



Optimal Location and Sizing of Distributed Generation (DG) To Minimize Power Loss Using Particle Swarm Optimization (PSO)

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ABSTRACT: Growing concerns over environmental impacts, conditions for improvement of the whole distribution network, and rebate programs offered by governments have contributed to an increment in the number of DG units in commercial and domestic electrical power output. It is known that the non optimal size and non optimal placement of DG units may lead to high power losses, bad voltage profiles. Therefore, this paper introduces a sensitivity analysis to determine the optimal sitting and sizing of DG units. A new methodology PSO for the placement of DG in the radial distribution systems to reduce the active power losses and to improve the voltage profile. A two-stage methodology is practiced for the optimal DG placement. In the first stage Power System Analysis Toolbox (PSAT), an open source MATLAB software package for analysis and design of small to medium size electric power systems for power flow and in the second stage, PSO is used to find the optimal size and site of DG in distribution systems. The effectiveness of the proposed method is demonstrated through IEEE 15-bus standard test systems.

KEYWORDS: DG, PSAT, PSO, Loss minimization, Radial distribution system.

I. INTRODUCTION

The increasing demand on the power system has posed a challenging task to power system engineers in maintaining a reliable system economically. In the heavily loaded network, the load current drawn from the source would increase. This may lead to an increase in voltage drop and system losses [13-14], [17-18]. The performance of distribution system becomes inefficient due to the reduction in voltage magnitude and increase in distribution losses. With this regard, changing environment of power systems design and operation has necessitated the need to consider active distribution network by incorporating DG unit [1]. DG is grid-connected or stand-alone electric generation units located within the electric distribution system at or near the end user. The integration of DG in distribution system would lead to improving the voltage profile and reduce active power loss in Power supply[3-6]. Optimization is a mathematical tool which can be used to locate and size the DG units in the system, so as to utilize these units optimally within certain limits and constraints. The optimal power flow problem has been introduced by Carpentier in 1962 [1]. It has taken over decades to develop efficient algorithms for its solution because it is a very large, non-linear mathematical programming problem. Many different mathematical approaches have been applied for seeking its solution [8-10]. The methods discussed in the literature use one of the following five methods [2][11][12]. They are (i) Lambda iteration method as found in economic dispatch problem solving, (ii) Gradient method, (iii) Newton-Raphson Method, (iv) Linear programming and (v) Interior point method. Apart from analytical approaches, there also exist heuristic search methods.

Newly developed heuristic approaches called PSO has been introduced [7]. This method combines social psychology principles and evolutionary computation to motivate the behavior of organisms such as fish schooling, bird flocking, etc. A novel PSO algorithm for distribution system for minimization of active power loss, voltage drop with respect to their loading capabilities. This method thoroughly avoids premature convergence as well as convergence towards global optima. J.Z. Zhu [1], has proposed an improved method to study distribution network reconfiguration (DNRC)



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

based on a refined genetic algorithm (GA). The DNRC model, in which the objective is to minimize the system power loss, is set up. In order to get the precise branch current and system power loss, a 15-bus radial distribution network load flow (RDNLf) method is presented in the study. The refined genetic algorithm is also set up, in which some improvements are made on chromosome coding, fitness function and mutation pattern. Altaf Q.H. Badar, B.S. Umre, A.S. Junghare,[2] has presented Particle Swarm Optimization Algorithm, with dynamic weights, applied to reduce the real power loss in a system. Particle Swarm Optimization with detailed study on weights of particle movements is used. Particle Swarm Optimization has been applied to IEEE 6 bus system to present the case. P. Ravibabu, K. Venkatesh, and C. Sudheer Kumar[3], has presented Network reconfiguration of an electrical distribution system is an operation to alter the topological structure of the distribution system by changing the status (open/closed) of sectionalizing and tie switches. This presents a new approach for optimal network reconfiguration of a Distribution system using genetic algorithm to determine the optimal network reconfiguration. The switches are taken into consideration for crossover process. After obtaining a number of solutions from the combinational analysis, the optimal solution is selected based on the fitness function, i.e., the solution is having the minimum index value. The proposed approach is tested on an IEEE 15-bus system. Duong Quoc Hung et[5]. all investigated the problem of multiple distributed generator (DG units) placement to achieve a high loss reduction in large-scale primary distribution networks. An improved analytical (IA) method is proposed in this paper. This method is based on IA expressions to calculate the optimal size of four different DG types and a methodology to identify the best location for DG allocation. For Graphical environment (Simulink) Matlab-based commercial, research and educational power system tools have been introduced. In This paper PSAT tool is used for evaluating the voltage profile and total I²R loss of the system. The PSAT toolbox, an open source Matlab software package for power flow, continuation power flow, optimal power flow, small-signal stability analysis, and time-domain simulation [16]. The toolbox is also provided with a complete graphical interface and a Simulink-based one-line network editor [19][21]. The proposed improved based method has been tested on a 15-bus test system.

II. BASIC PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle swarm optimization is a heuristic global optimization method put forward originally by Doctor Kennedy and Eberhart in 1995(Kennedy J, Eberhart, R, 1995; Eberhart, R, Kennedy J, 1995) It is developed from swarm intelligence and is based on the research of bird and fish flock movement behavior[15][7].

In the basic particle swarm optimization algorithm, particle swarm consists of “i” particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition, according to the following three principles:

- (1) To keep its inertia
- (2) To change the condition according to its most optimist position
- (3) To change the condition according to the swarm’s most optimist position.

The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surroundings (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO [15][20].

Each particle moves to the new position using velocity according to its own experience as called P_{best} . G_{best} is the overall best value obtained so far by any particle in the population. By time to time, the PSO consists of velocity changes of each particle towards its P_{best} and G_{best} . Each particle tries to modify its current position and velocity according to the distance between its current position and P_{best} , and the current position and G_{best} [15]. After finding the best values the particle updates its velocity and position. The velocity of each particle can be modified by equation.

$$V_i^{K+1} = wV_i^K + c_1r_1(P_{best\ i}^K - X_i^K) + c_2r_2(G_{best\ i}^K - X_i^K) \quad (1)$$

V_i^{k+1} =velocity of particle at iterations

W=weight function

C1 & C2 =-weight coefficient both equal to 2

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

$r1$ & $r2$ =random number between 0 and 1

X_i^k =current position of particle at iteration

P_{best} = best position of particle i^{th} up to the current iteration

G_{best} = best overall position found by the particle up to the current iteration.

Weight function is given by: $W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} * iter$

Where

W_{max} =initial weight equal to 0.9

W_{min} =initial weight equal to 0.4

$iter_{max}$ =maximum iteration number

$iter$ =current iteration number

The new position can be modified by

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (2)$$

The unique process for establishing PSO is as follows:

1. Initialize population of particle with random position and velocities and D dimensions in the random search space.
2. Identify the particle in the swarm through the best achievement so far, and assign its index to the changeable.
3. For every particle, assess the desired optimization fitness function in i th variables. Evaluate particle's robustness evaluation with its. If present value is better than, then set equal to the current value, and equals to the current location in D-dimensional space.
4. Update the velocity and position of particles according to equations.
5. If reached to termination criteria such as minimum fitness or maximum iteration, then STOP process and return to the best solution otherwise repeat steps from 3 to5.

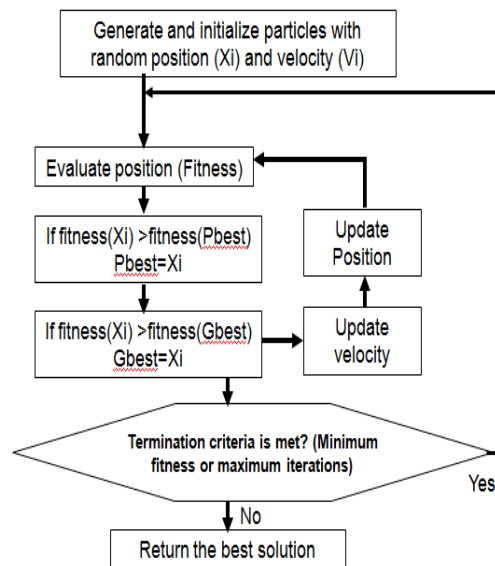


Fig. 1: Basic PSO flow chart

III. OBJECTIVE FUNCTION

As the main objective of this work is to determine the optimal location and sizing of the distributed generation in the distribution network to minimize the losses (active power loss), the following objective function is selected as:



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

$$F_l = \min P_{loss} = \sum_{k=1}^{ntl} |I_k|^2 * R_k \quad (3)$$

Where

F_l is the objective function to minimize power losses.

P_{loss} is the active power loss.

ntl is the number of lines in the distribution system.

Subjected to constraints:

$$V_i^{min} \leq V_i \leq V_i^{max} \quad (4)$$

$$I_i \leq I_i^{max} \quad (5)$$

$$V_{DG}^{min} \leq V_{DG} \leq V_{DG}^{max} \quad (6)$$

$$P_{DG}^{min} \leq P_{DG} \leq P_{DG}^{max} \quad (7)$$

Where,

P_{DG} : real power generations of DG.

V_i : voltage magnitudes at bus i .

V_{DG} : voltage magnitudes at bus i .

I_i : i th feeder current loading.

IV. PROBLEM FORMULATION

The problem formulation for the optimal location and sizing of the distributed generation in the distribution network to minimize the active power loss includes the power flow with and with-out distributed generation in the distribution system. The distributed generation is considered as active power sources at a particular voltage, which is at unity power factor.

The load flow equations are [20][6]:

$$P_i = \sum_{k=1}^n |V_i| |V_k| |Y_{ik}| \cos(\delta_i - \delta_k + \theta_{ik}) = P_{Gi} - P_{Di} \quad (8)$$

$$Q_i = \sum_{k=1}^n |V_i| |V_k| |Y_{ik}| \sin(\delta_i - \delta_k + \theta_{ik}) = Q_{Gi} - Q_{Di} \quad (9)$$

$$P_i^{min} \leq P_i \leq P_i^{max}$$

$$Q_i^{min} \leq Q_i \leq Q_i^{max}$$

$$V_i^{min} \leq V_i \leq V_i^{max}$$

$$P_{DG}^{min} \leq P_{DG} \leq P_{DG}^{max}$$

Where,

P_i, Q_i : real and reactive power flow at bus i .

P_{Di}, Q_{Di} : real and reactive loads at bus i .

V_i, V_k : voltage magnitudes at bus i and k .

P_{DG_i} : real power of DG at bus i .

N : total number of buses.

δ_i, δ_k : voltage angles of bus i and k .

Y_{ik} : magnitude of the ik th element in bus admittance matrix.

θ_{ik} : angle of the ik th element in bus admittance matrix

V. PSAT IMPLEMENTATION OF TEST SYSTEM

In this work, we have presented the load flow simulation results of the 15-bus distribution System using PSAT, an advanced open source Power System Analysis Toolbox [16].

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

A. IEEE-15 Bus Radial Distribution System Modelling

This section illustrates the modeling and implementation of the 15-bus test system, which is given below. The single line diagram of IEEE 15-bus test system is given in Fig. 3. This depicts the model of the IEEE 15-bus network built using the PSAT Simulink library (see Fig. 2). Once defined in the Simulink model, one can load the network in PSAT and solve the power flow. Power flow results can be displayed in a GUI and exported to a file in several formats including, notepad, Excel and LaTeX[19]. PSAT also allows displaying bus voltages and power flows within the Simulink model of the currently loaded system.

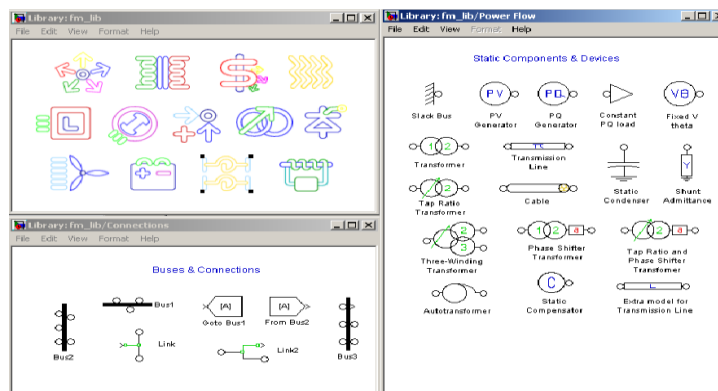


Fig. 2: The PSAT Simulink model library

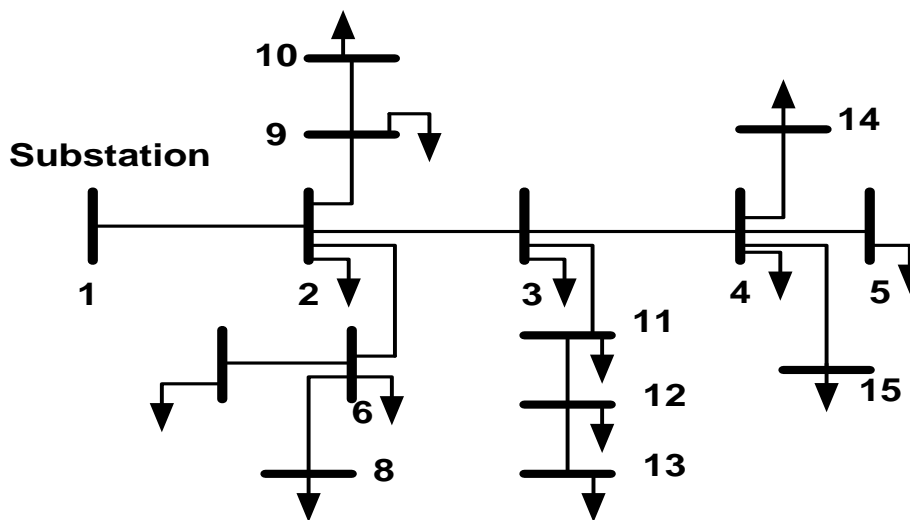


Fig. 3: IEEE 15-bus distribution test system

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

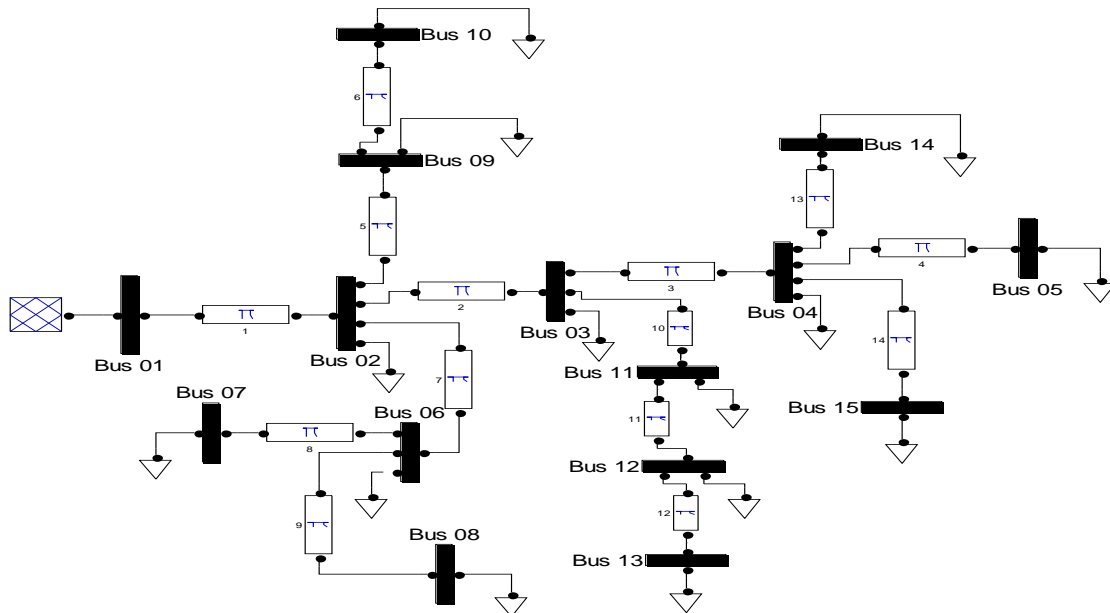


Fig. 4: The PSAT Simulink model of IEEE 15-Bus distribution system

VI. RESULTS ANALYSIS

The proposed algorithm is tested using both a 15-bus radial test system. The base values used are 100 MVA and 23 kV. A DG size is considered in a range of 1 kW to–30 kW. In this study, it is considered that the DG is operated at unity power factor. The first bus is considered as the feeder of electric power from the generation/transmission network. The remaining buses of the distribution system except the reference buses are considered for the placement of a DG of given size from the range considered.

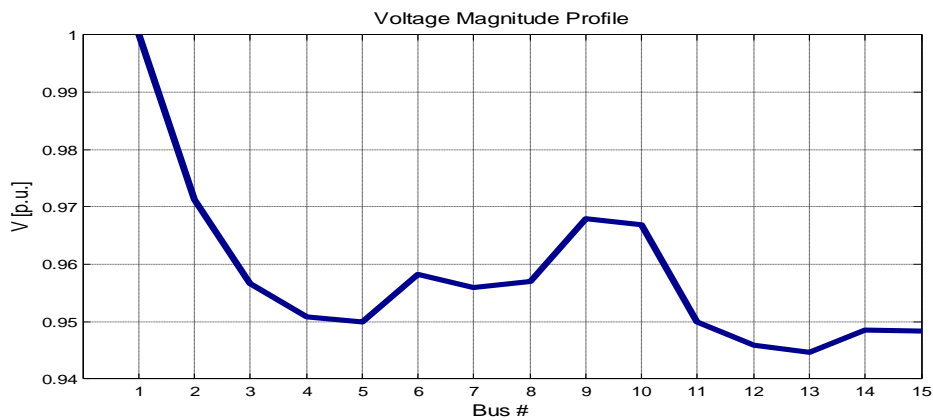


Fig. 4: Voltage profile of 15 bus system with-out DG

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

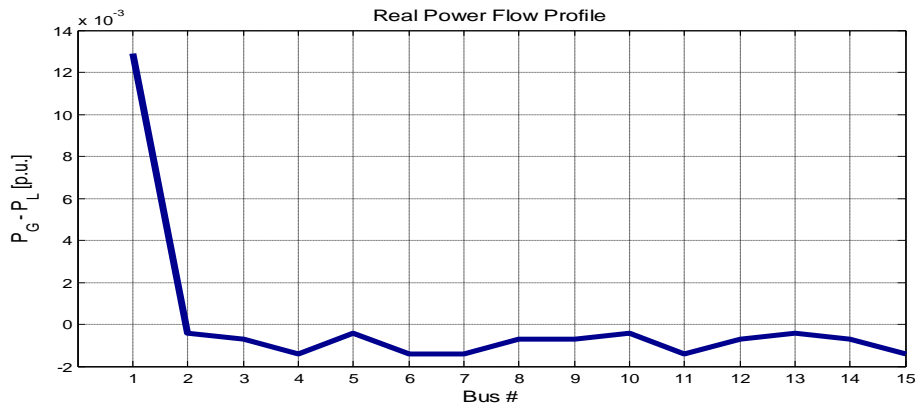


Fig. 5: The active power loss at buses with DG

Table-1: Active, Reactive power loss and Voltage of 15-bus system with-out and with DG

Bus No.	With-out DG			With DG		
	Active Power Loss	Reactive Power Loss	VOLTAGE PROFILE (V)	Active Power Loss	Reactive Power Loss	VOLTAGE PROFILE (V)
1.	0.00181	0.00242	1	0.00029	0.00039	1
2.	0.00059	0.00082	1	9.00E-05	0.00012	1
3.	0.00024	0.00048	1	0.00015	0.0003	1
4.	4.00E-05	4.00E-05	0.98934	2.00E-05	2.00E-05	0.9964
5.	0.00013	0.00013	0.98453	0.00016	0.00016	1
6.	0.00101	0.00101	0.98666	0.00083	0.00083	0.9915
7.	1.00E-05	1.00E-05	0.98572	1.00E-05	1.00E-05	0.99026
8.	0.00023	0.00031	0.98601	0.00015	0.00021	0.99003
9.	0.00028	0.00028	0.97995	0.00039	0.00039	0.98871
10.	0.00019	0.00027	0.98705	0.00019	0.00026	0.99008
11.	2.00E-05	2.00E-05	0.98327	1.00E-05	1.00E-05	0.99696
12.	0.0004	0.0004	0.97816	0.00031	0.00031	0.98694
13.	5.00E-05	7.00E-05	0.99083	6.00E-05	8.00E-05	0.99269
14.	5.00E-05	7.00E-05	0.9882	2.00E-05	3.00E-05	0.99086
15.	1.00E-05	1.00E-05	0.98732	1.00E-05	1.00E-05	0.99033

Table-2: Total Real and Reactive power loss of the 15-bus radial system

PARAMETER	WITH-OUT DG	WITH DG
REAL POWER [P.U.]	0.062	0.015
REACTIVE POWER [P.U.]	0.057	0.012



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2015

Table-3: Size and location of DG in the 15-bus radial system

Work	Method	Optimum location	Optimum DG size (pu)	Power loss (pu)		% Of Loss Reduction
				Without DG	With DG	
Proposed	PSO	Bus 3	0.999	0.062	0.015	75.80%

The results show the overall losses of the system are reduced by optimal placement of the DG, which is shown in fig. 5, and voltage profile improvement in fig. 5. The value of the optimal location and its parameters using with the PSO are given in the table 1, table 2 and table3. The voltage profiles of the overall system are also improved as shown in fig. and 5, and tables 1.

VII. CONCLUSIONS

The results clarified the efficiency of this algorithm for the improvement of the voltage profile, reduction of power losses of the grid, and also for increasing the voltage stability margin and maximum loading.

The conclusions for the objectives are given as:

- Voltage profile is significantly improved by placing DG in Distribution system.
- Particle Swarm Optimization is proposed for finding the optimal size of DG and the location is found where loss is minimized.
- Size and location of DG Estimated for loss minimization.
- Active Power losses have been reduced by 75.80%

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