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Optimal DG Placement for Loss Reduction using Fuzzy and Flower Pollination Algorithm

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ABSTRACT

This paper presents a new methodology using Fuzzy and Flower Pollination Algorithm for the placement of DG units in electrical distribution systems to reduce the power losses and to improve the voltage profile. Electrical energy plays an important role in day-to-day life. Keen interest is taken on all possible sources of energy from which it can be generated and this led to the encouragement of generating electrical power using renewable energy resources such as solar, tidal waves and wind energy. Due to the increasing interest on renewable sources in recent times, the studies on integration of distributed generation to the power grid have rapidly increased. The distributed generation (DG) sources are added to the network mainly to reduce the power losses by supplying a net amount of power. In order to minimize the line losses of power systems, it is equally important to define the size and location of local generation. There have been many studies, to define the optimum location of distributed generation. In this paper, Fuzzy approach is used to find the optimal locations of DG units and Flower Pollination Algorithm is used to find the optimal sizes of DG units. The suggested method is programmed under MATLAB software and is tested on 15-bus and 33-bus test systems and the results are presented.

Keywords: *Distributed generation allocation, Power losses, Loss Sensitivity Factors, Voltage Profile, Fuzzy Approach and Flower Pollination Algorithm.*

1. INTRODUCTION

"Distributed Generation", [1] is defined as small-scale generation located at or near the load centres. It has also been called as on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy. Distributed generation is done through various small-scale power generation technologies. Distributed energy resources (DE) refers to a variety of small, modular power-generating technologies that can be combined with energy management and storage systems and used to improve the operation of the electricity distribution system, whether or not those technologies are connected to an electricity grid. Distributed generation is a technology which reduces the amount of energy lost in transmitting electricity because the electricity is generated very near load centre, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed. Much analysis's has been done on DG unit Placement.

The objective of the DG placement problem is to determine the locations and sizes of the DG's so that the power loss is minimized. Even though considerable amount of research work was done in the area of optimal DG placement [1 to 12], there is still a need to develop more suitable and effective methods for the optimal DG placement. Some of the methods used for the optimal DG placement problem are efficient. Their efficiency entirely depends on the goodness of the data used. Fuzzy approach provides a remedy for any lack of uncertainty in the data. Fuzzy approach has the advantage of including heuristics and representing engineering judgments into the optimal DG placement problem. The solutions obtained from a fuzzy approach can be easily analyzed to determine optimal DG locations. The global optimization method is more useful in obtaining the optimal DG sizes. Flower pollination algorithm (FPA) is a computational intelligence metaheuristic that takes its metaphor from flowers proliferation role in plants. [13 to 16].

In the first stage, fuzzy approach proposed by H. Ng *et al.*, [9] M. Damodar Reddy and V.C. Veera Reddy [11, 12] is used to find the optimal DG locations. In the second stage, Flower Pollination Algorithm is used to find the optimal sizes of the DGs. The proposed method is tested on 15-bus, 33-bus, 34-bus, and 69-bus test systems and the results are presented.

2. PROBLEM FORMULATION

The total real power loss (P_L) in a distribution system having *n* number of branches is given by:

$$P_L = \sum_{i=1}^{n} I_i^2 \; Ri \qquad (1)$$

Here I_i is the magnitude of the branch current and R_i is the resistance of the *ith* branch, respectively. The branch current can be obtained from the load flow solution. The branch current has two components, active component (*Ia*) and reactive component (*Ir*). The loss associated with the active and reactive components of branch currents can be written as:

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$$P_{La} = \sum_{i=1}^{n} I_{ai}^2 \ Ri \quad (2)$$

$$P_{Lr} = \sum_{i=1}^{n} I_{ri}^2 \ Ri \quad (3)$$

For a single-source radial network, the loss P_{La} associated with the active component of branch currents cannot be minimized because all active power must be supplied by the source at the root bus. However, supplying part of the reactive power demand locally can minimize the loss P_{Lr} associated with the reactive component of branch currents. This paper presents a method that minimizes the loss due to the reactive component of the branch current by optimally placing the capacitors and there by reduces the total loss in the distribution system.

3. IDENTIFICATION OF OPTIMAL DG LOCATIONS USING FUZZY APPROACH

This paper adopted the fuzzy approach proposed by H. Ng *et al.*, [9] M.Damodar Reddy and V.C.Veera Reddy [11, 12] to determine suitable locations for capacitor placement. Two objectives are considered while designing a fuzzy approach for identifying the optimal capacitor locations. The two objectives are: (i) to minimize the real power loss and (ii) to maintain the voltage within the permissible limits. Voltages and power loss indices of distribution system nodes are modelled by fuzzy membership functions. A fuzzy inference system (FIS) containing a set of rules is then used to determine the DG placement suitability of each node in the distribution system. DG's can be placed on the nodes with the highest suitability. In the first step, load flow solution for the original system is required to obtain the real and reactive power losses. Again, load flow solutions are required to obtain the power loss reduction [18] by compensating the total reactive load at every node of the distribution system. The loss reductions [18] are then, linearly normalized into a (0-1) range with the largest loss reduction [18] having a value of 1 and the smallest one having a value of 0. Power Loss Index value for n^{th} node can be obtained using equation 4.

$$PLI_{(n)} = \frac{(Lossreduction\,(n) - Lossreduction\,(\text{min}))}{(Lossreduction\,(\text{max}) - Lossreduction\,(\text{min}))} \quad (4)$$

These power loss reduction [18] indices along with the p.u. nodal voltages are the inputs to the Fuzzy Inference System (FIS), which determines the node more suitable for capacitor installation. In this paper, two input and one output variables are selected. Input variable-1 is power loss index (PLI) and Input variable-2 is the per unit nodal voltage (V). Output variable is DG suitability index (DGSI). Power Loss Index range varies from 0 to 1, P.U. nodal voltage range varies from 0.9 to 1.1 and DG suitability index range varies from 0 to 1. Five membership functions are selected for PLI. They are L, LM, M, HM and H. All the five membership functions are triangular as shown in Figure-1. Five membership functions are selected for voltage. They are L, LN, N, HN and H. These membership functions are trapezoidal and triangular as shown in Figure-2. Five membership functions are selected for DGSI. They are L, LM, M, HM and H. These five membership functions are also triangular as shown in Figure-3.

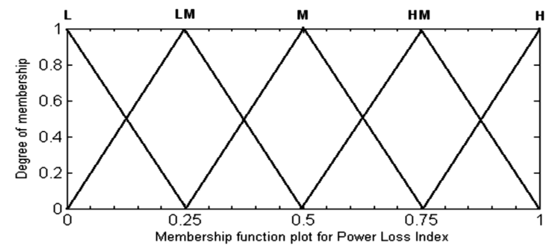

Figure-1. Membership function plot for P.L.I.

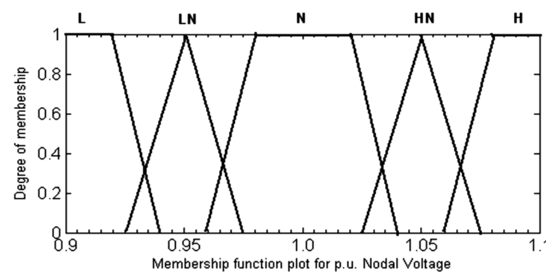

Figure-2. Membership function plot for p.u. nodal voltage.

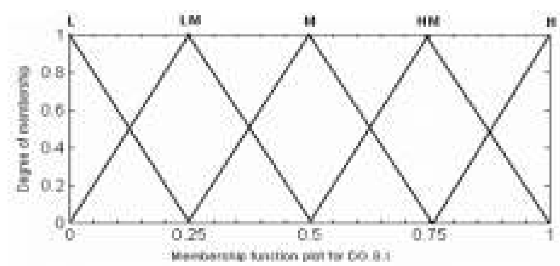

Figure-3. Membership function plot for DG.S.I.

For determining the suitability of DG placement at a particular node, a set of multiple-antecedent fuzzy rules has been established. The inputs to the rules are the voltage and power loss indices and the output is the suitability of DG placement. The rules are summarized in the fuzzy decision matrix in Table-1. The consequents of the rules are in the shaded part of the matrix. Optimal DG locations are identified based on the highest DG suitability index values.

Table - 1: Decision matrix for determining the DG location

AND		Voltage				
		L	LN	N	HN	H
PLI	L	LM	LM	L	L	L
	LM	M	LM	LM	L	L
	M	HM	M	LM	L	L
	HM	HM	HM	M	LM	L
	H	H	HM	M	LM	LM

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4. FLOWER POLLINATION ALGORITHM (FPA)

Flower Pollination Algorithm (FP) was founded by Yang in the year 2012. Inspired by the flow pollination process of flowering plants. Flower pollination is an intriguing process in the natural world. Its evolutionary characteristics can be used to design new optimization algorithms. In this paper, we propose a new algorithm, namely, flower pollination algorithm, inspired by the pollination process of flowers.

Algorithm to find the DG sizes using Flower pollination algorithm

In nature, the main purpose of the flowers is reproduction via pollination. Flower pollination is related to the transfer of pollen, which is done by pollinators such as insects, birds, bats, other animals or wind. Some flower types have special pollinators for successful pollination. The four rules of pollination have been formulated based on the inspiration from flowering plants and they form the main updating equations of the flower pollination algorithm

1. Cross-pollination occurs from the pollen of a flower of different plants. Pollinators obey the rules of a Lévy distribution by jumping or flying distant steps. This is known as global pollination process.
2. Self-pollination occurs from the pollen of the same flower or other flowers of the same plant. It is local pollination.
3. Flower constancy is the association of pollinators and flower types. It is an enhancement of the flower pollination process.
4. Local pollination and global pollination are controlled by a probability between 0 and 1, and this probability is called as the switch probability.

In the real world, a plant has multiple flowers and the flower patches release a lot of pollen gametes. For simplicity, it is assumed that each plant has one flower producing a single pollen gamete. Due to this simplicity, a solution (x_i) in the present optimization problem is equal to a flower or a pollen gamete. For multi-objective optimization problems, multiple pollen gametes can be considered.

In the flower pollination algorithm, there are two key steps involving global and local pollination. In the global pollination step, the first and third rules are used together to find the solution of the next step x_i^{t+1} using the values from the previous step (step t) defined as x_i^t Global pollination is formulized in Eq. (1).

$$x_i^{t+1} = x_i^t + L(x_i^t - g*) \quad \text{------- (1)}$$

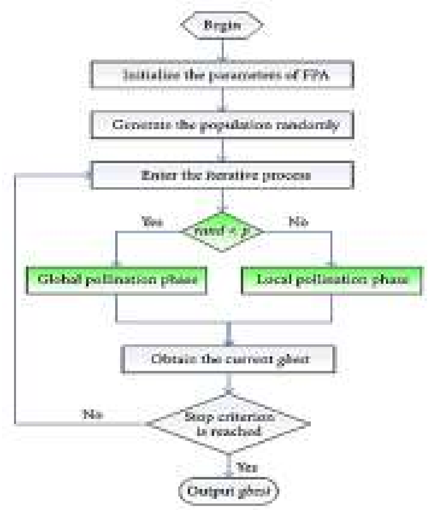
The subscript i represents the i^{th} pollen (or flower) and Eq. (1) is applied for the pollen of the flowers. g^* is the current best solution. L is the strength of the pollination, which is drawn from a Lévy distribution. The second rule is used for local pollination with the third rule about flower constancy. The new solution is generated with random walks as seen in Eq. (2).

$$x_i^{t+1} = x_i^t + \varepsilon(x_j^t - x_k^t) \quad \text{------ (2)}$$

Where x_j^t and x_k^t are solutions of different plants. ε is randomized between 0 and 1.

According to the fourth rule, a switch probability (p) is used in order to choose the type of pollination which will control the optimization process in iterations. The details of the optimization process can be seen in the pseudo code which is given for the flower pollination algorithm.

Flowchart of FPA



5. RESULTS

Fuzzy approach is used to find the optimal dg locations and FPA is used to find the optimal dg sizes.

5.1. Results of 15-bus system

The proposed algorithm is applied to 15-bus, 33-bus [17] test systems and the results are presented in Tables 2 and 3 respectively.

Table 2: DG Unit sizes at the preferred bus locations for 15-bus system

Bus No.	DG Unit size in kVA
6	546
3	769
11	364
Minimum bus voltage in p.u.(before)	0.9451
Minimum bus voltage in p.u. (after)	0.9923
Total power loss in kW (before)	61.7339
Total power loss in kW (after)	4.6685
Reduction in power loss (%)	92.44 %

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Table-3: DG Unit sizes at the preferred locations for 33-bus system

Bus No.	DG Unit size in kVA
6	1843
28	92
Minimum bus voltage in p.u. (before)	0.8793
Minimum bus voltage in p.u(after)	0.9664
Total power loss in kW (before)	368.9625
Total power loss in kW(after)	35.4085
Reduction in power loss (%)	90.40%

6. RESULTS

In this paper, a two-stage methodology of finding the optimal locations and sizes of dg for loss reduction [18] in distribution systems is presented. Fuzzy approach is proposed to find the optimal dg locations and Flower Pollination Algorithm is proposed to find the optimal dg sizes. Based on the simulation results, the following conclusions are drawn.

By installing dg at all the optimal locations, the total real power loss of the system has been reduced significantly and bus voltages are improved substantially. The fuzzy approach is capable of determining the optimal dg locations based on the DG.S.I. values. The proposed Flower Pollination Algorithm iteratively searches the optimal dg sizes corresponding to minimum loss.

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