Optimization of Distributed Generation using Genetics Algorithm and Improvement in Multiobjective Function

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Abstract—In Distribution system , Distributed Generators are commonly used to provide active and reactive power Compensation .Generally More losses occurs in distribution system due to high concentration of inductive loads, so proper installation of Distributed generators are necessary with optimal site and size. The power feeds from DG units located near to load centre provide an opportunity for system power losses reduction, cost reduction, voltage profile improvement, voltage stability improvement and environmental friendliness and increasing reliability. In this Paper presents Genetics Algorithm optimization techniques for finding the Optimal Location and size of DG System .The objectives of this technique is Minimization of Active Power Losses, Better Voltage Profile and Improvement in voltage stability index with security constraints in distribution system network and performed in MATLAB R2015a Software. The proposed GA optimization technique implemented on 33-bus and 69-bus Standard test radial distribution system.

Keywords:- GA (Genetics Algorithm), RDS(Radial DistributionNetwork), DG(DistributedGeneration), VSI (Voltage Stability Index), Radial distribution System, MOF (Multi Objective function).

1. INTRODUCTION :-

For Distributed Generation different countries uses various words same like that : 'dispersed generation' , 'embedded generation', 'decentralized generation' ,'distributed energy resources'(DER). DG is defined as a generator with small scale capacity of electricity connected close to its load and i.e. not a part of centralized power generation system [1]. A distribution system is an interface between power transmission system and consumer. . As compared to transmission system, the X/R ratio for distribution system is low, that causes high power losses and a drop in voltage magnitude along with radial distribution lines [3] .Due to increases in power load demand, power system faces many problems like: power losses, energy losses, voltage node disturbances, Voltage Stability issues, voltage stability indexes, DG penetration etc. [2]. To overcome these problems In Traditionally, DG and Capacitor are installed in power system network to compensate for power loss reduction, improvement in voltage profile and enhancement in voltage stability indexes. Distributed Generation is most widely used in

Distribution network system because i.e. providing both active as well as reactive power but capacitor provides only reactive power to the power system network [4].

In last few years, the traditional electric energy sources, are replaces with DG has becomes an efficient and clean way. Now-a-days, DGs are the part of distributed energy resources (DERs) which also involved energy storage and receptive loads. Basically, Distributed generation (DG) integration in a distribution system has increased due to high penetration levels. For improvement in technical benefits of DG integration by using optimal allocation of DG in a power system network [5].Optimal DG location and sizing in a power distribution network with the aim to reducing system active power losses and improving the voltage profile and improvement in voltage stability index[4][6].The problem is formulated as an optimization problem and solution is obtained using genetic algorithm (GA)[7].The locations are decided on the basis of active power injection at various nodes. This approach helps in reducing the computational efforts of selecting appropriate location. GA follows the idea of survival of the fittest - Better and better solutions evolve from previous generations until a near optimal solution is obtained .in this paper optimization technique genetics algorithm for optimal location and size is discuss.

2. PROBLEM FORMULATION:-

A. *Objective function*

Single Objective function:- In this objective function Optimal DG installation in radial distribution system for minimization of active power losses; improvement in node voltage disturbances, maximization of voltage stability index with all operating constraints are discussed below:

(a)Active power loss minimization:-The major amount of losses in power system is in distribution system network during power delivery. To deliver power at minimum losses of utilities is primary objective for power system. The Optimal placement of DG is mainly studied with the minimization of active power losses, the active power losses can be defined as:

$$F_1 = \text{Min}\ (P_{Loss}) \qquad (1)$$

Where P_{Loss} is the active power loss of the radial Distribution System and given by:

$$P_{Loss} = \sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}(Q_iP_j - P_iQ_j) \qquad (2)$$

Where $\alpha_{ij}=r_{ij}\cos(\delta_i-\delta_j)/V_iV_j$,$\beta_{ij}=r_{ij}\sin(\delta_i-\delta_j)/V_iV_j$,

here P_i , Q_i ,N, r_{ij}, Vi ,δ_i are the active and reactive power, total number of nodes in system ,resistance of branch between node i and j ,voltage magnitude and angle of ith node individually..

(b) Improvement in Node Voltage Disturbances: - The measure value of voltage quality appeared across system nodes i.e. called node voltage disturbances. For improving Node voltage profile DGs are connected near to load centre and i.e. also considered as a objective function is defined as:-

$$F_2 = \sum_{i=1}^{N}(V_i - 1)^2 \qquad (3)$$

(c)Maximization of Voltage Stability Index:-At heavy load condition in distribution system the minimization of node voltage disturbances is not sufficient for security purposes so, we introduced a one of objective function is maximization of voltage stability index .basically VSI is the capacity of node at heavy loading condition to maintain its voltage profile within the allowable limits.VSI of radial distribution network is defined as:-

$$F_3 = VSI_{ij} = V_j^4 - 4\left(P_ir_{ij} + Q_ix_{ij}\right)V_j^2 - 4\left(P_ix_{ij} - Q_ir_{ij}\right)^2 \qquad (4)$$

Multi objective function:-In this function no. of functions to be optimized synchronously within specified constraints. In this paper multi objective function combines minimization of active power losses, improvement in node voltage disturbances and maximization of voltage stability index which is optimized simultaneously.

$$MOF = (\alpha_1F_1+\alpha_2F_2+\alpha_3F_3) \qquad (5)$$

Where penalty (weight) co-efficient $\alpha_1=1$, $\alpha_2=0.65$, $\alpha_3=0.35$ with function F_1 = minimization of active power losses, F_2 = minimization of node voltage disturbances, F_3 = maximization of voltage stability index.

(B)System operating constraints:-The single and multi objective functions are subjected to following constraints in discussed below:-

Equality constraints:-

Power balance constraints: - The total active power supplied by DGs and total reactive power supplied by DGs must satisfy the power constraints as respectively;

$$P_i = V_i\sum_{j=1}^{N} V_jY_{ij}\cos\left(\theta_{ij} + \delta_j + \delta_i\right) \quad \forall\, i \qquad (6)$$

$$Q_i = -V_i\sum_{j=1}^{N} V_jY_{ij}\sin\left(\theta_{ij} + \delta_j + \delta_i\right) \quad \forall\, i \qquad (7)$$

Where $\mathbf{Y_{ij}}$ and θ_{ij} are representing the elements of Y bus matrix and Impendence angle between ith and jth node individually.

Inequality constraints:-

Bus Voltage limit:-The Voltage constraints within upper and lower limits of alteration of voltage at the nodes of distribution system and constraint defined as:-

$$V_i^{min} \leq V_i \leq V_i^{max} \quad (8)$$

Where V_i^{min} V_i^{max} is the minimum and maximum values of bus voltage individually .The voltage limit varies between $\mathbf{V_{max}}$ (1.05p.u.) and $\mathbf{V_{min}}$ (0.95p.u.) at all system buses.

Thermal limits:-The current at different branches with specified limits which is given by:-

$$I_{ij} \leq I_{ij}^{max} \quad (9)$$

Where I_{ij}^{max} is the maximum loading of the distribution line connected between ith and jth bus; I_{ij} is the current flowing through the branch connected between the ith and jth branch.

Power limits of DG:-The active and reactive power sizes of DG at ith bus are specified within certain limits i.e. given by:-

$$P_{DG,i}^{min} \leq P_{DG,i} \leq P_{DG,i}^{max} \quad (10)$$

$$Q_{DG,i}^{min} \leq Q_{DG,i} \leq Q_{DG,i}^{max} \quad (11) \quad (8)$$

Where $P_{DG,i}^{min}$,$P_{DG,i}^{max}$ are the minimum and maximum values of active power at ith DG respectively and $Q_{DG,i}^{min}$,$Q_{DG,i}^{max}$ are the minimum and maximum values of reactive power at ith DG respectively.

3. Genetics Algorithm Optimization (GAO):-

GA introduced by American Scientist John Holland in 1960 Afterwards his student David E. Goldberg extended GA in 1989.

Genetics Algorithm based on one of the most famous Darwin's Evolutionary theory which is generally used Meta-heuristics optimization techniques and concept of this Algorithm is 'Survival of Fittest'.GA simulates the process of evolution and follows the natural selection process.

Basic Parameters :-

In this paper some basic parameters uses and defines before starting a discussion on genetics algorithm.

Population – population is a group of solutions in the current generation and also be represented as sets of chromosomes. Population for initially i.e. first generation is normally created randomly.

Gene – A gene is one component function of a chromosome.

Chromosomes – A chromosome is the complete sets of genes (parameters) which explain a recommended solution to the problem i.e. solved by genetics algorithm.

Allele – Allele is derived form of gene which is takes for a particular chromosome.

Flow chart of Genetics Algorithm (GA) is shown in below figure 1:

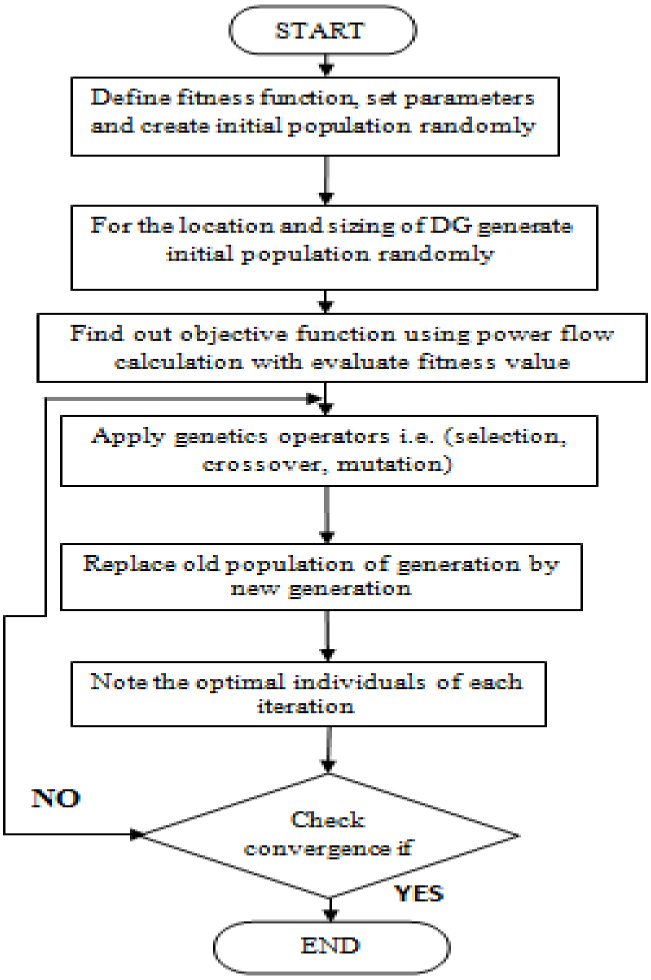

Figure1. Flow chart of Genetics Algorithm

Fitness Function – A fitness function is explained as fitness of each chromosomes that will be regenerate and survive for next generation which is suitable for objective function to be optimized.

Genetic Operators – For genetic composition of the regeneration, these contains crossover, mutation, selection, etc.

A simple genetic algorithm that included four operators:-

i) Selection: In GA Selection operator is selecting individuals with high fitness .these individuals grouping and created new population according to the fitness value to keep the better individuals for the next generation. Normally methods of selection involved: Roulette Wheel selection, truncation selection, tournament selection etc.

ii) Crossover: It is next step of selection and changes the coding of chromosomes from the parent (or first) generation to the next generation with a specific probability.

iii) Mutation: Mutation is provides genetics diversity from generation to next generation with a low probability. In this genetic operator neglect some genes losing during the selection and crossover steps.

iv) Replacement: Replacement is last stage of GA and used to decide which individuals get replaced in a population.

Controlling parameters: - The controlling factors used in proposed GA method for both the study system are as follows:

population size **n=100**, maximum iteration count T_{max}**=100**, loss co-efficient (for Power flow equation) **α=0.5, β=0.1**, Crossover probability **(P_c) = 0.9,**

Steps in Basic Genetic Algorithm:-

Step1. Define the fitness function f(x) corresponding to problem to be solved.

Step2. Generate initial population of n chromosomes randomly initially for DG allocation.

Step3. For finding objective function using power flow calculation (determine active power losses, voltage disturbances, VSI with specified limits) and evaluate the fitness f(x) of each chromosome x in the population.

Step4. Applying genetics operator selection, crossover, and mutation create the new population of chromosomes using old generation.

Step5. Replace the old population of chromosomes by new generation.

Step6. For convergence checking the maximum no .of iteration is reached, if yes then stop and gives the best solution when no return to step 3 and find out optimal solution using next steps.

4. CASE STUDIES:-

In these studies, GA method is implemented on two IEEE Standard distribution system of 33-bus and 69-bus radial Distribution system.the simulation results and performance of proposed GA is compared and discussed with various optimization techniques provides in this paper for different case studies [6].

A. Study System –1:-

For this study system, the optimal location and sizing problem is formulated and solved for a Standard 33 bus radial Distribution System. It has a **Base voltage=12.66 kV** and active power demand = **3.715MW**, reactive power demand **2.300 kVAr.** The simulation results collected are compared and analyzed for some cases shown in this paper.

I) Base Case [Case-I]:-

In this case without any DG installation shown in Table1. The table considered optimal DG size, Location, values of objective functions and multi objective function (using weight co- efficient).

II).Three DG Operated at Unity Power Factors (UPFs) [Case-II]:-

In this case, three DGs are suggested in the distribution system on three different nodes .The simulation results received by proposed method are compared with various existing methods in this paper and described in Table 1. The table considered Optimal DG size, Location, Values of objective functions and multi objective function (using weight co- efficient) the bold values in table represent the optimal solution with compared to other methods .The GA methods compared to PSO, GA/PSO, TLBO, QOTLBO with improvement in objective functions.

III)Four DG Operated at UPFs[Case-III]:- In this case, Four DGs are suggested in the distribution system on four different nodes .The simulation results received by proposed GA method are compared with various existing methods in this paper and are Explained in Table 1. The table considered Optimal DG size Location, Values of objective functions and multi objective function (using weight co- efficient) the bold values in table represent the optimal solution with compared to other methods .The GA methods compared to PSO, GA/PSO, IMOHS with improvement in objective functions.

We concluded that the Case-II provides best solution as compared to case–I and case–III. Better voltage profile obtained for all cases w.r.t. base case and also improves the value of voltage stability index for case–II as compared to case –I and case–III.

B. Study System -2:-

For this study System ,the Optimal location and sizing problem is formulated and solved for a Standard 69- bus radial distribution system .it has a **Base voltage=12.66 kV** and active power demand of=**3.715MW,** reactive power demand =**2.300 kVAr .** The simulation results received are compared and analyzed for some cases shown in this paper.

I) Base Case [Case-I]:-

In this case without any DG installation shown in Table 2. The table considered optimal DG size, Location, values of objective functions and multi objective function (using weight co- efficient).

II) Three DG Operated at Unity Power Factors (UPFs) [Case-II]:-

In this case, three DGs are suggested in the distribution system on three different nodes .The simulation results received by proposed method are compared with various existing methods in this paper and are explained in Table 2. The table considered Optimal DG size, Location, Values of objective functions and multi objective function (using weight co- efficient) the bold values in table represent the optimal solution with compared to other methods .The GA methods compared to PSO, GA/PSO, TLBO, with improvement in objective function. The voltage profile of the system for all cases with respect to base case shown in Fig: 2 and Fig: 3 for 33 and 69 bus system respectively.

We concluded that the Case-II provides best solution as compared to case–I and better voltage profile obtained for all cases w.r.t. base case and also improves the value of voltage stability index for case–II.

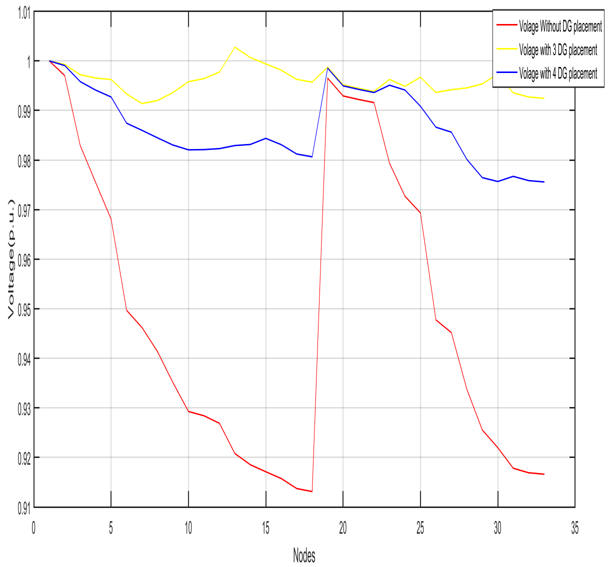

Fig.2: Node voltage profile for system-1 for different cases

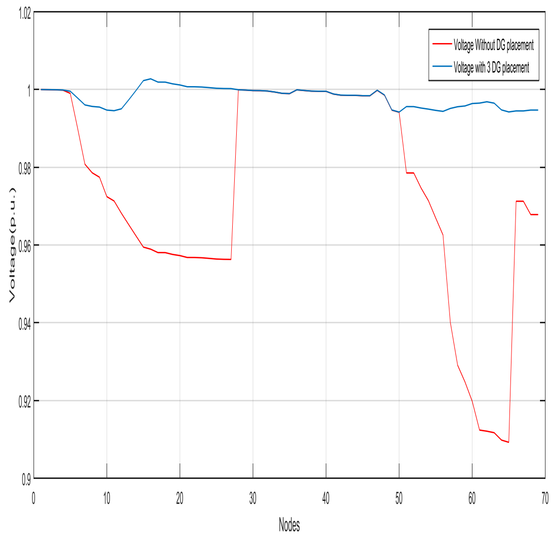

Fig.3: Node voltage profile for system-2 for different cases

Genetics Algorithm used for various field i.e. discuss in **below:-**

For machine learning (categorization and predication), optimization, Automobile design, Engineering design(to design the structure of machine, factories and buildings), Robotics,

Table 1: Comparison results for IEEE 33-bus system

CASE	USED METHOD	OPTIMAL DG LOCATION	OPTIMAL DG SIZE(MW)	VALUE OF OBJECTIVE FUNCTION			MULTI OBJECTIVE FUNCTION
				F1 (MW)	F2	F3	
I.	**BASE CASE**	—	—	0.2025	0.1170	0.6989	0.5232
II.	PSO	8,13,32	1.177,0.982,0.830	0.1053	0.0335	0.9256	0.4510
	GA/PSO	11,16,32	0.925,0.863,1.200	0.1034	0.0124	0.9508	0.4442
	TLBO	12,28,30	1.183,1.191,1.186	0.1247	0.0011	0.9503	0.4580
	QOTLBO	13,26,30	1.057,1.054,1.741	0.1034	0.0011	0.9530	0.4376
	GA	25,30,13	0.9090,1.6840,1.6580	**0.0958**	**0.0007**	**0.9701**	**0.4359**
III.	PSO	6,15,25,31	0.830,0.833,0.541,0.648	0.0713	0.0109	0.8776	0.3855
	GA/PSO	14,24,26,32	0.663,1.023,0.867,0.664	0.0682	0.0130	0.8903	0.3878
	IMOHS	6,14,24,31	0.937,0.667,1.012,0.731	0.0678	0.0111	0.8891	0.3862
	GA	7,15,24,31	0.8884,0.6810,0.9420,0.7760	**0.0670**	**0.0080**	**0.9049**	**0.3889**

Table 2: Comparison results for IEEE 69-bus system

CASE	USED METHOD	OPTIMAL DG LOCATION	OPTIMAL DG SIZE (MW)	VALUE OF OBJECTIVE FUNCTION			MULTI OBJECTIVE FUNCTION
				F1(MW)	F2	F3	
I.	**BASE CASE**	__	__	0.22470	0.0993	0.6870	0.5296
II.	PSO	17,61,63	0.9925,1.1998,0.7956	0.08320	0.0049	0.9676	0.4250
	GA/PSO	21,61,63	0.4105,1.1926,0.8849	0.08110	0.0031	0.9768	0.4249
	TLBO	13,61,62	1.0134,0.9901,1.1601	0.08217	0.0008	0.9745	0.4237
	GA	16,61,62	0.8002,1.1724,0.9970	**0.08060**	**0.0006**	**0.9778**	**0.4233**

Ecological model, Economic model (to solve financial and investment problems), computer game playing, for better decision making and management, Bio-mimetic invention, Computer Aided Molecular design, traffic ,trip and shipment routing (Solving Travelling Salesmen Problem), Evolvable Hardware , Optimized Telecommunication system etc.

5. CONCLUSIONS:-

In this paper presents proposed GA method to solve location and sizing problems for DGs simultaneously using standard test distribution system of 33-bus and 69-bus Radial Distribution System. The proposed method was implemented to 33-bus and 69-bus system with three different objective functions .In order to prove superiority of other optimization techniques and compared with GA/PSO,PSO,TLBO,QOTLBO 33 bus system and GA/PSO,PSO,TLBO for 69 bus system. Proposed Method gives less active power losses in comparing with the results of other popular optimization techniques. After DGs installation, the both RDS have major improvement in voltage profile and increase in voltage stability index for the Proposed GA method.

Multi-objective studies can be done by the proposed algorithm.The best location analyzed by GA for three DGs placement at 25, 30, 13 bus number that reduces active power losses from 0.2025MW to 0.0958MW at normal load condition with improved voltage losses 0.1170p.u. to 0.0007p.u. And maximize the value of voltage stability index 0.6989 to 0.9701. For four DGs placement at 7,15,24,21 bus number that reduces losses from 0.2025MW to 0.0670MW with improved voltage losses 0.1170p.u. to 0.0080p.u. And maximize the value of voltage stability index 0.6989 to 0.9049 at normal load condition for 33 bus system. The best location analyzed by GA for three DGs placement at 16, 61, 62 bus number that reduces active power losses from 0.2247MW to 0.0806MW at normal load condition with improved voltage losses 0.0993p.u. to 0.0006p.u. And maximize the value of voltage stability index 0.6870 to 0.9778 for 69bus system.

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