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Optimal Placement and Sizing of Distributed Generators by Using Voltage Indexing & Heuristic Method

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Abstract— Now-a-days, Determination of optimal location and size of Distributed Generation units is one of the major problems of distribution network. Optimum locations and sizes of DG sources have profoundly impacted on the system losses of a distribution system. In this paper, authors' presents a method to identify the optimal location and size of DGs based on the voltage stability index (VSI) and particle swarm optimization (PSO) algorithm to obtain the minimum loss reduction and voltage profile improvement. Multiple DG placements are used to find the optimal DG location and its size which corresponding to the minimum loss reduction. The load flow analysis on distribution use forward-backward sweep methodology. The performance of this proposed methodology is tested on IEEE 33 & 69-Bus distribution system.

Keywords- *PSO, Distribution system, voltage stability index*

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I. INTRODUCTION

To maintain voltage stability as labor is a major problem. Improve voltage stability by distributed generation is adopted by many utilities worldwide [5, 6]. A smart power system means the system should be satisfying various operating criteria for stability at any time. Now -a –days, the smart power system has the challenged with the increasing load demands from the domestic and commercial sectors [1, 2]. The large demand gap of electricity between utilities and consumers has caused congestion in transmission lines which lead to instability in the power system operation [3]. The significance of the power system instability is the blackouts [4]. So the major concerns of smoothly operation of power system to maintain the voltage stability during operation. The main objective of all utilities in throughout the world to enhancement of voltage stability by injection of distributed generation [5, 6].

In the radial and mesh distribution system, the optimize location and sizing of DGs are the main problem. The reactive power losses increases and voltage profile decreases by improper the integration the DGs to the proper buses in distribution system. The literature has been shown in various references. W. El-Khattam [7] describes a successive elimination algorithm to site and size the DGs. N. S. Rau [8] describes a new heuristic method based on cost benefit analysis to optimally determine the capacity and location of the DG from the prospect of a distribution company. R. Rao[9] has used a mixed integer programming (MIP) formulation with branch and bound optimization for an industrial power plant. A. R. Wallace [10] deals with a genetic algorithm optimization for deploying a DG resource in a distribution system. In [11], the problem of determining size and location of DG has been formulated to minimize the cost of power, energy losses and the total required reactive power. Nowadays, electrical power systems are facing different technical, economical and environmental issues. The Presence of distributed generation (DG) in distribution systems has significant impacts. Due to the following reasons, efficient solving of DG allocation problem is very significant and important from technical, economical parameters [12].

- By proper placing of DGs, the reliability of power system is improved and power quality is enhanced.
- By proper placing of DGs, the investment and operational costs are decreased.
- By proper placing of DGs, the harmful environmental effects of power generation are mitigated

The Distributed Generation (DG) is not a new approach to generate the green energy, but it is very emerging approach to mitigate the electricity generation problem. It is the heart of the electrical power system. It mainly depends upon the installation and operation of a portfolio of small size, compact, clean electric power generating units at or near an electrical load [12].

By proper placement and size of DG unit in the distribution system, the power system achieves the optimized performance, minimizing power loss, enhancement in the voltage profile and reduced in total harmonic distortion (THD). Nowadays, the application of distributed generation systems is increase. The heuristic algorithms are the different type's viz. Particle Swarm Optimization (PSO), Simulated Annealing, Genetic algorithm (GA),Krill Herd Algorithm and Shuffled Bat Algorithm, etc. In the present study, for the sizing of DGs, the methodology applies the Particle Swarm Optimization

(PSO).In this paper Voltage Stability Index (VSI) approach is used to optimal placement of DGs and a particle swarm optimization (PSO) algorithm is presented, to solve and sizing problem DG units in the radial distribution system (RDS).

Firstly a brief literature review about distributed generation and optimization technique in section I. Section II explains the Distributed Generation Technology. The algorithm of PSO and flow chart of load flow is shown in Section III. A problem formulation is discussed in Section IV. The results and discussion are presented in Section V. And finally the conclusion is given in Section VI.

II. DISTRIBUTED GENERATION TECHNOLOGY

As known, distributed generation signify the electric power generation within distributed network to meet the rapid energy demand of consumers. However, There are many terms and definitions used for explain DG and that's create a various perspectives:

- The Electric Power Research Institute (EPRI) defines distributed generation as generation from 'a few kilo-watts up to 50 MW' [13].
- International Energy Agency (IEA) defines distributed generation as generating plant serving a customer on-sit or providing support to a distribution network, connected to the grid at distributed level voltages [14].
- The International Conference on large High Voltage Electric Systems (CIGRE) defines DG as 'smaller than 50-100 MW' [15].

Although there are variations in definitions, however, the concept is almost same. DG can be treated as small scale power generation to mitigate the consumer energy demand. Distributed Generation can come from a variety of sources and technology. Here, we will consider the Distributed Generation as an Electric power source connected directly to the distribution system.

III. PARTICLE SWARM OPTIMIZATION

One of the most recent meta heuristic algorithms is the Particle Swarm Optimization (PSO) is a population based stochastic optimization technology [16,17] by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking and fish schooling.

The PSO algorithm is inspired by birds but this algorithm is not based on animal behavior. Basically the behavior to solve optimization problems. In PSO, each member of the population is called a particle and the population is called a swarm [18].

PSO Algorithm to Determine the Size of DG

Step 1: Choose the parameters that are to be optimized by using PSO. Here the parameters are real and reactive powers that are injected through DG into distributed system i.e size of DG in order to minimize the losses and improve voltage.

Step 2: Choose the size of swarm.

Step 3: Generate the random values for DG size.

Step 4: Run the load flow and obtain the voltage profile and losses of the system.

Step 5: Also obtain the location of the DG to be placed by using VSI (Voltage Stability Index).

Step 6: Assume the fitness function as the real loss as we need to find the optimal DG size that minimize the losses to a maximum extent.

Step 7: Randomly initialize the position and velocity of swarm.

Step 8: By placing different sizes of DG in the location obtained by VSI, compute and store the fitness function of all particles in the swarm.

Step 9: Assume the initial randomly generated sizes of DG as pbest.

Step 10: Iterate through all the values of fitness function and the particle with minimum loss is considered as the gbest.

Step 11: Initialize the acceleration coefficients as c1=2 and c2=2

Step 12: Initialize the loop and iteration count. For each particle calculate and update the velocity and position.

$$v_{ij}^{t+1} = v_{ij}^{t} + c_1 r_{1j}^{t}\left(P_{best,i}^{t} - x_{ij}^{t}\right) + c_2 r_{2j}^{t}\left(G_{best,i}^{t} - x_{ij}^{t}\right)$$

$$x_{ij}^{t+1} = x_{ij}^{t} + v_{ij}^{t+1}$$

Step 13: Run the load flow after placing DG and obtain the new fitness function for each particle. If the new fitness value for any particle is better than previous pbest value then pbest value for that particle is set to present fitness value. Similarly gbest value is identified from the latest pbest values.

Step 14: If it reaches maximum iteration count then terminate the loop and plot the results. Otherwise increment the iteration count and go to step 12.

Step 15:gbest value gives the size of DG

Table 1 shows the DG optimal size, location and corresponding real power loss with VSI technique corresponding for IEEE-33 buses

Cases	**DG position**	***DG Rating (KW)***	***Active Power loss (KW)***	***Reactive Power Loss (KVAR)***
Without DG			210.9824	143.0219
With DG	Bus 18	150	135.7104	91.6952
	Bus 17	150		
	Bus 16	519		
	Bus 15	150		

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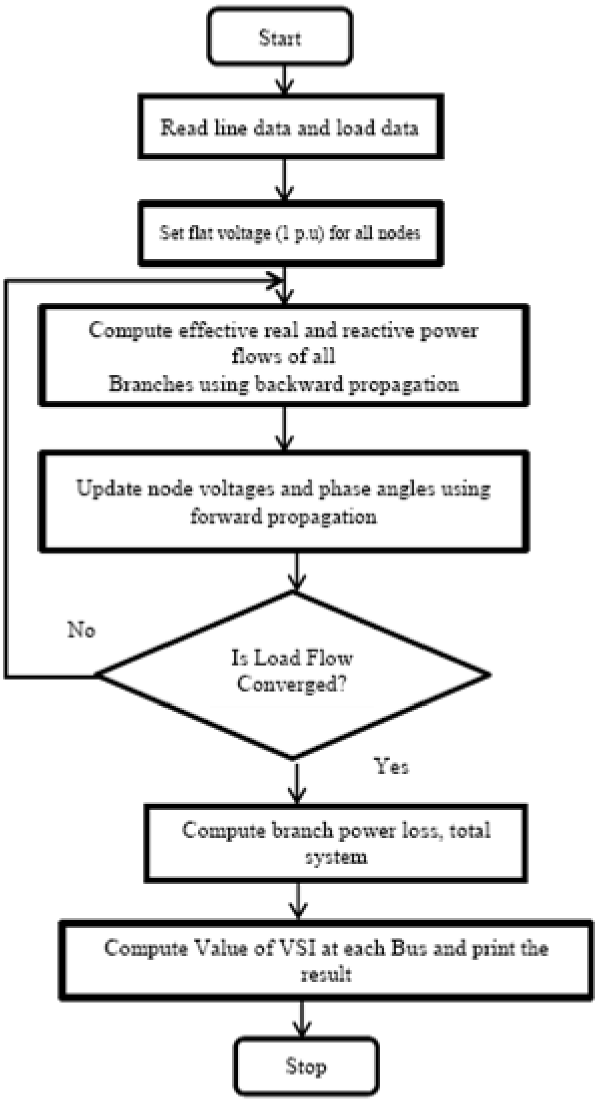

Fig. 1 Flow Chart for forward and backward based Load Flow Program with VSI technique

IV. PROBLEM FORMULATION

The objective of this research is to minimize the active power loss and reactive power losses in the distribution network as well as to improve the voltage profile of the distribution system by using the optimal placement and sizing problem of distributed generator.

To optimize the location of DGs, indexing method is used viz. VSI. To calculate the value of VSI, the load flow program is used based on Backward/Forward Sweep method. The minimum value of VSI is carried out for optimal location of DG in radial distribution system. The PSO (Particle Swarm Optimization) algorithm is used to calculate the minimize loss of distribution system and find out the optimal sizing of DGs, The programming of load flow analysis and PSO algorithm is written in MATLAB software.

The formulation for system power loss minimization

$$f = Min.P_{loss}\{DG(n_{DG}, C_{DG})\} \quad (1)$$

subject to: C_{DG} and n_{DG}

Where C_{DG} = (Size) or capacity of DG

n_{DG} = Bus number of DG installation

Constraints

Load balance constraint: The following equations should be satisfied at each bus.

$$P_{gn_i} - P_{dn_i} - V_{ni}\sum_{j=1}^{N} V_{nj} Y_{nj} \cos(\delta_{ni} - \delta_{nj} - \theta_{nj}) = 0 \quad (2a)$$

$$Q_{gn_i} - Q_{dn_i} - V_{ni}\sum_{j=1}^{N} V_{nj} Y_{nj} \sin(\delta_{ni} - \delta_{nj} - \theta_{nj}) = 0 \quad (2b)$$

Where n_i = 1, 2, 3, … … … … . . n_n

P_{gn_i} =Active power output of the generator at bus n_i

Q_{gn_i} =Reactive power output of the generator at bus n_i

P_{dn_i} = Active power demand at bus n_i

Q_{dn_i} = Reactive power demand at bus n_i

n_n = Total no. of buses

V_{ni} =Voltage of bus n_i

Voltage constraints:

The voltage at each bus must be kept within its maximum and minimum standard values.

$$V_{ni}^{min} \le V_{ni} \le V_{ni}^{max} \quad (3)$$

DG technical constraints: The DG capacity or size is limited by the energy resources at any given location, so it is necessary the size of DG should be between the maximum and the minimum levels.

$$P_{gi}^{min} \le P_{gni} \le P_{gi}^{min} \quad (4)$$

V. SIMULATION RESULTS

In this paper, two cases are considered (i) IEEE-33 buses and IEEE-69 buses. For the both cases, the location of multi DGs is identified by VSI method and sizing of multi DGs are find out by PSO algorithm. Fig.1 shows that the algorithm for determine the value of VSI based on load flow program. Fig.2 and Fig.3 represent the voltage profile of IEEE-33 and IEEE-69 buses respectively. Fig.4 and Fig.5 represent the VSI values for each bus in IEEE-33 and IEEE-69 buses respectively. Fig. 6 and Fig. 7 show that convergence of PSO.

Table 2 shows the DG optimal size, location and corresponding real power loss with VSI technique corresponding for IEEE-69 buses

Cases	DG position	*DG Rating (KW)*	*Active Power loss (KW)*	*Reactive Power Loss (KVAR)*
Without DG			186.6332	81.3668
With DG	Bus 65	150	75.4539	35.2489
	Bus 64	150		
	Bus 61	150		
	Bus 63	1502		

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The load flow is done on the IEEE 33 and IEEE 69 bus system and the voltages are shown in fig.1 and fig.2 respectively.

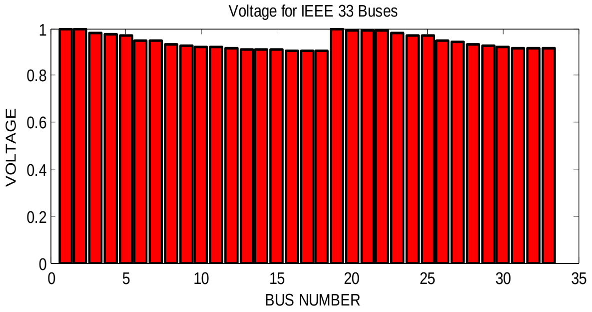

Fig. 2 Voltages for IEEE 33 bus system

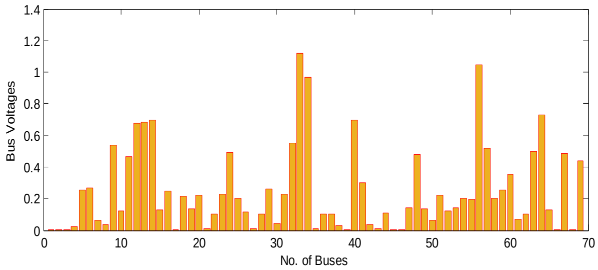

Fig. 3 Voltages for IEEE 69 bus system

The load flow is done on the IEEE 33 and IEEE 69 bus system and the voltage stability index (VSI) are shown in fig.3 and fig.4 respectively.

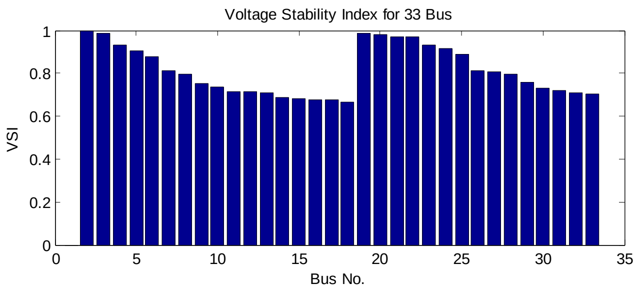

Fig. 4 VSI for IEEE 33 bus system

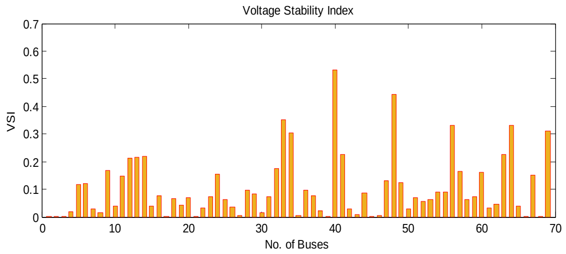

Fig. 5 VSI for IEEE 69 bus system

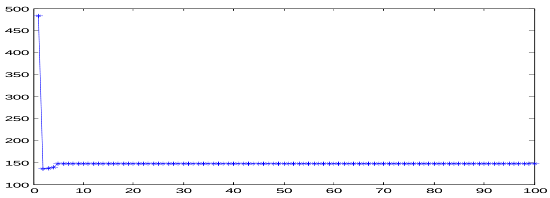

Fig. 6 convergence for PSO for IEEE 33 bus system

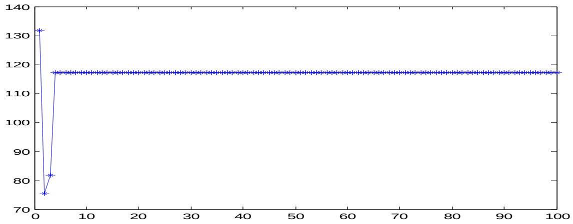

Fig. 7convergence for PSO for IEEE 69 bus system

VI. *Conclusion*

In this paper, authors apply VSI method on IEEE-33 and IEEE-69 buses and obtained the location of DGs. Four optimal locations are identified and optimal sizing of DGs by a particle swarm optimization algorithm is find out for minimizing the total real power loss satisfying the constraints. This methodology is fast and accurate in determining the optimal sizes and locations. The methodology is tested on 33 and 69 bus systems. By installing DG at optimal locations, the total power loss of the system has been reduced and the voltage profile of the system is also improved.

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