CONGESTION MANAGEMENT IN DEREGULATED POWER SYSTEM: A REVIEW

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Abstract: The TOA (Transmission Open Access) has resulted in the problem of overcrowding in the transmission network. This overcrowding in the transmission network is called as congestion. Congestion has caused the problem in managing transmission network. The problem of congestion occurs when transmission network fails to transfer power according to the demand. Several methods have been proposed to manage congestion. Congestion management in todays deregulated power system plays a crucial role. The two main functions of congestion management are collecting money from the users and giving them back to investors. This paper unites the work of various publications on congestion management, it includes various congestion management methods, causes of congestion management and minimizing the risk involved in various congestion management methods in various countries are reviewed here.

Keywords: Deregulation, Demand response, TSO, Power market, GENCOs, ISO, ESIs, ATC, OPF

LIST OF ACRONYMS
GENCOs: Generating Companies.
ATC: Available Transfer Capacity
TSO: Transmission System Operator
ISO: Independent System Operator
LMP: Locational Marginal Price
ZCM: Zonal Congestion Management
ESIs: Electric Supply Industries
EPPO: Energy Policy and Planning Organization, NEPO
NEPO: National Energy Policy Office, EPPO
OPF: Optimal Power Flow
RTOs: Regional Transmission Organizers
IPPs: Independent Power Producers
SCs: Scheduling Coordinators
CASIO: California ISO
ANEM: Australian National Electricity Market

I. INTRODUCTION

To deal with the problem of congestion or overcrowding in transmission several methods are implemented all over the globe such as auctioning (explicit and implicit auction) methods [1], nodal and zonal pricing methods etc. To have a proper congestion management a proper coordination is needed between GENCOs and ISO [2, 3]. Changing of traditional power system to an unbundled system where generation and transmission are managed by two different utilities is called restructuring of power system [4].

Vertically integrated system where all the three functions of generation, transmission and distribution are managed by a single company is now changed to a competition based power market. This changing scenario of power system has led to overcrowding in transmission because there is lack of transfer capability to transmit all traded transactions [5]. Due to congestion there is a violation of conditions under which the grid operates such as operational, physical and policy constraint. As each and every transaction needs the maximum benefits so the problem of congestion is prone in competitive environment power market as compared to traditional power system. Congestion management includes both technical and financial tool which refers to congestion relief work and also price allocation methods [6].

Classification of Congestion Management methods and the techniques for solving congestion management problem are in [7] and [8] deals with the websites which deals with the issues of

congestion management. Pricing mechanism and schemes of congestion management are discussed in [9]. TSO plays a key role in congestion management [9]. The aim of TSO is to identify user who is using a particular transmission network [10] so that TSO can charge an appropriate transmission charge from that user during congestion.

The main aim of congestion management [11] is to provide a MW schedules which are prepared from ISO depending on load forecasting with proper security of system and its reliability, so that overall profit of all the participants is maximized and the power market is settled at such an economic stage which is in coordination with MW schedules. If we curtail the non-firm transactions the problem of heavy conges tion is solved [12].

II. METHODS OF CONGESTION MANAGEMENT

Congestion in transmission should be managed so as to utilize the transmission network in an efficient manner. Congestion may cause damage to power system components [13]. Therefore congestion management has become important in present deregulated environment.

Congestion Management Methods Based On Power Market: Different models for power market have been developed all over the world. This part reviews the congestion management issues and linked mechanisms used in electricity markets [13].

Generation re-dispatch: Firstly the required number of generators which are least expensive are selected to meet the demand and the market-clearing price is decided by the most expensive bid which has been accepted. Second step is done by ISO which evaluates whether transmission constraints will occur under unconstrained dispatch. If there is violation of constraint, a generation re-dispatch will be executed by an ISO [14].

Market splitting: The power exchange is split into different bid or price areas. When congestion is predicted, ISO splits its grid and a zone-based dispatch of market is carried out. The spot price of each geographical area is determined in such a manner that expected transmission in between two geographical is equal to total transfer capability of the transmission network. As a result spot price of surplus area will fall down and that of the deficit area will increase.

Nodal price method: For efficient use of transmission grids as well as generation resources by providing appropriate economic signal, use of nodal price is done. Nodal price is the marginal cost of providing next increment of power at a particular bus. Each participant is charged in accordance with the nodal price.

Demand response programs**:** In order to have a proper competitive market there should be enough encouragement for consumers to participate in energy market functioning. Demand response programs provide such opportunities to consumers to act as a player in the energy market [15]. Demand response programs are defined as the incentive payments which are designed to provide the less use of electricity at times when wholesale market prices are high. [16].

Analogy of facts devices on congestion management: The basic barrier which is caused by congestion is to violate the main objective of restructuring which is to supply the most economical power to the customers. Due to congestion the cost of power supply increases because of addition of large congestion cost. FACTS devices increase the total transfer capability of transmission network and in addition it reduces the congestion charges by controlling voltage, reactive power and power system stability. Static series synchronous compensator improves TTC (Total Transfer Capability). The FACTS controllers may effectively be applied in managing transmission network power flows. Modeling of SSSC FACTS controller is done in [17] for dealing with the problem of congestion management. A proper loop flow controller by the use of DC- link and UPFC is presented in [7].

Computing techniques for congestion management: Solution to the problem of congestion management is also provided by developing numerical algorithms using computing techniques

Congestion Management Based On Genetic Algorithm: Congestion management is a non-linear optimization problem, having a concept of social welfare. Genetic algorithm method has been proved a powerful for achieving the goal of optimum basically counter trading [18]. Genetic algorithms [19] are very successful in congestion management by smart definition of chromosomes.

Fuzzy Logic Approach**:** Nowadays, deregulated environment of power system initiates the use of optimization techniques in collaboration with the

implementation of fuzzy logic. To select an appropriate transaction strategy, fuzzy opinion matrix idea is used in [20]. Similarly, an approach based on symbolic simulation with optimization library function is used in [21] to overcome the problem of congestion.

Congestion Management on ATC: In this method information of day-ahead ATC (Available Transfer Capacity) is uploaded on a website which is known as OASIS (Open Access Same Time Information System) by an ISO/TSO. Anyone who wish to do transactions, may access webpage of OASIS and have information whether his transaction is feasible or not. Electronic scheduling is implemented by OASIS [22].

Congestion Management Based On OPF: The aim of this method is to maximize customers profit and minimize generator cost [8]. OPF is often the obvious choice of many researchers for congestion management. Optimizing method is an effective tool for solving congestion. A mathematical formulation [23] for congestion management includes formulation for bilateral and multilateral dispatches, power balance constraints formulation and strategies for transaction curtailment. ISO have to implement some transaction reduction policies [24] with adequate participation of market participants. To minimize deviation from scheduled transaction is the main objective of these policies.

IV. NODAL AND ZONAL BASED CONGESTION MANAGEMENT

Nodal and zonal approaches are used to solve the problem of congestion. In the starting stage of deregulation zonal approach is more accurate however nodal approach is more accurate but it is not preferred in the changing stage of restructuring because it is complex. In zonal approach the overall system is divided into several zones based on sensitivity indices [25, 26] or several contributing factors like load contribution factor [27] and generator contributing factor. The most sensitive zone generators with un-even distribution of sensitivity indices are identified and selected for re-scheduling their results or outputs to solve congestion. Lines having severe and frequent congestion separate their zones. For this inter-zonal and intra-zonal method of congestion management which uses phase-shifters and transformer taps play a significant role without any generation re-scheduling [28, 29].

Intra-zonal refers to overcrowding of transmission network inside a particular zone and overloading of transmission network between different zones or areas is called inter-zonal congestion management. In [30] an efficient method for transmission cost allocation which uses nodal pricing is proposed. A zonal congestion management method with the use of phase-shifter is proposed in [31].

Framing and allocation of congestion charges is one of the essential functions of congestion management. Nodal and zonal pricing are two methods of evaluation of congestion charges and each is complimented by their respective congestion revenue rights [32] and transmission rights [33]. A complete comparative analysis of pricing schemes involved in Deregulated power market is done in [34]. Congestion revenue rights [35] are greatly influenced by distribution factors.

Nodal pricing method takes into account locational marginal prices and calculates it at each node. Zonal pricing method is carried out in two steps: first method involves the aggregation of single nodes into zones based on some criteria and second is calculation of zonal prices. A new approach based on nodal responsibility is used to allocate congestion cost and losses to the nodes in given in [36].

V. PROBLEMS INVOLVED IN CONGESTION MANAGEMENT

Restructuring of power sector is a very difficult job. This is all because numerous factors affect congestion management in different proportions. In traditional power system problem of congestion was very less prominent and if it occurs it could be easily solved by generator re-dispatching by preventive or corrective measures. But in today's scenario where deregulation is present any present any change in generator output will affect economic benefits of other participating units.

Position of generating companies in deregulated environment and their optimal bidding techniques are drastically affected due to congestion in transmission network. To save the position of bidding strategies in the competitive environment of systematic approach is needed [37]. There are differences with the objectives of GENCOs because of their marketing strategies. The situation of congestion severely affects bidding techniques

[38]. Market participants develop their market strategies with the help of information revealed by LMP. To forecast LMP (Locational marginal price) in an area neuro-fuzzy price forecasting methods [39] acts as effective tool.

As each market participants aims to maximize their profit, generation re-dispatching influence the benefit of other participants. Secondly, the curtailment of bilateral transactions needs simultaneous and equal reduction at both sides. All these things make congestion management a difficult and challenging task. Apart from this congestion management becomes costlier when congestion is severe.

The regulating bids and offers for supply and consumption of electricity increases because of congestion alleviation charges. There is a lack of alignment between market participants and regulatory body, which is a major problem noticed in congestion management. Deregulation has brought a change in the power sector, has become more flexible in comparison to traditional power system involving vertically integrated utilities. Because of all these issues difficulty in performing congestion management measures is increasing day by day. The only way left is re-scheduling which is quiet costly method. Therefore, congestion puts a constraint in power market and in many cases it degrades the theme of restructuring by making market non-competitive.

VI. CASES OF CONGESTION MANAGEMENT

The cases in various countries like Thailand, Switzerland, U.K, Australia and Nordic countries are reviewed here in this paper.

Congestion Management in Thailand: Nearly, all electric supply industries (ESIs) all over the world are presently under the developing and restructuring stage. Thailand is a developing country and it is at its initial stage to adopt deregulated system [40]. In Thailand, the NEPO (presently EPPO) responded to this change in the ESI by concurring EGAT to sign PPA contracts with SPPs and IPPs. After 1997, economic crisis and restructuring of ESIs in Thailand was accelerated. Under this competitive environment, GENCOs which offer electricity price to customers will have benefits in market. This causes the change in power-flow and cause congestion in transmission. Congestion management process in Thailand is discussed in [40]. It discusses ZCM in transition stage and steps involved in it and nodal congestion management in fully competitive and deregulated environment.

Congestion Management in Japan: The power transmission network of Japan is different from other countries. In their transmission network there is no problem of loop flow with tie lines, as there are two transmission lines in one interconnection route. Each company is obliged to provide electricity to all consumers of its area. There are two schemes governing congestion management in Japan. The first method is based on calculation of ATC which is obtained by reducing TTC by necessary margin. Second one is the prevention of intentional overestimates which means a charge is imposed on scheduled charges and this congestion charge is based on use-it or loose-it technique. Congestion management in japan is discussed in [41].

Congestion Management in Switzerland: Swiss TSOs have developed a new day-ahead concept for transmission congestion management [42]. This involves three automatic processes which are congestion forecast, system methodology and implementation. The DACF (Day-ahead congestion forecast) consist of three parts, first is preparation of Swiss DACF datasheet, second is collection and merging of all DACF datasheets and last is load flow calculations. OPF software package is used in determining congestion elimination, OPF consist of two measures: re-dispatch and topological measures. Topological measures consist of the change of operating status of network elements, substation reconfiguration and transformer tap adjustments whereas re-dispatch eliminates congestion by using optimal solutions.

Transmission Congestion Management in Nordic Countries: In Nordic countries the task of congestion management is carried in Nordal Project. Two broad parameters of congestion management are presented and adopted in [43]. These are capacity alleviation and capacity allocation. Rules for congestion management include firstly evaluating the possibility of counter trade and second is the evaluation of capacity of transmission line.

In Nordic countries counter trading and market splitting methods are utilized for congestion management. Simulation of counter trading is very effective in congestion management. A scheme with new idea of "CONTRACTs FOR DIFFERENCES" was proposed by Nordic Power Exchange in November 2000 [44].

Transmission Congestion Management in California: Deregulation was adopted in California in 1998. The lack of proper implementation of deregulation caused havoc in the energy market in 2000. Since that time California ISO is continuously working on its energy market design to make it more flexible and better. In California congestion in transmission is recently been addressed through the use of LMP markets which are organized by Regional Transmission Organizers (RTO) [44]. RTO adopts Zonal congestion management and ZPES (Zonal Portfolio Energy Schedules).

Through submission of "Adjusment Bids" SCs [45, 46] can participate in the transmission congestion management process. The submitted adjustment bids by SCs are incremental and decremental. These "Adjustment bids" can be used by ISO for ZCM (Zonal Congestion Management) including inter zonal and intra zonal transmission congestion management. Some special features of California ISO (CASIO) are discussed in [47, 48]. Some of these features are least role in forward power market, least rescheduling of generators to eliminate congestion, no forced trade and allocating transmission network to cost effective users.

Congestion management in ANEM (Australian National Electricity Market): As suggested by name it is a market oriented approach which controls power transactions and manages problem of congestion [49]. Physical management is the common technique when congestion is in limits whereas financial management is used when congestion becomes material to handle. A revised policy was announced by ministerial council of energy in December 2003, this policy ensures a privilege of transporting power from generating source to the load center, it encourages competition among users and provision of reliable and secured power supply.

VII. CONCLUSION

Managing congestion has become a crucial task in the present scenario of deregulation. Deregulated power system is growing day by day with new advances. The developing challenges and encouraging factors are forcing the development of new techniques and ideas. These techniques are devised to make the power system cost effective, efficient and beneficial to each and every customer. A review of the techniques available for congestion management since last four years is collectively reviewed in this paper. The problems associated with transmission congestion management are also discussed here. A survey of existing transmission congestion management methods and their use in various countries have been discussed in this paper. An attempt has been made to have a brief review of all emerging trends in area of congestion management, however the list of trends and techniques used in congestion management is not exhaustive.

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