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A Hybrid of GA and PSO for Optimal DG Location and Sizing in Distribution Systems with Load Uncertainty

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ABSTRACT

Locations and capacities of DG sources have profoundly impacted on the system losses in a distribution network. In this paper, a novel combined (GA) / (PSO) is presented for optimal location and sizing of DG on distribution systems. The objective is to minimize network power losses, to obtain better voltage regulation and to improve the voltage stability within the frame-work of system operation and security constraints in radial distribution systems. Load uncertainty has been modeled using fuzzy data theory**.** This multi-objective optimization problem is transformed to single objective problem by employing fuzzy optimal theory. A detailed performance analysis is carried out on 52 bus Hamadan power networks to demonstrate the effectiveness of the proposed methodology.

Keywords: Distributed generation, Location and Sizing, Losses, Fuzzy optimal theory.

LIST OF ABBREVATIONS AND SYMBOLS USED

n_n: Total number of buses in the given RDS
n_i: Receiving bus number (n_i=2,3,...,n)
m_i: Bus number that sending power to bus n_i ($m_2=n_1=1$)
i: Branch number that fed bus n_i
$N=n_n-1$: Total number of branches in the given RDS
N_{DG} Total number of DG
C_{DG}: Capacity of DG
n_{DG}: Bus number of DG installation
P_{gni} :Active power output of the generator at bus n_i
Q_{gni} : Reactive power output of the generator at bus n_i
P_{dni} :Active power demand at bus n_i
Q_{dni}: Reactive power demand at bus n_i
$P_{ni}(n_i)$:Total real power load fed through bus n_i
$Q_{ni}(n_i)$: Total reactive power load through bus n_i
$P_{gni}^{\min}$: Minimum active power of DG at bus n_i
$P_{gni}^{\max}$:Maximum active power of DG at bus n_i
P_{RPL} : Real power losses of n_n-bus distribution system
V_{ni} : Voltage of bus n_i
V_{mi} : Voltage of bus m_i
$V_{ni}^{\min}$: Minimum voltage at bus n_i
$V_{ni}^{\max}$: Maximum voltage at bus n_i
V_{rated} : Rated voltage (1 p.u.)
$\left|s_{ni}^{\max}\right|$: Maximum apparent power at bus n_i
Y_{ni}: Admittance between bus n_i and bus m_i
θ_{ni} : Phase angle of $Y_i = Y_{ni}\angle\theta_{ni}$
δ_{ni} : Phase angle of voltage at bus n_i ($V_{ni}=V_{ni}\angle\delta_{ni}$)

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δ_{mi} :Phase angle of voltage at bus m_i
I_{ni} : Current of branch i
R_{ni} : Resistance of branch i
X_{ni} : Reactance of branch i
SI (n_i) : Voltage stability index of node n_i. (n_i = 2, 3, n)
β_1 : Penalty coefficient, 0.32
β_2 :Penalty coefficient, 0.3
K_1: Penalty coefficient (k_1= 0.6)
K_2: Penalty coefficient (K2=0.35)
C_1 , C_2: Constants
r_1 , r_2 : random numbers in [0, 1]
J_{best} : Global best position associated with the whole neighbourhood experience
W: Weight inertia
f_1 : Network Real power losses
f_2 : Network voltage profile
f_3 : Network *voltage stability index*
$f^{avrage}{}_i$ = value for each one of the objective functions at average,
$f_i^{offpeak}$ = value for each one of the objective functions at off-peak,
$f^{peak}{}_i$ = value for each one of the objective functions at peak,
$f^{tot}{}_i$ = value for each one of the objective functions at total range (6 months),

I. INTRODUCTION

Distribution systems are usually radial in nature for the operational simplicity. Radial Distribution Systems (RDS) are fed at only one point which is the substation. The substation receives power from centralized generating stations, through the interconnected transmission network. The end users of electricity receive electrical power from the substation through RDS which is a passive network. Hence, the power flow in RDS is unidirectional. High R/X ratios in distribution lines result in large voltage drops, low voltage stabilities and high power losses. Under critical loading conditions in certain industrial areas, the RDS experiences sudden voltage collapse due to the low value of voltage stability index at most of its nodes.

Recently, several solutions have been suggested for complementing the passiveness of RDS by embedding electrical sources with small capacities to improve system reliability and voltage regulation [1], [2].

Such embedded generations in a distribution system are called dispersed generations or distributed generations (DG).

Distributed generation is expected to play an increasing role in emerging electrical power systems. Studies have predicted that DG will be a significant percentage of all new generations going on lines. It is predicted that they are about 20% of the new generations being installed [3].

In order to achieve the aforementioned benefits, DG size has to be optimized. Researchers have developed many interesting algorithms and solutions. The differences are about the problem which is formulated, methodology and assumptions being made. Some of the methods are mentioned in [4] as analytical approaches [5] numerical programming, heuristic [6-7]. All methods own their advantages and disadvantages which rely on data and system under consideration. Generally the allocation problem formulation of distributed generation is non linear, stochastic or even a fuzzy function as either an objective function or constraints. Generally, in all formulations the objective function is to minimize the real power losses and improve voltage; while abiding into all physical constraints equations in terms of voltage and power. The variable limits in the optimization procedure must also be obeyed.

The problem of optimal DG location and sizing is divided into two sub problems, where the optimal location for DG placement is the first and how to select the most suitable size is the second. Many researches proposed different methods such as analytic procedures as well as deterministic and heuristic methods to solve the problem. Keane and Malley [8] solved for the optimal DG sizing in the Irish system by using a constrained linear Programming (LP) approach. The objective of their proposed method was to maximize the DG generation. The nonlinear constraints were liberalized with the goal of utilizing them in the LP method. A DG unit was installed at all the system buses and the candidate buses were ranked according to their optimal objective function values. Kashem [9] developed an analytical approach to determine the optimal DG sizing based on power loss sensitivity analysis. Their approach was based on minimizing the distribution system power losses. The proposed

method was tested using a practical distribution system in Tasmania, Australia. Griffin [10] analysed the DG optimal location analytically for two continuous load distributions types, uniformly distributed and uniformly increasing loads. The goal of their studies was to minimize line losses. One of the conclusions of their research was that the optimal location of DG which is highly dependent on the load distribution along the feeder; significant losses reduction would take place when DG is located toward the end of a uniformly increasing load and in the middle of uniformly distributed load feeder.

Acharya et al [11] used the incremental change of the system power losses with respect to the change of injected real power sensitivity factor developed by Elgerd [12]. This factor was used to determine the bus and causing the losses to be optimal when hosting a DG. They proposed an exhaustive search by applying the sensitivity factor on all the buses and ranked them accordingly. The drawback of their work is the lengthy process of finding candidate locations and the fact that they sought to optimize only the DG real power output. Rosehart [13] dealt with only the optimal location portion of the DG integration problem. They developed two formulations to assess the best location for hosting the DG sources. The first is a market based constrained optimal power flow that minimizes the cost of the DG generation power, and the second is voltage stability constrained optimal power that maximizes the loading factor, distance to collapse. Both formulations were solved by utilizing the interior point (IP) method. Outcomes of the two formulations were used in ranking the buses for DG installations. The optimal DG size problem was not considered in their paper.

Reche Lopez et al [14, 15] used the binary particle swarm optimization approach to determine the optimal location for biomass-based power plants. The proposed algorithm also offers the supply area for the biomass plant. The optimal location can be addressed as a nonlinear optimization problem. The profitability index is the fitness function for the binary optimization algorithm.

Nafeh [16] developed a new formulation for optimizing the design of a photovoltaic (PV) -wind hybrid energy home system, incorporating storage battery. This formulation is carried out with the purpose of arriving at a selection of the system economical components which can reliably satisfy the load demand. Genetic algorithm (GA) optimization technique is utilized to satisfy two known purposes. Kristin Jordal et al [17] used the genetic algorithms enabling a division of the optimization parameters into two groups; one where the values are at their optimum at the limit of the investigated parameter range, and other where there actually is an optimum within the investigated range. It was found that the process has a severe efficiency penalty caused by using heat from hydrogen combustion for the reforming process.

Gandomkar et al [18] hybridized two methods to solve DG sizing problem. They combined GA and simulated annealing meta-heuristic methods to solve optimal DG power output. Hajabdollahi et al [19] considered fast and elitist non-dominated sorting genetic algorithm (NSGA-II) with continuous and discrete variables applied to obtain maximum energy efficiency with minimum total annual cost per produced steam energy as a two objective functions.

Halim [20] deals with the estimation of electricity production from hydraulic and thermal sources using the Genetic Algorithm (GA) with time series (TS) approach. Two forms of the mathematical models are developed, of which one is exponential and the second is polynomial. The power form of the Genetic Algorithm-Time Series (GATS) model is used for the thermal electricity production. Haghifam [21] proposed the ant colony optimization method as an optimization tool for solving the DG sizing and location problems. Minimized objective function for used method was the global network cost. N. Khalesi and Haghifam [22] considered multi-objective function to determine the optimal locations to place DGs in distribution system to minimize power loss of the system and enhance reliability improvement and voltage profile. Time varying load is applied in this optimization to reach pragmatic results meanwhile all of the study and their requirements are based on cost/benefit forms. Finally to solve this multi-objective problem a novel approach based on dynamic programming is used. Naresh [23] considered an analytical expression to calculate the optimal size and an effective methodology to identify the corresponding optimum location for DG placement for minimizing the total power losses in primary distribution systems.

In our latest published papers [24, 25], the optimal location and sizing of DG in distributed systems were programmed by employing only the GA method and a novel hybrid Genetic Algorithm (GA) / Particle Swarm Optimization (PSO) [26] respectively. In those works, contrary to this work, the objective function dimensions are reduced to one, using the penalty coefficients.

A new combined algorithm is proposed to evaluate the DG site and size in Distribution network. In this method, site of DG is searched by GA and its size is optimized by PSO. Also, fuzzy optimal theory is used to transform the multi objective problem to single objective problem. First the initial population for DG size and site are produced randomly, then the load flow was run. Using the given cost function was implemented to optimize the size of DG which was calculated by PSO for the known site. In the next step the new site of DG was calculated by GA to optimize the cost function. The GA is run by the predetermined iteration and in each iteration for a candidate site, the size of DG was re-optimized by PSO which this reduces the search area for the GA and gives better optimization in each iteration. Considering multi-objective optimization problem, this article introduces total satisfied degree by employing the fuzzy optimal theory, which makes a good way to transform multi-objective into single objective.

The simulation results showed that the proposed combined Fuzzy GA/PSO method is better than the GA and PSO in terms of solution quality and number of iterations.

This paper is organized as follow; Problem formulation in section II, optimal sitting and sizing of DG in section III, application study and numerical results in section IV, discussions in section V and the conclusion in section VI.

II. PROBLEM FORMULATION

DG's sitting and sizing could have been affecting the operation of distribution system. To optimize these effects, the three terms objective functions were considered. These terms which are modeled according to the system loads and the lines impedances are: power losses, voltage profile and voltage stability. This objective function with three different dimensions is converted to a single dimension objective function using fuzzy set theory.

A. *Power Losses*

The real power losses in a system is given by (1).

$$f_1 = P_{RPL} \qquad (1)$$

P_{RPL} is the real power losses of n_n-bus distribution system, and is expressed in components as:

$$P_{RPL} = \sum_{i=2}^{n_n} (P_{gni} - P_{dni} - V_{mi} V_{ni} Y_{ni} \cos(\delta_{mi} - \delta_{ni} + \theta_{ni})) \qquad (2)$$

B. *Improve voltage profile*

The objective function to improve voltage profile is,

$$f_2 = \sum_{ni=1}^{n_n} \left(V_{ni} - V_{rated}\right)^2 \qquad (3)$$

C .*Voltage stability index*

Fig.1 shows a branch of radial system. In radial distribution system each receiving node is fed by only one sending node,

From Fig.1

$$I_i = \frac{V_{mi} - V_{ni}}{R_{ni} + jX_{ni}} \qquad (4)$$

$$P_{ni}(ni) - jQ_{ni}(ni) = V_{ni}^* I_{ni} \qquad (5)$$

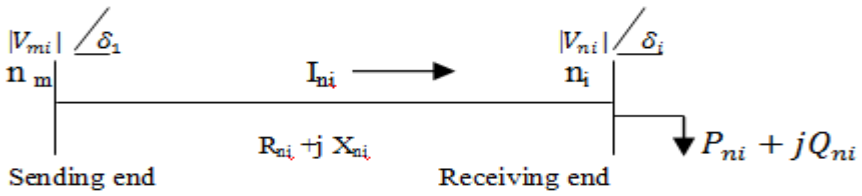

Fig. 1. Representative Branch of a radial distribution system

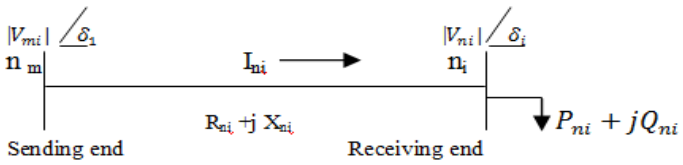

Fig. 1. Representative Branch of a radial distribution system

When distributed generation is connected to distribution network, the index of voltage stability for distribution network will be changed. This index, which can be evaluated at all nodes in radial distribution systems, was presented by Charkravorty et.al [25]. Equations used to formulate this index are presented in [27], to solve the load flow for radial distribution systems. Equation (6) represents the voltage stability index. Using (4) and (5):

$$SI(n_2) = |V_{mi}|^4 - 4\left[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}\right]|V_{mi}|^2 - 4\left[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}\right]^2 \qquad (6)$$

Objective function for improving voltage stability index is,

$$f_3 = \left(\frac{1}{(SI(ni))}\right) \qquad n_i = 2, 3, n_n \qquad (7)$$

For stable operation of the radial distribution systems, $SI(n_i) > 0$ for i= 2 , 3...، n_n, so that; there exists a feasible solution. It is very important to identify weak buses for nodes with minimum voltage stability index that are prone to voltage instability. Investigating the voltage stability index behaviour demonstrate that the buses which experiencing large voltage drops are weak and within the context of remedial actions. So, it makes sense to act on controls that will improve the voltage magnitudes at weak buses.

D. Three fuzzy-subordination functions of optimized objectives

Because the dimensions of three optimized objectives are different. In this article, three optimized objectives are transformed into single objective by using the fuzzy theory, which are expressed by linear-partition function of fall half trapezoid [29].

$$\mu_i = \begin{cases} 1 & f_i \le f_i^{\min} \\ \dfrac{f_i^{\max} - f_i}{f_i^{\max} - f_i^{\min}} & f_i^{\min} \le f_i \le f_i^{\max} \\ 0 & f_i \ge f_i^{\max} \end{cases} \qquad (8)$$

Where i= 1, 2, 3; μ_1 μ_2, and μ_3 stand for the fuzzy subordination of three optimized objectives respectively, such as the system network loss, the improvement in voltage profile and the voltage stability index; $f1$, f 2 and f 3 stand for upper and lower limit values of three objective functions, respectively; f_1^{mim} , f_2^{min} and f_3^{min} are the best value that achieved from optimizing three objectives. λ is the total satisfied degree.

$$\lambda = Max(\min\{\mu_1, \mu_2, \mu_3\}) \qquad (9)$$

E. *Fuzzy model of load points*

In this study, uncertainty in the distribution system has been modelled through fuzzy numbers. Load of each point is described according to fig.2 as a triangular fuzzy number. Three parameters (P_R, P_M, P_L) indicate the expected load will be something around P_M, but it will not be less than P_L or more than P_R. Equation (10) represents the fuzzy model of load point.

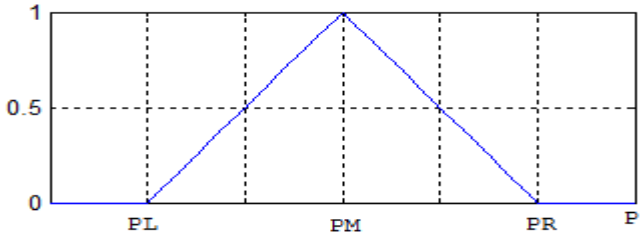

Fig .2. Load as a triangular fuzzy number

$$\mu_P = \begin{cases} 0 & P \le P_L \ OR \ P \ge P_R \\ \dfrac{P - P_L}{P_M - P_L} & P_L \le P \le P_M \\ \dfrac{P_R - P}{P_R - P_M} & P_M \le P \le P_R \end{cases} \qquad (10)$$

The studies were considered for 6 months (2months at average range, 3 months at off peak range and 1 month at peak range), each of the objective functions would have been calculated based on Equation (11):

$$f^{tot}_{i} = (2\, f^{avrage}_{i} + 3\, f_i^{offpeak} + f^{peak}_{i})/6 \qquad (11)$$

F. *Fuzzy power flow*

The power demand at each node can be represented using a value P_L (the "most favourable" demand), a value P_R (the "most unfavourable" demand), and a value P_M (demand with the highest possibility of existence in the future that corresponds to the value 1 of the membership function μ_P. A fuzzy power demand represents simultaneously a large set of possible values of the power demand in the future, at a given node on the distribution network, describing the intrinsic uncertainty of such future demand. Fuzzy power flows (also represented by fuzzy triangular numbers) are transmitted by the lines of the distribution network to supply the fuzzy power demands of the nodes.[32]. There are different power flow solution techniques, among these methods the reported in [31] was chosen for its accuracy and computational time. Such fuzzy power flows and the fuzzy voltages at nodes are calculated with power flow method that converted to the fuzzy power flow with applying the fuzzy numbers theory [32]. Since load of the network has been modelled in triangular fuzzy model, implementation of the fuzzy load flow program, various results such as active and reactive transmitted power, voltage of buses in addition to active and reactive power loss has been calculated in triangular fuzzy form. In order to obtain required value of the objective function, these values must first be transformed from fuzzy case to a specified case.

G. *Constraints*

i. Load balance constraint

For each bus, the following equations should be satisfied.

$$P_{gni} - P_{dni} - V_{ni}\sum_{j=1}^{N} V_{nj}Y_{nj}\cos\left(\delta_{ni} - \delta_{nj} - \theta_{nj}\right) = 0 \qquad (12)$$

$$Q_{gni} - Q_{dni} - V_{ni}\sum_{j=1}^{N} V_{nj}Y_{nj}\sin\left(\delta_{ni} - \delta_{nj} - \theta_{nj}\right) = 0 \qquad (13)$$

Where n_i= 1,2, ... n_n

ii. Voltage limits

The generator voltage will be the load/bus voltage plus some values related to impedance of the line and the power flows along that line. It is evident that the larger the impedance and power flow, the larger the voltage rises. The increased active power flows on distribution network have a large impact on the voltage level because resistive elements of the lines on distribution networks are higher than other lines. This leads to an X/R ratio of approximately 1 rather than a more typical value of 5 on transmission networks. The voltage must be kept within standard limits at each bus [28, 30].

$$V^{\min}_{ni} < V_{ni} < V^{\max}_{ni} \qquad (14)$$

iii. DG technical constraints

As DG capacity is inherently limited by the energy resources at any given location, it is necessary to constrain capacity between the maximum and the minimum levels**.**

$$P_{gni}^{\min} \le P_{gni} \le P_{gni}^{\max} \qquad (15)$$

iv. Thermal limit

Final thermal limit of distribution lines for the network must not be exceeded.

$$\left|S_{ni}\right| \le \left|S_{ni}^{\max}\right| \qquad i = 1...N \qquad (16)$$

III. OPTIMAL SITING AND SIZING OF DISTRIBUTED GENERATION

The optimal sitting and sizing problems of distributed generation are formulated as a multi-objective constrained optimization problem. This paper uses novel combined Fuzzy GA/PSO for solving the problems of optimal sitting and sizing DG. The results were compared to PSO and GA.

A. GENETIC ALGORITHMS (GA)

In GA algorithm, the population has n chromosomes that represent candidate solution; each chromosome is an m dimensional real value vector where m is the number of optimized parameters. Therefore each optimized parameter represents a dimension of the problem space.

Step 1 (initialization): set the time counter t=0 and generates randomly n chromosomes. $[X_j(0), j=1,\ldots,n]$, where $x_j(0) = [x_{j,1}(0), x_{j,2}(0), \ldots, x_{j,m}(0)]$. $x_{j,k}(0)$ is generated in search space $[x^{\min}{}_k, x^{\max}{}_k]$ randomly.

Step 2 (fitness): evaluate each chromosome in the initial population using the objective function, J. search for the best value of the objective function J_{best}. Set the chromosome associated with J_{best} as the global best.

Step 3 (time updating): update the time counter t=t+1.

Step 4 (new population): create a new population by repeating the following steps until the new population is completed:

- Selection: select two parent chromosomes from a population according to their fitness
- Crossover: with a crossover probability, cross over the parents to form a new child.
- Mutation: with a mutation probability method mutates new child at each chromosome.
- Acceptance: place new child in a new population

Step 5 (replacement): use new generated population for a further run of algorithm.

Step 6: if one of the stopping criteria is satisfied then stop, else go to step 2.

Fig 3 shows the flow chart optimal sitting and sizing of distributed generation.

B. PARTICLE SWARM OPTIMIZATION (PSO)

In PSO algorithm, the population has n particles that represent candidate solutions. Each particle is an m dimensional real valued vector where m is the number of optimized parameters. Therefore each optimized parameter represents a dimension of the problem space. The PSO technique can be described in the following steps in Fig 4:

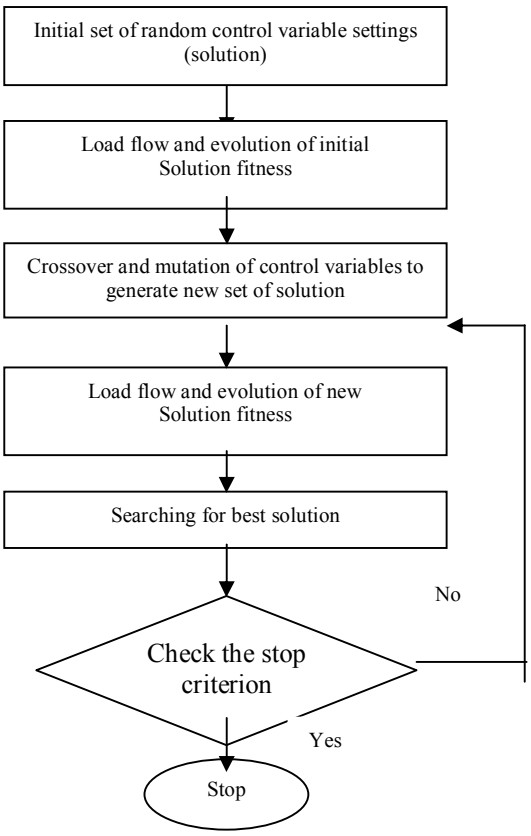

Fig.3. GA for optimal sitting and sizing of DG

Step1: (initialization) : set the time counter t=0 and randomly generate n chromosomes, $[x_j(0), j=1,...,n]$, where $x_j(0)=[x_{j,1}(0), x_{j,2}(0),...,x_{j,m}(0)]$. $x_{j,k}(0)$ is randomly generated in search space $[x^{\min}{}_k, x^{\max}{}_k]$. $V_j(0)$ is randomly generated for evaluation of the objective function. For each particle, set $x^*{}_j(0)=x_j(0)$ and $j^* j = j_j$, j=1... n. Search for the best value of the objective function J_{best}. Set the particle associated with J_{best} as the global best, $x^{**}(0)$ with an objective function of j^{**}. Set the initial value of the w (0) =0.98.

Step 2 (time updating): update the time counter t=t+1.
Step 3 (weight updating): update the inertia weight.
Step 4 (velocity updating): using the global best and the individual best to change the particle velocity in the following equation:

$$v_{j,k}(t) = \omega(t)v_{j,k}(t-1) + c_1 r_1 (x^*_{j,k}(t-1) - x_{j,k}(t-1) + c_2 r_2 (x^{**}_{best} - x_{j,k}(t-1))) \quad (17)$$

Step 5 (position updating): based on the updated velocity, each particle changes its position according to the following equation.

$$Xj,k(t) = Xj,k(t-1) + Vj,k(t) \quad (18)$$

If a particle violates is position limits in any dimension set its position at the proper limit.

Step 6: each particle is evaluated according t the updated position .if $j_{\min} < j^*$ then updates individual best as $x^*_j(t) = x_j(t),\ j_i = j_i^*$.

Step 7: now search for the minimum value, if $j_{\min} < j^{**}$ then updates global best as $j^{**} = j_{\min}$ and $x^{**} = x_{\min}(t)$

Step 8: if one of the stopping criteria is satisfied then stop, else go to step 2.

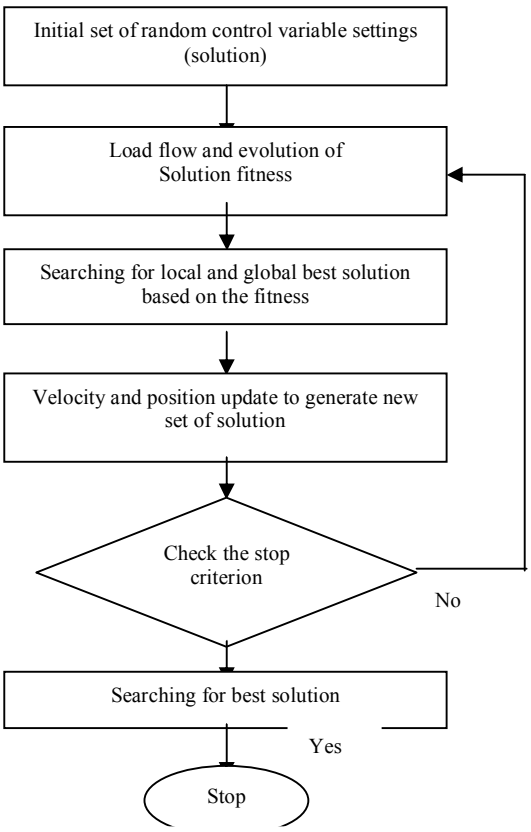

Fig.4. PSO for optimal sitting and sizing of DG

C. PROPOSED METHODOLOGY

D. This is a searching technique developed for optimal sitting and sizing of DG. The problem consists of two parts. The first is the optimal location of DG and the second is the optimal sizing. Result for the first part is an integer which is either a bus number where DGs are suggested to be installed. This needs an integer-based optimization algorithm. GA has been chosen

to play this role because of its attractive quality. The answer obtained from GA solution is used in PSO algorithm to optimize the sizing for DG according to fuzzy objective function. PSO has the fast convergence ability which is a great attractive property for a large iterative and time consuming problem. Interaction between the two algorithms as shown in Fig 5 goes as follows.

- Initialization: Set the time counter t = 0 and generate randomly n chromosomes, this represent n initial candidates sitting of DG.
- Fitness using PSO according to fuzzy objective function: Evaluate each chromosome and optimal sizing of DG
  - Initialize particle population, modified matrix and contain size of DG.
  - Calculate the objective values which are the total real power losses and the voltage profile improvement.
  - Record objective function as the best candidate of particle and the minimum value as the current overall global best of the group.
  - Update the velocity (v) and position.
  - Check the stop criterion if it is satisfied then stop.
- Time updating: Update the time counter t=t+1.
- New population: Create a new population of sitting of DG by repeating the following steps until the new population is completed:
  - Selection - Crossover - Mutation
- Fitness using PSO according to fuzzy objective function and time updating.
- Check the stop criterion, if it is satisfied then stop, else go to time updating.
-

IV. APPLICATION STUDY AND NUMERICAL RESULTS

The proposed method for optimal sitting and sizing of DG has been implemented in the MATLAB and tested for several power systems. The case study is a radial system with the total average load of 5.51 MW, 4.22 MVar, 52 bus and 51 branches as it has been shown in Fig. 6. The peak load and off peak load have been modelled 1.2 and 0.85 times average load respectively. The real power loss in the system pre installation is 227 (kW) while, the reactive power loss in the system is 153.8 (kvar) Calculating method that used, is based on [33]. Gave the rating active power of distributed generation is 1.8 MW; power factor is 1.The optimization is performed using GA/PSO software package was written for simulation of optimal sitting and sizing of DG in radial distribution systems. The parameters of GA/PSO used for solving the problem presented in this paper are furnished in Table-I. Table II shows the values objective functions pre installation.Simulation results of proposed algorithm and objective function optimization based on both sitting and sizing of DG in the network are showed in Table III. The GA/PSO results are compared with a PSO and GA. In the first table, the objective function is P_{loss} which is minimized to find out the best result. The Table III shows the methods which are compared, location, DG size, real power loss and profile voltage and voltage stability which are basic columns.

Table: I GA/PSO, GA and PSO PARAMATERS

Method	Pop. size	Selection method	Cross over	Mutation		Algorithm Termination
GA/PSO	GA=30 PSO=20	Normalized Geometric Selection	Simple Xover	Binary Mutation		Maximum Number of Generation (30)
GA	50	Normalized Geometric Selection	Simple Xover	Binary Mutation		Maximum Number of Generation (60)
Parameters PSO		C_1	C_2	r_1	r_2	-------
PSO	40	2	2	1	1	Maximum Number of Generation (40)

Table II: pre installation values of objective functions for 52 bus

Objective function	f_1 (P.U.)	f_2 (P.U.)	f_3 (P.U.)
Value			
52 bus	0.227	0.2603	1.1897

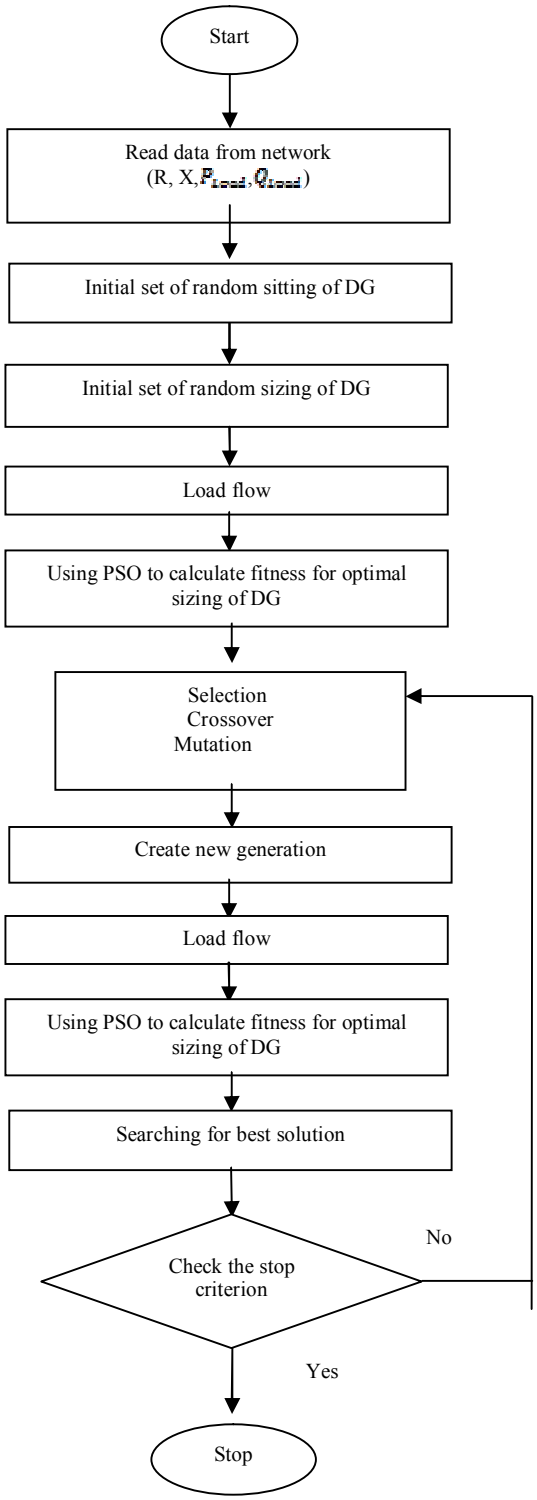

Fig.5 GA/PSO for optimal sitting and sizing of DG

From the results presented in Table III, they can observe that GA/PSO is effective for optimal sitting and sizing of DG. The voltage stability index is given in Fig.7 .The voltage profile of each bus in 52 bus distribution given in Fig.8. The results show that the different voltage level while pre and post installation of DG. Pre installation of DG, voltage level from bus 40 is low .After installation of DG; the voltage level of that bus is improved. Furthermore, the voltage levels at all nodes of the RDS

have improved. It is evident that the voltage stability index of the nodes in the radial distribution system, before installation, is very poor. The resulted after installation of DG shows that the stability index at all nodes of the RDS has improved.

From these results, we can confirm that the voltage level is improved and voltage stability index compared with the result of (PSO and GA) by application of the proposed method

Table III: Performance analysis of 52 bus radial distribution system

Method	f_1 (P.U.)	f_2 (P.U.)	f_3 (P.U.)	Bus. No	DG Size (MW)
GA/PSO	0.1131	0.163	1.006	32 27	1.4925 1.302
GA	0.11506	0.171	1.0537	29 30	1.5 0.4228
PSO	0.1144	0.169	1.0103	32 25	0.9816 0.8297

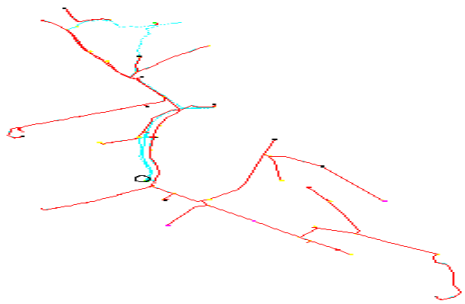

Fig.6.Single line diagram of a 52 bus Hamadan power networks.

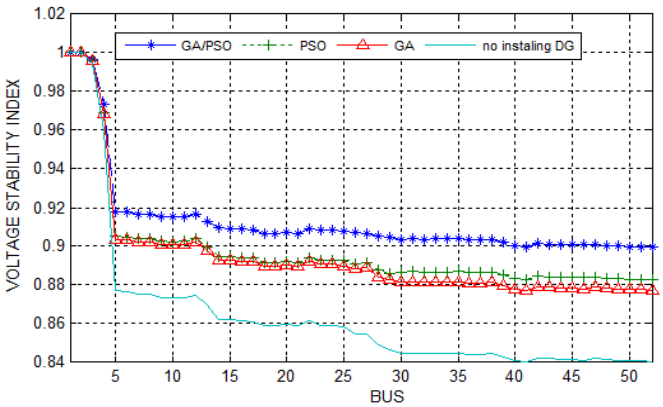

Fig. 7. Voltage stability index of 52 bus radial distribution system.

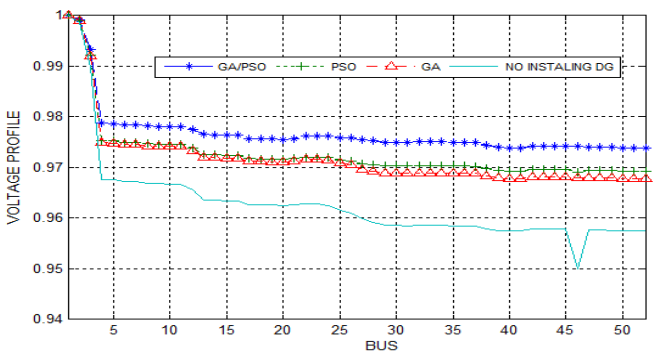

Fig. 8. Voltage levels for a 52 bus radial distribution system

Fig.9 shows the worst, best and average objective functions for GA/PSO, GA and PSO in 52 bus radial distribution systems. with considering the worst objective function, GA/PSO reduced objective function 52% relative GA and 11% relative PSO. Fig.9 shows these results. Regarding the best and average objective function, the similar trend was observed. Variance of objective function for fifty initial populations was calculated. Although the variance of GA and PSO is 0.0864 and 0.0542, respectively, GA/PSO has the variance of zero given in Fig.10. That implies that GA/PSO methods provide high quality solutions.

The results of the detailed performance analysis are illustrating in Fig.7 to 10.In these networks; the $\frac{R}{X}$ ratio is approximately equal to three. This means that the network is highly resistive in nature and needs to supplemented with distributed real power source.

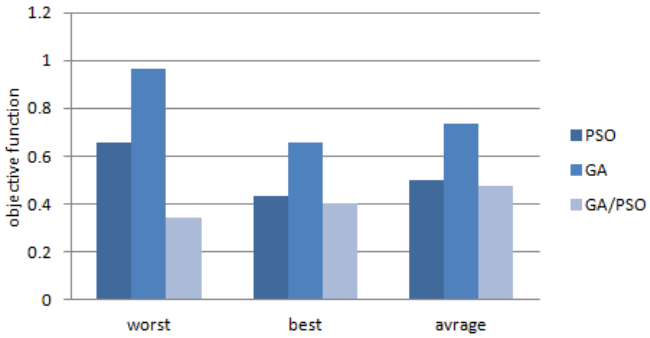

Fig.9: the Worst, the best and the average of objective function

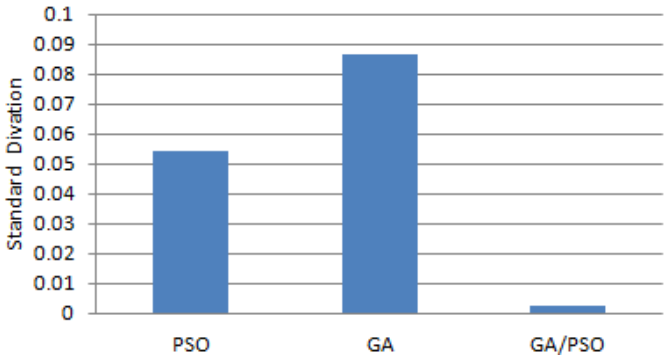

Fig.10: Variances of objective function

V. DISCUTIONS

The worst, the best and the average of the objective functions to improve loss in system 52-bus for all three methods are illustrated and compared in Fig.9. The best and the worst are from the fuzzy GA/PSO method and the GA, respectively. Looking at the worst objective functions results reveal that the value for combined method is at 14% compared to 37% and 24% for the GA and the PSO respectively. By considering the best and average objective functions, similar trends were observed.

The fuzzy GA/PSO method is converted to solution in minimum number of iterations and the PSO is the least. But the running time for the PSO was faster in comparison with the other two and the least is for GA.

In Fig. 10, variance for the objective functions is illustrated. The variance is calculated for the fifty initial populations. The output variances for GA and PSO are at 0.0864 and 0.0542 respectively, but it has found to be almost at zero for the fuzzy GA/PSO method. This is an indication of output uniformity for the combined method and non- uniformity for the others. Having zero variance is demonstrating that the combined proposed method is preferred in comparison with the other two.

As shown in Fig. 10, this implies that the combined method is providing high quality solutions.

Amongst the three, the combined method showed less objective function value in comparing with GA and PSO, Table III.

Voltage stability index in bus 52 from the case study system was low before DG installation. This could cause instability in the networks in the presence of disturbances. After DG installation, the three methods showed major improvements, Figs 7. Besides, the Figs 8 is demonstrating that the voltage regulation index is at highest for Fuzzy GA/PSO and for the GA is the lowest.

VI. CONCLUSION

When installation and operation of distributed generation supplies are implemented based on optimization procedures, it can provide significant technical and economical advantages for the distribution companies. Regarding the various parameters which are effective in optimally locating the DG units, solving this problem has always been concerned with special complexity. On the other hand, uncertainty in the load data which is inevitable, has further added to this complexity.In the paper combined method was proposed to solve location and capacity problems for DG. In this method, GA and PSO methods were used to determine the location and to calculate the capacity of DG respectively. The fuzzy optimal theory was used to convert this multi-objective optimization problem to single objective. This Fuzzy GA/PSO combined method was implemented for the 52 bus system to minimize the losses, to increase the voltage stability and to improve the voltage regulation index. Results from combined method were compared to the results from the other methods and advantages and disadvantages were discussed. Results showed that the proposed method is better; one of its advantages is the uniform answers with negligible value for the variances. At the same time, it was able to find the best optimized solution for the system. Considering active power losses, reactive power and the value for objective function, it can be concluded that the combined method exhibited a higher capability in finding optimum solutions.

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Appendix
PERFORMANCE ANALYSIS OF 52 BUS RADIAL DISTRIBUTIONS (LOAD)

Sending bus	Receive bus	P(KW) average range	Q(KW) average range
1	2	0	0
2	3	0	0
3	4	0	0
4	5	0	0
4	6	0.1660	0.1025
6	7	0	0
6	8	0.0217	0.0134
8	9	0	0
9	10	0	0
10	11	0.0780	0.0483
8	12	0.2310	0.1433
12	13	1.6360	1.0120
13	14	0	0
13	15	0.1400	0.0867
15	16	0	0
16	17	0.3159	0.1955
17	18	0	0
18	19	0	0
18	20	0.0716	0.0443
17	21	0.1476	0.9100
15	22	0.0178	0.0110
22	23	0	0
22	24	0	0
24	25	0	0
25	26	0	0
26	27	0	0
27	28	0.9220	0.5710
28	29	0	0
29	30	0	0
30	31	0	0
29	32	0.1060	0.0662
32	33	0	0
33	34	0	0
32	35	0	0
35	36	0.1920	0.1189
36	37	0	0
29	38	0.1060	0.0660
38	39	0	0
39	40	0.3030	0.1870
40	41	0.2430	0.1510
38	42	0	0
42	43	0.3010	0.1860
43	44	0	0
44	45	0	0
43	47	0	0
47	48	0	0
48	49	0.1885	0.1170
49	50	0.1760	0.1090
50	51	0	0
51	52	0	0

PERFORMANCE ANALYSIS OF 52 BUS RADIAL DISTRIBUTIONS
(RESISTANCE AND REACTANCE)

Sending bus	Receive bus	R(Ω)	X(Ω)
1	2	0.0612	0.0414
2	3	0.4080	0.2760
3	4	1.0200	0.6900
4	5	0.1469	0.0994
4	6	0.0204	0.0138
6	7	0.0286	0.0193
6	8	0.0204	0.0138
8	9	0.0245	0.0166
9	10	0.0061	0.0041
10	11	0.0245	0.0166
8	12	0.0571	0.0386
12	13	0.1469	0.0994
13	14	0.0490	0.0331
13	15	0.0204	0.0138
15	16	0.0204	0.0138
16	17	0.2448	0.1656
17	18	0.0204	0.0138
18	19	0.1020	0.0690
18	20	0.0816	0.0552
17	21	0.0816	0.0552
15	22	0.0612	0.0414
22	23	0.0490	0.0331
22	24	0.0245	0.0166
24	25	0.0979	0.0662
25	26	0.0469	0.0317
26	27	0.1224	0.0828
27	28	0.0979	0.0662
28	29	0.0979	0.0662
29	30	0.0245	0.0166
30	31	0.2448	0.1656
29	32	0.0163	0.0110
32	33	0.4080	0.2760
33	34	0.0734	0.0497
32	35	0.0979	0.0662
35	36	0.0163	0.0110
36	37	0.0490	0.0331
29	38	0.1346	0.0911
38	39	0.1754	0.1187
39	40	0.0979	0.0662
40	41	0.0979	0.0662
38	42	0.0163	0.0110
42	43	0.0245	0.0166
43	44	0.0490	0.0331
44	45	0.1224	0.0828
43	47	0.0857	0.0580
47	48	0.0734	0.0497
48	49	0.1224	0.0828
49	50	0.0245	0.0166
50	51	0.0734	0.0497
51	52	0.0734	0.0497