A REVIEW ON CONGESTION MANAGEMENT OF POWER SYSTEMS

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Abstract - In the past few decades, restructuring has overtaken all possible domains including the electric supply industry. Restructuring has brought about considerable changes by the virtue of which electricity is now a commodity and has converted into deregulated one. As the power demand is increasing so does increase of burden over transmission lines, with this increased burden over the transmission lines they may suffer from problem known as Congestion. Congestion could be very severe for the power system operations, as it can cause system failure or it can damage whole system. It can be led by if the system is unable to transfer the power as the required demand. Congestion can be managed by using Congestion management methodologies, such as, Generator Rescheduling, Optimal Placement of Distributed Generator (DG), by placing FACTS devices, Cost-free Methods, Nodal Pricing, Load Shedding, Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Local Marginal Pricing (LMP), Transformer Taps, Integrating Non-Renewable Energy Sources and the other Non-Linear Programming Algorithms to relieve Congestion. In this paper a review of various published paper has been used to describe the congestion and its significance and to mitigate congestion.

Keywords— Power System, Congestion Management (CM), transmission, Optimization, power flow, demand response (DR), deregulation, methods.

I. INTRODUCTION

With the initiation of 4th Industrial Revolution the power we use is considered to be a commodity which we are provided by many providers. Earlier the Power was provided by single operator in a particular area/region known as regulated market (Provider) or regulated power system, but now days being an essential commodity there are many players which provide the electricity in similar area/region known as deregulated power system [1]. In Deregulated power system the power generation companies (GENCO), power transmission companies (TRANSCO), power distribution companies (DISCO), independent system operator (ISO), retailer (RESCO) are different identities which operate in a single power system [3]. As the power requirement is increasing so does the burden over the transmission lines to deliver power to the distribution end which would lead to congestion problem in the power network. The Congestion in transmission line lead to transmission and overall system security [1].

In Deregulated market competition over power transactions could create congestion when the transmission system is unable to process all the transactions unless it violates the system operational constraints [2]. Congestion management needs to be done so that congestion in lines can be relieved. Congestion occurs when flow of power in the transmission line is greater than the allowable line limit [4]. Congestion also occur when an overloaded transmission line operate above the thermal bounds and the line limits are being violated [5].

To operate power system in a secure, reliable and stable condition, the network must operate within the power system operational limits i.e. physical and system limitations, but when the system operate beyond these limits the system moves toward the state of congestion [6] [7]. The Thermal limitation of line and transformer operational limits are considered to be the physical limits of the power system where as transient stability, dynamic stability, voltage limitation in a node and reliability of system are considered to be system limitations of transmission network, together these limits become system operational limits which are responsible for the network congestion [7].

Congestion also takes place due to the mismatching of generation and load in the network. Congestion is also caused by unexpected eventualities such as outages of generation, raise of unexpected load demand, and the failure of equipment [8].

Congestion in the power systems must be taken care off immediately to maintain system security and to avoid black-outs or the whole system failure.

II. CONGESTION MANAGEMENT TECHNIQUES

Congestion in Transmission lines can be managed in two ways i.e. Technical methods and Non-Technical methods. The Non-Technical Methods are the non-cost-free methods which are market based as well as non-market-based methods. In non-technical market-based methods we can manage congestion by power auctioning, market splitting, counter trading, re-dispatching of load, curtailment of load, nodal pricing, zonal pricing whereas in non-market-based methods the congestion can be managed by first-come first-served basis and pro rata/uplift charge (Congestion charged). The technical methods are the cost-free methods which help in removing congestion without introducing any extra cost to existing system such as out-aging of congested lines, operation of transformer taps/phase shifters, operations of FACTS [1][6].

The Congestion in transmission line consist of many variables which make the congestion problem a non-linear program which can't be solved by direct methods. So, we have to remove the congestion by using optimization techniques viz. Genetic Algorithm (GA),Particle Swarm Optimization (PSO), Bacterial Foraging Algorithm(BFA), Expert System Approaches and evolutionary strategies [9][11].

III. METHODS OF CONGESTION MANAGEMENT

Nodal Pricing

Nodal pricing also named as Local marginal pricing (LMP) is a method utilized for bi-lateral market settlement in the deregulated system. LMP includes the cost of generation, cost of transmission loss and transmission congestion cost by which GENCOS apply price-based unit commitment and ISO (Independent System Operator) manages congestion and voltage profile to avoid violations [12].

In [13] Y.R. Sood et all. describes the IEEE 30 bus test system with deregulated model which determines LMP and the size of non- firm transactions with pool demand and generation to maximize social welfare is analysed. LMP must be paid at each node and congestion cost is paid as variation of LMP between the node transaction multiplied with the energy volume for the exchange. In [14] A. Naresh, M. Nadarajah (2007) describes a voluntary market is given either it is pool or a bilateral, where the market participants can purchase and sell electrical energy using LMP and minimize the social cost by trading. In [15] Murali et al. point-out DC optimal power flow (DCOPF) based on Bat algorithm used for minimizing fuel cost and improve social welfare which provide better performance than Linear Programming (LP) and GA.

PACM (Price Area Congestion Management)

Price area congestion management can be straightforwardly applied in the event of a radial network where there are no loop flows. For PACM every member submits their bids and the demand for next day for the inter-zonal and intra-zonal are calculated to tackle congestion may predicted [36].

If no congestion arises throughout market settlements, the market will negotiate at single price, which will be the same for all as if no price areas existed. If congestion in system occur, the price areas are independently decided at cost that placate transmission constraints. Market income from this cost variation is remunerated to the Service Operator (SO) and he further uses it for grid enhancement. Two-sided contracts that stretch price areas must buy the load's power in its price area in order to justification for the contribution to congestion and to jeopardize the contract to the financial outcome of congestion. This form of congestion mitigation system is used in Nordic countries as well in India [11].

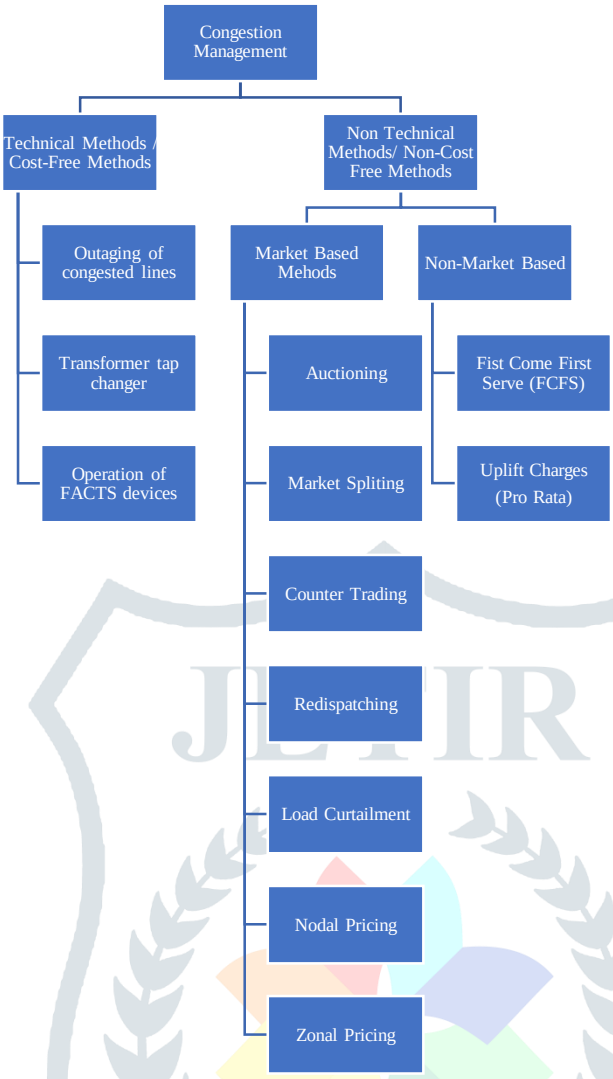

FIGURE 1: CONGESTION MANAGEMENT METHODS

FACTS (Flexible AC Transmission Systems) devices

FACTS are versatile device operate to mitigate power system problem. FACTS device such as thyristor-controlled series capacitor (TCSC), unified power flow controller (UPFC), static var compensator (SVC), interline power flow controller (IPFC), static synchronous series compensator (SSSC), static synchronous compensator (STATCOM) etc can be used for congestion management [38].The optimal sizing of an SVC based on PSO and PSO algorithm is used to realize the objective of reducing transmission line losses by considering the cost function and SVC is chosen as compensating device [16].The use of cost-free method for relieving congestion in the network by installing FACTS devices is most important cost-free techniques as the devices are flexible to regulate the active power and reactive power for reducing congestion in the transmission line [17].

In [18] Likitha et al suggest an effective location of TCSC for power system congestion management by reducing total reactive power loss in the system and load curtailment. In [19] Singh et al. propose a congestion management method utilizing ideal arrangement of TCSC in deregulated systems. The OPF is designed as a maximization problem in the form of Mixed Integer Nonlinear Programming (MINLP) problem to enhance the social welfare. In [20] Suganya et al. propose a method for congestion mitigation using UPFC in a deregulated network. The bid function submitted by GENCO's is considered as linear bid function for analysis. The ISO regulates the output of GENCO's to mitigate congestion based on the qualifying bids. In [21] Duong et al. have proposed an optimal location of TCSC using min cut algorithm to relive line congestion in restructures environment. The various works based on the optimal power flow problem, optimization techniques and impact of FACTS devices in congestion management has been discussed in the following section.

ATC based congestion management

It is an extent of the trade capacity while remaining in the transmission organize for further business movement well beyond officially dedicated employment. Mathematically, Available Transfer Capability (ATC) is defined as the maximum transfer capability (MTC), minus the transmission reliability margin (TRM), minus the sum of existing network promises (which includes retail customer service) and the capacity profit margin (CBM) [36].

ATC = MTC - TRM – (ETC + CBM)

Typically, the non-technical methods depend upon the statistics about the ATC so as to make choices while permitting the following arrangement of purchases. Thus, computation of ATC payoff a lot of significance concealed by similar market architecture. This kind of practice is followed in USA. Every ISO monitors ATC of each specific teeming channel. ATC is upload over the website of Open Access Same-time Information System (OASIS) managed through ISO's. This is a standout amongst the most essential technique for diminishing congestion and is by and by in numerous zones [11][36].

Genetic Algorithm

Since, congestion is a non-linear problem, so we unable to solve it using direct methods. Instead of that we apply non-linear programming approach to solve these kinds of problem, such as; GA, PSO, Ant Colony Optimization (ACO) technique, etc. The Genetic Algorithm is a population search method and is based on the mechanics of natural genetics and natural selection. The next generation is produced by the simulation of the natural processes of reproduction, gene crossover and mutation. The Genetic Algorithm uses the information of current population to direct the next search [6].

In [22], GA method is used to accommodate the congestion mitigation issue, the authors used CIGRE 33-bus specimen system and 432-bus Italian based EHV system to legitimize their effort. In [23], perfectly single target and multi-target enhancement strategies for commendable decision of position and capacity of FACT device in the grid.

Particle Swarm Optimization

The particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality It solves a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity [1][6][11][20].

PSO shares numerous similarities with evolutionary computation strategies, e.g., GA, ACO. The Structure is presented with a mass of unpredictable settlements and investigates for optima by invigorating maturity. In comparison to GA, PSO has no headway overseers, e.g., mutation and crossover. In PSO, the potential courses of action, called particles, fly through the issue space by following the present impeccable particles. In Contradict from GA, the main aim of PSO are that PSO is certainly difficult to acknowledge and there are very few parameters to alter [6].

In [24] an improved conventional PSO for ideal position of FACTS i.e., TCSC and SVC, a new variation represented considerable authority in multi-target optimization problem and known as non-dominated sorting PSO (NSPSO).In [25] introduced a time-varying increasing speed coefficient in the classical PSO and called as PSO-TVAC which is used for the ideal congestion management. The following methods were tested over IEEE-30 and IEEE-118 systems. Results were set side by side with original PSO and PSO with time fluctuating inertia weight (PSO-TVIW).

Ant Colony Optimization (ACO)

The ant colony optimization algorithm (ACO) is an anticipation method for taking care of calculation issues which can be reduced to finding incredible routes through diagrams. In ACO, all artificial ant looks for an acceptable answer to a given improvement issue. ACO to apply in an optimal problem is converted into the issue of obtaining the best way on a weighted graph. The artificial ants (hereafter ants) cumulatively build results by moving over the chart. The result development process is speculative and is biased by a pheromone model, i.e., a lot of parameters related with diagram segments (either node or edge) whose qualities are improved at runtime by the ants [11].

Other methods

The Fundamental issue in mitigating congestion is the, transmission line capacity and generation capability of the system. In [28], [29], [30] proposed a GA take care of the analytically devise issue for the system congestion. GA in addition to FACTS devices or with the generator rescheduling (GR) strategy which worked as a blend in congestion mitigation techniques. The proposed methodology is useful in escalation mechanism which able to clear congestion and minimize system operational costs [31].

A Generator Sensitivity Factor (GSF) and flower pollination algorithm (FPA) are used to pick the quantity of generators to be used in GR strategies for congestion clearance. The use of FPA in addition to accelerated decision taking for GR methods is the best approach [26][27].

The transmission line congestion and the use of FACTS devices are essentially connected because of their role in power conveyance framework improvement. In [32] the improvement of FACTS devices in additional to ideal approaches using the Strength Pareto Evolutionary Algorithm (SPEA). The proposed methodology enhances the position and sizing of TCSC and SVC devices in a system. A continuous demand response (DR) calculation is proposed with the streamlining approach by Stackelberg game-based demand response (SGDR) algorithm [33]. These optimization algorithms are planned for accomplishing the optimal capacity control of devices with response to continuous cost changes with an insignificant calculation load.

In [34] proposed a technique to mitigate congestion considering both practical and voltage deviation perspectives, by utilizing Artificial bee colony (ABC) algorithm and Fish School Optimization (FSO) algorithms. These techniques are executed with the purposed of accomplishing the minimization of expense for overseeing congestion and guaranteeing least voltage fluctuations after load aggravation. The outcomes acquired in contrasted with the PSO calculation technique, and affirmed that the expense of rescheduling utilizing FSO is less in all the cases contrasted with different strategies considered. Subsequently, presumed that the ABC and FSO optimization techniques are valuable in mitigation congestion with economic and specialized contemplations.

In [35] General Algebraic Modelling System (GAMS) based optimization strategy is utilized in taking care of the nonlinear programming issue in enhancing the location of TCSC. OPF and sensitivity-based techniques have been utilized to limit the operational expense and acquiring the ideal location of TCSC in a complex system, respectively. The two strategies are optimized using GAMS and the outcomes are compared; thus, it has been concluded that GAMS is an efficient optimization method used for both OPF and sensitivity-based methods.

IV. CONCLUSION AND FUTURE WORK

Congestion is a very serious problem to the power system which can damage the system if not taken care-off immediately. It can damage equipment's, lines and also cause blackout in an area or collapse whole system. The importance of congestion management identifies that congestion management as one the key issues to maintain security and reliability of transmission networks. Congestion management balances the system and solves financial issues arising from the congestion. New challenges and factors focus on the use of newer technologies to create efficient methods that enhance power system performance in the shortest amount of time to relieve congestion. In this paper, congestion management methodologies and techniques has been presented. An extensive endeavour has been made to demonstrate the significance of the congestion mitigation technique to mitigate congestion issue with an overview of the emerging technologies.

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