion and Creation of It in Deregulated Power System

Rohit N. Chaudhary
Department of Electrical Engineering,
V V P Engineering College, Rajkot
Gujarat Technological University
rohitpatel_6472@yahoo.com

***Abstract*-With increasing demand for electric power all around the globe, electric utilities have been forced to meet the same by increasing their generation. In deregulated electricity market, most of the time power system operates near its rated capacity as each player in the market is trying to gain as much as possible by full utilization of existing resources. In deregulated environment, the transmission Congestion Management (CM) is one of the critical and important tasks of the System Operator (SO). The electric power that can be transmitted between two locations on a transmission network is limited by several transfer limits such as thermal limits, voltage limits and stability limits with the most restrictive applying at a given time. Congestion can lead to price volatility and system instability, which can deteriorate the electricity market operation.**

Keywords— ***TCDF, ATC, CM, ISO, OPF***

I. INTRODUCTION

With increasing demand for electric power all around the globe, electric utilities have been forced to meet the same by increasing their generation. In deregulated electricity market, most of the time power system operates near its rated capacity as each player in the market is trying to gain as much as possible by full utilization of existing resources. The purpose of deregulation in power system is to improve the competition and make new choices and economic benefits to consumers. Electric power systems, around the world, have been forced to operate to almost their full capacities due to the environmental and/or economic constraints to buildnew generating plants and transmission lines. Different problems like system security and its control, optimal bidding and transmission management has arisen as a consequence of this.

In deregulated environment, the transmission Congestion Management (CM) is one of the critical and important tasks of the System Operator (SO). The electric power that can be transmitted between two locations on a transmission network is limited by several transfer limits such as thermal limits, Voltage limits and stability limits with the most restrictive Applying at a given time. When such a limit is reached, the system is said to be congested.

The methods which aregenerally used to manage congestion include rescheduling of generator outputs, supplying reactive power or physically curtail of load. System operators generally use the first option as much as possible and the last one as the last resort. Network overloading can be reduced by some controls such as Real power generation rescheduling, phase shifting transformers, flow control through HVDC link(s), line switching, load shedding. Congestion is a consequence of the network constraints characterizing a finite network capacity that obstacle the simultaneous supply of power from an associated set of power transactions.Congestion can lead to price volatility and system instability, which can deteriorate the electricity market operation.

II. PRINCIPLE OF NETWORK CONGESTION

When the producer and consumer of electricity try to produce and consume power that would cause the transmission system to run at or beyond single or more transfer limit, then the system is said to be congested. So Congestion is the situation where the necessity for transmission capacity exceeds the network security limits. Line outages and higher demand of load are the main reasons of congestion.

A.Effect of Network Congestion

Consider a simple example of a two zone system connected by an interface, shown in Figures.Let each zone has a 100 MW constant load. Zone A has 200 MW generator with an incremental cost of Rs.200/ MWh. Zone B has 200 MW generator with an incremental cost of Rs.400/ MWh. Here we are suppose that both the generators bid their incremental cost.

Now, we are assuming that there will be no transfer limit between Zone A and Zone B, then whole 200 MW load is taken from generator A at Rs.200/MWh. As shownin figure (a).

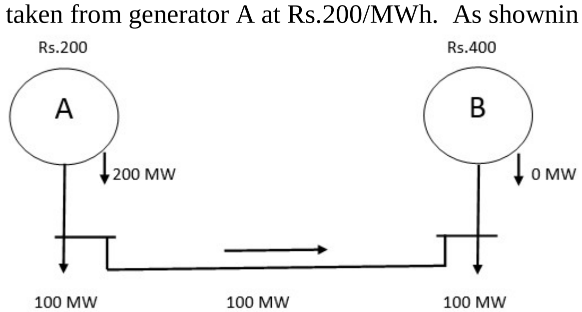

Figure (a): No-Congestion

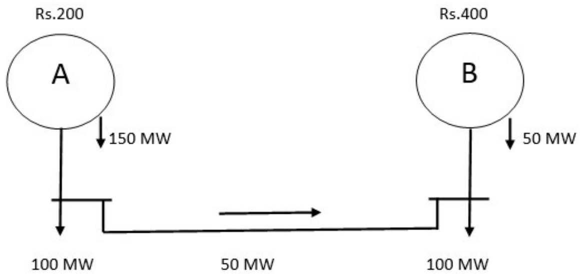

Figure (b) with 50 MW Transfer limit

But if there is a transfer limit of 50 MW on transmission line connected between Zone A and Zone B, then 150 MW will be taken from A at the cost of Rs.200/MWh and the remaining 50 MW must be taken from generator B at the cost of RS.400/MWh, as shown in figure (b). The all over cost of 200 MW in non-Congested market is Rs.40000/h. But in congested market, the overall cost is 50000/h. Congestion has produce 25% inefficiency in the market of the optimal cost, even without strategic behaviour of the generator.

B. Reasons of Congestion

Technical reason: Some unexpected contingencies such as generation outage, tripping of transmission line, sudden increase of load demand or failure of equipment's lead to rescheduling of power supply which may be not proper and result in congestion.
Commercial reason: Competition among the market players to take more profit tends to lack of coordination between the generation and the transmission utilities. Due to which overload of line and hampers further flow of power.

C. Approach to handle Congestion

In discrete types of market, There are different methods utilize for congestion relief. There are mainly three different methods adopted for tackle the congestion. They are listed below.

1. Available Transfer Capacity (ATC) based Congestion Management
2. Price Area Congestion Management
3. Optimal Power Flow (OPF) based Congestion Management

ATC based congestion management method is used in United State, Price area congestion management method is proposed in Nordic Pool, OPF based congestion management method is utilized in United Kingdom.

D. Generation Rescheduling

The method of rescheduling of generation is based on cluster / zone method as in [5] and it is briefly presented in this section.

Congestion Management by cluster / zone based method

This method utilizes two set of sensitivity indexes and that are PTCDF (real Power Transmission Congestion Distribution Factor) & QTCDF (reactive Power Transmission Congestion Distribution Factor). But for our case, we only consider the real power generation rescheduling. So we can say it simply as TCDF (Transmission Congestion Distribution Factor).

The values of TCDFs have been utilized to recognizing several congestion clusters for a given system.
The Congestion zone of type-1 is the one which has large and non-uniform TCDFs. The Congestion zone of type-2 having less effect then zone-1, due to which it has small and similar TCDFs. So the transactions in Congestion zone-1 have serious and unequal impact on the flow of transmission line. Transaction outside the most sensitive zone will take very little part to the line flows. Thus, the recognition of most sensitive congestion zone has reduced the effort of System Operator in identifying the participants for Congestion Management which reduces the computational burden. This method is also applicable if more than one transmission lines get congested at a time.

Transmission Congestion Distribution Factor (TCDF)

Transmission Congestion Distribution Factors are defined as the change in real power flow in transmission line-*k* connected between buses*i* and *j* due to unit change in the power injection (ΔP_i) at bus-*i*.

Mathematically, TCDF for line-*k* can be written as:

$$TCDF_i^k = \frac{\Delta P_{ij}}{\Delta P_i}$$

Methods to find TCDF

Method 1: Utilizing TCDFs obtained with dc load flow model.
Method 2: Utilizing TCDFs obtained with decoupled ac load flow model.
Method 3: Utilizing TCDFs obtained with coupled ac load flow model.

E. Formulation of Problem

Most of the market from all over the globe will try to reduce the rescheduling cost at minimum level. Due to new transaction of power exchange will result in congestion of transmission grids with controversy of real power losses.
If we reduce losses up to minimum level then we can utilize the power with more efficiency. The optimal rescheduling of generation problem has been done with an objective.
Minimizing the real power losses.

1.Objective Function – Loss minimization

The objective function of rescheduling real power generation using loss minimization is given by,

$$Minimize\ P_L = \sum_{\substack{i=1 \\ i\neq s}}^{N_{GT}} \sum_{\substack{j=1 \\ j\neq i}}^{N_{GT}} \left(2B_{ij} P_j + B_{io}\right) \Delta P_i$$

……………………………………..(4.1.1)

Subject to,

$$\sum_{\substack{i=1 \\ \neq s}}^{N_G} \left(\left(\mathrm{TCDF}_i^k \right) \Delta P_i \right) + F_k^0 \leq F_k^{max} \qquad k = 1,2 \ldots\ldots N_l$$

……………………………………... (4.1.2)

$$\Delta P_i^{min} \leq \Delta P_i \leq \Delta P_i^{max} \qquad i = 1,2 \ldots\ldots N_G , i \neq s$$

……………………………………… (4.1.3)

$$P_i^{min} \leq P_i + \Delta P_i \leq P_i^{max} \qquad i = 1,2 \ldots\ldots N_G , i \neq s$$

……………………………………… (4.1.4)

Where, P_L is the overall system loss. B_{ij} and B_{io} are the elements of B loss matrix. N_{GT} is the total number of generators. Equation (4.1.2) gives line flow constraints utilizing TCDF for congested lines. Equation (4.1.3) represents ramp limits for Generating companies. F_k^0 Is the power flow due to all contracts settled on line-k in advance.Equation (4.1.4) limits the output of every generation companies. [4]

Technical methods of congestion management.

(a) Utilization of transformer taps or phase shifter
(b) Utilization of FACTS devices
(c) Load shedding or curtailment of load
(d) Rescheduling of power generation.

F. Results and Discussion

Here, we are taking 6-Bus system to evaluate that how a Congestion has occur in a system when the load will change. Results shows that when we change the load on bus-4 and bus-5 then the loading limit of line-7 will be violated which is connected between bus-1 and bus-2. The power flow limit of line-7 should be taken as 30 MW. The line diagram for IEEE-6 Bus system is shown in below figure.

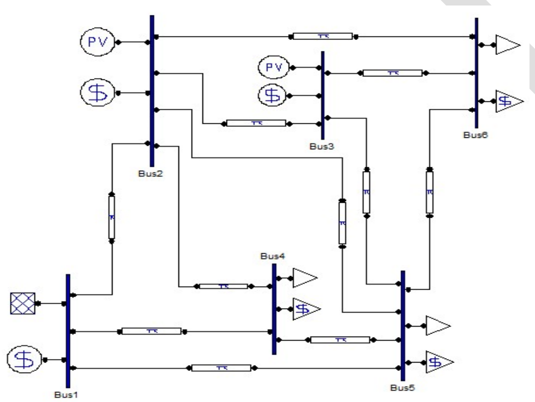

Figure 5.1: Sample 6 - Bus test system

Power Flow Report has been generated in MATLAB tool "PSAT 2.1.8" Environment and compare with N-R load flow programing. The Network Statistics and power flow results are also shown below.

Buses-6, Lines-11, Generators-3, Loads-3,Bus-1 (Swing Bus), Buses-2 & 3 (Generation Buses), Buses- 4, 5 & 6 (Load Buses)

Case- 1 without Congestion

Power Flow Results (PSAT)

Table 5.1
Power Flow Results (without congestion-PSAT)

Bus	Voltage [KV]	Phase [Deg.]	Power Gen. [MW]	Load [MW]
Bus-1	400	0	103.0399	0
Bus-2	400	-3.89660	50	0
Bus-3	400	-4.16479	60	0
Bus-4	372.756	-4.33824	6.66E-14	67
Bus-5	366.871	-5.36524	3.33E-14	67
Bus-6	373.857	-6.13407	2.22E-14	70

Line Flow Results (PAST)

Table 5.2
Line Flow Results (without congestion-PSAT)

From Bus	To Bus	Line	Power Flow	Power Loss
Bus 1	Bus 2	7	**27.6448 MW**	**0.924677MW**

Real Power Generation: 213.0399 MW

Real Power Load: 204 MW

System Real Power Losses: **9.039936 MW**

Power Flow Results (MATLAB)

Table 5.3
Power Flow Results (without congestion-PSAT)

Bus	Voltage [KV]	Phase [Deg.]	Power Gen. [MW]	Load [MW]
Bus-1	400	0	102.455	0
Bus-2	400	-3.8391	50	0
Bus-3	400	-4.0998	60	0
Bus-4	374	-4.3519	-	67
Bus-5	369.2	-5.4131	-	67
Bus-6	374.80	-6.1058	-	70

Line Flow Results (MATLAB)

Table 5.4
Line Flow Results (without congestion-MATLAB)

From Bus	To Bus	Line	Power Flow	Power Loss
Bus 1	Bus 2	7	**27.231 MW**	**0.898 MW**

Real Power Generation: 212.455 MW

Real Power Load: 204 MW

System Real Power Losses: **8.455 MW**

Case-2 with Congestion

Power Flow Results (PSAT)

Table 5.5
Power Flow Results (with congestion-PSAT)

Bus	Voltage [KV]	Phase [Deg.]	Power Gen. [MW]	Load [MW]
Bus-1	400	0	122.5653	0
Bus-2	400	-4.74931	50	0
Bus-3	400	-5.15166	60	0
Bus-4	371.6861	-5.29060	9.99E-14	76
Bus-5	365.6320	-6.46584	2.66E-13	76
Bus-6	373.6045	-7.10733	-2.2E-14	70

Line Flow Results (PSAT)

Table 5.6
Line Flow Results (with congestion-PSAT)

From Bus	To Bus	Line	Power Flow	Power Loss
Bus 1	Bus 2	7	**33.80518 MW**	**1.3734 MW**

Real Power Generation: 232.5653 MW

Real Power Load: 222 MW

System Real Power Losses: **10.56528 MW**

Power Flow Results (MATLAB)

Table 5.7
Power Flow Results (with congestion-MATLAB)

Bus	Voltage [KV]	Phase [Deg.]	Power Gen. [MW]	Load [MW]
Bus-1	400	0	121.959	0
Bus-2	400	-4.6888	50	0
Bus-3	400	-5.0829	60	0
Bus-4	372.8	-5.3009	-	76
Bus-5	368.0	-6.5084	-	76
Bus-6	374.80	-7.0753	-	70

Line FlowResults (MATLAB)

Table 5.8
Line Flow Results (with congestion-MATLAB)

From Bus	To Bus	Line	Power Flow	Power Loss
Bus 1	Bus 2	7	**33.367 MW**	**1.339 MW**

Real Power Generation: 231.959 MW

Real Power Load: 222 MW

System Real Power Losses: **9.959 MW**

Here, results are tabulated in two different environment and they are PSAT tool and Mat-Lab programing. The mismatch between two environmental results are shown here.

In PSAT, Line flow results in Table 5.2 and Table 5.6 shows that line-7 would get congested due to increase in load at Buses 4 & 5. Power flow in line-7 is 33.80518 MW after the congestion occurred, which has power flow limit up to 30 MW.

In Mat-Lab Programing, Line floe results in Table 5.4 and Table 5.8 shows that line-7 would get congested due to increase in load at Buses 4 & 5. Power flow in line-7 is 33.367 MW after the congestion occurred.The system losses in both of the cases has also mentioned here. Line data and Bus data are taken from. [8]

CONCLUSION

This paper review with the concept of congestion in deregulated power system. The occurrence of congestion has been shown with example. Reasons of congestion and way's to tackle congestion was listed in this paper. Two objective functions are introduce to cope the congestion. At last the results shows that how a congestion was created in 6-bus deregulated power system. PSAT tool and MATLAB programing results are compared.

REFERENCES

[1] A.R.Abhayankar, S.A.Kharapade, *"Introduction to Deregulation in Power Industry",* Indian Institute of Technology Bombay.

[2] S.A. Kharapade, *"Congestion Management"*, Indian Institute of Technology, Mumbai.

[3] Richard D Christie, Bruce F Wollenberg, Ivar Wangensteen, *"Transmission management in the deregulated environment"*, in proceedings of the IEEE, Vol 88, No.2,pp. 170—194, February 2000.

[4] S.Charles Raja, P.Venkatesh and B.V.Manikandan, *"Transmission Congestion Management in Restructured Power Systems"*, Emerging Trends in Electrical and Computer Technology, (20 II).

[5] Ashwani Kumar, S.C. Srivastava, S.N. Singh, *"A zonal congestion management approach using ac transmission congestion distribution factors"*, Electric Power Systems Research 72 (2004).

[6] S. Charles Raja, S.A.WaajithaBanu, Dr. P. Venkatesh *"Congestion Management Using GAMS/CONOPT Solver."* IEEE- International Conference on Advances in Engineering, Science and Management (ICAESM -2012) March 30, 31, 2012.

[7] National Programmed on Technology Enhanced Learning (NPTEL), http://nptel.iitk.ac.in/

[8] Wood, A.J., and Wollenberg, B.F. *"Power Generation Operation and Control"*, New York: John Wiley & sons, 1996.