Transmission Congestion Management Considering Optimal Location and Capacity of Distributed Generations

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Abstract: In present scenario, congestion management has become a challenging task due to no. of reasons like increased demand, economic and operational constraints. There is need for efficient and fast responding technology. In this regard, optimal placement and sizing of DGs is utilized in this work for managing network congestion. The preferred location of DGs is decided based on line flow sensitivity factor (LFSF). These LFSF values of all the load buses are computed with respect to congested lines. The mathematical formulation of CM problem is presented with an objective to find out optimal value of the DGs such that cost is minimized. Genetic algorithm (GA) has been exploited to solve this optimization problem. The considered approach is implemented on modified IEEE-30 bus system to confirm the usefulness.

***IndexTerms* – Congestion Management, Distributed Generation.**

I. INTRODUCTION

In past few decades, the demand for electricity has increased substantially. A number of factors affect this rapid rise in electricity demand. With this increased demand the role of transmission network becomes crucial for suitable operation, especially under restructured environment. The different limitations such as stability limit, voltage limit and thermal limits enforce restrictions on power wheeling capability of transmission lines. The violation of any of prior discussed limits considerably affects the transmission network operation and this may also cause a threat to system security. Under this state of limits violation, the system is said to be congested [1].

The occurrence of transmission network congestion restrains competition and as a result, economic generating units cannot be entirely dispatched. Consequently, transmission network congestion is highly detrimental and should be alleviated for the secure and reliable operation of the system. Several techniques have been presented in the literature to tackle the issues of transmission congestion. A thorough study of different approaches incorporated for managing network congestion is presented in [2-3].

Vlachogiannis [4] proposed mechanism to evaluate the share of each generator to the transmission line flows, system loads, and line power losses in systems and it has been utilized to relieve transmission congestion. In [5] authors have proposed an auction-based means to relieve transmission congestion. A mechanism for pool, bilateral, and multilateral dispatch coordination incorporating congestion and transmission charges is presented in [6]. An optimal power flow based model to manage the transmission congestion through least curtailment of contracted power has been presented in [7]. In [8] authors have inspected relationship between real and reactive nodal prices and evaluated the impact of congestion to develop appropriate price signal in the pool paradigm.A mechanism based on optimal power flow (OPF) to manage transmission congestion and available transfer capability (ATC) determination has been proposed in [9].

Further, a number of researchers in their work have proposed flexible ac transmission systems (FACTS) to deal with the concern of transmission congestion. In order to manage transmission congestion by means of the optimal placement and sizing of unified power flow controller (UPFC) is presented in [10]. An approach based on the combination of demand response and FACTS devices is proposed in [11] .In [12] authors presented that load shedding carry out important task with overload alleviation. In [13] a generation rescheduling-based method for managing transmission congestion employing Ant lion optimiser (ALO) is presented. A multi-objective approach for managing network congestion by means of generation rescheduling and load shedding is presented in [14]. DGs are optimally placed in accordance with Z_{BUS} based factors to relieve congestion in [15].

This paper aims to manage transmission congestion with optimal placement and sizing of Distributed Generators. Sensitivity factor have been utilized to decide on the optical placement of DGs pertaining to the overloaded lines. Subsequent to determine the optimal location of DG placement, the mathematical problem has been formulated to decide on the optimal capacity of DG with an objective of minimum cost of generation. Genetic algorithm (GA) has been exploited to solve this optimization problem.

This paper has been structured as follows: The mathematical formulation of considered problem is discussed in Section 2. Genetic Algorithm has been described in Section 3. In sections 4 steps to determine the location and size of DGs have been discussed. Section 5 includes the results of implementing the considered approach on standard test system followed by conclusion in Section 6.

II. MATHEMATICAL PROBLEM FORMULATION

2.1 Line Flow Sensitivity

To determine the sensitivities of each load bus to the line power flows of the overloaded lines, line flow sensitivity factor (LFSF) is evaluated based on [16]. This sensitivity is represented as :

$$\mathrm{LFSF} = \frac{\Delta S_{mn}}{\Delta P_k} \qquad (1)$$

Where, ΔS_{mn}, implies the change in apparent power flow in line connected between bus-m and bus- n and ΔP_k, signifies change in real power injection at node'k'.

2.2 Formulation for CM Problem

The aim of this optimization problem is to decide on the optimal value of the DGs to be attached with the existing system such that DGs cost is minimum. The objective function is defined as :

$$\text{Minimize} \quad TC_{dg} : \sum_{g=1}^{ndg} F_g P_{dg} \qquad (2)$$

Subject to

$$P_{ge} - P_{de} = \sum_{n=1}^{nb} V_e V_f Y_{ef} \cos(\delta_e - \delta_f - \theta_{ef}) \qquad (3)$$

$$Q_{ge} - Q_{de} = -\sum_{n=1}^{nb} V_e V_f Y_{ef} \sin(\delta_e - \delta_f - \theta_{ef}) \qquad (4)$$

$$P_g^{\min} \le P_g \le P_g^{\max} \qquad (5)$$

$$Q_g^{\min} \le Q_g \le Q_g^{\max} \qquad (6)$$

$$\delta^{\min} \le \delta \le \delta^{\max} \qquad (7)$$

$$V_e^{\min} \le V_e \le V_e^{\max} \qquad (8)$$

$$S_k \le S_k^{\max} \qquad (9)$$

So, objective Eq. (2) refers to the minimization of total DGs generating cost considering the linear nature of generator cost. The constraints mentioned in Eq. (3) and Eq. (4) corresponds to the active and reactive power balance equations respectively. The constraints corresponding to Eq. (5) and Eq. (6) represent the restrictions on the real and reactive generation capacity on the generator respectively. The bus angle limit and the voltage limit at each bus is set by the constraint represented in Eq. (7) and Eq. (8) respectively. The MVA flow limit restriction of the transmission line is represented by Eq. (9).

III. GENETIC ALGORITHM

Genetic algorithm [17] is an extensively recognized evolutionary algorithm which utilizes the natural evolutionary principles of selection, mutation and crossover applied to a population of solutions among which the best solution is chosen. These heuristics provide a wide range of probable solutions.

The common genetic algorithm processed as follows:

1. To begin with, generate a population of random values representing feasible solutions to the problem.
2. Calculate fitness of each member of the population
3. Elect individuals from population to be parents.
4. Generate children by exercising crossover and mutation operation onto the parent.
5. Repeat steps 2-4 till the desired result is achieved or maximum numbers of iterations are executed.

IV. STEPS TO DETERMINE SIZE AND LOCATION OF DGs USING GA

1. Read the test system data.
2. Create the contingency.
3. Perform power flow analysis with considered contingency.
4. Check for the limit violation.
5. LFSF values of all the load buses are computed with respect to congested lines.
6. Buses which have highest negative LFSF values are opted for optimal DG location.
7. The optimal sizes of DGs are determined using GA. In order to attain this, first generate a population of random values representing feasible solutions to the problem.
8. Calculate fitness of each member of the population
9. Elect individuals from population to be parents.
10. Generate children by exercising crossover and mutation operation onto the parent.
11. Repeat steps 8 - 10 till the desired result is achieved or maximum numbers of iterations are executed.

V. RESULTS AND DISCUSSIONS

The considered approach is tested on modified IEEE- 30 bus test system which comprise of 21 load buses, 41 power transmission lines and 6 generators [18]. Table 1 presents modified real power generation value of used test system.

Table 1 Real power generation of modified IEEE 30 bus system

Sl. No.	Generator Bus No.	Modified real power output (Pg) in MW
1	1	176.86
2	2	48.2540
3	5	20.96
4	8	22.4133
5	11	12.3975
6	13	12.00

At first, contingency is created by opening the transmission Line-4(connected between bus-3 and bus-4) for introducing congestion in the system. Thereafter load flow analysis is executed to determine the amount of violation, the details of which is presented in Table 2. It can be observed from the table that with the opening of mentioned line Line-1 (connected between bus-1 and bus-2) becomes overloaded.

Table 2 Contingency case considered

Outage of Line	Congested lines	Line limit (MVA)	Line power flow (MVA)	% violation
Line 3-4	Line1-2 (connected between bus-1 and bus-2)	130	178.04	36.95

In order to mitigate transmission congestion, the DGs are placed at the suitable locations after determining LFSF values. The information regarding the preferred load buses based on LFSF values with respect to congested lines are given in Table 3.

Table 3 DGs preferred location based on LFSF value

S.No.	Preferred location (Bus No.)	LFSF value
1	Bus -30	-1.2278
2	Bus -26	-1.2070
3	Bus - 29	-1.2053
4	Bus - 19	-1.1941

It can be viewed from Table 3 that bus-30 and bus-26 possess the most negative LFSF value thus they are chosen as preferred location to place the DGs from view point of congested line. Subsequent to placement of DGs their optimal capacity has been determined using GA. To achieve this, objective function presented in section 2 is applied to assess the fitness value. DGs size is altered between minimum and maximum capacity which is considered as 1 MW and 50 MW respectively. The optimal capacity obtained with application of GA is presented in Table 4. With the placement of optimal size of DGs at selected location it is observed that congestion is relieved.

Table 4 Optimal capacity of DGs obtained using GA

Bus No.	Optimal size of DGs using GA
30	37.48 MW
26	5.96 MW
Total production cost of DGs (TC_{dg})	**1327.04 ($/h)**

VI. CONCLUSION

In this paper, an attempt is made to manage transmission congestion with optimal placement and sizing of Distributed Generators. Sensitivity analysis has been carried out to place the DGs at optimal location. These sensitivity values of all the load buses have been evaluated with respect to congested lines. Genetic Algorithm is employed to realize the optimal size of the DGs. It is presented that with the placement of optimal size of DGs at selected location the congestion is relieved.

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APPENDIX

Nomenclature

e, f	Index for buses in network
k, g	Index for line k and generating unit g respectively
nl, ng, nb, nd,	Total number of lines, generators, buses, and loads respectively
V_e, δ_e	Magnitude of voltage and voltage phase angle at bus-e
P_{ge} ,Q_{ge}	Active power generated and reactive power generated at bus-e
P_k,	Active power flow in line k
ΔP_{ge}	Variation in real power generation at bus-e
TC_{dg}	Total production cost of DGs in $/h
Y, G, B, θ	Admittance, conductance, susceptance and admittance angle
P_{de} , Q_{de}	Active power demand and reactive power demand at bus-e
$P_g^{\max}$, $P_g^{\min}$	Higher and lower limits of active power generation at unit g
$Q_g^{\max}$, $Q_g^{\min}$	Higher and lower limits of reactive power generation at unit g
$V_e^{\max}$, $V_e^{\min}$	Higher and lower limits of voltage magnitude at bus m
$S_k^{\max}$	Maximum limits of apparent power flow in line k