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Optimization of Location and Capacity DGs Using HPSO Approach Case Study on the Electrical Distribution Network of North Kerman Province

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Abstract: Development of distribution systems lead in higher system losses and poor voltage regulation. Consequently, an efficient and effective distribution system has become more urgent and crucial. Hence, number, location and capacity of distributed generation can be optimized using evolutionary algorithm. This paper uses a hybrid optimization method based on discrete particle swarm optimization and imperialist competitive algorithm with the objective to minimize the overall cost of annual energy losses and depreciation on the cost of distributed generation in order to improve productivity. Furthermore, the Backward-Forward sweep iterative method was adopted to solve the radial load flow analysis. Simulations are carried out on 69-bus radial distribution network using Hybrid PSO approaches in order to show the accuracy as well as the efficiency of the proposed solution technique.

Key words: Distributed generation · Particle swarm optimization · Imperialist competitive algorithm · Radial distribution systems and Backward-Forward sweep

INTRODUCTION

Distributed Generation (DG) may play an increasingly important role in the electric power system organization and market. Unlike traditional generation, the aim of distributed generation is to generate part of required electrical energy on small scale closer to the places of consumption and interchanges the electrical power with the network. The sitting of distributed generator in distribution feeders is vulnerable to have an impact on the operations and control of power system, a system designed to operate with large, central generating facilities. Distributed Generation can be defined as an electrical power source linked directly to the distribution network or on the consumer side of the meter. It may be implied in simple term as small-scale electricity market. From distribution system planning point of view, DG is a plausible alternative for new capacity, particularly in grid reinforcement, reducing power losses and on-peak operating costs, improving voltage profiles and load factors, differing or eliminating for system upgrades and improving system integrity, reliability and efficiency [1-3] and has great benefits such as short lead time and low investment risk since it is built in modules, small-capacity modules that can track load deviation more closely, small physical size that can be installed at load centers and does not need government approval or search for utility area and l and availability and existence of a large range of DG technologies [2,4]. Analytical approaches for optimal placement of DG with unity power factor is to minimize the power loss of the system. The planning of the electric system at the presence of DG requires defining of several factors including the best technology to be used, the number and the capacity of the units, the best location, the type of network connection, etc. The effect of DG on operating characteristics of the system such as electric losses, voltage profile, stability and reliability needs to be appropriately assessed. The problem of DG allocation and sizing is importance crucial task. Installing DG units at no optimal places may result in an increase in system losses, costs and therefore, having an undesired effect on the system. There may be many locations that do not have overload or voltage problems, where the DG can be located and provide the necessary control [5].

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As a result, using an optimization method capable of indicating the best solution for a given distribution network can be very useful for system planning engineers. Selecting the best places for installing DG units and their preferable sizes in large distribution systems is an elaborate optimization problem.

This paper presents analysis of Particle Swarm Optimization (PSO) based system power loss minimization approach and system energy loss minimization approach for optimal sizing and placement of DG in electrical power systems. The methods are presented to find optimal size and bus location for placing DG using power loss and energy loss minimization in a networked system based on bus admittance, generation information and load distribution of the system. The proposed methods are tested by simulations on 69-bus of Kosar feeder in the presence of 4-DG, 6-DG and 8-DG. An effectiveness of proposed methods is tested by determining the optimal size and bus for placing DG under voltage and line loading constraints with uniform loading conditions in system power loss minimization and in system energy loss minimization.

Power Flow Analysis Method : The methods proposed for solving distribution power flow analysis can be classified into three categories: Direct methods, Backward-Forward sweep methods and Newton-Rap son (NR) methods. The Backward-Forward Sweep method is an iterative means to solving the load flow equations of radial distribution systems which has two steps. The Backward sweep, which updates currents using Kirchhoff's Current Law (KCL) and the Forward sweep, which updates voltage using voltage drop calculations [6].

Backward Sweep: The Backward Sweep calculates the current injected into each branch as a function of the end node voltages. It performs a current summation while updating voltages. Thus, for each iteration k, branch currents are aggregated from loads to origin [7].

$$J^K = T.\ I^K \tag{1}$$

The relationship between nodal currents J^K and branch currents J^K is set through an upper triangular matrix T accomplishing the Kirchhoff Current Laws (KCL). Each element T_i^k of I^k associated to node i is calculated as function of injected powers S_i and its voltage profile V_i^k as shown below:

$$T_i^k = \frac{S_i^*}{V_i^{k*}} \tag{2}$$

Where n is the number of bus and (*) is the conjugate of a complex number.

Forward Sweep: The Forward Sweep calculates node voltages as a function of the currents injected into each bus. Nodal voltage vector V is updated from the origin to loads according the Kirchhoff's Voltage Laws (KVL), using previously calculated branch currents vector J, branch impedances vector Z. Branch impedances are corresponded to a distribution line model containing series positive sequence impedance for line or transformer.

$$V^{k+I} = V_0 - T^T.D_z.J^k = V_0 - T^T.D_z.T.J^k \tag{3}$$

Where V_0 is a n-elements vector with all entries set at voltage at origin (swing node) V_0 and branch impedances D_z is the diagonal matrix of vector Z.

Convergence: Updated voltages are compared with previous voltages in order to perform convergence check in [7].

$$\varepsilon \le V_i^{k+I} - V_i^k : i = I,...,n \tag{4}$$

Formulation: The goal of optimization technique, Evolutionary Programming is then to assign values, from the allowed domain, to the unknowns such that the objective function is optimized and all constraints are satisfied. In this work, EP is used to minimize the power losses in order to obtain the optimal location and sizing of DG. The optimization of DG location and sizing for solving the power generation problem involve several equations and constraints i.e. equality constraints and inequality constraints. The equality constraints are the nodal power balance equations, whereas the inequality constraints are the confined control or state variables. The objective function is optimization of power losses in the power system. This real power loss can be calculated by [8-10].

The Objective Function: Evolutionary algorithms are usually designed to maximize or minimize the objective function, which is a measure of the quality of each c andidate solution [11]. After control variables are coded, the objective function will be evaluated. These values are the measures of quality, which is used to compare different solutions. The better solution joins the new population and the worse one is neglected. Here Total Power Loss in the Distributed Generation is used in formulation of the objective function. Therefore objective function takes the following from:

$$Minf = W_1 f_{loss}(r) + W_2 f_{ENS}(r) \tag{5}$$

Where $f_{loss}(r)$ loss power for load is level r and f_{ENS} is energy not supplied for load is level r and W_1 is the weighting factor and can be written as following equations

$$f_{loss}(k) = C_N(r) \times E_{loss}(r) \tag{6}$$

Where $C_N(r)$ is the saving per MW reduction in the peak power loss and $E_{loss}(r)$ is loss power for load level r and is defind as equation

$$E_{loss}(r) = h_r \times \sum_{i=I}^{n} \sum_{j=I}^{n} R_{ij} \left| I_{ij}(r) \right|^2 \tag{7}$$

Where R_{ij} and I_{ij} are resistor impedance between buses I and j, respectively. h_r is the duration of time.

$$f_{ENS}(r) = \frac{h_i}{8760} \sum U_i\left(pL_i(r)\right) - min\left\{PL_i(r), P_{DGi}^{max}\right\} * cshed_{i(r)} \tag{8}$$

In which U_i is an average of outage, $C_{shed\ i(r)}$ is the cost of power outage and P_{DGi}^{max} is the maximum electric power by DG. The inequality constraint on voltage of the each bus,

$$|V_i| min \le V_i \le |V_i| max \tag{9}$$

The inequality constraint on P_{DGi} of each DG is given by:

$$P_{DCi} min \le P_{DGi} \le P_{DGi} max \tag{10}$$

Algorithms: In the present paper, as mentioned, particle swarm optimization algorithm is the second EA which is used to solve the DG allocation problem. Its key concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. It lies somewhere on between evolutionary programming and the genetic algorithms. Some of the features of PSO are adaptability, diverse response, proximity, quality and stability (Clerk and Kennedy, 2002). There are three versions of PSO: real, binary and discrete codifications. As the decision variables of the present problem are of discrete type, hence, Discrete Particle Swarm Optimization (DPSO) method is used in this paper.

- Produce an initial population *P* and create the empty external non-dominated set *Q*.
- Paste non-dominated members of *P* into *Q*.
- Remove all the solutions within *Q*, which are covered by any other members of *Q*. If the number of externally stored non-dominated solutions exceeds a given maximum *N'*, prune *Q* by means of clustering.
- Calculate the fitness of all individuals in *P* and *Q*.
- Use binary tournament selection with replacement and select the individuals from *P* and *Q* until the mating pool is filled.
- Apply crossover and mutation operators as usual.
- If the maximum number of generations is reached, then stop, else go to step 2.

RESULTS

To study the proposed method, actual power network of Kosar feeder of Kerman Province, Iran is simulated in Cymedist. Figure 1 illustrates the single-line diagram of this network. The initial data for load flow solution based on the Backward Forward sweep are selected as: $S_{base}=10^4$; $\varepsilon=0.0001$; $h_r=8760$.

The properties of the three conductors used in the analysis of this system are given in Table 1.

The parameters used in PSO algorithm are: Number of Iterations is 100; Number of swarms is 100; Revolution rate is 0.1, ω is set as 0.9 and both the acceleration coefficients as 0.5 in this paper. Simulation results on 4-DG, 6-DG and 8-DG are presented in Table 2 and demonstrate lower total loss in compare to the others.

The voltage profile based on DG selection in the system after Hybrid PSO implementation is compared with Conventional distributed generation design and depicted in Figure 3. It can be seen that the voltage profile conducted by PSO and Hybrid PSO optimization algorithms are almost resembled yet, having better improvement in compare with conventional method.

Fig 1: Single-line diagram of actual power network of Kosar feeder of Kerman Province in Cymedist

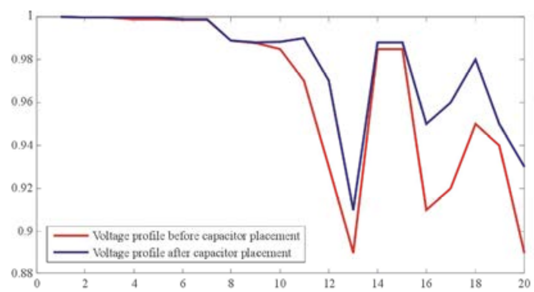

Fig 2: Voltage profile of 20 bus system before and after capacitor placement

Table 1: Conductor properties

Type	R [Ω/km]	X [Ω/km]	Cmax [A]	A [mm^2]	Cost [Toman/m]
Hyena	0.1576	0.2277	550	126	2075
Dog	0.2712	0.2464	440	120	3500
Mink	0.4545	0.2664	315	70	2075

Table 2: Total power loss comparison for dissimilar number of DG's

	Location [#bus]	Total Capacity [MW]	Loss[KW]
1-DG	13	1.3429	86.274
3-DG	51219	1.0774	76.16
		0.7597	
		1.0205	
5-DG	38101418	1.1219	52.974
		0.7619	
		1.0723	
		1.0774	
		0.8597	

CONCLUSION

This paper presented simulation approach for the optimal size and placement of a DG using evolutionary approaches with the aim to minimize the overall cost of annual energy losses and depreciation on the cost of DGs in order to improve productivity. The power losses, voltage magnitude and current flow magnitudes were computed exerting the Backward Forward sweep method. The performance of the proposed evolutionary approaches (Hybrid PSO) in comparison with conventional PSO was considered using a 20-bus actual power network of Kosar feeder of Kerman Province. The power loss reduction and voltage profile improvement has been successfully carried out illustrating the effectiveness of the proposed approaches. The results reveal potential of using Hybrid PSO for improving plant productivity and economy.

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