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Optimal placement and sizing of DG based on Novel Index and PSO method for Minimization of Losses

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Abstract—This paper presents mainly optimal placement of Distributed Generator (DG) and sizing based on novel index and Particle Swarm Optimization (PSO) to minimize the losses .The index is mainly proposed for DG placement considering stable node voltages referred as power stability index(PSI). The PSO algorithm is proposed for DG sizing at a particular bus. The new analytic approach is adopted to visualize the impact of DG on losses, voltage profile and voltage stability. The proposed method is tested on 12-bus radial distribution system using ETAP.

Index Terms— Distribution generators, radial distribution system, power stability index, particle swarm optimization, power loss reduction, voltage stability.

1 INTRODUCTION

The main purpose of power system is to deliver power to load in a reliable manner. In the present scenario electrical power demand is increasing rapidly, due to this generation can't reach to the existing demand so, there is a need of extra power or emergency power which has to be connected in the distribution system [1]. As there is an increase in load, the performance of distribution system becomes inefficient due to the reduction in voltage magnitude and increase in distribution system losses. Distribution system has a very significant position in the power system since it is the main point of link between bulk power and consumers. The radial distribution system is used because of its simple construction and low cost so, effective planning of radial distribution network is required to meet the present growing domestic, industrial and commercial load day by day. In radial distribution system as load is increased there will be decrease of voltage stability, voltage profile. Distributed generation is going to play a major role in power systems, the renewable resources such as; hydro, wind, solar, geothermal, biomass and ocean energy are the sources of energy [2],[3]. Distributed generation, which generally consists of various types of renewable resources, can be defined as electric power generation within distribution networks or directly on the customer side of the system [4]. DG affects the flow of power and voltage conditions on the system equipment. DG placement in radial distribution system may impact either positively or negatively depending on the distribution system operating conditions and the DG characteristics. Positive impacts are generally called 'system support benefits', and include voltage support and improved power quality, loss reduction, transmission and distribution capacity release, improved utility system reliability. On account of achieving above benefits, the DG must be reliable of the proper size and at the proper location. Distributed Generation is a small generator spotted throughout a power system network, providing the electricity locally to load customers. DG can be an alternative for industrial, commercial and residential applications. DG makes use of the latest modern technology which is efficient, reliable, and simple enough so that it can compete with traditional large generators in some areas [5].

2 PROPOSED METHOD

2.1 Power stability index

This method proposes a new algorithm for DG placement for distribution system based on a novel index. The index is developed considering stable node voltages referred as PSI. An index is derived for finding the most optimum location of DG based on the most critical bus in the system that can lead to system voltage instability when the load increases above certain limit [6]. Consider a simple two bus network without and with DG as shown in fig1 and fig2.

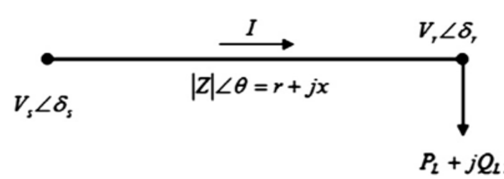

Fig1.A two bus network

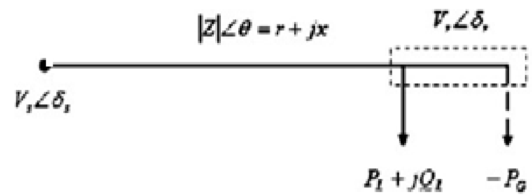

Fig2.Active power support

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From Fig1 we can write

$$S_L = P_L - jQ_L = V_r I_r \text{ ....(1)}$$

$$V_r = V_s - I_r Z \text{ .... (2)}$$

Where

$$I_r = \frac{\left(P_L - jQ_L\right)}{V_r^*} \text{ .... (3)}$$

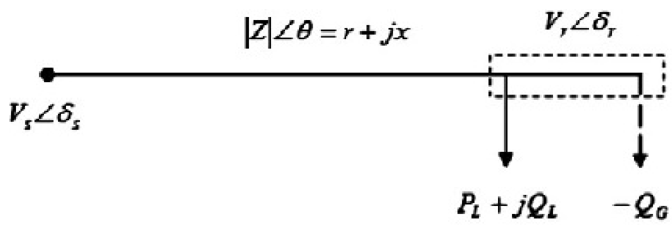

Fig3.Reactive power support

From fig2 & fig3 we can write

$$I_r = \frac{\left(\left(P_L - P_G\right) - j\left(Q_L - Q_G\right)\right)}{V_r^*} \text{ .... (4)}$$

Substitute Ir from above (4) into (2) and separate into real and imaginary parts will give

$$P_L - P_G = \frac{\left(V_r V_s \cos(\theta - \delta_s + \delta_r)\right)}{Z} - \frac{\left(V_r^2 \cos\theta\right)}{Z} \text{ ...(5)}$$

$$Q_L - Q_G = \frac{\left(V_r V_s \sin(\theta - \delta_s + \delta_r)\right)}{Z} - \frac{\left(V_r^2 \sin\theta\right)}{Z} \text{ ... (6)}$$

Rearranging (5) will give

$$V_r^2 - \frac{\left(V_r V_s \cos\left(\theta - \delta\right)\right)}{\cos\theta} + \frac{\left(Z\left(P_L - P_G\right)\right)}{\cos\theta} \text{ ..... (7)}$$

local best known position is the best solution that achieved by each particle so far. The global best known position is the best solution among all the achieved

Where $\delta = \delta_s - \delta_r$

The (7) is a quadratic equation. For stable node voltages (7) should have real roots, i.e., discriminant B^2 - 4AC >0 which results in proposed index referred as PSI given in (8)

$$\text{PSI} = \frac{\left(4r_{ij}\left(P_L - P_G\right)\right)}{\left(V_i \cos\theta - \delta\right)^2} \le 1 \text{ ....(8)}$$

Under the stable operation, this value should be less than unity closer the value of PSI to zero, more stable will be the system.

2.2 Particle swarm optimization

The PSO was developed by J.Kennedy and R.Eberhart in 1995.It was originally used for solving continuous nonlinear functions. The idea of PSO comes from a simplified social system like bird flocking or fish schooling. Imagine a group of birds is searching for food in an n-dimension area (n equals the number of control variables) [7]. None of these birds knows where the food is. However, they know which bird is nearest to the food (assume the closest bird to the food is Bird A). The best strategy for the rest of birds to find the food is following Bird A and searching its neighboring area. In PSO, each single solution (particle) can be viewed as a "bird" [8].

The position of each particle can be expressed as $x_i=(x_{i1},x_{i2},\ldots,x_{in})$. The initial solutions in PSO are randomly selected and then PSO will continually search for optimal value by updating the solution in each iteration [9]. The fitness value of the particle is related to the objective function and the velocity of the particles $v_i=(v_{i1},v_{i2},\ldots v_{in})$ is related to its pervious velocity, global best known position, and local best known position[10].

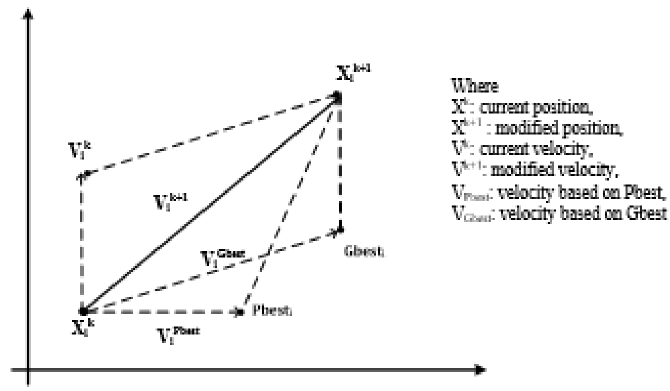

Fig4. Concept of modification of a searching point by PSO

$$V_{id}^{(t+1)} = w.V_{id}^t + c1.r1\left(Pbest_{id} - X_{id}\right) + c2.r2\left(gbest - X_{id}\right) \text{ ....(9)}$$

$$X_{id}^{(t+1)} = X_{id}^t + V_{id}^{(t+1)} \text{ .... (10)}$$

where, t is number of iterations, r1 and r2 are random numbers, w is inertia weight given by (11).

$$W = \frac{\left(W_{\max} + \left(W_{\max} - W_{\min}\right)\right)}{iter\max_t^*} \text{ .... (11)}$$

Algorithm for solving DG location problem using PSO:

Step1: Read the input data (a) Line data (b) Bus data (c) Limits (d) DG size

Step2: Select the parameters of PSO

(i) Population size (ii) acceleration constants (iii) inertia weight (w)

Step3: Calculate the voltages and losses by NR method

Step4: location of the particle is (x)

$$X\left(i, j\right) = X_{\min} + \left(X_{\max} - X_{\min}\right) \text{ .... (12)}$$

Step5: Initialisation of population of particles for finding the location with random Positions. Set the iteration count k=0

Step6: Initialisation of random velocities of the particles

Step7: Check the power balance constraint

Step8: Check the voltage constraint

Step9: Calculate the total loss and voltage in each bus by using the objective function

Step 10: Evaluate the fitness function

Step11: Finding the local best and global best values

Step12: Updating the velocity of each particle following the equation,

$$V_{id}^{(t+1)} = w.V_{id}^t + c1.r1\left(Pbest_{id} - X_{id}\right) + c2.r2\left(gbest - X_{id}\right) \text{ .... (13)}$$

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$$X_{id}^{(t+1)} = X_{id}^{t} + V_{id}^{(t+1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(14)}$$

Step13: Check whether the updated velocities are within the limits or not

Step14: Now the position of each particle will be modified

Step15: calculate the new fitness values .If this value are better than previous Values then assign the current values as local best

Step16: If stopping criteria is reached, when the iteration number reaches the maximum value, go to step 17. Otherwise, set the iteration count k=k+1, and go back to step 7

Step17: The latest global best is the optimal solution to the target problem. The best position is optimal location of DG and corresponding values are the minimized loss and improved voltages [11].

The PSO parameters like Population size, acceleration constants, inertia weight are selected as shown in 1 to run PSO algorithm in MATLAB.

TABLE1
PSO PARAMETERS

S.no.	Parameters	value
1	population size	30
2	maximum iterations	100
3	constriction factors c1,c2	2.05
4	inertia weight factor W_{min}	0.4
5	inertia weight factor W_{max}	0.9

3 PROBLEM FORMULATION

The objective function of this DG placement is mainly to reduce the losses. In the proposed algorithm of DG sizing the fitness function considered for minimization of total active power losses (P_{Loss}), given by the equation

$$f = \min P_{loss} = \sum_{i=1}^{n} |I_i|^2 R_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(15)}$$

where I is the line current in branch i

R is the resistance of the branch i

N is the total number of branches

Subjected to system constraints include bus voltages

$$0.95 \le V_{bus}^{n} \le 1.05 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(16)}$$

3.1 Optimal placement

The PSI is used to find the optimum placement of DG. The PSI values using (8) is calculated for each line in the given network and sorted from the highest to the lowest value. For the i - j line having the highest value of PSI, the DG should be placed at j-bus

3.2 Optimum Sizing

To find the optimum DG corresponding size, PSO algorithm is used here. Once the optimum location of DG is known, the amount of active power of DG changes from 0% to 100% of the total active load, with generation and voltage constraints given in (17) and (18).

$$0 \le P_{dg} \le P_{load} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(17)}$$

$$V_{i\,\min} \le V_i \le V_{i\,\max} \quad \ldots\ldots\ldots\ldots\ldots \text{(18)}$$

The Gbest value obtained from PSO program gives the DG size without violating the given constraints [12].

4. RESULTS AND DISCUSSION

The proposed method is tested on 12-BUS radial distribution system as shown in fig5. A computer program has been written in MATLAB to calculate the power stability indices on various buses and thus founded the optimum location and DG size is also found at that location by developing PSO program in MATLAB knowing the Gbest value. The construction of 12-bus radial distribution system is mainly done in ETAP software as shown in fig6 and load flow analysis is also carried out in ETAP software.

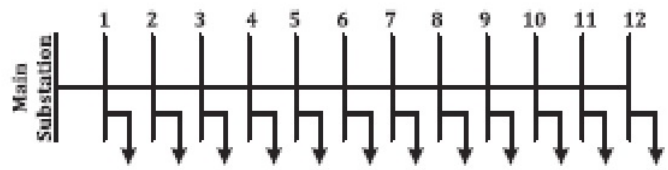

Fig5.Radial distribution system

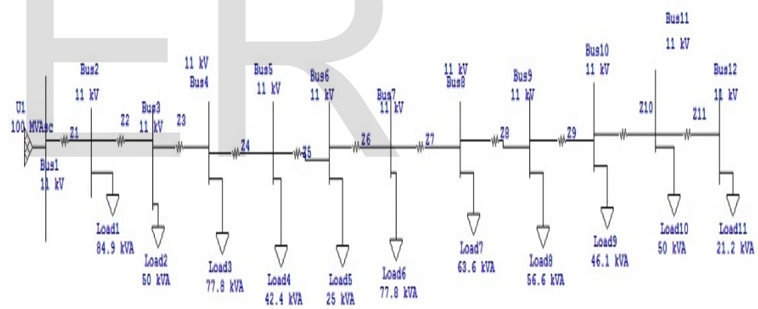

Fig6.Radial distribution system without DG

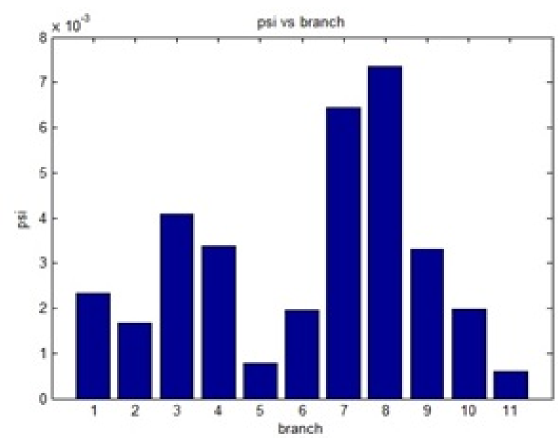

Fig7.Power stability index

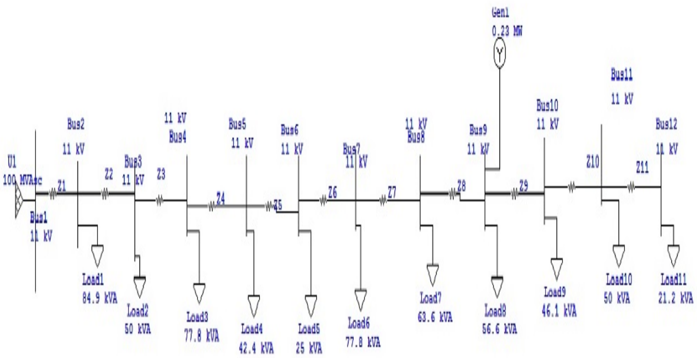

Fig8.Radial distribution system with DG

From fig 7 the highest PSI is observed at 8th branch,8th branch is between 8th and 9th bus so, DG is placed at 9th bus in radial distribution system in ETAP software as shown in fig8.

Branch Losses Summary Report

From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
0.426	0.388	-0.423	-0.386	3.0	1.2	100.0	99.5	0.53
0.364	0.327	-0.361	-0.326	2.4	1.0	99.5	99.0	0.49
0.322	0.297	-0.319	-0.295	3.4	1.4	99.0	98.2	0.78
0.266	0.242	-0.262	-0.241	3.5	1.5	98.2	97.2	0.98
0.234	0.212	-0.233	-0.212	1.0	0.4	97.2	96.9	0.30
0.214	0.198	-0.213	-0.197	0.7	0.3	96.9	96.7	0.25
0.162	0.146	-0.160	-0.146	1.9	0.5	96.7	95.9	0.76
0.119	0.104	-0.118	-0.104	1.3	0.4	95.9	95.2	0.72
0.081	0.068	-0.081	-0.068	0.3	0.1	95.2	94.9	0.25
0.050	0.040	-0.049	-0.040	0.1	0.0	94.9	94.9	0.08
0.013	0.013	-0.013	-0.013	0.0	0.0	94.9	94.8	0.02
				17.5	6.8			

Branch Losses Summary Report

From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
0.198	0.195	-0.198	-0.195	0.7	0.3	100.0	99.7	0.25
0.138	0.136	-0.138	-0.135	0.4	0.2	99.7	99.6	0.19
0.098	0.106	-0.098	-0.105	0.4	0.2	99.6	99.3	0.25
0.043	0.051	-0.043	-0.051	0.1	0.1	99.3	99.1	0.17
0.014	0.022	-0.014	-0.022	0.0	0.0	99.1	99.1	0.02
-0.006	0.007	0.006	-0.007	0.0	0.0	99.1	99.1	0.00
-0.060	-0.047	0.060	0.047	0.2	0.1	99.1	99.4	0.27
-0.105	-0.092	0.105	0.092	0.9	0.3	99.4	100.0	0.61
0.090	0.075	-0.089	-0.075	0.3	0.1	100.0	99.7	0.26
0.055	0.045	-0.055	-0.045	0.1	0.0	99.7	99.7	0.08
0.015	0.015	-0.015	-0.015	0.0	0.0	99.7	99.6	0.02
				3.1	1.1			

Fig9.Losses without DG placement

Fig10.Losses with DG placement

The load flow results which are obtained from ETAP software as shown in fig9 and fig10 which gives the details of total losses of active and reactive power.

TABLE 2
OPTIMAL PLACEMENT AND SIZE OF DG

Test system	Optimum placement	Optimum DG size
12-bus system	9th bus	0.230MW

The DG placement at 9th bus is obtained from PSI .The DG size in 2 is 0.230MW this value DG placement in radial distribution system gives minimum losses beyond this value the losses will further increase.

TABLE.3
EFFECT OF DG PLACEMENT ON LOSSES

Test system	without DG system losses(MW)	proposed method system losses(MW)
12-bus system	0.0175	0.0031

In 12-bus radial distribution system without DG placement and with DG placement using proposed method with DG size 0.230MW the active power losses is given in 3.

5 End Sections

5.1 Appendices

Radial distribution system of 12-bus .The generation size is 0.426MW, base voltages and base power are 11KV and 100MVA.The below 4 and 5 gives the test data of 12-bus system i.e., branch impedance values and bus load values.

TABLE 4
BRANCH DATA

Line no.	from	to	R(Ω)	Q(Ω)
1	1	2	1.093	0.455
2	2	3	1.184	0.494
3	3	4	2.095	0.873
4	4	5	3.188	1.329
5	5	6	1.093	0.455
6	6	7	1.002	0.417
7	7	8	4.403	1.215
8	8	9	5.642	1.597
9	9	10	2.890	0.818
10	10	11	1.514	0.428
11	11	12	1.238	0.351

TABLE 5
BUS LOAD DATA

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Bus no.	P(MW)	Q(MW)
1	0.00	0.00
2	0.06	0.06
3	0.04	0.03
4	0.055	0.055
5	0.03	0.03
6	0.02	0.015
7	0.055	0.055
8	0.045	0.045
9	0.04	0.04
10	0.035	0.03
11	0.04	0.03
12	0.015	0.015

4 CONCLUSION

The power stability index based approach is to determine the optimal location for DG placement in radial distribution system has been presented. The power stability index to find the optimal location has been derived from the load flow equations. A particle swarm optimization algorithm has been proposed to find the size of the DG. The proposed methodology gives optimal DG size by minimizing the total system losses and satisfying the voltage and other constraints. The voltage profile has been improved with DG placement. The total real and reactive power losses have been decreased and the system loading capacity automatically increases with the proposed method.

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