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Optimal Placement of DG in Distribution System to Mitigate Power Quality Disturbances

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Abstract**—**Distributed Generation (DG) systems are considered an integral part in future distribution system planning. Appropriate size and location of distributed generation plays a significant role in minimizing power losses in distribution systems. Among the benefits of distributed generation is the reduction in active power losses, which can improve the system performance, reliability and power quality. In this paper, Artificial Bee Colony (ABC) algorithm is proposed to determine the optimal DG-unit size and location by loss sensitivity index in order to minimize the real power loss, total harmonic distortion (THD) and voltage sag index improvement. Simulation study is conducted on 69-bus radial test system to verify the efficacy of the proposed method.

Keywords—Distributed generation, artificial bee colony method, loss reduction, radial distribution network.

I. INTRODUCTION

ELECTRIC power systems are evolving from today's centralized bulk system, with generation plants connected to the transmission network, to the future's more decentralized system, with smaller generating units connected directly to distribution networks near demand consumption. This type of generating unit is defined as Distributed Generation (DG) [1]. Penetration of DG is a new challenge for traditional electric power systems, as it changes network power flows, modifying energy losses. This causes an impact on network operation and planning practices of distribution companies with both technical and economic implications [2]-[4].

The penetration of DG may impact the operation of a distribution network in both beneficial and detrimental ways. Some of the positive impacts of DG are: voltage support, power loss reduction, support of ancillary services and improved reliability, whereas negative ones are protection coordination, dynamic stability and islanding. In order to maximize benefits and minimize problems, technical constraints concerning the interconnection of DG units and their penetration levels are being adopted worldwide. Furthermore, the presence of DG in the deregulated market has raised new regulatory issues, concerning financial incentives, cost allocation methods, generation management techniques, etc.

Nowadays poor power quality causes tremendous financial losses in deregulated power systems. It is estimated that power quality problems cost industry and commerce in the European Union about 100 billion Euros per annum [5]. Today's electric power systems are connected to many non-linear loads. These include power electronic equipments, arc discharge devices, electronic control equipment by semiconductor devices, saturated magnetic devices, rotating machines, and residential loads with switch-mode power supplies such as computers. Harmonics can cause maloperation of control devices, additional losses in capacitors, transformers, transmission lines and rotating machines, additional noise in motors, telephone interference, or causing parallel and series resonances.

Harmonic distortion has existed on electric power systems for many years. Recently, however, electric utilities have designated more resources to monitoring and analyzing the presence and effects of distortion on system and customer devices. This increased awareness is the result of concerns that harmonic distortion levels may be increasing on many electric power systems [6], [7].

Distribution networks are presently attracting increasing interest by all electrical market stakeholders. In the recent years in fact, due to economical, environmental and political reasons, the traditional power system, characterized by centralized bulk power production and wide/long transmission networks, is increasingly supported also by energy-resources connected to the distribution grid, a tendency commonly denoted as distributed generation (DG). Determination of appropriate location and optimal size of DG with respect to network configuration and load distribution in a radial distribution feeder is a main challenge in the changing regulatory and economic scenarios.

Several researchers have worked in this area. DGs are placed at optimal locations to reduce losses. Some researchers presented some power flow algorithms to find the optimal size of DG at each load bus [8], [9]. Wang and Nehrir have shown analytical approaches for optimal placement of DG in terms of loss [10]. Chiradeja has quantified the benefit of reduced line loss in radial distribution feeder with concentrated load [11]. Further, many researchers have used evolutionary computational methods for finding the optimal DG placement. Mithulananthan has used GA for placement of DG to reduce the losses [12]. Celli and Ghiani have used a multiobjective evolutionary algorithm for the sizing and placement of DG [13]. Nara et al. have used Tabu search algorithm to find

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optimal placement of distributed generator [14]. T.N Shukla have proposed genetic algorithm for optimal allocation of DG to reduce system losses. [15].

This paper is proposed to find the optimal location of DG by loss sensitivity index and size of DG by using an Artificial Bee Colony (ABC) method to reduce the loss with the consideration of harmonic effects.

II. PROBLEM FORMULATION

The problem is formulated to determine the optimal DG size and location in a radial distribution system by minimize the real power loss, THD and voltage sag. To find the optimal location of DG by loss sensitivity index and size of the DG is using an Artificial Bee Colony (ABC) algorithm.

A. Loss Minimization

The losses depend on the line resistance and currents are usually referred to as thermal losses. Therefore loss of any distribution system can be calculated as

$$P_L = \min \sum_{k=1}^{n-1} R_k \left|I_k\right|^2 \tag{1}$$

P_L is total system loss,
R_k is resistance of k^{th} line,
$\left|I_k\right|$ is absolute of k^{th} line current.

The inequality constraints are those associated with the bus voltages and DG to be installed.

1. The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimization process. That is ± 5% of the nominal voltage value.

$$V_{max}^{sys} \geq V_i^{sys} \geq V_{min}^{sys}$$

2. The inequality constraint is the DG-unit size

$$S_{max}^{DG} \geq S_i^{DG} \geq S_{min}^{DG}$$

where

$$S_{max}^{DG} = 80\%\, of\, S_{load}$$

$$S_{min}^{DG} = 10\%\, of\, S_{load}$$

B. Harmonic Power Flow

To solve the DG placement problem with harmonic distortion consideration, it is necessary to perform harmonic power flow calculations under different harmonic orders such that harmonic rms voltages and THD of bus voltages can be obtained as follows

Step 1: Calculate V for fundamental case from general load flow

Step 2: Calculate the harmonic load impedance Z_L^h where $Z_L^h = R_L + jhX_L$ for h^{th} order harmonic

Step 3: Calculate the harmonic injection current I_{Li}^h

$$I_{Li}^h = \%\ of\ harmonic\ injection \times I_{Li} \quad \text{where } i = 1, 2 \ldots n$$

Step 4: Calculate the line impedance Z^h

$$Z^h = R + jhX$$

Step 5: Calculate the Z_{bus}^h matrix

Step 6: Calculate the harmonic voltages V^h

$$V^h = \left[Z_{bus}^h\right]\left[I^h\right]$$

Step 7: Calculate the Total Harmonic Distortion (THD)

$$THD(\%) = \frac{100}{\left|V_i^1\right|}\sqrt{\sum_{h=2}^{nh}\left|V_i^h\right|^2} \tag{2}$$

where V_i^1 =fundamental voltage, V_i^h =hth order of harmonic voltage

C. Voltage Sag Calculation

Voltage sag is a decrease to between 0.1 pu and 0.9 pu in rms voltage or current at the power frequency for durations from 0.5 cycles to one minute. The duration of voltage sag is not a function of system topology, and is usually related to other parameters. The magnitudes of voltage dips are strongly dependent on the path from which the fault current is supplied and the equivalent impedances among the node under study, the source and the faulted points. As the result, only the magnitude of voltage sags has been considered in this paper. In radial distribution networks the following simplified equation can be applied to calculate the sagged voltage at bus *i* (Point of Common Coupling (PCC)) caused by a fault at node j [16]:

$$V_{ij}^{sag} = \frac{Z_{ij} + Z_t}{Z_s + Z_{ij} + Z_t} \tag{3}$$

where V_{ij}^{sag} is the sagged voltage at PCC during the fault at node *j*, Z_s is the source impedance at PCC, Z_{ij} is the impedance between PCC and fault location *j* and Z_t is the fault impedance. This equation is derived by assuming the pre fault voltages equal to 1 p.u. To study the worst case, Z_t is considered zero.

The voltage sag index can be calculated as

$$\text{Voltage sag index} = \sum_{i=1}^{NPCC} \sum_{j=1}^{n} \left| V_{ij}^{Sag} \right|^2 \qquad (4)$$

where *NPCC* is number of Point of Common Coupling.

According to (4), higher value of voltage sag index means the bus voltages remains higher during the faults and hence shows the improvement in power quality.

III. ARTIFICIAL BEE COLONY (ABC) ALGORITHM

Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honeybees. ABC as an optimization tool provides a population based search procedure in which individuals called food positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. In this algorithm [17], [18], the colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts. First half of the colony consists of the employed artificial bees and the second half includes the onlookers. For every food source, there is only one employed bee. In other words, the number of employed bees is equal to the number of food sources around the hive. The employed bee whose food source has been abandoned becomes a scout [19].

Thus, ABC system combines local search carried out by employed and onlooker bees, and global search managed by onlookers and scouts, attempting to balance exploration and exploitation process [20].

The ABC algorithm creates a randomly distributed initial population of solutions ($f = 1,2,\ldots,E_b$), where 'f' signifies the size of population and 'E_b' is the number of employed bees. Each solution x_f is a D-dimensional vector, where D is the number of parameters to be optimized. The position of a food-source, in the ABC algorithm, represents a possible solution to the optimization problem, and the nectar amount of a food source corresponds to the quality (fitness value) of the associated solution. After initialization, the population of the positions (solutions) is subjected to repeated cycles of the search processes for the employed, onlooker, and scout bees (cycle = 1, 2, …, *MCN*), where *MCN* is the maximum cycle number of the search process. Then, an employed bee modifies the position (solution) in her memory depending on the local information (visual information) and tests the nectar amount (fitness value) of the new position (modified solution). If the nectar amount of the new one is higher than that of the previous one, the bee memorizes the new position and forgets the old one. Otherwise, she keeps the position of the previous one in her memory. After all employed bees have completed the search process; they share the nectar information of the food sources and their position information with the onlooker bees waiting in the dance area. An onlooker bee evaluates the nectar information taken from all employed bees and chooses a food source with a probability related to its nectar amount. The same procedure of position modification and selection criterion used by the employed bees is applied to onlooker bees. The greedy-selection process is suitable for unconstrained optimization problems. The probability of selecting a food-source p_f by onlooker bees is calculated as follows:

$$P_f = \frac{fitness}{\sum_{f=1}^{E_b} fitness_f} \qquad (5)$$

where $fitness_f$ is the fitness value of a solution f, and E_b is the total number of food-source positions (solutions) or, in other words, half of the colony size. Clearly, resulting from using (5), a good food source (solution) will attract more onlooker bees than a bad one. Subsequent to onlookers selecting their preferred food-source, they produce a neighbor food-source position $f+1$ to the selected one f, and compare the nectar amount (fitness value) of that neighbor $f+1$ position with the old position. The same selection criterion used by the employed bees is applied to onlooker bees as well. This sequence is repeated until all onlookers are distributed. Furthermore, if a solution f does not improve for a specified number of times (limit), the employed bee associated with this solution abandons it, and she becomes a scout and searches for a new random food-source position. Once the new position is determined, another ABC algorithm (*MCN*) cycle starts. The same procedures are repeated until the stopping criteria are met.

In order to determine a neighboring food-source position (solution) to the old one in memory, the ABC algorithm alters one randomly chosen parameter and keeps the remaining parameters unchanged. In other words, by adding to the current chosen parameter value the product of the uniform variant [-1, 1] and the difference between the chosen parameter value and other "random" solution parameter value, the neighbor food-source position is created. The following expression verifies that:

$$x_{fg}^{new} = x_{fg}^{old} + u\left(x_{fg}^{old} - x_{mg}\right) \qquad (6)$$

where $m \neq f$ and both are $\in \left\{1,2,\ldots,E_b\right\}$. The multiplier u is a random number between [-1, 1] and $g \in \left\{1,2,\ldots,D\right\}$. In other words, x_{fg} is the g^{th} parameter of a solution x_f that was selected to be modified. When the food-source position has been abandoned, the employed bee associated with it becomes a scout. The scout produces a completely new food source position as follows:

$$x_{fg}^{(new)} = min\left(x_{fg}\right) + u\left[max\left(x_{fg}\right) - min\left(x_{fg}\right)\right] \qquad (7)$$

where (7) applies to all g parameters and u is a random number between [-1, 1]. If a parameter value produced using (6) and/or (7) exceeds its predetermined limit, the parameter can be set to an acceptable value. In this paper, the value of the parameter exceeding its limit is forced to the nearest (discrete) boundary limit value associated with it. Furthermore, the random multiplier number u is set to be between [0, 1] instead of [-1, 1].

Thus, the ABC algorithm has the following control parameters: 1) the colony size CS, that consists of employed bees E_b plus onlooker bees E_b ; 2) the limit value, which is the number of trials for a food-source position (solution) to be abandoned; and 3) the maximum cycle number MCN .

The proposed ABC algorithm for finding size of DG at selected location to minimize the real power loss is as follows:

Step 1: Initialize the food-source positions x_f (solutions population), where $f = 1,2,\ldots,E_b$. The x_f solution form is as follows.

Step 2: Calculate the nectar amount of the population by means of their fitness values using

$$Fitness = \frac{1}{1 + powerloss} \tag{8}$$

Step 3: Produce neighbor solutions for the employed bees by using (6) and evaluate them as indicated by Step 2.

Step 4: Apply the greedy selection process.

Step 5: If all onlooker bees are distributed, go to Step 9. Otherwise, go to the next step.

Step 6: Calculate the probability values P_f for the solutions x_f using (5).

Step 7: Produce neighbor solutions for the selected onlooker bee, depending on the value, using (8) and evaluate them as Step 2 indicates.

Step 8: Follow Step 4.

Step 9: Determine the abandoned solution for the scout bees, if it exists, and replace it with a completely new solution using (7) and evaluate them as indicated in Step 2.

Step 10: Memorize the best solution attained so far.

Step 11: If cycle = MCN, stop and print result. Otherwise follow Step 3.

IV. RESULTS AND ANALYSIS

To check the validity of the proposed ABC algorithm, 69 - bus radial distribution system was considered. The Control parameters of ABC method are colony size (*Cs)* is 30 and *MCN* is 20.The radial distribution feeder has 69- buses with rated voltage of 12.6 kV. The line and load data of this system are considered from [22]. The original total power loss in the system is 224.6056 kW and the minimum voltage is 0.9092 p.u. The typical harmonic spectrum of these nonlinear loads [21] is provided as Table I. Initially, a load flow was run for the case study in both fundamental frequency and harmonics frequencies without installation of DG. Being the most sensitive node, bus 61 [15] is selected as the first candidate location for DG placement in the 69-bus system. Four points of common coupling have been considered (Busses 18, 24, 27, and 58). The results are summarized in Table II.

TABLE I
LOAD COMPOSITION IN TERMS OF HARMONIC SOURCES

Bus number	Harmonic injection current	Order of injected harmonic
9	91 %	3
21	91 %	3
33	80 %	3
48	80 %	3
53	91 %	3

TABLE II
SUMMARY OF TEST RESULTS

Description	Without DG	With DG
DG location		61
DG size (kW)		1877.49
Minimum voltage (p.u)	0.9092	0.9684
Total loss (kW)	224.6056	82.8829
Loss reduction (%)		63.09
Total THD (%)	12.1974	12.0733
Voltage sag index	36.0013	46.0006

The voltage profile of 69-bus system with and without DG is given in Table III, harmonic voltages and THD of 69-bus system without DG and with DG are given in Table IV.

According to this table, the minimum voltage occurs in bus 65 (0.9092 p.u) and the maximum THD takes places in buses 25, 26 and 27 (0.382 %) without DG. the minimum voltage is improved in bus 65 (0.9791 p.u) and the maximum THD reduces in buses 25, 26 and 27 (0.3785 %) with DG.

The results from Table II, installing DG size of 1877.49 kW at bus 61 will reduce the total real power losses from 224.6056 kW to 82.8829 kW. This amounts to a reduction of 63.09% in total power loss. The minimum voltage of the system is improved from 0.9092p.u to 0.9684p.u after DG placement. It can also be seen that the total THD is decreased from 12.1974 % to 12.0733 % and the voltage sag index is improved from 36.0013 to 46.0006. Results of voltages, harmonic voltages and THD of 69-bus system without DG and with DG are shown Table III. Branch losses of the system are shown Fig. 1.

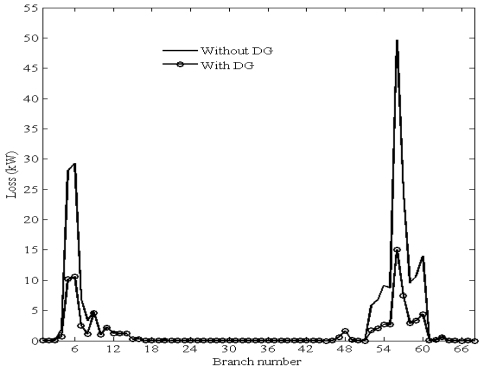

Fig. 1 Branch losses of the 69-bus system

TABLE III
VOLTAGE PROFILE OF 69-BUS SYSTEM

Bus number	Without DG		With DG	
	Voltage (p.u)	Angle (rad)	Voltage (p.u)	Angle (rad)
1	1.0000	0.0000	1.0000	0.0000
2	1.0000	0.0000	1.0000	0.0000
3	0.9999	0.0000	0.9999	0.0000
4	0.9998	0.0001	0.9999	0.0000
5	0.9990	0.0003	0.9994	-0.0001
6	0.9901	-0.0008	0.9952	-0.0035
7	0.9808	-0.0021	0.9908	-0.007
8	0.9786	-0.0024	0.9897	-0.0079
9	0.9775	-0.0025	0.9892	-0.0083
10	0.9725	-0.0039	0.9843	-0.0097
11	0.9714	-0.0043	0.9832	-0.0101
12	0.9682	-0.0052	0.9801	-0.0110
13	0.9653	-0.006	0.9772	-0.0117
14	0.9624	-0.0068	0.9744	-0.0125
15	0.9596	-0.0076	0.9716	-0.0133
16	0.9590	-0.0077	0.971	-0.0134
17	0.9582	-0.008	0.9702	-0.0137
18	0.9582	-0.008	0.9701	-0.0137
19	0.9577	-0.0081	0.9697	-0.0138
20	0.9574	-0.0082	0.9694	-0.0139
21	0.9569	-0.0084	0.9689	-0.0141
22	0.9569	-0.0084	0.9689	-0.0141
23	0.9568	-0.0084	0.9688	-0.0141
24	0.9567	-0.0085	0.9687	-0.0142
25	0.9565	-0.0085	0.9685	-0.0142
26	0.9564	-0.0085	0.9685	-0.0142
27	0.9564	-0.0086	0.9684	-0.0142
28	0.9999	0.0000	0.9999	0.0000
29	0.9999	0.0001	0.9999	0.0001
30	0.9998	0.0000	0.9998	0.0000
31	0.9997	0.0000	0.9998	0.0000
32	0.9997	0.0000	0.9997	0.0000
33	0.9995	-0.0001	0.9995	-0.0001
34	0.9992	-0.0002	0.9992	-0.0003
35	0.9992	-0.0003	0.9992	-0.0003
36	0.9999	0.0001	0.9999	0.0000
37	0.9997	0.0002	0.9998	0.0001
38	0.9996	0.0002	0.9996	0.0002
39	0.9995	0.0002	0.9996	0.0002
40	0.9995	0.0002	0.9996	0.0002
41	0.9988	0.0004	0.9989	0.0004
42	0.9986	0.0005	0.9986	0.0005
43	0.9985	0.0005	0.9985	0.0005
44	0.9985	0.0005	0.9985	0.0005
45	0.9984	0.0005	0.9984	0.0005
46	0.9984	0.0005	0.9984	0.0005
47	0.9998	0.0001	0.9998	0.0001
48	0.9985	0.0009	0.9986	0.0008
49	0.9947	0.0033	0.9947	0.0033
50	0.9942	0.0037	0.9942	0.0036
51	0.9786	-0.0024	0.9897	-0.0079
52	0.9786	-0.0024	0.9897	-0.0079
53	0.9747	-0.0029	0.9887	-0.0098
54	0.9714	-0.0033	0.988	-0.0115
55	0.967	-0.004	0.9872	-0.0138
56	0.9626	-0.0046	0.9864	-0.0162
57	0.9401	-0.0115	0.9843	-0.029
58	0.9291	-0.015	0.9833	-0.0354
59	0.9248	-0.0164	0.9829	-0.0379
60	0.9198	-0.0183	0.9828	-0.0409
61	0.9124	-0.0195	0.982	-0.0451
62	0.9121	-0.0195	0.9818	-0.0451
63	0.9117	-0.0196	0.9814	-0.0452
64	0.9098	-0.0199	0.9796	-0.0454
65	0.9092	-0.0200	0.9791	-0.0455
66	0.9713	-0.0043	0.9832	-0.0101
67	0.9713	-0.0043	0.9832	-0.0101
68	0.9679	-0.0053	0.9798	-0.0111
69	0.9679	-0.0053	0.9798	-0.0111

TABLE IV
RESULTS OF HARMONIC VOLTAGE AND THD OF 69-BUS SYSTEM

Bus number	Without DG	With DG	Without DG	With DG
	Harmonic voltage (p.u)		THD (%)	
1	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0006	0.0006
3	0.0000	0.0000	0.0012	0.0012
4	0.0000	0.0000	0.0025	0.0024
5	0.0001	0.0001	0.0128	0.0127
6	0.0009	0.0009	0.0888	0.0877
7	0.0017	0.0016	0.1699	0.1679
8	0.0019	0.0018	0.1897	0.1876
9	0.0020	0.0019	0.2004	0.1981
10	0.0030	0.0030	0.308	0.3045
11	0.0030	0.0030	0.3107	0.3072
12	0.0031	0.0031	0.3205	0.317
13	0.0032	0.0032	0.3343	0.3308
14	0.0034	0.0033	0.3483	0.3448
15	0.0035	0.0034	0.3626	0.3591
16	0.0035	0.0035	0.3652	0.3617
17	0.0035	0.0035	0.3702	0.3667
18	0.0035	0.0035	0.3703	0.3668
19	0.0036	0.0036	0.3746	0.3711
20	0.0036	0.0036	0.3773	0.3738
21	0.0037	0.0036	0.3818	0.3783
22	0.0037	0.0036	0.3818	0.3783
23	0.0037	0.0036	0.3819	0.3784
24	0.0037	0.0036	0.3819	0.3784
25	0.0037	0.0036	0.3820	0.3785
26	0.0037	0.0036	0.3820	0.3785
27	0.0037	0.0036	0.3820	0.3785
28	0.0000	0.0000	0.0028	0.0028
29	0.0003	0.0003	0.0258	0.0258
30	0.0005	0.0005	0.0502	0.0502
31	0.0005	0.0005	0.0547	0.0547
32	0.0008	0.0008	0.0780	0.078
33	0.0014	0.0014	0.1352	0.1352
34	0.0014	0.0014	0.1353	0.1352
35	0.0014	0.0014	0.1353	0.1353
36	0.0000	0.0000	0.0012	0.0012
37	0.0000	0.0000	0.0012	0.0012
38	0.0000	0.0000	0.0012	0.0012
39	0.0000	0.0000	0.0012	0.0012
40	0.0000	0.0000	0.0012	0.0012
41	0.0000	0.0000	0.0012	0.0012
42	0.0000	0.0000	0.0012	0.0012
43	0.0000	0.0000	0.0012	0.0012
44	0.0000	0.0000	0.0012	0.0012
45	0.0000	0.0000	0.0012	0.0012
46	0.0000	0.0000	0.0012	0.0012
47	0.0000	0.0000	0.0026	0.0025
48	0.0000	0.0000	0.0046	0.0046
49	0.0000	0.0000	0.0046	0.0046
50	0.0000	0.0000	0.0046	0.0046
51	0.0019	0.0018	0.1897	0.1876
52	0.0019	0.0018	0.1897	0.1876
53	0.0020	0.0019	0.2009	0.1986
54	0.0020	0.0019	0.2016	0.1993
55	0.0020	0.0019	0.2025	0.2002
56	0.0020	0.0019	0.2035	0.2011
57	0.0020	0.0019	0.2083	0.206
58	0.0020	0.0019	0.2108	0.2084
59	0.0020	0.0019	0.2118	0.2094
60	0.0020	0.0019	0.2129	0.2105
61	0.0020	0.0019	0.2147	0.2122
62	0.0020	0.0019	0.2147	0.2123
63	0.0020	0.0019	0.2148	0.2124
64	0.0020	0.0019	0.2153	0.2128
65	0.0020	0.0019	0.2154	0.213
66	0.0030	0.0030	0.3107	0.3072
67	0.0030	0.0030	0.3107	0.3072
68	0.0031	0.0031	0.3206	0.3171
69	0.0031	0.0031	0.3206	0.3171

V. CONCLUSION

In this paper a harmonic penetration study and voltage sag calculation has been performed for 69-bus radial distribution network in a power quality oriented. Artificial Bee Colony (ABC) algorithm is proposed to find the optimal size of DG for maximum loss reduction of a radial distribution system. By introducing DG in the system, voltage profile can be improved because DG can provide a portion of the real power to the load locally. The results obtained by the proposed method show that the presence of DG at appropriate location reduces real power loss, total harmonic distortion (THD), voltage sag and improve the voltage profile.

REFERENCES

[1] T. Ackermann, G. Anderson and L. Soder, “Distributed generation: Definition,” Electric power systems research, vol. 57, pp. 195–204, 2001.

[2] T. Ackerman and V. Knyazkin, “Interaction between distributed generation and the distribution network: Operation aspects,” Proceedings of the second international symposium on distributed generation power system market aspects, Stockholm, Sweden, October 2002.

[3] G. Joos, B.T. McGillis, D. Ga, F.D. Liana and R. Marceau, “The potential of distributed generation to provide ancillary services,” Proceedings of the IEEE power engineering society summer meeting, Seattle, WA, pp. 16–20, July 2000.

[4] T. Hoff, H.J. Wenger and B.K. Farmer, “The value of grid-support photovoltaic in providing distribution system voltage support,” Clean power research conference, Napa, CA, 1995.

[5] H.D. Keulenaer, “The Hidden Cost of Poor Power Quality,” European copper institute, pp. 1–7, 2003.

[6] A.E. Emanuel, J. Janczak, D.J. Pileggi and E.M. Gulachenski, “Distribution feeders with nonlinear loads in the NE USA: Part I - Voltage distortion forecast,” IEEE Truifs. Power Delev, vol.10, pp. 340-347, January 1995.

[7] A.W. Mansoor, M. Grady, A.H. Chowdhury and M.J. Samotyj, “An investigation of harmonics attenuation and diversity among distributed single-phase power electronic loads,” IEEE Transaction on power delivery, vol. 10, pp. 467-473, January 1995.

[8] N.S. Rau and Y.H. Wan, “Optimum location of resources in distributed planning,” IEEE Transaction on power system, pp.14–20, 1994.

[9] J.O. Kim, S.W. Nam, S.K. Park, and C. Singh, “Dispersed generation planning using improved hereford ranch algorithm,” Electrical power system research, 1998.

[10] C. Wang and M. Nehrir hashem, “Analytical approaches for optimal placement of distributed generation sources in power systems,” IEEE Transaction on power system, pp.2068–2076, 2004.

[11] P. Chiradeja, “Benefit of distributed generation: a line loss reduction analysis,” IEEE/PES transmission and distribution conference & exhibition: Asia and Pacific, China Dalian; pp. 1–5, 2005.

[12] N. Mithulananthan, O. Than and Phu Le Van, “Distributed generator placement in power distribution system using genetic algorithm to reduce losses,” Thammasat Int J science technology, pp. 55–62, 2004.

[13] G. Celli, E. Ghiani, S. Mocci and F. Pilo, “A multi objective evolutionary algorithm for the sizing and sitting of distributed generation,” IEEE Transaction power system, pp.750-757, 2005.

[14] K. Nara, Y. Hayashi, K. Ikeda and T. Ashizawa, “Application of tabu search to optimal placement of distributed generators,” IEEE PES Winter meet, pp.918-923, 2001.

[15] T.N. Shukla, S.P Singh, Srinivasarao and K.B. Naik, “Optimal sizing of distributed generation placed on radial distribution systems,” Electric power components and systems, Vol. 38, pp. 260-274, 2010.

[16] P. Heine, M. Lehtonen, “Voltage sag distributions caused by power system faults,” IEEE Transactions on power systems, vol.18, pp.1367–1373, 2003.

[17] Dervis karaboga and Bahriye basturk, “Artificial bee colony (ABC) optimization algorithm for solving constrained optimization problems,” Springer-verlag, IFSA 2007, LNAI 4529, pp. 789–798, 2007.

[18] D. Karaboga and B. Basturk, “On the performance of artificial bee colony (ABC) algorithm,” Elsevier applied soft computing, vol. 8, pp.687–697, 2007.

[19] S. Hemamalini and P. Sishaj simon, “Economic load dispatch with valve-point effect using artificial bee colony algorithm,” xxxii national systems conference, NSC 2008, pp.17-19, 2008.

[20] S. Fahad, Abu-mouti and M. E. El-Hawary “Optimal distributed generation allocation and sizing in distribution systems via artificial bee colony algorithm,” IEEE transactions on power delivery, Vol. 26, No. 4, 2011.

[21] Saeed Jazebi, Behrooz Vahidi “Reconfiguration of distribution networks to mitigate utilities power quality disturbances,” Electric power system research, pp. 9-17, 2012.

[22] N. Rugthaicharoencheep, S. Sirisumrannukul, “Feeder reconfiguration with dispatchable distributed generators in distribution system by tabu search,” Universities power engineering conference (UPEC), IEEE Proceedings of the 44th International conference, pp. 1-5, 2009.