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Enhancement of Distribution System Loadability DG under Reconfigured Environment

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Abstract

Objectives: In this paper a comprehensive analysis of DG is done under initial configuration (base case) as well as with the feeder reconfigured environment in order to minimize the losses and to enhance voltage stability index. **Methods/Analysis**: In today's trend delivery of power to customers have become a major issue in the field of power systems, one as such solution to this issue is usage of small units named as Distributed Generators (DG) entered the area of distribution systems. **Findings**: With the involvement of DG's, a given system can achieve an improvement in terms of reliability, stability and reduction of losses. It just not only by using DG alone will solve the issue, but also mainly we have to focus on its location, size and the type which has to be used. **Application /Improvement**: For this analysis a standard IEEE 33-bus and 69-bus test distribution system is taken under nominal load consideration and the results are tabulated.

Keywords: Distributed Generation, Distribution System, Real Power Loss, Reconfiguration, Voltage Profile, Voltage Stability Index

1. Introduction

An Electrical power system comprises of generation, transmission, distribution networks. Since distribution systems are being complex and large it may lead to high system losses and poor voltage regulation. In this scenario due to increment in load at load centers, power has to be supplied in order to reduce the power loss which has increased in the system. Majority of power industry companies in developing countries are undergoing restructuring. Radial distribution networks have most conventional configuration which feeds load from a single source, where power flow is typically unidirectional so simplistic protection devices are adequate. In radial distribution systems two types of switches are normally employed tie line switches (Normally Open) and sectionalising switches (Normally Closed). The switching topology of above mentioned switches are altered so as to maintain the radiality in the network.

The reconfiguration technique to the meshed distribution system initially closing all the switches there by opening the consecutive switches which produces minimum loss an extension was proposed with basic difference of opening one switch after other for optimal flow[1,2]. The same algorithm with simplified formulae for the reduction of line loss[3]. The different radial configurations are generated, originating a sequence of man oeuvres to be performed on network[4]. Reconfiguration problem is also modeled by Graphical Representation and it is solved by Graph Chain Representation technique[5].

Reconfiguration is a phenomenon in which changing the structure of a topological network either by opening or closing the switches in the distribution system. While maintaining the radial structure of the network, a heuristic search which consists of repeated application of branch exchange, where some loads are switched from one feeder to other feeder[6]. Over the last few decades, implementations of DG on grids around the world have been steadily increasing[7]. DG is defined as the electrical generation which is directly connected to the loads at the distribution end typically varies from few kW to tens of MW[8]. In order to reduce loss and improve reliability of distribution system

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the combination of DG and main network is considered[9]. For optimal location and size of DG unit for minimizing the power loss and improve voltage profile of system.

In this paper a comprehensive analysis is done in analyzing the size, location and type of DG to be placed in order to minimize the losses, enhancement of voltage stability index. In Section 2 mathematical relations are formulated for minimizing power loss based on different constraints. As losses will be minimized with the placement of DG and the voltage levels are to be within the limits so in Section 3 voltage stability index is analyzed. Optimal location of DG plays a vital role in enhancing the performance of system a GA based approach is used to find exact and accurate location shown in Section 4. A sample system of 33-bus and 69-bus system are shown and discussed in section 5 which are further tested with optimal placement of DG and results are shown in section 6.

2. Problem Formulation

In order to determine direction of power flow in the system, it is crucial due to the presence of reconfiguration techniques and DG in the distribution network. Reconfiguring a network with or without the presence of DG unit's produces, the minimum amount of power loss by applying formulae which is developed. The objective function of the study is:

$$\text{Minimize } P_{losses} = \sum_{i=1}^{n} |I_i|^2 R_i \tag{1}$$

Where

I_i = Line current.

R_i = Line resistance.

Several constraints of the power system have been taken into consideration.

- Constraints of Distributed Generator operation:

$$p_i^{min} \leq p_{Dg,i} \leq p_i^{max} \tag{2}$$

- Constraints of DG:

$$\sum_{i=1}^{k} P_{DG} < P_{Load} + P_{Losses} \quad ,k = no.of\ DG \tag{3}$$

- Equality Constraint :

$$\sum_{i=1}^{k} P_{DG} + P_{Substation} = P_{Load} + P_{Losses} \tag{4}$$

d) Voltage limits :

$$V_{min} \leq V_{bus} \leq V_{max} \tag{5}$$

3. Voltage Stability Index

An index which states the ability of the system, stable or unstable under normal operating conditions and also after being subjected to disturbances. As disturbance increased in load demand or change in system conditions a system is said to enter to voltage instability which causes a progressive and uncontrollable drop in voltage[10,11]. Instability occurs in the form of a progressive fall or rise of voltages of interconnected buses after reconfigured. In power system the reason to meet the demand for the reactive power is the main factor causing instability.

A VSI has been developed from the commonly used quadratic equation to calculate the line sending end voltages in load flow analysis which can be written as

$$V_r^4 + 2V_r^2(PR + QX) - V_s^2V_r^2 + \left(\mathbf{P}^2 + \mathbf{Q}^2\right)|\mathbf{Z}|^2 \tag{6}$$

Where

V_r is the node voltage at the receiving end

V_s is the node voltage at the sending end

P is active power

Q is reactive power

R line resistance

X line reactance

Equation (1) and (6) represents the objective functions for minimization of losses and improving the voltage stability. By combining the two equations the overall objective function is given by

$$\text{Minimize } F_1 = W_1 P_{loss} + W_2 \frac{1}{VSI} \tag{7}$$

where

W_1= 0.5 and W_2= 0.5

W_1 and W_2 is weight factors

After the load flow study, the voltages of all nodes and the branch currents are noted, and then P and Q can be calculated at the receiving end of each line.

7. Optimal Sizing and Sitting of Dg using Ga

If power losses and voltage stability index are within the limits, DG can be placed at any optimal location among 33-bus or 69-bus as proposed in the system. Taking only a DG into consideration, it has to be accurately located for optimal performance of the system.

GA is an iterative procedure which begins with a randomly generated set of solutions referred as initial population from which groups are selected, called selection and henceforth it follows as shown.

Selection: This process is used to identify the best individual for crossover

Crossover: The best individual gone to crossover to produce off springs.

Mutation: Some individuals are randomly modified, in order to reach other points of the search space.

Fitness Function: This defines the objective of the work. Reduction of real power loss is the core of this work

The control flow diagram for emplacement and size of DG is shown in Figure 1. In solving for placement and sizing of DG problem requires defining the objective function is to be optimized in satisfying of equality and inequality constraints. The fitness function to be evaluated here is reducing power loss. GA selects the required power ratings of the DG set and location for this placement.

5. System Under Study

In 33-bus system network has 33 buses, 32 sectionalizing switches, 5 tie switches represented as shown in Figure 2. The total load real and reactive power load of the system is 3.715 MW and 2.3 MVAR respectively and the system MVA base (S_{base}) is 100 MVA. The base voltage (V_{base}) is 12.66 KV. The 69-bus system network consists of 69 buses, 68 sectionalizing switches, 5 tie switches represented as shown in Figure 3. The total load of the system is 3.8 MW and 2.68 MVAR. The maximum active output of DG in this study is set to 3 MW.

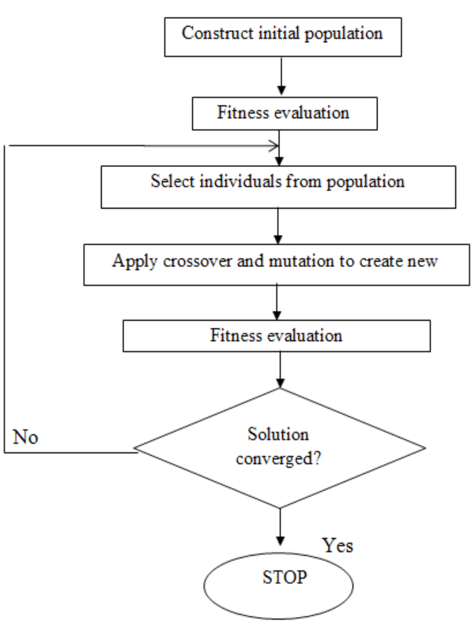

Figure 1. Flow chartfor GA approach.

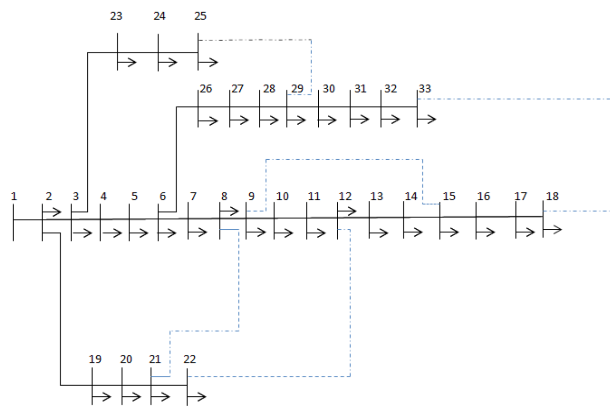

Figure 2. 33-Bus radial distribution system.

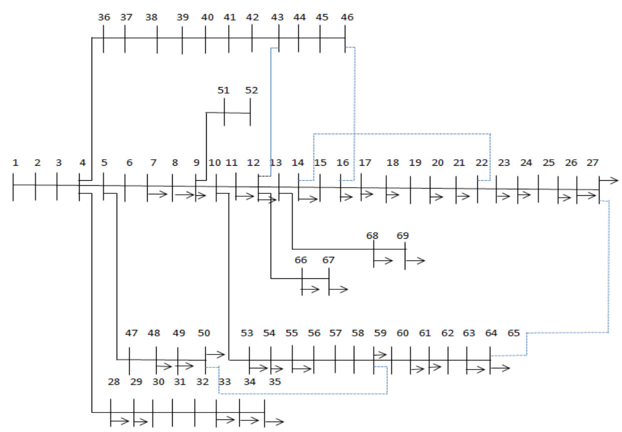

Figure 3. 69-bus radial distribution system.

6. Result and Discussion

A comprehensive analysis of DG under initial configuration, feeder reconfigured environment is considered in order to minimize the losses and also to enhance voltage stability index. Further a standard IEEE 33-bus and 69-bus test distribution system is taken under nominal load consideration and results are as tabulated.

Test system I

It is a 33 bus radial distribution system[12] which consisting of 32 sectionalizing switches and five tie switches. In this network, tie switches (normally open) are numbered from 33 to 37, sectionalizing switches (normally closed) are numbered from 1 to 32. The load data and line data are taken from[13], the total load on the system i.e., real and reactive power loads on the system is 3.715 MW and 2.3 MVAR. GA approach is used for optimal placement and size of DG unit for minimizing the power loss and improves voltage profile of system. The maximum active output of DG in this study is set to 3MW.Under normal load condition the placement and size of DG are given in Table 1.

In this system tie switches 33,34,35,36 and 37 are opened as initial configuration, the loss in real power loss is 223.87 kW. If the same network is reconfigured with 8, 13,14,28,33 switches opened, the power loss is reduced to 118.057 kW when compared with initial configuration. The impact of reconfiguration on active loss reduction can be observed which accounts to 47.26 % (223.87 kW to 118.05 kW). If the initial network is configured with installation of only DG when tie switches are opened the power loss will be 201.51 kW by placing DG in location 32 of size 200 kW. The impact of DG on the network reduces active loss to 5.96 % (223.87 kW to 201.511 kW). Again, if the same initial configured network run with installation of DG with reconfiguration, the power loss will be 101.79 kW by placing DG in location 26 of size 400 kW when 8, 13,14,28,33 switches opened.

In this system for initial configuration, the minimum voltage produced is 0.9134 p.u. When this system runs with installation of only DG it produces minimum voltage of 0.9165 p.u, when the same initial configured network is replaced with reconfigured configuration the minimum voltage produced is 0.9483 p.u. By placing a DG in the reconfigured network the minimum voltage produced is 0.9486 p.u.

For minimum Voltage Stability Index (VSI), the initial configured network will have min VSI of 0.6954 p.u in location 17 when the DG is installed to this configured network the min VSI is increased and is 0.7500 p.u in location 17 this can be observed for Figure 4. Similarly the reconfigured network will have min VSI of 0.8115 p.u in location 16 when the DG is installed to this reconfigured network the min VSI obtained is made to get increased, it will be 0.8523 p.u in location 16 this can be observed from Figure 5.

Table 1. Results of 33 bus Radial Distribution System

	Base case	Only reconfiguration	OnlyDG installation	DG installation after reconfiguration
Switches opened	33,34,35,36,37	8,13,14,28,33	33,34,35,36,37	8,13,14,28,33
P_{loss}(kW)	223.87	118.057	201.511	101.79
Location	…...	……	32	26
Size (p.u)	……	……	0.002	0.004
Minimum voltage(p.u)	0.9134	0.9483	0.9165	0.9486
VSI(p.u)	0.6950	0.8115	0.75002	0.8523
F_1	112.65	59.636	101.417	51.476

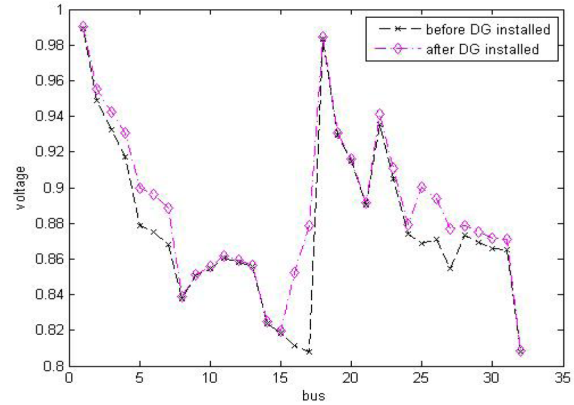

Figure 4. VSI for initial configuration – 33 bus Radial Distribution System.

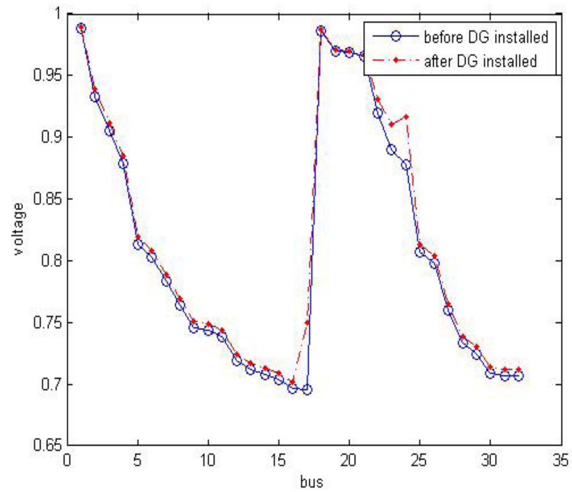

Figure 5. VSI for reconfigured network – 33 bus radial distribution system.

Test system II

It is a 69 bus RDS[14] has 68 isolating switches and five tie switches. In this network, tie switches (normally open) are numbered from 69 to 73, sectionalizing switches (normally closed) are numbered from 1 to 68. The total load on the system i.e., real and reactive power loads on the system is 3.8 MW and 2.68 MVAR. A GA approach is used for optimal placement and size of DG unit to minimize the active power loss and boost the node voltage of the system. The maximum active output of DG in this study is set to 3 MW. Under normal load condition the placement and size of DG are given in Table 2.

In this system tie switches 69,70,71,72 and 73 are opened as initial configuration, the active power loss is 224.17 kW. If the same network is reconfigured with 9, 12,17,26,58 switches opened, the active power loss reduced to 155.3 kW when compared with initial configuration. The impact of reconfiguration on loss reduction has been observed that it is better than, which accounts to 30.72 % (224.17 kW to 155.3 kW). If the initial network is configured with installation of only DG when tie switches are opened the power loss will be 199.09 kW by placing DG in location 64 of size 200kW. The impact of installation of DG on power loss reduction can be observed which accounts to 25.08 % (224.17 kW to199.09 kW). Again, if the same initial configured network operated with the installation of DG under reconfigured network, the power loss is 119.26kW by placing DG in location 63 of size 900 kW with switches 9, 12,17,26,58 opened. The impact of reconfiguration on active loss reduction accounts to 46.79% (224.17 kW to 119.26 kW) it is observed from Table 2.

In this system, for initial configuration, the minimum voltage produced is 0.91p.u. When this system runs with installation of only DG it produces minimum voltage of 0.921p.u, when the same initial configured network is replaced with reconfigured configuration the minimum voltage produced is 0.9296 p.u. By placing a DG in the reconfigured network the contribution is felt at the installed place with a minimum voltage produced as 0.9459p.u.

Table 2. Results of 69 bus Radial Distribution System

	Base case	Only reconfiguration	Only DG installation	DG installation after reconfiguration
Switches opened	69,70,71,72,73	9,12,17,26,58	69,70,71,72, 73	9,12,17,26,58
P_{loss}(kW)	224.17	155.30	199.09	119.26
Location	…...	……	64	63
Size (p.u)	……	……	0.002	0.009
Minimum voltage (p.u)	0.91	0.9296	0.921	0.9459
VSI (p.u)	0.6867	0.7387	0.6881	0.807
F_1	112.81	78.32	100.27	60.24

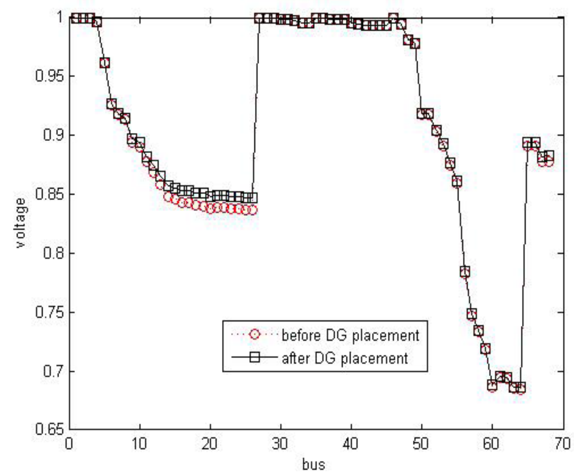

Figure 6. VSI for initialconfiguration–69 bus radial distribution system.

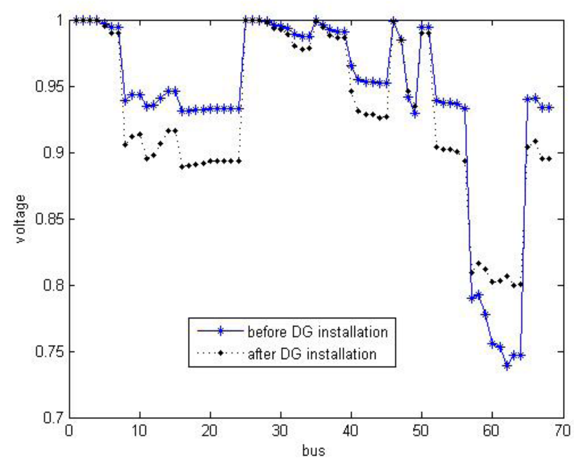

Figure 7. VSI for reconfigured network–69 bus radial distribution system.

Considering the Voltage Stability Index (VSI), the initial configured network will have a min VSI of 0.6867 p.u in location of bus 60 when the DG is installed to this location after reconfiguration the min VSI is increased to 0.6881 p.u in same location which can be observed from Figure 6. Similarly the reconfigured network will have min VSI of 0.7387 p.u in the location bus of 62, when the DG is installed the min VSI gets increased to 0.807 p.a. in the same location which can be observed from Figure 7.

7. Conclusion

From the detailed comprehensive analysis the work suggests various optimal location, size and type of DG to be placed in a radial distributed system under initial and feeder reconfiguration environment. A GA based approach is implemented in the system for optimal placement, yielded best results for improving the load ability. It has been observed that the losses were minimized, Voltage Stability Index has been enhanced found to be within the limits.

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