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Optimal placement of DG in a Distributed Generation Environment

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Abstract

The paper proposes optimal placement of fuel cells and sizing of Distributed Generators (DG) in distribution networks are determined using optimization. The objective is to improve the reliability indices. The placement and size of DGs are optimized using a Genetic Algorithm (GA). To evaluate the proposed algorithm, the IEEE 34 buses distribution feeder,is used. And it also proposes new methodology using Particle Swarm Optimization approach (PSO) for the placement of Distributed Generators (DG) in the radial distribution systems to reduce the real power losses and to improve the system reliability. A hybrid objective function is used for the optimal DG placement. It has two parts, in first part the power loss purpose as one index named Power Loss Reduction Index is considered .in second part the effect of DG on reliability improvement of system is considered and it is considered as one index named as Reliability Improvement Index. The proposed method is tested on standard IEEE 12 bus test system and the results are presented and compared with different approaches available in the literature. The proposed method has outperformed the other methods in terms of the quality of solution and computational efficiency.

Key words: Distributed generation, distribution system, Genetic Algorithm (GA). particle swarm optimization, power loss

1. Introduction

The electric power system normally includes a generating system, a transmission system, power substations and the distribution network. The distribution networks were designed to extract power from the power substations and distribute it to the loads. It was not designed to have generators directly connected to it. In the recent years, the electrical power utilities are undergoing rapid restructuring process worldwide. Indeed, with deregulation, advancement in technologies and concern about the environmental impacts,competition is particularly fostered in the generation side thus allowing increased interconnection of generating units to the utility networks. These generating sources are called as distributed generators (DGs).Deployment of distributed generators (DG) within just distribution network is becoming more inviting on account of many benefits which small scale generation could possibly to enhance the electric power resources . The particular distributed generation (DG) can be constituted within a new emphasis for the electrical power generation .

DG is an electric power generation source connected directly to the distribution network or on the customer side of the meter.” Using DG can enhance the performance of a power system in many aspects. Employing DG in a distribution network has several advantages as reduction in line losses, emission pollutants, overall costs due to improved efficiency & peak saving. Improvement of voltage profile, power quality, system reliability and security and the disadvantages are reverse power flow, injected harmonics,Increased fault currents depending on the location of DG units. DG also has several benefits like energy costs through combined heat and power generation, avoiding electricity transmission costs and less exposure to price volatility.With the connection of DG in a system power losses are reduced. For a particular DG capacity there is a location in the system such that if we connect DG at that location power losses are minimum in comparison when same DG is connected at any other point. That particular location where power losses are minimum is known as Optimum location.

2. Distributed generator:

Distributed generator is now commonly used in distribution system to improve the overall performance of the distribution system. Major advantages of using distributed generator in distribution system are: it reduces total power losses in the system, improvement in voltage profile and reliability of the system and many more. There are different types of distributed generators are in literature. Some of them are wind power, solar power, hydroelectric power, tidal power, small hydro power, photovoltaic cells, fuel cells etc. Among the different types of distributed generators, this work considers fuel cells for distributed generation. The fuel cells are generated because of its renowned advantages over the conventional resources that are increased efficiency, increased reliability, less maintenance, excellent part- load performance, modularity and fuel flexibility, low chemical, acoustic and thermal emissions. A fuel cell is an electrochemical device that converts chemical energy directly into electrical energy. The fuel cell unit uses hydrogen and oxygen to perform the required chemical reaction and produce power.

3. Problem formulation

The fuel cells installation at optimal location ultimately leads to various factors such as line loss reduction, improved voltage stability, reliability and security. The optimum location and sizing of the fuel cell are the optimization problems with nonlinear objective function having corresponding constraints.

The objective of DGs placement in a radial feeder is to maximize the distribution network reliability under certain constraints. As a brief reminder, we will look at the standard reliability performance indices, such as system average interruption duration index (SAIDI) ,system average interruption frequency index (SAIFI) and energy not supply index (AENS) and the composite index obtained as a combination of all three. They are defined as follows:

(1) $SAIFI = \Sigma\lambda_i N_i / \Sigma N_i$
where N_i is the number of customers of load point i and λ_i is the failure rate.

(2) $SAIDI = \Sigma\, u_i\, N_i / \Sigma N_i$
where u_i is the outage time.

(3) $AENS = \Sigma\, L_{a(i)}\, u_i / \Sigma N_i$

Where $L_{a(i)}$ is the average load connected to load point i.
For the purpose of optimization, we define a composite reliability indices and capacity of DG units through weighted aggregation of these indexes.

Power loss reduction: DG sources are normally placed close to load centers and are added mostly at the distribution level. A common strategy for sizing and placement of DG is either to minimize system power loss or system energy loss of the power systems. The voltage at each bus is in the acceptable range and the line flows are within the limits.The formulation to determining the optimal size and location of DG in a system is as follows:
Loss Reduction Factor Index per node is defined as the ratio of percentage reduction in loss from base case when a DG having size DGS KW is installed at bus i, to the DG size at that bus. Power Loss Reduction Index (PLRI) is expressed as:

$PLRI = (PIoss_{Base} - PIoss_{DGi}) / PIoss_{Base}$
where After the iterative solution of bus voltages, line flows and line losses can be calculated. The complex powers Sij from bus I to j and Sji from bus j to i are:

Sij=ViI*ij
Sij=VjI*ji
The power loss in line i-j is the algebraic sum of the power flows determined from the above equations.
$pIoss = \Sigma\, \Sigma\, \mathrm{Re}\{S\, ji\, Sij\}$
Reliability Improvement Index (RII) is illustrated as:

$RII = (AENS_T - AENS_i) / (AENS_T$
where,
ENST : The total average energy not supplied when the fault happened in sequence in all the sections in

the case of without DG.
ENSi : The total average energy not supplied when the fault happened in sequence in all the sections
with the i-combination of DG.

Multiobjective based problem formulation: The multiobjective index for the performance calculation of distribution systems for DG size and location planning with load models considers all previous mentioned indices by giving a weight to each index. The PSO-based multiobjective function (MOF) is given by:

MOF = W1*PLRI+W2*RII
where,
W1+W2 = 1
These weights are indicated to give the corresponding importance to each impact indices for the penetration of
DG with load models and depend on the required analysis (e.g., planning, operation, etc.). The weighted normalized
indices used as the components of the objective function are due to the fact that the indices get their weights by translating their impacts in terms of cost.

GA-based optimization method:
Due to the discrete nature of allocation and sizing problem, it undergoes a number of local minima. To deal appropriately with this issue, using a reliable optimization method is required. The optimization methods are mainly divided into analytical and heuristic methods. The analytical methods show higher accuracy compared with the heuristic methods in the smooth functions. However, the objective function in the discrete problems is non-smooth which reduce the accuracy of the analytical method and lead them occasionally to be stuck in the local minima. For optimizing this type of functions, the heuristic algorithms play an acceptable role. They are based on the random values and if only one of these random values is located close to the global minimum, they can find acceptable solution [12]. In this paper Genetic Algorithm (GA) is used to achieve optimal response.GA simulates the biological processes that allows the consecutive generations in a population to adapt to their environment. Genetic Algorithm is unconstrained optimization methods, which model the evolutionary adaptation in nature. They work with a population of solutions and create new generations of solutions by
appropriate genetic operators. The description and comments of algorithm implementation are presented as follows.

Step1: convert the problem variables to Codes used for GA operators
In this method any bus is encoded by three bits. The first bit indicates the presence or absence of DG units and next two bits represent the capacity of the unit is installed in bus. So length of each chromosome is equal to: 3 multiplied by number of buses. Capacity of distributed generation units 0.3, 0.6, 0.9, 1.2 MW is intended.
Step2: The initial population
To each of the chromosome genes are randomly assigned to zero or one. The initial population consists of 20 members
Step3: Calculation of reliability indices and the objective function
In this step Constraints are examined and if the answer is not satisfactory, a large number as a penalty factor is added to the objective function.
Step4: The GA operators (Roulette Wheel Selection,Cross Over, Mutation)
To avoid trapped in local minimum during the program, amount of mutation probability is changed and amount of cross over probability has been selected 0.2.

PSO-based optimization method: Particle Swarm Optimization, as an optimization tool, consists of a characteristic called particle (Mithulananthan *et al*., 2000). Each particle in order to move to optimum position, changes its position with time.Particles move around in a multi dimensional search space, during Xight. Each particle according to its own experience, and the experience of neighboring particles, adapt its position. Other characteristic in the PSO approach is called swarm.
Step1: Initialization (: In this step d, n, T, itermax, w, c1, c2 and velocities are assigned. In this step, the lower and higher bound of regional constraints is specified too. Based above d initial particles are generated in random in the range of regionalconstraint. Set iteration = 1.
Step2: Objective function calculation: In this step the objective function and fitness value of each particle qi,d is calculated

Step3: Velocity modification: In this step the velocity of each particle is modified based on bellow equation, and then generate the new particles.

Step4: Upgrading of qbest, sbest: If the fitness value of each particle is better than the previous qbest,then qbest is updated with the current value.If the best qbest is better than sbest, then sbest will be substituted with the best qbest. This is the end of iteration

4. Simulation & results:

To validate the proposed method of GA, the IEEE 34 buses distribution feeder, as shown in Figure , is studied. The reliability index weights are chosen as follows:

WSAIFI = 0.31, WSAIDI = 0.31, WAENS = 0.31 and WPDG = 0.07. The target values of the reliability indices are set as follows: SAIFIT = 10, SAIDIT = 100, AENST = 350 and PDGT = 1000. They are empirically justified and indicate the satisfactory level of reliability.

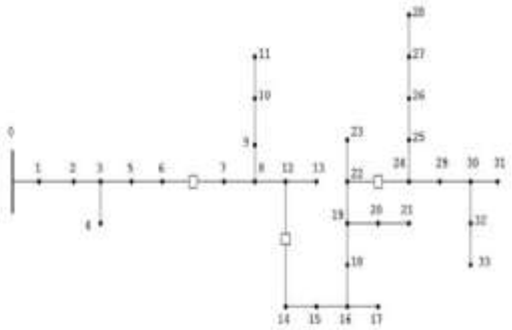

Fig. 1 : Test system

TABLE I. COMPARISON OF OUTPUTS BEFORE AND AFTER INSTALLATION OF DGS

	SAIFI	SAIDI	AENS	OBF
Without DGs	8.7	92.4	461.4	**0.58**
With DGs	1.2	5.2	25.9	**0.22**

To validate the proposed method of PSO:

The proposed methodology is tested on test systems to show that it can be implemented in distribution systems of various configuration and size. The test system is a 12 bus system with the total load of 761.04 KW and 776.50 KVAR and base voltage 11KV. A single line diagram of the test system is shown in Fig. 1.A computer program has been written in MATLAB 7to calculate the optimum location and sizes of DG at various buses using GA and reparative load flow method

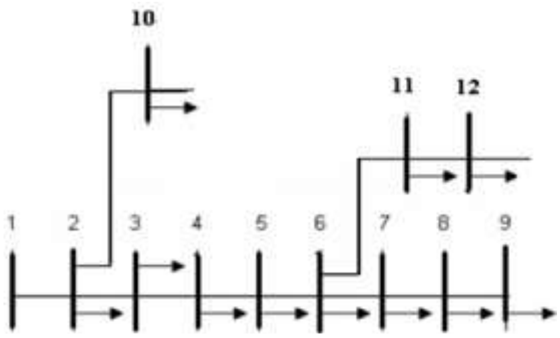

Fig. 2: Test distribution system

Table 2: Optimal DG unit sizes for 12-bus radial distribution system

Test system	Optimal locations 1	Optimal DG size in KW	Power loss in KW		AENS	
			Without DG	With DG	Without DG	With DG
12bus	3	437.21	280.08 KW	200.20	75.7 Kwh/yr	45.3
	6	450.65		210.87		54.7
	7	477.00		230.45		66.2
	11	513.07		240.45		70.7

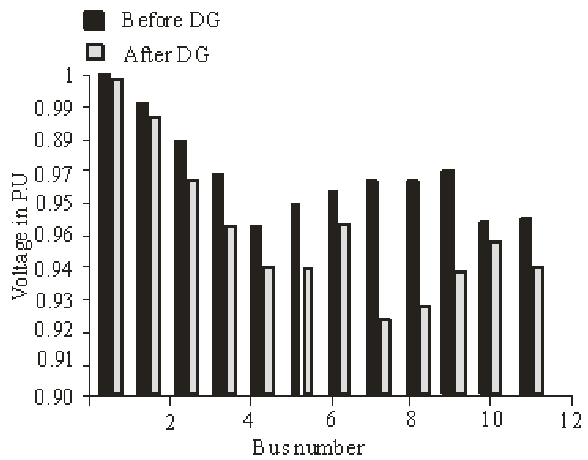

Fig. 3: Voltage profile before and after DG injection having optimum value

CONCLUSION

This paper presents a problem formulation with GA, solution for the placement and sizing of DGs optimally.To evaluate the proposed algorithm, the IEEE 34 buses distribution feeder, is used. The results are finally compared with the no DG condition and it show that reliability indices especially Energy Not Supply index (ENS) has improved considerably with optimal placement of distributed generation and beneficiary companies acquire more benefits.

A PSO based distributed generator placement technique in a distribution system for reducing the total real power losses and improve system reliability in the system is presented in the paper. The PSO approach gives both optimal size and the locations as outputs. This study shows that the proper placement and size of DG units can have a significant impact on system loss reduction. It also shows how improper choice of size would lead to higher losses than the case without DG. However, in practice there will be many constraints to be considered in selecting the site. In this paper an objective function with aim to minimizing power loss and minimizing energy not supplied following fault is distribution system is considered and with PSO is optimized.

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