Concept and Formulation of Congestion Management in Electricity Markets

[1]Madhukar Anand, [2]Sonali Khanna, [3]Ravinder Singh, [4]Sumit Saroha
[1,2,3]Student, [4]Assistant Professor
Department of Electrical and Electronics Engineering,
Dronacharya Group of Institutions, Greater Noida, India

Abstract: - In deregulated electricity markets congestion in the transmission is one of the technical problems. There are two types of congestion management methodologies to relieve it. In both techniques one technique is non-cost free methods and another is cost-free technique, among them first technique resolve the congestion on the basis of economic point of view whereas another resolve technically. Along with this, the optimal dispatch solution using security constrained economic dispatch eliminates the possible occurrence of congestion. The transmission congestion management involves set of rules and regulation to resolve congestion and ensure control over generators and loads for maintain the system security and reliability within acceptable level. In a deregulated market structure, the market must be modelled so that the market participants engage freely in transactions and play as per market forces, but in a manner that does not threaten the security of the power system. So the main aim of this paper is to explain various congestion management schemes considering both technical as well as economic points.

Index Terms— **Power Trading, Congestion, Deregulation, Electricity Act**

I. INTRODUCTION

Almost all electricity industries all over the world are regulated to some extent by following very competitive businesses such as auto manufacturing, airlines, communication and banking are all heavily regulated with myriad government requirements defining what they must, can, and cannot do, and what and to whom and when they must report their activities. Regulation of electric utilities is not the only way as government can control the electric power industry within its jurisdiction, but also on the anther way is to own and operate the power company directly, as a government utility. 'Deregulation in power industry is a restructuring of the rules and economic incentives that government has set up to control and drive the electric power industry.' As the terms suggest, they represent fundamentally opposite idea. But either concept is necessarily good or bad. Both regulation and deregulation make sense, and one or other is preferable under certain conditions [1, 2].

Transmission congestion occurs when there is insufficient energy to meet the demands of all customers. The term is somewhat misleading, because no actual congestion occurs in the transmission system. These systems don't slow down, and electricity doesn't become blocked or delayed because the transmission system can't be stretched beyond its limits. Attempting to operate a transmission system beyond its rated capacity is likely to result in line faults and electrical fires, so this can never occur. The congestion is actually a shortage of transmission capacity to supply a waiting market, and the condition is marked by systems running at full capacity and proper efficiency which cannot serve all waiting customers [3, 4].

When congestion occurs in a competitive market, there is a risk of price gouging from utilities that control transmission services. Regulatory bodies are aware of this risk, and most jurisdictions have built safeguards into their free-market regulations to insure that abusive pricing does not occur, and that congestion-related energy cost increases reasonably reflect the extra costs incurred in alleviating the condition. And the only ways the congestion can be alleviated are to tune the system to increase its capacity, add new transmission infrastructure, or decrease end-user demand for electricity. Congestion management is a key function of any independent system operator (ISO) in the restructured power industry. Improper congestion management will sabotage the security and reliability of the power system and as well as treading of electricity.

For developing countries, the main issues have been a high demand growth coupled with inefficient system management and irrational tariff policies. This has affected the availability of financial resources to support investments in improving generation and transmission capacities. In such circumstances, many utilities were forced to restructure their power sectors under pressure from international funding agencies. So the private investor's can resolve the above said problems regarding electricity in deregulated electricity environment.

The rest of paper has been organized as follows: The next section describes problem formulation. Section 3 discusses the India Scenario of Deregulation and electricity act 2003; Section 4 describes in brief Congestion Management in Deregulated Electricity Markets; Section 5 discusses the Classification of Congestion Management Mechanisms: Section 6 fall the light on different Congestion Management based on Cost Allocation Methods and finally Section 7 concludes the present work.

II. PROBLEM FORMULATION

This paper formulates the concept of congestion management in electricity markets. On the basis of world scenario and Electricity Act 2003 in India this paper gives the details about concept of congestion management and fall the light on different methods (technical and economical) to tackle the congestion.

III. Structure of a Deregulated Electricity Market

The first step in the restructuring process was to separate out the generation activities from that of the distribution and transmission, following was to introduce competition in generation activities, either through the creation of power pools, provision of direct bilateral contracts or bidding the spot markets. So in competitive electricity market there may be several generation companies, Independent Power Producers (IPP) or/and Non-Utility Generators (NUG).

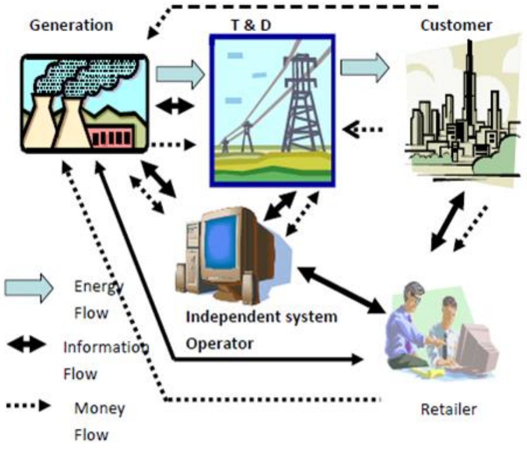

Fig. 1 Structure of a Deregulated Electricity Market

Deregulation Scenario in India

In India, the power sector was mainly under the government ownership under various states and central government utilities, till 1991. The remarkable growth of physical infrastructure was facilitated by four main policies:

(1) Centralized supply and grid expansion
(2) Large support from government budgets
(3) Development of sector based on indigenous resources
(4) Cross subsidy.

In mid 1990s, Orissa began a process of fundamental restructuring of the state power sector. Under the World Bank (WB) loan, the state decided to adopt, what is known as WB-Orissa model of reform. This consisted of a three pronged strategy of:

- Unbundling the integrated utility in three separate sectors of generation, transmission and distribution,
- Privatization of generation and distribution companies and,
- Establishment of independent regulatory commissions to regulate these utilities.

Soon afterwards, several other states such as Andhra Pradesh, Haryana, Uttar Pradesh, Rajasthan etc. also embarked on similar reforms and also availed loans from multilateral development banks such as WB and Asian Development bank, etc. Meanwhile, some moderate steps were taken towards reforms until the Electricity Bill 2003 was approved by Parliament in May 2003. This unified central legislation passed after 10 drafts. The Bill now replaces pervious three acts on electricity of 1910, 1948 and 1998 (with their amendments).

The Electricity Act 2003

The conceptual framework underlying this new legislation is that the electricity sector must be opened for competition. The Act moves towards creating a market based regime in the power sector. The Act also seeks to consolidate, update and rationalize laws related to generation, transmission, distribution, trading and use of power [5, 6]. It focuses on:

- Creating competition in the industry
- Protecting consumer interest
- Ensuring supply of electricity to all areas
- Rationalizing tariff
- Lowering the cross-subsidization levels

IV. Congestion Management in Deregulated Electricity Markets

One of the principal characteristics of a competitive structure is the identification and separation of the various tasks which are normally carried out within the traditional organization so that these tasks can be open to competition whenever practical and profitable. The management of congestion is somewhat more complex in competitive power markets and leads to several disputes. Congestion may be alleviated through various ways. Among the technical solutions, we have system re dispatch, system reconfiguration, out-aging of congested lines, operation of FACTS devices and operation of transformer tap changers.

There are two types of congestion:

- Static congestion

- Dynamic congestion.

Static congestion: This congestion is caused by the thermal, voltage limit and stability limit.

Thermal Limits: Thermal limits establish the maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period before it sustains permanent damage by overheating. **Voltage Limits:** System voltages and changes in voltages must be maintained within the range of acceptable minimum and maximum limits. The lower voltage limits determine the maximum amount of electric power that can be transferred.

Stability Limits: The transmission network must be capable of surviving disturbances through the transient and dynamic time periods (from milliseconds to several minutes, respectively). Immediately following a system disturbance, generators begin to oscillate relative to each other, causing fluctuations in system frequency, line loadings, and system voltages. For the system to be stable, the oscillations must diminish as the electric system attains a new stable operating point. The line loadings prior to the disturbance should be at such a level that its tripping does not cause system-wide dynamic instability.

Dynamic congestion: Power system may undergo discrete change in system configuration due to outage and contingencies which will affect system dynamic performance and might threaten the system stability. So the available resources must be utilized to maintain system security. This management is called Dynamic congestion management.

V. CLASSIFICATION OF CONGESTION MANAGEMENT MECHANISMS

The congestion management schemes are strongly coupled with the overall market design. Efficient allocation of scarce transmission capacity to the desired participants of the market is one of the main objectives of congestion management schemes. Thus, distinction among them can be made based on market based congestion management methods and other methods. Market-based solutions to congestion are deemed fairer as they contribute better to economic efficiency than other methods. Methods other than market based make use of some criteria to allocate the transmission capacity. These methods are supposed to introduce some kind of arbitrariness as they do not contribute towards efficient pricing of congested link.

Table I Classification of congestion management schemes

Non - market Methods		Market Based Methods	
1	Different Types of Contract	1	Explicit Auctioning of network capacity
2	First come first serve	2	Nodal pricing (OPF based congestion management)
3	Pro - rata methods	3	Zonal pricing
4	Curtailment	4	Price area congestion management
		5	Re - dispatch
		6	Counter trace

1. Explicit Auctioning: Most of the power exchanges across the world work on the principle of uniform pricing. In this method, the clearing price and clearing volume of electricity corresponds to the point of intersection of the Aggregate Demand curve and Aggregate Supply curve. All the suppliers are paid based on the clearing price, irrespective of their offer. This means that price is set by the last accepted offer of supply. In the alternative approach, referred as discriminatory pricing or "payas- bid" method, each supplier is paid as per its bid. Each buyer pays a price, which is the weighted average of the price for all suppliers cleared by the PX (as used by BETTA, UK). OMEL (Spain) uses a different kind of pricing mechanism in which the buyer of the highest bid gets the electricity at the second highest bid price (Vickery auction).

2. Nodal Pricing: In nodal prices, the participants pay or receive a price, which depends on the node or the point of connection in the transmission grid, through which the participant injects or draws power. Price at each node depends on congestion in the transmission lines.

3. Zonal Pricing: In zonal pricing, the entire market is divided into a no of zones and all participants (buyers/sellers) belonging to a single zone pay or receive a uniform price, irrespective of the congestion occurring in the transmission line inside the zone. Zonal prices differ from one zone to another depending on congestion in transmission lines between the zones. In India, zonal pricing system is followed and the entire country is divided into 10 zones or areas.

4. Price area congestion management: In area pricing, at the time of congestion the electricity is purchased from the local area and the price is depend on the demand. Like zonal area the price each area has different price depend on the congestion.

5. Re-dispatching: It is exercised as a command and control scheme, i.e., ISO curtails or increases injections without market based incentives. As generators have to be reimbursed, the ISO has an incentive to keep re-dispatch cost low.

6. Counter trading: It is based on the same principles as re-dispatching, however, it may be considered market oriented. Rather than applying command and control, the ISO will buy and sell electricity at prices determined by a bidding process. The principle of counter trading is thus a buy back principle which consists of replacing the generation of one generator ill- placed on the grid as regards to congestion by the generation of a better placed generator. The ISO has to buy electricity downstream of the congestion at higher cost and sell it upstream. Thus, there is no congestion rent, instead a congestion cost for ISO. This cost exposure is also regarded as an incentive for investment into grid capacity. Counter trading is used for real time congestion relief in the Norwegian system [1-4, 7, 8].

VI. Congestion Management based on Cost Allocation Methods

An efficient transmission pricing mechanism should recover transmission costs by allocating the costs to transmission network users in a proper way. The transmission costs may include:

- Running costs, such as costs for operation, maintenance, and ancillary services.
- Past capital investment.
- Ongoing investment for future expansion and reinforcement associated with load growth and additional transactions.

The running costs are small compared with the capital investment (or embedded transmission costs). Consequently, transmission charges for embedded cost recovery would largely exceed running costs over the investment recovery period. The study objectives and market structures are main factors for choosing algorithms in the evaluation of transmission pricing. Regardless of the market structure, it is important to accurately determine transmission usage in order to implement usage-based cost allocation methods.

However, determining an accurate transmission usage could be difficult due to the nonlinear nature of power flow. This fact necessitates using approximate models, sensitivity indices, or tracing algorithms to determine the contributions to the network flows from individual users or transactions.

In the following, we discuss major transmission cost allocation methods. Some of these methods are used widely by electric utilities, while others are still in developmental stages.

1. Postage-Stamp Rate Method: Postage-stamp rate method is traditionally used by electric utilities to allocate the fixed transmission cost among the users of firm transmission service. This method is an embedded cost method, which is also network configuration. In other words, the charges associated with the use of transmission system determined by postage-stamp method are independent of the transmission distance, supply, and delivery points or the loading on different transmission facilities caused by the transaction under study. The method is based on the assumption that the entire transmission system is used, regardless of the actual facilities that carry the transmission service. The method allocates charges to a transmission user based on an average embedded cost and the magnitude of the user's transacted power.

2. Contract Path Method: The contract path method is also traditionally used by electric utilities to allocate the fixed transmission cost. It is likewise an embedded cost method that does not require power flow calculations. This method is based on the assumption that transmission services can be represented by transmission flows along specified and artificial electrical path throughout the transmission network. The contract path is a physical transmission path between two transmission users that disregards the fact that electrons follow physical paths that may differ dramatically from contract paths. The method ignores power flows in facilities that are not along the identified path. After specifying contract paths, transmission charges will then be assigned using a postage-stamp rate, which is determined either individually for each of the transmission systems or on the average for the entire grid. As a consequence, the recovery of embedded capital costs would be limited to artificial contract paths.

3. MW-Mile Method: The MW-mile method is an embedded cost method that is also known as a line-by-line method because it considers, in its calculations, changes in MW transmission flows and transmission line lengths in miles. The method calculates charges associated with each wheeling transaction based on the transmission capacity use as a function of the magnitude of transacted power, the path followed by transacted power, and the distance traveled by transacted power. The MW-mile method is also used in identifying transmission paths for a power transaction. As such, this method requires dc power flow calculations. The MW-mile method is the first pricing strategy proposed for the recovery of fixed transmission costs based on the actual use of transmission network.

4. Unused Transmission Capacity Method: The difference in a facility capacity and the actual flow on that facility is called the unused (unscheduled) transmission capacity. To guarantee the full recovery of all embedded costs, it is assumed that all transmission users are responsible to pay for both the actual capacity use and the unused transmission capacity.

5. MVA-Mile Method: The MVA-mile method is an extended version of the MW-mile method. The extension is proposed to include charges for reactive power flow in addition to charges for real power flow. It has been shown that monitoring both real and reactive power, given the line MVA loading limits and the allocation of reactive power support from generators and transmission facilities, is a better approach to measuring the use of transmission resources. The tracing methods that will be discussed later in this chapter can be used for this purpose. In addition, the sensitivity approach with ac power flow studies can be used to determine the network usage of reactive power flow. Other approaches have been also proposed to decompose network flows into real and reactive components associated with individual transactions.

6. Counter-flow Method: The counter-flow method argues that transmission users should be charged or credited based on whether their transactions cause flows or counter flows with regard to the direction of net flows. The method suggests that if a particular transaction flows in the opposite direction of the net flow, then the transaction should be credited (i.e., the transaction would pay a negative charge). This suggestion differs from the traditional MW-mile approach and other usage-based allocation pricing rules, where each transaction pays for its usage regardless of the flow's directions. An example of the counter-flow method is zero counter-flow pricing, which proposes that only those that use the transmission facility in the direction of net flow should be charged in proportion to their contributions to the total positive flow. One of the difficulties in using this method is that it would be hard for transmission service providers to arrange payments to users with counter-flows.

7. Distribution Factors Method: Distribution factors are calculated based on linear load flows. In general, generation distribution factors have been used mainly in security and contingency analyses. They have been used to approximately determine the impact of generation and load on transmission flows. In recent years, these factors are suggested as a mechanism to allocate transmission payments in restructured power systems, as these factors can efficiently evaluate transmission usage. To recover the total fixed transmission costs, distribution factors can be used to allocate transmission payments to different users. By using these factors, allocation can be attributed to transaction-related net power injections, to generators, or to loads. The distribution factors are Generation Shift Distribution Factors (GSDFs or A factors), Generalized Generation Distribution Factors (GGDFs or D factors), Generalized Load Distribution Factors (GLDFs or C factors).

9. AC Power Flow Methods: Many ac-based approaches have been proposed to allocate transmission cost. Among them there are flow sensitivity indices, full ac power flow solutions, and power flow decomposition. The ac flow sensitivity indices method uses the same logic as the dc flow distribution factors, but the sensitivity of transmission flows to bus power injections are derived from ac power flow models. The full ac power flow solutions method uses full ac power flow calculations or utilizes optimal power flow studies. In these methods, more detailed cost information is usually required to study the impact of wheeling transactions. The power flow decomposition method would decompose network flows into components associated with individual transactions plus one component to account for the nonlinear nature of power flow model. For each transaction, the algorithm determines real and reactive flow components of the transmission network usage, the net power imbalance, and the contribution of participating generators to real-power loss compensation.

10. Tracing Methods: Tracing methods determine the contribution of transmission users to transmission usage. Tracing methods may be used for transmission pricing and recovering fixed transmission costs. There are basically two tracing methods, which are recognized as the Bialek's tracing method and the Kirschen's tracing method.

VII. CONCLUSION

The present day structure of power system makes the congestion management is universally become an important activity of power system operators. It is found that after inaction of electricity act 2003 in India congestion comes more into play with role of power system operator. This paper also fall the light on different techniques for solving congestion problem with the consideration of both technical and economic parameters. After deregulation in electricity role of power system operator is more predominant.

REFERENCES:

[1] M. Shahidehpour, H. Yamin, and Z. Li, Market operations in electric power systems: forecasting, scheduling, and risk assessment. John Wiley & Sons, Inc., New York, 2002.

[2] G. Yesuratnam and D. Thukaram, "Congestion management in open access based on relative electrical distances using voltage stability criteria", Electric Power Systems Research, vol. no. 77, pp. 1608-1618, 2007.

[3] Loi Lei Lai, Power System Restructuring and Deregulation, Trading, performance and Information Technology, City University, London, UK, John Wiley& sons Ltd., April 2002.

[4] A.S.Nayak and M.A.Pai, "Congestion Management in Restructured Power systems using an optimal power flow Framework", University of Illinois, PSERC Publication, 2002.

[5] A.R. Abhyanakar and S.K. Khaparde, "Introduction to Deregulation in Power Industry", Indian Institute of Technology Bombay.

[6] Website of "Bureau of Energy Efficiency", http://www.beeindia.in/

[7] www.wikepidia.com

[8] www.google.co.in