Placement of Distributed Generation for Improvement of Voltage Profile in Distribution System

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Abstract- Distributed Generation is an approach that employs small-scale technologies to produce electricity close to the end users of power.When total system load is more than its generation capacity that makes relieving of load on the feeders not possible and hence voltage profile of the system will not be improved to the required level. In order to meet required level of load demand, DG units are integrated in distribution network to improve voltage profile, to provide more reliable and less uninterrupted power supply. Voltage stability is an important problem in the emerging world of technologies and development, the main objectives in operating an electric power system is to maintain a proper voltage level thought DG. Voltage Stability Index method is to be used for determining DG placement candidates. A Voltage Stability Index method is to be executed on the system and the bus with a minimum voltage at the collapse point is defined as the most sensitive bus to voltage collapse. This bus is to be selected as a candidate for DG placement.

Keyword—*Distributed generation (DG), distribution system, optimum power flow, voltage profile, voltage stability.*

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I. INTRODUCTION

The Distributed Generation energy sources can be classified into conventional and non-conventional. The conventional sources include combustion turbines, reciprocating engines, micro turbines and fuel cells. Natural gas and petroleum are used for these forms of distributed generation. However, there is growing trend towards using non-conventional sources. This is evidently, due to the fact that natural gas and petroleum sources are fast depleting and also due to growing environmental concerns. Biomass, solar and wind energy distributed generation systems are being increasingly added to the grids and this trend will increase in future. The non-conventional energy sources have the disadvantage of high investment cost, where a significant part of this investment cost is the cost of power electronics interface. Voltage Stability Index method is to be used for determining DG placement candidates. A Voltage Stability Index method is to be executed on the system and the bus with a minimum voltage at the collapse point is defined as the most sensitive bus to voltage collapse. This bus is to be selected as a candidate for DG placement. The bus, which has the biggest participation factor in each mode, is to be selected as another candidate for DG placement. Thereafter, the DG will be installed at one of the candidates and a continuation power flow method will be carried out on the system with the installed DG to determine the system maximum loading. This procedure is repeated for all candidates. The bus with highest loading factor is to be selected as the best candidate bus for DG placement

II. METHODOLOGY

An equivalent two-bus system of a distribution network is used for the analysis of voltage stability. The Voltage Stability Index technique is implemented on well-known 33-bus radial distribution network.

A. Load Flow Approach

This is a simple and efficient method for solving radial distribution networks. The proposed method involves only the evaluation of a simple algebraic expression of voltage magnitudes and no trigonometric functions as opposed to the standard load flow case. Thus, computationally the proposed method is very efficient and it requires less computer memory. The proposed method can easily handle different types of load characteristics. [D. Das *et al.*, 1995].

A two bus equivalent of a typical network is shown in Fig.

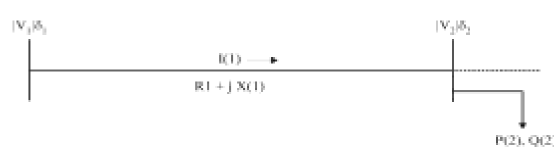

Fig 2. Electrical equivalent

$$I(1)=\frac{|V(1)|\angle\delta(1)-|V(2)|\angle\delta(2)}{R(1)+jX(1)}$$

$$P(2)-jQ(2)=V^{*}(2)I(1)$$

$$\frac{|V(1)\angle\delta(1)-|V(2)||\angle\delta(2)}{R(1)+jX(1)}=\frac{P(2)-jQ(2)}{V^{*}(2)}$$

$$|V(1)||V(2)|\angle\delta(1)-\angle\delta(2)-|V(2)|^2=[P(2)-jQ(2)][R(1)+jX(1)]$$

$$|V(1)||V(2)|\cos[\delta(1)-\angle\delta(2)]-|V(2)|^2+j|V(1)||V(2)|\sin[\delta(1)-\angle\delta(2)]$$
$$=[P(2)R(1)+Q(2)X(1)]+j[P(2)X(1)-Q(2)R(1)]$$

Separating real and imaginary parts of equation we obtain

$$|V(1)||V(2)|\cos[\delta(1)-\angle\delta(2)]-|V(2)|^2=$$
$$P(2)R(1)+Q(2)X(1)$$

Therefore,

$$|V(1)||V(2)|\cos[\delta(1)-\delta(2)]=|V(2)|^2+P(2)R(1)+Q(2)X(1)$$

and

$$|V(1)||V(2)|\sin(\delta(1)-\delta(2))=P(2)X(1)-Q(2)R(1)$$

Squaring and adding above equation, it obtains,

$$|V(1)|^2|V(2)|^2=\left[|V(2)|^2+P(2)R(1)+Q(2)X(1)\right]^2+\left[P(2)X(1)-Q(2)R(1)\right]^2$$

or

$$|V(2)|^4-[|V(1)|^2-2P(2)R(1)-2Q(2)X(1)]|V(2)|^2$$
$$+[P^2(2)+Q^2(2)][R(1)^2+X(1)^2)]=0$$

Let,

$$b(1)=[|V(1)|^2-2P(2)R(1)-2Q(2)X(1)]$$
$$c(1)=[P^2(2)+Q^2(2)][R(1)^2+X(1)^2)]$$

From Eqs.

$$|V(2)|^4-b(1)|V(1)|^2+c(1)=0$$

From above eq., it is seen that the receiving end voltage $|V(2)|$ has four solutions. When P, Q, R, X and V are expressed in per unit, b(1) is always positive because the term $2\{P(2)R(1)+Q(2)X(1)\}$ is very small as compared to $|V(1)|^2$ and also the term 4c (1) is very small as compared to b^2 (1). Therefore $\{b^2(1)-4c(1)\}^{\frac{1}{2}}$ is nearly equal to b(1) and hence the first two solutions of $|V(2)|$ are nearly equal to zero and not feasible. The third solution is negative and so not feasible .The fourth solution of $|V(2)|$ is positive and feasible. Therefore, the solution of above eq. is unique. That is

$$|V(2)|=0.707[b(1)+\{b^2(1)-4.0c(1)\}^{\frac{1}{2}}]^{\frac{1}{2}}$$

Where P(2) and Q(2) are total real and reactive power loads fed through node 2.

Real and reactive power losses in branch 1 can be given by:

$$LP(1)=\frac{R(1)*[P^2(2)+Q^2(2)]}{|V(2)|^2}$$

$$LQ(1)=\frac{X(1)*[P^2(2)+Q^2(2)]}{|V(2)|^2}$$

B. Voltage Stability Evaluation Using Voltage Stability Index Method

The high R/X ratio of the distribution lines results in large voltage drops, low voltage stability and power losses. Under critical loading conditions in certain industrial areas, RDS experiences sudden voltage collapse due to low value of voltage stability index at most of its nodes. The effect of DG capacity and location on voltage stability analysis of radial distribution system is investigated. The analysis process is performed using a steady state voltage stability index. This index can be evaluated at each node of radial distribution system. A new steady state voltage stability index is proposed for identifying the node, which is the most sensitive to voltage collapse.

A feasible load flow solution of radial distribution networks will exist if

$$b^2(1)-4c(1)\geq 0$$

$$\{|V(1)|^2-2P(2)R(1)-2Q(2)X(1)\}^2-4.0\{P^2(2)+Q^2(2)\}\{R(1)^2+X(1)^2)\}\geq 0$$ After simplification,

$$|V(1)|^4-4.0\{P(2)X(1)-Q(2)R(1)\}^2-4.0\{P(2)R(1)+Q(2)X(1)\}|V(1)|^2\geq 0$$ Let,

$$|V(1)|^4-4.0\{P(2)X(1)-Q(2)R(1)\}^2-4.0\{P(2)R(1)+Q(2)X(1)\}|V(1)|^2$$ By using this voltage stability index, one can measure the level of stability of radial distribution networks and thereby appropriate action may be taken if the index indicates a poor level of stability. For stable operation of the radial distribution networks, SI (2) ≥ 0. The node where the value of the stability index is found minimum can be treated as more sensitive to the voltage collapse. After the load flow study, the voltages of all the nodes are known, the branch currents are known, therefore P(2) and Q(2) for m = 2,3,4….n can easily be calculated and hence one can easily calculate the voltage stability index of each node.

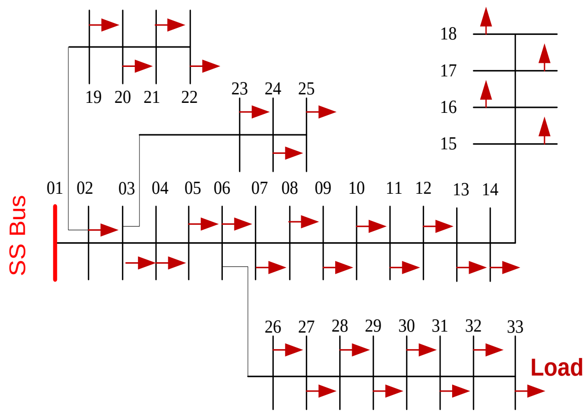

Fig 3. Distribution test system of 33 buses.

III. RESULTS

A. Results of the Impact of the DG Units on Voltage Profile

The selection is achieved by developing various case studies (the cases are equal to the number of the system buses which are located in the main feeders). In each case, a DG unit is installed at a certain bus, and the changes of the system voltages are observed. The installed DG unit is assumed to generate constant power of 4.5 MW at unity power factor (about 30% of the penetration level), and the system load demand is taken at the peak value.

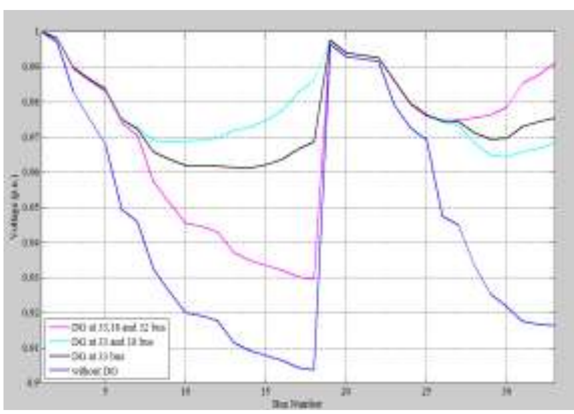

Fig 4. Voltage profile for different placement scenarios (PL=40%)

Two DGs in buses 33 and 18, VSI shows that bus 32 is the most sensitive bus to voltage collapse, while the modal analysis presents buses 12, 22, 28, 25 and 15 as critical buses. Finally, bus 32 is selected as the best place for the third DG. The system active and reactive losses for different placement scenarios when the DGs active power is limited to 0.4 total load and no voltage regulation is performed by DG

B. Results of the Impact of the DG Units on active and reactive losses

Fig shows the impact of the DG unit on voltage stability margin and maximum loadability. The DG unit is installed at bus 40. This PV curve represents the voltage stability at bus 33. The load demand in bus is 2.166 MW, which corresponds to in Fig 4. When the DG unit generates 4.4 MW, the voltage moves from (0.924 p.u) to (0.959 p.u.). Thus the voltage stability margin is improved by 0.82 MW. Fig 5. shows the impact of the DG units on voltage (moves to) and the maximum loadability (moves to). This result only represents one size and location. However, the size and location can also have an impact on the voltage stability. The rest of this section presents the impact of the size and location of the DG units on both the voltage and the maximum loadability. The study of the impact of the DG size is conducted by installing one DG unit in one of the candidate buses, and then finding the maximum loadability and the voltage of the system. The DG unit is varied from 0 to 16 MW.

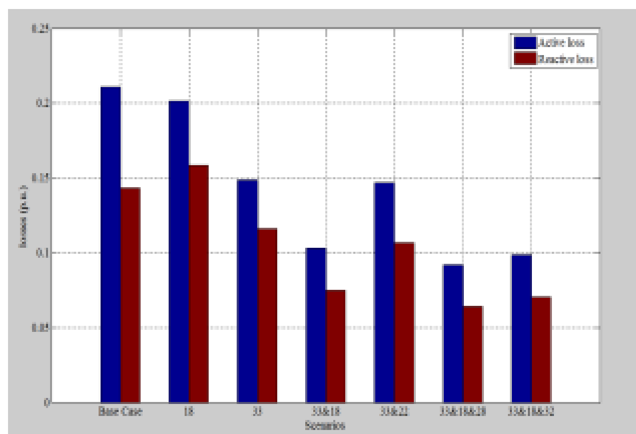

Fig5. Active and reactive losses

Then, the same method is applied for the other candidate buses. Alternatively, the impact of the DG location study is achieved by developing 26 cases (the cases are equal to the number of the system buses which are located in the main feeders). In each case, a DG unit is installed at a certain bus, and the maximum loadability is observed.

Thus, applying optimization method can solve the problem of placement and sizing of the DG units to improve the voltage stability margin.

C. Results of the DG Sizes and Locations

The results for the scenario which are presented in this Section are given in Tables 1.

Table 1 Results of the dg location and size, scenarios

DGs Penetration Level	Placement Situation	Candidate Bus by VSI	ALR	RLR	VI
Base Case (0%)		–	–	–	0.1143
20%	Sit. 1	33	32.22	29.38	0.0691
	Sit. 2	18	41.83	42.23	0.0314
	Sit. 3		–	–	–
40%	Sit. 1	33	28.42	18.87	0.0417
	Sit. 2	18	30.99	47.41	0.0189
	Sit. 3	32	53.08	50.53	0.0209
60%	Sit. 1	33	-0.9932	-24.89	0.0280
	Sit. 2	18	34.17	22.57	0.0045
	Sit. 3	28	71.48	48.38	0.0049

IV. CONCLUSION

In this paper, Voltage stability index method is used for determining DG placement candidates, while the loading parameter is the comparison index for selecting the best DG places. The placement algorithm is executed on the well-known 33-bus radial distribution network, and the results show the remedial effect of DGs, both in loss reduction and voltage profile improvement in normal operation, and enhancement of the loading parameter in the case of voltage instability. The ranking method is executed over the obtained candidates to provide a priority list from the viewpoint of reactive power compensation in the case of shortage. The main objective is to serve a high amount of load as possible with a higher voltage when a shortage occurs, while the placement algorithm seeks the maximum VSM in the presence of a voltage-stability problem. The results show that the best candidate for DG placement is different from the best location for reactive power compensation. So the long-term DG placement problem can be solved by the proposed placement algorithm, while the short-term reactive powers issues can be addressed by the ranking method.

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