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Research Article

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METAHEURISTIC BASED TECHNIQUES FOR OPTIMAL SIZING AND SITING OF DISTRIBUTED GENERATIONS IN RADIAL DISTRIBUTION NETWORK

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ABSTRACT

An artificial intelligent (AI) based approach for optimal insertion and sizing of distributed generations (DGs) in distribution network is addressed in this research study. The objective function is constituted by considering different functions and this function is optimized by using AI based techniques. Further, basic objective of this study is to minimize the designed function under given constraints. The objective function is consisting system active power loss with DG and active power loss without DG, the ratio of bus voltage after DG to bus voltage before DG, and reciprocal of index of voltage stability. In this research article GA, PSO and GA-PSO hybrid based techniques are investigated to optimize the designed objective function. The proposed algorithms are applied on IEEE 69-bus test distribution network. From the simulation results it realized that all considered techniques produced almost similar results but computational time of GA is more further it is observed that GA-PSO based hybridized technique is better in terms of optimization of different parameters. It is concluded on basis of results that GA-PSO based technique is slightly better as compare GA, PSO in reference loss minimization, and system voltage improvement.

Keywords: Distributed Generations, Distribution network, Minimization of Network Loss, GA, PSO, GA-PSO based hybrid technique, DG.

INTRODUCTION

Commonly, all distribution networks are configured as radial structure. The configuration of such systems is very much simple as they are feeding by one source. In reference to distribution network the R/X (resistance to inductive reactance) ratio of these networks is more hence the power loss in such systems is more than that of transmission system. That is the reason the power loss of distribution systems needs to address in strategically in order to minimize. Further, in conventional radial distribution network the flow of power take place in unidirectional while the power flow becomes bidirectional as on when any other source like DGs are connected in the network as it is shown in Fig. 1. Therefore, it is crucial to minimize the power loss of distribution network when DGs are connected in these systems. Moreover, it is also equally important that the optimal size DG should be connected at optimal position otherwise it will lead towards increase the system losses and voltage instability.

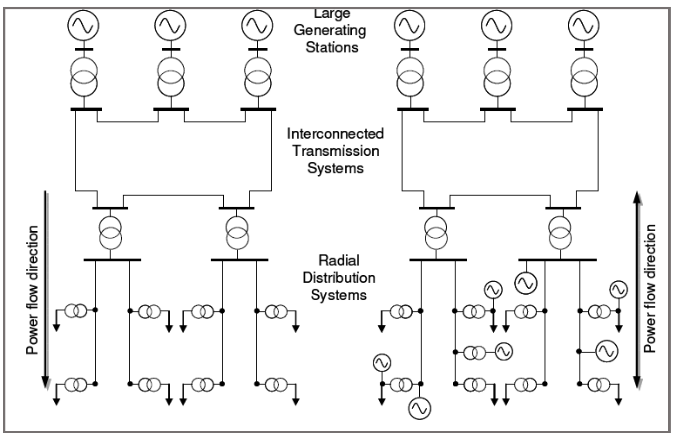

Fig.1: Structures of a typical electrical power system, (a) without DG (b) with DG

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Since radial distribution networks are feeding by one source therefore the users which are connected at far end get reduced and fluctuating voltage profile due to load demand on the system is not remain constant and the requirement of reactive power is change continuously. The load profile is changing in nature which leads towards voltage instability at the most of the buses of the system [1] and [2]. Many of the researchers have found that distributed generators (DG) may be the possible solution of above mentioned drawbacks of distribution system if they are placed and sized optimally in distribution network [1], [2], [3], [4], [5], [6], [7], [8], [9], [12], [13], [14] [15], [16], [17]. DGs are competent to inject real and reactive component of power depending upon their types and these problems are arises due to excessiveness and scarcity of reactive power [3]. Further, DGs are competent to produce the power at low or without emission of greenhouse gases (GHG) which is mainly responsible for global warming. Further, DGs are emerging as an alternative source of power generation which has significant role in future in order to setting up new generation stations and expansion and restructuring of existing power generation units. According to available literature the power generation capacity of DGs will be 20% of total installed capacity across the world in future [4]. There are many reasons for increasing the infiltration level of DGs in distribution network which are given below

- Many DG technologies are existing in advanced and mature phase such as gas turbine, wind turbine generator (WTG), solar photovoltaic (SPV), fuel cell etc.
- The DG technologies are available in small range which is varies from few kW to few MW
- The installation of DGs technologies is easier one as it required less space and less investment
- The DGs units are placed at customer end therefore transmission and distribution costs are reduced or ignored.
- DG offers many advantages such as low environmental pollution, improved system bus voltage profile and reliability and minimize the system loss which in turn saving the cost of system.

- Generally, DGs are installed at close to load center therefore transmission and distribution costs are deferred

Related literature

This section of present research article highlights the work / investigations performed by several researchers for integration of DGs and renewable energy source (RES) in distribution networks. Pisică et al. [1] addressed a GA based technique for integration of DG in distribution network in optimal manner. The authors constituted an objective function in order to minimize the network power loss and investment cost. Moradi et al. [2] highlighted a differential evolution based optimization technique for optimal sizing and sitting of DG in distribution network for minimization of system power loss. Kansal et al. [3] investigated hybrid optimization technique for optimal sizing and sitting of different DGs to improve system voltage and minimize system loss. Salama [4] presented a review regarding various types of DG technologies and their definition. Zeinalzadeh et al. [5] addressed a novel particle swarm optimization (PSO) based method for optimal installation of DG for reduces network losses and improve bus voltage of network. Ghaffarzadeh and Sadeghi [6] highlighted a biogeography-based optimization approach for optimum placement of DG unit in distribution network in order to decrease system real power loss and enhance bus voltage. Authors of this research study also investigated the performance of PSO and GA approaches for considered function with reference to DG placement and sizing in distribution network. Gomez-Gonzalez et al. [7] proposed a novel SFLA based optimization method for probabilistic load flow for optimal installation of SPV type DG by considering uncertainties of solar radiation and obtained results are compared with Monte Carlo simulation based method. Devi and Geethanjali [10] applied a new and novel BFOA for installation of DG to diminish the system power loss and enhance bus voltage [10]. Khalesi et al. [11] have addressed the dynamic programming based approach for optimum installation and sizing of DG to decrease network power loss and improve system reliability by considering time varying load. Dulău et al. [12] highlighted the existence of major types of DG technologies and their optimization techniques for optimum sizing and placement in distribution network so that one can extract their potential in efficient manner. Roy and Sultana [13] projected a new QOTLBO approach for optimum allocation of DG to reduce network loss, improve index of voltage stability along with deviation of voltage in distribution network. Singh and Parida [14] offered a new method to categorize (rank wise) the node for installation of DG unit in order to diminish system power loss and enhance network bus voltage. Ramadan [16] proposed PSO based optimization technique for optimum integration of wind operated DG for minimization of system power loss and better bus voltage. Kumar et al. [17] applied a mixed integer non-linear programming (MINLP) based approach for optimal integration multiple DG units the objective of the research was to decrease the overall cost of fuel [17].

Formulation of problem

The reason of methodology presented in this research study is to optimize considered function which is combination of three functions. These functions include network losses, bus voltage and stability of voltage. Furthermore, prime and foremost objective is to combine all these functions to make a solitary function this function is known as fitness function and finally optimize this function [1], [2].

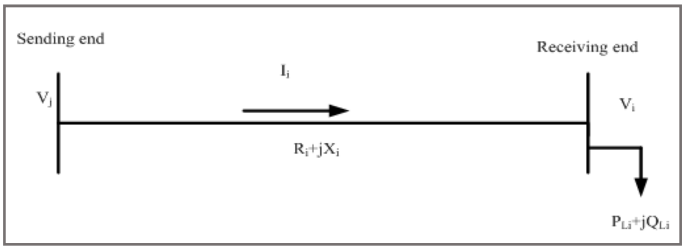


Fig. 2 Representation of two bus distribution network

Fig. 2 represents a two bus distribution network having two buses j and i. The X_i and R_i are the branch inductive reactance and resistance between bus j and i respectively

Objective function

In present research article the objective function is designed by taking three different functions as power loss of system, voltage profile of different buses of considered network and finally system stability is considered as third function. The description of the objective function is given as follows

$OF = Min(k_1 f_1 + k_2 f_2 + k_3 f_3)$ Where k_1, k_2 and k_3 are constants and f_1, f_2 and f_3 are defined as follows and $k_1+k_2+k_3 = 1$ is the weighting factor whose sum is equal to one

Network Power Loss

The active power loss of distribution network is a crucial and fundamental factor and need elaborate in detail and its description is explained as below. As it is factor of great importance therefore the priority is given as highest i.e. (0.5) to this factor. Here, the first function f_1 comprises network real power loss with DG and without DG. Therefore, f_1 may be represent as

$f_1 = \frac{\text{System power loss with DG}\left(P_{LDG}\right)}{\text{System power loss without DG}\left(P_L\right)}$ Where P_{LDG} and P_L are explained as under

$$P_{LDG} = \sum_{i=1}^{n-1}\left(I_i - DI_{dg}\right)^2 R_i$$

$P_L = \sum_{i=1}^{n-1}\left(I_i^2 R_i\right)$ Where

I_i = i^{th} branch current (in Ampere)
R_i = i^{th} branch resistance (in Ω)
I_{dg} = Injected current from DG (in Ampere)

Bus voltage profile

As on when DG unit is placed in distribution system it injects the current in distribution system. Due to this the magnitude of current get reduced which in turn reduces the system losses and improve system bus voltage. Hence, the voltage profile at each bus increased. i.e. ± 5% deviation of bus voltage is allowed. The, second function is f_2 and it is acknowledged as voltage deviation index (VDI). In projected scheme the goal is to minimize the VDF

Second function f_2 is

$f_2 = \frac{\sum_{i=1}^{n}\left(V_{bdi} - 1\right)}{\sum_{i=1}^{n}\left(V_i - 1\right)}$ Where V_{bd} is voltage magnitude when DG is placed and V_i bus voltage before DG placement here n represents the buses number of considered network and 'i' varies from 1 to n

Voltage stability index (VSI)

If changes in load are significant the network is capable to retain voltage in tolerable limit without losing the synchronism is termed as voltage stability. As distribution systems are operated in voltage stability limits, if reactive power is not supplied in adequate amount the voltage stability limit of system is not remain in stable domain. Therefore, it is necessary to incorporate the VSI factor in objective function. The third function that is f_3 is represented in the form of voltage stability index (VSI), it is given as Further, I_i (branch current between bus j and k) is determined by applying following formula

$$I_i = \frac{V_j - V_k}{R_i + jX_i} \tag{1}$$

$$P_i + jQ_i = V_i I_i^* \text{ or } I_i = \frac{P_i - jQ_i}{V_i^*} \tag{2}$$

VSI is given as

$$VSI_i = |V_j|^4 - 4[p_i(i)R_i + q_i(i)X_i]|V_j|^2 - 4[p_i(i)R_i + q_i(i)X_i]^2 \tag{3}$$

For improvement of *VSI*, f_3 is given by reciprocal of *VSI*, therefore

$$f_3 = mean\left\{\sum_{i=2}^{n} \frac{1}{VSI_i}\right\} \tag{4}$$

For stability the value of $VSI_i > 0$, the value of *i* varies from *2, 3….n* and *n* indicates the total number of bus of the test distribution system.

Constraints

For load balancing constraints following equation must be satisfied

$$P_{IG} - P_{LI} - V_i \sum_{k=1}^{n} V_k Y_{ik} \cos(\partial_i - \partial_{ik} - \theta_{ik}) = 0 \tag{5}$$

$$Q_{GI} - Q_{LI} - V_i \sum_{k=1}^{n} V_k Y_{ik} \cos(\partial_i - \partial_{ik} - \theta_{ik}) = 0 \tag{6}$$

Where, i is total number of branches and varies from 1 to n-1 and n is total number bus in considered network

System voltage constraints, the node voltage is varies between lower and upper limit i.e. five percent variation is allowed in either side further node voltage not goes below minimum voltage and simultaneously not exceeds the maximum value of voltage

$V_i^{\min} < V_i < V_i^{\max}$ where, i = 1, 2 . . . . . . n

Current constraints is given as

$I_i \le I_i^{\max}$; $i = 1, 2, 3.......n-1$ Here n is total number of bus

Moreover, three different functions which are described earlier are combined together in order to constitute the final objective function which is to optimized is expressed as follows

$$OF = \left[f_1 + f_2 + \frac{1}{f_3}\right] \tag{7}$$

The considered is optimized by applying by GA and PSO based optimization techniques

Optimal placement and sizing of DG using GA and PSO

The present research article is focused on optimal placement and optimal sizing of DGs in radial distribution network which are capable to inject active power is performed. In present paper the considered objective function is optimized by GA, PSO and GA-PSO hybridized based optimization technique.

Genetic Algorithm (GA)

GA starts searching from the set of population. It is a population based optimization technique in which random population is selected in order to find out random solution. This randomly generate group of solutions is known as chromosomes of the problem. The process of GA is described as follows

Step 1: First of all generate initial population in order to obtain a solution of n chromosomes and set time counter

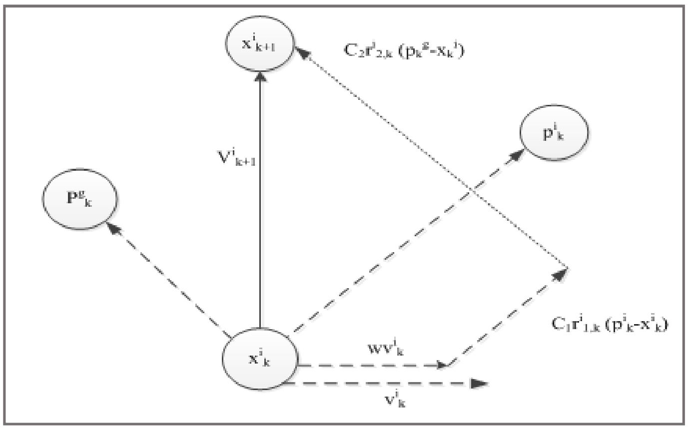
Step 2: Determine fitness value of objective function for each solution in the initial population and search optimum value of considered function

Step 3: Updates the time counter

Step 4: Apply mutation and crossover and generate a new population which is assigned by user

Step 5: Now run algorithm for newly generated population

Step 6: If stopping criterion is met then stop the algorithm.



(5)

Fig.3 Position and velocity updating criterion for PSO based optimization technique

(6)

Fig.3 shows the updating and variation of searching point by PSO based technique. Further, for projected technique the maximum and minimum size of DG units considered in between 2×10^6 kW to 100 kW respectively.

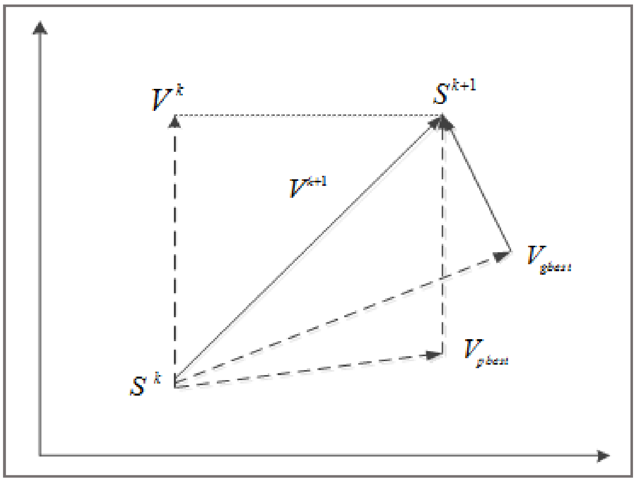


Fig. 4 Variation of searching points on the basis of PSO technique

Variation of points to be search in search-space to find out optimal location for DG placement in case of PSO based optimization technique is shown in Fig. 4

Description of PSO based algorithm

This is a nature inspired based optimization approach. The process of this approach is based on fish schooling and flocking of birds.

Following steps are involved in order to incorporate the PSO technique

Step 1: Initialize the population in order to find out appropriate solution

Step 2: Seek best values for objective function as P_{best}

Step 3: Renew time counter t = t +1

Step 4: Updates inertia weights

Step 5: Update particle velocities according to following equations

$$v_{i,it} = w \times v_{i,it-1} + c_1 \times rand_1 \times \left(pbest_{i,it-1} - x_{i,it-1}\right) + c_2 \times rand_2 \times \left(gbest_{i,it-1} - x_{i,it-1}\right) \times \left[1 + \frac{-range}{\max ite} \times \left(Ite - 1\right)\right]$$

$$x_{i,it} = x_{i,it-1} + v_{i,it}$$

Proposed methodology

In this proposed approach an appropriate installation and sizing of DG in order to optimize the fitness function which is made up by adding three different functions. The first function is constituted by taking real power loss before and after DG. Moreover, second function is also the ratio system bus voltage with DG and bus voltage without DG. Finally, third function is reciprocal of voltage stability index (VSI). The present research study is separated in two fold one is the optimum placement of DG unit and second part is the optimum sizing of DG. Moreover, in present research paper the minimum and maximum value of size of DG is 10 kW and 2 MW is considered to simulate the algorithm.

RESULT AND DISCUSSIONS

In the present paper the proposed algorithm is tested on IEEE 69-bus and 85-bus test distribution systems. Except root bus all buses are considered for DG placement. Further, in considered network which are consider as 69-bus, and 85-bus having bigger search space therefore the applied methods require more computational time which is major drawback of the technique.

IEEE 69-Bus Distribution System

Fig. 5 is used for representation of single- line diagram of IEEE 69-bus test radial distribution network. This system has a total peak load of (3.80219 + j2.69460) MVA. Table 1 represents the details of various results obtained by GA, PSO and hybrid optimization technique before and after DG placement for IEEE 69-bus distribution system. The GA based method provides bus number 62, 60 and 59 are obtained as candidate buses where DG could be placement. Moreover, their corresponding DGs sizes are 0.13267 MW, 1.52783 MW and 0.94396 MW. The method reduces system power loss from 225.07161 kW to 22.214 kW. Moreover, the value of different functions considered in proposed technique is obtained by GA as f_1 = 0.09870, f_2 = 0.34071 and f_3 = 1.00436 respectively. And optimal positions of buses where DG unit can be installed are obtained as 62, 60 and 59 respectively. Further, the various results obtained by PSO as bus number 24, 21 and 25 are obtained as candidate buses for DG placement. Their corresponding DGs sizes are 0.59092 MW, 1.00354 MW and 0.06320 MW respectively. The method reduces system power loss from 225.07161 kW to 20.304 kW. Moreover, the value of functions considered in proposed technique is obtained by PSO as f_1 = 0.09021, f_2 = 0.54175 and f_3 = 1.11099. Again, GA-PSO hybrid optimization method also produced similar kind of results as bus number 25, 15 and 27 are obtained as candidate buses for DG placement. Their corresponding DGs sizes are 1.18889 MW, 0.45816 MW and 1.08090 MW. The method reduces system power loss from 225.07161 kW to 18.180 kW. Moreover, the value of functions considered in proposed technique is obtained by GA-PSO hybrid as f_1 = 0.08077, f_2 = 0.57047 and f_3 = 1.06753. The detailed results are presented in Table.1 which are obtained by GA, PSO and GA-PSO hybrid based optimization techniques for IEEE 69-bus radial system. From these results it is concluded the power loss reduction capability of PSO based method is more as compare to other technique. Fig. 6 represent the convergence of objective function by GA based optimization technique and Fig. 7 represents the convergence of objective function by PSO based optimization technique. From these figures it is observed that PSO based optimization technique has faster rate of convergence as compare to GA based optimization technique which demonstrate that GA require more simulation time than PSO. Fig. 8 shows the system voltage profile before and after DG placement using GA, PSO and GA-PSO based optimization techniques. From this figure it is observed that GA-PSO based hybrid method improves system voltage profile more as compare to GA and PSO based technique. Fig. 9 represents the voltage stability index (VSI) at different bus which is evaluated by equation 3, from this figure it is observed that bus 1 has the highest value of VSI with 1.0 while bus 27 with 0.9840 has the lowest value of VSI in GA based optimization. Moreover, from this figure it is observed that bus 29 has the highest value of VSI with 1.01720 while bus 65 with 0.69608 has the lowest value by PSO based optimization. Further from Fig. 9 it is observed that minimum value of VSI is exists at bus number 27 with 0.8058 by GA-PSO based hybridized method. Moreover, it is observed that GA take more time for convergence as it converge after 100 iterations while PSO take lesser time for convergence as it converge after 20 iterations only. Additionally, system loss reduction capability of all three methods is almost similar but GA-PSO hybrid has slightly more loss reduction capability and voltage improvement capability. Again from this table it is noticed that the system loss reduced significantly by all these methods.

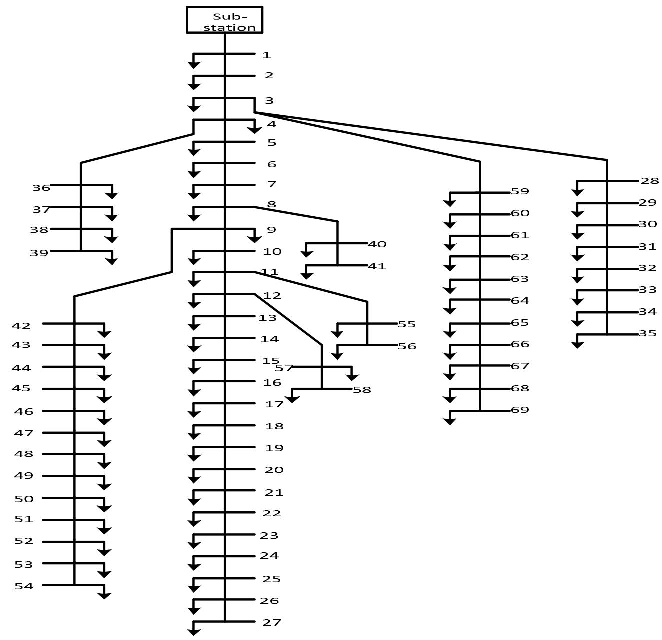


Fig. 5 Single line diagram for IEEE 69-bus radial distribution network

Table 1: Various results obtained by GA, PSO and GA-PSO based hybrid optimization technique for multiple DG placements for IEEE 69- bus test system

S.No.	Optimization technique	Candidate bus for DG placement	DG size (in MW)	System power loss before DG (in kW)	System power loss after DG (in kW)	Fitness function value
		62	0.13267			f_1=0.09870
1.	GA	60	1.52783	225.07161	22.21472	f_2=0.34070
		59	0.94396			f_3=1.00436
	PSO	24	0.59092			f_1=0.09021
2.		21	1.00354	225.07161	20.30404	f_2=0.54175
		25	0.06320			f_3=1.11099
		25	1.18889			f_1=0.08077
3.	GA-PSO Hybrid	15	0.45816	225.07161	18.18008	f_2=0.57047
		27	1.08090			f_3=1.06753

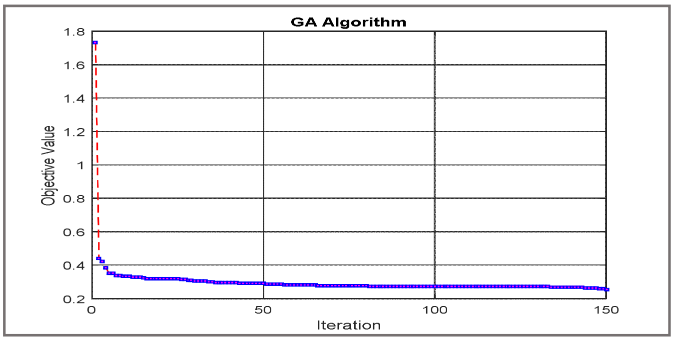


Fig.6 Variation of objective function by GA based optimization technique for IEEE- 69 bus

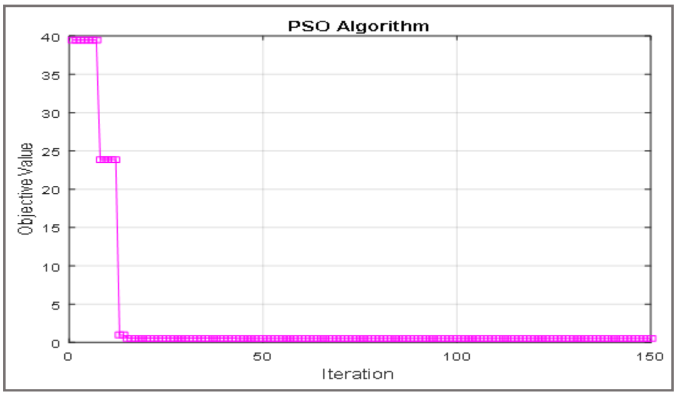


Fig.7 Convergence of objective function by PSO based optimization technique for IEEE 69-bus system

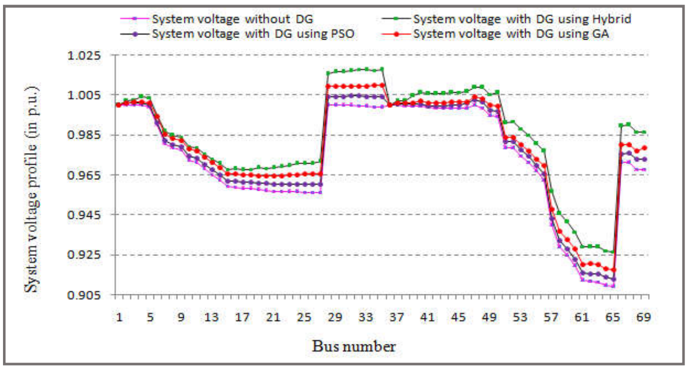


Fig.8 System voltage profile for IEEE-69 bus distribution network at different buses before and after DG placement by GA, PSO and hybrid based optimization technique

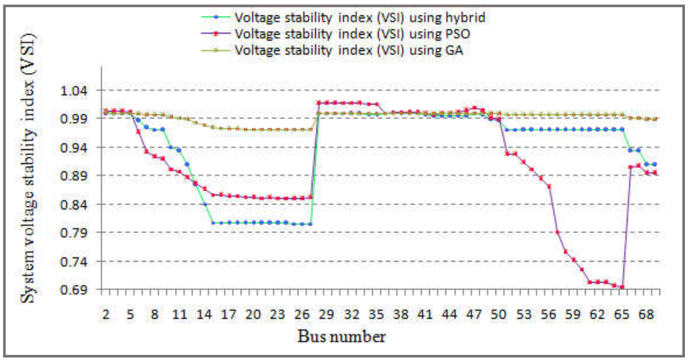


Fig.9. System voltage stability index (VSI) at various buses for IEEE 69-bus system by GA, PSO and GA-PSO based hybridized optimization technique

CONCLUSIONS

The present article focuses on optimum placement and optimum capacity of DG in distribution system is proposed. The objective function is designed by considering three functions. These function are as system loss, system voltage and system voltage stability index. The optimization of considered objective function by three different optimization techniques by GA, PSO, and GA-PSO hybrid optimization methods is the main goal of this research paper. On the basis simulation results it is observed that system loss reduced considerably and system voltage profile improved significantly. Additionally, GA, PSO and GA-PSO based hybridized method have been applied for optimization of DG locations and sizes. It is concluded that by means of achieved results that PSO, GA, and hybrid GA-PSO provide almost similar outcomes in reference of bus voltage enhancement and system loss minimization. But hybrid GA-PSO based optimization method is slightly additional efficient in respect of bus voltage improvement and system power loss reduction is concerned. Finally, it is concluded that GA-PSO based hybrid method provides better results.

REFERENCES

1. Pisic, C. Bulac, and M. Eremia, “Optimal Distributed Generation Location and Sizing using Genetic Algorithms,” IEEE Bucharest Power Tech Conf. 2009, no. 1, pp. 1–6, 2009.
2. M. H. Moradi, M. Abedini, S. M. R. Tousi, and S. M. Hosseinian, “Optimal siting and sizing of renewable energy sources and charging stations simultaneously based on Differential Evolution

algorithm," Int. J. Electr. Power Energy Syst., vol. 73, pp. 1015–1024, 2015.
3. S. Kansal, V. Kumar, and B. Tyagi, "Hybrid approach for optimal placement of multiple DGs of multiple types in distribution networks," Int. J. Electr. Power Energy Syst., vol. 75, pp. 226–235, 2016.
4. M. M. A. Salama, "Distributed generation technologies , definitions and benefits," Electr. Power Syst. Res., vol. 71, no. January, pp. 119–128, 2004.
5. A. Zeinalzadeh, Y. Mohammadi, and M. H. Moradi, "Optimal multi objective placement and sizing of multiple DGs and shunt capacitor banks simultaneously considering load uncertainty via MOPSO approach," Int. J. Electr. Power Energy Syst., vol. 67, pp. 336–349, 2015.
6. N. Ghaffarzadeh and H. Sadeghi, "A new efficient BBO based method for simultaneous placement of inverter-based DG units and capacitors considering harmonic limits," Int. J. Electr. Power Energy Syst., vol. 80, pp. 37–45, 2016.
7. F. Jurado, "A binary SFLA for probabilistic three-phase load flow in unbalanced distribution systems with technical constraints," Int. J. Electr. Power Energy Syst., vol. 48, pp. 48–57, 2013.
8. T. Gözel and M. H. Hocaoglu, "An analytical method for the sizing and siting of distributed generators in radial systems," Electr. Power Syst. Res., vol. 79, no. 6, pp. 912–918, 2009.
9. A. Y. Hatata, G. Osman, and M. M. Aladl, "An optimization method for sizing a solar / wind / battery hybrid power system based on the arti fi cial immune system," Sustain. Energy Technol. Assessments, vol. 27, no. 2018, pp. 83–93, 2018.
10. S. Devi and M. Geethanjali, "Application of Modified Bacterial Foraging Optimization algorithm for optimal placement and sizing of Distributed Generation," Expert Syst. Appl., vol. 41, no. 6, pp. 2772–2781, 2014.
11. N. Khalesi, N. Rezaei, and M. Haghifam, "DG allocation with application of dynamic programming for loss reduction and reliability improvement," Int. J. Electr. Power Energy Syst., vol. 33, no. 2, pp. 288–295, 2011.
12. L. Ioan, M. Abrudean, and D. Bic, "Distributed generation technologies and optimization," Procedia Technol., vol. 12, pp. 687–692, 2014.
13. S. Sultana and P. K. Roy, "Multi-objective quasi-oppositional teaching learning based optimization for optimal location of distributed generator in radial distribution systems," Int. J. Electr. Power Energy Syst., vol. 63, pp. 534–545, 2014.
14. A. K. Singh and S. K. Parida, "Novel sensitivity factors for DG placement based on loss reduction and voltage improvement," Int. J. Electr. Power Energy Syst., vol. 74, pp. 453–456, 2016.
15. N. Jain, S. N. Singh, and S. C. Srivastava, "PSO based placement of multiple wind DGs and capacitors utilizing probabilistic load flow model," Swarm Evol. Comput., vol. 19, pp. 15–24, 2014.
16. H. S. Ramadan, A. F. Bendary, and S. Nagy, "Particle swarm optimization algorithm for capacitor allocation problem in distribution systems with wind turbine generators," Int. J. Electr. Power Energy Syst., vol. 84, pp. 143–152, 2017.
17. A. kumar and K. S. S. Manish kumar, "Optimal Location of WT based Distributed Generation in Pool based Electricity Market using Mixed Integer Non Linear Programming," Mater. Today Proc., vol. 5, no. 1, pp. 445–457, 2018.

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