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CONGESTION AND ITS EFFECTS ON DEREGULATED POWER SYSTEM MARKET- A REVIEW

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ABSTRACT

A deregulated market is the one where there are more than one entities responsible for all the functions of generation, transmission, and distribution. In other words, in deregulation, the functions of generation, transmission, and distribution are dis-aggregated. Each function is performed by a separate company.Prior to this, the power industry was a vertically integrated system where a single entity was responsible for all the functions of generation, transmission, and distribution. So, in a deregulated market, the customer bill consists of two components: one from the power distribution and transmission network operator (Transco) and the other from the power generating company (Genco). As the number of participants increases, the market becomes more competitive. This leads to overloading and congestion of transmission lines.

Keywords-Congestion, Conventional methods, FACTS, Optimization.

I. INTRODUCTION

During the 1990s, a large number of electric utilities and power companies adopted an open market system from vertically integrated mechanisms. In developing world, it helped in bettering their system management and tariff policies. This also helped in improving their generation and transmission capabilities. In developed countries, it enabled in decreasing the price of electricity. Also, the choices available for the customers for purchasing electricity increased. But, there was a number of challenge associated with it like a suitable auction strategy for electric power, maintaining system stability and reliability, managing transmission congestion, and maintaining market equilibrium [1, 2].

Congestion occurs when all the transactions of power cannot be allowed due to overloading of line. Thus, by congestion management techniques, we make the system more efficient by reducing or completely eliminating the transmission line overloading [3, 4].

On the basis of the economy involved, congestion management methods can be categorized as:

(1) Cost-free methods, and (2) Non-cost free methods.

Cost-free methods include installments of transformer taps, use of FACTS devices, and modification of network topologies. They are called cost-free as the cost involved is nominal. The non-cost free method includes rescheduling of generation and curtailment of the load.

The conventional congestion management includes general nodal pricing method, price control theme, using the genetic algorithm (GA) for managing congestion, fuzzy logic, voltage stability, use of FACTS devices to reduce line loading, and market-based analogy [5].

II. CONVENTIONAL METHODS OF CONGESTION MANAGEMENT

2.1 Nodal Pricing Method

This technique is based on Optimal Power Flow (OPF). In this method, various economic and technical specifications are modeled. These specifications include generator's cost functions, demand elasticity, generation limits, and line power flow limits. The OPF problem aims to reach an optimum power transfer situation keeping the network constraints unviolated.

The solution of the optimization problem gives a number of parameters. One of these is the nodal price, which is the price at each node. In this method, the nodal prices are decided as per the spatial location of the node, known as Locational Marginal Prices (LMP). The LMP at a given bus represents the cost incurred when at that given bus, load is further added. It is an aggregation of supplying energy marginal cost, cost of losses due to increment and transmission congestion cost, if any, arising from the increment and congestion, if any, arising from that increment [6, 7]. The LMP leads to a heavy surplus generation which is used to pay the 'contract rights'. This contract right holder can feed power from one node and withdraw from another [8]. In [5], authors discuss the method for calculation of LMP. Here, they obtain LMP from 'Transposed Jacobian Matrix'.

In [9], a control scheme is proposed for congestion management using nodal prices in electrical power systems. This control scheme enables in achieving optimal power balance. Besides this, the author also presents a controller for detecting steady state line flow constraints.

In [10], the author proposes a generalized optimal deregulated model for deregulated power system market and they have applied this model to an IEEE-30 bus system. They also aim to determine the nodal price or the LMP at various nodes of the power system.

Kang et al. aim to eliminate the congestion with an optimization model [11]. This model is based on sequential network partition and congestion contribution identification. The authors implement this model on an IEEE-39 bus system and they conclude that this method is quite effective [12].

2.2 Uplift Cost

In former UK pool, the uplift cost was inclusive of the transmission constraints. It, when added to the Pool Purchase Price (PPP) gives the Pool selling Price (PSP). It is equal to the difference between the total cost of supply with and without constraints. The uplift cost consists of transmission services uplift (costs incurred due to the physical limitations of the network), energy was (costs of demand forecast errors and generator shortfalls), reactive uplift (maintains system voltage within limits), unscheduled availability payments (the capacity payment paid to gensets that are available but are not needed to run). The components are explained in detail in [3]. The uplift cost can be known mathematically as follows:

PPP= SMP+ Capacity Payment (CP)

PSP= PPP+ Uplift

where

SMP: it is the bid price of the most expensive generator, i.e. the marginal unit, required to meet forecast demand in a market period

PPP: Pool Purchase Price; it is the price calculated before the day of trading.

PSP: Pool Selling Price; it is the price paid by the buyers and paid to the generators.

CP: It is the payment for any available capacity, irrespective of whether the generators generated or not. It may rise during periods of shortages but falls when system capacity exceeds demand.

Uplift: It covers the costs of transmission (including transmission system losses) and is the difference between the unconstrained schedule and the cost on the trading day bid price.

If in an unconstrained dispatch environment, a private generator is selected but it is not allowed to generate due to the system constraints, adjustment calculations are made to provide compensation for the generators.

$$\text{Adjustment}_{\text{constrainedOFF}} = (\text{Capacity- Generation})^* (\text{PPP-Bid Price})$$

Now, if the original dispatch violates the security constraints, re-dispatch is required.

These adjustment costs are then included in generator incomes.

Generator incomes = [(capacity)*(PPP) + Adjustment]

However, the generators are not charged for congestion exclusively. Hence, this method does not provide right information regarding setting up of new transmission lines.

2.3 Price Area Congestion Management (PACM)

PACM is a technique mainly used in countries where the power system market is open access, bilateral, de-centralized and day ahead type. In PACM, there are multiple generators and loads in each area. The bids offered by them is also different [6]. Initially, a system price (P_s) is calculated considering the overall bids and offers in the area. In case the line flow crosses the limiting value, we calculate limiting area price, $P_{o.}$ From this, the capacity fee, P_c is calculated where:

$P_C = P_S - P_O$

This capacity fee is then used in deciding whether an additional unit should be installed or not.

2.4 Congestion Management based on ATC

ATC refers to the ‘‘Available Transfer Capability’’. It is a measure of the transmission capability left in the transmission line above its committed uses.

$$\text{ATC} = \text{TTC - TRM} – (\text{existing transfer commitments} + \text{CBM})$$

where

TTC: it is the maximum amount of power which can be transferred over the network under all security constraints.

TRM: it is the margin required for uncertainties in the system conditions.

CBM: the margin reserved by load serving entities for generation reliability requirements.

2.5 Flexible AC Transmission System (FACTS) devices

On the basis of the economy involved, congestion management methods are classified as:

- Cost-free measures, and
- Non-cost free measures.

The cost-free measures include installation of FACTS devices like thyristor controlled series compensator (TCSC) and unified power flow controller (UPFC).

On the basis of their connection in the circuit, FACTS devices are categorized as:

1. Series controller,
2. Shunt controller, and
3. Combined series-shunt controller.

Thyristor controlled series compensator (TCSC), static synchronous series compensator (SSSC) and Thyristor controlled phase-angle regulator (TCPAR) are series controllers. STATCOM (static synchronous compensator) and SVC (static var compensator) are shunt connected in the network. These controllers inject reactive power at the buses where the voltage is below the desired value. UPFC (unified power flow controller), which comes under combined series–shunt controllers, simultaneously performs the function of both, series as well as shunt controller i.e. it helps in alleviating congestion as well as supporting voltages in the system [14].

Reddy et al. [15] have used Genetic Algorithm (GA) to find the optimal location of the FACTS devices. GA can be used to solve both constrained and unconstrained optimization problem, which are not well suited for other standard optimization techniques.

In [16], the author incorporates Interline Power Flow Controllers (IPFC) based an optimal power flow method. The IPFCs are controllers used for power flow control in the systems. IPFCs are used to solve complex congestion management problems.

In order to determine the optimal location of the Static Synchronous Compensators (STATCOM), Karami et al., in [17], make use Artificial Intelligence in their optimization problem to find the solution. The authors also work to determine the capacity of an optimally located IPFC for managing power flow congestion simultaneously.

In [18], Gitizadeh and Kalantar use TCSC and SVC to reduce the problem of congestion. For problem formulation, they make use of a Sequential Quadratic Programming (SQP). This is done to evaluate static security margin with congestion reduction constraints when FACTS devices are present.

Rajalakshmi et al., through their simulation results on an IEEE 14 bus system, establish that how the line flows in heavily loaded lines can be reduced by proper installation of FACTS devices. In this paper, in order to reduce the total VAR losses in the system, a method is proposed where the FACTS devices are placed on the basis of their performance index [19].

Surender Reddy et al. have construed a single objective and multi-objective optimization in order to determine the optimal location, choice, and size of SVC and TCSC [20, 21].

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III. OPTIMIZATION TECHNIQUES FOR CONGESTION MANAGEMENT

Congestion management is a non-linear program. It involves a large no. of variables. It requires optimization algorithms for finding its solutions [22]. Following are some of the most common optimization techniques for managing congestion in the transmission lines.

3.1 Genetic Algorithm (GA)

Genetic Algorithm is a very popular approach for solving a no. of non-linear programming problems. In GA, the algorithm continuously iterates each individual solution. This algorithm stochastically picks individuals from the current population and it is used to produce next generation [23].

Granelli et al. aim to determine the optimal topological configuration of the transmission system [24]. They use 33-bus CIGRE sample test system and 432-bus EHV Italian network to validate their work.

For multi-objective optimization, SPEA inter-zone. For a multi-objective function, there exists no unique solution. So, the objective is the determination of all the trade-off solutions.

3.2 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is another Algorithm used for determining the optimal location of FACTS devices while minimizing the cost of installation and improving the loadability of the system. PSO is a computational method for optimization of a given problem by iteratively working to improve a candidate solution [25, 26]. Saravanan et al. have used PSO to determine the most suitable location of TCSC, SVC, and UPFC [27]. The authors use IEEE 6, 30, 118 bus systems and a Tamil Nadu Electricity Board 69 bus system as a test. After simulation, it is found that the cost of installation of UPFC is much higher than TCSC. Also, it gives better load ability than UPFC [28]. On systems with highest installation cost, UPFC gives maximum system load ability [29, 30].

3.3 Bacterial Foraging Algorithm

Panigrahi and Ravikumar Pandi, in [30], work to reduce the problem of congestion by generation rescheduling. They propose an ideology based on “Theory of natural selection”. The author’s combine the Bacterial Foraging Technique with the Nelder-Mead method in order to optimize the congestion cost.

The author’s combine the Bacterial Foraging Technique with the Nelder-Mead method in order to optimize the congestion cost. The authors come to a conclusion that Bacterial Foraging Algorithm outperforms swarm optimization as well as GA.

IV. CONCLUSION

In this paper, a thorough review of congestion management has been presented in this paper. It discusses the importance of optimization tools in alleviating congestion. All the major algorithms used across the world for managing congestion have been discussed. The role of FACTS devices in congestion management has also been discussed.

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