

Improved Voltage Stability and Loss Reduction in Distribution Network

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Abstract: Analysis of the effect of Distributed Generation (DG) capacity and location on voltage stability enhancement of real distribution network is presented in this study. Voltage instability occurs in power system when the system is unable to maintain an acceptable voltage profile under an increasing load demand. The analysis is performed using steady state voltage stability. To improve the system voltage stability, it is necessary to consider voltage stability constraint for planning and operation of distribution system; this study presents a method to find the steady state voltage stability region of each bus of a distribution power system.

Key words: Voltage stability, PQ curve, radial distribution, distribution network, India

INTRODUCTION

Distributed Generation (DG) is defined as the generation which is dispersed throughout a utility service territory and either connected to the utilities distribution system or small isolated system. Distributed Generation (DG) resources included (wind turbine, photovoltaic fuel cell, biomass, micro turbine, small hydro electric plant, etc.). In present scenario, distribution grid is increasing world wide with the development of national economy and the improvement of people's life. Load demand in distribution network are sharply increasing like transmission network. The operation condition of distribution network is more and more close to voltage stability boundaries. Although, there always exist important regulatory and business issues concerning the integration of DG in the grid, technical considerations are often viewed as a critical factor affecting the development of new installation (Taylor, 1994; Huang and Znao, 2001). The steady state voltage and reactive power control in distribution system can be properly controlled by co-coordinating the available voltage and reactive power control equipment such as on load tap changer, substation, shunt capacitor and feeder determining the optimum set point of equipment from offline calculation. Distributed generation may increase the risk of under voltage. Lower voltage this risk can be reduced or even be mitigated, if the voltage and reactive power control.

At any point of time, a power system operating condition should be stable; meeting various operational criteria and it should also be secure in the event of any credible contingency present day. Power systems are being operated closer to their stability limit due to economic and environment constraints. Voltage instability phenomenon

are the one in which the receiving end voltage decreases well below its normal value and does not come back even after setting restoring mechanism, such as VAR compensator or continuous to oscillate for lack of damping against the disturbance.

IMPACT OF DISTRIBUTED GENERATION UNIT IN POWER SYSTEM

Distribution systems are traditionally passive and designed to operate with such unidirectional energy flow as the transmission system designed for two way power flow; in planning and operating. It is assumed that electric power always flows from the secondary winding of the transformer (Taylor, 1994; Huang and Znao, 2001) in substation to the end of feeder. With newly introduced distributed generation, the distribution system becomes an active system with both energy generation and consumption at the formerly exclusive load nodes. Bidirectional power flow should now be incorporated in the hierarchical network design and its operation criteria (Van Thong *et al.*, 2005). Voltage stability analysis often requires examination of a lot of system state and many contingency scenarios. For this reason, the approach based on steady state analysis is more feasible and it can also provide global insight of the voltage reactive power problem (Huang and Znao, 2001).

In the operation of a power system at any given time, there must be balance between the electricity supply and the demand. A power system should therefore, be able to maintain this balance under both normal condition (steady state) and after disturbance (transient). The stability of a power system is defined as a property of a power system that enables it to remain in a state of equilibrium after being subjected to a disturbance.

(Kundur *et al.*, 1994). The operating condition of a power system is described according to physical quantities. Such as the magnitude and phase angle of the voltage at each bus and the active/reactive power flowing in each line. If these quantities are constant over time, the system is considered to be in disturbance (Grainger and Steuenson, 1968). The disturbance can be small or large depending on their origin and magnitudes. For instance, small variation in load and generation are type of large disturbance (Grainger and Steuenson, 1968). Distributed system network are designed to receive power from the transmission line and then distribute it to customer, thus real power and reactive power both flow in one direction, however when DG unit are installed in distribution system the direction of the real and reactive power may be reversed, therefore the penetration of DG unit into distribution system effects the stability of the system and as the penetration level increase, stability becomes a significant issue. Any fault occurring in the distribution system might cause voltage and angle instability (Grainger and Steuenson, 1968; Chiang and Jean-Jumeau, 1995).

Voltage stability: Voltage stability refers to the ability of a power system to maintain steady and acceptable voltage at all buses in the system after being subjected to a disturbance from a given initial operating condition. The main factor causing voltage instability is inability to meet the reactive power demand (Kundur *et al.*, 1994). Voltage stability can be classified as smaller or large based on the disturbance type. Small voltage stability refers to the ability of the system to control the voltage when small perturbation occurs, such a change in the load. Large voltage stability refer to the ability of the system to control the voltage after being subjected to large disturbance such as load outage, fault and large step change in the load. Voltage stability can be evaluated by two different method of analysis, i.e., static and dynamic.

Static analysis: This method examines the viability of the equilibrium point represented by a specified operating condition of the power system. This method allows the examination of a wide range of system condition. The electric utility industry depends on P-V and Q-V curve in order to determine stability o selected bus (Fig. 1).

P-V curve: P-V and Q-V curve are generated by executing a large number of power flow using power flow method in this case, a power system is typically modeled with non-linear differential algebraic equation (Fig. 2):

$$x = f(x, \lambda) \quad (1)$$

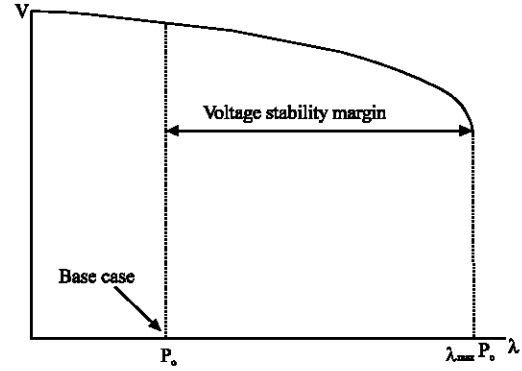


Fig. 1: P-V curve or nose-curve

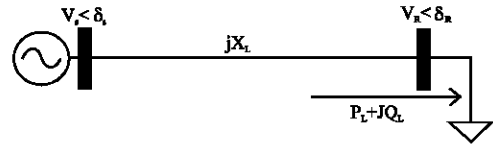


Fig. 2: Single machine PV-bus supplying a PQ load bus

Where, $x \in R^n$ represent a state vector including the bus voltage magnitude (v) and (δ) $\lambda \in R^m$ is a parameter vector that represent the real and reactive power demand at each load bus:

$$O = f(x, \lambda) \quad (2)$$

The parameter λ varies in the load. Therefore, the power flow equation also λ varies.

Dynamic analysis: Dynamic analysis can show the real behaviour of the system such as loads (dynamic and static), DG units, automatic voltage and frequency control equipment and the protection systems. The overall power system is represented by a set of first order differential equations, as given in Eq. 3:

$$\dot{X}f(x, V) \quad (3)$$

And a set of algebraic equations:

$$I(x, V) = Y_N V \quad (4)$$

with a set of known initial conditions (X_0, V_0).

Where:

X = State vector of the system

V = Bus voltage vector

I = Current injection vector

Y_N = Network node admittance matrix

LINE LOSS REDUCTION ANALYSIS

Electrical line loss occurs when current flow through transmission and distribution system the magnitude of the loss depends on amount current flow and the line resistance. If DG is used to provide energy locally to the load, line loss can be reduced because of the decrease in current flow in same part of the network.

Line loss analysis for system without DG: Schematic of the system for this analysis is shown in Fig. 3. Line loss on a distribution feeder is equal to the product of line current squared times the line resistance. Therefore, line loss equation for a three phase system is defined as:

$$\text{Loss}_B = \frac{rL(P_L^2 + Q_L^2)}{3V_p^2}$$

Line loss analysis with DG: Assuming that the line is short, voltage drop along the line is neglected. Schematic of this system is shown in Fig. 4.

The complex power supplied by the DG equals to $S_G = P_G + jQ_G$. Thus, DG output current is given as:

$$I_G = \frac{(P_G - jQ_G)}{3V_p}$$

The line loss with the integration of DG is a combination of two parts:

- Line loss from source to the location of DG
- Line loss from DG location to the location of load

Simulation of line loss reduction analysis: The influence of varying DG location and varying DG power output are discussed. In order to evaluate the effect of DG power output to the system loss both of load and DG power are set at 0.85 lagging the DG power output are varied over seven values 0.2, 0.4, 0.6, 0.8 and 1.0, 1.2 and 1.4 pu while the amount of load is kept constant at 2.0 pu.

From Fig. 5, it is clearly seen that DG can reduce the line loss in the system this is due to the fact that DG supplies a portion of real and reactive power to the load, Fig. 5 show that the DG rating increase higher than 2.0 pu the rate of line loss reduction actually decline. The suitable rating of DG mainly depend on the amount and location of load in the feeder.

The location of DG also plays a vital role for electrical line loss. To study this affect, the locations of DG are varied along the feeder: 20 (location 1), 40 (location 2),

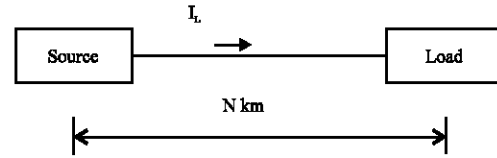


Fig. 3: A simple radial distribution system without WTG

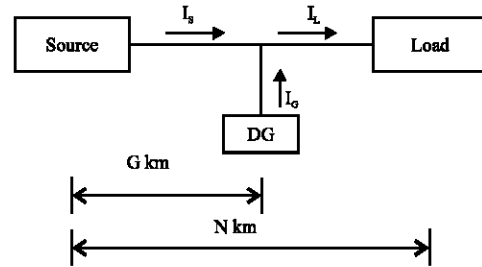


Fig. 4: Schematic of a radial system with the inclusion of DG

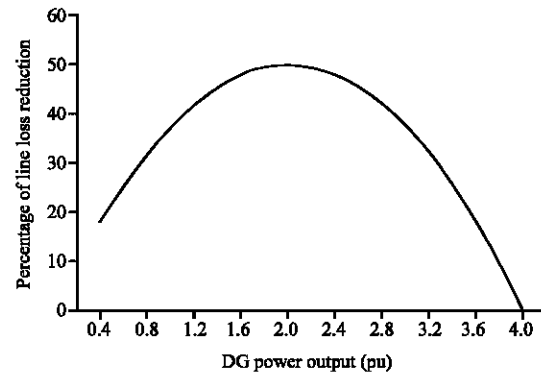


Fig. 5: Variation of line loss reduction with DG power output

60 (location 3), 80 (location 4) and 100% (location 5) from the source while load and DG power factors are kept at 0.85 lagging. PULR are calculated once again by thirteen and the results are shown in Fig. 6.

Figure 6 clearly indicate that both of rating and location of DG are highly sensitive to the line loss in the system. The results show that the line loss reduces as DG is installed closer and closer to the load. However, this fact only applies for the case that DG rating is well matched with the amount of load. If the ratio of DG power output to the amount of load increases beyond the suitable point, the DG that installed near the load will cause more electrical line loss than the one that installed far away from the load. This is because load cannot consume all the power supplied by DG.

Since, the DG can be operated in either lagging or leading power factor mode, its operating power factor also

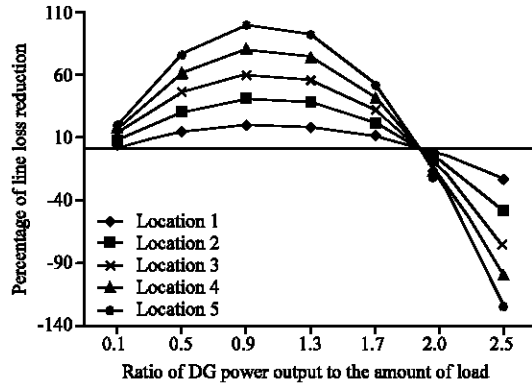


Fig. 6: Variation of line loss reduction with different DG power output and location

has an impact on feeder line loss to evaluate the influence of DG operating power factor. DG power factor is set to operate at 0.8 lagging and 0.9 leading. It is seen in Fig. 6 that line loss reduction exhibits the higher value under lagging power factor condition than leading power factor (Kundur *et al.*, 2004).

CONCLUSION

Distributed Generation affect the voltage profile of the system by power injection. It can improve and support the voltage profile and voltage stability of the distribution system. The location of DG has a major impact on the voltage stability of the system the power factor of DG has a strong influence on voltage rise. In this study, case of distributed generation is one of the many strategies electric utilities are considering to operate their system in the deregulated environment. In elusion, of DG at the

distribution level result in several benefits, among which are congestion relief, loss reduction and over all improvement of energy efficiency reliability and loss reduction in DG network the result clearly indicate that DG can reduce the electrical line loss, however the inclusion of DG does not always guarantee the line loss for DG network rating, location and operating power factor are important factor for line loss reduction.

REFERENCES

- Chiang, H.D. and R. Jean-Jumeau, 1995. Toward a practical performance index for predicting voltage collapse in electric power systems. IEEE Trans. Power Syst., 10: 584-592.
- Grainger, J.J. and W.D. Steuenson, 1968. Power System Analysis. McGraw-Hill, New York, USA.
- Huang, G.M. and L. Znao, 2001. Measurement based voltage stability monitoring of power system. <http://www.pserc.wisc.edu/ecow/get/publicatio/2001public/indicator.pdf>.
- Kundur, P., N.J. Balu and M.G. Lauby, 1994. Power System Stability and Control. McGraw-Hill, New York, USA.
- Kundur, P., J. Paserba, V. Ajjarapu, G. Andersson and A. Bose *et al.*, 2004. Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions. IEEE Trans. Power Syst., 19: 1387-1401.
- Taylor, C.W., 1994. Power System Voltage Stability. 1st Edn., McGraw-Hill, Ohio, USA., ISBN: 0-0706-3184-0.
- Van Thong, V., J. Driesen and R. Belmans, 2005. Power quality and voltage stability of distribution system with distributed energy resources. Int. J. Distributed Energy Resour., 1: 227-240.