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Chapter - 1

Deregulated Power System Management using Custom Power Devices

P. Marimuthu, V. Moorthy and Kalyan Sagar Kadali

Abstract

Congestion in a transmission system is due to temporary overloading of transmission elements, but when it is not addressed properly, it may lead to outages of critical transmission paths and in-turn lead to cascaded outages threatening the system security. In a day ahead market, due consideration has to be given while executing the contracts that the approved contracts should not create any congestion even in a contingency condition. The system operator is responsible for deciding the necessary actions to ensure that no violations of the network constraints occur in a deregulated electricity market. Various works have been carried out in congestion management pertaining to deregulated power system in the last three decades. This chapter reviews the various strategies proposed in the literature for congestion management.

Keywords: DPS, CPD, DG.

I. Introduction

Generally, the transmission network is limited by several limits such as stability limits, voltage limits and thermal limits with most of these limits are applicable at a given time in order to operate the electric network securely. As electric demand is increasing all over the globe, the electrical utilities forced to increase their generation in order to meet the demand. Major objective of the electrical utilities after deregulation is to operate this large electric power network securely and economically. Priority is given to the minimum price generator to meet the demand economically. As the power flow through the transmission lines which provides economical operation increases, chances of reaching the limits also increases. The system is said to be congested if such a limit is reached [1]. Operation of power system within limits is necessary to maintain the security of the network, failing of these limits results in major blackouts and have large social and economic consequences. Therefore, controlling the transmission network for the congestion management is the most fundamental problem [2]. In order to manage congestion, the methods adopted by system operators are generally rescheduling, load curtailment, active and reactive power support. In deregulated environment the market operator uses the available resources nearly at its rated capacity as each player wants to maximize his profit [3]. Therefore, rescheduling is the more general approach taken by the system operator in deregulated environment [1-4], while load curtailment is the last option available with the operator. It becomes a challenging task to alleviate congestion with random variation in power transaction. Thus, optimal selection of generator is necessary for the dispatch of power in congested line to mitigate congestion. The generator sensitivity index to select the generator for optimal rescheduling to manage congestion is most common congestion strategy for large power network and have been reported in [1-4]. During rescheduling, the generation either gets increased or decreased to maintain the congestion in the network.

2. Distributed Generators (DG)

In recent years Distributed Generators (DG) are widely adopted for congestion management due to the technological advancement in power system [1-4]. DG in contrast with the traditional central power plant is used to satisfy local load [1]. Different categories of DGs include fuel cells, wind, photovoltaic (PV), geothermal, biomass and gas turbine. Technical merits of DG penetration involve congestion management, voltage profile improvement, loss reduction, and system reliability. Benefits of DG is more predominant in highly congested area and can be achieved if placement of DG is carried out with its optimal location and sizing. Improper placement may result in collapse of entire network which leads to huge social and economic loss. In deregulated environment congestion in network creates large difference in Locational Marginal Price (LMP) and is a signal to find degree of congestion in the network. LMP is widely adopted pricing mechanism in market like NYISO, CAISO etc. The price in LMP composed of price due to energy, congestion, and losses in the network. Therefore, LMP at each bus vary with the increment in losses as well as congestion. LMP attains higher value in congested area than non-congested area. In such scenario DG could have significant impact and can be very helpful in minimizing LMP difference as it can supply power in particular direction, at specific time when load surpasses the transmission capacity. Authors in [8] proposed congestion management strategy by optimally placing and sizing of DG. Authors placed the DG at maximum LMP node and they have reformulated the OPF by considering the cost function in order to find the optimal size. The results show that they reduced the LMP at some extent. Later, authors in [1] proposed transmission congestion rent (TCR) based approach for optimal placement of DG by suggesting that highest LMP approach may create congestion in other lines. Authors calculated the optimal size of DG by evaluating social welfare at all possible sizes and the size which revenues the maximum social welfare is considered as the optimum size for DG. The results show that they minimized the LMP difference at large extent. TCR based approach is proposed by authors [1-5] for optimal placement of DG, FACTS and find very promising results. All the authors discussed here used some methods to find the optimal location while they didn't pay much attention on optimal sizing of DG. They have fixed the DG size, obtained by evaluating all possible sizes, or obtained by modifying OPF by incorporating cost coefficients of DG.

2.1 OPF Based Congestion Management

Location Marginal Price (LMP) is the widely adopted pricing mechanism in competitive electricity market like NYISO, CAISO etc. LMP is calculated at each bus and it is the signal for congestion in competitive market and the degree of connectedness in a line is calculated through transmission congestion cost (TCC). TCC is the LMP difference across line multiplied with the active power flow in that line. Therefore, difference in LMP between two nodes is minimum if the line is congestion free and it is more during congestion. Many authors have taken LMP difference as an objective for optimal placement of FACTS. Authors in considered this objective for optimal placement of TCSC. While authors in [1] has optimally sized and placed the distributed generators (DG) in the power network. TCC has been considered by the authors in [2] for optimal placement of FACTS. If top 5-10 best locations are obtained for optimal placement then almost all methods returns one or many of the common locations. Therefore, from the priority table, location of single/multiple FACTS device can be obtained.

2.2 Congestion Management Using SVC

In restructured power system market, planning and operation have to be reformulated as construction of new transmission set up is not a straightforward job. If the consumer demand is high the transmission lines operate close to their capacity or sometimes get overloaded. Violation of voltage and line flows limit leads to voltage instability. Voltage stability is the ability of power system to maintain voltages at all load buses within acceptable limits under normal operating conditions and under disturbance

[3]. Reasons for voltage collapse are heavy loading, fault or reactive power shortage [3]. Voltage collapse occurs after maximum load ability point which leads to blackout of the total system [3]. For secure operation of power system reactive reserves are necessary [3]. System should remain secure under all contingencies. FACTS devices are used for maintaining voltage stability in a power system. They can change impedance, voltage magnitude and phase angle and hence reduce losses in heavily loaded lines, improve stability and improve power system security under contingency situations [4], [3]. Voltage stability improvement is done by using SVC and STATCOM which improves reactive power flow in power system [3]. Multi Objective genetic algorithm and PSO has been used for voltage stability enhancement using FACTS devices [3].

2.3 Congestion Management Using TCSC

Sensitivity based approaches have been developed for determining optimal location of TCSC and effect of TCSC on outage of a line to relieve congestion has been studied [4]. TCSC optimal location to reduce line overloading under contingencies has been discussed in references [1-4]. In reference [3] congestion relief and voltage stability enhancement in unbundled electricity market has been discussed using multiple FACTS devices. Congestion cost reduction using FACTS devices has been discussed in reference [4]. Congestion management using transmission congestion distribution factor has been studied and identification of congestion zones is done and congestion is reduced in those zones which are congested [5]. Multi objective congestion management work described in reference [4] gives more accurate results than conventional single objective solution. Differential evolution algorithm is applied for improving power system security under single line outage for reducing congestion and reducing bus voltage deviations. Installation of TCSC and reduction in LMPs in the congested lines and maximization of social welfare has been discussed [4]. PSO-TVAC is used for optimally placing TCSC for congestion management [4]. Contingencies are ranked using real power flow performance index and line outage distribution factor, TCSC is placed at optimal location for reducing line overloading [5]. Management of congestion using bee colony optimization and cost minimization is also done [1]. TCSC is placed at best location for social benefit, reducing congestion in transmission lines [2]. Sensitivity based method is used to optimally locate TCSC to solve optimal dispatch problem [5]. Ranking of contingencies has been done to find most severe line outages; this ranking is done by finding a performance index which is dependent in bus voltage violations and line overloads [4].

3. Optimization Technique

Step by Step Approach for Finding the Optimal Location and Sizing

Algorithm 1: Optimal location calculation for FACTS placement

1. Initialize network, load and bid data
2. Run OPF to obtain the LMP at each bus
3. Calculate TCC in each line
4. Find the line having maximum TCC value
5. Check the LMP at both the nodes of line found in step 4
6. Node having high LMP will be optimal location for FACTS placement

Algorithm 2: Optimal sizing of FACTS device using FPA_PSO Algorithm

1. Initialize population size, FPA and PSO parameters, and network details
2. Run FPA module to find the optimal size of FACTS devices
    a. Population Initialization
    b. Run OPF and calculate fitness using equation
    c. Find best solution
    d. Global/Local pollination using equation
    e. Check violation limit of population
    f. If current iteration limit < Maximum iteration then go to step b
    g. Exit
3. Run PSO module to increase the solution quality
    a. Population initialization with the final solution of FPA module
    b. Generate velocity of each population
    c. Run OPF and calculate fitness using equation
    d. Find best solution
    e. Update velocity and position using equation
    f. Check violation limit of population
    g. If current iteration limit < Maximum iteration then go to step c
    h. Exit

4. Final solution.

5. Exit

4. Performance Testing Anlaysis

The methodology presented in this chapter is tested on IEEE-30 bus system, which in IEEE-30 bus system is given in Figure. System has 41 transmission lines and 6 generators connected at bus 1, 2, 5,8,11 and 13. Total generation is 345 MW and total load is 283.46 MW. There are many ways to simulate congestion such as fixing the line limit and percentage reduction in line limit, while generator and line outages are the common way of creating congestion in the network. In this paper fixing the line limits are considered to simulate congestion. Initially, in normal operating condition, it is considered that the network is congestion free. Therefore, network is made congested by fixing the line limit connecting bus 6 and bus 8 to 30 MVA.

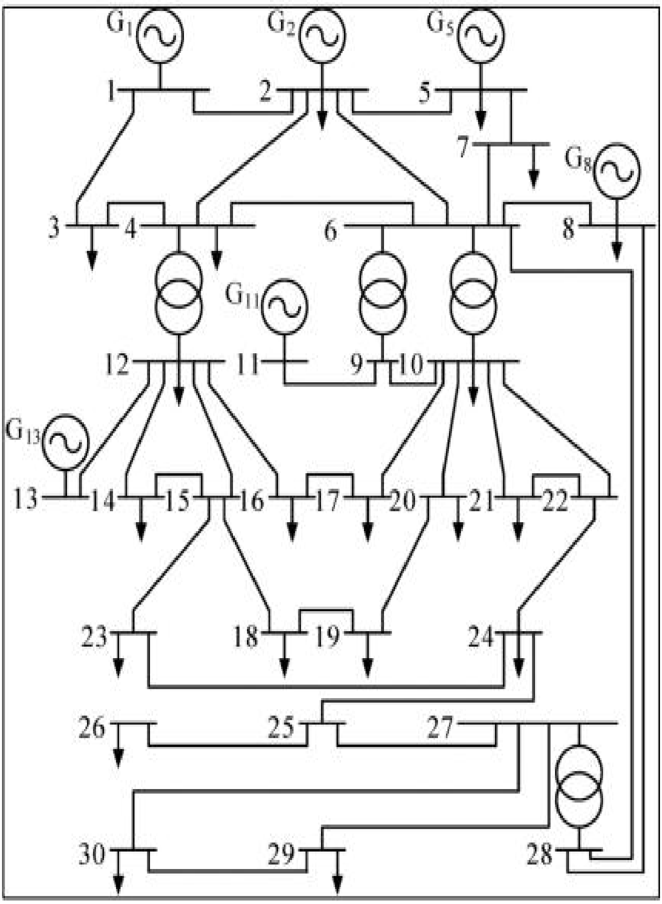

Fig 1: IEEE 30-Bus System

Table 1: Generators Data in IEEE 30-Bus System

Bus Number	P_G (MW)		Q_G (MVAR)		Bid Coefficients	
	P_G^{min}	P_G^{max}	Q_G^{min}	Q_G^{max}	a_i	b_i
1	0	80	-20	150	0.038	20
2	0	80	-20	60	0.25	20
13	0	40	-15	44.7	0.01	40
22	0	50	-15	62.5	0.01	40
23	0	30	-10	40	0.01	40
27	0	55	-15	48.7	0.01	40

Conclusion

This presents a methodology to optimally locate and place the single/multiple FACTS devices in deregulated environment. Transmission congestion cost (TCC) which is difference in LMPs multiplied with active power flow in that line are used for optimal placement of FACTS devices while hybrid flower pollination and particle swarm optimization is employed to find the optimal sizing. Optimal sizing is modelled as multi-objective optimization problem which comprises real power losses in the network, transmission congestion cost, and installation cost. In deregulated environment uniformity in LMPs is the signal for congestion free network that’s why 70% of the weight is given to TCC. Optimal allocations of FACTS devices make the LMPs uniform and significantly reduce the congestion cost of the network.

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