

Optimal Placement of Distributed Generation for Power Quality Improvement using Hybrid ABC-CS Algorithm

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Abstract—Distribution generation (DG) is a term that refers to the production of electricity near the consumption place. On a local basis, there are opportunities for electric utilities to use DG to reduce peak loads, provide auxiliary services such as reactive power and voltage support, and improve power quality. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences. Hence, the Dg is placed in the power system to reduce the power loss and increase the power quality. This paper presents a new hybrid optimization algorithm to determine the optimal DG location and size to minimize the total power loss, total harmonic distortion (THD), and voltage sag index improvement. The proposed hybrid optimization algorithm combines the behavior of the Artificial Bee Colony and Cuckoo Search (ABC-CS) algorithm. The DG units are optimally placed by considering the objectives like voltage profile and power loss. The implementation results suggest that the proposed system for the DG placement produces better performance, so that power system quality can be achieved.

Index Terms— Distribution Generation (DG), artificial bee colony algorithm (ABC), cuckoo search (CS), power quality, voltage profile, power loss, total harmonic distortion (THD), and total cost.

I. INTRODUCTION

The electric power system is being developed by today's unified group system, with generating plants with transmission systems, with the future more decentralized system, particularly with fewer generating units associated with close demand use of the distribution system. This type of generating unit is characterized as DG [1]. DGs contribute to applying competitive energy policies, diversification of energy resources, reducing on-peak operating costs, deferral of network upgrades, lower losses and lower transmission and distribution costs, and potential increase of service quality to the end customer. [2, 3].

The penetration of DG can affect the operation of the distribution network in a beneficial and detrimental way [4-6]. Some of the positive effects of DG include voltage support, power loss reduction, auxiliary services support and improved reliability, but negative ones include protection coordination, functional stability and

islanding [7].

Power quality is a client-driven issue concerning the attributes of power supply that influence the execution of client equipment, for example, microelectronic gadgets and power electronic gadgets. Unexplained equipment excursions or shutdowns; periodic hardware damage or component disappointment; flighty control of process performance; random lockups and information mistakes, power system segment overheating is mostly brought about by poor power quality [8]. Because of the related significant financial losses, issues of the quality of power conveyed to the clients have turned into an essential issue. Recent studies demonstrate that 80-90% of all power quality issues are from on location issues, instead of utility issues [9].

Harmonic distortion has been present in electrical energy systems for a long time. Of late, on the other hand, electric power utilities have deployed more assets to examine and analyze the near and unclear effects on systems and client gadgets. This extended mindfulness is the result of worries that the levels of harmonic distortion may be expanding in many electrical energy systems [10-11].

Voltage sag represents the most astounding rate of equipment interferences. Voltage magnitude and duration are fundamental attributes of voltage sag. The voltage sag magnitude, which is the remaining voltage amid the occasion, depends not just on the fault sort and fault area but additionally on different components, for example, pre-fault voltages, transformer connection, and fault impedance. The duration of voltage sag is characterized as the time during which the voltage magnitude (RMS voltage) is beneath a given voltage threshold [12].

Based on the above synthesis determination of a suitable location and ideal size of DG concerning system design and load distribution in a radial distribution feeder is a principle challenge in the evolving administrative and monetary situations [13]. Some of the researchers in this area are, in [14] presented power flow-based algorithms to obtain the optimal size of DG at each load bus. In [15] proposed optimal placement of DG in the power system in terms of loss. In [16] a genetic algorithm has been used for optimal placement of DG to reduce the losses. A multi-objective evolutionary algorithm is presented in [17] for the optimal sizing and placement of DG. In [18] tabu search algorithm is used to find the optimal location and in [19-20] presented a combination of two evolutionary algorithms to obtain the optimal size and location of DG.

II. PROPOSED DG PLACEMENT AND SIZING BASED ON ABC-CS

With the ever-increasing demand for electricity consumption and increasing open access particularly in the restructured environment, power quality problem is frequent. For maximizing the benefits and to improve the power quality of the system, proper location and sizing of distributed generators are necessary.

The process flow of the proposed system has four phases that have been illustrated below. The first phase is the formation of Objective Function with Power Quality Performance. This phase is used for calculating the three parameters such as power loss minimization, voltage sag index, and THD. DG location and sizing are based on the ABC-CSO algorithm. DG placement is based on total power loss, voltage profile, and total cost (fuel and installation). In addition, the DG size is mainly depending on the voltage sag index and THD. This work is implemented and simulated in MATLAB and also it is compared with some existing methods. The flowchart of the proposed system is shown in figure 1.

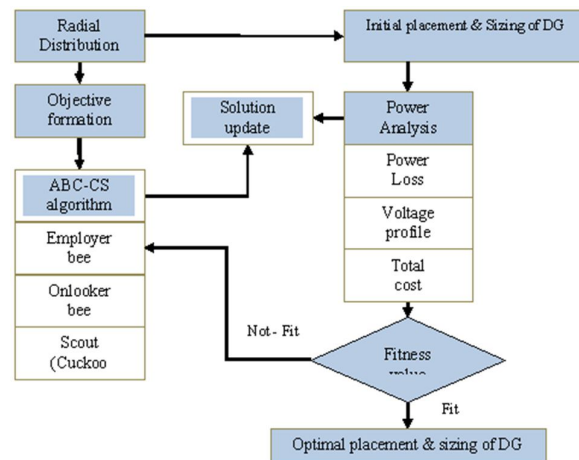


Figure 1: Flowchart of the proposed framework

The problem is formed to calculate the optimal DG placement and size in a distribution network by minimizing the real power loss, total harmonic distortion and voltage sag. To obtain the optimal location and size of the DG an ABC - CS algorithm is utilized.

Sizing by ABC-CS Algorithm: In the planned framework, DG placement and sizing are based on the ABC-CS algorithm. The detailed methodology is as follows: The following equation (2.4) expresses the objective function RDS is used for minimizing the THD and RPL and it increases the voltage sag index. $in(f1) =$

$$\min(P_{loss}, Q_{loss}, THD, 1/VSI) \quad (2.4)$$

Initialization: In the initialization phase, the DG is located randomly in the bus system. The initial data format is shown the Figure 2. The initial location of ABC-CS is randomly fixed as the $1-B_n$. Where the bus system is represented as B_n . In general, the DG size is initialized in the range of 0-2MW and the number of DG for placement is fixed $1-D_n$. Where the amount of DG units is D_n .

Employed Bee Phase: In the employed bee phase, the data fitness value is computed which is expressed in the equation (2.5). The calculation of fitness function is based on two different parameters such as total PL and voltage profile. The iteration value is added up to 1, i.e. iteration $i=1$.

$$F = \min \left[\frac{f_1}{f_2} \right] \quad (1)$$

$$\Phi = \text{Max} \left\{ \frac{F(x) + B(x)}{2} \right\} \quad (2)$$

Onlooker Bee Phase: The optimal location for placing the DG and the location (i.e., food sources) is improved in the onlooker bee phase. The appropriate location with a high voltage profile and less power loss is obtained by using the best solution for the onlooker bee phase.

Selection Process: The ABC selection process is used to calculate the new solution's better fitness and find the probability.

The ABC algorithm used in the optimal DG placement utilizes the four various selection processes.

1. **Global probabilistic selection process:** The food source selected by the artificial onlooker bee and the selected food source is mainly based on the probability value which is related to that food source (p_i). The food source is given in the following equation (3).

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \quad (3)$$

2. **Local probabilistic selection process:** In the local probabilistic selection process, the region is extracted with the help of employed bees. The aforementioned visual information is used for identifying the food source which is around the source of the memory. The source in the memory is expressed in the following equation (4).

$$v_{ij} = x_{ij} + \Phi_{ij} (x_{ij} - x_{kj}) \quad (4)$$

Where the randomly selected indexes are $K \in \{1, 2, \dots, SN\}$

3. **Greedy selection process :** In general, greedy selection process is a local selection process which is processed by onlooker bees and employer bees. The bee forgets the present source and memorizes the source of candidate in equation (3), when the candidate source nectar amount is better than the present source. On the other hand, the bee holds the present one in the memory.
4. **Random selection process:** The equation (4) used for the random selection process that is occurred by the scouts. The scout will identifies a new food source which changed by x_i^* that is expressed in equation (5).

$$x_i^j = x_{\min}^j + \text{rand} [0,1] (x_{\max}^j - x_{\min}^j) \quad j \in \{1, 2, \dots, D\} \quad (5)$$

Where, x_i is the abandoned source.

CS based Scout Bee Phase:

In modern PS, the optimal placement of DG is occurred by using the ABC-CS and the overall process of the optimal DG placement using ABC-CS is shown in the Figure 2. The random locations of DG are obtained by initializing the power system data or bus data. For the ABC-CS, the number of DG and its size is initialized. The employee bee phase calculates the fitness value and this value should be related to the respective initial value. For an additional process, some solutions are selected by using the onlooker bees. The optimal DG location are found by processing the scout bee phase which depends on the CS.

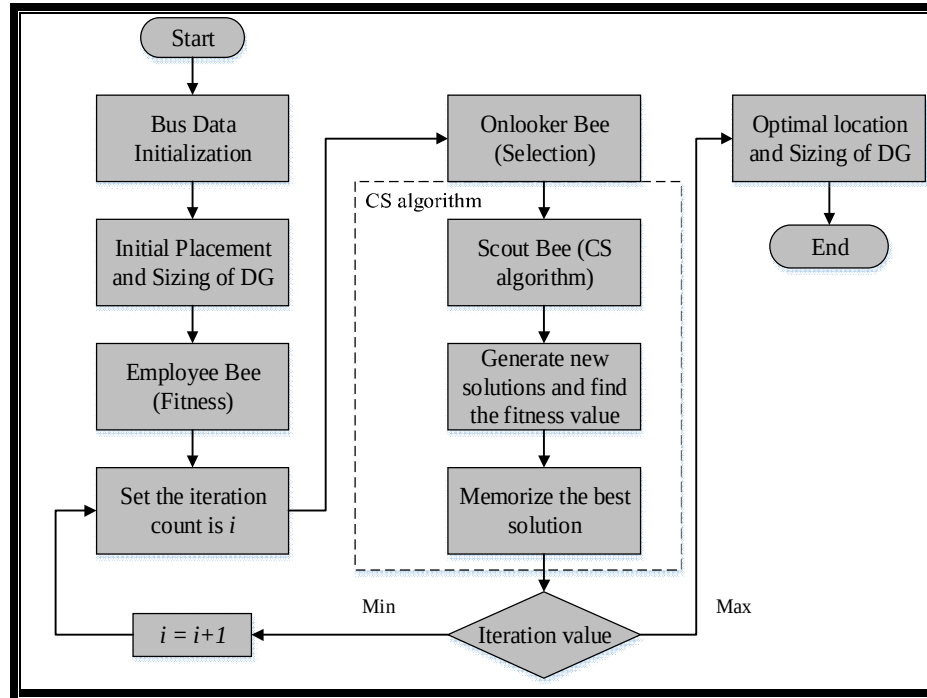


Figure 2: Proposed technique flow chart

III. EXPERIMENTAL RESULTS AND DISCUSSION

In this proposed methodology ABC-CS algorithm is implemented for finding the optimal DG placement and its size. In this paper MATLAB/Simulink is used for the simulation purpose. There are two bus systems are used to evaluate the optimal DG placement and sizing such as IEEE 33 bus system and IEEE 69 bus system.

A. Case - 1: IEEE 33 bus system

The IEEE 33 bus RDS is a main radial distribution feeder which is operated in voltage level of 12.66kV. This IEEE 33 bus RDS has 33 bus and 32 branches. The overall reactive and active loads of the 33 bus test system are 2300kVAr and 3715kW respectively. In IEEE 33 bus RDS, the real and reactive power value of the base values are 202.32 kW and 135.04kVAr respectively.

The Results of ABC-CS obtained for placing DG in 33 bus system are shown below. In each bus, the DG unit optimal size is computed without reference bus. The power loss at kW and voltage profile is calculated after placing the DG in optimally selected bus. The results from the IEEE 33 and 69 bus RDS is given in the Table 1.

At first, the load flow is given for different case studies such as harmonics frequency and fundamental frequency without DG installation. The IEEE 33 bus RDS with and without DG placement is shown in Figure 3. After placing the DG, the real power losses are reduced to 63.35kW from 202.32 which is shown in Figure 4. During the faults, the bus voltage is high due to the greater value of voltage sag index. The power quality improvement is shown by the ODGP.

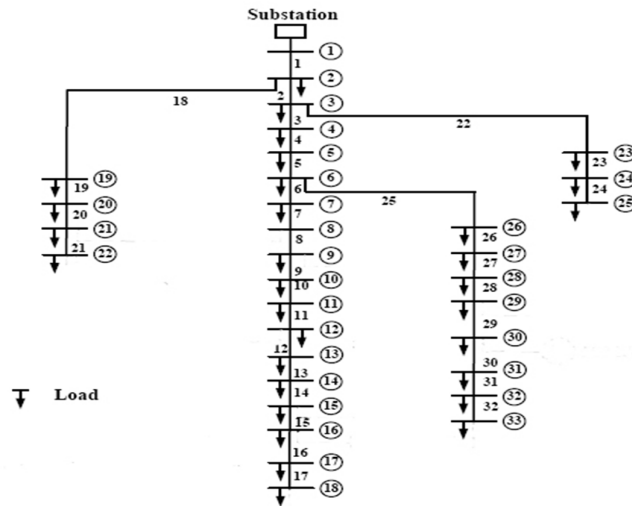


Figure. 3: SLD of IEEE 33 bus RDS

TABLE. I:

Specifications	IEEE 33 Bus RDS results		IEEE 69 Bus RDS results	
	Without DG	With DG	Without DG	With DG
RPL(kW)	202.320	63.350	225.0	68.1
Reactive PL (kVAr)	135.040	57.560	102.1	39.480
Min. Voltage (p.u)	0.91360	0.9787	0.9	0.9812
Number of DGs	-	1	-	3
Location of DG	-	25	-	61
Size of DG in MW	-	1.570	-	1.450
Type of DG	-	3	-	3
Power Factor of DG	-	0.9820	-	0.90
Cost of Energy loss in \$/kWh	106339.4	33296.80	118307.3	35793.4
DG cost in \$/h	-	52.650	-	45.451
Total THD (%)	6.98	5.45	12.16	12.032
Voltage Sag Index	25.07	31.08	36.073	46.043

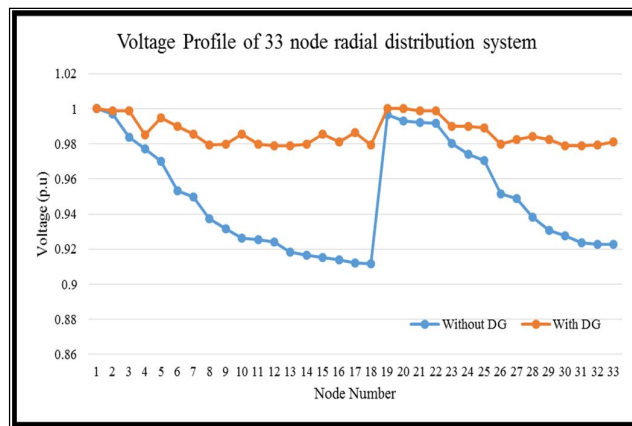


Figure 4: IEEE 33-bus RDS voltage profile

The type of the DG used in this work is PQ which is used for injecting both the real and reactive power. The optimal working PF of DG is found to be 0.982 as a result of this the total savings in the energy losses go further improved.

B. Case - 2: IEEE 69 bus system:

Generally, the IEEE 66 bus RDS is a main radial distribution feeder which is operated in voltage level of 12.66kV. This IEEE 33 bus RDS has 69 bus and 68 branches. The overall reactive and active loads of the 69 bus system are 2693.6kVAR and 3890.70 kW respectively. The following Figure 5 shows the 69 bus RDS.

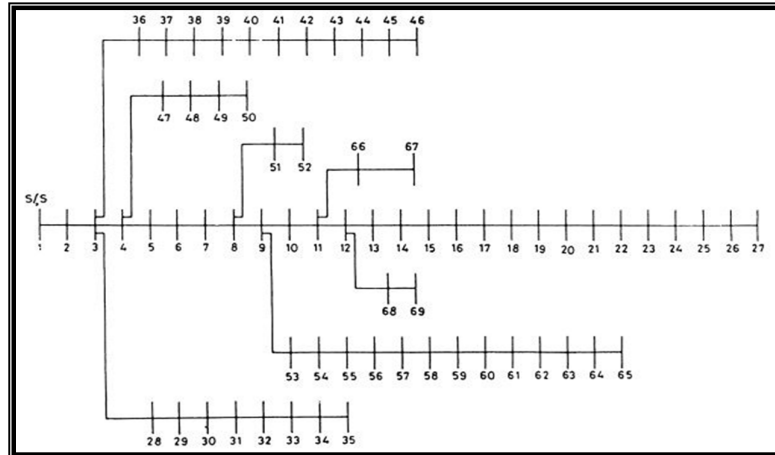


Figure. 5. Single line diagram of IEEE 69 bus system

The IEEE 69 bus voltage profile of with and without DG placement is given in Figure 6.

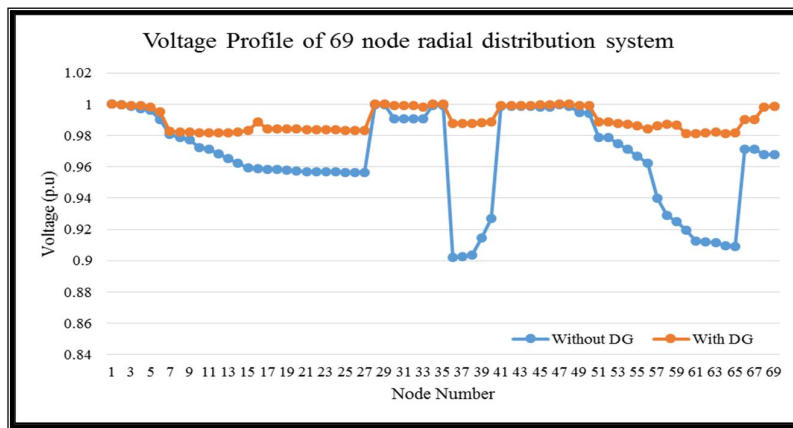


Figure 6. IEEE 69-bus RDS voltage profile

The type of the DG used in this work is PQ which is used for injecting both the real and reactive power. The optimal working PF of DG is identified as 0.90 as a result of the total savings in the energy losses go further improved. From the results conclude that the DG is located in an optimal location with an effective size. By placing the DG's in optimal location, the following measures are reduced such as THD, RPL and voltage sag and also it enhances the voltage profile. The DG present in the power systems provides the load in local manner and significantly decreases the active and reactive power of substation and also it decreases the distribution system power loss.

C. Practical System-12 Bus Radial System

The practical radial network of 12 Buses is also analyzed in this work. Generally, this practical system is a 11 kV rural feeder which is placed in Bangalore, India. The practical system is located about 40km far from the city,

Karnataka state in India. The following Figure 7 shows 12 bus practical system. In Appendix-D, the line and load data of the 12 bus system is provided.

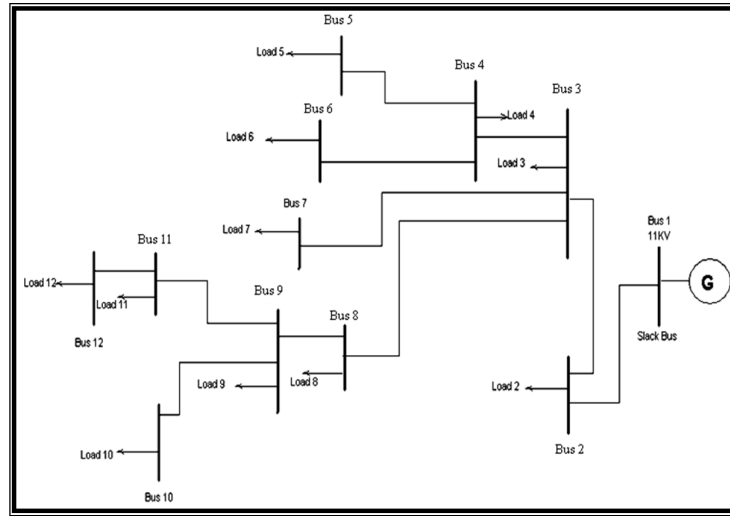


Figure 7. Twelve-bus practical test system

Results of ABC-CS obtained for placing DG in 12 bus practical test system are shown below. In each bus, the optimal size of DG unit is computed without reference bus. The power loss per unit and voltage profile is calculated after placing the DG in optimally selected bus. The results from the 12 bus practical test system is given in the Table III.

TABLE II. 12 BUS PRACTICAL TEST SYSTEM RESULTS

Specifications	Without DG	With DG
RPL (kW)	160.07	68.100
Reactive PL (kVAr)	72.1	37.38
Min. Voltage (p.u)	0.9	0.972
Number of DGs	-	3
Location of DG	-	8
Size of DG in MW	-	1.35
Type of DG	-	3
Power Factor of DG	-	0.947
Cost of Energy loss in \$/kWh	68307.3	35793.4
DG cost in \$/h	-	25.451
Total THD (%)	15.462	14.234
Voltage Sag Index	39.073	45.044

The 12 bus practical test system voltage profile of with and without DG placement is given in Figure 8. The Table 2.9 shows the harmonic spectrum of the nonlinear loads in practical 12 bus RDS. At first, the load flow is given for different case studies such as harmonics frequency and fundamental frequency without DG installation. The practical 12 bus radial distribution system's voltage profile for with and without DG placement is shown in Figure 7. After placing the DG, the real power losses are reduced to 68.10kW from 160.09 which is shown in Figure 8. The reactive power losses are reduced to 37.38kVAR from 72.13kVAR. The THD% also improved as per the results obtained. As the DG is linked directly into the DS, voltage sag performance index also got improved. During the faults, the bus voltage is high due to the greater value of voltage sag index. The power quality improvement is shown by the ODGP.

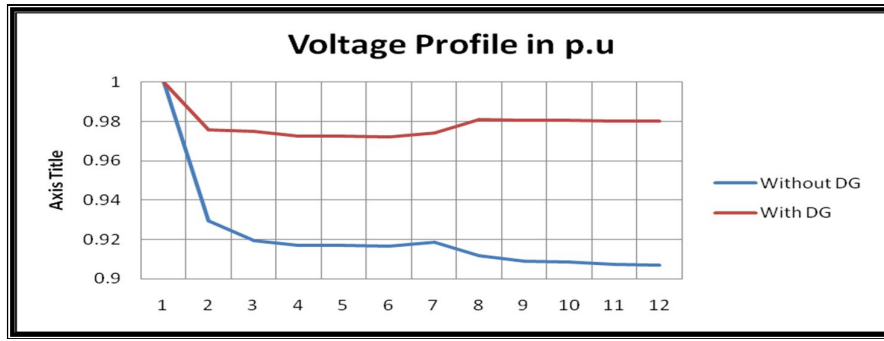


Figure 8: Voltage Profile of Practical 12 Bus RDS

TABLE III. COMPARISON OF RESULTS OF IEEE 69 BUS RDS

Parameters	Without DG	Proposed Method [ABC-CS]	GVK Murthy et. al[100]	Varesi et. al [99]
		With DG	With DG	With DG
Real Power Loss (kW)	225.091	68.101	72.8	73.6
Reactive Power Loss (kVAr)	102.132	39.48	36.8	38.9
Min. Voltage (p.u)	0.9019	0.9812	0.9782	0.9682
Number of DGs	-	1	1	1
DG Location (Node Number)	-	61	61	60
DG Size (MW)	-	1.45 (61)	1.65 (61)	1.45 (60)
DG Type	-	Type 3	Type 3	Type 3
Power Factor	-	0.8	0.75	0.65
Cost of Energy loss (\$/kWh)	118307.304	35793.36	38873.9	39876.3
Cost of DG (\$/h)	-	45.45	48.4	49.7
Total THD (%)	12.16	12.03	12.14	13.19
Voltage Sag Index	36.07	46.04	45.06	44.89
Time(s)		0.61	0.79	0.75

IV. CONCLUSION

DG unit Placement is encouraged in the power system to maintain the power quality. While the interconnection of DG unit in an existing power system leads power quality problem, to overcome this issue it is essential to place the DG in optimal manner. In this paper a novel hybrid optimization technique is proposed based on ABC and CS algorithm for the placement and sizing of DG in power system. A CS for DG placement and sizing problem in the radial distribution system to reduce total real power losses and improve voltage stability with imposed voltage constraint is presented in the paper. The ABC-CS provides both optimal location and sizing of DG as the outputs. It is demonstrated that the proposed method is capable of saving a significant amount of power, achieve improvement in voltage stability, and voltage profile by comparing the results among pre and post installation of DG. The performance of the proposed method is analyzed based on the voltage profile, power loss, loss reduction percentage, total cost and total harmonic distortion. As a result, the total cost and total harmonic distortion for DG placement has been reduced. The proposed method provided better performance for all aspects and reduced the loss while placing DG unit.

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