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Voltage Stability Assurance Based Optimal Location and Sizing of Distribution Generation in Radial Distribution System

Vericherla N Malleswari, K. Chandra Sekhar
Assoc. Professor, Dept of Electrical and Electronics Eswar College of Engineering
Professor, Department of Electrical and Electronics RVR & JC College of Engineering
Corresponding Author: Vericherla N Malleswari

***Abstract**: In general during light loading conditions, the feeder voltage may raise significantly and vice versa for heavy loading conditions. In addition, the increasing trend of different Distribution Generation (DG) is focusing the need of feeder voltage regulation within the specified limits due to reversal of power flow from load centers to the generation centres. In this paper, the locations of multiple types of DG systems are placed optimally based on voltage stability index and the optimal sizing of DG systems are obtained using Time–Variant Acceleration Coefficient–Particle Swarm Optimization (TVAC–PSO). The proposed methodology is applied on a standard 12-bus radial distribution system and the simulation results are validating the proposed methodology for real-time applications.*

***Keywords**: Radial distribution system, distribution generation, optimal location and sizing, time–variant acceleration coefficient–particle swarm optimization.*

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I. Introduction

The electric power generation sources in different form placed near to the load centres and integrated directly to the distribution networks are termed as Distributed Generation (DG). Since there are wide ranges of applications for DGs, in most developed countries decentralization of power system suggest that DG will have a large share of power generation in the future. But research and developments are required more to overcome the barriers that are currently faced by the DG systems. Some of the goals to be accomplished by the DG systems are lower capital costs, lower emissions and higher efficiency. Several new technologies are being developed and promoted for DG. They range in capacities from a few kilowatts to 100 MW and include micro turbines, fuel cells, photovoltaic systems, wind energy systems, diesel engines, gas turbines and battery storage.

On the other side, the Radial Distribution Systems (RDS) have been suffering with low voltage profile at the tail–end nodes which need to regulate within the acceptable limits for secure and reliable operation. Since the voltage drop due to reactive power (volt–ampere–reactive, var) transfer over the network is predominate in nature than active power (watt) transfer, the local var compensation is essential to improve the voltage profile across the network. In addition, the supplementary benefits like power factor improvement, loss reduction, efficiency, low conductor size, lessen the burden on braches, loadability improvement and economic benefits etc., are highly dependent on proposer var compensation at appropriate locations. Hence, the DG integration can reduce burden on the feeder by and/or real power injection and reactive power injection/withdrawal from the feeder.

In the literature, various researchers have focused on this problem. Based on the loss sensitivity coefficient factors defined as the change of real power loss w.r.t. change of reactive power as well as normalized voltage magnitudes, the optimal locations for capacitor banks have been ranked in [1, 2]. Particle Swarm Optimization (PSO) algorithm has been used for the optimal rating of the capacitor banks towards loss minimization [1]. With an objective of net annual saving in initial investment for the capacitors, Plant Growth Simulation (PGS) is applied for the optimal ratings of capacitors [2]. With the consideration of harmonic distortion, the optimal capacitor and sizing problem has been addressed using PSO algorithm in [3]. The Gravitational Search Algorithm (GSA), Simulated Annealing (SA) and Interior Point algorithm are used for loss minimization and net savings maximization [4]. A fuzzy optimization approach for volt/var control using under–load tap–changer (ULTC) and capacitors in the presence of wind generation uncertainty has proposed in [5].

Simultaneous optimization of multiple objectives without degrading another so–called multi–objective optimization problem and is essential for multiple solutions known as pareto–optimal solutions which can help decision–maker for satisfactory operation without compromising in the targeted benefits. In [6], non–dominated sorting genetic algorithm (NSGA) and in [7], genetic algorithm (GA) for optimal var compensation using capacitor banks by considering rms voltages and their total harmonic distortion has proposed respectively. In [8], PSO algorithm has proposed for solving the multiple locations, types, and sizes of capacitors at different load levels. In [9], modified teaching–learning based optimization (MTLBO) algorithm is applied to solve the automatic voltage regulators (AVRs) in the presence of distribution generators (DGs). The authors have taken multiple primary objectives of operating energy cost, total loss and voltage deviation and obtained various pareto–optimal solutions by considering different combinations of primary objectives. The results have also been compared with GA, PSO and basic TLBO [10] algorithms. In [11] presented an approach for optimal placement of DG in radial distribution system by novel power loss sensitivity, power stability index and voltage stability index and also in presence of load growth and combined power factor. A new methodology for placement of DG based on VSI is proposed in [12]. The voltage stability index finds the most critical bus which may leads to the instability of the system when there is an increment in load. In [13] considered two scenarios for the location of the DG, the first is to reduce only the real power loss and the second is to find the optimal location using Voltage Stability Index (VSI). The Fast Voltage Stability Index (FVSI) and Line Stability Factor (LQP) are taken into account for the maximum power transfer capacity. The location and size depends on single instantaneous demand at peak.

In light of these works, the optimal location and sizing of DG is a complex, non–linear and multi–objective optimization problem and which can be solved effectively using heuristic algorithms. Among all these heuristic algorithms, PSO is easier to apply and able to solve complexity in various optimization engineering problems. The PSO algorithm has numerous applications in the power system optimization problems [14]. Hence in this work also, the advanced versions i.e., Time–Variant Acceleration Coefficient PSO (TVAC–PSO) [15] is adopted and compared with basic Particle Swarm Optimization (PSO).

Problem Formulation

A. Modeling of DG Systems

Based on active power controlling capability, these sources can be classified as dispatchable or non–dispatchable. Small hydro power plants and biomass–based gas turbines are the examples of dispatchable where the active power is controllable by adjusting their input fuel consumption where as solar and wind generation sources which are non–controllable are the examples for non–dispatchable since their output is dependent on meteorological conditions.

- ***Type–1:*** Photovoltaic, micro turbines and fuel cells which are incorporated to main grid with the help of converters/inverters are good examples of this model. In this model, the real power load at bus–i will be reduced by an amount equal to DG real power output with unity power factor and is given by:

$$P_{di,new} = P_{di,base} - P_{DG,i} \tag{1}$$

- ***Type–2:*** Synchronous compensators such as gas turbines and capacitors are the examples for this type of modeling. In this model, the reactive power load at bus–i will be reduced by an amount equal to DG reactive power output with zero power factor and is given by:

$$Q_{di,new} = Q_{di,base} - Q_{DG,i} \tag{2}$$

- ***Type–3:*** Synchronous generators or wind farm is the example for this type of modeling. The power factor lies between 0 and 1. In this model, the active power will be reduced by an amount equal to DG active power and reactive power will be either increment/decrement by an amount equal to DG reactive power load at bus–*i* and is given by:

$$P_{di,new} + jQ_{di,new} = \left(P_{di,base} - P_{DG,i}\right) + j\left(Q_{di,base} \pm Q_{DG,i}\right) \tag{3}$$

As per the above five models, the DGs will decrease either active or reactive or both and causes to decrease net loading effect on the feeder. The decreased load has to balance and usually it may happen at slack bus in load flow studies. By the redistribution of power flows with reduced load, the net voltage profile, transmission loss and security margin can improve significantly.

B. Algorithm for Optimal Sizing

Since the uncertainty of DG penetration can cause to either increase or decrease the feeder voltage significantly, it is required to regulate the feeder voltage within the acceptable range as well as to minimize total real power losses in the network. The proposed methodology is capable to regulate the feeder voltage suitably for any loading conditions by limiting the DG sizes irrespective of locations and type by satisfying the following objective function.

$$\min\left\{\left(\frac{1}{n_b}\sum_{n_b}\left|V_s - V_i\right|\right) + \sum_{br} I_{br}^2 R_{br}\right\} \tag{4}$$

where V_s and V_i are the sub-station bus voltage and bus-i voltage respectively; I_{br} and R_{br} are the branch current and resistance respectively; *nb* and *br* are the number of buses and number of branches respectively.

The objective function is optimized using Time Varying Acceleration Coefficient – Particle Swarm Optimization (TVAC–PSO) [15], which works based on the following position and velocity equations:

$$X_i^{k+1} = X_i^k + V_i^{k+1} \tag{5}$$

$$V_i^{k+1} = \omega^k . V_i^k + c_1^k .rand_1 \otimes \left(P_{lbest,i}^k - X_i^k \right) + c_2^k .rand_2 \otimes \left(P_{gbest,i}^k - X_i^k \right) \tag{6}$$

$$\omega^k = \omega_{\max} - \left(\frac{\omega_{\max} - \omega_{\min}}{k_{\max}} \right) \times k \tag{7}$$

$$c_i^k = c_{i,\max} - \left(\frac{c_{i,\max} - c_{i,\min}}{k_{\max}} \right) \times k \qquad i = 1,2 \tag{8}$$

According to [16], the best parameters are: $\omega_{\max} = 0.4$, $\omega_{\min} = 0.9$; towards local best: $c_{1,\min} = 2$, $c_{1,\max} = 0.4$; and towards global best: $c_{1,\min} = 0.4$, $c_{1,\max} = 2$.

C. Assessment of DG Impact on Voltage Stability

Based on the voltage profile for a specific loading condition, stability of the network can be calculated. From the literature, the following stability indices are used for different types of DG locations. For more stable, these indices should be as low as possible. The impact of DG is analyzed by computing these indices before and after DG penetration.

Power Stability Index (PSI) given in [12] is used to analyze the impact of Type – 1 DG on network performance.

$$PSI_q = \frac{4 r_{pq} P_q}{\left\{ \left| V_p \right| \cos\left(\theta_{pq} - \delta_{pq} \right) \right\}^2} \tag{9}$$

Line Stability Index (LSI) given in [17] is used to analyze the impact of Type – 2 DG on network performance.

$$LSI_q = \frac{4 x_{pq} Q_q}{\left\{ \left| V_p \right| \sin\left(\theta_{pq} - \delta_{pq} \right) \right\}^2} \tag{10}$$

Stability Index (SI) given in [18] is used to analyze the impact of Type – 3 DG on network performance.

$$SI_q = 0.5 \left| V_q \right|^2 - r_{pq} P_q - x_{pq} Q_q \tag{11}$$

where P_q and Q_q are the active and reactive power loads at bus *q* respectively; r_{pq}, x_{pq} and θ_{pq} are the resistance, reactance and impedance angle of the branch between *p* and *q* respectively; V_p is the voltage magnitude at bus *p*; $\delta_{pq} = \left(\delta_p - \delta_q \right)$ is the load angle difference of buses *p* and *q*.

II. Results and Discussions

A. 12-Bus Test System

This test system has 12 nodes connected by 11 branches as given in [19]. The system operating voltage is 11 kV. The base MVA is considered as 100. By applying BW/FW sweep load flow, the test system suffers with 20.7117 kW real power and 8.0393 kVAr reactive power losses for the nominal load model. By normalizing the voltage magnitudes (*Norm (i) = V(i)/0.95*) [1, 2], the locations are finalized i.e., buses 9, 10, 11 and 12 respectively. The network performance in terms of real power loss, minimum and maximum voltage in the network and minimum of all bus stability indexes before and after optimized DG penetration is given in Table 1 for Type-1, Table -2 for Type-2 and Table-3 respectively.

Table 1. Optimized Type-1 DG penetration and its impact in 12-bus system

DG Locations	Size (kW)	$V_{\min}$ (p.u)	$V_{\max}$ (p.u)	F_1 (kW)	F_2 (p.u)	min (PSI_q)
Base	0	0.9434(12)	1.0000(1)	20.7117	0.0015	0.007(12)
12	14.511	0.9973(12)	1.0378(1)	17.5051	0.0006	0.003(12)
12, 11	52.884	0.9973(12)	1.0405(1)	15.0509	0.0004	0.004(11)
12, 11, 10	79.613	1.0000(12)	1.0489(1)	14.7006	0.0006	0.002(12)
12, 11, 10, 9	110.944	1.0001(12)	1.0328(1)	10.6430	0.0002	0.001(12)

From the Table 1, for Type-1 DG of 14.511 kW only at bus 12, the real power loss is decreased to 17.505 kW considerably and stability also is increased. For the penetration of 52.884 kW (39.3585 kW at bus 11 and 13.5260 kW at bus 12), the losses are further decreased to 15.0509 kW. For 3 DGs with 79.613 kW (30.2207 at bus 10, 34.4907 kW at bus 11 and 14.9020 kW at bus 12), the losses are decreased to 13.5046 kW.

Similarly, when we have 4 DGs with 110.944 kW (32.4042 kW at bus 9, 33.0704 kW at bus 10, 32.2603 kW at bus 11 and 3.2093 kW at bus 12), the losses are decreased to 10.6430 kW significantly.

Similarly, by observing F_2 value, the average voltage deviation index is also moderated effectively and it can be an indicator to have proper voltage profile across the network as well as voltage stability.

The similar understanding can have from the Table 2 for Type-2 DGs in the network. The Type-2 DG penetration of 14.599 kVAr at bus 12 is caused to decrease the loss to 17.6742 kW. The optimized Type-2 DG penetration of 44.5413 kVAr (29.7258 kVAr at bus 11 and 14.8155 kVAr at bus 12) is caused to decrease the losses to 15.9935 kW. The optimized Type-2 DG penetration of 68.7920 kVAr (25.3642 kVAr at bus 10, 28.7445 kVAr at bus 11 and 14.6833 kVAr at bus 12) is caused to decrease the losses to 14.7006 kW. The optimized Type-2 DG penetration of 109.235 kVAr (39.6123 kVAr at bus 9, 29.0422 kVAr at bus 10, 29.3573 kVAr at bus 11 and 11.2231 kVAr at bus 12) is caused to 13.2854 kW.

Table 2. Optimized Type-2 DG penetration and its impact in 12-bus system

DG Locations	Size (kVAr)	V_{min} (p.u)	V_{max} (p.u)	F_1 (kW)	F_2 (p.u)	min (LSI_q)
Base	0	0.9434(12)	1.0000(1)	20.7117	0.0015	0.0093 (12)
12	14.972	0.9941(12)	1.0378(1)	17.6742	0.0006	0.0002 (12)
12, 11	44.541	0.9966 (12)	1.0472(1)	15.9935	0.0005	0.0001(12)
12, 11, 10	68.792	1.0002(12)	1.0380(1)	13.5046	0.0003	0.0001(12)
12, 11, 10, 9	109.235	0.9853 (12)	1.0468 (1)	13.2854	0.0002	0.0001 (12)

The results for Type-3 DG are given in Table 3. The Type-3 DG penetration of 21.037 kVA at bus 12 is caused to decrease the loss to 16.5 kW. The optimized Type-2 DG penetration of 68.925 kVA (49.6633 kVA at bus 11 and 19.262 kVA at bus 12) is caused to decrease the losses to 12.281 kW. The optimized Type-2 DG penetration of 109.303 kVA (39.884 kVA at bus 10, 49.611 kVA at bus 11 and 19.808 kVA at bus 12) is caused to decrease the losses to 9.4943 kW. The optimized Type-2 DG penetration of 163.114 kVA (52.685 kVA at bus 9, 41.6152 kVA at bus 10, 48.3068 kVA at bus 11 and 20.507 kVA at bus 12) is caused to 6.349 kW.

Table 3. Optimized Type-3 DG penetration and its impact in 12-bus system

DG Locations	Size (kVA)	V_{min} (p.u)	V_{max} (p.u)	F_1 (kW)	F_2 (p.u)	min (SI_q)
Base	0	0.9434(12)	1.0000(1)	20.7117	0.0015	0.4445 (11)
12	21.037	0.9955 (11)	1.0451 (1)	16.500	0.0005	0.4949 (11)
12, 11	68.925	0.9952 (9)	1.0353 (1)	12.281	0.0003	0.4939 (9)
12, 11, 10	109.303	0.9880 (11)	1.0210 (1)	9.494	0.0001	0.4859 (9)
12, 11, 10, 9	163.114	0.9955 (12)	1.0199 (1)	6.349	0.00008	0.4941 (8)

III. Conclusion

By minimizing loss and average voltage deviation index simultaneously, the multi-objective optimization problem of DG optimal location and sizing is solved by using TVAC-PSO algorithm. By performing the load flow and normalizing the voltage profile, the locations are ranked. For different type of DGs and according to their nature of generation i.e., active and/or reactive power, different type of stability indices are computed and compared the stability of system before and after DG installation. The simulations are carried for single DG and multiple DGs on a standard 12-bus radial distribution system and the results are validating the proposed methodology for ensuring voltage stability in RDS by integrating proper type and number of DGs optimally.

References

[1]. Prakash, K., and M. Sydulu. "Particle swarm optimization based capacitor placement on radial distribution systems." *Power Engineering Society General Meeting, 2007. IEEE*. IEEE, 2007.

[2]. Rao, R. Srinivasas, S. V. L. Narasimham, and M. Ramalingaraju. "Optimal capacitor placement in a radial distribution system using plant growth simulation algorithm." *International journal of electrical power & energy systems* 33.5 (2011): 1133-1139.

[3]. Yu, Xin-mei, Xin-yin Xiong, and Yao-wu Wu. "A PSO-based approach to optimal capacitor placement with harmonic distortion consideration." *Electric Power Systems Research* 71.1 (2004): 27-33.

[4]. Shuaib, Y. Mohamed, M. Surya Kalavathi, and C. Christober Asir Rajan. "Optimal capacitor placement in radial distribution system using gravitational search algorithm." *International Journal of Electrical Power & Energy Systems* 64 (2015): 384-397.

[5]. Liang, Ruey-Hsun, Yu-Kai Chen, and Yie-Tone Chen. "Volt/Var control in a distribution system by a fuzzy optimization approach." *International Journal of Electrical Power & Energy Systems* 33.2 (2011): 278-287.

[6]. Milosevic B, Begovic M. Capacitor placement for conservative voltage reduction on distribution feeders. IEEE Trans Power Delivery 2004; 19:1360–7.

[7]. Masoum MAS, Ladjevardi M, Jafarian A, Fuchs EF. Optimal placement, replacement and sizing of capacitor Banks in distorted distribution networks by genetic algorithms. IEEE Trans Power Delivery 2004;19: 1794–801.

[8]. Yu X-m Xiong X-Y, Wu Y-w. A PSO-based approach to optimal capacitor placement with harmonic distortion consideration. Electr Power Syst Res 2004;71:27–33.

[9]. Niknam, Taher, Rasoul Azizipanah-Abarghooee, and Mohammad Rasoul Narimani. "A new multi objective optimization approach based on TLBO for location of automatic voltage regulators in distribution systems." *Engineering Applications of Artificial Intelligence* 25.8 (2012): 1577-1588.

[10]. Rao, R.V., Savsani,V.J., Vakharia,D.P., 2011. Teaching–learning-based optimization: a novel method for constrained mechanical design optimization problems. Comput.-AidedDes.43,303–315.
[11]. V.V.S.N. Murty and Ashwani Kumar, "Optimal placement of DG in radial distribution systems based on new voltage stability index under load growth", Electrical Power and Energy Systems ,2015; 69: 246–256.
[12]. M.M. Aman, G.B. Jasmon, H. Mokhlis and A.H.A. Bakar, "Optimal placement and sizing of a DG based on a new power stability index and line losses", Electrical Power and Energy Systems.,2012; 43: 1296–1304.
[13]. A. Parizad , A. Khazali and M. Kalantar, "Optimal Placement of Distributed Generation with Sensitivity Factors Considering Voltage Stability and Losses Indices", Electrical Engineering (ICEE)., 18th Iranian Conference, 2010.
[14]. J. Kennedy and R. Eberhart, "Particle swarm optimization," in Proc. IEEE Int. Conf. Neural Netw. (ICNN), Nov. 1995, vol. 4, pp. 1942–1948.
[15]. A. Ratnaweera, S. K. Halgamuge and H. C. Watson, "Self-organizing hierarchical particle swarm optimizer with time-varying acceleration coefficients," in IEEE Transactions on Evolutionary Computation, vol. 8, no. 3, pp. 240-255, June 2004.
[16]. Hong Zhang, Masumi Ishikawa, "Characterization of particle swarm optimization with diversive curiosity," Neural Computing and Applications, vol. 18, no. 5, pp 409–415, June 2009.
[17]. R. Ranjan and D. Das, Voltage stability analysis of radial distribution networks, Electric Power and Energy System 31:5, 501-511(2003).
[18]. M. Moghavvemi and M.O. Faruque, "Technique for assessment of voltage stability in ill -conditioned radial distribution network," IEEE Power Engineering Review(January-2001),58–60.
[19]. D. Das, H. S. Nagi and D. P. Kothari, "Novel method for solving radial distribution networks," in IEE Proceedings - Generation, Transmission and Distribution, vol. 141, no. 4, pp. 291-298, Jul 1994.

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