International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Performance Evaluation of DG Interconnected Radial Distribution System

Gaurav Chauhan[1]*, Sakshi Bangia[2]

Submitted: 07/02/2024 **Revised**: 15/03/2024 **Accepted**: 21/03/2024

Abstract

The distribution system has become very complex entity due to increase in power system utilities, so it is very difficult task to improve the voltage profile and to maintain the quality of power of such complex system. Distribution generation (DG) can play major role to enhance the power quality of the system and also improves the reliability of the system. DGs act as an active distribution system and form the link between high voltage transmission line and low voltage utility. This helps in reducing the active power loss of the system. This paper presents optimizing techniques for DG model in terms of operating point, size and location to minimize the active power loss of overall system. For the proposed objective functions the variation in power loss can be observed with respect to DG current injection. The load characteristics have been taken into consideration to develop the proposed techniques and the system has been treated as constant current model. The proposed system has been simulated and verified by MATLAB software for RDS (radial distribution system).

Keyword: DG units, Loss Sensitivity analysis,distribution system, optimal placement and size of DG

1. Introduction

The small generating units in cooperation with energy storage system along with energy management are termed as Distributed Generation (DG). It generally installed near the utility as to improve the reliability and operation of the power system network. These systems can be operated as grid connected or stand alone mode. The size of DG may vary from a kilowatt to a few megawatts.

The power loss reduction is major problem in low voltage distribution system and it can be achieved by multiple ways such as capacitor placement [12], conductor grading, using high voltage distribution system and DG placement. All the methods mentioned have an involvement of passive element in order to reduce power loss except DG placement. Along with the DG placement capacitors also improves the voltage profile and reduces the power loss but DGs can reduce the power loss to the extent double that of capacitor. [2], [9].

Although the dg units are connected to the secondary distribution system and cannot be dispatched by central operator but the play a significant role in system reliability, continuity of power, system stability, short circuit operation and power flow for the suppliers and consumers [3], [4].

[1]Department of electrical Engineering, J.C. Bose University of Science and Technology, YMCA, Faridabad, Haryana, India
[2]Department of electrical Engineering, J.C. Bose University of Science and Technology, YMCA, Faridabad, Haryana, India

2. Problem Formation

The proper placement of DG in the distribution system plays an important role in loss reduction and power quality improvement. On the basis of size of DG, the proposed technique provides the optimal placement of DG units in distribution system under consideration. There are various factors which affects the power quality and stability of the system

1. Voltage instability
2. Reactive and active powers
3. System power losses

Power losses

Power system losses are variable quantity which is affected by multiple factors depending on the system configuration. Few factors which affect the power losses are transmission line parameters, transformer parameters, distribution system configuration, protecting devices etc. There can be further real or/and reactive power losses in the system [11]. Reactive power is due to the storage or nonlinear component in the system and makes the flow of real power possible. The real and rective power losses in the system are given by the following equation

$$Ploss = \sum_{i=1}^{Nbr} |Ii^2| \text{ ri}$$

$$Qloss = \sum_{i=1}^{Nbr} |Ii^2| \text{ xi} \tag{1}$$

Where
nbr represents the total number of branches in the system,
Ii represents ith branch current magnitude,
xi and ri represents ith branch reactance and resistance, respectively.

The different loads connected to the system also affect the power losses. The further analysis is made for the system consisting of loads consuming constant current with and without interconnection of DG. representing loads with CCL (constant current models).

DS with CCL (Constant Current Load) model

The current drawn by the constant current load (which is considered in the study) does not depend on the voltage of the source or feeder. The equation (2) represents the relation between the voltage and the power consumed by the load under consideration.

$$\frac{P}{Po} = \frac{V}{Vo} \tag{2}$$

Figure 1 represents the system under consideration with N buses and (N-1) CCL (constant current loads).

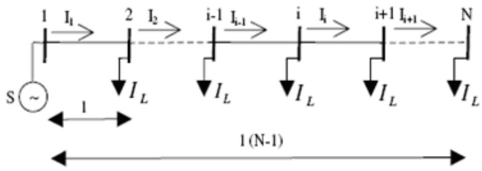

Fig 1. System with N-bus and N-1 loads

In figure 1 S represents the substation and the voltage at ith bus can be represented in terms of substation voltage and voltage drop till but I.
Series expansion gives the following relation,

$$Vi = v_1 - I_z \sum_{j=1}^{i-1} (I_j) \tag{3}$$

$$V_i = v_1 - I_z \left[(i-1) N - \frac{i-1}{2} i\right] I_l \tag{4}$$

Initial power system losses are represented as:

$$Pini(Loss) = I_r \left[\left(\frac{n-1}{6}\right) N(2N-1)|Ii^2|\right] \tag{5}$$

$$Qini(Loss) = I_x \left[\left(\frac{n-1}{6}\right) N(2N-1)|Ii^2|\right]$$

Figure 2 represents the interconnection og DG at bus k and the current injected to the network is given by $I_{DG} \angle \theta_{DG}$.

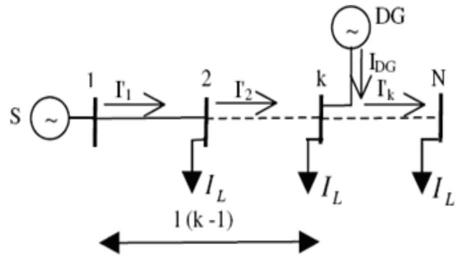

Fig 2. Radial distribution system with DG at bus-k

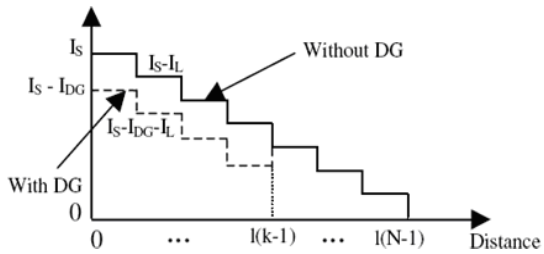

Fig 3. System current with and without DG interconnection

It is quite clear from the figure 3 that current drawn from the substation is reduced to the considerable value after integration of DG at bus k in the system. But there is no effect on the flow of current after bus k till the utility end.

The ith branch current in the presence of DG is given by,

$$I'_i = I_I - I_{DG} ; \; i \leq k \quad (6)$$

The ith bus voltage in the presence of DG is represented as,

$$V^{DG}_{i,i*1} = V_i = l_z(I - 1)I_{DG} ; \quad i \leq k \quad (7)$$

and $V^{DG}_{i,i*1} = V_i = l_z(k - 1)I_{DG} ; \quad i \leq k$

There is considerable amount of improvement in the voltage profile due to the DG interconnection than can be seen from equation (7). Equation (8) represents the voltage at different buses before and after the interconnection of DG.

$$\Delta V^{DG}_i = l_z(i - 1)I_{DG} \quad i \leq k \quad (8)$$

$$\Delta V^{DG}_i = l_z(k - 1)I_{DG} \quad i > k$$

Thus, the effect on real and reactive power of the system is as follows,

$$Ploss = I_r[\sum_{i=1}^{k-1}|Ii - Idg|^2| + \sum_{i=k}^{n-1}|Ii^2|]$$

$$Qloss = I_x[\sum_{i=1}^{k-1}|Ii - Idg|^2| + \sum_{i=k}^{N-1}|Ii^2|] \quad (9)$$

The active and reactive power losses with DG interconnection can be represented in terms of power losses without DG interconnection as shown in equation 10, by rearranging Equation (9)

$$P_{DG(Loss)} = P_{ini(Loss)} + f_{Loss}I_r|I_{DG}|$$

$$Q_{DG(Loss)} = Q_{ini(Loss)} + f_{Loss}I_x|I_{DG}| \quad (10)$$

Where $f_{Loss} = (k\text{-}1)I_{DG} - 2|I_L| \, Cos(\theta_L - \theta_{DG})[(K\text{-}1)N - \frac{K-1}{2}k]$

And θ_L represents load current angle. So the reduction in active and reactive power losses can be represented by

$$\Delta P_{Loss} = f_{Loss} I_r |I_{DG}|$$

$$\Delta Q_{Loss} = f_{Loss} I_x |I_{DG}| \quad (11)$$

It is quite clear from Equation (11) that the reduction in the losses is only possible when f_{loss} i.e. loss factor is negative. Floss is a function of location and size of DG. Equation (12) represents the derivative of power loss with respect to DG injected current,

$$\frac{\delta Ploss}{\delta|IDG|} = 2I_r(k-1)I_{DG} - 2I_r|I_L| \; Cos(\theta_L - \theta_{DG})[(K-1)N - \frac{K-1}{2} k] \quad (12)$$

Similiarly;

$$\frac{\delta Qloss}{\delta|IDG|} = 2I_x(k-1)I_{DG} - 2I_x|I_L| \; Cos(\theta_L - \theta_{DG})[(K-1)N - \frac{K-1}{2} k] \quad (13)$$

The differentiation of active and reactive power w.r.t phase of injected DG current is given by,

$$\frac{\delta Ploss}{\delta|IDG|} = -2I_r|I_L||I_{DG}|[(K-1)N - \frac{K-1}{2} k]Sin(\theta_L - \theta_{DG})$$

$$\frac{\delta Qloss}{\delta|IDG|} = -2I_x|I_L||I_{DG}|[(K-1)N - \frac{K-1}{2} k]Sin(\theta_L - \theta_{DG}) \quad (14)$$

Active and reactive power losses of the system are affected by variation in injected DG current in terms of phase and magnitude. The proposed sensitivity analysis helps in assessing the variation in power losses due to operating point and injected DG current.

The minimum power losses are obtained when the derivative of power loss w.r.t. injected DG current becomes zero. So the equation of maximum injected DG current when the power loss is minimum is,

$$|I_{DG}|_{max} = \frac{|IL| \; Cos(\theta L - \theta DG)[(K-1)N - \frac{k(k-1)}{2} k]}{k-1} \quad (15)$$

3. System Under Study

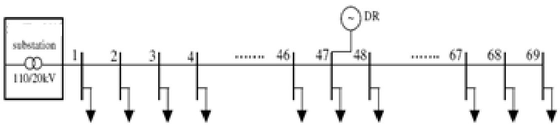

Fig 4. Single line diagram of system

Above figure represent the single line diagram of system under study and the parameters are shown below

System details:

Type:	Radial DS
Length:	48 KM
Impedance, z1:	0.6672+j0.3745ohm/KM
System voltage:	22 KV

4. Results And Discussions

In the system under consideration the DG delivers only real power while connecting at bus 47. In order to deliver only real power, the phase of the substation voltage is made equal to the injected current by DG. To inject real power only, the phase of DG current and local voltage at connection point are made equal. For a constant current model, the sensitivity of losses and actual power losses in terms of output DG current is represented in figure 5.

The variation in power losses with respect to increase in DG output current is such that it decreases initially and starts to increase. So the required condition to achieve the minimum value of DG current is to make the derivative of power losses with respect to injected DG current equals to zero.

Figure 6 represents the reactive power losses for the system under consideration which is quite similar to real power loss curve at the maximum DG injected dg current of 1.35 p.u. for the constant current load.

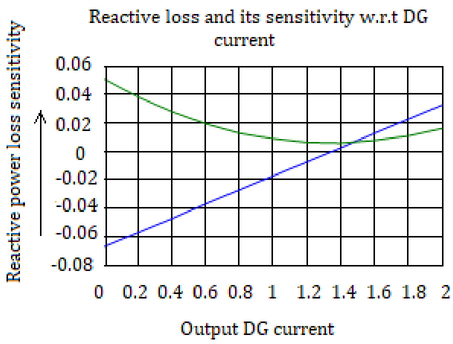

Fig 5. Sensitivity and active power losses w.r.t. DG current

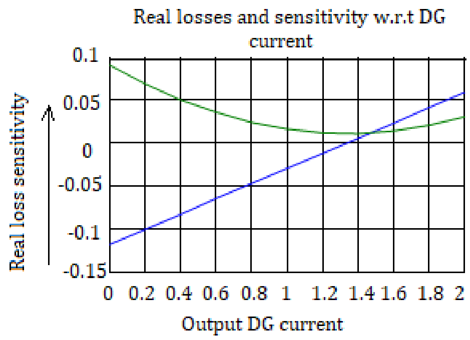

Fig 6. Reactive power losses and sensitivity w.r.t. DG current

For the constant current and impedance model of load, Figure 7 and 8 represents the sensitivities in real and reactive powers with respect to phase angle of DG injected current. It is quite clear from the figure 7 and 8 that the slope of real and reactive loss sensitivity curve is negative i.e. initially they decreases with respect to injected DG current and after reaching certain point there is a increment in the losses and that point is considered to be optimal point of the injected DG phase current. At the optimal point the value of real and reactive loss is minimum.

With the same analysis, the optimal value of injected DG current or the size of DG can be determined for the different location of DG in power system network. DG is mostly connected to the distribution side of the system as the losses are more in the distribution system.

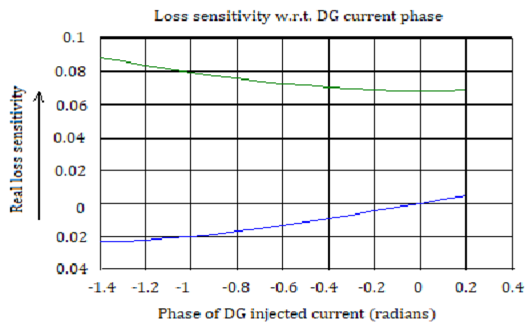

Fig 7. Real power loss sensitivity analysis w.r.t DG phase current.

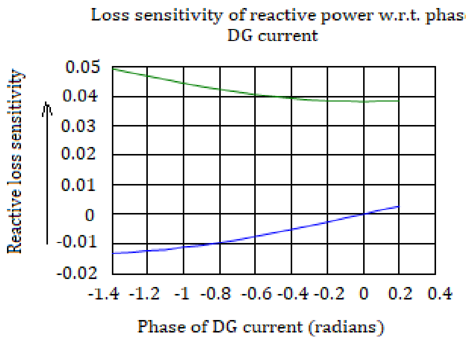

Fig 8. Reactive power loss sensitivity analysis w.r.t. phase of DG current

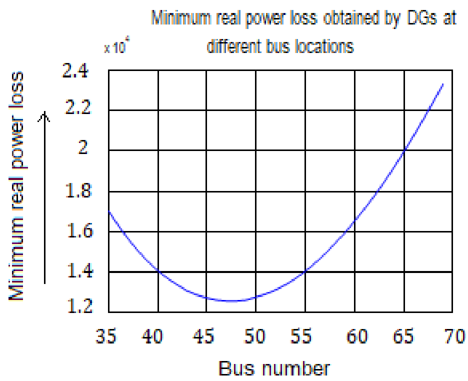

Fig 9. Real power loss (minimum) with respect to optimal size of DG

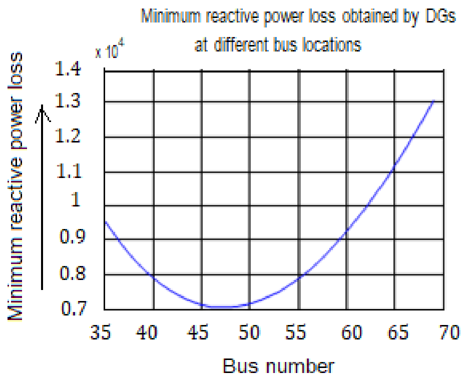

Fig 10. Reactive power losses (minimum) with respect to optimal sizes of DG

The system under consideration is evaluated for the DG connected at different locations (one at a time) from bus number 35 to bus 69. Optimal size of DG is considered with the help of sensitivity analysis and real and reactive power losses are calculated for each case which is shown in figure 9 and 10 respectively. It is quite clear from the figure 9 and figure 10 that the optimal location of the DG, where it gives minimum real and reactive power losses is at bus number 47.

Voltage profile of the system is also been evaluated for two cases i.e. with and without interconnection of DG and the results are represented in figure 11. It is clear from the voltage profile curve shown in figure 11 that the proposed technique not only reduces the power losses but also improves the voltage profile of the system. The minimum system voltage is approximately 0.92p.u. under the case when the system is not connected to DG. The minimum system voltage is around 0.98p.u. when the optimal size of DG is connected to the system.

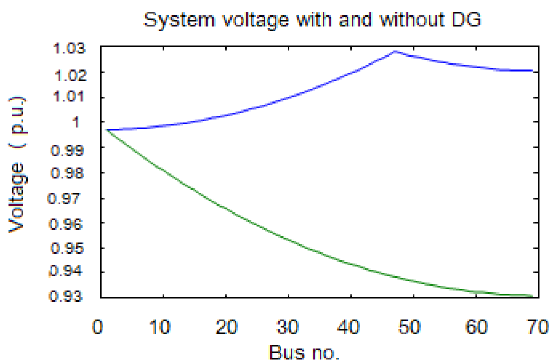

Fig 11. Voltage profile curve with and without DG

5. Conclusion

The result presented during this study gives the understanding and effectiveness of the optimal DG placement in terms of loss reduction and voltage profile improvement in the low voltage system. The proper utilization and planning of DG has also been presented during the study. There is no fix model of optimal DG as it varies from system to system and is affected by load characteristics, DG objectives and system characteristics. It is quite clear from the results presented the optimal size and placement of DG unit not only reduces the system losses but also improves the voltage profile to the significant level when switched to without DG interconnection to DG interconnected system.

6. Declaration

I declare that the authors have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper and he results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration (from you or one of your Contributing Authors) by another publisher.

Funding

Not applicable

7. References

[1] P Chiradeja, R Ramakumar, 2004. "An Approach to Quantify the Technical Benefits of Distributed Generation". IEEE Transactions on Energy Conversion.; 19(4): 764–773.

[2] W Caisheng, M H Nehrir 2005. "Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems". IEEE Power Engineering Society General Meeting**;** ISSN: 1932 – 5517.

[3] K M Jagtap, D K Khatod, 2015, "Allocation of distribution network losses with different types of distributed generation", Annual IEEE India Conference (INDICON),; 2325-9418.

[4] T-H Chen, M-S Wang, N-CHE Yang 2007, "Impact of Distributed Generation on Voltage regulation by ULTC Transformer using various existing methods", Proceedings of the 7th WSEAS International Conference on Power Systems,; sept,15-17.

[5] CLT Borges, DM Falcao 2003. "Impact of Distributed Generation Allocation and Sizing on Reliability, Losses, and Voltage Profile". IEEE Bologna Power Tech Conference Proceedings. Bologna.; 2.

[6] Siti et. Al. 2010, "Implementation of DG for loss minimization and voltage profile in distribution system", 4th International Power Engineering and Optimization Conference (PEOCO).

[7] Yogesh P. Patel; Ashvin G. Patel 2012, "Placement of DG in Distribution System for loss reduction", IEEE Fifth Power India Conference-12.

[8] J Mutale, G Strbac, N Jenkins, S Curcic, 2010. "Allocation of Losses in Distribution Systems with Embedded Generation". IEE Proceedings of Generation, Transmission and Distribution; 147; 1: 7–14.

[9] R Jahani, H C Nejad, A S Malekshah, 2011. "Applying a new advanced intelligent algorithm for optimal distributed generation location and sizing in radial distribution systems". Australian Journal of Basic and Applied Sciences; 5(5): 642-649.

[10] A Augugliaro, S Favuzza, L Dusonchet, , 2004. "Voltage Regulation and Power Losses Minimization in Distribution Networks by an Evolutionary Multiobjective Approach". IEEE Transactions on Power Systems; 19(3); 1516–1527.

[11] J J Jamian, M W Mustafa, H Mokhlis, M A Baharudin 2012. "A New Particle Swarm Optimization Technique in Optimizing Size of Distributed Generation". International Journal of Electrical and Computer Engineering (IJECE); 2(1): 137-146.

[12] A Sadighmanesh, K Zare, M Sabahi 2012. "Distributed Generation unit and Capacitor Placement for Loss Voltage profile and ATC Optimization". International Journal of Electrical and Computer Engineering (IJECE); 2(6): 774- 780