Allocation and Estimation of DG Capacity in Distribution Networks by Particle Swarm Optimization

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Abstract

This paper presents optimal placement and estimation of distributed generation (DG) capacity using Particle Swarm Optimization (PSO) approach in the radial distribution systems to reduce the real power losses and to gain voltage profile improvement. Furthermore, the proposed method focuses on the installation of the DGs and takes more number of significant parameters into account compare to the previous studies which consider only a few parameters for their optimization algorithms. Some of the so-called cost parameters considered in the proposed approach is loss reduction, voltage profile improvement, fuel price and costs of load prediction for each bus. Using an optimal PSO Algorithm, the proposed optimization method, a destination function that includes all of the cost parameters, has been optimized. This method is also capable of changing the weights of each cost parameter in the destination function of the PSO Algorithm and the matrix of coefficients in the DIGSILENT environment. The cost parameters are variables dependent on the status and position of each bus in the network, putting forth an optimal DG placement. The proposed method has been applied and simulated on a sample IEEE 33-bus network. The obtained results show that any change in the weight of each parameter in the destination function of the PSO Algorithm and in the matrix of coefficients leads to a meaningful change in the location and capacity of the prospective DG in the distribution network.

Keywords: *Distributed Generation (DG), Distribution Network, Optimization, PSO Algorithm*

I. INTRODUCTION

Distribution system provides a final link between the even in the same building. Active Distribution Network has several advantages like reduced line losses, voltage profile improvement, reduced emission of pollutants, increased overall efficiency, improved power quality and relieved T&D congestion. Hence, utilities and distribution companies need tools for proper planning and operation of Active Distribution Networks. The most important benefits are reduction of line losses and voltage stability improvement. They are crucially important to determine the size and location of DG unit to be placed. Studies indicate that poor selection of location and size would lead to higher losses than the losses without DG (Kim, 2001a, b). In EI-hattam and Salma (2004), an analytical approach has been presented to identify appropriate location to place single DG in radial as well as loop systems to minimize losses. But, in this approach, optimal sizing is not considered. Loss Sensitivity Factor method (LSF) (Graham *et al*., 2000) is based on the principle of linearization of the original nonlinear equation (loss equation) around the initial operating point, which helps to reduce the amount of solution space. The LSF method has widely used to solve the capacitor allocation problem. Optimal placement of DG units is determined exclusively for the various is tributed load profiles to minimize the total losses. They have iteratively increased the size of DG unit at all buses and then calculated the losses; based on loss calculation they ranked the nodes. Top ranked nodes are selected for DG unit placement. The Genetic Algorithm (G.A) based method to determine size and high voltage transmission system and the consumers. A radial distribution system has main feeders and lateral distributors. The main feeder originates from substation and passes through different consumer loads. Laterals are connected to individual loads. Generally radial distribution systems are used because of their simplicity. Power loss in a distribution system is high because of low voltage and hence high current that don't consider in Keane and O'Malley (2005). The overall efficiency can be improved using DG units. Utilities are continuously planning the expansion of their existing electrical networks in order to face the load growth and to properly supply their consumers. Distribution system provides a final link between the high voltage transmission system and the consumer. Electricity networks are in the era of major transition from stable passive distribution networks with unidirectional electricity transportation to active distribution networks with bidirectional electricity transportation. Distribution networks without any DG units are passive since the electrical power is supplied by the national grid system to the customers embedded in the distribution networks. It becomes active when DG units are added to the distribution system leading to bidirectional power flows in the networks (Zareipour *et al*., 2004). In an active distribution network the amount of energy lost in transmitting electricity is less as compared to the passive distribution network, because the electricity is generated very near the load center, perhaps even in the same building. Active Distribution Network has several advantages like reduced line losses, voltage profile improvement, reduced emission of pollutants, increased overall efficiency, improved power quality and relieved T&D congestion. Hence, utilities and distribution companies need tools for proper planning and operation of Active Distribution Networks. The most important benefits are reduction of line losses and voltage stability improvement. They are crucially important to determine the size and location of DG unit to be placed. Studies indicate that poor selection of location and size would lead to higher losses than the losses without DG (Kim, 2001a, b). In EI-hattam and Salma (2004), an analytical approach has been presented to identify appropriate location to place single DG in radial as well as loop systems to minimize losses. But, in this approach, optimal sizing is not considered. Loss Sensitivity Factor method (LSF) (Graham *et al*., 2000) is based on the principle of linearization of the original nonlinear equation (loss equation) around the initial operating point, which helps to reduce the amount of solution space. The LSF method has widely used to solve the capacitor allocation problem. Optimal placement of DG units is determined exclusively for the various distributed load profiles to minimize the total losses. They have iteratively increased the size of DG unit at all buses and then calculated the losses; based on loss calculation they ranked the nodes. Top ranked nodes are selected for DG unit placement. The Genetic Algorithm (G.A) based method to determine size and location of DG unit is used in (Ault and McDonald, 2000; Caisheng and Nehrir, 2004). They have addressed the problem in terms of cost, considering cost function may lead to deviation of exact size of the DG unit at suitable location. It always gives near optimal solution, but they are computationally demanding and slow in convergence. In this paper, a new objective function to calculate optimal location and optimum size value for DG is proposed. The DG is considered to be located in the primary distribution system and the objective of the DG placement is to improve the voltage profile and short circuit level at each bus of system. The cost and other associated benefits have not been considered while solving the location and sizing problem. In this study a multi objective function consist of reliability and power loss function is considered and in follow solved with PSO. This study proposes a Particle Swarm Optimization (PSO) algorithm for optimal placement of Distributed Generation (DG) in a primary distribution system to minimize the total real power loss. The PSO provides a population-based search procedure in which individuals called particles change their positions with time.

II. THE PROPOSED METHOD

In the present study, for the above mentioned purpose, a destination function should be defined that includes all of the proposed parameters. The destination function, which is going to be minimized in this study and includes loss, voltage profile, fuel price and cost of load prediction for each bus, is as follows:

$$\left[F(x) = K_1.C_{Loss} + K_2.C_{VPI} + K_3.C_F + K_4.C_L\right]\left(\$/KW\right) (1)$$

where is the cost of loss in all lines, is the cost voltage profile improvement, is the cost of the fuel used by DG sources and is the cost of load prediction for each bus and for the buses in which the load amount is not predictable. DGs must save energy and this requirement incurs costs which have been taken into account in the above function. To define the destination function in (1), we have to make all parameters per unit to make them additive, this was accomplished by applying “” coefficients (-). To calculate the cost of loss, first load flow is carried out in DIGSILENT software and then the results are used to calculate the losses and ultimately they are multiplied by the loss price. To calculate the cost of voltage profile improvement for each bus, the voltage difference for each bus is calculated before and after DG installment and the difference figure is multiplied by the cost of voltage profile improvement. [11]. It is noteworthy that each of the coefficients of the fuel price and load prediction have been defined in DIGSILENT environment in the form of a matrix where these parameters are variable of each bus. Such values are shown in Tables 1-12. This paper has two major goals: 1) Improvement of voltage profile, 2) Loss reduction. There are also some limitations based on which the destination function should be defined [12]:

According to the first limitation the loss reduces when DG exists. Also, second limitation states that the authorized voltage of a certain bus depends on the minimum and maximum voltages of the bus.

III. SIMULATION NETWORK :-

In the proposed work, in order to observe and compare the results with those of the specified destination function, an IEEE 13-bus distribution network has been selected as a sample. It should be noted that the specified destination function can be generalized to be used for all distribution networks with any number of buses. Moreover, the optimization algorithm of the destination function is a PSO Algorithm. The single line diagram of the network is illustrated in Fig. 1.

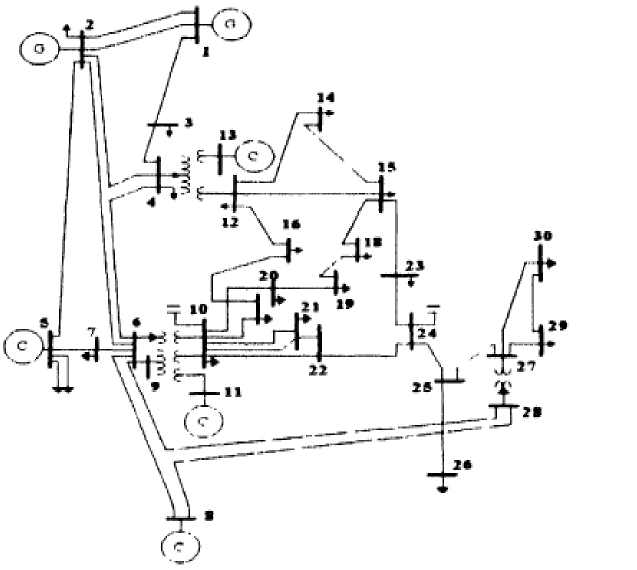


Fig. 1: Single line Diagram for IEEE 33-bus Distribution Network

IV. THE PSO ALGORITHM PROCEDURE

The particle swarm optimizer (PSO) algorithm is first present by Dr. Kennedy and Dr. Eberhart, and is a random evolution method based on intelligent search of the group birds. It has quick convergence speed and optimal searching ability for solving large-scale optimization problems [14].

The PSO-based approach for solving OPDG problem to minimize the loss takes the following steps:

Step 1: Input line and bus data, and bus voltage limits.

Step 2: Step 2: Calculate the loss using distribution load flow based on backward-forward sweep.

Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions in the solution space. Set the iteration counter k=0.

Step 4: For each particle if the bus voltage is within the limits, calculate the total loss. Otherwise, that particle is infeasible.

Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower than Pbest, set this value as the current Pbest, and record the corresponding particle position.

Step 6: Choose the particle associated with the minimum individual best Pbest of all particles, and set the value of this Pbest as the current overall best Gbest.

Step 7: Update the velocity and position of particle.

Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index k=k+1, and go back to Step 4.

Step 9: Print out the optimal solution to the target problem. The best position includes the optimal locations and size of, DG, and the corresponding fitness value representing the minimum total real power loss.

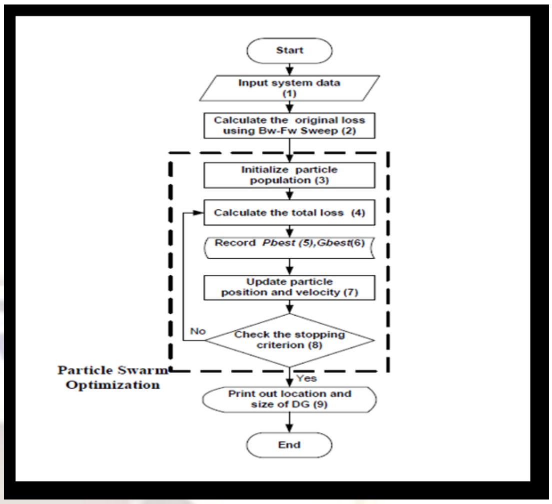


Figure. 2. PSO Computational Procedure

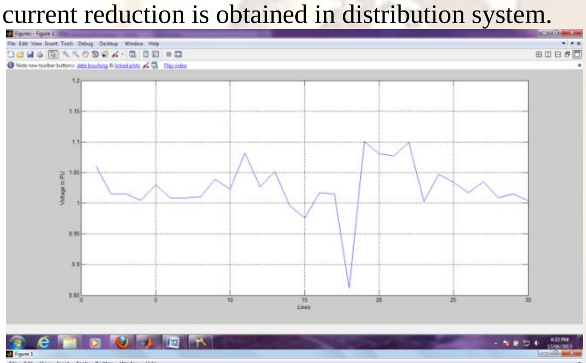
In this paper the optimization algorithm of the destination function is a PSO Algorithm whose population size=200, Maximum generation (k max) = 100. Max*k*

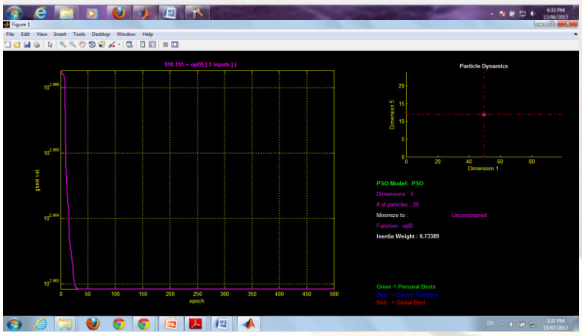
V. SIMULATION :-

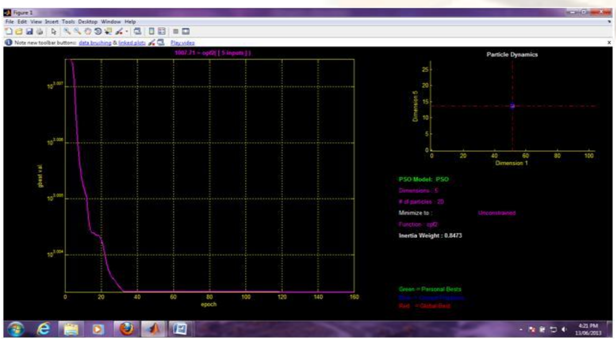
This study aims to optimize the placement of DG and assess DG capacity using weight coefficients for various parameters independently taking cost into account. The coefficients of the first case shown in Table 3 include loss-reduction parameters like voltage profiles, fuel price and load prediction in the destination function of the PSO Algorithm shown by (-) in the destination function. However, other coefficients shown in Table 4 are related to the weight of parameters for the effects of fuel price and load prediction which are defined in an input matrix for the simulation software. In this case, since parameters related to loss reduction and voltage profile are calculated automatically, the coefficients of these parameters are not considered in the input matrix for the software. Thus, generally, parameters for any network have two conditions of weight coefficients with any number of buses. This has been achieved using PSO algorithm optimization in DIGSILENT environment. The parameter changes are illustrated because they are variable in each bus. Optimization is carried out with PSO Algorithm using a cost function. For this purpose, changes in the coefficients of the parameters are specified due to their variability in each bus. Optimization of the destination function has been carried out using a PSO Algorithm. To assess the effect of loss reduction, voltage profile coefficient, fuel price and load prediction cost on the program, the program output was examined under two conditions (1), (2). For this purpose, different coefficients were applied to destination function parameters. Table 3 presents coefficients applied to parameters under the first condition, where parameters may vary depending on the place of the bus. 1*k*4*k*

V. Result

Optimal placement and sizing of DG in distribution network is an optimization problem with continuous and discrete variables. Many researchers have used evolutionary methods for finding the optimal DG placement and sizing. This paper proposes a hybrid algorithm PSO for optimal placement and sizing of distributed generation (DG) in radial distribution system to minimize the total power loss and improve the voltage profile. The proposed method is tested on a standard 33 bus radial distribution system and simulation results carried out using MATLAB software. The simulation results indicate that PSO method can obtain better results than the simple heuristic search method and PSO algorithm. The method has a potential to be a tool for identifying the best location and rating of a DG to be installed for improving voltage profile and line losses reduction in an electrical power system. Moreover, current reduction is obtained in distribution system.







VI. CONCLUSION

A method based on PSO method was proposed in this optimal DG allocation research. Optimization program implemented and tested on IEEE 33 Bus Sytem. In this research, the PSO method was conducted succesfully to obtain optimal solution. The PSO generated more optimal solution than PSO methods using active power losses reduction parameter. The highest power losses reduction was generated by PSO method. However, PSO method needed more iterations to convergence compared to two other methods. The voltage profile after DG installation using PSO method within standar voltage limit 0.95 - 1.1 pu.

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