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OPTIMAL LOCATION AND SIZING OF DISTRIBUTED GENERATION UNITS IN DISTRIBUTION SYSTEMS

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Abstract

The mushrooming Distributed and Dispersed generation units are extending their supporting hands towards meeting the growing demands of the consumers day to day. But the efficient usage of the generators units is possible only if they are optimally located and sized. The aim of this project is to determine the optimal location and also the size of the distributed generation units to reduce the power losses in the system. Using pre-determined sensitivity indices, the distributed generation location is located. Sensitivity indices identify the most critical locations in the system where the installation of distributed generation can have the greatest impact on reducing power losses. By analyzing the sensitivity indices, the optimal locations for installing distributed generation can be identified. Genetic algorithm[10] is used to determine the optimal size of the distributed generation to minimize power losses. A computational method known as a "genetic algorithm" uses natural selection and evolution to optimize a solution. It is a powerful tool which finds the optimal solution in a large search space. MATLAB software is used to run the simulation. The loading of the distributed generation at the suggested location and size is able to generate the best results in terms of improving the voltage profile and minimising power loss, according to the numerical simulation.

Keywords: Distributed generation, Genetic Algorithm, Voltage Stability Index

Introduction

Power generating plants often have capacities between 150 and 1000 MW due to economies of scale, which requires massive infrastructure including land and high capital expenses. These large power facilities require extra high voltage (EHV) transmission lines along with the substations, hence they cannot be located close to load centres. There is a substantial financial requirement for the power lines and substations. The transmission lines are susceptible to natural disasters because of their intricate nature. Due to challenges from the economy and the environment, traditional power companies have changed their methods for producing electric power. The most practical way to replace the traditional method of producing energy is to use the distributed generation, where the DG is conveniently located closer to load centres. The primary concept behind distributed generation is that it involves small-scale production. To determine the best location and size for distributed generation (DG), that will maximise its benefits, numerous strategies have been put forth [1]. The voltage-based pre-developed sensitivity indices were employed to select an appropriate location for the distributed generator. Pre-developed sensitivity indices were used to locate the best location for the distributed generator by relating to changes in the voltage stability index to change in the injected active and reactive power at a bus. Using the Genetic Algorithm (GA) optimization technique, the ideal capacity sizing for the distributed generator was found.

Methodology

Best Site for DG: Based on two sensitivity techniques that are focused with voltage regulation and power loss, the best site for DG is identified. The Voltage Sensitivity Index (VSI) and the Loss Sensitivity Index (LSI) are used to classify and rank the network nodes as per their readiness to receive new generation. To evaluate a network's capacity to safely absorb distributed resources that are offered, It will be depicted as a steady-state system using power flow equations. Irreversible power flow Jacobian, which connects changes in angles and voltages to changes in power injections,

$$\begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix}^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

The most of power losses are ohmic. These result from the transmission lines electricity flow.

$$\text{P loss} = P(\delta, V)$$

$$\text{Q loss} = Q(\delta, V)$$

According to the Loss Sensitivity Index (LSI)

$$\text{LSI} = W\left[\frac{\partial Ploss}{\partial P}\right] + (1-W)\left[\frac{\partial Ploss}{\partial Q}\right]$$

Where W= Weighing factor which depends on X/R ratio.

By analyzing the fluctuations in the predeveloped voltage stability index with respect to the change of active and reactive power injection at bus will help us to find the distributed generator's ideal position. A Voltage Sensitivity Index (VSI) used is given as:

$$\text{VSI} = W\left[\frac{\partial V}{\partial P}\right] + (1-W)\left[\frac{\partial V}{\partial Q}\right]$$

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Sensitivity indices for each load bus were computed, and the buses with the greatest sensitivity values were chosen for DG installation. Sensitivity indices is obtained from the voltage stability index [2].

The voltage stability index is as below:

$$L_i = \left[4\left[V_{O_i} V_{L_i} \cos\theta_i - V_{L_i}{}^2 \cos\theta_i{}^2 \right] \Big/ V_{O_i}{}^2 \right]$$

Genetic Algorithm:

A Genetic algorithm is one that incorporates some of the genetic concepts [3]. The major guiding ideas in the application of GA are "Natural Selection" and "Evaluation Theory," which are genetic principles.

The GA combines the genetics' adaptive properties with the way that search is conducted through a randomised information exchange. From the current population, to produce the next generation, a genetic algorithm uses two rules at each stage. These include:

i. The individuals (parents) which are responsible for the population of the next generation are chosen using selection criteria.

ii. The Solutions for the second generation population are generated through "Reproduction "through selected genetic operators[4].

These consist of:

a) Crossover—In this case, two parents merge to produce offspring for the next generation.

b) Mutation: In this process, random modifications are made to each parent in order to create children.

Implementation

Optimal location using VSI:

A distribution system will be taken into consideration to determine the best location for DG and then the voltage, angle, power flow through the entire system is calculated by performing load flow analysis.

At every bus voltage stability index and voltage sensitivity indices [5] are calculated by considering voltage constraints.

The bus with the highest voltage sensitivity is the location where the DG is installed[6], following which the load demand is justified. The flow chart to identify the Optimal location of DG is as shown below.

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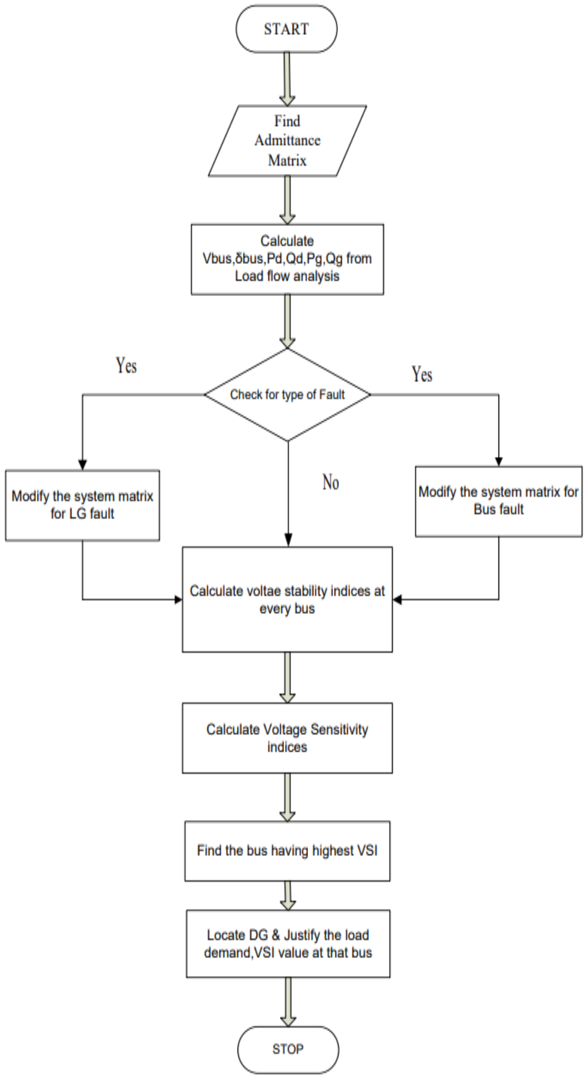

FIG:1 optimal location of DG.

Optimal size using Genetic Algorithm:

The algorithm to identify the optimal size of DG is discussed below:

Step1: Choose the population size and fix the minimum and maximum power generations for the DG

Step 2: Generate initial randomly coded strings as population members in the first generation.

Step 3: Decode the population to determine the strings power generation.

Step 4: To reduce overall network losses, carry out the load flow that was designed with injected real and reactive power at the appropriate site identified by the sensitivity analysis, ensuring that the voltage constraint is maintained.

Step 5: Evaluate the fitness function.

Step 6: Execute the Genetic Algorithm operators they are selection, crossover, mutation.

Step7: Steps 3 to 6 are repeatedly performed for all the number of generations at selected suitable locations determined from the sensitivity analysis. To reduce overall network losses, this process is performed at the ideal DG size at a suitable site.

The flow chart for optimal size of DG is discussed below:

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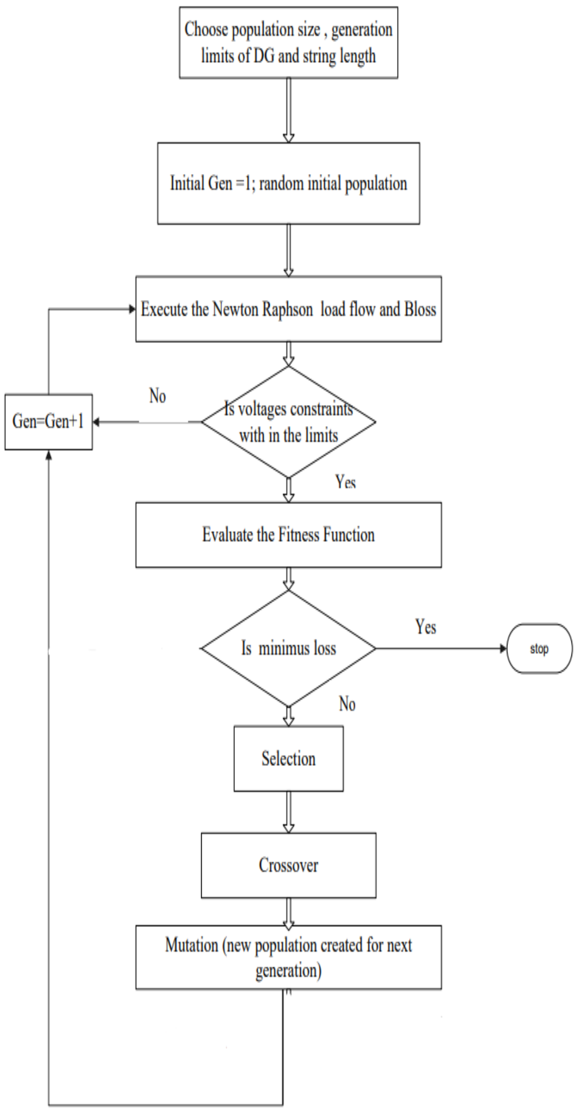

FIG:2 Optimal size of DG.

Results

A 33bus radial distribution system is selected for the study. The performance of the system by connecting DG units to the system is studied by using MATLAB [7] programme. The programme's main module employs the Newton-Raphson technique load flow. By the above approach 5 DGs are placed at bus number 2,4,26,33,31 with their capacities of 307 KW, 351 KW, 896 KW, 373 KW, 244 KW.

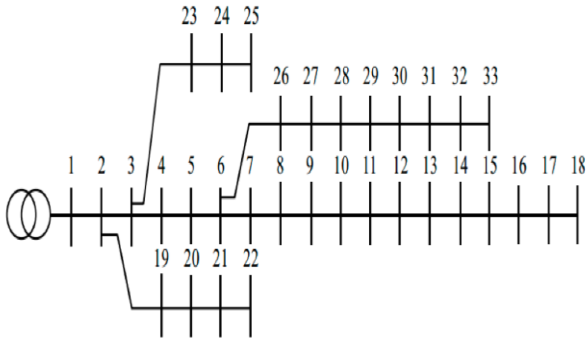

FIG3: 33 Bus system

The comparison graph with and without placement of DG is shown below.

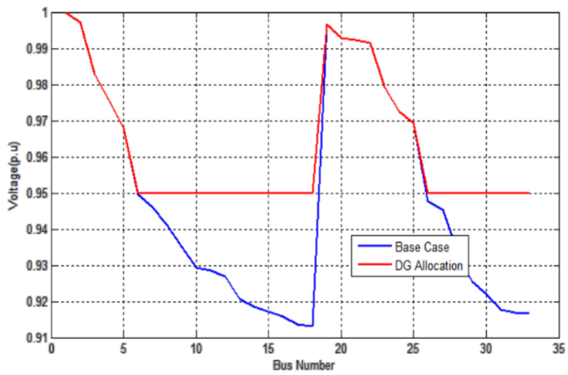

FIG 4: Voltage profile with 5 DG

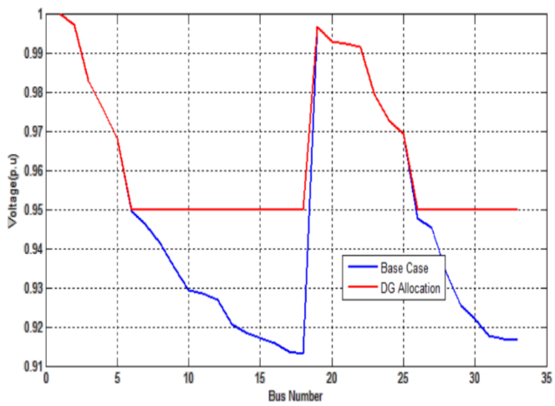

FIG 5: Voltage profile with 9 DG

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Conclusion

The optimal location of the DG has been computed through voltage stability index and the and the sizing of those DG units has been investigated through Genetic Algorithm[8]. The usage of GA for sizing of DG has shown that it effectively reduces the total power losses in the system and is efficient.

The more number of DG units increases the performance of the system, while the less number of DGs results in the saturation in their performance.

Limitations & Future Scope

The DGs has to be located correctly and sized properly, if not the distribution system will be adversely affected.

The inclusion of DGs and energy storage to the distribution system reduces the intermittent nature of renewable DG input while simultaneously supplying continuous, environmentally friendly power. Therefore, studying how renewable DGs affect energy storage is highly advised.

For different load models [9] we generally use the static load model, consequently the placement and sizing of the DG changes, so we need to focus on different voltage dependent load models.

The distribution system is extensive and complex. This appear focuses on a very small scale distribution network. So it is recommended to focus on distribution systems of larger extent.

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