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Optimum location and sizing of Distributed Generator and capacitor in a Power Distribution Network using Genetic Algorithm

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Abstract— **The work presents a novel method which is used for determining the optimum placement of a Distributed Generator in a Distribution Network for improving the average voltage simultaneously reducing the system losses. Program for optimum placement of Distributed Generator and capacitor using Genetic Algorithm has been implemented on a modified 24 bus Hassan Water Works Power System and the results are shown to be encouraging. It is hoped that the method presented will help to improve the voltage profile and system efficiency especially for rural areas where the long distribution lines are seen.**

Index Terms—**Artificial Intelligence Techniques, Distributed Generator, Genetic Algorithm, Load Flow, Newton Raphson, Power Distribution Network, Renewable Energy Sources.**

I. INTRODUCTION

Voltage control is a very important aspect in power system. Operational Voltage ratings of the different buses in the power system including the generating buses, switching substation buses, receiving substation buses and distribution substation buses should be within the allowable limits for satisfactory operation of all the electrical equipments. There are many voltage control methods in use in power system to keep the voltage levels within the enviable limits. The voltage control is mandatory because both, the purchaser and the power system apparatus are intended to operate within a range of voltages. At low voltages, various types of equipments perform poorly in terms of life span and reliability [1].

These methods suffered from long duration of computation with less accuracy. Therefore new techniques for optimization called the "Artificial Intelligence Techniques" of following types are used for better results [2].

- Genetic algorithm
- Evolution strategies
- Particle swarm optimization
- Ant colony optimization
- Bee colony optimization
- Fuzzy logic optimization

Renewable sources have been used very frequently because there is less environmental pollution, small size, less cost and a very good impact.

II. Methodology

The method developed for the improvement of power quality, Genetic Algorithm (GA) has been used for optimization. The fitness function has been calculated using a developed Newton Raphson method. The GA is as described below [5]:

1. Choose the population of size (50-100). The population will consist of strings. Strings are also called as schemata.
2. Initialize each schema with random values as follows
 t1 = bus number at which DG has to be placed (range 2 to 24)
 t2 = Size of DG (range 0.1 to 2.1)
 t3 = bus number at which the capacitor has to be placed (range 2 to 24)
 t4 = capacitor capacity (range 0.3 to 0.5)
3. In initial population, t1, t2, t3 and t4 are randomly selected within the range and the desired numbers of strings are formed. This is the's' matrix.
4. Run the Newton Raphson load flow on these strings and the average voltage and system losses are obtained. The fitness function is defined and the fitness function is obtained for all the strings. The fitness function is given by

$$F = Vavg + (1/Sys\_Loss)$$

5. The Roulet wheel selection is performed on the strings, and the new population is obtained. In this process, the weaker strings are replaced by the strong ones. The string of 360/ (n/2) is replaced by 360/n + 360/ (n/2), 'n' being the number of strings.
6. The crossover is done after the roulette wheel. In crossover, out of the total number of strings (50), only 20 strings are involved to form the next new population.
7. Perform the load flow again with the new population to find the fitness function.
8. Repeat the above steps 2 to 7 till convergence. The convergence point is that point where the values of fitness function, average voltage and system loss reach a maximum constant value.
9. Find the maximum value of fitness function 'F'. The combination, in which the fitness function is maximum, is the optimum place for the placement of DG and capacitor.

The single line diagram of 24 bus radial system is as

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shown below.

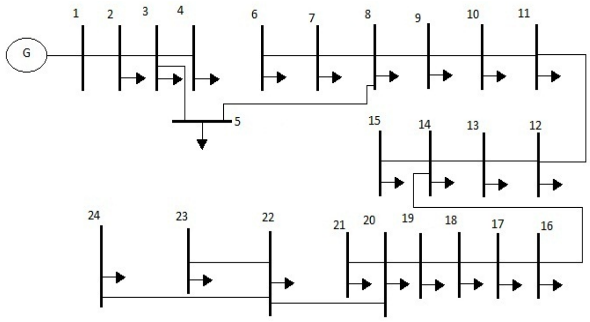

Figure1. Single line diagram of 24 bus radial system

After running the Genetic Algorithm for the power system shown above, the results are tabulated as follows:

TABLE I
BUS VOLTAGE MAGNITUDES FOR ALL THE BUSES BEFORE AND AFTER PLACING THE DG IN PER UNIT VALUES

Bus no.	Voltage before placing the DG (p.u.)	Voltage after placing the DG (p.u.)
1	1.0600	1.0600
2	1.0002	1.0213
3	0.9664	1.0007
4	0.9658	1.0010
5	0.9394	0.9843
6	0.8935	0.9560
7	0.8936	0.9561
8	0.8982	0.9605
9	0.8895	0.9559
10	0.8694	0.9464
11	0.8685	0.9460
12	0.8421	0.9344
13	0.8295	0.9290
14	0.8192	0.9248
15	0.8188	0.9244
16	0.8087	0.9216
17	0.7937	0.9208
18	0.7777	0.9205
19	0.7635	0.9209
20	0.7204	0.9233
21	0.7201	0.9231
22	0.6619	0.9323
23	0.6566	0.9286
24	0.6574	0.9291

In Figure 2, the bus voltage magnitudes before and after placing the DG are shown. The blue bar represents the voltage before placing the DG and the maroon bar represents the voltage after placing the DG. It is clearly seen that after placing the DG, the voltage profile improves [6].

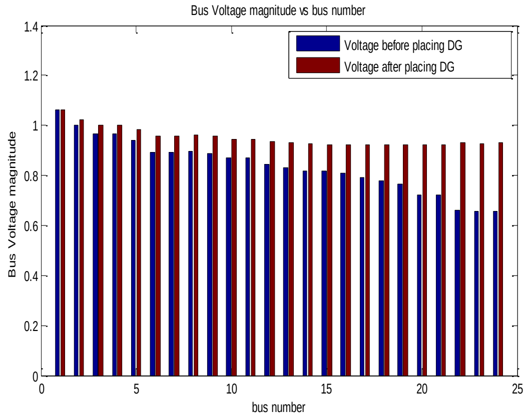

Figure 2. Bus voltage magnitudes before and after placing DG

Figure 3 shows the rise in the fitness value in steps. GA gives 3.6 for 5 iterations, it increases till 3.7 for 10 iterations and finally it increases till 3.94 and remains constant, that is it converges at the end of 11th iteration. After 11th iteration, the value is found to be constant and the further improvement in the fitness value is not seen indicating GA has searched the optimum values and converged [7].

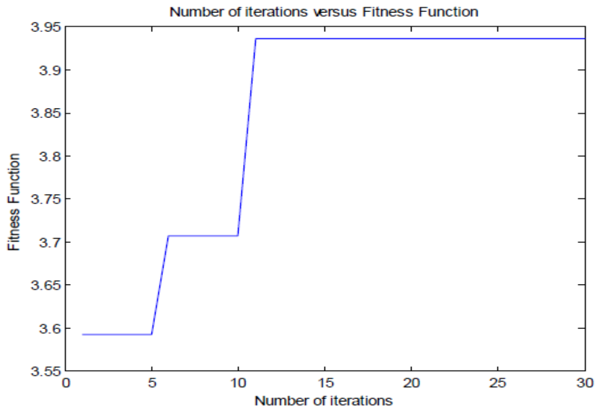

Figure 3. Convergence of Fitness Function values

Figure 4 shows the rise in the average voltage in steps. GA gives 0.944 for 5 iterations, and then it increases till 0.942 for 10 iterations and finally it reaches 0.9508 and converges at the end of 11th iteration [8]. After the 11th iteration, the value is found to be constant and the further improvement in the average voltage is not seen indicating GA has searched the optimum values [9].

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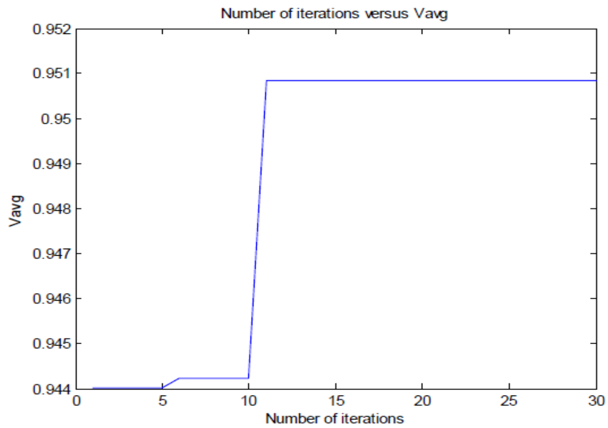

Figure 4. Convergence of Voltage values

Figure 5 shows the drop in the system loss in steps [10]. GA gives 0.375 for 5 iterations, then gives 0.36 for 10 iterations and finally it reaches the value 0.335 at 11th iteration and converges showing that there is no further improvement in the system loss indicating GA has searched the optimum values [11].

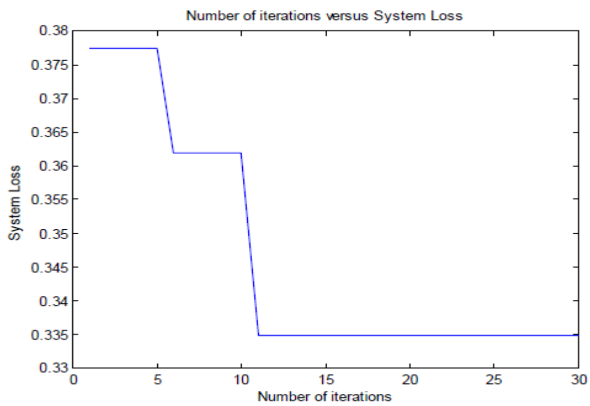

Figure 5. Convergence of System loss

The optimum place and size of the DG is
Optimum bus to place the DG = 22
Generator Capacity = 1.2p.u.

It is observed that with the placement of DG, the average voltage and system losses have been improved, but to further improve the average voltage and reduce the system loss, placement of capacitor is done [12]. Simultaneous placement of DG and capacitor gives the best results. After running the Genetic Algorithm with DG and capacitor, the following results of voltages are obtained [13].

TABLE II
BUS VOLTAGE MAGNITUDES FOR ALL THE BUSES WITH DG AND CAPACITOR IN PER UNIT VALUES

Bus no.	Voltage before placing the capacitor (p.u.)	Voltage after placing the capacitor (p.u.)
1	1.0600	1.0600
2	1.0213	1.0289
3	1.0007	1.0121
4	1.0010	1.0115
5	0.9843	0.9993
6	0.9560	0.9774
7	0.9561	0.9775
8	0.9605	0.9817
9	0.9559	0.9786
10	0.9464	0.9725
11	0.9460	0.9722
12	0.9344	0.9654
13	0.9290	0.9624
14	0.9248	0.9601
15	0.9244	0.9598
16	0.9216	0.9597
17	0.9208	0.9631
18	0.9205	0.9674
19	0.9209	0.9722
20	0.9233	0.9846
21	0.9231	0.9844
22	0.9323	1.0084
23	0.9286	1.0049
24	0.9291	1.0055

In Figure 6, the bus voltage magnitudes before and after placing the capacitor are shown [14]. The blue bar represents the voltage before placing the capacitor and the maroon bar represents the voltage after placing the capacitor. It is clearly seen that after placing the capacitor, the voltage profile improves [15, 16, 17 and 18].

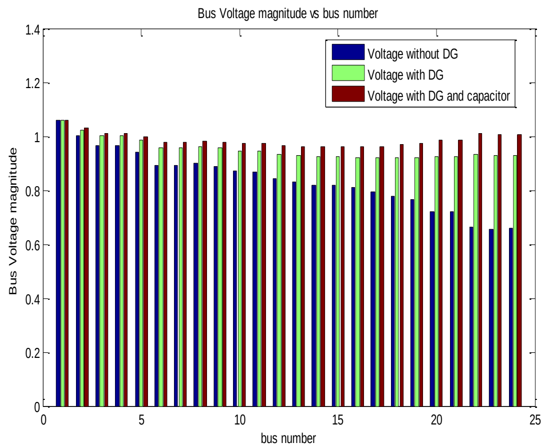

Figure 6. Bus voltage magnitudes with DG and capacitor

The optimum place of DG and capacitor and their size is
Bus no. to place the DG = 22
Generator capacity = 1.6p.u.
Bus no. to place the capacitor = 19
Capacitor capacity = 0.5p.u. [19, 20].

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CONCLUSIONS

In the work presented, it is shown that by placing a DG optimally, it is possible to improve the performance of Distribution Network in terms of improved average voltage and reduced loss.

It is shown that without DG, the average voltage was 0.8381p.u. and the system loss was 1.2277p.u., after placing the DG at bus no. 22 with generator capacity of 1.2p.u., the average voltage improved to 0.9508p.u. and system loss reduced to 0.3349p.u. Further, after placing the DG at bus no. 22 with generator capacity of 1.6 p.u. and capacitor at bus no. 19 with capacity 0.5p.u., the average voltage was 0.9862p.u. and system loss reduced to 0.2202p.u. In the present work, network performance has been shown to improve by the inclusion of a single DG and capacitor optimally. In future work, it can be extended for the inclusion of multiple DG's and capacitors. The work can be extended for further investigation of optimum DG placement with regard to optimum system security as well [21].

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