Optimum Distributed Generation Allocation Using PSO in order to Reduce Losses and Voltage Improvement

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Abstract

The technology advancement in Distributed Generations (DG) has significantly influenced the environmental pollution. In power system, more especially in distribution networks, DGs can able to mitigate the total losses of the network which effectively has significant effects on environmental pollution. Optimal location and size of DG in distribution networks is one of the important issues of the power system. This paper aims to investigate the best solution for optimal operation of distribution networks by taking into consideration of DG. The optimal allocation of DG can be considered as an integer problem that can be formulated by metaheuristic methods. In this paper, the Particle Swarm Optimization (PSO) algorithm has been used to solve the DG placement and sizing. The IEEE 34 bus test system has been utilized to demonstrate the effectiveness of the PSO algorithm on herein mentioned problem. The result illustrates the losses minimization and voltage profile improvement.

1 Introduction

The management of power system has been facing with the major changes during the past decades. The willing to create a competitive environment has caused to develop various sectors such as generation, transmission and distribution. These developments and the other issues such as the environmental pollution, construction problems of the new transmission lines, and technology development to the construction of small generation units has caused the increase in the utilization of Distributed Generation (DG).

Researches of Electric Power Research Institute (EPRI) has figured out that more than 25 present capacities of DGs installed until 2010. DGs are able to connect to distribution network in most of the cases without transmission lines. Accordingly, the impacts of DGs on losses and voltages of networks should be investigated comprehensively on distribution networks operation and planning [1, 2].

The optimal operation of distribution networks applies to optimum use of resources and equipment's control such as the ability of transformers tap ganging based on loads, AVRs and capacitors. The optimization of DG allocation has applied to minimize of the objective function with considering the technical problem constraint. In the past, distribution networks were not able to connect the DG resources into the main utility grid. While present networks are able to simply connect DGs into the utility grid. More utilization of DG into the network may cause serious impacts on conventional distribution networks. The problem formulation of optimal utilization of DG aims to reduce grid losses based on active power resources control pattern[3, 4].

In recent years, researchers have been developed the optimum allocation of the DG in distribution networks. Several methodologies based on analytical tools and optimization programming methods have been executed [5–8]. In [7] the optimal sizing of DG by Improved Analytical (IA) method and Harmony search algorithm used but the optimum placement of DG has not considered. The optimization based algorithms have also been utilized by many researchers[6, 8]. In [6] the optimum allocation of wind-based DG unit presented by using particle swarm optimization technique. The results compared with analytical approach and verified. In [8] the dynamic programming application performed for DG allocation in terms of loss reduction and reliability improvement.

Consequently, according to literature reviewed of the DG allocating problem in networks planning, the objective functions of distribution network planning need to be modified for future networks. It can provide the appropriate patterns to control their impacts and effects on distribution networks. This paper presents the impacts of connected DG into distribution networks and investigates the optimum locations and sizes of DGs using PSO algorithm. The section II discusses the PSO algorithm that is used for minimization of total cost of the network.

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2 Particle Swarm Optimization

The swarm intelligent algorithm is one of the evolutionary computation methods that produced by Eberhart and Kennedy to solve the optimization problems [9]. The algorithm is based on particles movement towards the optimal point. The algorithm should be initialized by number of population and each particle is moved based on the Best Personal Position (Pbest) and Best Global Position (Gbest) which are obtained from neighbours particle's information. According to Fig 1 the basis of PSO can be explained as following:

Initially, candidate's positions in PSO algorithm are assumed in search space as initial input population. All points are based on Euclidean distance in a various categories. The instance, in Fig 1 X_i is consisting of three factors tracer. The function of each particle in the search space is calculated and in each category is determined the value of particle depending on the target function is minimized or maximized. Thus, the best member of each category is determined. On the other hand, with regard to previous information of each particle the best point can be identified that it's already discovered. Therefore the optimal point of each category and each particle is determined. The first recognition is in each category corresponding to the global optimum and the second recognition is corresponding to the personal or local optimum point.

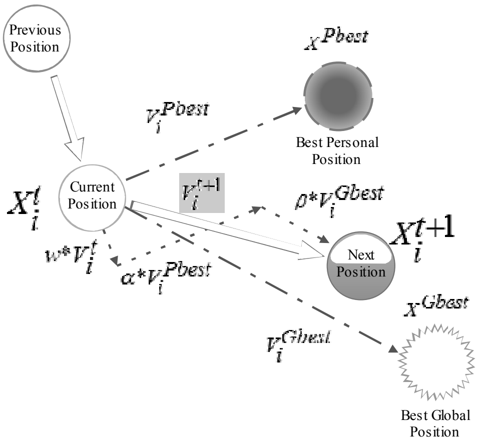

Fig 1: Principle of PSO particle movement [10]

According to Fig 1 and with this information, the particle can move in the direction of the following vector equation [11]:

$$V_i^{t+1} = (w * V_i^t) + \alpha(X^{Pbest} - X_i^t) + \beta(X^{Gbest} - X_i^t) \qquad (1)$$

$$X_i^{t+i} = X_i^t + V_i^{t+1} \qquad (2)$$

where,

X_i^t	Current position of Particle

$$X^{Pbest} = \begin{cases} X^{Pbest(j)} & if \quad OF^{j+1} \geq OF^j \\ X_i^t & if \quad OF^{j+1} \leq OF^j \end{cases} \qquad (3)$$

$$X^{Gbest} = \begin{cases} X^{Gbest(j)} & if \quad OF^{j+1} \geq OF^j \\ X^{Pbest(j+1)} & if \quad OF^{j+1} \leq OF^j \end{cases} \qquad (4)$$

X^{Pbest}	Best personal position of Particle
X^{Gbest}	Best global position of Particle
V_i^t	Velocity of particle *i* for previous vector
V_i^{t+1}	Velocity of particle *i* towards next position
w	Inertia weight factor
$\alpha \,\&\, \beta$	Acceleration coefficient
OF	Objective Function

Therefore, PSO algorithm is able to achieve the best optimal global point with sequence iteration.

2.1 Methodology

The minimization of objective function is the main aim of distribution network planning. The objective function variables have a non-linearity correlation. Therefore, the optimal operation has non-linear and discrete optimization problem. PSO is a metaheuristic method as explained formerly is based on creating an initial random solution. Fig 2 illustrates the flowchart of PSO algorithm. The algorithm has been explained as follows subsections:

1) *Initialization*

The initial placement and sizing of DG units configuration has been given in first step of algorithm. The function model generation and setting the random population, iteration number, initial particles weight and velocity into the search space has been inputted as well.

2) *objective function calculation*

The objective function parameters has been calculated based on the initial input parameters and summation of each particle.

3) *Determine Pbest*

The parameters of objective function related to the position of each particle is compared with the corresponding value in previous position with lower objective function is listed as Pbest for the current iteration as equation (3) [12].

4) *Determined Gbest*

The best result of the Pbests for all the particles will be appointed as the Gbest as dedicated in equation (4) [12].

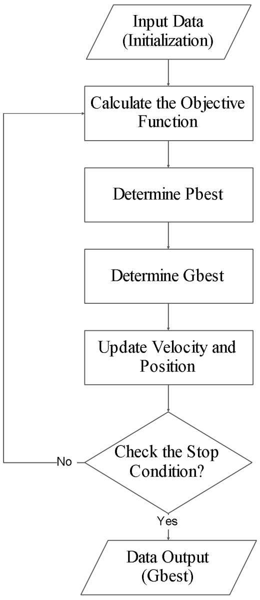

Fig 2: PSO algorithm

5) *Velocity and position updating*

By using equations (1) and (2) the position and velocity of particles is calculated for next iteration. α&β are acceleration coefficients that can be calculated as follows:

$$\alpha = c_1 r_1 \tag{5}$$

$$\beta = c_2 r_2 \tag{6}$$

where,

c_1	Personal learning coefficient
c_2	Global Learning coefficient
r_1 & $r_2 \sim U(0,1)$	Uniformly distributed random numbers

6) *Check stop condition*

Depends on objective function there are different modes of finalization of the algorithm. The stop condition is shown in Fig 3.

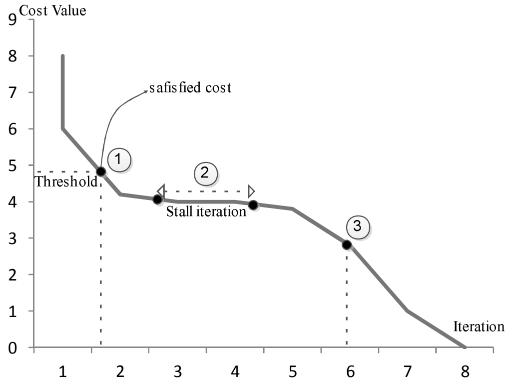

Fig 3: Stop Conditions

The following describes a few methods for stopping the loop iteration:

a) The algorithm can be finalized after achieving to satisfy cost and desired value of the objective function.
b) After achieving the stall iteration. That means after the specified time has elapsed or number of iterations without any improvement in outcome.
c) After the specified time has elapsed or number of state iterations.

The algorithm might be stopped by calling one the above conditions and the results can be printed in the output files.

3 The impacts of DGs on voltage drop and transformer tap position

Due to the small ratio of X to R in distribution networks and the radial structure of these grids, the impact of DGs on distribution network voltage is significant. By considering this issue, the voltage drop for the network cab be written as follows [13]:

$$\Delta V = V_1 - V_2 = (R + jX)I \tag{7}$$

$$I = \frac{P - jQ}{V_2^*} \tag{8}$$

$$|\Delta V|^2 = \frac{(RP + XQ)^2 + (RP - XQ)^2}{V_2^2} \approx \frac{(RP + XQ)^2}{V_2^2} \tag{9}$$

where, ΔV is the line voltage drop, $R + jX$ is the line impedance, Q is the reactive power, P is the active power, V_1, V_2 and I are the Bus 1 and 2 voltage amplitude and the current flow through the line, respectively.

The above equations should consider as one of the constraint of the optimization problem. This constraint can be considered as penalty factor into the objective function.

The transformer tap positions can be influenced by voltage improvement in distribution networks which is important for voltage regulation. Once the voltage at secondary terminal of transformer has improved as possible close to one per unit, the tap position steps can be situated in initial position. This act can gives more opportunity to voltage regulation by tap changer and will be increased the lifecycle of transformers that would be cost effective [14]. It means that, the voltage improvement by allocating DG units into the distribution network will be caused more flexibility of transformer tap changer to regulate the voltage.

4 Objective function and problem formulation

Your full paper should be submitted online via the conference website. It should be expected that after your submission, your final paper will be published directly from the PDF you send without any further proof-reading. Therefore, it is advisable for the authors to print a hard copy of their final version and read it carefully. The objective function and constraints are formulated in this section. DG placement and sizing have influenced on the total network losses in distribution networks. Therefore, the power losses reduction and voltage improvement will be obtained from the following objective functions (A & B) in the radial distribution network. The power losses and voltage improvement formulations have obtained from references [15, 16].

4.1 Power losses formulation

The total power losses equation can be introduced as follows [15, 16]:

$$L_{real\ power} = \sum_{i=2}^{n} (APO_i - APD_i - (Vs_i * Vr_i * Ysr_i * \cos(\delta r_i - \delta s_i + \theta y_i)) \tag{10}$$

where,

$L_{real\ power}$	Real Power Losses
APO_i	Active power from output bus *i*
APD_i	Active power on demand bus *i*
Vs_i	Voltage from sending bus *i*
Vr_i	Voltage on receiving bus *i*
Ysr_i	Admittance of sending and receiving bus *i*
δs_i	Phase angle of sending bus *i*
δr_i	Phase angle of receiving bus *i*
θy_i	Phase angle of $Y_i < \theta_i$

4.2 Improve the voltage profile

The drop voltage equation can be written as follows [15, 16]:

$$V_P = \sum_{i=1}^{n} (Vr_i - V_{rate})^2 \qquad (11)$$

where,

V_P	Voltage profile objective function [p.u.]
V_{rate}	Rated voltage [p.u.]

Those equations (10) and (11), represents the main objective function which can be written as follows in equation (12).

$$Z = Min[(L_{real\ power} + \gamma * V_P) + DP] \qquad (12)$$

where, γ is the violation coefficient and DP is the Penalty factor (derived from problem constraint) Z Evaluation function (minimized with PSO).

4.3 The problem constraints

The following shows the problem constraints of distribution network planning:

Bus voltage	$V_i^{\min} \le V_i^t \le V_i^{\max}$
Current feeders	$I_{fi} \le I_{fi}^{rated}$
Reactive power of capacitors	$Q_{ci}^{\min} \le Q_{gi}^t \le Q_{ci}^{\max}$
Maximum power line transaction	$\left\lvert P_{ij}^{line} \right\rvert^t \le P_{ij\ \max}^{line}$

5 Case Study

The test case that used in this paper is the IEEE_34 node which is shown in Fig 4. This case has been used to demonstrate the functionality of the proposed algorithm in order to find the optimum placement and sizing of the DG into the predefined test case. There are a few initial assumptions of the DG sizes and constraints whish are specified as follows:

- The number of iteration, population, C_1&C_2 and $w_{damping}$ are considered 1000, 30, 2, 0.99 respectively.
- Maximum number of DG units: 34 units (all nodes)
- Minimum power generation for each DG unit: 100kW
- Maximum power generation for each DG unit: 1MW
- Voltage constraint ($0.95 \le V_{node} \le 1.05$)
- DG units are considered as constant output generation with unit power factor.

Table 1 shows the comparison between the IEEE 34 standard and optimum DGs allocation cases. As obtained from the result, after allocating the optimum DG to the standard test case, the losses of the network have been reduced, significantly. The total loss of the network is reduced from 273.05kW to 83.01kW. It should be noted, the losses reduction is obviously causes the total cost decreases. In Fig 5 indicates the voltage profile improvement after DG installation which is within the standard voltage range. The optimization cost reduction based on iteration number is shown in Fig 6. It illustrates the proposed algorithm is gradually convergence to the minimum possible losses which has been defined in optimum DG case in Table 1. In addition, Table 1 indicates the minimum and maximum voltages of the network for both cases. The distance voltage drop profile **Error! Reference source not found.** is shown in Fig 7. It shows the voltage profile has been improved by allocating the optimum DG compares to standard case.

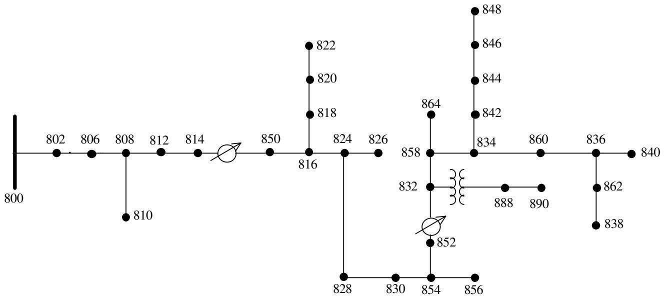

Fig 4: IEEE 34 buses diagram

Table 1: Comparison between standard and optimum case illustrates the transformer tap changer position which is extremely important in terms of voltage regulation controller of the transformers. The transformer tap positions number has been decreased in optimized DG allocated case compare to standard case. It means that, transformers have more flexibility in order to voltage regulation if position of tap changer is close to zero. The results of tap position shows the positive impact of DG on transformer tap position which may cause to increase the transformer lifecycle. For instance, in 'reg1a' the initial tap position was situated at 14, but after DG implementation it changed to 6. The maximum tap position is 16 steps, which means before DG allocation transformer was able to improve the voltage just two more tap steps while after DG it has been 10 tap steps.

	Standard case	After optimum DGs allocation	
Total Losses[kW]	273.05	83.01	
Min.voltage[p.u.]	0.9237	0.9528	
Max.voltage[p.u.]	1.05	1.05	
Numbers of DG units	No DG units	5 DG units	Bus858:150 kW Bus862:200 kW Bus846:100 kW Bus888:100 kW Bus890:200 kW
		Total DG	750 kW

Table 1: Comparison between standard and optimum case

	Standard case		After optimum DGs allocation	
	Tap[p.u]	Position	Tap[p.u]	Position
reg1a	1.08750	14	1.03750	6
reg1b	1.02500	4	1.00000	0
reg1c	1.03125	5	1.00000	0
reg2a	1.08125	13	1.05000	8
reg2b	1.08125	13	1.03750	6
reg2c	1.08125	13	1.03125	5

Table 2: Transformer taps changer comparison

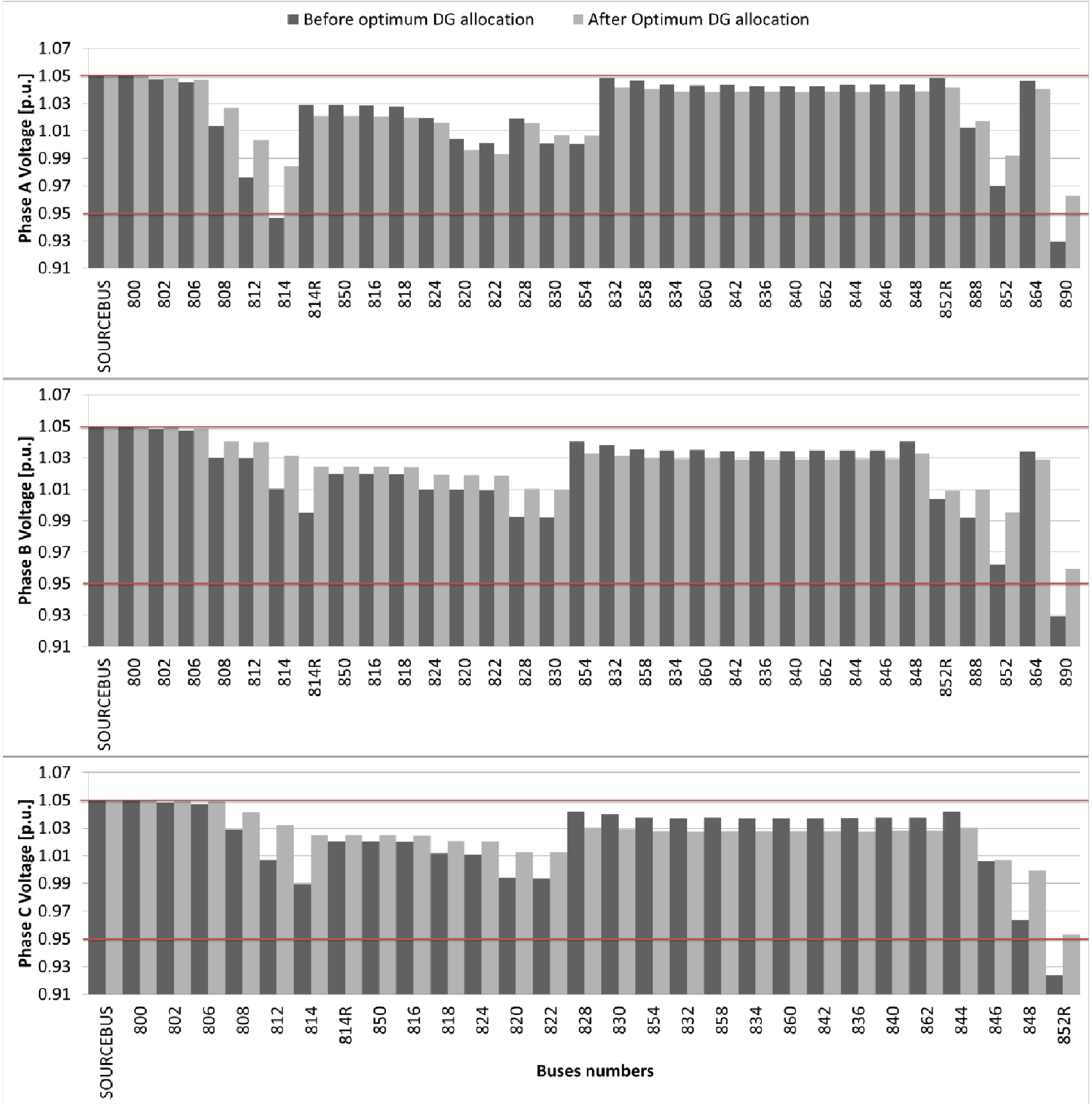

Fig 5: The voltage comparison before and after DG allocation

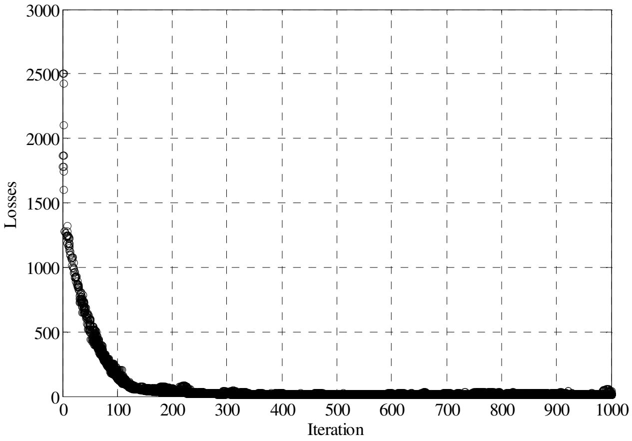

Fig 6: The losses minimization

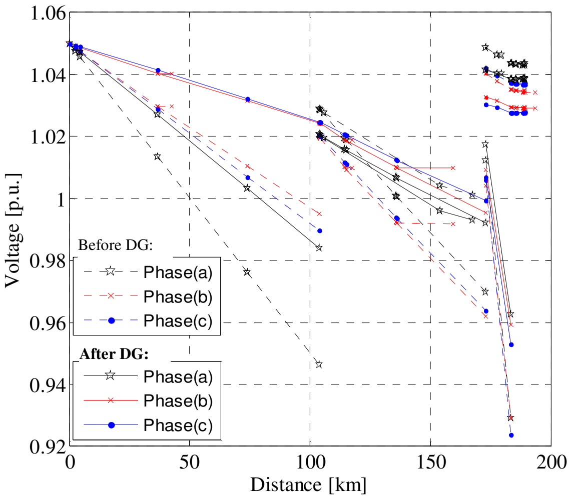

Fig 7: The voltage dorp in distance for both before and after DG allocation

Conclusion

The more connection of DG needs more studies about their impacts on distribution networks. One of the studies that tried to discuss in this paper is optimal placement and sizing of DGs. The Particle Swarm Optimization (PSO) has used to solve the objective functions of optimum DG placement and size in distribution network. The results carried out the total losses can be minimized significantly by allocating the optimum size of DG in the optimum placement. In addition the minimum voltage profile of network is reinforced to the specified standard range and generally voltage profile has improved. It can be summarized, using DG units in distribution networks is the proper solution in planning to reinforce the network operation, if the size and placement of units allocated adequately.

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