Overview of Congestion Management in Deregulated Power System: Review

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Abstract— The rise in competition in the energy market has enabled an optimal transmission system in the electricity sector. The utilization of the transmission system makes some lines congested due to some constraints capacities of the line, which is a big problem for the system operator. Congestion Management is one of the main issues that threaten the system security and the most challenging tasks System Operator in deregulated Power System. A lot of attention has been given to the congestion management in the last years due to its benefits such as having a secure and reliable system. Congestion is the situation when technical constraints or economic restrictions are violated, which has a negative effect on the electricity market. The congestion management permits to alleviate the violated constraint. System operators try to manage congestion, which otherwise increases the cost of the electricity and also threatens the system security and stability. Several methods are proposed to solve the issue of congestion. This paper presents the overview and comparative studies of the research methods that are used for Congestion Management in deregulated power systems.

Keywords— Congestion management, Electricity market, System operator, transmission system**.**

I. INTRODUCTION

With the growth of the population in the world and the increased of the electricity demand, the transmission system plays an important role however the existence of some constraints of it. There is a quantity of power that can be flowed between two buses at different points of the grid. This does not permit to deliver all the amount of power for the different contracts, bilateral, multilateral and to fulfil the pool demand. Forcing to satisfy all the demand leads the violation of some constraints such as voltage limit and line limit. It is referred to as congestion. Congestion whether in monopoly system or in deregulated system cannot be allowed. It leads the system not be secure and reliable. Then, congestion management has become the center of many researches in deregulated electricity market. According to reference [1], congestion in transmission systems is a situation where the demand for transmission capacity exceeds the transmission grid capabilities; this condition might result in a violation of network security limits, such as thermal, voltage stability, or angular stability.

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II. PROBLEM FORMULATION AND CONSTRAINTS

Congestion in deregulated power systems is an optimization problem. The most commonly method used is the minimization of the total cost of congestion. Congestion management with total cost of congestion minimization can be evaluated by [2][3][4]

Minimize $TC = \sum_{j=1}^{ng}(C_k\,\Delta Pgj^{+} + D_k \Delta Pgj^{-})$ $\$/hr$ (1)

TC: total congestion cost in $/hr,
C_k : Incremental biding cost,
D_k : Decremental biding cost,
ΔPgj^{+} : Amount of active power increment in the generator j
ΔPgj^{-} : amount of active power decrement in the generator j.

The most commonly constraints used are shown in [3]
Equality constraints:
Power Balance

$P_{gi} - P_{di} - \sum_{j=1}^{N}|V_i|\,|V_j||Y_{ji}|\cos(\delta_i - \delta_j - \theta_{ij}) = 0$ (2)

$Q_{gi} - Q_{di} - \sum_{j=1}^{N}|V_i|\,|V_j||Y_{ji}|\sin(\delta_i - \delta_j - \theta_{ij}) = 0$ (3)

$P_{gi} = P_{gi}^{c} + \Delta Pgj^{+} - \Delta Pgj^{-}$;i=1,2,…,ng (4)

$P_{dk} = P_{dk}^{c} \quad ; k = 1,2,\ldots\ldots, Nd$ (5)

Inequality constraints:
Power generation limit:

$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max}$,i=1,…..,ng (6)

$Q_{Gi}^{min} \le Q_{Gi} \le Q_{Gi}^{max}$, i=1,…..,ng (7)

Incremented or decremented real power limit:

$(P_{gi} - P_{Gi}^{min}) = \Delta P_{Gi}^{min} \le \Delta P_{Gi} \le \Delta P_{Gi}^{max} = (P_{Gi}^{max} - P_{gi})$ (8)

$\Delta Pgj^{+} \ge 0; \quad \Delta Pgj^{-} \ge 0$ (9)

III. CONGESTION MANAGEMENT METHODS

Many methods have been used in congestion management. Two of them are fluently used:

A- Flexible AC Transmission System (FACTS) Device

Facts device is used in congestion management for many purposes. Reference [5] proposed a multi-objective for congestion management by locating and sizing Series FACTS and the newly developed Grey Wolf Optimizer. Optimal location of TCSC was proposed in [6] using PSO. In [7], the authors proposed a review article on the various publications on congestion management in past few decades using FACTS

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devices and the Study of Various Cases for Congestion Management in Different Countries. In [8], it performed the best location of FACTS device like TCSC and UPFC by using sensitivity based Eigen value analysis and the performance analysis. The proposed approach had a capability to enhance the Voltage stability, small signal stability and minimize the real power loss in the power systems network. The authors presented an effective approach for optimal allocation and optimal sizing of Thyristor Controlled Series Compensator (TCSC) to reduce the congestion in day-ahead power market. Active Power Spot Price Index (APSPI) was used to reduce the solution space effectively and to determine the best location of TCSC in the system[9]. Reference [10] proposed also a review of congestion management by deciding optimal location of Facts device. They proposed new indices to voltage drop compensation, also congestion rent contribution method. Comparative studies in restructured power system has been proposed in [11] by the optimal placement of TCSC using sensitivity approach and pricing method.

B- Optimization techniques and expert system

Congestion problem is non-linear problem. Many optimization techniques and expert systems have been used in congestion management.

In [12] Genetic Algorithm based rescheduling of generators is developed to alleviate the congestion. In reference [13],the authors proposed an efficient method for transmission line over load alleviation in deregulated power system. The sensitivity factor of the congested line is used to select the generators and the active power of the participating generators is rescheduled using Cuckoo Search (CS) algorithm for relieving congestion. In the other hand, [14] presented a Genetic Algorithm (GA) based new reconfiguration algorithm of the network which will able to identify the most congested area of power network and fabricate the least loss condition after alleviating overload and overvoltage as well as ensuring efficient network operation.

According to [15], the authors used adaptive real coded biogeography based optimization to minimize rescheduling power and hence minimize the congestion cost. In the other hand, Intelligent method is proposed for congestion management in power system in [16]. According to reference [17], congestion management in hybrid electricity market for hydro-thermal was proposed. In [18]-[4] , PSO algorithm was used to minimize the reschedule of the generator Output with different objectives functions. A real coded genetic algorithm was used to find the optimal generation rescheduling for relieving congestion [19]. According to reference [20], the authors proposed a new model for power system CM by considering power system uncertainties based on chance-constrained . For the reference [21], congestion relief procedure has been discussed and compared with the objective of rescheduling cost minimization and proposed objective of real power loss minimization. Modified Grey Wolf Optimizer Used for Congestion Management in a Deregulated Power Systems was proposed [22]. The authors [23] proposed an approach considering the Risk of Cascading Failures for congestion management. In the other hand, reference [24] proposed a novel algorithm called DEKH algorithm in the congestion management in a deregulated system with market analysis. It proposed that the market analysis calculates the impact factors in each zone. The major contribution is, it utilizes both active and reactive power cost functions in the objective function since the reactive power plays a vital role in the congestion relief at low congestion cost. In the other hand, reference [25] proposed a novel PSO strategy for transmission congestion management. In this research, Particle Swarm Optimization (PSO) with varying inertia weight strategy, with two variants e1-PSO and e-2 PSO are applied for optimal solution of active and reactive power rescheduling for managing congestion. The generators sensitivity technique is opted for identifying participating generators for managing congestion.

In the other hand in [26] , the authors proposed a probabilistic model to reduce the probability of line congestions and voltage violations in a smart grid located in a radial distribution network. Renewable distributed resources and a high penetration of Electric Vehicles (EVs) are considered. A probabilistic power flow based on the point estimate method is firstly used to compute the distribution functions of the line flows and node voltages. Next, a congestion management strategy is proposed in order to keep the line flows and node voltages within the appropriate range at a given confidence level. The strategy is based on the sensitivity distribution factors: Power Transfer Distribution Factors (PTDFs) and Voltage Distribution Factors (VDFs). Reference [27] proposed a flower pollination algorithm (FPA) for congestion management (CM) problem of deregulated electricity market. Nature-inspired FPA is based on the characteristics of pollination process of flowering plants. The aim of employing FPA is to effectively relieve congestion in the transmission line by means of rescheduling of real power output of the generators. In the other hand a new method to manage congestion based on low power tracing was proposed in reference [28]. In power systems, lines and transformers transmit energy which is a comprehensive reflection of the active power and reactive power. Thus the causes of congestion should include the active and reactive power. The results of sensitivity analysis method may be inaccurate because only the effect of active power is considered. When there exists congestion, the analytical relationships between the line power and generator outputs can be obtained by power flow tracing. Then the power vectorgraph is made, and congestion can be eliminated effectively by adjusting relevant power components in four quadrants. Penguin search optimization algorithm is used by Ravish Yadav to reduce congestion on IEEE-30 bus system & its comparison to PSO (Particle swarm optimization). Although PSO also reduces congestion but PeSOA is better than PSO in the reference [29].

In the other hand, an obvious technique of congestion management is rescheduling the power outputs of generators in the system. Generation sensitivity factor has been used to identify the generators, which affects more on the congested line. However, all generators in the system need not to take part in congestion management [30].

In reference [31], a contribution has been made with another technique for reliving the congested power flow in a transmission line has been introduced using Fuzzy Logic with Interline Power Flow Controller. For this approach a fuzzy logic controller are proposed to control the interline power flow controller device depending on real and reactive

power. Fuzzy logic controller is uncertainty, which has been developed to solve the congestion management problem

In [32], the authors used the locational dependence of congestion cost and a comparison of the voltage stability margin based approach. For them, system security needs to be ensured especially in a hybrid network. Renewable Energy Sources are present which might disturb the network due to their intermittent nature. Voltage stability margin based congestion management strategy based on scheduling of generator and demand unit as per their effective bids. In the other hand, Distributed Generation (DG) is used on congestion management in Deregulated Electricity Market. Two different methods for optimal placement of DG to manage congestion are proposed which are based on the highest locational marginal price of buses and difference of locational marginal prices between two buses in reference [33]. According to [34] the authors presented the various methods of congestion reduction in Indian power sector. The authors proposed in reference [35] a method using optimal power flow topology for congestion management in power system. In reference [36] the authors developed a method using market splitting based approach for relieving congestion. In reference [37] the authors employed an Heuristic search algorithms incorporating wireless technology method to minimize the congestion cost. In reference [38], an approach using Generation rescheduling to relieve congestion is proposed. It is formulated as an optimal power flow (OPF) and solved by employing Particle Swarm Optimization.

The authors in reference [39] tried to find the optimal rescheduling of active power generations based on real power sensitivity index of the generators so as to minimize the congestion cost. In [40], the authors proposed the using of a novel Satin bowerbird optimization for real power rescheduling of generators for congestion management.

In reference [41], the authors proposed the application of MATPOWER for the analysis of congestion and its using to determine the generator sensitivity factor.

The authors developed in reference [2] an optimal real power rescheduling of generation using a novel ant lion optimizer for congestion. Changing the pattern of real power generation from generators are used for congestion management and black hole algorithm (BHA) is used for identifying the optimal generation pattern for avoiding congestion in reference [3]. In reference [42], real and reactive power rescheduling based congestion management is used to relieve the transmission congestion. To have an optimal rescheduling of the generator, black hole algorithm (BHA) is performed.

In reference [43] a Combined Economic and Emission Dispatch (CEED) by employing a novel technique of optimization through Artificial Bee Colony (ABC) algorithm. In reference [44] generator rescheduling is proposed as the congestion management technique. The authors used the generator sensitivity factor to identify the generator participating in congestion management and Firefly algorithm is used to find the optimal rescheduling. An Improved Differential Evolution (IDE) algorithm was presented in reference [45] to alleviate Congestion in transmission line by rescheduling of generators while considering voltage stability. In reference [46] Artificial Bee Colony algorithm was used for real power rescheduling to relieve congestion. The authors computed the generator sensitivity factor for the congested lines.

The authors proposed in reference [47] a concept of transmission congestion penalty factors and its implementation to control power overflows in transmission lines for congestion management. They used a Re-dispatch methodology for cost of transmissions network to its user.

In reference [48] the congestion management of Locational Marginal Pricing (LMP) with minimum line loss, less cost, line flow, better sensitivity and better performances in optimal power flow and control flow. In reference [49] it deals with the power trading in electricity market to ensure regular supply at competitive rates with multi congestion case. They proposed a method to compute MCP and LMP for Pool based transaction.

Reference [50] made a review on congestion management in the deregulated power market. It reviews some of the congestion management (CM) methods including the nodal pricing method, differential evolution (DE), addition of renewable energy sources, extended quadratic interior point (EQIP) based OPF, mixed integer nonlinear programming, particle swarm optimization (PSO), cost-free methods and Genetic Algorithm (GA). In [51] an overview of transmission congestion occurring in the deregulated electricity market is presented. In this paper, are presented the definitions and the reasons due to which transmission congestion occurs. Reference [52] presented a review on congestion and its effects on deregulated power system market. They made a presentation of the methods used in congestion management.

The proposed paper, Varaprasad Janamala developed some of the technical and non-technical approaches using simple case studies[53].

IV. RESEARCH NEEDS

This paper presents a review of the literature based on congestion management in deregulated environment. Many efforts have been done over the last decade in research to try various solution methodologies for solving congestion which is a very complex optimization problem. Nonetheless, a number a research needs exist as outlined below:

1- Most research considers only the minimization of the congestion cost and ignore that there is no cost for congestion in deregulated electricity market. It is important to forecast the congestion then the system operator will not have to put any cost for congestion management.

2- With the development of novel optimization algorithm, this will permit to have a good performance when we have the congestion in the system.

V. CONCLUSION

Congestion management became a center of interest in deregulated electricity market. It permits to secure the grid from the violation of some constraints. This paper presents a summary of some previous works in the area of congestion management. It constitutes a tool for future work in the same area. From the previous works, the main method used in congestion management is the rescheduling of the generators output with minimum cost congestion. For many works, IEEE 30 bus system test is used for different case studies. Congestion

can be due to the outage of line, the sudden increased of the load or again the reduction of the line limit.

VI. Appendix

Comparison of different optimization algorithms for Congestion Management applied on IEEE 30 Bus System.

TABLE I
SIMULATION RESULTS FOR DIFFERENT ALGORITHMS FOR IEEE 30-BUS SYSTEM

No	Congestion Management Methods	Type of contingency	CM Cost ($/MWH)	Referenc
1	Particle Swarm Optimization	Outage of line 1-2	538.95	[4]
2	Novel Satin Bowerbird		421.58	[40]
3	Novel flower pollination		519.62	[27]
4	Artificial Bee Colony Algorithm		2867.3	[46]
5	Improved Differential Evolution		1655.65	[45]

The IEEE 30 Bus system data is in [4].

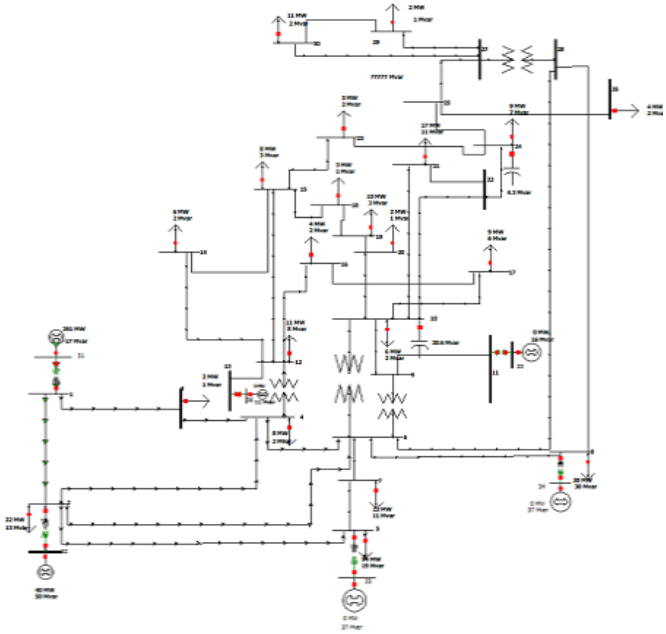

Fig. 1: IEEE 30-bus system

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