

Introducing Distribution Generation in Distribution Network

Rajesh Kumar Samala* and N. Ramaraj**

Abstract: By introducing Distributed Generation (DG) in distribution network we can find lot of advantages. With DGs including there is a minimization of power losses (active & reactive) and voltage profile improvement etc., By optimally sized and sited DGs in the network we can attain the above mentioned advantages. This paper presents a Distribution Generation (DG) allocation method in radial distribution network using Genetic Algorithm (GA). The aim is to reduce active power losses and compensating reactive power while keeping the best voltage profiles in the system within specified limits. The recommended scheme is programmed using MATLAB software. In GA randomly generates initial population, determines system losses and bus voltages of every population member by means of power flow calculation remain the member with the best configuration as a reference and re-generate the new population for the next iteration based on the current population and based on the reference. The proposed algorithm is tested on 33 bus radial distribution network. The simulation result shows that power loss in distribution network.

Keywords: Radial distribution system, Power losses, Voltage profile, GA.

1. INTRODUCTION

In DG placement problem, DG placements and sizes must be selected in such a way that we should achieve the best efficient and economical distribution network. In general distribution network has as many nodes and it is very difficult to find out the best DG siting and sizing by manual. There are various optimization methods used in the literature. In many of the present techniques, population based evolutionary algorithms are used as optimization techniques they are Particle Swarm Optimization (PSO), Evolutionary Programming (EP), Genetic Algorithm (GA) [1], etc.,

In general the DG units are mainly the Non-conventional energy sources, is affected by different factors or uncertainties such as wind speed, solar radiation, environmental factors, geographical topography, political factors, etc. For example, solar radiation may not be available same throughout the year and round the clock and wind generators or turbines cannot be located near residential places, because of the interference in the form of public reactions and legislations from environmental organizations. Another trouble is application of the Plug-in Electric Vehicle (PEV) which should need more concentration. Though, there are different factors or uncertainties that can possibly lead to probable risks in determining the best siting and sizing of DGs in distribution network [2]. Some of the factors or uncertainties are possibility output power of a PEV due to its alteration of charging/discharging schedule [3], in wind power generation because of frequent changes in wind velocity, in a solar power generation because of the possibility radiation intensity, unstable fuel prices and future unsure load increase. The most necessary uncertainty to account for the time-varying characteristics of both generation and demand of power are these increasing introductions of variable non-conventional generators with wind power, being the most essential of them.

2. CALCULATION OF LOAD FLOW

Let us assume a flat voltage profile i.e., at each node set the voltage value equals to 1.0 pu, and the flow chart for load flow is shown in Figure 1. The updated effective load flows in every branch are obtained

* Ph.D. Scholar, Dept. of EEE, Vignan University, Vadlamudi, Guntur, A.P, India. Email: rajeshkumar_samala@yahoo.co.in

** Professor, Dept. of EEE, Vignan University, Vadlamudi, Guntur, A.P, India. Email: ramaraj_gm@yahoo.com

using equations (1) and by considering the node voltages of the previous iteration. The purpose of the forward sweeping is to find the voltages at every node and their angles using equation (2) starting from the feeder source node.

$$P_{i+1} = \sum_{j=i+1}^{NB} PL_j + \sum_{j=i+1}^{NB-1} LP_j \quad \text{for } i = 1, 2, 3, \dots, NB-2$$

$$Q_{i+1} = \sum_{j=i+1}^{NB} QL_j + \sum_{j=i+1}^{NB-1} LQ_j \quad \text{for } i = 1, 2, 3, \dots, NB-2 \quad (1)$$

$$V_{i+1} = [\{P_{i+1}R_i + Q_{i+1}X_i - 0.5|V_i|^2\}^2 - (R_i^2 + X_i^2)(P_{i+1}^2 - (R_i^2 + X_i^2)(P_2^2 + Q_2^2))^{1/2} + Q_{i+1}X_i - 0.5|V_i|^2]^{1/2} \quad (2)$$

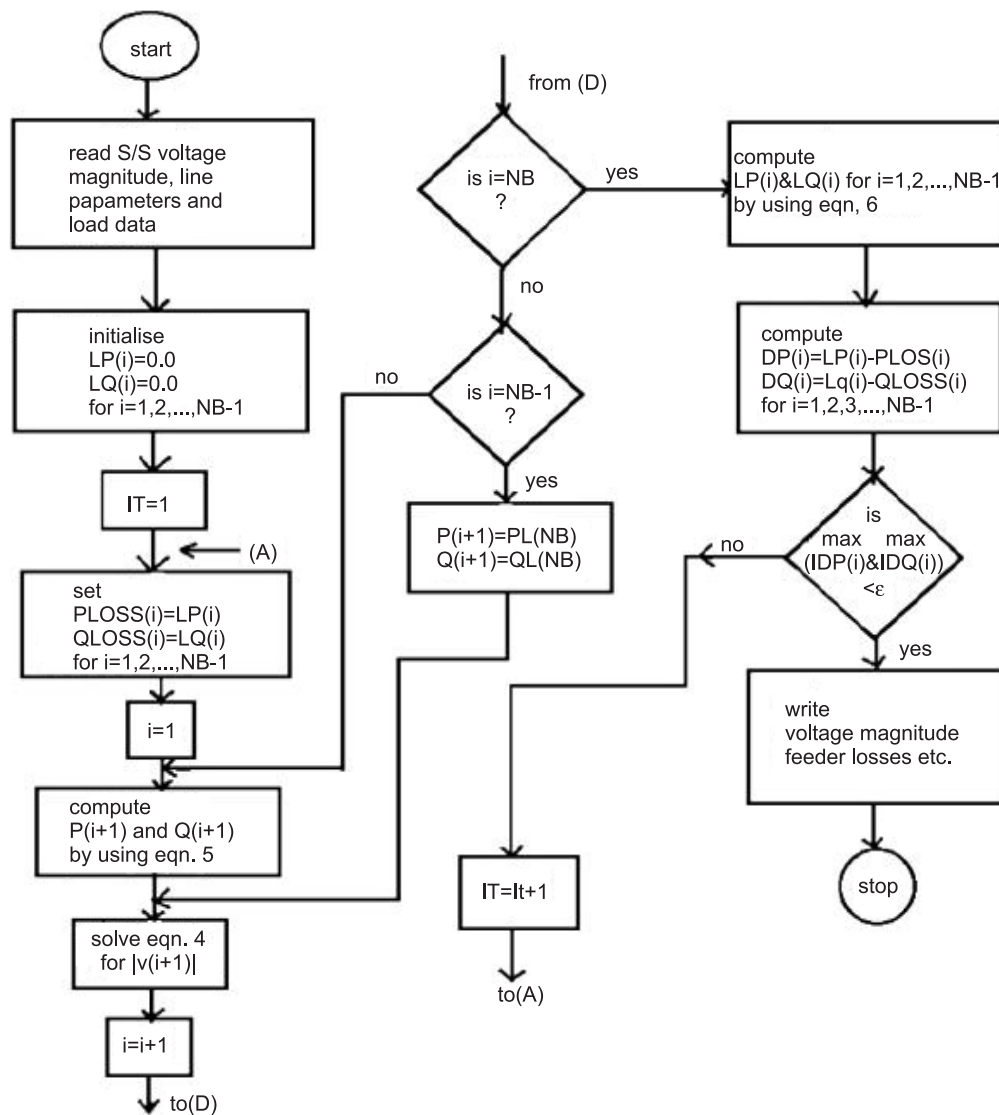


Figure 1: Flow chart for the algorithm of radial distribution network

The algorithm for load flow is as follows:

Step 1: Read the number of buses and nodes in the given system. Read the line resistance and reactance for all the branches. Read real and reactive power at all the nodes.

Step 2: Initialize all the variables.

Step 3: Set the convergence criteria i.e. tolerance, $\text{tol} = 0.1$.

Step 4: Set the real and reactive power for all the nodes to zero. $\text{Loss}_{ap}(i) = 0$; $\text{Loss}_{aq}(i) = 0$

Step 5: Set the bus count $k = 1$.

Step 6: Set initially $P_{\text{aloss}}(i) = \text{Loss}_{ap}(i)$; $Q_{\text{aloss}}(i) = \text{Loss}_{aq}(i)$;

Step 7: Set the bus count $i = 1$.

Step 8: Find the total real and reactive power at the node $(i + 1)$, by utilizing equations 1.

Step 9: Find the voltage at every nodes at $(i + 1)$ node, i.e. $|V_{a(i+1)}|$ by utilizing equation 2.

Step 10: Advance the bus count by 1, i.e. $i = i + 1$.

Step 11: Check whether bus count $i = \text{NB}$ or not, if yes go to step 3 otherwise go to next step.

Step 12: Check whether bus count $i = (\text{NB}-1)$ or not, if yes set $P_{a(i+1)} = P_{\text{aload}(\text{NB})}$ · $Q_{a(i+1)} = Q_{\text{aload}(\text{NB})}$. Then go to step 3 otherwise go to step 8.

Step 13: Determine the real and reactive power losses at the i^{th} node $\text{Loss}_{ap}(i)$, $\text{Loss}_{aq}(i)$.

Step 14: Determine the difference of real and reactive power losses at all the nodes. $D_{ap}(i) = |\text{Loss}_{ap}(i) - P_{\text{aloss}}(i)|$ $D_{aq}(i) = |\text{Loss}_{aq}(i) - Q_{\text{aloss}}(i)|$ For $i = 1, 2, \dots, (\text{NB}-1)$.

Step 15: Check whether $|D_{ap}(i)|_{\text{max}}$ and $|D_{aq}(i)|_{\text{max}}$ is less than the convergence criteria. If yes go to next step, otherwise go to step 6.

Step 16: Note the voltage magnitude at every node and also note the real and reactive power losses at every node. Note the number of iterations taken.

Step 17: Stop.

Distribution Systems Algorithm for Load Flow

The algorithm steps for load flow solution of distribution network is given as:

Step 1: Read the distribution network line data and bus data.

Step 2: Find the every node current or node current injection matrix. The relationship can be expressed as $-[I] = [S/V]^* = [(P - jQ)/V]^*$

Step 3: Find the Bus Injection to Bus Current (BIBC) matrix.

Step 4: Determine the branch current by using BIBC matrix and current injection matrix. The relationship can be expressed as $-[IB] = [\text{BIBC}] [I]$

Step 5: Form the Branch Current to Bus Voltage (BCBV) matrix. The relationship therefore can be expressed as $-[\Delta V] = [\text{BCBV}] [IB]$

Step 6: Determine the Direct Load Flow (DLF) matrix. The relationship will be:

$$[\text{DLF}] = [\text{BCBV}] [\text{BIBC}] \text{ and } [\Delta V] = [\text{DLF}] [I]$$

Step 7: Set Iteration $k = 0$.

Step 8: Iteration $k = k + 1$.

Step 9: Update voltages by using equations

$$I_i^k = I_i^r(V_i^k) + jI_i^i(V_i^k) = [(P_i + jQ_i)/V_i^k]^* \text{ and } [\Delta V^{k+1}] = [\text{DLF}] [I^k] \text{ and } [V^{k+1}] = [V^0] + [\Delta V^{k+1}]$$

Step 10: If $\max [(|V(k+1)| - |V(k)|) > \text{tolerance}]$ go to step 6.

Step 11: Find branch currents and losses from final node voltages.

Step 12: Display the node voltage magnitudes and angle, branch currents and losses.

Step 13: Stop

The above algorithm steps are shown in Flowchart given in Figure 2.

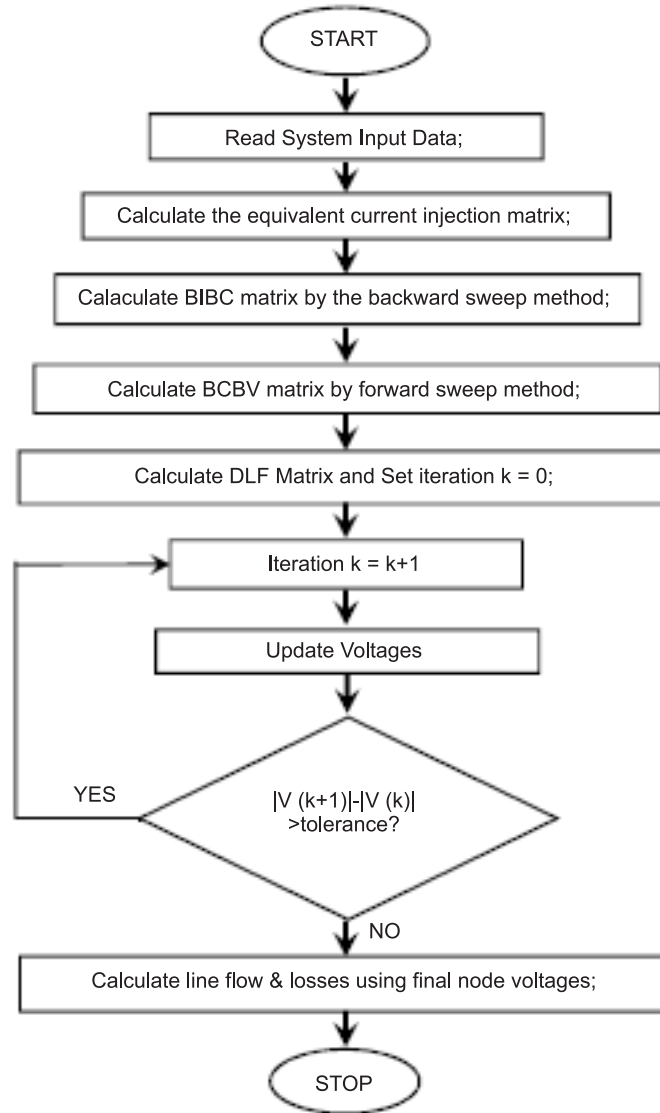


Figure 2: Flowchart for load flow solution for radial distribution network

3. DG INTEGRATION IN TO LOAD FLOW

Let us assume that a one end radial distribution network with N branches and a DG is to be placed at node i and α be a set of branches connected between the source and node i . It is known that, the DG supplies active power (P_{Gi}^{DG}) to the networks, but in case of reactive power (Q_{Gi}^{DG}) it is depend upon the source of DG, either it is supplies to the networks or consume from the systems. Because of this active and reactive power an active current ($I_{DG_i}^r$) and reactive current ($I_{DG_i}^i$) flows through the system and it changes the active and reactive component of current of branch set α . The current of other branches are unaffected by the DG.

Total Apparent Power at i^{th} node:

$$S = S_{D_i} = \sum P_{D_i} + jQ_{D_i} \quad i = 1, 2, 3, \dots, N_B \quad (3)$$

Current at i^{th} node:

$$I_D = I_{D_i}^{\text{without_DG}} = (S_{D_i}/V_i)^* \quad (4)$$

To interconnect the DG system, the active and reactive power demand at i^{th} node at which a DG unit is located, is modified by:

$$\begin{aligned} P_{D_i}^{\text{with_DG}} &= P_{D_i}^{\text{without_DG}} - P_{G_i}^{\text{DG}} \\ Q_{D_i}^{\text{with_DG}} &= Q_{D_i}^{\text{without_DG}} - Q_{G_i}^{\text{DG}} \end{aligned} \quad (5)$$

DG power at i^{th} node:

$$S_{DG_i} = \sum P_{G_i}^{\text{DG}} + jQ_{G_i}^{\text{DG}} \quad i = 1, 2, \dots, N_B \quad (6)$$

Total new apparent power at i^{th} node:

$$S = S_{D_i} - S_{DG_i} \quad (7)$$

So, new current at i^{th} node:

$$I_D = I_{D_i}^{\text{with_DG}} = [(S_{D_i} - S_{DG_i})/V]^* \quad (8)$$

Now the updated system power can be expressed in matrix form

$$[S] = [S_{Di}] - [S_{DG_i}] \quad (9)$$

Genetic Algorithm

Evolutionary calculation was introduced in the 1960s by I. Rechenberg in his work “Evolution methods”. His idea was then developed by other researchers. Genetic Algorithms (GAs) were invented by John Holland at the University of Michigan. This led to Holland’s book “Adaptation in Natural and Artificial Networks” published in 1975. The objectives of their research have been twofold: (1) to abstract and rigorously explain the adaptive processes of natural systems and (2) to design artificial systems software that retains the important mechanisms of natural systems. The essential idea of research on Genetic Algorithms has been robustness, the balance between efficiency and efficacy necessary for survival in several different environments. In 1992 John Koza has used Genetic Algorithm to develop programs to perform certain tasks. He called this method “Genetic Programming” (GP).

Traditional Algorithms vs GA

Genetic Algorithms are different from general optimization and search methods as given below:

1. GAs work with coding of the parameter set, not the parameters themselves.
2. GAs search from a population of points, not a single point.
3. GAs use probabilistic transition rules, not deterministic rules.

Description of Genetic Algorithm

The Genetic Algorithm is a search algorithm that iteratively transforms a set (called a population) of mathematical objects (typically fixed-length binary character strings), each with an associated fitness value,

into a new population of offspring objects using the Darwinian principle of natural selection and using operations such as crossover (sexual recombination) and mutation [4].

Algorithm for DG Allocation

A set of steps have been mentioned beneath to tackle the DGs location difficulty:

Step 1: Read the distribution networks line data and bus data (i.e. branch impedance, real and reactive power of every load node) and specify the DG parameters.

Step 2: Run load flow analysis of distribution networks and save every node voltage and every branch current magnitudes of the networks and total power loss.

Step 3: Set GEN = 0

Step 4: Randomly generate the initial population. Where the chromosomes are representing the randomly generated values of tap number, tap positions, tap settings, DGs number, DG positions, and DG active power value, etc.

Step 5: Decode the initial population and update the load-data and bus-data (i.e. tap settings, and DG ratings) to the systems matrixes according to their respective positions.

Step 6: Run the load flow analysis of distribution networks with updated system data. Also find total power loss for each population.

Step 7: Find the objective function and the fitness value for each and every chromosome.

Step 8: Perform the elitism and save the population.

Step 9: GEN = GEN + 1

Step 10: Prepare the generate pool from starting population by utilizing Roulette Wheel Selection method.

Step 11: Perform crossover on the every mating chromosome pair and generate one offspring from every parent's chromosome pair;

Step 12: Perform mutation on the offspring produced by the crossover operation.

Step 13: Decode the set of offspring and determine the DG siting and sizing for every chromosome.

Step 14: Run load flow for each offspring to determine the objective function and assign fitness to every offspring.

Step 15: Perform the elitism and select the η_{pop} perfect chromosome from the current population and the offspring's. Replace the initial population by selected perfect population and use it for the next generation.

Step 16: Go to step 9, till the solution converges.

Step 17: Stop

The standard optimization methodology of DG siting difficulty is shown in flowchart in Figure 3.

4. CASE STUDY AND RESULT

IEEE 33 bus network includes 33 nodes and 32 branches shown in Figure 4. The base voltage for this network is 12.66 KV and base MVA is 10. The tolerance is 0.00001p.u. and number of iteration needed is 2. Bus voltage magnitudes in p.u. and phase angle in degree at every bus are shown in Table 1 and real and reactive line losses in every branch in KW and KVAR respectively, are shown in Table 2. Voltage profile of the system is shown in Figure 5.

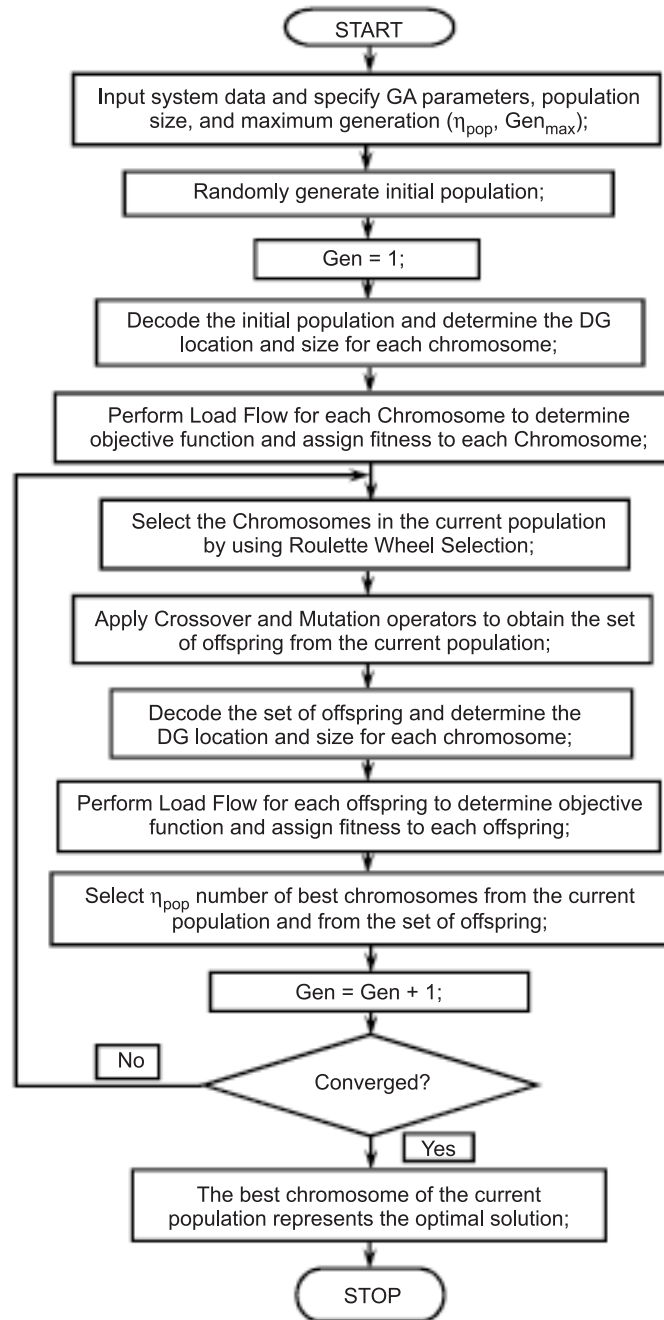


Figure 3: Flowchart of DG allocation with basic Genetic Algorithm

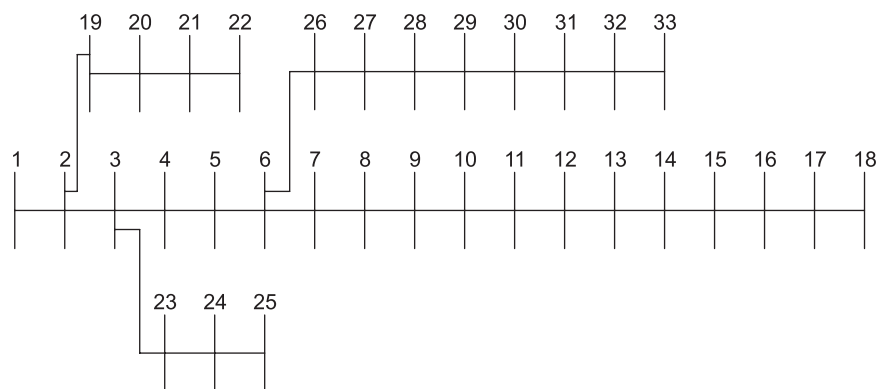


Figure 4: Distribution system of IEEE 33 bus

Table 1
Voltage magnitude and Phase angle of IEEE 33 bus network

<i>Bus Number</i>	<i>Voltage Magnitude (pu)</i>	<i>Phase angle (degree)</i>
1	1.0000	0
2	0.9972	0.0147
3	0.9839	0.0904
4	0.9770	0.1516
5	0.9701	0.2138
6	0.9531	0.1275
7	0.9498	-0.0864
8	0.9373	-0.2323
9	0.9316	-0.3029
10	0.9262	-0.3637
11	0.9254	-0.3575
12	0.9241	-0.3476
13	0.9185	-0.4349
14	0.9164	-0.5085
15	0.9151	-0.5439
16	0.9139	-0.5660
17	0.9120	-0.6380
18	0.9115	-0.6472
19	0.9967	0.0039
20	0.9931	-0.0629
21	0.9924	-0.0821
22	0.9918	-0.1024
23	0.9804	0.0606
24	0.9739	-0.0257
25	0.9707	-0.0681
26	0.9513	0.1644
27	0.9489	0.2169
28	0.9384	0.2978
29	0.9308	0.3731
30	0.9276	0.4713
31	0.9238	0.3959
32	0.9229	0.3752
33	0.9227	0.3683

Table 2
Active and Reactive line losses of IEEE 33 bus network

<i>Branch</i>		<i>Active Line Losses (kW)</i>	<i>Reactive Line Losses (kVAR)</i>
<i>Sending End</i>	<i>Receiving End</i>		
1	2	11.0729	5.5365
2	3	45.9580	23.4266
3	4	17.1532	8.7271
4	5	16.0729	8.1715
5	6	32.7726	28.2832

Branch		Active Line Losses (kW)	Reactive Line Losses (kVAR)
Sending End	Receiving End		
6	7	1.6564	5.4647
7	8	9.9722	7.1990
8	9	3.5476	2.5490
9	10	3.0097	2.1359
10	11	0.4685	0.1562
11	12	0.7434	0.2446
12	13	2.2398	1.7630
13	14	0.6118	0.8055
14	15	0.2989	0.2657
15	16	0.2353	0.1717
16	17	0.2098	0.2803
17	18	0.0443	0.0347
18	19	0.1583	0.1521
19	20	0.8197	0.7386
20	21	0.0989	0.1156
21	22	0.0429	0.0567
22	23	3.0101	2.0494
23	24	4.8474	3.8260
24	25	1.2097	0.9457
25	26	2.2211	1.1368
26	27	2.8235	1.4357
27	28	9.5845	8.4535
28	29	6.6364	5.7771
29	30	3.2984	1.6752
30	31	1.3406	1.3252
31	32	0.1795	0.2090
32	33	0.0111	0.0172

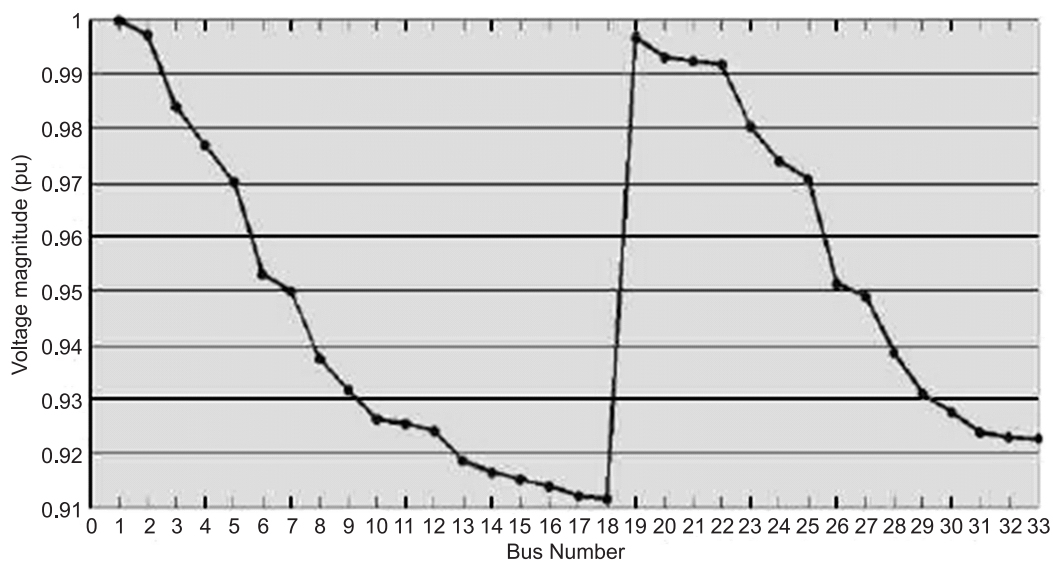


Figure 5: Voltage profile of IEEE 33 bus network

5. CONCLUSIONS

The siting and sizing of DG units in power distribution networks is becoming more important. Therefore, utility companies have started to change their electric infrastructure to adapt to DGs because of the advantages of DG siting and sizing on their distribution networks. These advantages consist of minimizing power losses, improving voltage profiles, minimizing emission impacts and improving power quality. Other advantages are avoiding upgrading the present power networks and preventing a minimization of T&D system capacity during the planning phase. However, achieving these advantages depends highly on the capacity of the DG units and their locating placement in the distribution networks. In this work, an innovative approach for management of DG power is represented. The load flow difficulty has been solved by GA load flow strategy.

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