

# An Optimization Based Algorithm for Allocation of Distribution Generation and to determine impact of DG Penetration Level in RDS

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## Abstract

With increasing demand on conventional distribution systems, distributed energy sources are placed near the consumer premises to maintain the reliability of supply. DG also includes the benefits of reduced power loss, improved voltage profile and also reduced transmission and distribution costs. Placement of DG sources have some impact on existing distribution system. The impacts may be technical, economical or environmental. In this paper we have introduced technical and economic benefits of DG. Planning of DG size and location is necessary to obtain the satisfactory performance. In this paper inertia weight particle swarm optimization (IPSO) algorithm is used to minimize the objective function. In this IPSO method, DGs are randomly placed and size is obtained then these results are compared with previous results then optimal location and sizes are obtained. Here, objective function is the function of impact indices on distribution system due to placement of DG. Forward-backward sweep method is considered for studying the load flow of radial distribution system over various techniques available.

**Keywords:** Distributed Generation(DG), Power Flow, Placement And Sizing, Improved Particle Swarm Optimization (IPSO), Objective function

## Introduction

Now a days electricity demand is increasing rapidly, with this increasing demand on the distribution system, losses also increases hence voltage profile will become poor. To overcome this, distributed sources are provided over conventional generating stations because of the improved technical, economical and environmental benefits. Integration of DGs in distribution system leads to reduced loss and improved voltage profile. Distributed generators are the smallest generating units placed near the consumer premises by the consumer itself or by the generation capacity is range from 1 kilowatt to 10 Megawatts. DG technologies may be renewable or non-renewable. But renewable sources like wind or solar power technologies are preferred due to its environmental benefits.

## Impact Indices

There are several impact indices in order to describe the impacts on distribution system due to the presence of DG. In this paper, three indices will be

Computed in order to describe their effect due to the presence of DG. These indices are defined as follows

2.1 Real Power Loss Index (ILP): The real power loss index is defined as

$$ILP = [P_{LDG}] / [P_L] \quad (1)$$

where  $P_{LDG}$  and  $P_L$  are the real power losses with DG and without DG in the distribution system.

2.2 Voltage Deviation Index (IVD): One of the advantages of proper location and size of the DG is the improvement in voltage profile. this index can be defined as

$$IVD = \sum_{i=1}^n \frac{V_{ref} - V_i}{V_{ref}} \quad (2)$$

where  $n$  is the no of buses. the  $V_{ref}$  and  $V_i$  are the reference voltage and system bus voltages in p.u respectively. The minimum value of IVD indicates the performance of the distribution is better.

2.3 Cost of Energy Losses (CL): The annual cost of energy loss is given by

$$CL = (TRPL) * (K_p + K_e * L_{sf} * 8760) \$ \quad (3)$$

Where TRPL: Total Real Power Losses  $K_p$ : annual demand cost of power loss (\$/kW)  $K_e$ : annual cost of energy loss (\$/kW h)  $L_{sf}$ : loss factor. Loss factor is expressed in terms of load factor ( $L_f$ ) as below

$$L_{sf} = k * L_f + (1 - k) * L_f^2 \quad (4)$$

The values taken for the coefficients in the loss factor calculation are:  $k = 0.2$ ,  $L_f = 0.47$ ,  $K_p = 57.6923$  \$/kW,  $K_e = 0.00961538$  \$/kW h.

## Problem Form.01.2ulation

### 3.1 Single objective problem formulation

The objective is to determine combination of optimal location and size of distributed generators that minimize the indices individually under system constraints. The operating constraints are power balance, voltage profile of the system feeder and radial structure of the distribution system. The objective function for the minimization is described as follows:

$$F = \min (\text{index}) \dots \text{with DGs} \quad (5)$$

Subjected to constraints:

$$\text{Power balance constraints: } \sum P_{DG_i} = \sum P_{D_i} \quad (6)$$

$$\text{Voltage limits: } V_{\min} \leq V_i \leq V_{\max} \quad (7)$$

$V_{\min}$  and  $V_{\max}$  is minimum and maximum voltage limits of  $i$ th bus

Real power generation limits:

$$P_{DG_{\min}} \leq P_{DG_i} \leq P_{DG_{\max}} \quad (8)$$

Reactive power generation limits:

$$Q_{DG_{\min}} \leq Q_{DG_i} \leq Q_{DG_{\max}} \quad (9)$$

### Multi Objective Problem Formulation

Solving multi objective problems has traditionally consisted of converting all objectives into a single objective function. The ultimate goal is to find the solution that minimizes or maximizes this single objective while maintaining the system constraints. The optimization solution results in a single value that reflects a compromise between all objectives. A simple and still very popular method is the weighted aggregation method. This is a special case of the utility function method, which converts the multi objective problem into a single objective problem by applying weights to each individual objective vector. In this paper, optimal placement and sizing of distributed generators in a radial distribution system is determined by multi-objective optimization approach. A multi-objective function is designed to minimize real power loss of the system and maximize the voltage profile of the system under different system constraints. Designed multi-objective function is optimized using inertia weight particle swarm optimization method (IPSO).

The multi objective problem is to determine optimal location and size of DG units which minimizes the total real power losses and to improve the voltage profile of the system under different system operating constraints. The operating constraints are voltage profile of the system, radial structure of the distribution system, real and reactive power generation limits and power balance constraint. The objective function of the problem is

$$f_1 = \min(\text{ILP}) \quad (10)$$

$$f_2 = \min(\text{IVD}) \quad (11)$$

$$f_3 = \min(\text{CL}) \quad (12)$$

$$\sum_{i=1}^n W_i = 1, \text{ where } W_i \in [0, 1] \quad (13)$$

$$F(i) = W_i * (\text{Performance Indices}) \quad (14)$$

Here  $i=1, 2, 3, \dots, n$ -number of nodes and

$W$  is the weighing factor which tells that which index should get more importance and also

$f_1, f_2, f_3$ , are three different objective functions, using weight factor method multi objective function is expressed as follows

$$f_{mo} = W_1 * f_1 + W_2 * f_2 + W_3 * f_3$$

(15) where  $W_1, W_2$ , and  $W_3$  are weight factors assigned to impact indices .

$$\text{Minimize } f = \min(f_{mo})$$

(16) Subjected to constraints given in equations (6), (7), (8) and (9)

### Practice Swarm Optimization (PSO)

Particle swarm optimization (PSO) algorithm is a population based optimization method that has gained much popularity among researchers since after its introduction. The algorithm mimics bird's behavior during flight in space. Each of the bird in the aggregation of the birds called swarm is represented as a particle. These particles that form the swarm searches for food based on their own experience and that of the other particles within the same swarm. The PSO have been studied by many researchers and several newer versions have been developed for applications in different real-world problems and are found to be robust and fast in solving nonlinear non-differentiable multimodal problems. The search process is similar to the social behavior of flying birds when searching for food.

The individual bird called particles or swarm flies in the optimization problem hyperspace to search for optimal food location. The position and velocity of the particles is always changing and adjusted according to the cooperative communication among the particles and each individual's own experience simultaneously. Therefore the particle changes position by balancing its social and individual experience.

Initialize randomly generated solution with set of particles.

Let,  $X_m^k$  = position of the particles

$V_m$  = velocity of particles

The velocity of the particle:

$$V_m^{k+1} = \omega V_m^k + C_1 \text{rand}(pbest_m^k - X_m^k) + C_2 \text{rand}(gbest^k - X_m^k) \quad (17)$$

$$\omega = \omega_{\max} - \frac{(\omega_{\max} - \omega_{\min})}{iter_{\max}} * iter \quad (18)$$

Where,  $\omega$  = inertia weight

$V_m^k$  = previous particle velocity

$C_1, C_2$  = acceleration coefficients generally taken in between [1, 2]

$pbest_m^k$  = personnel best of the particle ‘m’ based on own experience

$gbest_m^k$  = global best of the particle ‘m’ referred to entire swarm

Update the position of the particle by using Eq

$$X_j^{k+1} = X_j^k + V_j^{k+1} \tag{19}$$

**Implementation of IPSO algorithm**

The flowchart for implementation of IPSO algorithm is shown in figure 1 and the algorithm was presented in the following

Step 1: Read the input system data and initialize population, number of particles, limits of DG size, voltage limits, parameters of algorithm etc.

Step 2: Calculation of objective function equation by using Forward-Backward sweep based distribution load flow.

Step 3: Calculation of pbest i.e. objective function related to each particle in the population of the current iteration is compared with it in the previous iteration and the position of the particle enjoying a lower objective function as pbest for the current iteration is recorded:

$$pbest_m^{k+1} = \begin{cases} pbest_m^k & \text{if } f_m^{k+1} \geq f_m^k \\ x_m^{k+1} & \text{if } f_m^{k+1} \leq f_m^k \end{cases} \tag{20}$$

Where, k is the number of iterations, and f is objective function evaluated for the particle.

Step 4: Calculation of gbest i.e. the best objective function associated with the pbest among all particles in the current iteration is compared with that in the previous iteration and the lower value is selected as the current overall gbest.

$$gbest_m^{k+1} = \begin{cases} gbest_m^k & \text{if } f_m^{k+1} \geq f_m^k \\ pbest_m^{k+1} & \text{if } f_m^{k+1} \leq f_m^k \end{cases} \tag{21}$$

Step 5: Velocity updating, after calculation of the pbest and gbest the velocity of particles for the next iteration should be modified by using equations (17) and inertia weight (18)

Step 6: Check the velocity components constraints occurring in the limits from the following conditions,

If  $V_{id} > V_{max}$ , then  $V_{id} = V_{max}$  (or) If  $V_{id} < -V_{max}$  then  $V_{id} = -V_{max}$

Step 7: Position updating, the position of each particle at the next iteration (k+1) is modified using equation (19)

Step 8: If the number of iterations reaches the maximum i.e. iter = itermax, then go to step 9. Otherwise, go to step 2.

Step 9: The individual that generates the latest gbest is the optimal locations and sizes of DGs with minimum power loss.

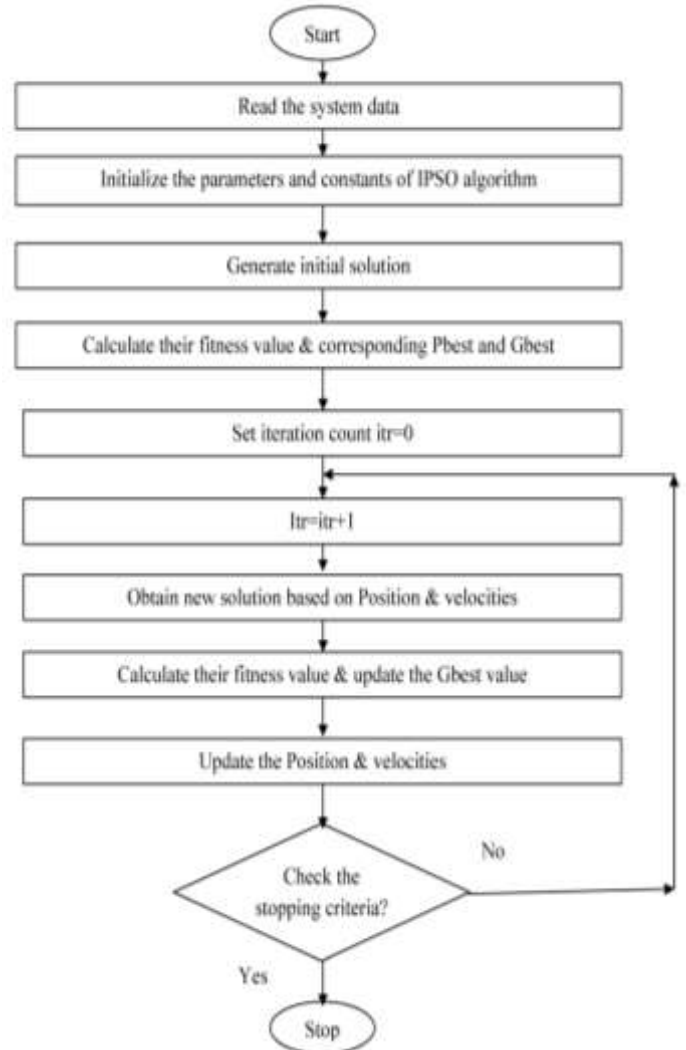


Fig. 1 Flowchart for IPSO algorithm

**Results and Discussion**

**5.1 Test System**

The IPSO algorithm for distribution system was tested the 33 bus systems. The 33 bus system has 32 sections with the total load 3.72 MW and 2.3MVar. the minimum and maximum voltage values are set at 0.95 and 1.05 p.u respectively. the base values used are 100MVA and 12.66kV. A DG size is considered in a range of 0.1MW to 1.2 MW. Results obtained from the load flow before and after placement of DG for the 33-bus radial distribution system are as shown below in the table1.

The reduction in the real power loss and improvement in voltage profile after placing DG in distribution system can be observed from table and waveforms.

**TABLE 1 LOAD FLOW RESULTS BEFORE AND AFTER PLACING DG OF A 33-BUS SYSTEM**

	Without DG	With DG

Bus No	Voltage (p.u)	Power Loss(MW)	Voltage (p.u)	Power Loss(MW)
1	1.0000	0	1.0000	0
2	0.9970	1.2292	0.9986	0.3992
3	0.9829	5.2036	0.9931	1.5580
4	0.9754	2.0033	0.9901	0.6651
5	0.9680	1.8830	0.9874	0.6075
6	0.9495	3.8524	0.9792	1.2380
7	0.9460	0.1944	0.9768	0.0449
8	0.9323	1.1859	0.9722	0.2085
9	0.9260	0.4260	0.9713	0.0718
10	0.9202	0.3615	0.9709	0.0737
11	0.9193	0.0564	0.9710	0.0152
12	0.9178	0.0898	0.9714	0.0302
13	0.9116	0.2717	0.9728	0.1359
14	0.9093	0.0743	0.9734	0.0601
15	0.9079	0.0364	0.9720	0.0318
16	0.9065	0.0287	0.9707	0.0250
17	0.9045	0.0256	0.9688	0.0224
18	0.9038	0.0054	0.9683	0.0047
19	0.9965	0.0161	0.9981	0.0160
20	0.9929	0.0832	0.9945	0.0829
21	0.9922	0.0101	0.9938	0.0100
22	0.9916	0.0044	0.9932	0.0043
23	0.9793	0.3181	0.9918	0.0645
24	0.9726	0.5143	0.9897	0.0936
25	0.9693	0.1287	0.9909	0.0990
26	0.9476	0.2599	0.9787	0.1244
27	0.9450	0.3327	0.9782	0.1685
28	0.9336	1.1294	0.9744	0.6130
29	0.9254	0.7828	0.9719	0.4638
30	0.9218	0.3893	0.9720	0.2823
31	0.9176	0.1593	0.9680	0.1432
32	0.9167	0.0213	0.9672	0.0192
33	0.9164	0.0013	0.9669	0.0012

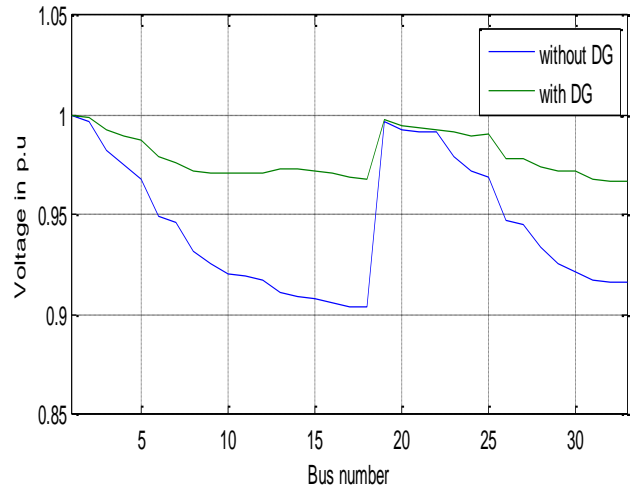


Fig. 2 Voltage Profile of 33-bus system

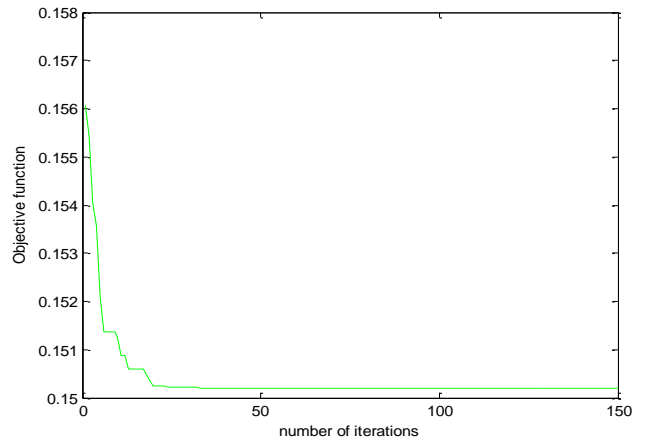


Fig. 3 Convergence Characteristics Of 33-Bus System

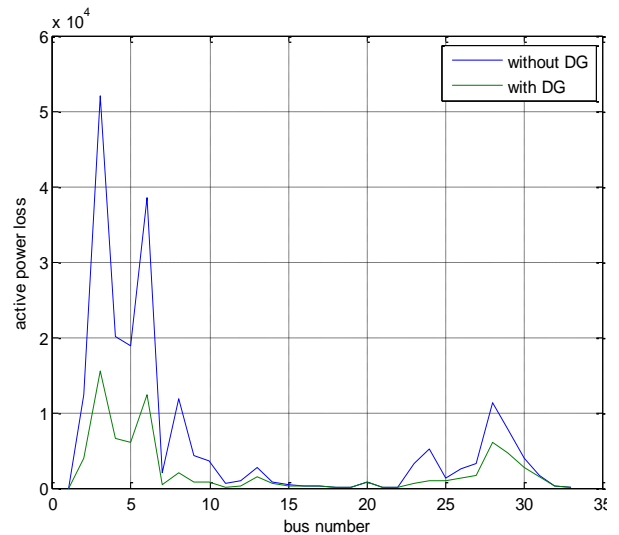


Fig. 4 Real Power Loss of 33-bus system

**Conclusion**

In this paper, multi-objective optimization problem is formulated to determine the optimal location and sizing of DG by considering various impact indices (like active power loss index, voltage deviation index, and cost of energy losses in distribution system due to presence of distributed generation) as objective function with pre-specified constraints such as voltage and active power limits. Multi-objective function for this proposed method is a combination of these three impact indices. IPZO (inertia weight particle swarm optimization) algorithm is used to solve this optimization problem and obtained optimal location and sizing of DG for IEEE 33-bus radial distribution system. The results are compared with forward and backward sweep algorithm. Results obtained shows that voltage profile is improved, real power losses are decreased and also cost of energy losses are reduced after placing DG.

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Bus No.	Rated capacity of DG in percentage of total load								
	0%	10%	20%	30%	40%	50%	60%	70%	80%
2	10.09	9.91	9.73	9.57	9.42	9.29	9.18	9.09	9.01
3	10.09	9.74	9.39	9.09	8.82	8.58	8.39	8.22	8.09
4	10.09	9.47	8.89	8.39	7.94	7.57	7.25	7.00	6.81
5	10.09	9.24	8.46	7.78	7.20	6.71	6.31	6.00	5.77
6	10.09	9.01	8.05	7.22	6.51	5.93	5.46	5.11	4.87
7	10.09	8.88	7.84	7.00	6.33	5.84	5.51	5.33	5.30
8	10.09	8.81	7.75	6.92	6.30	5.88	5.66	5.61	5.73
9	10.09	8.74	7.67	6.88	6.36	6.07	6.01	6.17	6.52
10	10.09	8.71	7.65	6.91	6.46	6.27	6.34	6.63	7.14
11	10.09	8.70	7.66	6.96	6.56	6.44	6.58	6.97	7.58
12	10.09	8.71	7.69	7.02	6.67	6.61	6.82	7.28	7.97
13	10.09	9.74	9.42	9.17	8.97	8.83	8.75	8.72	8.75
14	10.09	9.74	9.47	9.28	9.18	9.17	9.24	9.39	9.62
15	10.09	9.75	9.49	9.34	9.30	9.35	9.49	9.73	10.06
16	10.09	9.75	9.51	9.38	9.36	9.44	9.62	9.91	10.29
17	10.09	8.83	7.74	6.81	6.04	5.43	4.96	4.64	4.46
18	10.09	8.69	7.48	6.48	5.67	5.05	4.61	4.33	4.21
19	10.09	8.52	7.20	6.13	5.29	4.68	4.28	4.08	4.06
20	10.09	8.39	6.98	5.87	5.03	4.44	4.09	3.97	4.05
21	10.09	8.27	6.80	5.66	4.83	4.29	4.01	3.97	4.16

**APPENDIX - 1 ANALYSIS OF PENETRATION  
LEVEL OF DG VS % OF REAL POWER LOSSES IN A RDS**