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OPTIMAL PLACEMENT OF MULTIPLE TYPE DGs IN RADIAL DISTRIBUTION SYSTEM USING SENSITIVITY BASED APPROACH

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ABSTRACT

This paper proposes a simple and useful approach based on some sensitivity methods for optimal placement of multiple type Distributed Generations (DGs) in radial distribution system (RDS). It presents three sensitivity methods, load flow technique, voltage constraint and proposed algorithm. The cost benefit analysis is also considered. The proposed approach is implemented on 33 bus test system.

Key words: Distributed generation, radial distribution system, optimal location, optimal size, sensitivity methods.

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1. INTRODUCTION

The power demand of electrical distribution system is uniformly rising day by day, which in turn causes the increase in load burden and the degradation of voltage profile [1-3]. The node voltages of distribution system get reduced at a farther distance from the substation than at nearby nodes. Thus, there is always a demand for reactive power compensation for improvement in the voltage profile [4,5]. While comparing with transmission systems, the distribution systems have a low X(reactance)/R(resistance) ratio, which results large loss of power and a drop in voltage (V). There are a lot of possibilities for power loss reduction and voltage profile improvement such as allocation of DG, capacitor, etc. [6,7]. The allocation of DG in distribution system provides active power and hence decreases the load burden. It results in the reduction in peak demand loss, energy loss and improvement in voltage profile, power factor and stability of distribution system [8].

2. PROBLEM FORMULATION

2.1. DG Modeling

Depending on the type of DG, connection method and mode of operation, DG units are modeled as PQ (active- reactive power) or PV bus. As the PQ bus, DG units are modeled into three multiple types [9]:

- DG units having fixed P and Q power generations.
- DG units having defined values of P and power factor (PF).
- DG units having variable Q generation.

As PV bus, DG units are modeled having defined values of P and V.

In proposed work, four types of DGs are considered:

- Type 1 DG: DG which injects P only, i.e., DG at unity PF (kW) such as photo voltaic system, fuel cells, etc.
- Type 2 DG: DG which injects Q only for voltage improvement, i.e., DG at zero PF (kVAR) such as capacitors, synchronous condenser, etc.
- Type 3 DG: DG which injects both P and Q, i.e., DG at 0.9 PF lag (kVA) such as synchronous generators.
- Type 4 DG: DG which injects P but consumes Q, i.e., DG at 0.9 PF lead (kVA) such as induction generators used with turbines.

3. PROPOSED APPROACH BASED ON SENSITIVITY METHODS

From the reported literature, it is revealed that some of the authors propose different sensitivity indices in their research works providing different optimal DG locations. In this approach, some of the sensitivity indices are considered and implemented which result the same DG location so that impacts of using constant load on optimal placement of DG at unity, zero, 0.9 lag and 0.9 lead PF can be analyzed.

3.1. Combined Power Loss Sensitivity (CPLS) Method

Combined power loss sensitivity consisting of real and reactive power loss is derived as [10]:

Combined power loss sensitivity w.r.t. to reactive power,

$$\frac{\partial Sloss}{\partial Q_2} = \frac{\partial Ploss}{\partial Q_2} + j\frac{\partial Qloss}{\partial Q_2} \quad (1)$$

Combined power loss sensitivity w.r.t. to real power,

$$\frac{\partial Sloss}{\partial P_2} = \frac{\partial Ploss}{\partial P_2} + j\frac{\partial Qloss}{\partial P_2} \quad (2)$$

where Ploss, Qloss and Sloss are real, reactive and combined power losses; P_2 and Q_2 are real and reactive powers at the receiving or load end of simple RDS.

3.2. Voltage stability index (VSI) method

The voltage stability index is given as [11]:

$$VSI = \frac{4X}{V_1^2}\left(\frac{P_2^2}{Q_2} + Q_2\right) \leq 1 \quad (3)$$

where V_1 is the sending end bus voltage; and X is reactance of simple RDS.

3.3. Power Stability Index (PSI) Method

The power stability index is defined as [12]:

$$PSI = \frac{4r_{ij}(P_L - P_G)}{[|V_i|Cos(\theta-\delta)]^2} \leq 1 \qquad (4)$$

where P_L is total real power loss; P_G is the real power support for the system; r_{ij} is the resistance of i-j line; θ is the line impedance angle; δ is the voltage angle; and V_i is the magnitude of voltage at bus i.

3.4. Power Flow Method

The traditional methods of load flow, for example Newton Raphson method and its modifications, fast decoupled load flow methods, etc. provide best results in analysis of transmission systems but are not suitable for distribution systems. In this work, forward-backward sweep load flow method as discussed in [13] is used for obtaining the efficient power flow in distribution system.

3.5. Voltage Constraint

The forward-backward sweep load flow is used for the determination of sensitivity indices. The node/bus is selected as candidate node (optimal location) at which sensitivity indices, i.e., CPLS, VSI, PSI are maximum and voltage constraint is satisfied. The voltage constraint is given as [10]:

$$Normalized\ V(i) < 1.01 \qquad (5)$$

Following formula is used for the calculation of normalized voltages for all buses.

$$Normalized\ V(i) = \frac{V(i)}{0.95} \qquad \forall i = 1,2,3, \ldots\ldots N \qquad (6)$$

where N is the number of buses in the system.

3.6. Proposed Algorithm

Figure 1 illustrates the proposed algorithm. It provides a simple and useful approach based on sensitivity methods for optimal placement of multiple type DGs. It gives the information about the realization of proposed approach to obtain the simulation results. It is tested on 33 bus test system [14]. Based on the mathematical model [10], the annual cost of energy losses and cost of DG powers is evaluated.

4. RESULTS AND DISCUSSION

The optimal placement of DG at unity, zero, 0.9 lag and 0.9 lead PF in RDS is determined using a useful approach based on sensitivity methods with consideration of constant load. The proposed approach is executed by developing a computer software program/code in MATLAB version R2014a environment and tested on IEEE 33 bus test system having $(MVA)_{Base}$ = 100 MVA and $(kV)_{Base}$ = 12.66 kV. The results are found for total power loss, voltage profile, minimum bus voltage, cost of energy losses, real and reactive power obtained from DGs, annual saving in cost of energy losses, without and with placement of multiple type DGs. The Forward-Backward Sweep load flow is employed in this work.

In this paper, three sensitivity indices, i.e., CPLS, VSI, and PSI are utilized to solve the DG placement problem. For i-j line having the highest values of sensitivity indices, the DG will be located at jth bus. The optimal location is represented by the bus at which these sensitivity indices are highest and value of normalized voltage is less than 1.01. Based on sensitivity based profiles, it is observed that sensitivity indices are highest at 24th and 25th buses but the value of normalized voltage is more than 1.01. So these buses are not taken for the DG optimal location. Then 8th number bus is a next sensitive bus and normalized voltage value is less than 1.01 on this bus. Hence it is considered for the DG optimal location. After placement of DG at 8th bus and change of DG sizes in steps, total real power loss variation with DG size is obtained which follows the parabolic curve. The size of DG with minimum loss is considered as optimal size.

The real and reactive power losses are 210.9824 kW and 143.0219 kVAR respectively without placement of DG. The substation real and reactive powers are 3930.9824 kW and 2443.0219 kVAR respectively. As mentioned before, 8th number bus is the optimal bus for 33 bus test system. After placement of DG at 8th bus and change of DG sizes in steps, total real power loss variation with DG size at unity, zero, 0.9 lag and 0.9 lead PF is shown in Figure 2. Total real power loss is minimum with DG of 1800 kW, 1100 kVAR, 2100 kVA and 1100 kVA at unity, zero, 0.9 lag and 0.9 lead PF respectively. These DG sizes with minimum losses are selected as optimal sizes.

With the DG placement of 1800 kW at bus 8 at unity PF, real and reactive power losses are 118.1325 kW and 82.9376 kVAR respectively. The substation real power reduces to 2130.9824 kW without any reactive power change from the substation. With DG of 1100 kVAR at zero PF, real and reactive power losses are 172.2353 kW and 119.0192 kVAR respectively. The substation reactive power reduces to 1343.0219 kVAR without any real power change from the substation. With DG of 2100 kVA at 0.9 lag PF, real and reactive power losses are 84.4975 kW and 62.1017 kVAR respectively. The substation real and reactive powers reduce to 2040.9824 kW and 1527.6319 kVAR respectively. With DG of 1100 kVA at 0.9 lead PF, real and reactive power losses are 173.8169 kW and 118.2546 kVAR respectively. The substation real and reactive powers reduce to 2940.9824 kW and 2922.5119 kVAR respectively.

The minimum bus voltage is 0.9038 p.u. without DG. It is improved to 0.9433 p.u., 0.9271 p.u., 0.9532 p.u. and 0.9210 p.u. with DG at unity, zero, 0.9 lag and 0.9 lead PF respectively. The corresponding voltage profile obtained is shown in Figure 3. The cost of energy losses is reduced to a large extent due to reduced total power loss. The cost of energy losses is $ 16983 without DG. It is reduced to $ 9509, $ 13864, $ 6802 and $ 13991 resulting an annual saving of $ 7474, $ 3119, $ 10181 and $ 2992 with DG at unity, zero, 0.9 lag and 0.9 lead PF respectively. The summary of results obtained without and with placement of multiple type DGs considering constant load is given in Table 1.

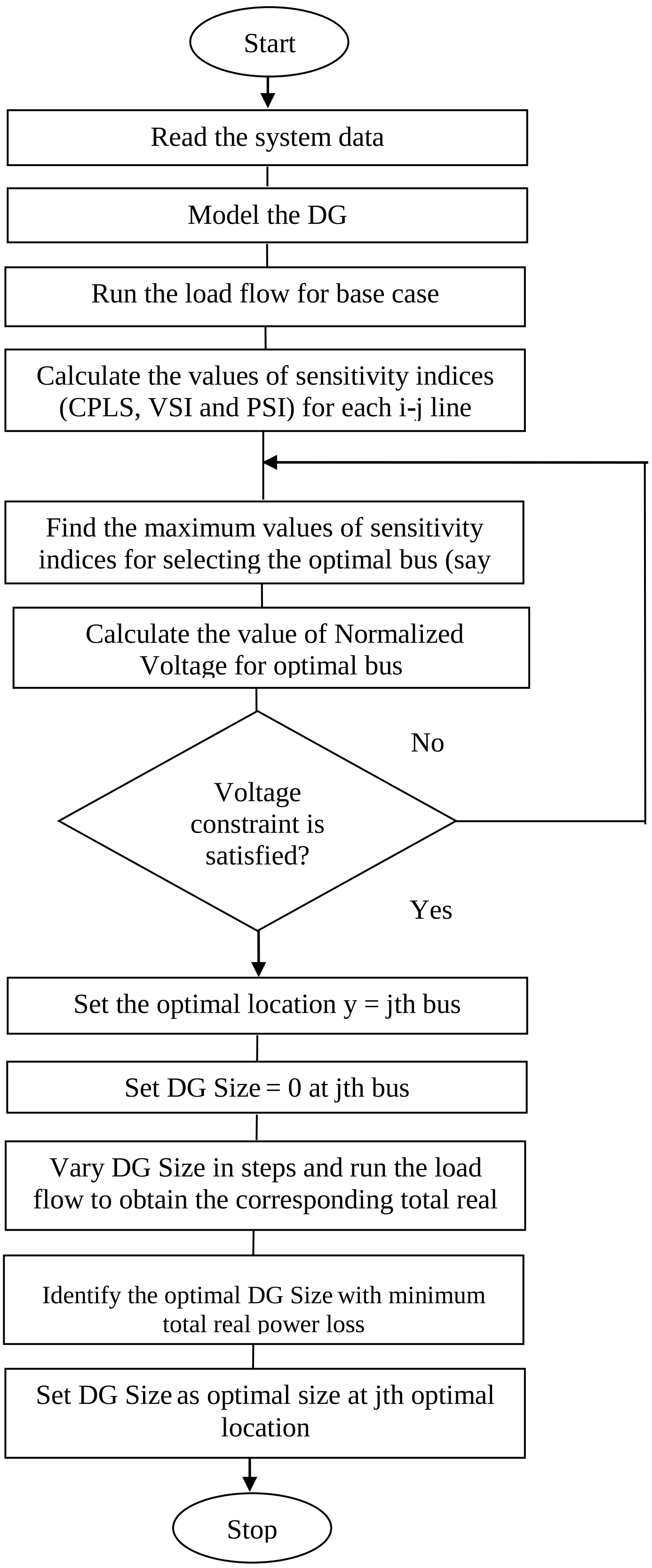

Figure 1 Proposed algorithm for optimal placement of multiple type DGs

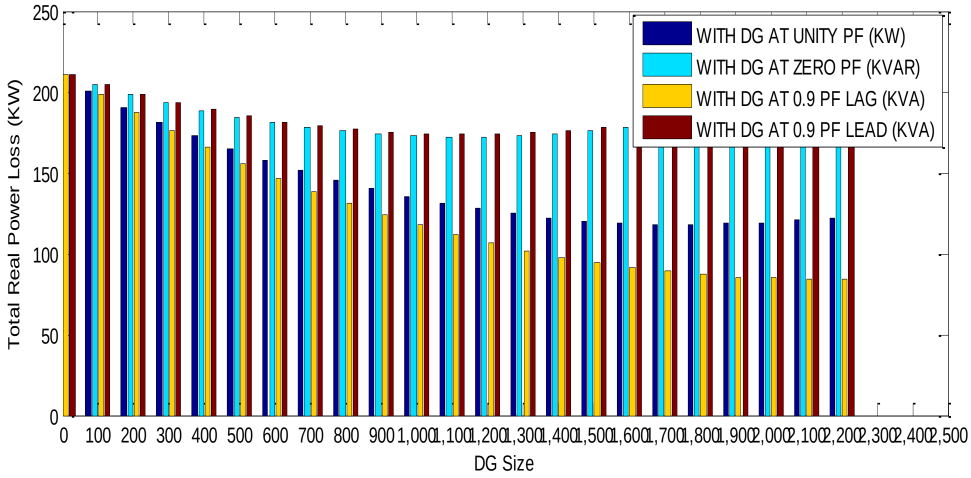

Figure 2 Total real power loss variation with DG size

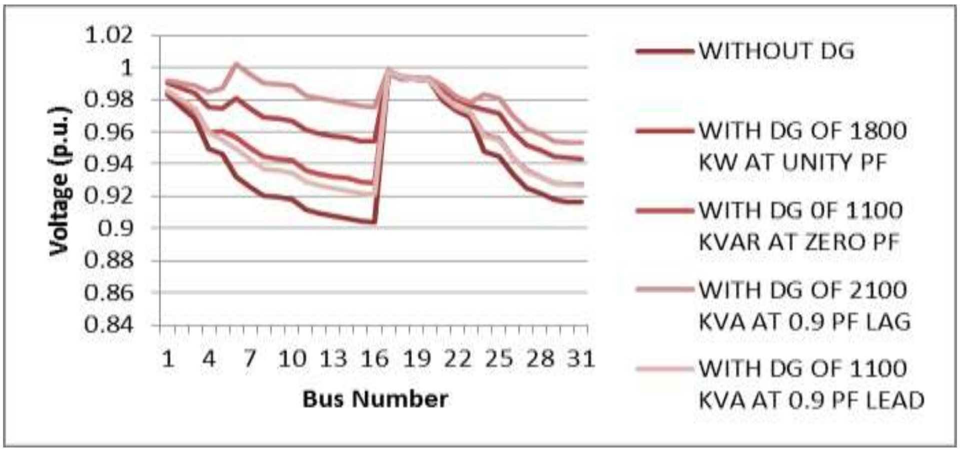

Figure 3 Voltage profile for 33 bus test system

Table 1 Summary of results for 33 bus test system

	Without DG	With DG at unity PF (kW)	With DG at zero PF (kVAR)	With DG at 0.9 PF lag (kVA)	With DG at 0.9 PF lead (kVA)
DG location bus	--	8	8	8	8
DG size	--	1800	1100	2100	1100
Total real power loss (kW)	210.9824	118.1325	172.2353	84.4975	173.8169
Total reactive power loss (kVAR)	143.0219	82.9376	119.0192	62.1017	118.2546
Minimum bus voltage (p.u.)	0.9038	0.9433	0.9271	0.9532	0.9210
Real power from substation (kW)	3930.9824	2130.9824	3930.9824	2040.9824	2940.9824
Reactive power from substation (kVAR)	2443.0219	2443.0219	1343.0219	1527.6319	2922.5119
Cost of PDG ($/MW h)	--	36.2500	--	38.0500	20.0500
Cost of QDG ($/MVAR h)	--	--	14.1183	3.6762	1.9256
Cost of energy losses ($)	16983	9509	13864	6802	13991
Savings in cost of energy losses ($)	--	7474	3119	10181	2992

5. CONCLUSIONS

In this paper, the optimal placement of DG at unity, zero, 0.9 lag and 0.9 lead power factors in radial distribution system is determined using a simple and useful approach based on sensitivity methods. The results are obtained for total power loss, voltage profile, minimum bus voltage, cost of energy losses, real and reactive powers obtained from DGs, annual saving in cost of energy losses. It is concluded that DG at lagging power factor provides the highest reduction in total power loss, improvement in voltage profile and minimum bus voltage, reduction in the cost of energy losses and thereby highest saving in the cost of energy losses. Therefore it gives the best optimal solution.

REFERENCES

[1] Brown, R.E. Electric Power Distribution Reliability. CRC Press, 2008.

[2] Jagtap, K.M. and Khatod, D.K. Loss allocation in radial distribution networks with various distributed generation and load models. Int. J. Electr. Power Energy Syst. 75, 2016, pp. 173-186.

[3] Poornazaryan, Bahram, Karimyan, Peyman, Gharehpetian, G.B. and Abedi, Mehrdad. Optimal allocation and sizing of DG units considering voltage stability, losses and load variations. Int. J. Electr. Power Energy Syst. 79, 2016, pp. 42-52.

[4] Horowitz, S.H. and Phadke, A.G. Power System Relaying. Baldock, John Wiley and Sons, 2014.

[5] Ameli, Amir, Ahmadifar, Amir, Shariatkhah, Mohammad-Hossein, Vakilian, Mehdi and Haghifam, Mahmoud-Reza. A dynamic method for feeder reconfiguration and capacitor switching in smart distribution systems. Int. J. Electr. Power Energy Syst. 85, 2017, pp. 200-211.

[6] Ackermann, T., Andersson, G. and Sder, L. Distributed generation: A definition. Elect. Power Syst. Res. 57, 2001, pp. 195-204.

[7] Rad, H. Kiani and Moravej, Z. An approach for simultaneous distribution, sub-transmission, and transmission networks expansion planning. Int. J. Electr. Power Energy Syst. 91, 2017, pp. 166-182.

[8] Ackermann, T. and Knyazkin, V. Interaction between distributed generation and the distribution network: operation aspects. Proceedings IEEE PES Transmission and Distribution Conference and Exhibition, 2002, pp. 1357-1362.

[9] Karimyan, Peyman, Gharehpetian, G.B., Abedi, M. and Gavili, A. Long term scheduling for optimal allocation and sizing of DG unit considering load variations and DG type. Int. J. Electr. Power Energy Syst. 54, 2014, pp. 277-287.

[10] Murthy, V.V.S.N. and Kumar, Ashwani. Comparison of optimal DG allocation methods in radial distribution systems based on sensitivity approaches. Int. J. Electr. Power Energy Syst. 53, 2013, pp. 450-467.

[11] Murthy, V.V.S.N. and Kumar, Ashwani. Optimal placement of DG in radial distribution systems based on new voltage stability index under load growth. Int. J. Electr. Power Energy Syst. 69, 2015, pp. 246-256.

[12] Aman, M.M., Jasmon, G.B., Mokhlis, H. and Bakar, A.H.A. Optimal placement and sizing of a DG based on a new power stability index and line losses. Int. J. Electr. Power Energy Syst. 43(1), 2012, pp. 1296-1304.

[13] Murthy, V.V.S.N. and Kumar, Ashwani. Comparison of optimal capacitor placement methods in radial distribution system with load growth and ZIP load model. Frontiers in Energy 7(2), 2013, pp. 197-213.

[14] Sharma, Sharmistha, Bhattacharjee, Subhadeep and Bhattacharya, Aniruddha. Quasi-oppositional swine influenza model based optimization with quarantine for optimal allocation of DG in radial distribution network. Int. J. Electr. Power Energy Syst. 74, 2016, pp. 348-373.