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Energy Procedia 14 (2012) 990 – 995

Energy Procedia

ICAEE 2011

Multiobjective Optimization for Optimal Placement and Size of DG using Shuffled Frog Leaping Algorithm

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Abstract

There has been a great interest in integration of distributed generation (DG) units at distribution level in the recent years. DGs can provide cost-effective, environmental friendly, higher power quality and more reliable energy solutions than conventional generation. For maximum power loss reduction, proper sizing and position of distributed generators are ardently necessary. This paper presents a simple method for optimizing cost and optimal placement of generators. A simple vector based load flow technique is implemented on 38 bus distribution systems. This paper presents a new methodology using a new population based meta heuristic approach namely Shuffled frog leaping algorithm for the placement of Distributed Generators (DG) in the radial distribution systems to reduce the real power losses and cost of the DG. The paper also focuses on optimization of weighting factor, which balances the cost and the loss factors and helps to build up desired objectives with maximum potential benefit. The proposed method has outperformed the other methods in terms of the quality of solution and computational efficiency.

Keywords- Distributed Generation; Optimization Algorithms; Shuffled Frog Leaping Algorithm;.

1. Introduction

Electric utilities are now seeking upcoming new technologies to provide acceptable power quality and higher reliability to their customers in restructured environment. Investments in distributed generation (DG) enhance environmental benefits particularly in combined heat and power applications. DG may come from a variety of sources and technologies. DGs from renewable sources, like wind, solar and biomass are often called as 'Green energy'. In addition to this, DG includes micro-turbines, gas turbines,

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doi:10.1016/j.egypro.2011.12.1044

diesel engines, fuel cells, sterling engines and internal combustion reciprocating engines. DG refers to small sources ranging between 1kW and 50MW electrical power generations, which are normally placed close to consumption centers. DG renders a group of advantages, such as, economical, environmental and technical. The economical advantages are reduction of transmission and distribution cost, electricity price and saving of fuel. Environmental advantages entail reductions of sound pollution and emission of green house gases. Technical advantages cover wide varieties of benefit, like, line loss reduction, peak saving, increased system voltage profile and hence increased power quality and relieved transmission and distribution congestion as well as grid reinforcement. So, optimal placement of DGs and optimal sizing attract active research interests. Several researchers have worked for loss reduction [1-7] by placing the DG in the distribution systems. In these Wang and nehrir [1] have used the analytical method for placement of DG to reduce loss. Devi and Subramanyam [2] uses analytical method with fuzzy as optimization approach for reduction in loss. Mahat et al.[3] uses a analytical method using the extra loss formula. Later the researchers using Metaheuristic techniques for optimization. Griffin [4] used Heuristic iterative search approach, Golshan and Arefifar [5] used Tabu Search, Ardakani et al.[6] used partical swarm optimization and Falaghi and Haghigam[7] used Ant colony optimization for the loss reduction.

This paper presents a simple search approach determining for optimal size and optimal placement of DG using vector based load flow study. Both optimal DG size and optimal bus location are determined to obtain the best objective. In this paper the DGs are modeled as negative PQ load model. In load flows the injected power is aided to the bus as a negative load. The multi-objective optimization covers optimization of both cost and loss simultaneously. The cost coefficients of DG are taken from Ref. [8].

2. Problem formulation

The main objective of the power flow solution has been directed towards optimization of Objective function (OF) governed by the relation

$$OF = C(P_{DG}) + W * P_{loss} \tag{1}$$

where, P_{DG}-Power generated by DG; $C(P_{DG})$ - total cost of DG as a function of DG rating, P_{DG}; W-weighting factor; P_{loss} - total active power loss.

Total cost of DG is given by

$$C(P_{DG}) = a_{DG} + b_{DG} P_{DG} + c_{DG}(P_{DG})^2 \tag{2}$$

Where, a_{DG}, b_{DG} and c_{DG} are the quadratic cost coefficient of specified DG. Total active power loss is given by

$$P_{loss} = \sum_{i=1}^{nl} I_i^2 R_i \tag{3}$$

Where, I_i and R_i are current and resistance of circuit branch i, n_l is the number of circuit branches.

3. Shuffled Frog Leaping Algorithm (SFLA)

The SFLA is a real coded population based meta-heuristic optimization method that mimics the memetic evolution of a group of frogs when seeking for the location that has the maximum amount of available food. It is based on evolution of memes carried by the interactive individuals and a global exchange of information among themselves [9]. In essence, it combines the benefits of the local search tool of the PSO [10] and mixing information from Parallel Local Searches to move toward a global solution [11]. PSO is an Evolutionary Optimization method which is based on the metaphor of social interaction and communication such as Bird Flocking and Fish Schooling. PSO is initialized with random solutions (swarm), every individual or potential solution, called Particle, flies in the dimensional problem space with a velocity which is dynamically adjusted according to the flying experiences of its own and its social group [12]. In the SFLA, the population consists of a set of frogs [13] with the same structure but different adaptabilities. Each frog represents the feasible solution to optimization problem and is partitioned into subsets referred to as memeplexes. The different memeplexes are considered as different cultures of frogs, each performing a local search.

Overview of SFLA

Assume that the initial population is formed by generating 'F' frogs randomly pop (i), i =1,2,…., F. Evaluate the fitness *fit(i)* of i^{th} frog by a know method and arrange the frogs in ascending order of their fit values. This goes as initial step before forming the memeplex as shown in Fig.1 [14]

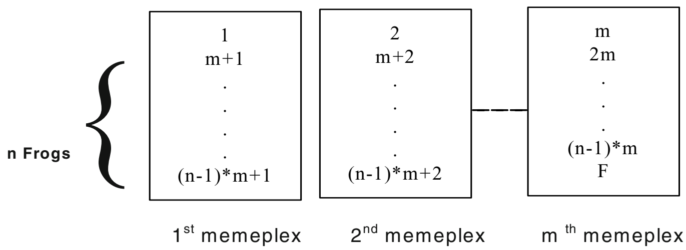

Fig. 1. Memeplex formation according to Frog fitness

In each memeplex assume n-frogs for m-memeplexes. Then, F frogs will be equal to 'mn'. The entire population [14] of F frogs is partitioned into m memeplexes according to their fitness values. If F=30, m=5 then n equals to 6. In Fig.1, the F^{th} frog will have the highest fitness value and 1st frog will be with lowest fitness value. For each memeplex, the best value will appear as the last entry and is named as 'i_{mbest}'. Among those i_{mbest} values of all m-memeplexes, the best will be taken as global best and termed as 'f_{best}'.

4. SFLA for Optimal DG Placement and Size for Cost and Loss Minimization

SFLA is used to find the optimal placement and size of the DERs. The frog is a combination of bus number and DER value. A frog represents the location and value of DER. For every frog, get the fitness value by placing DER value at DER bus. For all frogs, get the fitness values and arrange them in the ascending order. According to the fitness value, find the Population best (P_{best}) and Global best (G_{best}) frogs. G_{best} is the best among the iterations. Update the low fitness frogs towards the P_{best} as well as G_{best}. DER with Power rating of 0.63p.u is considered for the studies. Fig. 2 shows the flowchart of SFLA implementation for optimal placement and size of the DERs. In this paper 32 frogs are divided into 4 memeplexes. Each memeplex contains 8 frogs. Maximum number of generations is limited to 100.

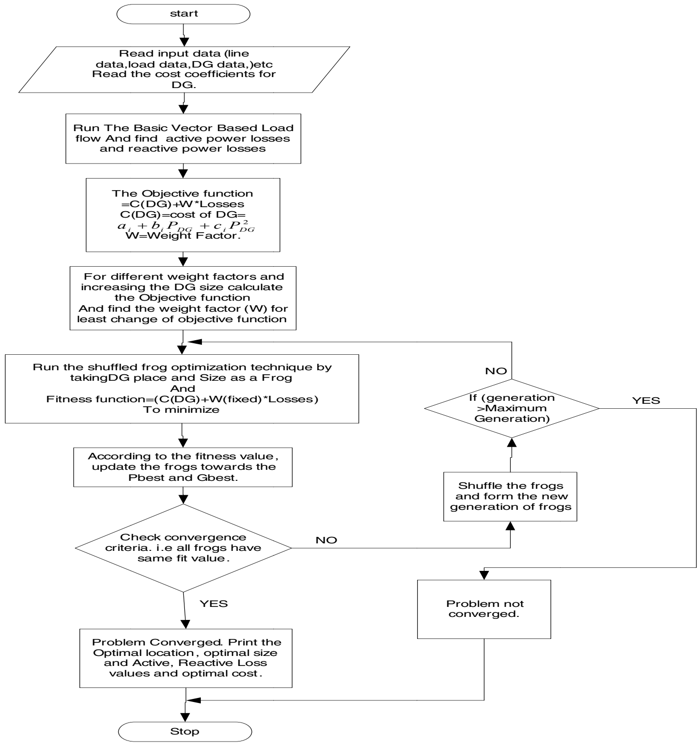

Fig. 2. Flow chart for the optimal placement and size of DG for cost and loss minimization

5. Results And Discussion

In this paper, 38-bus distribution system [15] is considered to test the proposed algorithm. DG with power rating of 0.63 p.u is considered for the studies.

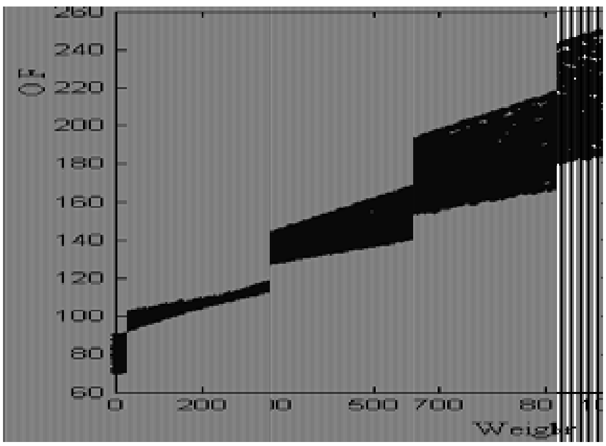

Fig. 3. Variation of OF as a function of DG size for 38 bus system.

5.1. Calculation of Objective Function

The total line losses of a system are obtained by using vector based distribution load flow technique. In order to find the weighted factor, run the SFLA for finding optimal location of DG by considering loss minimization as the only objective function. Then fix the DG in the optimal location, which is 14th bus in the considered 38 bus distribution system. Then vary the DG rating from minimum to maximum by considering the different weighted factor and evaluate objective function, OF (which includes minimization of cost and loss) and this variation is shown in the Fig.3. It is seen that from the Fig.3 that the optimum value of weighting factor is close to 200 for any range of DG.

5.2. System Optimum results

Table 1. Optimal placement of DG for minimum OF

Weight Factor	Optimal Placement of DG	Ploss (KW)	DG size (KW)	DG Cost($)
200	17	15.18	25.03	34.893

From the Table.1, the minimum OF is obtained when DG with rating 25.03KW is placed at bus number 17.

Table 2.Comparison of losses and cost with different objective functions.

	Bus No	DG Value (100*KW)	Cost of DG($)	Ploss (100*KW)
NO DG	0	0	0	0.18197
DG with loss min as OF	14	0.63	42.3369	0.1241
DG with loss min and cost as OF	17	0.2503	34.8933	0.1518

From the table 2, it is observed that when loss minimization is considered as the objective function 31.8% of the loss is reduced. When both loss and cost minimizations are considered as the objective function only 15% loss is reduce, but 17.58% of the DG cost is also reduced.

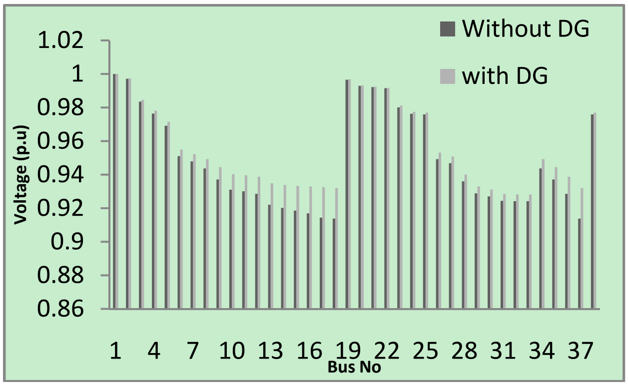

Fig. 4. Voltages profile before and after DG placement with Multi Objective Function.

From figure 4, it is observed that the voltage profile is improved after the placement of DG and hence automatically loss will reduce.

6. Conclusion

From the above studies on 38 bus distribution systems, the major contributions in the present work are:

- The optimized value of weighting factor is computed.
- The optimum locations and optimal sizes of DG are obtained.
- Due to the placement of optimal DG size at its optimum location it is observed that the voltages of all buses are improved and the losses are reduced substantially, thus paving way for the savings in the cost of the DG.

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