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Optimal Allocation of DG Units for Radial Distribution Systems using Genetic Algorithm

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Abstract- This paper proposes a Genetic Algorithm (GA) based technique for the optimal allocation of Distributed Generation (DG) units in the power systems. In this paper the main aim is to decide optimal number, type, size and location of DG units for voltage profile improvement and power loss reduction in distribution network. GA fitness function is introduced including the active, reactive power losses and the cumulative voltage deviationvariables with selecting weight of each variable. Two types of DGs are considered and the distribution load flow is used to calculate exact loss. Load flow algorithm is combined appropriately with GA till access to acceptable results of this operation. The suggested method is programmed under MATLAB software. The effectiveness of the proposed methodology was tested on Standard IEEE33 bus system and found maximum loss reduction for each of two types of optimally placed multi-DGs.

Index terms- Genetic Algorithm, Distributed Generators, Cumulative Voltage Deviation, Active and Reactive Power Loss, Weight, Load Flow.

I. INTRODUCTION

A distribution system provides a final link between high voltage transmission systems and consumer services. The power loss is significantly high in distribution systems because of lower voltages and higher currents, when compared to that in high voltage transmission systems. Studies have indicated that as much as 13% of total power generated is consumed as i^2rlosses. Reactive currents account for a portion of these losses. Reduction of total loss in distribution systems is very essential to improve the overall efficiency of power delivery. The pressure of improving the overall efficiency of power delivery has forced the power utilities to reduce the loss, especially at distribution level. The alternative after considering the above factor is to introduce distributed and dispersed generation which can be conveniently located closer to load centres. The main idea behind the distributed Generation (DG) is that generation in small scale and can be easily placed closer to the point of consumption [1].

By definition, the distributed or dispersed generators are small size generators, which can come from traditional or some revolutionary technologies or it is an electric power source connected directly to the distribution network or on the customer side of the meter as mentioned in [2]. DG is expected to play an increasing role in emerging power systems. Studies have predicted that DG will be a significant percentage of all new generation going online. Different resources can be used in DG, such as wind turbines ,photovoltaic, fuel-cells, biomass, micro turbines, small hydroelectric plants, etc., ranging from sub-kW to multi-MW sizes) [3],[4].

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Its impact on distribution systems may be either positive or negative depending on the system's operating condition DGs characteristics and location. The potential positive impacts are improving system reliability, loss reduction, and deferment of new generation and improving power quality. To achieve these benefits, DG must be reliable, dispatchable, of appropriate size, and at suitable locations. More important, DGs should be properly coordinated with protection systems [5].

The planning of the electric system with the presence of DG requires several factors to be taken into considerations, such as: the best technology to be used, the number and the capacity of the units, the best location, the type of network connection,etc. The impact of DG in system operating characteristics, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated. The problem of DG allocation and sizing is of great importance. The installation of DG units at non-optimal places can result in an increase in system losses, implying in an increase in costs and, therefore, having an effect opposite to the desired. For that reason, the use of an optimization method capable of indicating the best solution for a given distribution network can be very useful for the system planning engineer. The selection of the best places for installation and the preferable size of the DG units in large distribution systems is a complex combinatorial optimization problem. Genetic algorithms offer a new and powerful approach to these optimization problems made possible by the increasing availability of high performance computers at relatively low costs. These algorithms have recently found extensive applications in solving global optimization searching problems when the closed-form optimization technique cannot be applied. Genetic algorithms (GAs) are parallel and global search techniques that emulate natural genetic operators.

In this paper, two types of DG units are considered as follows:

Type 1: DG is capable of minimizing real and reactive power losses at unity power factor.

Type 2: DG is capable of minimizing both real and reactive power losses at 0.8 power factor.

The Genetic Algorithm is used as the optimization technique to minimize the real and reactive power losses and to improve the voltage profile. The best solution is achieved by minimizing the Fitness Function "objective function" which includes the cumulative voltage deviation, active and reactive power losses under some constraints.

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II. DISTRIBUTED GENERATIONS

A general definition was then suggested in which are now widely accepted as follows: ''Distributed Generation is an electric power source connected directly to the distribution network or on the customer site of the meter''. The definitions of DG do not define the technologies, as the technologies that can be used vary widely. However, a categorization of different technology groups of DG seems possible, such as, non-renewable DG and renewable DG. From distribution system planning point of view, DG is a feasible alternative for new capacity especially in the competitive electricity market environment and has immense benefit such as : Short lead time and low investment risk since it is built in modules, Small-capacity modules that can track load variation more closely, Small physical size that can be installed at load centres and does not need government approval or search for utility territory and land availability, Existence of a vast range of DG technologies.

For these reasons, the first signs of a possible technological change are beginning to arise on the international scene, which could involve in the future the presence of a consistently generation produced with small and medium size plants directly connected to the distribution network (LV and MV) and characterized by good efficiencies and low emissions. This will create new problems and probably the need of new tools and managing these systems.

III. GENETIC ALGORITHM

Genetic Algorithm is a general-purpose search techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings. Their basic principle is the maintenance of a population of solutions to a problem (genotypes) as encoded information individuals that evolve in time. Generally, GA comprises three different phases of search: Phase 1: creating an initial population; phase 2: evaluating a fitness function; phase 3: producing a new population. A genetic search starts with a randomly generated initial population within which each individual is evaluated by means of a fitness function. Individual in this and subsequent generations are duplicated or eliminated according to their fitness values. Further generations are created by applying GA operators. This eventually leads to a generation of high performing individuals. There are usually three operators in a typical genetic algorithm the first is the production operator (elitism) which makes one or more copies of any individual that posses a high fitness value; otherwise, the individual is eliminated from the solution pool; the second operator is the recombination (also known as the 'crossover') operator. This operator selects two individuals within the generation and a crossover site and carries out a swapping operation of the string bits to the right hand side of the crossover site of both individuals. Crossover operations synthesize bits of knowledge gained from both parents exhibiting better than average performance. Thus, the probability of a better offspring is greatly enhanced; the third operator is the 'mutation' operator. This operator acts as a background operator and is used to explore some of the invested points in the search space by randomly flipping a 'bit' in a population of strings. Since frequent application of this operator would lead to a completely random search, a very low probability is usually assigned to its activation.

IV. PROBLEM FORMULATION

In this paper, the number, location and size of DG units are decided in such way that minimum system power loss and desired voltage profile is obtained. So it is needed to define system power loss as a function of DG size and system bus voltages. So we have:

The total I^2R loss (P_L) in a distribution system having n number of branches is given by:

$$P_{Lt}=\sum_{i=1}^{n} I_i^2 R_i \quad (1)$$

Here I_i is the magnitude of the branch current and R_I is the resistance of the i^{th} branch respectively. The branch current can be obtained from the load flow solution. The branch current has two components reactive component (I_r). The active and reactive components written as:

$$P_{La}=\sum_{i=1}^{n} I_{ai}^2 Ri \quad (2)$$

$$P_{Lr}=\sum_{i=1}^{n} I_{ri}^2 Ri \quad (3)$$

Note that for a given configuration of a single-source radial network, the loss P_{La} associated with the active component of branch currents cannot be minimized because all active power must be supplied by the source at the root bus. However by placing DGs, the active components of branch currents are compensated and losses due to active component of branch current are reduced.

The solving of placement and sizing of DG units problem requires to define the Fitness Function that can be optimized in the presence of some constraints. The fitness function is selected for reducing power losses and increasing of voltage stability margin in the system or reducing cumulative voltage deviation.GA starts the process by automatically proposing different DG sizes within the proposed DG size limits and internally executes the load flow program which is properly linked with GA package till the minimum solution is obtained for the suggested location. This process is repeated for each of the proposed locations.

A. Objective Function

A precise evaluation for the Objective Function has been selected. The main goal of the proposed algorithm is to determine the best locations and size for new Distributed Generation resources by minimizing different function, related to project aims. Two main goals are taken into considerations to determine the Objective Formula that is used in point of start: Power Losses reduction and voltage profile improvement. The Fitness Function is determined as following:

$$F=WP*PL+Wq*PL+Wq*CVD \quad (4)$$

Where:

PL: Active Power Loss

QL: Reactive Power Loss

CVD: Cumulative Voltage Deviation

F: Fitness Function.

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The active and reactive power losses are obtained from load flow program. The cumulative voltage deviation norm is defined as "the normalized sum of the deviations of the obtained value from the desired value at every node on the feeder. The desired value being 1.0 p.u and the obtained value being the value obtained from the three-phase distribution power flow [9]. In this work the CVD is determined the same way as following:

$$CVD=\sum_{i=1}^{n}|1-V_i| \quad (5)$$

Where

N: The total number of nodes

WP, *Wq*and *WV:* The Objective Function weights (Active, Reactive power losses and Cumulative Voltage Deviation weights), subjected to:

$$WP+Wq+Wv=1 \quad (6)$$

B. Constraints

The main constraints in the optimization process in the proposed methodology are:

1. Active and reactive power losses constraints
2. Voltage Constraints

Active and reactive power losses constraint:

The losses after installing DG in power grid should be less than or equal losses before installing DGs.

PL with DG ≤ PL without DG

QL with DG ≤ QL without DG

Voltage constraint:

To ensure the voltage of any bus should be within predefined limits the following constraint is considered:

$V_{bus\ min} \leq V_{bus} \leq V_{bus\ max}$

V_{bus} : bus voltage

$V_{bus\ max}$: maximum bus voltage

$V_{bus\ min}$: minimum bus voltage

V. PROPOSED METHODOLOGY

A. General Aspects

The available locations to install the suggested distributed generators are selected among the nodes with the lowest voltage value in addition to the physical factors and right of way which are considered as important factors affecting this selection. The nodes with the lowest voltage are identified by applying load flow program; it is found they are mainly the terminal nodes. Some intermediate nodes are also selected when noticed that their voltage is low after siting the DG at the terminal nodes. Based on previous criteria, eight locations at nodes 6, 8, 15, 18, 27, 30, 31 and 32 in this work are suggested. The maximum number of DGs allowed for installation in this application is three.

B. Genetic Algorithm "GA" Method Main Program

The proposed methodology is composed mainly of applying Load flow program interacted with GA program using Input System Data under MATLAB package as shown in Figure (2). The main modules of the proposed technique are explained as following:

Input System Data

Input system data module includes:

Network data: Buses data and Lines data

DG data: Number of locations, number of DGs, DG types and DG sizes

Objective function data: Weights

Load Flow Program

A power-flow study for a system operating under actual or projected normal operating conditions is called a base case. The results from the base case constitute a benchmark for comparison of changes in network flows and voltages under changing in network topology. System weakness such as low voltages, line over-loads, or loading conditions deemed excessive can be discovered and removed by making design studies involving changes and/or additions to the base case system.

DGs, number of buses, number of lines, type of buses, voltage magnitude and its angle, slack bus selection, load at each bus. All these data are previously defined by the operator. The distribution load flow was used for the calculation of line losses, which is written in MATLAB [11]. After installation of the DG unit, the power-flow program is executed and then the objective function calculated. The developed algorithm which is programmed in MATLAB reduces the computation time.

GA Program

Genetic Algorithm is a general-purpose search techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings. Their basic principle is the maintenance of a population of solutions to a problem (genotypes) as encoded information individuals that evolve in time [12]. GA Program comprises three different phases of search [13]: phase 1: creating an initial population; phase 2:evaluating a fitness function; phase 3: producing a new population. The proposed GA method starts with a randomly generated initial population (chromosomes) within which each individual is evaluated by means of a fitness function as in figure (2). Individuals and subsequent generations are duplicated or eliminated according to their fitness values. Number of iterations should be selected to obtain the needed convergence and accuracy. All obtained solutions and satisfy all constraints are registered and finally compared. The least solution which is less than the base case is considered the optimum solution for the proposed location. If no solution is less than the base case, the proposed location is considered unsuitable for adding DGs. The GA is executed again to study the problem at the next suggested location. Comparison between all solutions can be done to identify the best solution. Further generations are created by applying GA operators. This eventually leads to a generation of high performing individuals as following: (i) they rely on the information obtained by the evaluation of several points in the search space. Each "current point" is called an individual, and the set of "current point" is called the population. The algorithm keeps this set of "current points", instead of keeping a single "current point" as would be the case of in most optimization algorithms. (ii) The population converges to a problem optimum through sequential applications, at each iteration of genetic operators. Genetic algorithm that yields good results in many practical problems is composed of three operators: 1.Crossover:

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The individuals, randomly organized pair wise , have their space locations combined, in such a way that each former pair of individuals gives rise to a new pair.2.Mutation: Some individuals are randomly modified, in order to reach other points of the search space. 3. Selection: The individuals, after mutation and crossover, are evaluated. They are chosen or not chosen for being inserted in the new population through a probabilistic rule that gives a greater probability of selection to the "better" individuals.

Fitness Function

Fitness Function (Objective Function) extracts its required data from Input Data System. The losses and node voltages are used as an evaluation function, called objective function, to search the optimal size and location of DG. In this work, the cumulative voltage deviation weight is chosen with the highest priority where the voltage has the most important effect of network operation. Active power loss weight is chosen the next priority after Cumulative voltage deviation and higher than the reactive power loss where it is more effective. The weights are chosen as following:

$W\,p$=0.35

Wq= 0.1 and

W v = 0.55

The fitness function is computed when DG is added at each of the selected eight nodes, for each methodology. It is calculated with simultaneous operations as shown in Figure (2). This procedure is for just one DG unit. For allocating of two DG units, this procedure is followed and then optimal size and location for first DG unit is decided. This DG unit with optimal size is put in the decided optimal location and again the solution method is used to decide optimal size and location for second DG unit. This algorithm is used for optimal allocating of multi-DGs in the power system. Sometimes just one DG unit is achieving desired goals but after years it is needed to add another DG unit(s). Usually, because of economic issues, the place of first DG unit is kept unchanged. This used such a methodology in this paper.

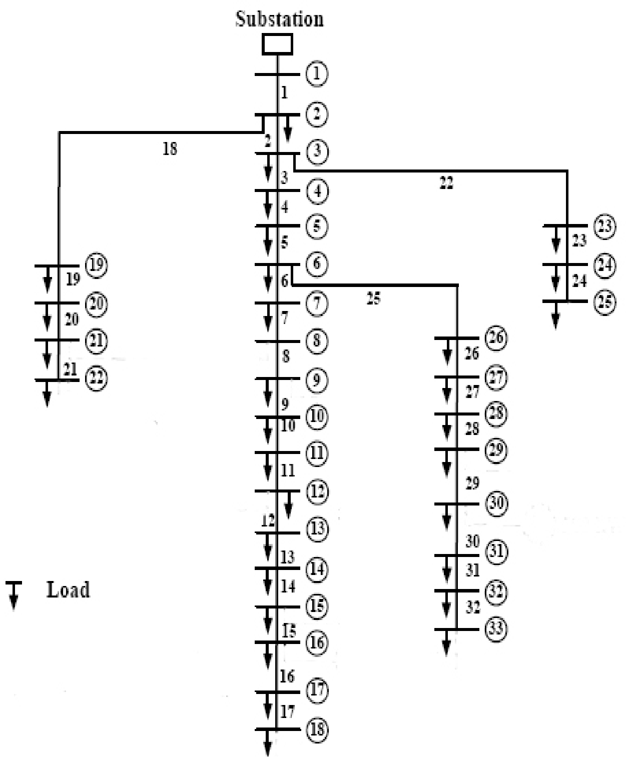

Fig1.single line diagram of 33 bus test system

VI. CASE STUDIES

In this paper simulations are carried out on Standard IEEE 33 bus test system [10] .First a type1 DG unit is put in the test system and the methodology mentioned in last section is applied in order to find optimal size and location ofDG unit. Then a type 2 DG unit is used, applying proposed methodology, optimal size and location of DG unit is decided. This process is exactly repeated for type 1 and type 2 DG units, separately. After the evaluating the results,Optimal type, size, number and place of DG unit(s) are decided. Schematic diagram of the 33 bus test system used in this paper is shown in Fig 1.

VII. SIMULATION RESULTS

As mentioned before, a distribution load flow is performed on the 33-bus test systems in order to calculate the P_{loss} and Q loss in absence of DG unit(s) in the system. Obtained results are shown in table 1. Then during 3 steps, the number of DG units used in the test power system, varies from 1 to 3. In each step, the type of DG unit(s) is also changed from 1 to 2. Using the Genetic Algorithm, optimal size, location, type and number of DG units are decided. The results obtained from simulations for DG type 1 and type 2 for system power loss reduction, are shown in tables 2 and 3, respectively. It should be noted that, results obtained for system voltage profile improvement are shown in Figs 3 and 4.

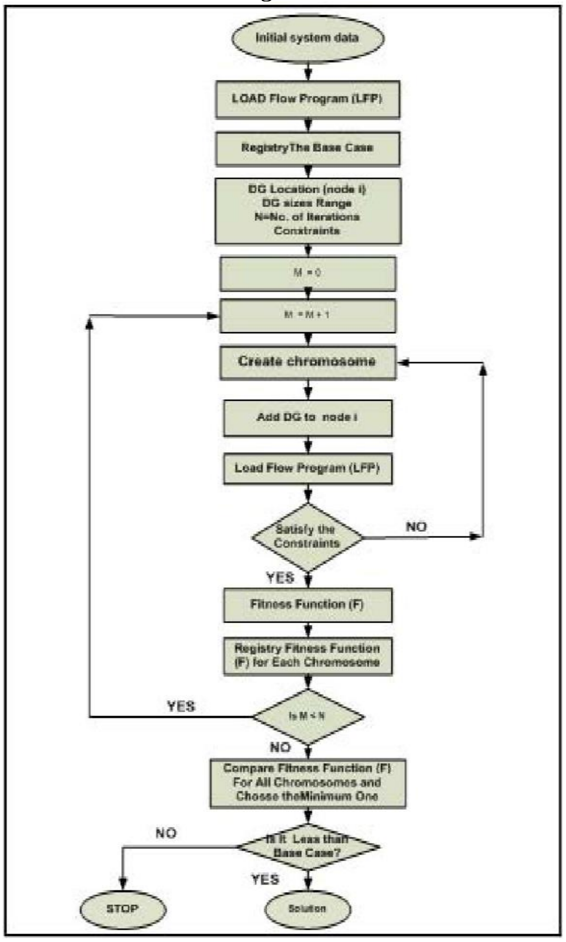

Figure 2: Genetic Algorithm Method

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system	Real power loss (Ploss)	Reactive power loss (Qloss)
33	203.908	166.8

Table1: System Power Losses In Absence Of Dg Units

System	Bus number	Size (KW)	Real power loss (Ploss)	Reactive power loss (Qloss)
33	30	3.93	173.027	113.774
	10	1.99		
	25	2.97		

Tabe2: Optimal Sizes and Locations of Type One Dg Units Used In 33-Bus Test Systems

Results obviously show that the more the number of DG units the less the system power loss and the better the system voltage profile. In practice, Due to economical issues, it is not advisable to use more than 3 DG units in power systems. Adding 4th DG unit to the system does not make a considerable change in system power loss reduction and voltage profile improvement. These results can be clearly obtained from tables 2 and 3 and Figs 2 and 3.the system real and reactive power losses are low with DG than without DG. It is also clearly shown that the losses with DG only are higher than the power losses with DG and power factor of 0.8.So optimal allocation of DG units in power systems, not only reduces power loss and improves voltage profile, but also increases the active power transfer capacity of transmission line.

System	Bus number	Size (KW)	Real power loss (Ploss)	Reactive power loss (Qloss)
33	30	2.91	138.452	82.264
	10	0.7456		
	25	1.99		

Tabe3: Optimal Sizes and Locations of Type Twodg Units Used In 33-Bus Test Systems

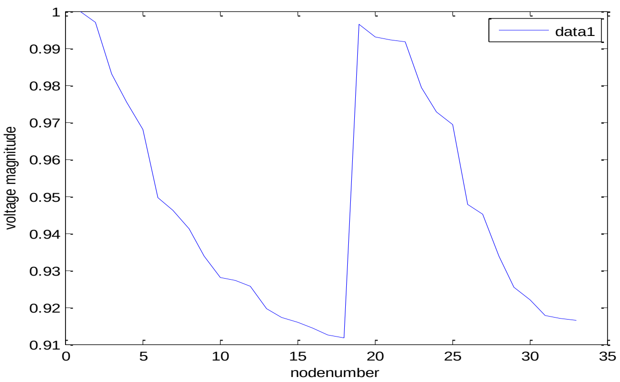

Fig. 3: Voltage profile of 33-bus test system without DG units

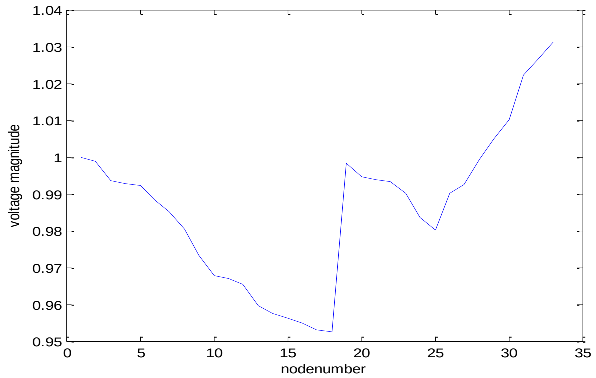

Fig. 4: Voltage profile of 33-bus test system with DG units

VIII. CONCLUSION

Increasing the number of DG units in power system can reduce system power loss and improve voltage profile. Type of DG units is another important factor. Results prove that using type 2 DG units has better impact on system power loss reduction and system voltage profile improvement. Using type 2 DG units reduce system power loss about 70% more than type 1 DG units. Place and size of DG units are also other important factors that affect on system power loss and voltage profile. In this paper a Genetic Algorithm for optimal placement of multi-DG is proposed which efficiently minimizes the total real power loss, satisfying transmission line limits and constraints. The proposed methodology is so fast and efficient and at the same time so accurate in determining the size, type, number and location of DG unit(s).

REFERENCES

[1] N. Mithulananthan, than OO and LE van phu, "Distributed Generator Placement In Power Distribution System Using Genetic Algorithm To Reduce Losses", Thammasat Int. J. Sc. Tech., vol. 9, no. 3, July-September 2004.
[2] T. Ackermann, G. Andersson, and L.Söder, "Distributed Generation: A Definition Proceedings Of The First International Symposium On Distributed Generation And Market Aspects, June 11-13, 2001, Royal Institute Of Technology, Sweden
[3] S. A. Papathanassion, "a technical evaluation framework for the connection of dg to the distribution network," electric power systems research.77, pp. 24 – 34, 2007.
[4] W. El-Khattam, and M.M.A. Salama, "Distributed Generation Technologies, Definitions And Benefits", Electric Power Systems Research. 71, pp.119–128, 2004.
[5] Yiming Mao, and Karen N. Miu ,"Switch Placement to Improve System Reliability for Radial Distribution Systems with Distributed Generation" , IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 18, NO. 4, NOVEMBER 2003.
[6] H. Khan and M.A. Choudhry. Implementation of distributed generation algorithm for performance enhancement of distribution feeder under extreme load growth.International Journal of Electrical Power and Energy Systems. 2010, 32 (9): 985-997.
[7] A. L. Devi, B. Subramanyam, "Sizing of DG Unit Operated at Optimal Power Factor to Reduce Losses in Radial Distribution. A Case Study," Journal of Theoretical and Applied Information Technology (JATIT), 2005 – 2008.
[8] D.Q. Hung, N. Mithulanathan and R.C. Bansal. Multiple distributed generators placement in primary distribution networks for loss reduction. IEEE Transactions on Industrial Electronics.(In Press).
[9] SujathaKotamarty, SarikaKhushalani and Noel Schulz, "Impact of distributed generation on distribution contingency analysis", Electr. Power Syst. Res. (24 January 2008), doi:10.1016/j.epsr.2008.01.020.

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[10] S. Ghosh , S.P. Ghoshal and S. Ghosh. Optimal sizing and placement of DG in network system.International Journal of Electrical Power and Energy Systems. 2010, 32 (8): 849-856.
[11] M. Padma Lalitha, V.C. Veera Reddy, N. Usha. 2009. DG placement using Fuzzy for maximum loss reduction in radial distribution system. International journal of computers applications in engineering, technology and sciences.
[12] M. Gandomkar,M. Vakilian,M. Ehsan, " A combination of genetic algorithm and simulated annealing for optimal DG allocation in distribution networks", CCECE/CCGEI,Saskatoon, May 2005 IEEE, PP.645-648.
[13] Y. Alinejad-Beromi(1) , M. Sedighizadeh(2) , M. R. Bayat(1) , M. E. Khodayar(3) "Using Genetic Alghoritm for Distributed Generation Allocation to reduce Losses And Improve Voltage Profile "(1)University of Semnan, Iran (2)Islamic Azad Univ.ofSafeh, Iran. (3) Sharif Univ. Tehran,Iran. proceedings of world academy of science, engineering and technology volume 27 february 2008 issn 1307-6884.
[14] D. Singh, D. Singh and K.S. Verma. Multi-objective optimization for DG planning with load models.IEEE Transactions on Power Systems. 2009, 24 (1): 427-436.
[15] R.M. Kamel and B. Karmanshahi.Optimal size and location of DGs for minimizing power losses in a primary distribution network.Transaction on Computer Science and Electrical and Electronics Engineering. 2009, 16 (2): 137-144.

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