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Voltage Profile Improvement of distribution system Using Particle Swarm Optimization

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Abstract:
Distributed generations (DGs) play an important role in distribution networks. Distributed generation (DG) exists in distribution systems and is installed by either the utility or the customers. Distributed Generators (DGs) are now commonly used in distribution systems to reduce the power disruption in the power system network. Due to the installation of DGs in the system, the total power loss can be reduced and voltage profile of the buses can be improved due to this power quality of the distribution system is improved. Studies show that non-optimal locations and non-optimal sizes of DG units may lead to losses increase, together with bad effect on voltage profile. So, this paper aims at determining optimal DG allocation and sizing. To do so, the optimization technique named Particle Swarm Optimization (PSO) is used .this Particle Swarm Optimization (PSO) approach), capable to establish the optimal DG allocation and sizing on a distribution network. This paper presents optimal placement and estimation of distributed generation (DG) capacity using Particle Swarm Optimization (PSO) approach in the distribution systems to reduce the real power losses and to gain voltage profile improvement. The proposed (PSO) based approach is tested on an IEEE 30-bus test system.
Keywords—DG, PSO, Power Loss, Voltage Profile

I. Introduction

Distributed generation is any electricity generating technology installed by a customer or independent electricity producer that is connected at the distribution system level of the electric grid [1].
With the increasing expanding of network construction in the modern power system and the rapid development of renewable energy resource, distributed generation (DG) has become an important form of electrical source. More and more DGs are connected into the power distribution system. It is predicted that DG would have a share of about 20% of new generating units being on lined [2]. DG effects in distribution network depend on several factors such as the DG place, technology issues, capacity and the way it operates in the network. DG can significantly increase reliability, reduce losses and save energy while is cost effective, though it suffers from some disadvantages because of the isolated power quality functioning, and voltage control problems. Generally, planners assess DG functioning in two respects: costs and benefits. Cost is one of the most important factors that should be considered regarding DG application[3]. So, to reach to these targets, loss reduction and voltage profile improvement of the electric system with the presence of DG requires the definition of several factors such as, the best technology to be used, the number and the capacity of the units, the best location, the type of network connection and etc. The problem of DG allocation and sizing is of great importance. The installation of DG units at non-optimal places and with non-optimal sizing can result in an increase in system losses, damaging voltage state, voltage flicker, protection, harmonic, stability and implying in an increase in costs and, therefore, having an effect opposite to the desired [4,5]. Several optimization techniques have been applied to DG placement and sizing, such as genetic algorithm [6], tabu search [7], heuristic algorithms [8,9] and analytical based methods [10], analytical method to place DG in radial as well as meshed systems to minimize power loss. However, this method only optimizes location and considers size of DG as fixed. In this paper, Particle Swarm Optimization algorithm (PSO) is presented as the optimization technique for the allocation and sizing of DG in distribution networks in order to loss reduction in distribution network with minimum economic cost test system. The 30 bus test feeder is selected to test proposed method [11].A lot of technologies are used for DG sources such as photo voltaic cells, wind generation, combustion engines, fuel cells etc.[12][13]. Usually, DGs are attached with the already existing distribution system and lot of studies is performed to find out the best location and size of DGs to produce highest benefits. The different characteristics that are considered to identify an optimal DG location and size are the minimization of transmission loss, maximization of supply reliability,

maximization of profit of the distribution companies etc.

Due to wide-ranging costs, the DGs are to be allocated properly with best size to enhance the performance of the system in order to minimize the loss in the system and to improve different voltage profiles, while maintaining the stability of the system. The effect of placing a DG on network indices will be different based upon its type and location and (predict) load at the connection point. There are lot of variety of potential benefits to DG systems both to the consumer and the electrical supplier that allow for both greater electrical flexibility and energy security .

II. Voltage Sag

Most of the power quality problems that experienced by consumers are voltage sags. IEEE Standard 1159-1995 states that voltage sag is a brief decrease in the rms line voltage of 10 to 90 percent of the nominal RMS voltage[17]. The duration of voltage sag is 0.5 cycle to 1 minute. Voltage sag is not a complete interruption of power; it is a temporary drop of supply voltage made the voltage delivered to the consumer is not at the rated voltage. The European standard 50160 defines voltage sag as a sudden reduction of the supply voltage to a value between 90% and 10% of the declared supply voltage, followed by a voltage recovery after a short period of time. The MS IEC 61000 series define voltage sag as a sudden reduction in voltage to a value between 90% to 10% of nominal voltage for duration of 10 ms to 60 second. Risky of voltage sag will depend on the magnitude and duration of it and on the sensitivity of electronic equipments. Voltage sags typically appear when there is an abrupt increase in load such as starting large motor loads. It also appears after symmetrical and asymmetrical faults, motor starting, load switching or transformer energizing. Weather such as lightning, animal contact, contamination of insulators, construction accidents, motor vehicle accidents, falling or contact with tree limbs also contribute in voltage sags. A short circuit fault is a typical cause of voltage sag. Single line to ground faults on the utility system is the most common cause of voltage sags in an industrial plant [14].

III. Particle Swarm Optimization (PSO)

PSO was formulated by Edward and Kennedy in 1995. The thought process behind the algorithm was inspired by the social behavior of animals, such as bird flocking or fish schooling. PSO is similar to the continuous GA in that it begins with a random population matrix. Unlike the GA, PSO has no evolution operators such as crossover and mutation. The rows in the matrix are called particles (same as the GA chromosome). They contain the variable values and are not binary encoded. Each particle moves about the cost surface with a velocity. The particles update their velocities and positions based on the local and global best solutions:

$$\mathrm{V}_{\mathrm{m,n}}^{\mathrm{new}} = \mathrm{V}_{\mathrm{m.n}}^{\mathrm{old}} + \Gamma_1 \times r_1 \times (\mathrm{p}_{\mathrm{m.n}}^{\mathrm{local\ best}} - \mathrm{p}_{\mathrm{m,n}}^{\mathrm{old}}) + \Gamma_2 \times r_2 \times (\mathrm{p}_{\mathrm{m,n}}^{\mathrm{global\ best}} - \mathrm{p}_{\mathrm{m,n}}^{\mathrm{old}}) \qquad (1)$$

$$\mathrm{p}_{\mathrm{m,n}}^{\mathrm{new}} = \mathrm{p}_{\mathrm{m,n}}^{\mathrm{old}} + \mathrm{V}_{\mathrm{m,n}}^{\mathrm{old}}$$

$\mathrm{V}_{\mathrm{m,n}}$ Particle velocity;

$\mathrm{P}_{\mathrm{m,n}}$ Particle variables ;

$\Gamma_1 = \Gamma_2$ Independent uniform random numbers;

G1 = G2 Learning factors

$\mathrm{p}_{\mathrm{m,n}}^{\mathrm{local\ best}}$ Best local solution

$\mathrm{p}_{\mathrm{m,n}}^{\mathrm{global\ best}}$ Best global solution

for each particle then adds that velocity to the particle position or values. Velocity updates are influenced by both the best global solution associated with the lowest cost ever found by a particle and the best local solution associated with the lowest cost in the present population. If the best local solution has a cost less than the cost of the current global solution, then the best local solution replaces the best global solution.

The particle velocity is reminiscent of local minimizes that use derivative information, because velocity is the derivative of position. The constant G1 is called the cognitive parameter[18]. The constant G2 is called the social parameter. The advantages of PSO are that it is easy to implement and there are few parameters to adjust [15].The particle swarming becomes evident as the generations pass. The largest group of particles ends up in the vicinity of the global minimum and the next largest group is near the next lowest minimum. A few other particles are roaming the cost surface at some distance away from the two groups. Figure (1) shows plots of $p_{m,n}^{local\ best}$ and $p_{m,n}^{global\ best}$ as well as the population average as a function of generation. The particle $p_{m,n}^{global\ best}$ serves the same function as elite chromosome in the GA. The chaotic swarming process is best illustrated by following the path of one of the particles until it reaches the global minimum in this implementation the particles frequently bounce off the boundaries.

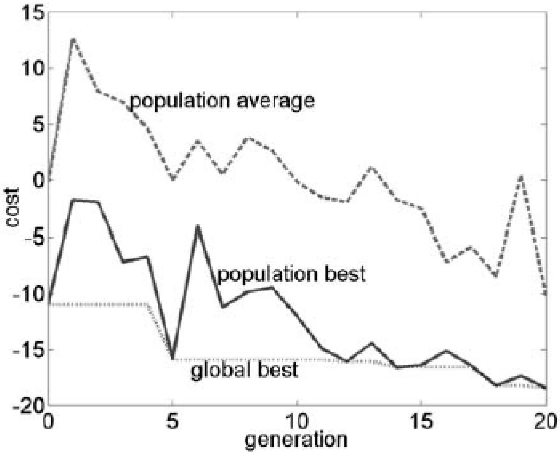

Fig.1. Convergence of the PSO algorithm.

PSO is a optimization technique to evaluate the optimal solution. here pso algorithm is used to calculate optimal power flow in each bus of IEEE 30 bus system and also calculate the losses in each bus ,based on the pso result we select the optimal location of DG and its capacity.

IV. Problem Formulation

Optimal DG placement and sizing problem is formulated as a constrained nonlinear integer optimization problem.

Objective Function: The objective function aimed at best location of DG in order to minimize economic losses of buses due to interruption caused with voltage sag and that of the DG installation and sum of active power of DG injected to system.

Total real power is defined by

$$\text{Ploss} = \Sigma_{i=1}^{n} \; Ploss_i \qquad (1)$$

It should be pointed out that the cost of the real power loss per unit is fixed. Also, the cost of the active power injection per unit is constant.

Constraints: Another significant part of the optimization model that needs to be defined is the constraints. There are two types of constraints: equality and inequality.

A. Equality Constraints

These constraints are related to the nonlinear power flow equations. In many published papers, the power flow equations are the real and reactive power mismatch equations. The reason for this is that modified versions of conventional power flow programs such as Newton Raphson method and Gauss-Siedel method are widely used. In this work, the power flow representation is based on newton raphson method.The equality constraints are expressed in a vector form as follows:

$$F\,(x^i, u^i) = 0$$

x^i vector of state variables like voltage magnitude

u^i vector of DG size

Be equal to zero of F, is associated with satisfying all of the load flow of network.

B. Inequality Constraints

The inequality constraints are those associated with the bus voltages and DG to be installed.

I : Bus Voltage Limits: The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimization process.

$$V_{min} \le |V_i| \le V_{max} \qquad (2)$$

Where

V_{min} lower bound of bus voltage limits;

V_{max} upper bound of bus voltage limits;

$|V_i|$ rms value of the th bus voltage

II : Number and Sizes of DGs:

There are constraints associated with the DGs themselves. DGs that are commercially available come in discrete sizes. That is, the DGs to be deal with are multiple integers of the smallest capacitor size available and this matter itself is because of coordination between sizes of DGs to be installed with what is available in practical method. This constraint is as follows:

$$P_{inject\,-DGi} \le \text{L } P_o,\ \text{L}=1, 2 \ldots n \qquad (3)$$

P_o smallest DG size available

Also, the total active power injection is not to exceed the total active power demand in distribution system

$$\Sigma_i^n \; Ploss_i < Ploss_T$$

Where

$Ploss_T$ total active power demand

This paper has two major goals: 1) Improvement of voltage profile, 2) Loss reduction. There are also some limitations based on which the destination function should be defined.

1) (Loss with DG) $<$ (Loss without DG)
2) $V_{bus}^{min} \leq V_{bus} \leq V_{bus}^{max}$

According to the first limitation the loss reduces when DG exists. Also, second limitation states that the authorized voltage of a certain bus depends on the minimum and maximum voltages of the bus .

In the proposed work, in order to observe and compare the results with those of the specified destination function, an IEEE 30-bus distribution network has been selected as a sample. It should be noted that the specified destination function can be generalized to be used for all distribution networks with any number of buses. Moreover, the optimization algorithm of the destination function is a PSO Algorithm. The single line diagram of the network is illustrated in Fig. 3

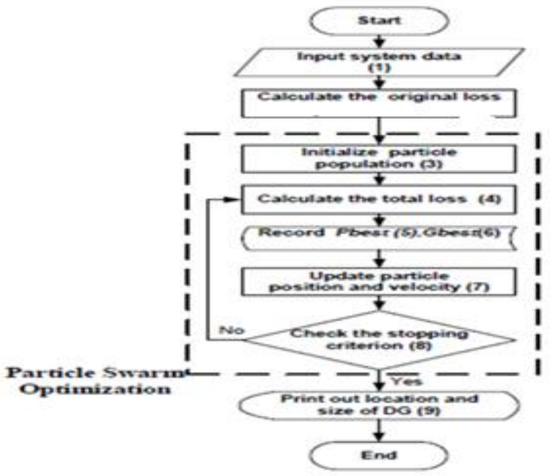

Figure 2. PSO Computational Procedure.

V. The PSO Algorithm Procedure

The particle swarm optimizer (PSO) algorithm is a random evolution method based on intelligent search of the group birds. It has quick convergence speed and optimal searching ability for solving large-scale optimization problems[18] .

The PSO-based approach for solving OPDG problem to minimize the loss takes the following steps:

Step 1: Input line and bus data, and bus voltage limits.
Step 2: calculate the power flow between the buses using newton raphson method.
Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions in the solution space. Set the iteration counter k=0.
Step 4: For each particle if the bus voltage is within the limits, calculate the total loss. Otherwise, that particle is infeasible.
Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower than Pbest, set this value as the current Pbest, and record the corresponding particle position.
Step 6: Choose the particle associated with the minimum individual best Pbest of all particles, and set the value of this Pbest as the current overall best Gbest.
Step 7: Update the velocity and position of particle.
Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index k=k+1, and go back to Step 4.
Step 9: Print out the optimal solution to the target problem. The best position includes the optimal locations and size of, DG, and the corresponding fitness value representing the minimum total real power loss.

In this paper the optimization algorithm of the destination function is a PSO Algorithm whose population size=100,Maximum generation (K_{max})= 500.

VI. Result and Discussion

The proposed method is implemented using MATLAB 2011 and tested for IEEE 30 bus system. Which is shown in Figure 3.The optimization algorithm in the present study is a PSO Algorithm, The overall control strategy for power management in the Distributed Generation system is discussed in this paper. The system performance under different operating conditions is evaluated and discussed as well. The buses are connected in loop thus it is considered as a power system. The optimal number of DGs to be connected in the system identified is found to be 5 for 3 MW each rating. Table 1 shows the optimal locations of DGs and its capacity.

Table1.shows the optimal locations of DGs and its capacity.

S.No	DG Location	Capacity in MW
01	06	03
02	11	03
03	22	03
04	25	03
05	28	03

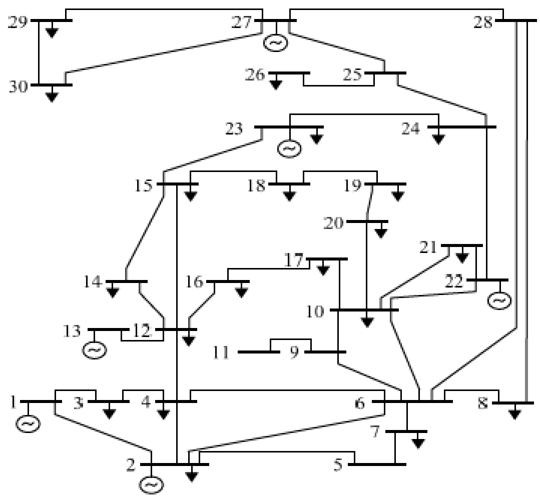

Fig.3: Single line Diagram for IEEE 30-bus Distribution Network

line loss reduction index is defined by :

$$LII = \frac{LL_{WDG}}{LL_{WODG}} \quad (4)$$

Where LL_{WDG} LL_{WODG} are the losses incurred with and without DG presence, respectively. This indicator can have the following implications under the following three conditions:

- . LII<1: DG reduces loss
- LII=1: DG is not effective
- LII>1: DG increases loss

VPII indicates voltage profile improvement and shows the effect of DG placement on the voltage profile which is defined as follows [16]:

$$\text{VPII} = \frac{VP_{WDG}}{VPW_{WODG}} \quad (5)$$

where VP_{WDG} and VP_{WODG} the voltage profiles with and without DG presence, respectively, and can be interpreted as follows under the following conditions:

- VPII<1: DG has a negative effect on network voltage
- VPII=1: DG is not effective
- VPII>1: DG has a positive effect on network Voltage

Table 2 shows the system bus voltage profile with and without DGs

Bus	Without DG Bus voltage (PU)	With DG bus Voltage (PU)
1	1.0600	1.0600
2	1.0430	1.0430
3	1.0245	1.0271
4	1.0148	1.0180
5	1.0100	1.0100
6	1.0133	1.0162
7	1.0076	1.0093
8	1.0100	1.0100
9	1.0510	1.0570
10	1.0442	1.0545
11	1.0820	1.0820
12	1.0544	1.0603
13	1.0710	1.0710
14	1.0352	1.0441
15	1.0231	1.0356
16	1.0417	1.0495
17	1.0359	1.0455
18	1.0098	1.0244
19	1.0052	1.0209
20	1.0117	1.0268
21	1.0315	1.0439
22	1.0308	1.0439
23	1.0057	1.0222
24	1.0044	1.0220
25	1.0039	1.0299
26	0.9723	0.9992
27	1.0186	1.0379
28	1.0092	1.0148
29	0.9955	1.0067
30	1.0050	1.0196

The total power losses after DGs T_L is 2.37 MW.

VII. Conclusion

In this paper, optimal location of DG using Particle Swarm Optimization was tested for a IEEE 30 bus system. The effects of the significant parameters have been shown. From the result it is clear that there is optimal enhancement in the system parameters. The voltage profile is improved and power loss is minimized. The proposed method uses many possible significant parameters into account to be formulized and optimized. The optimal number of DGs to be connected in the system was identified as 5 and these DGs should be located on the buses 06, 11, 22, 25 And 28 for minimization of total power loss. The power loss was reduced. Hence, the system performance is improved.

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