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Optimal Allocation and Sizing of Distributed Generation for Power Loss Reduction using Modified PSO for Radial Distribution Systems

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Abstract

For the purpose of improving the voltage profile and power losses reduction, this paper proposes allocation and sizing of Distributed Generation (DG) in radial distribution system (69 IEEE bus test system.). A simple and effective approach for power loss reduction (PLR) value is employed for the allocation while the sizing was by using the results from the allocation as local optimum in a modified PSO called Ranked Evolutionary particle swarm optimization (REPSO) in order to obtain the global optimum. Load simulations in power flow yielded improvement not only in power loss reduction but also in voltage profile. The proposed algorithm was found to be faster and gives more accurate results than the EP and PSO algorithms.

Keywords: Distributed Generation, Evolutionary programming,, Particle Swarm Optimization, Allocation and sizing, Power loss reduction.

1. Introduction

Energy resources in our modern fast paced world are fast depleting, hence it is indispensible that we find new ways of generating energy which is both self sustaining as well as easily manageable [1].The rising concern about environmental pollution has also made DG to be a convenient substitute of the fast depleting (fossil fuel) centralized systems. Their successfully integration into the network using new-generation technologies and power electronics have attracted many investors. Despite these advantages many issues are however, still pending concerning the integration of DGs within the existing power system networks; that require special attention [2–3]. Specifically the integration has changed the system from passive network to active networks and the change has serious impact on both the reliability and operation of the network as a whole [4]. In addition to that, the non-optimal placement of DG can result in an increase in the system power losses and the consequence is that the voltage profile can fall below the allowable limit [5]. Hence optimal placement of DG is highly required in order to minimize overall power system losses and therefore improve voltage profiles as utilities are seriously facing technical and non-technical issues, which may likely compound the situation.

Current and past researches have proposed many optimal placement methods ranging from analytical to optimization approaches that have successfully allocated and sized DG units [6-9]. Several Analytical methods have been proposed by many authors for various objectives. The authors in [7], have presented analytical method that determines the optimal location based on loss minimization objective for both transmission and distribution and networks. Similar work in [8], have used the exact loss equation to find the optimum location of DG and the DG was sized by using loss sensitivity equation based on minimum losses. The authors in [9], also presented the loss sensitivity factor based on equivalent current injection using two Bus-Injection to Branch-Current (BIBC) and Branch-Current to Bus-Voltage (BCBV) matrix. In [10], optimal sizing and placement of DG for a network system was done based on two objectives which are losses and cost function as an objective using a simple search algorithm. The method is simple but consumes alot of time during the search processes for both the best location and optimum size. Another author in [11], considers optimal size and location by minimizing loss and generation cost as a parameter together with DG power limits. Two programs named “Bloss” and “dpslack” for optimum sizing of DG were developed by considering DG min–max limits. The site was then selected by considering the minimum total power losses considering DG at each bus. Even though the approach is accurate but computation time is long and very tedious.

For methods based on optimization, many algorithms have been proposed by many researchers for optimal placement and sizing in distribution networks. In [12], optimal DG placement and reclosures based on reliability of the network was done by using Ant Colony Search (ACS) Algorithm. Also authors in [13] have introduced GA based optimization algorithm to optimize size and allocate multiple DG units for the purpose of minimizing power losses by taking into account the voltage limits of all the nodes in the system. In this case optimal location of DG and reclosers were found based on system reliability.

Reference [14] presented a GA-Fuzzy based optimal placement of DG as a multi-objective problem that considers system losses, system loading and DISCO`s profits as objectives. In [15], a hybrid of GA and PSO was employed for optimal location as well as capacity of DG, considering multi- objective constraints such as voltage regulation improvement, voltage stability and system losses.

In this paper, a hybridized PSO known as Ranked Evolutionary Particle Swarm Optimization (REPSO) approach has been used to determine the optimal size and location the DG units based on Power Loss Reduction value. The effectiveness of this approach is demonstrated on 69-test system. Overall, the method proposed is simple and requires less computational time for determining the optimum placement and size of DG when compared to other optimization algorithms.

2. Problem Formulation

Placement of DG units includes determination of the size, location as well as the number of units to be installed within the distribution system so that benefits are achieved while operational constraints are fully satisfied for varying load conditions. For radial distribution system, the total real power losses of the network can be determined by summing all power losses value at each branch:

$$P_{losses} = \sum_{i=1}^{n} |I_i|^2 R_i \quad (1)$$

Where n is the number of branches, I_i is the current magnitude and R_i is the resistance. The current I_i is determined from load flow using Newton-Raphson method. For single sources network all the power is supplied by the single sources but with DG penetration that are optimally located power loss reduction is achieved. This power losses reduction due to DG connection is determined as the difference of the power losses with DG and without DG connection. Thus, the new total power loss in the network after the DG connection is:

$$P_{losses-new} = \sum_{i=1}^{n} \left|I_i^{new}\right|^2 R_i \quad (2)$$

$$P_{losses-new} = \sum_{i=1}^{n} I_i^2 R_i - 2JI_i I_{DG} R_i - J.I_{DG}^2 R_i \quad (3)$$

Where J=1 for a feeder with DG connection or else J=0. Hence, the Power Loss Reduction (PLR) value for bus i with DG connection is obtained by subtracting equation (2) from (3) as;

$$PLR_i = P_{losses-new} - P_{losses} \quad (4)$$

$$PLR_i = -\sum_{i=1}^{n} (2JI_i I_{DG} + JI_{DG}^2) R_i \quad (5)$$

The bus that gives the highest value of PLR is selected as the optimal location of DG. The emphasis is to place the DG at a location that will give maximum loss reduction .To obtain the DG current that will give maximum loss reduction equation (5) is differentiated with respect to I_{DG} and equated to zero, hence the current is given by equation (6) below;

$$I_{DGi} = -\frac{\sum_{i=1}^{n} I_{ai} R_i}{\sum_{i=1}^{n} R_i} \quad (6)$$

The procedure is repeated for all the buses in order to obtain the highest power loss reduction value as the DG units are singly located. Assuming no significant change in voltage as DG units are connected, the power that can be generated is;

$$P_{DGi} = I_{DG}.V_i \quad (7)$$

Where V_i is the voltage magnitude of the bus i and the optimum DG size is obtained from equation (7) . The optimal location of the DG is bus i for maximum power loss reduction.

3. Ranked Evolutionary Particle Swarm Optimization Algorithm

The Rank Evolutionary Particle Swarm Optimization (REPSO) is a hybrid of Evolutionary Programming (EP) and PSO. Evolutionary Programming (EP) is a heuristic population-based search technique that is used for both random variation and selection. The search for an optimal solution is based on the natural process of biological evolution and is accomplished by using a parallel method in parameter space. EP explores the problem space by using a population of trials, as opposed to a single point, to demonstrate potential solutions to a problem. This makes EP less likely to get trapped in local minima. EP employs the tournament scheme in order to choose the survivals for the next generation. This selection is used to identify the candidates that can pass into the next generation from the combined population of the parents and offspring.

The population of individuals with better fitness functions are then sorted in ascending order. The first half of the population is then retained as the new individuals or parents to the next generation, and the others are removed from the pool. This process continues until the solution converges [16]. This is the reason why EP is combined with PSO to achieve a global optimal solution within a short time. This new approach is called REPSO algorithm that combines the merits of the EP and the particle swarm optimisation algorithm. The advantages are that of speed and accuracy when compared to traditional PSO [17]. By hybridizing the concept of "Ranking process" in Evolutionary Programming (EP) for finding the best particle in a population, the PSO is helped to achieve optimal point faster than usual and accuracy of the result is guaranteed. The algorithm is as shown in Fig. 1.0.

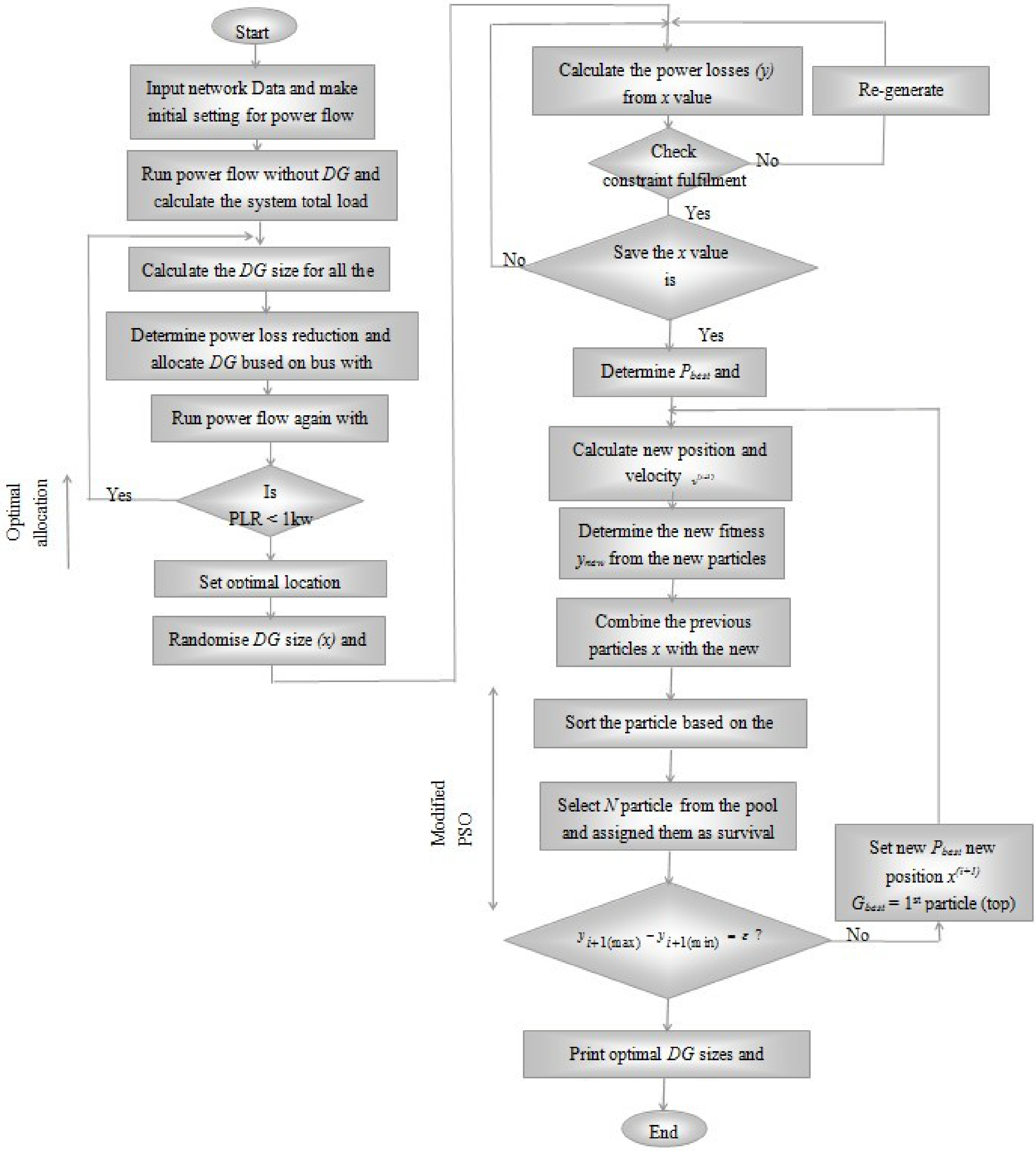

Figure 1.0 Flow chart for REPSO Algorithm

4. Results and Discussions

A program is written in MATLAB for the calculation of power loss for optimal DG placement and the optimum sizing was done by using REPSO.A 69-bus system as LV feeder with the line, bus data and load modelled as a constant power type are used for the simulations. The line loss without DG connection is as shown in Fig. 2.0 as the base case. The DG penetration will result in reduction of these losses in the network especially at the most critical locations.

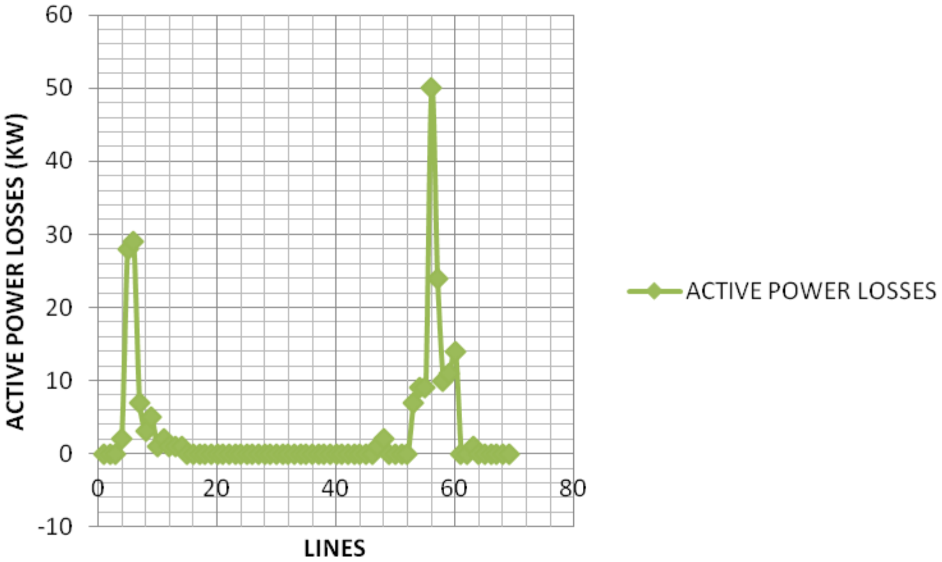

Fig. 2.0 Lines active power losses before DG connection

Table I shows the location and sizes of DG with percentage improvement of power loss reduction. The result shows that adding more than four DG to the network is not economical considering the power loss reduction.

Table I: Single DG placement

Iteration No.	Bus	DG size	PLR
1	61	1.8327	136.719
2	17	0.5155	11.170
3	50	0.7179	1.506
4	11	0.3156	1.221

The sizes obtained in Table I is local optimum since the placement was done by single placement. The locations where the DG units are placed are considered as optimal locations which are busses 61, 17, 50 and 11. With these locations sizes are determine using the REPSO algorithm. The DG sizes obtained are global optimum sizes that corresponds optimum location obtained during single placement.

The sizes of the DGs are dependent on the number of DG locations. It is better to distribute the DGs to various busses rather than concentrating them on a single bus. In this radial network only 4 DG units were installed without violating the system constraints. In the first placement only one was installed. In the second two DG units while third and forth three and four DG units were installed respectively as indicated in Table II with the power losses before and after DG installation. It can be observed from the table that as the number of DG units installed increases the power loss reduction also increases.

Table II: DG sizing result

DG Placement	Bus	DG size (MW)	Total installed DG	Loss without DG	Loss after DG installation	Power loss reduction savings
1st Placement	61	1.8982	1.8982		115.946	109.154
2nd Placement	61	1.4513				
	17	0.6736	2.1249		95.999	129.101
3rd Placement	61	1.2938				
	17	0.6736	2.8354	225.10	87.489	137.611
	50	0.8680				
4th Placement	61	0.7928				
	17	0.6736				
	50	0.8674	2.8087		73.509	151.592
	11	0.4749				

In Fig. 3.0 voltage profile improvement as DG penetration level increases in the network for the base case and the four placement cases are shown. In all the cases voltage profile has improved and the improvement is significant. The lowest voltage profile for all the buses is above statutory lowest limit.

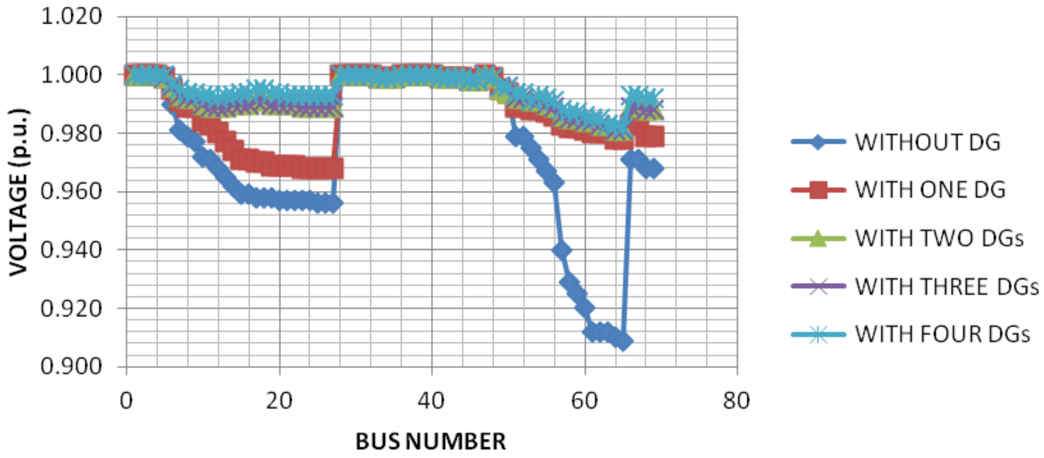

Fig. 3.0 Voltage profile Improvement with DG connection

The Fig.4.0 shows the PLR value that changes as the DG penetration increases. Typically during the first placement the bus with the highest PLR value is Bus 61 and is the best candidate for DG placement. The third and the forth placement power loss reduction difference is found to be insignificant when compared with the first two placements.

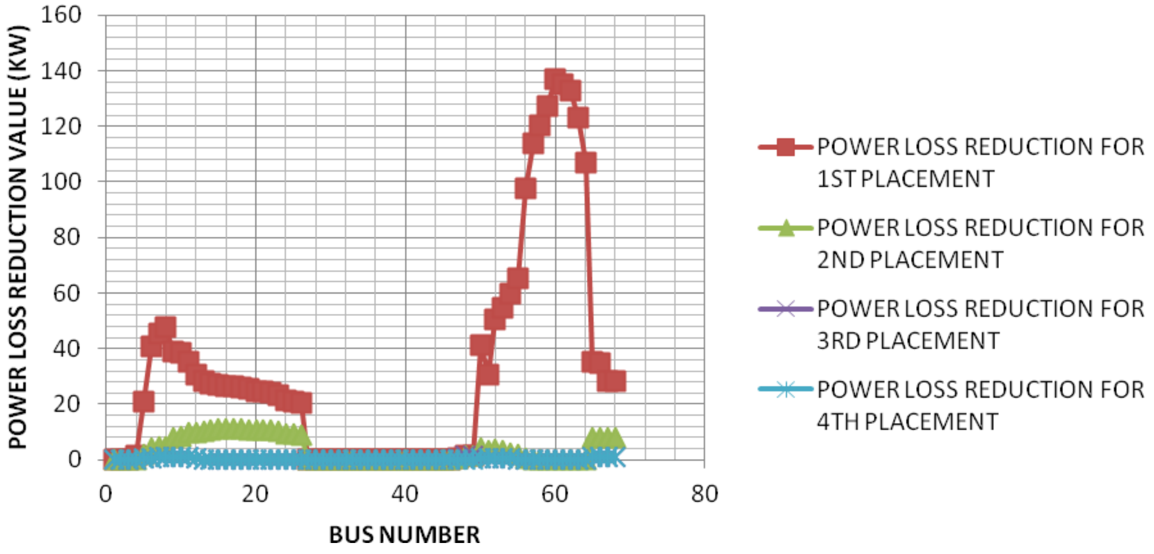

Fig. 4.0 Power Loss Reduction with increase in DG penetration

5. Conclusions

In this paper, a methodology for finding the optimal locations and sizes of DGs for Power loss reduction of radial distribution systems is presented. The DG placement method proposed is based on power loss reduction and a REPSO algorithm is proposed for finding the optimal DG sizes with all the necessary optimization constraints.

This methodology was tested on IEEE 69 bus system. The results show that DG installation at the optimal locations can improve voltage profile and at the same time reduces power losses of the network. The proposed algorithm gives faster and more accurate results when compared to EP and PSO algorithms.

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