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Optimal Placement of Solar and Facts DG's in Micro Grid Reduced Losses and Improving Voltage Profile

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ABSTRACT

The non conventional resources like sun and fuel cells are never ending, reliable and pollution less sources of power. When such limited size renewable sources situated close to the load centers are used for generating power, they are termed as distributed energy sources or distribution generation .A micro grid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. It can act either in grid connected or islanded mode. The use of DG in a micro grid gives advantages like power loss reduction, voltage profile improvement, increased reliability, power quality, stability etc. To determine the optimal placement by using loss sensitivity factors & stability factors, optimal sizing of multiple DGs by using Successive Sizing Method(SSM) and Sensitivity Factor Method(SFM) methods are used. The proposed technique was implemented on IEEE 33 bus system.

KEYWORDS: Distributed generation (DG), Fast Voltage Stability Index (FVSI), analytical expressions, radial distribution system, optimal placement, optimum sizing

1. INTRODUCTION

The demand for electricity is skyrocketing these days. With ever-increasing customer demand, a competitive environment has emerged in the generation and sale of power. This has paved the way for existing power industries to undergo restructuring and adopt deregulated market operation. The traditional vertically integrated utility has evolved and is now unbundled into one or more generation, transmission, and distribution companies.

The power supplied by small-scale generators is used by distribution companies. The introduction of micro grids into the system has increased the number of generator connections. These generators use both renewable and conventional energy sources. Because of the integration of various types of sources into distribution systems, the primary substation cannot serve as the sole source of power supply. As a result, distribution generators in a distribution system should be planned with both technical and economic benefits in mind.

DGs can be an alternative for industrial, commercial, and residential applications in a power system network that supplies electricity to nearby clients. In some locations, DGs attempt to compete with the conventional huge generators by utilizing the most recent technological advancements. When DGs function in parallel to the utility grid, they do so in a non-autonomous manner; however, if they are isolated from the grid, they operate in an autonomous manner. The ideal positioning and sizing of the DG have been carried out in [1] utilizing the successive sizing approach for both autonomous and non-autonomous modes of operation.

The deregulated market was established to change the way utilities and their clients see the production and distribution of electricity. With the imminent deregulation of the business, utility users will have the option of selecting their own buyer or using DG resources to satisfy their power needs. Deregulation's primary goal is to give consumers more options for energy suppliers while lowering costs and enhancing dependability and service. Customers and manufacturers are constantly looking for products with greater quality, control, dependability, and cost. This opened the door for the development of new DG goods and services. The cost of installing DG technology is currently quite high, however it is steadily declining, thus we could anticipate a short timeframe

2.PROPOSED METHODOLOGY

A. Problem Formulation

The objective function to minimize the total real power loss given by the exact loss formula as shown in (3.1) meeting the voltage constraints

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij}(P_iP_j + Q_iQ_j) + B_{ij}(Q_iP_j - Q_jP_i) \quad (1)$$

Where

$$A_{ij} = \frac{R_{ij}}{V_iV_j}\cos(\delta_i - \delta_j)$$

$$B_{ij} = \frac{R_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$$

P_i and Q_i are the active and reactive powers at i^{th} bus respectively.

P_j and Q_j are the active and reactive powers at j^{th} bus respectively. $V_i\angle\delta_i$ is the complex voltage at i^{th} bus.

$R_{ij} + jX_{ij} = Z_{ij}$ is the ij^{th} element of $[Z_{bus}]$ impedance matrix.

n be the number of buses.

Constraints: $V_{min} < V < V_{max}$

B. Types of DG

The Distribution Generations are classified into different types according to real power and reactive power injection or drawing. The real power injected categories DG is Type-I DG capable of injecting real power only.e.g. PV cells and Fuel cells. The reactive injected categories DG is Type-II DG capable of injecting reactive power only.e.g. Facts devices – STATCOM and Capacitor placement.

C. Optimal placement of DG

The candidate nodes for the placement of DGs are determined by using the sensitivity factors. A distribution line with an impedance *R+jX*is connected between 'i' and 'j' buses as shown in Fig.1 is considered to derive the following sensitivity factors.

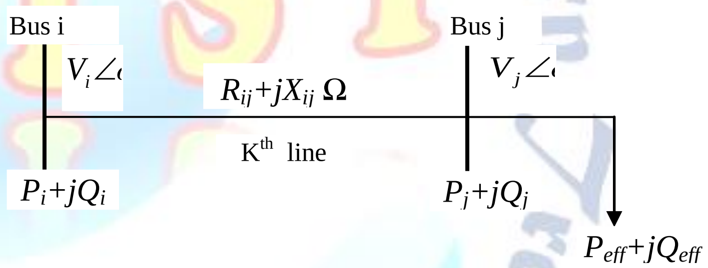

Fig. 1: Distribution line (k) diagram

Loss sensitivity factors (LSF) : Loss sensitivity factor method has been extensively used to solve the capacitor allocation problem

$$LSF1 = \frac{\partial P_{lineloss}(j)}{\partial P_{eff}} = \frac{2 * P_{eff}(j) * R_{ij}}{V_j^2} \quad (2)$$

$$LSF2 = \frac{\partial P_{lineloss}(j)}{\partial Q_{eff}} = \frac{2 * Q_{eff}(j) * R_{ij}}{V_j^2} \quad (3)$$

Where

$P_{eff}(j)$ = Total effective active power supplied beyond the node '*j*'.

$Q_{eff}(j)$ = Total effective reactive power supplied beyond node '*j*'

Power stability index (PSI) : Power stability index is developed considering stable node voltages. It is derived from finding the most optimum site of DG based on the most critical bus in the system that can lead to system voltage instability when the load increases above certain limit.

$$PSI_{ij} = \frac{4P_j R_{ij}}{\left[|V_i| cos(\theta - \delta) \right]^2} \quad (4)$$

Where

$$\delta = \delta_i - \delta_j$$

Fast voltage stability index (FVSI) :A fast voltage stability index is developed for the placement of DG to determine the most critical bus in the system. The index value lies in between zero to unity for stable condition.

$$FVSI_{ij} = \frac{4{Z_{ij}}^2 Q_j}{V_i^2 X_{ij}} \quad (5)$$

Line stability index (LSI) : Line stability index is used as one of the stability indices. The line stability index for a line should be always less than unity.

$$LSI_{ij} = \frac{4Q_j X_{ij}}{\left[|V_i| sin(\theta - \delta) \right]^2} \quad (6)$$

Type 1 DG

It is capable of injecting real power only. The power factor is unity in this type of DG. The optimal size of DG at each bus 'i' for the minimum loss is given by reduced equation.

$$P_{DGi} = P_{Di} - \frac{1}{A_{ii}} \sum_{\substack{j=1 \\ j \neq i}}^{n} (A_{ij} P_j - B_{ij} Q_j) \quad (7)$$

Type 2 DG

It is capable of delivering reactive power only. Here the power factor is zero and the optimal size for injecting reactive power type DG is given by the equation (8)

$$Q_{DGi} = Q_{Di} - \frac{1}{A_{ii}} \sum_{\substack{j=1 \\ j \neq i}}^{n} (A_{ij} Q_j + B_{ij} P_j) \quad (8)$$

E. Algorithm for optimal placement and sizing of DG

The fast voltage stability index is used to determine the optimal location, and analytical expressions are used for optimal sizing.

1. Use backward and forward sweep to run the load flow for the base case and find losses using the equation(1).

2. Use the following steps to determine the best locations for DGs.

a) The Fast Voltage Stability index, given by equation (5), is computed for all lines.

b) Create a priority list by ranking buses in descending order of FVSI values obtained.

c) Choose the highest value as the best location for the DG placement.

3. Estimate the size of the required DG units.

a) Select the type of DG to be used.

b) Determine the DG power factor.

c) Using equations, calculate the size of the DG at each location. (7) and (8) for two different types of DGs.

4. For two types of DG, place the obtained DG size from step (3) at the optimal location obtained from step (2).

5. Run the load flow and use theequation(1) to calculate losses.

3.NUMERICAL RESULTS

A. Load flow results

The backward and forward method [6], which takes advantage of the radial nature of distribution lines, was used for the system's load flow analysis. When compared to other methods, this method has a faster convergence and requires less computation time, especially for radial distribution systems. The IEEE 33 radial distribution network's real power losses are found to be 202.7 KW. The voltages of all the buses in the base case without DG are shown in the figure below. At bus 18, the minimum voltage is found to be 0.9131 P.U.

B. Optimum Placement of Multiple DG

Table 1: Priority list for Placement of Multiple DG

Rank	Bus	Index	Rank	Bus	Index	Rank	Bus	Index
1	30	0.0116	12	4	0.0047	23	2	0.0016
2	24	0.01	13	5	0.0042	24	18	0.0016
3	6	0.0088	14	7	0.004	25	12	0.0015
4	25	0.0086	15	9	0.0039	26	16	0.0014
5	3	0.0076	16	20	0.0039	27	26	0.0013
6	28	0.0062	17	10	0.0038	28	15	0.0011
7	8	0.0061	18	14	0.003	29	21	0.001
8	29	0.0061	19	17	0.0027	30	11	0.0008
9	31	0.0051	20	23	0.0024	31	33	0.0009
10	32	0.0051	21	22	0.0017	32	19	0.0005
11	13	0.0049	22	27	0.0017	33	1	0

Table 2: Comparison of SSM and SFM for simultaneous Placement of Type 1 DG and Type 2 DG

Case	Approach	DG Type	Bus Location	Installed DG Size	power loss (kW)	%loss reduction
No DG	-	-	-	-	202.7	-
2 DGs	SSM	Type 1 DG	6	2.4775 MW	51.827	74.43
		Type 2 DG	30	1.2368 MVAr		
2 DGs	SFM	Type 1 DG	6	2.5115 MW	51.8	74.44
		Type 2 DG	30	1.2547 MVAr		

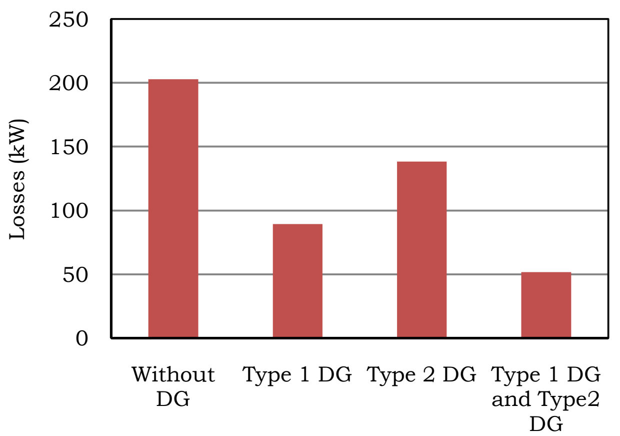

Fig. 2: Comparison of Losses for different types of DG by SSM

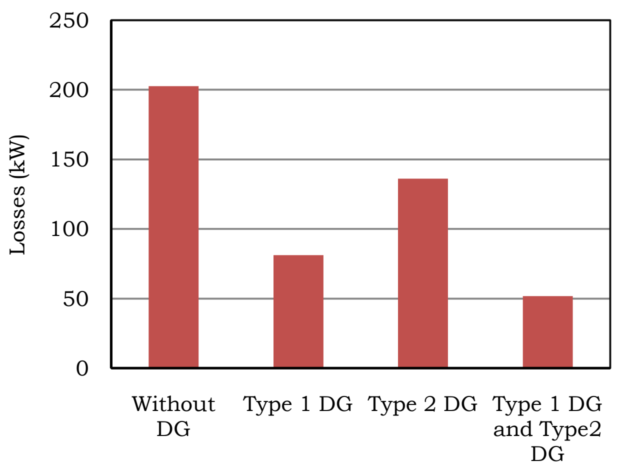

Fig. 3: Comparison of Losses for different types of DG by SFM

4. CONCLUSION

The optimal location and sizing of DG units has been done for radial distribution system for minimization of power loss thereby reducing the voltage deviation. An algorithm has been implemented in MATLAB.

The optimal placement of DG is done by considering sensitivity factors and sizing of DG by successive sizing method and sensitivity factor method. The study has been carried out on 33-bus radial distribution system with four types of DG. Finally we can conclude that

Losses are reduced in the system and hence efficiency is maximized.

Voltage profile is improved at all buses in the network. It is better improved with different types of DG placement

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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