AN APPROACH TO REDUCE REAL POWER LOSSS USING HARMONY SEARCH ALGORITHM

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Abstract: This paper presents a new methodology using Fuzzy and Harmony Search 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 harmony search algorithm based on intelligent behavior of crows for finding optimal locations and sizes of PV and capacitor simultaneously. The suggested method is programmed under MATLAB software and is tested on 15-bus and 33-bus test systems and the results are presented.

Index terms: Distributed generation allocation, Power losses, Loss Sensitivity Factors, Voltage Profile, Fuzzy Approach and Firefly algorithm

I. 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 analysed to determine optimal DG locations. The global optimization method is more useful in obtaining the optimal DG sizes. Harmony search algorithm is one of the new meta-heuristic methods in all the engineering fields [13].

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, Crow Search Algorithm (CSA) is used to find theoptimal locations and sizes of PV and capacitor. The proposed method is tested on 33-bus, 34-bus, and 69-bus test systems and the results are presented.

II. Problem Formulation

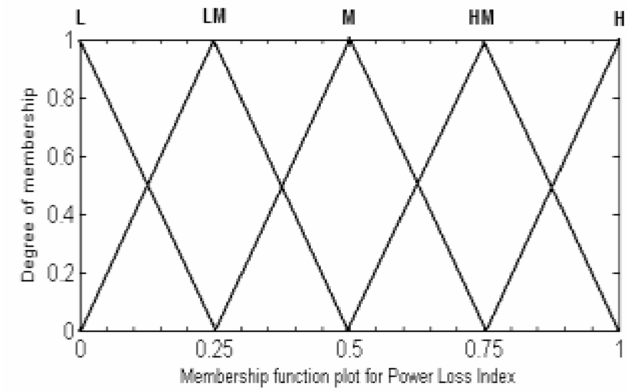
The total real power loss (P_L) in a distribution system having *n* number of branches is given by:

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

Here I_i is the magnitude of the branch current and R_i is the resistance of the i^{th} 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:

$$P_{ai} = \sum_{i=1}^{n} I_{ai}^{\;2} R_i \qquad (2)$$

$$P_{Lr} = \sum_{i=1}^{n} I_{ri}^{\;2} R_i \qquad (3)$$



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 thereby reduces the total loss in the distribution system.

III. 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.VeeraReddy [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 1and the smallest one having a value of 0. Power Loss Index value for nth node can be obtained using equation 4.

$$\text{PLI}_{(n)} = \frac{(Lossreduction\ (n) - Lossreduction\ (\min))}{(Lossreduction\ (\max) - Lossreduction\ (\min))} \qquad (4)$$

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 inFigure-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 inFigure-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.

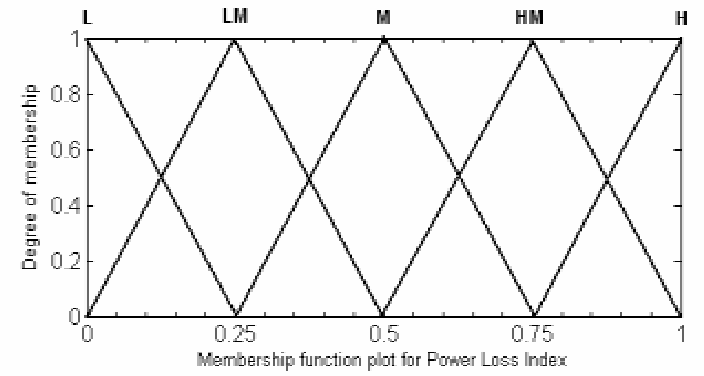


Figure-1. Membership function plot for P.L.I.

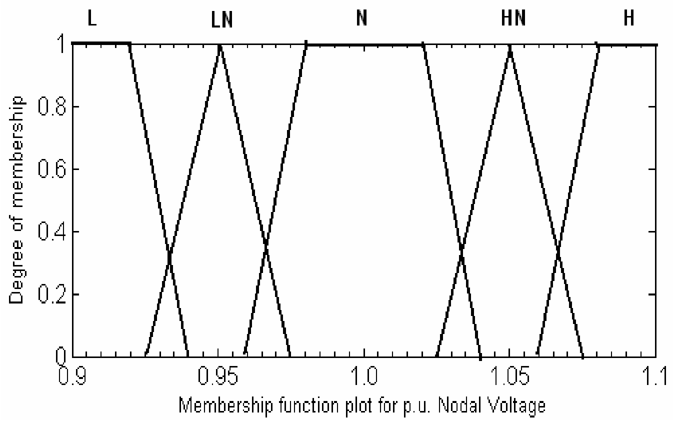


Figure-2. Membership function plot for p.u.nodal voltage.

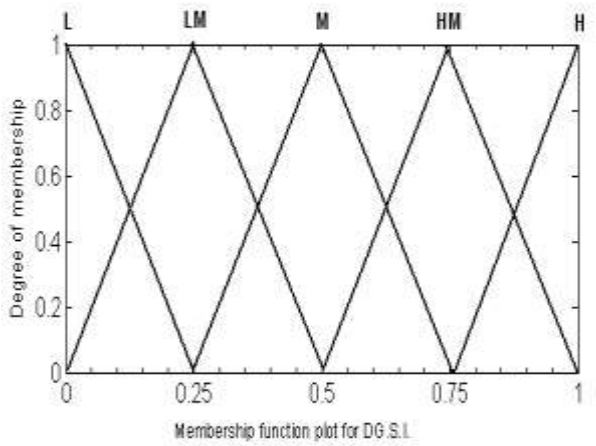


Figure-3. Membership function plot for DG.S.I.

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

IV. Harmony Search Algorithm

The harmony search algorithm (HSA) is a new meta-heuristic algorithm [13 to 16]. The harmony search algorithm (HSA) is simple in concept, few in parameters and easy in implementation. Harmony search algorithm is concept from natural musical performance processes. The musicians starting with some harmonies, they attempt to achieve better harmonies by improvisation and create iteratively new good solutions based on past solutions on random modifications. Finally HSA gives optimum value. This algorithm was originally developed for discrete optimization and later expanded for continuous optimization. It has been successfully applied to various computational optimization problems such as structural design, water network design, dam scheduling, school bus routing, sudoku game, music composition, benchmark and real-world problems. The HS algorithm initializes the Harmony

Memory (HM) with randomly generated solutions. The number of solutions stored in the HM is defined by the Harmony Memory Size (HMS). Then iteratively a new solution is created as follows. Each decision variable is generated either on memory consideration and a possible additional modification, or on random selection. The parameters that are used in the generation process of a new solution are called Harmony Memory Considering Rate (HMCR) and Pitch Adjusting Rate (PAR). After a new solution has been created, it is evaluated and compared to the worst solution in the HM. If its objective value is better than that of the worst solution, it replaces the worst solution in the HM. This process is repeated, until a termination criterion is fulfilled.

Algorithm to find the DG sizes using harmony search algorithm

After identifying the *n* number of optimal DG locations using fuzzy approach, the DG sizes in all these *n* optimal locations are obtained by using the Harmony Search Algorithm.

Step 1: Initialize all the parameters and constants of the Harmony search algorithm. They are Qmin, Qmax, hms, HMCR, PAR_{min} and PAR_{max}.

Step 2: Run the load flow program and find the total real power loss PLoss1 of the original system. (Before DG placement)

Step 3: Initialize the harmony memory i.e., generate [*hms* x *n*] number of initial solutions randomly within the limits, where *hms* is the harmony memory size and *n* is the number of . Each row represents one possible solution to the optimal DG-sizing problem. For example; *n* = 1 for one dg, *n* = 2 for two dgs, *n* = 3 for three dgs, *n* = 4 for four dgs and *n* = 5 for five dgs and *hms* = 10 for ten harmony, *hms* = 20 for twenty harmony, *hms* = 50 for fifty harmony, *hms* = 100 for hundred harmony and *hms* = 200 for two hundred harmony.

Step 4: Place all the *n* dg of the harmony vector i.e., each row of the Harmony vector at the respective optimal dg location and perform the load flow analysis and find the total real power loss PLoss2 and then obtain the loss reduction [18] (fitness value) using equation (5)

$$\text{Fitness Value} = \text{PLoss1} - \text{PLoss2} \qquad (5)$$

Repeat the same procedure for all the rows of the harmony vector to find Fitness values.

Step 5: Obtain the best fitness value by comparing all the fitness values.

Step 6: Start the improvisation (Iteration count is set to one).

Step 7: Improvisation of the New Harmony is generating a new harmony. A New Harmony vector is generated based on the following steps:

(i) **Random selection:** It is used to select one value randomly for a certain element of the new vector from the possible range (Qmin, Qmax) of values.

(ii) **Memory consideration:** It is used to choose the value for a certain element of the new vector from the specified HM range.

$$x'_i = x'_i \in \{x'_1, x'_2 \ldots x_{HMSi}\} \text{ with probability HMCR} \quad (6)$$

$$x'_i = x'_i \in X_i \text{ with probability (1-HMCR)} \quad (7)$$

Step 8: Pitch adjustment: It is used to adjust the values of the New Harmony vector obtained in step 7. (Between PARmin and PARmax).

$$x'_i = x'_i \pm rand(0,1)*bw \quad (8)$$

(bw - band width varies between a higher value and a lower value from first iteration to last iteration)

Step 9: Find the fitness values corresponding to the New Harmony generated and pitch adjusted in steps 7 and 8.

Step 10: Apply Greedy Search between old harmony and New Harmony by comparing fitness values.

Step 11: Update harmony memory, by replacing the worst harmony with the new best Harmony. Obtain the best fitness value by comparing all the fitness values.

Step 12: The improvisation (iteration) count is incremented and if iteration count is not reached maximum then go to step 7.

Step 13: The solution vector corresponding to the best fitness value gives the optimal dg sizes in n optimal locations.

V. RESULTS AND DISCUSSION

Results of 33-bus system:

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

Table 2: DG Unit sizes at the prefered bus locations for 33-bus system

Number of DG's placed	optimal Type1 location	optimal Size (MW)	Optimal Type2 (capacitor) location	Optimal Size (MVAr)	Loss with DG's (KW)			Loss Without DG (PLt) (KW)	% reduction in loss PLt
					Active PLa	Reactive PLr	Total PLt		
1	6	2.5180	30	1.2487	40.079	11.715	51.795	202.666	74.443
2	13	0.8399	12	0.4524	23.164	5.701	28.865		85.757
	30	1.1402	30	1.0411					
3	6	1.1736	3	0.8079	15.223	3.429	18.652		90.796
	14	0.6033	14	0.3351					
	31	0.6798	30	0.9923					
4	3	1.2687	7	0.3776	10.989	1.256	12.245		93.958
	7	0.8005	14	0.2720					
	14	0.5859	24	0.4715					
	31	0.6944	30	0.8947					

VI CONCLUSIONS

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 harmony search algorithm is proposed to find the optimal locations and sizes of PV and capacitor. 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 crow search algorithm iteratively searches the optimal locations and sizes of PV and capacitor.

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