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Genetic Algorithm based Optimal Allocation of Distributed Generators for Maximizing the Benefits

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Abstract: This paper proposes a Genetic Algorithm (GA) optimization technique for optimal allocation of Distributed Generators in the distribution network to maximize the benefits to the Local Distribution Company(LDC), as well as the customers connected to the system. The suggested methodology programmed under MATLAB software, helps to identify the optimal buses on which to connect these DG units. The benefits which are considered in this paper are postponement of upgrade investments, reduction of the cost of energy losses and reliability improvement. The implementation of the algorithm is illustrated on a 39-bus test system.

Keywords: Distributed Generation, Distribution system, Genetic Algorithm.

1.INTRODUCTION

Any plant that is used for generating electricity which is connected to the electricity distribution networks is known as Distributed Generator. Distributed Generation (DG) refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity and interdependencies and inefficiencies associated with transmission and distribution. DG implies the modular, small-scale generation of power from systems that are often relatively small, ranging in size from less than a KW to a few tens of MW. DG can be powered by both conventional and renewable energy sources. With the challenges currently facing electricity generation and for the sustainable energy supply infrastructure renewable DG becomes the vital option, since they are both inexhaustible and non-polluting. Optimal location and capacity are the main issue of studies done on the DGs as the proper sizing and placement of DG allow the system to gain the maximum benefits from the DG, on the other side, improper placement or sizing of DGs may cause undesirable effects.

There are a number of benefits that can be achieved from the installation of DG units, among which three are considered in this paper.

The first benefit is to postpone the upgradation investments. In [1], a multi-period optimal power flow was used in order to capture the effects of network investment deferral on DG expansion and to optimally allocate the DG units in a distribution network. In [2], an efficient methodology is proposed for the optimal allocation and sizing of switched shunt capacitors in radial distribution systems. The methodology proposed here is used to maximize the savings from reduced energy losses and due to costs that are avoided due to investment deferral in the network expansion. In [3], the investment deferral is brought by integrating Microgenerators (MGs) into distribution network. Here, a methodology is proposed to assess investment deferral resulting from MGs for the Extra High Voltage (EHV) Network. In [4], a novel methodology which is load flow based, is aimed at quantifying the benefits to a network in terms of investment deferral arising from connecting DG units in the distribution network. In [5], the decisions for optimal sizing and siting of DG units are obtained through a cost-benefit analysis which is carried out on an hourly basis. Here a new heuristic approach is proposed. In [6], the investment deferral produced by the connection of DG units is investigated on a generic distribution network. Here different DG locations and two different technologies i.e., CHP and wind power, with their corresponding security contributions, are considered. The authors of papers [1] to [5] only considered dispatchable DG units.

The second benefit is **to reduce the cost of energy losses.** Towards achieving this second benefit the analytical methods are used to determine the optimal location to place a DG in radial as well as networked systems to minimize the power loss of the system as in [7]. Here a time-varying load and DG power were considered. In [8], annual energy losses variations are computed when different penetration and concentration levels of DG are connected to a distribution network. In [9], analytical expressions for finding optimal size and power factor of 4 types of DG units. In [10], the authors proposed a multi-objective DG allocation approach to minimize the losses(real and reactive). However, all the works presented in the papers from[7] to [10] considered only conventional type of DG units with dispatchable DG sizes. However in [11], renewable DG units in the distribution system are considered. Here, a methodology has been proposed for optimally allocating different types of renewable DG units in the distribution system so as to minimize the annual energy loss. In [12] also, renewable DG units are considered, wherein, a multiperiod AC

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Optimal Power Flow(OPF) is used to determine the optimal accommodation of renewable DG units in a way that minimizes the system energy losses. In [13], a novel multi-objective planning framework is presented for the integration of stochastic and controllable Distributed Energy Resources(DERs) in the distribution grid.

In all the above literatures, the main focus was to reduce the total annual energy losses. This is not an accurate representation of LDC requirements, but considering the cost of annual energy losses is the true representation. So unlike the previous literatures that focused on minimizing the cost of the energy losses using fixed energy price, a methodology to evaluate the cost of energy losses in distribution systems utilizing **variable hourly cost of energy** is proposed in this paper.

The third benefit is **improved reliability of the power supply for different customers.** The publications [14] and [15] present some work in the areas of investigating the impacts of DG units on system reliability. In [14], a multi objective formulation for the siting and sizing of DG resources into existing distribution networks is proposed considering the system reliability. A method to determine optimal operating strategy is presented in [15], for DG incorporating reliability worth evaluation of a distribution system.

However, the publications [14] and [15] presented the work considering conventional dispatchable DGs only.

Referring to the above literatures, we can say that a very little work has been addressed the renewable DGs. Therefore, this paper presents a methodology which evaluates the economic benefits of addressing the renewable DGs.

The main factors that are considered in the present methodology are:

1. The uncertainty associated with the renewable DG output
2. Variable hourly cost of energy

The search space of optimal location and capacity of DGs is wide and different optimization methods are used in this field for the sake of power loss minimization, cost reduction, profit maximization and environmental emission reduction.

A Genetic Algorithm (GA) based methodology is employed to solve optimization problem that maximizes the benefit of the system by the optimal placement of DGs.

II. PROBLEM DESCRIPTION

A. Cost of System Upgrading(C_U)

This is the cost which includes the investments which are necessary to upgrade any distribution network so as to meet the growing energy demand with the inclusion of new generators or loads connected to the grid.

System upgrade cost is the sum of lines' reinforcement cost and protection and metering equipment upgrade costs.

The wind based DG is modelled by 14 states model and the load is modelled by 8 states model. The procedure for evaluating the cost of system upgrades is described as follows:

a) For each state s, go through steps b to d
b) For each year y, go through steps c to d
c) Update loads with annual rise, and run load flow analysis for stat s and year y
d) For each line, record the year y in which upgrade is required and calculate the corresponding Net Present Value (NPV) of the cost of upgrade of each line for each state s.
e) For each line, arrange the combined generation and load states in descending order according to the calculated NPV.
f) For each line, if the probability of the state corresponding to the maximum cost of upgrade is above the RF, proceed to step g; if not, proceed to the next state. If the sum of the probabilities of this state and the previous state(s) is higher than the RF go to step g; if not, proceed to next state and repeat the previous statement.
g) Record this upgrade cost and repeat step f for the next line.
h) The NPV of the required reinforcement investments during the period under study can be evaluated using the following formula:

$$NPV_{upgrade} = \sum_{k=1}^{M} NPV_k = \sum_{k=1}^{M} \frac{C_k}{(1+d)^{i_k}}$$

where NPV_k is the NPV of the reinforcement k; C_k is the cost of the reinforcement k; d is the discount rate; M is the total number of required reinforcements; i_k is the year when the reinforcement is required.

B. Cost of Energy Losses(C_L)

When the DG units are installed in a distribution network, the installation affects the energy losses. The cost of annual energy losses should be calculated hourly because the load keeps varying. So the variable hourly prices of energy is assumed to better assess the effect of renewable DG on system losses.

The cost of annual energy losses is evaluated by

$$C_{E_{loss\,y}} = \left(\frac{1}{N_y}\right) X \sum_{z=1}^{N_y} ([S_z]_{8760\ X\ N_s}\ X\ [P_{loss}]_{1\ XN_s})^T\ X\ C_{8760\ X\ 1}$$

Where S_z is a binary variable defined as,

$$S_z = []_{8760 \times N_s} \quad \forall z = 1,2,\ldots,N_y$$

Where N_s is the total number of states of the combined load and generation model; N_y is the total number of scenarios.

$$NPV_{loss} = \sum_{y=1}^{Yrs} \frac{C_{E_{loss\,y}}}{(1+d)^y}$$

C. Cost of Interruption(C_I)

The distribution system is an important link between the transmission-generation system and customers. These links are radial, which makes them susceptible to outage due to failures of a single element.

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The following assumption is made to evaluate the cost of interruption in the distribution networks with renewable DG connections.

Islanding mode of operation is assumed to be allowed, which benefits the customers. Islanded system means, a distribution network is fed from a transmission network, and when the connection to the transmission system is lost, the distribution network is islanded. The DG units can supply the system loads during scheduled or unscheduled outage events, which can improve system reliability.

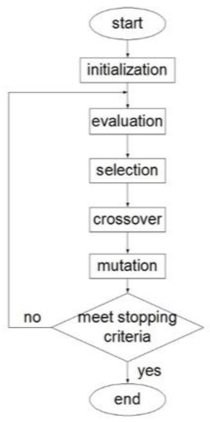
For an island to be successful, the generated power from all DG units within the island should be higher than or equal to a certain percentage of load required power.

The Genetic Algorithm is used in this paper to find the optimal bus for placing the DG and also to find the optimal size of the DG unit.

III. GENETIC ALGORITHM AND ITS IMPLEMENTATION

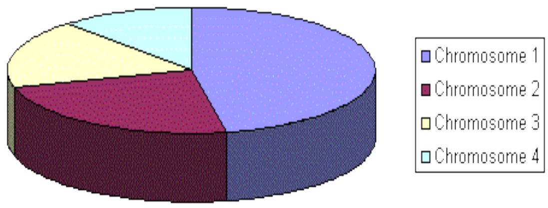
Genetic Algorithm (GA) is an optimization and search technique based on the principles of genetics and natural selection. GA is population based searching algorithm. The smallest unit of a GA is called a *gene*, which represents a unit of information in the problem domain. A series of genes, known as a *chromosome*, represents one possible solution to the problem. A series of chromosomes is known as *population*. Each gene in the chromosome represents one component of the solution pattern. The most common form of representing a solution as a chromosome is a string of binary digits. Each bit in this string is a gene. The process of converting the solution from its original form into the bit string is known as *coding*. The chromosome should in some way contain information about solution which it represents. The most used way of encoding is a binary string.

Generally GA comprises of following steps



The selection method used in the present paper is *Roulette Wheel selection.*

Roulette Wheel Selection method:
Parents are selected according to their fitness. The better the chromosomes are, the more chances to be selected they have. Imagine a wheel where are placed all chromosomes in the population, every has its place big accordingly to its fitness function, like on the following picture.



Chromosomes with bigger fitness value will be selected.

Crossover: Crossover selects genes from parent chromosomes and creates a new offspring. Crossover may be regarded as artificial mating in which chromosomes from two individuals are combined to create the chromosome for the next generation. The simplest way how to do this is to choose randomly some crossover point and everything before this point copy from a first parent and then everything after a crossover point copy from the second parent

The idea is that some genes with good characteristics from one chromosome may as a result combine with some good genes in the other chromosome to create a better solution represented by the new chromosome.

Chromosome 1	11011 | 00100110110
Chromosome 2	11011 | 11000011110
Offspring 1	11011 | 11000011110
Offspring 2	11011 | 00100110110

After a crossover is performed, **mutation** takes place. **Mutation** changes randomly the new offspring. For binary encoding we can toggle a few randomly chosen bits from 1 to 0 or vice versa. Mutation can then be following;

Original offspring 1	1101111000011110
Original offspring 2	1101100100110110
Mutated offspring 1	1100111000011110
Mutated offspring 2	1101101100110110

In this paper, a GA optimization technique has been used for finding the optimal sizes and locations of DG units. GA is utilized to find the optimal buses suitable for placing the DG.

The coding is done using MATLAB software. A set of chromosomes is created which indicates a set of buses. In this population of chromosomes, one bus which is considered to be the global best is chosen. With this global best bus, local best bus which is generated in each iteration is compared. If the local best variable is good compared to global best, then the local variable will replace the global best variable, otherwise the global best will remain untouched. At the end of all the iterations, the global best variable is nothing but the best bus number suitable to place the DG.

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IV. PROBLEM FORMULATION

In this paper, the proposed DG planning problem formulation is presented, which is classified as mixed integer nonlinear programming. For combining the effect of DG units' installation on system upgrade, energy losses and reliability, the following objective function is proposed.

Minimize:

Cost= Cost(s) of Objective(s)

$$+10^8 \text{ x } \sum_c^{nc} x_c - \text{Incentives} \quad (1)$$

where x_c is a binary variable corresponding to constraint c (the second term represents a penalty factor for violating constraint c); nc is the total number of constraints.

The cost(s) of objective(s) in (1) can be the individual cost or sum of different costs like system upgradation cost, cost of energy losses and cost of interruption.

Subject to

$$P_{G_{i_{sy}}} - P_{L_{i_{sy}}} = \sum_{k=1}^{n} V_{i_{sy}} V_{k_{sy}} Y_{ik}$$

$$\text{X} \cos(\theta_{ik} + \delta_{k_{sy}} - \delta_{i_{sy}}) \quad \forall i, s, y$$

$$Q_{G_{i_{sy}}} - Q_{L_{i_{sy}}} = -\sum_{k=1}^{n} V_{i_{sy}} V_{k_{sy}} Y_{ik}$$

$$\text{X} \sin(\theta_{ik} + \delta_{k_{sy}} - \delta_{i_{sy}}) \quad \forall i, s, y$$

where i and k are the bus number; n is the total number of buses in the system under study; s is the state number; y is the year under study; P_L and Q_L are the active and reactive power demands; P_G and Q_G are the active and reactive generated powers.

Voltage limits constraints:

$$V_{min} \leq V_{isy} \leq V_{max} \quad \forall i, s, y$$

Maximum penetration:

Maximum penetration is taken so as to limit maximum reverse power flow at 60% of substation rating during minimum load conditions

$$\sum_{i=1}^{n} P_{DGD_i} + P_{DGW_i} \leq 0.6 \, X \, P_{main} + 0.3 \, X \sum_{i=1}^{n} P_{L_i}$$

Where P_{DGD}, P_{DGW} and P_{main} are the generated power from dispatchable DG units, wind DG units and main substation respectively.

SAMPLE CASE STUDY

Consider the distribution system which contains a mix of residential, commercial and industrial customers. The system under study is a 39 bus system.

The buses are arbitrarily selected and located as shown in the fig.2

Four different cases are considered in this paper, which are

1) Base case
2) Dispatchable DG
3) Wind based DG
4) Mix of Dispatchable and wind based DG

There are different scenarios in each case. Table I gives the objectives and the Risk Factor(RF) for each scenario.

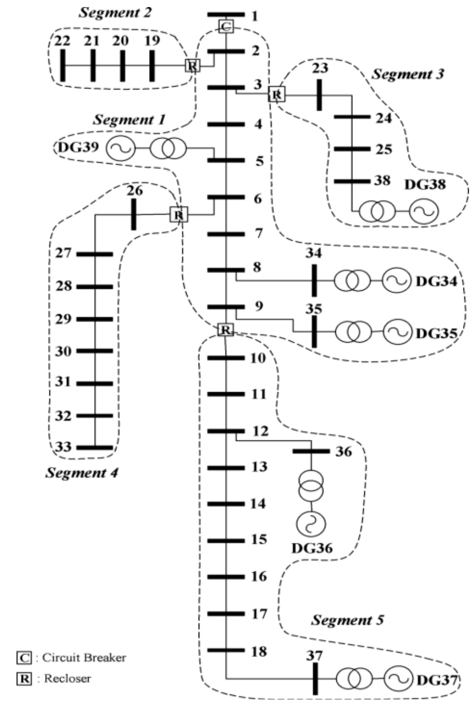

Fig.2 System under study

TABLE I
DIFFERENT SCENARIOS

Case	DG type	Scenario	Objective(s)	RF
A	No DG	A.0	No objectives (Base Case)	0
B	Disp.	B.1	UG	
		B.2	EL	
		B.3	INT	
		B.4	UG+EL+INT	
C	Wind	C.1.a	UG	3/8760
		C.1.b		6/8760
		C.2	EL	3/8760
		C.3	UG+EL	
D	Disp. And Wind	D.1	UG	
		D.2	EL	
		D.3	INT	
		D.4	UG+EL+INT	

* Disp.: Dispatchable DGs, Wind: Wind based DGs, UG: Cost of upgrade, EL: Cost of energy loss, INT: Cost of interruption, RF: risk factor.

RESULTS AND DISCUSSIONS

Table II shows the detailed study made for a 20-year period

Case A. Base Case Results(No DG)

The base case is defined by scenario A.0.

For this case,

$$\text{Total cost} = \text{UG} + \text{EL} + \text{INT}$$

2265683=1342301+234,532+688850

i.e., system upgrade cost's share is 59.2%, Energy Losses' share is 10.4%, whereas interruptions share is 30.4%. These costs are system independent. These costs show that the **system upgrade cost has the highest share.**

Case B. Dispatchable DG Results

The Dispatchable DG is denoted by four different scenarios and different objectives as shown in table I.

Scenario B1: The main objective is reduction of Upgradation Cost(UG)

As given in table II,

The cost of UG for scenario B1 =303,541

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The cost of UG for base case(i.e.,for A0)=1,342,301
Therefore, reduction in the cost of upgrades is 77.39%, which is very significant.
This saving in the cost we obtained, because the upgradation of the lines has been deferred or postponed to further years. For ex., required upgradation at 3rd year has been deferred to the 19th year.
Referring to table II,
The cost of EL for scenario B1=155,590
The cost of EL for base case=234,532
Therefore, reduction in the cost of EL is 33.7%, which represents a good result, because this is not the objective in this scenario.
The cost of interruption is not affected due to smaller capacities of DG units in segments 3 and 5.
The total cost for scenario B1=UG+EL+INT
303,541+155,590+688,850=1,147,981
The total cost for scenario A0=2,265,683
Therefore, the total saving is **49.3%**, which proves that the proposed methodology can reduce system cost significantly.

Scenario B2:The main objective is reduction of EL(Energy Loss):

As given in table I,
The cost of EL for scenario B1 =117,840
The cost of EL for base case(i.e.,for A0)=234,532
Therefore, reduction in the cost of Energy Losses is 49.76%
Referring to table II,
The cost of UG for scenario B2=736990
The cost of UG for base case=1342301
Therefore, reduction in the cost of UG is 45.1%
Again referring to table II,
The cost of Interruption for scenario B2 is 678,505
The cost of Interruption for base case is 688,850
which shows that there is a slight reduction in the cost of interruption, which is because of the higher capacities of DG units in segments 3 & 5 compared to scenario B1. Reducing the cost of interruption is anyway, not the main objective of this scenario.
The total cost for scenario B2=UG+EL+INT
736,990+117,840+678,505
The total cost for scenario A0=2,265,683
Therefore, the total % saving for scenario B2 is **32.3%**
Comment: Comparing the results of scenario B1 and B2 we can conclude that the system upgrade cost is more effective, since the total saving in scenario B1 is better than in B2.

Scenario B3: The main objective is reduction of cost of interruption (INT)

As given in table II,
The cost of INT for scenario B3 =563,443
The cost of INT for base case=688,850
Therefore, reduction in the cost INT is 18.2%
Referring to table II,
The cost of upgrade for scenario B3 =1,149,353
The cost of upgrade for base case=1,342,301
Therefore, the %saving is 14.4%
Again referring to table II,
The cost of EL for scenario B3 =168,163
The cost of EL for base case=234,532
Therefore, the %saving is 28.3%
Therefore, the total cost for scenario B3=UG+EL+INT
1,149,353+168,163+563,443=1,880,958
The total cost for scenario A0=2,265,683
Therefore, the total % saving for scenario B3 is **16.98%.**
Comment: The above result shows that the cost of interruption is the least effective cost in the case under study.

Scenario B4: The main objective is reduction of the three considered costs i.e., UG+EL+INT

As can be seen from the table II, the results are same as scenario B1
Conclusion: For the case under study, the upgrades cost is the most effective cost and the Interruption cost is the least effective cost.

Case C: Wind Based DG Results

Since in this case, only wind based DG units are considered, the cost of interruption is not affected. For evaluating the cost of lines' upgrades in case of wind based DG units, if the Risk Factor(RF) is taken to be zero, the cost is greater than or equal to the cost of lines' upgrade without DG.
The scenarios under this case are characterized by non-zero RF. The risk of overloading arises from neglecting one or more states that contribute the most in the reinforcement requirements. The different scenarios under this case are C1a,C1b,C2,C3. For the study of this case, RF is taken with different values for different scenarios as shown in the table II.

Scenario C1a: The main objective is reduction of Upgradation Cost(UG)

The RF value is taken as 3hrs./year. The results of the allocation problem show a savings of 8.49% for upgrade costs and 13.1% for the cost of energy losses

Scenario C1b: The main objective is reduction of Upgradation Cost(UG)

The RF value is taken as 6hrs/year. The results of the allocation problem show a savings of 27.11% for the upgrade costs and 20.6% for the cost of energy losses.
Comment: Comparing scenarios C1a and C1b, we can conclude that as the RF increases, the cost of upgrading keeps decreasing. i.e., as the risk of overloading the lines is increased, the expected upgrade costs keep decreasing as shown in the fig. 5. The curve shows that the reduction in the UG costs is not uniform. This is because, the costs depend upon the wind regime, load curve and system under study.

Scenario C2: The main objective is reduction of Cost of Energy Losses

RF taken in this scenario is 3hrs./year. Table II shows that cost of EL is reduced by 34.7% but the cost of UG is higher than the base case by 36.6%. But, reducing the UG cost is not the objective of this scenario.
Conclusion: Comparing scenarios C2 and B2, where the main objective of both is the reduce the cost of EL, the reduction in EL in scenario C2 (34.7%) is smaller compared to the scenario B2(49.76%). Hence we can conclude that this result is due to the variability and uncertainty of wind based DGs.

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Scenario C3: The main objective is reduction of Cost of Energy Losses and Upgradation costs i.e. UG+EL

RF taken in this scenario is 3hrs./year. The total savings in the costs of EL and UG is 6.48%. This value is slightly greater than scenario C1a.

Conclusion: When different scenarios in case C are compared, the results show that for wind based DG units, the most effective cost is the cost of energy losses. The ability of reducing the cost of upgrades and energy losses is limited in case of wind based DG units, because of their stochastic nature.

Case D:Wind and Dispatchable DG Results

Different scenarios under this case are D1,D2,D3 and D4

In this case, along with the dispatchable DGs, 40% of wind based DGs are assumed to be installed.

i.e., the capacities of the wind DG units ≥ two-thirds the capacities of the dispatchable DG units.

So the constraint should be,

$$\sum_{i=1}^{n} P_{DGW_i} \geq \frac{2}{3} \times \sum_{i=1}^{n} P_{DGD_i} \qquad (A)$$

Scenario D1: The main objective is reduction of Upgradation Cost(UG)

Referring to the table II and comparing the savings in the cost of upgrades in scenario D1 and scenario B1(the objective of both are the same), we can say that the savings in the cost of upgrades in D1(70.7%) is lower than the savings in the cost of upgrades in B1(77.39%). The reason for this is the green energy constraint (A).

As given in the table II, the capacity of the wind DG units is 0.6MW, which is exactly $\frac{2}{3}$ of the total capacity of the dispatchable DG units as given in the equation (A).

Scenario D2: The main objective is reduction of Energy Losses(EL)

Comparing the savings in EL in scenario D2 with the savings in scenario B2, we can say that the savings in D2(49.38%) is very close to savings in B2(49.76%). The only difference in this scenario is that this scenario comes with the higher DG capacities(both renewable and dispatchable) as compared to the DG capacities of scenario B2.

Scenario D3: The main objective is reduction of Interruption (INT) costs

Referring to the table II and comparing the results of Scenarios B3 and D3(the objectives of both are same), we can conclude that the maximum savings in the interruption cost in D3(12.97%) is smaller than the savings in the B3(18.21%) though the total DG capacity in D3 is higher than the total capacity in B3. The reason for this is the intermittent or stochastic effect of the wind based DGs which limit their contribution in reducing the interruption cost.

Scenario D4: The main objective is reduction of the three considered costs i.e., UG+EL+INT

Results of this scenario are found to be the same as scenario D1.

Comment: Referring to the table II and comparing D4 with B4(the objectives of both are the same), we can conclude that the total savings in D4(46%) is less than the total savings in B4(49.3%) but the total DG capacity in D4 which uses a mix of dispatchable and wind based DG units is more than the total DG capacity of B4 which uses only dispatchable DG units. In scenario B4, RF is 0 while in D4, risk of overloading is 3hrs./year.

CONCLUSION

In this paper, a GA based optimization approach is proposed to optimally allocate different types of DG units into the distribution system. The main aim of this paper is to consider the renewable DG units and their uncertainty and variability by defining a factor called Risk Factor(RF), which represents the expected duration of overloading the lines per year. This paper mainly concentrates on optimal allocation of different types of DGs in the distribution system, to maximize the benefits through the reduction of losses(energy and interruption) and by deferring or postponing the investment upgrades. The cost of interruption is calculated by considering the nonlinear, time dependent CDF, which gives more accurate results, as the effect of renewable DGs is mostly vary according to the time during islanded mode of the distribution network.

Moreover, the proposed methodology in the paper mainly considers the hourly cost of energy for calculating the Net Present Value(NPV) of the energy losses.

Using GA based optimization approach, the best locations for placing the different types of DG units are identified and the proposed methodology can be easily applied to any type of radial distribution system. Moreover, the proposed methodology can be applied to any type of DG units such as dispatchable or renewable DG units or in any combination of these DG units.

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Table II

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Detailed Results of Different scenarios

DG Type		No DG	Dispatchable				Wind				Wind and Dispatchable							
Scenario		A.0	B1	B2	B3	B4	C1a	C1b	C2	C3	D1		D2		D3		D4	
Objective			UG	EL	INT	UG+EL+INT	UG	UG	EL	UG+EL	UG		EL		INT		UG+EL+INT	
							RF=3/168	RF=6/168			Disp.	Wind	Disp.	Wind	Disp.	Wind	Disp.	Wind
DG units (MW)	DG34	0.0	0.5	0.3	0.0	0.5	0.0	0.3	0.4	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.0
	DG35	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.4	0.0	0.2	0.0	0.0	0.1	0.4
	DG36	0.0	0.0	0.2	0.7	0.0	0.0	0.2	0.3	0.1	0.2	0.0	0.2	0.0	0.4	0.4	0.2	0.0
	DG37	0.0	0.1	0.2	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.0	0.2	0.0	0.2	0.2	0.1	0.0
	DG38	0.0	0.2	0.4	1.1	0.2	0.5	0.6	0.7	0.2	0.3	0.1	0.3	0.2	1.1	0.5	0.3	0.1
	DG39	0.0	0.1	0.9	0.0	0.1	0.0	1.3	1.3	0.0	0.0	0.1	0.6	0.7	0.0	0.1	0.0	0.1
Total Penetration(MW)		**0.0**	**0.9**	**2.0**	**1.7**	**0.9**	**0.7**	**1.1**	**2.9**	**0.7**	**0.9**	**0.6**	**1.5**	**1.1**	**1.7**	**1.2**	**0.9**	**0.6**
NPV of cost os system upgrades	Lines' Upgrade	1,342,301	303,541	396,990	1,049,353	303,541	1,228,373	978,383	1,493,400	1,236,618	332,658		390,060		1,458,644		332,658	
	Metering Upgrade	0	0	40,000	40,000	0	0	0	40,000	0	0		40,000		40,000		0	
	Protection Upgrade	0	0	300,000	60,000	0	0	0	300,000	0	60,000		240,000		180,000		60,000	
	Total()	1,342,301	303,541	736,990	1,149,353	303,541	1,228,373	978,383	1,833,400	1,236,618	392,658		670,060		1,78,644		392,658	
	%saving	0.0	77.39	45.10	14.37	77.39	8.49	27.11	-36.59	7.87	70.75		50.08		-25.06		70.75	
NPV of cost of energy losses	Cost()	234,532	155,590	117,840	168,163	155,590	203,803	186,221	153,142	193,385	149,657		118,730		186,288		149,957	
	%saving	0.00	33.66	49.76	28.30	33.66	13.10	20.60	34.70	17.54	36.06		49.38		20.57		36.06	
NPV of cost of interruption	Seg1	109,775	109,775	109,775	109,775	109,775	109,775	109,775	109,775	109,775	109,775		109,775		109,775		109,775	
	Seg2	34,886	34,886	34,886	34,886	34,886	34,886	34,886	34,886	34,886	34,886		34,886		34,886		34,886	
	Seg3	194,375	194,375	189,928	137,731	194,375	194,375	194,375	194,375	194,375	189,944		189,944		150,557		189,994	
	Seg4	223,701	223,701	223,701	223,701	223,701	223,701	223,701	223,701	223,701	223,701		223,701		223,701		223,701	
	Seg5	126,114	126,114	120,215	57,351	126,114	126,114	126,114	126,114	126,114	121,954		121,893		80,584		121,954	
	Total	688,850	688,850	678,505	563,443	688,850	688,850	688,850	688,850	688,850	680,260		680,199		599,503		680,260	
	%saving	0.0	0.0	1.50	18.21	0.0	0.0	0.0	0.0	0.0	1.25		1.26		12.97		1.25	
Avg.annual EENS(KWh/Yr)		13,855	13,855	13,360	11,561	13,855	13,855	13,855	13,855	13,855	13,382		13,379		12,069		13,382	
Total Cost		2,265,683	1,147,981	1,533,335	1,880,958	1,147,981	2,121,026	1,883,454	2,675,392	2,118,852	1,222,875		1,468,989		2,464,434		1,222,875	
%Total savings		0.0	49.3	32.32	16.98	49.33	6.38	18.19	18.08	6.48	46.03		35.16		-8.77		46.03	