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Application of GA in Distribution System

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Abstract: Power loss minimization is an important aspect in distribution System where the load variation is more compared other systems. There are different methods to minimize the power loss like DG placement, capacitor placement, load balancing etc. Among those methods DG placement was much beneficial because it is directly related to real power loss. This paper is based on power loss minimization by the placement of distributed generators (DG) in distribution system. The location of DG is found with the help of voltage stability index (VSI) and DG size is varied in small steps and corresponding power loss is calculated by running the power flow and the result obtained is verified by genetic Algorithm. The simulation study is carried out on a 33 bus Distribution System by considering different load models.

Key words: Distributed generation % Voltage stability index

INTRODUCTION

In the modern world, day by day the load demand increases rapidly due to Industrial and Domestic needs. On the other hand the conventional energy sources are decreasing rapidly. In this case we need an alternative method to meet the load demand, distributed generation is meant for that. It has huge potential benefits about which this paper is concerned.

The distributed generation has been defined by many researchers [1, 2], but in general a distributed generation is nothing but a small generator which is connected at the consumer terminal. Placement of DG is an important factor because improper location may leads voltage instability and power loss. The Newton Rapson load flow method used in [3]. This method reduces the power loss and the cost factor very effectively, but the conventional method of load flow analysis was not applicable for distribution system because of its high R/X ratio, large value of resistance and reactance of the line and radial structure of the distribution system.

Tuba Gozel used loss sensitivity factor for determination of the optimal size and location of DG to minimize total power loss [4]. Andrew used Linear Programming Technique for placement of DG with multiple constraints [5]. Mallikarjuna used Simulated Annealing for determining the optimal location and size of DG units in a microgrid, given the network configuration and heat and power requirements at various load points [6]. Krueasuk used PSO to find optimal location and size of DG [7]. Lalitha used fuzzy approach to find optimal DG localization [8].

Hughifam used multi-objective function to minimize cost of energy losses, Investment cost of DG and Operation and maintenance cost [9]. Ochoa minimized real power loss and simple phase short circuit level [10]. Celli used multi objective approach, based on the non-dominated sorbing Genetic Algorithm has been adopted to solve the optimal placement of different types of generation simultaneously. He saved the energy in the form of greenhouse gas emission reduction [11]. Vinoth Kumar addressed minimizing the multi objective index using genetic algorithm for the optimal Placement of DG [12].

This paper minimizes the Power loss by the Placement of optimal size of DG and is organized as follows: Section-I: Defines the Objective Function. Section-II: The load flow analysis of distribution system by Power flow is a crucial part of power system design procedures and it is categorized into transmission power flow and distribution power flow. The distribution networks commonly have some special features such as: Unbalanced loads and unbalanced operation; being radial with sometimes weakly-meshed topology; and high resistance to reactance R/X ratios. Due to these features the conventional load flow like gauss sedial and Newton

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Rapson fail to solve. Hence we need a special method to solve the load flow on Distribution Systems, here network Topological based load flow has been considered for load flow Analysis [13, 14]. Section-III: Candidate Bus Selection by using VSI and Load Modelling is discussed. Section-IV: Explains Genetic Algorithm Technic. Section-V: Test Results and Discussion Section VI: The paper is Concluded.

Objective Function: The objective of the present optimization problem is to minimize the Distribution network power loss

$$\text{Min.}f_1 = \sum_{b=1}^{N_b} (I_b)^2 R_b \qquad (1)$$

Where,

N_b - Total number of branches in the given radial distribution system
b - Branch number
I_b - Branch current in branch b
R_b - Resistance of branch b

Load Flow Analysis for Radial Distribution System: The simple distribution system shown in Fig. 1 will be used as an example. The power injections can be converted into the equivalent current injections using Eq. (2)

$$I_i = (P_i + Q_i / V_i)^* \qquad (2)$$

And a set of equations can be written by applying Kirchhoff's Current Law (KCL) to the distribution network. Then, the branch currents can be formulated as a function of the equivalent current injections. For example, the branch currents *B*5, *B*3 and *B*1 can be expressed as,

$$B_5 = I_6$$
$$B_3 = I_4 + I_5$$
$$B_1 = I_2 + I_3 + I_4 + I_5 + I_6 \qquad (3)$$

Furthermore, the Bus-Injection to Branch-Current (*BIBC*) can be obtained as,

$$\begin{bmatrix} B1 \\ B2 \\ B3 \\ B4 \\ B5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 12 \\ 13 \\ 14 \\ 15 \\ 16 \end{bmatrix}$$

B = BIBC I

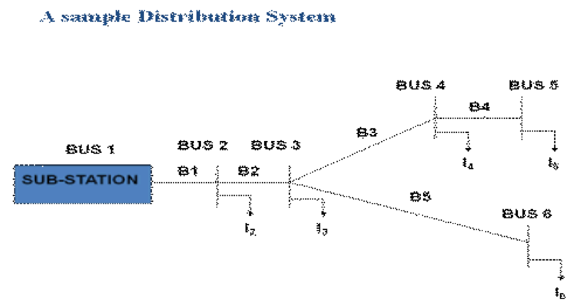

Fig. 1: A sample Distribution System

Algorithm for Formation of Bibc Matrix: The power injections can be converted to the equivalent current injection and the relationship between the bus-current injection and branch-current injections are obtained by Kirchhoff's current law (KCL) to the distribution network. The branch currents are formulated as equivalent of current injection.

Step (1): Create a null matrix of dimension m*n-1

Where,

m = Number of branches
n = Number of buses

Step (2): If a line section (B_k) is located between Bus *i* and Bus *j*, copy the column of the *i*-th bus of the *BIBC* matrix to the column of the *j*-th bus and fill *a* + 1 in the position of the *k*-th row and the j-th bus column.

Step (3): Repeat Procedure (2) until all the line sections are included in the *BIBC* matrix.

The building Procedure for BIBC matrix shown in Fig. 2. The algorithm can be easily expanded to a multi-phase line section or bus.

Algorithm for Formation of Bcbv Matrix: The BCBV matrix is responsible for the relations between the branch currents and bus voltages. The corresponding variation of the bus voltages, which is generated by the variation of the branch currents, can be found directly by using the BCBV

$$V_2 = V_1 - B_1 Z_{12} \qquad (4)$$
$$V_3 = V_2 - B_2 Z_{23} \qquad (5)$$
$$V_4 = V_3 - B_3 Z_{34} \qquad (6)$$

By using equ (4) and equ (5)

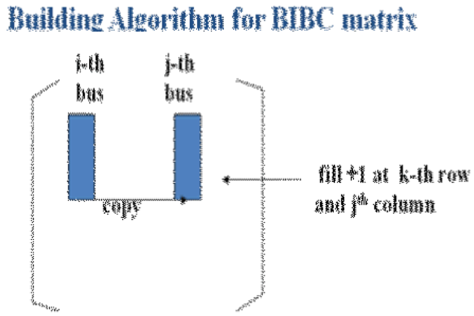

Fig. 2: BIBC matrix

The voltage of Bus 4 can be rewritten as,

$$V_4 = V_1 - B_1Z_{12} - B_2Z_{23} - B_3Z_{34} \qquad (7)$$

From Eq. (7), it can be seen that the bus voltage can be expressed as a function of the branch currents, line parameters and substation voltage. Similar procedures can be utilized for other buses and the Branch-Current to Bus Voltage (*BCBV*) matrix can be derived a

$$\begin{bmatrix} V1 \\ V1 \\ V1 \\ V1 \\ V1 \end{bmatrix} \begin{bmatrix} V2 \\ V3 \\ V4 \\ V5 \\ V6 \end{bmatrix} = \begin{bmatrix} Z_{12} & 0 & 0 & 0 & 0 \\ Z_{12} & Z_{23} & 0 & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & Z_{45} & 0 \\ Z_{12} & Z_{23} & 0 & 0 & Z_{36} \end{bmatrix} \begin{bmatrix} B1 \\ B2 \\ B3 \\ B4 \\ B5 \end{bmatrix}$$

) V = BCBV B

Step (1): Create a null matrix of dimension n-1*m

m = Number of branches
n = Number of buses

Step (2): If a line section (B_k) is located between Bus *i* and Bus *j*, copy the row of the *i*-th bus of the *BCBV* matrix to the row of the *j*-th bus and fill the line impedance (Z_{ij}) in the position of the j-th bus row and the k-th column.

Step (3): Repeat Procedure (2) until all the line sections are included in the *BCBV* matrix shown in Fig. 3.

Rewriting Eq. (10) in the general form, we have
~) V~BCBV~B~.

Algorithm for Distribution System Load Flow: A brief idea of how bus voltages can be obtained for a radial system is given below.

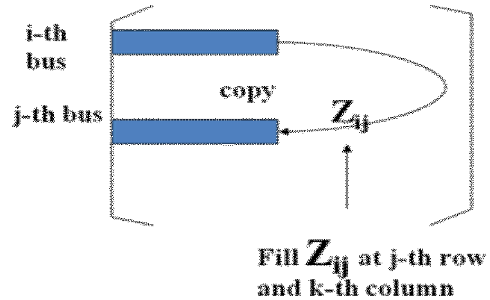

Fig. 3: BCBV matrix

- Input data.
- Form the *BIBC* matrix.
- Form the *BCBV* matrix.
- Form the *DLF* matrix.
- Iteration $k = 0$.
- Iteration $k = k + 1$.
- Solve the equations iteratively and update voltages $I_i^k = (P_i+Q_i /V_i)$

[ ) V^{k+1}] = [DLF] [I^k]

If $I_i^{k+1} - I_i^k$ >tolerance, go to step(6) else print result.

Candidate Bus Selection Using Voltage Stability Index: A system experiences a state of voltage instability when there is a progressive or uncontrollable drop in voltage magnitude following a disturbance, increase in load demand or change in operating condition. It is usually identified by an index called voltage stability index of all the nodes in radial distribution system [4].

$$VSI\ (n_2) = V_1^4 - 4[P_2R_1 + Q_2X_1]\ V_1^4 - 4[P_2X_1 - Q_2R_1]^2 \qquad (8)$$

Nodes with minimum voltage instability, in different laterals of the distributed system are chosen as the candidate location for placement of distributed generators.

Following steps are involved in optimal siting of the distributed generator

- Performed load flow to calculate the bus voltage magnitudes and total network power loss in the RDS.
- Compute the Voltage Stability Index (VSI).
- Select the buses with the highest priority(First, Second) and place DG.
- Run the power flow program again and find losses of power system.

- Check the voltage profile limitation at each bus of the system.
- Change the size of DG to small step and calculate loss by running load flow.
- Find the bus which lead to the lowest power system losses.

Load Modelling:

- A balanced load that can be represented either as constant power, constant current or constant impedance load has been considered here.
- The general expression of load is given below

$$P(m) = P_n [a_1 + a_2 V(m) + a_3 V(m)^2] \quad (9)$$

$$Q(m) = Q_n [b_1 + b_2 V(m) + b_3 V(m)^2] \quad (10)$$

Where,

P_n, Q_n - Nominal real and reactive power respectively
V(m) - Voltage at node m

For all the loads, equation (7) and equation (8) are modeled as

$$a1+a2+a3 = 1.0 \quad (11)$$

$$b1+b2+b3 = 1.0 \quad (12)$$

For Constant Power (CP) load $a_1 = b_1 = 1$ and $a_i = b_i = 0$ for i=2, 3. For Constant Current (CI) load $a_2 = b_2 = 1$ and $a_i = b_i = 0$ for i= 1, 3. For Constant Impedance (CZ) load $a_3 = b_3 = 1$ and $a_i = b_i = 0$ for i=1, 2

Genetic Algorithm:

Fitness Function: Genetic Algorithm work with population of individuals. Each individual stands for solution. The quality of solution is determined by fitness function. The fitness function is used to select individuals from current generation to advance in to next generation. This process is continued until there is no chance for best individuals in the population

Selection: Some of individual selected based on fitness function. These individual go mate and pass the genetic code to the next generation.

Cross Over: Selected individuals can be subjected to cross over with a probability P = 0.6-0.9 defined by the user. The sons have the properties and chacteristics of both their parents.

Mutation: The Cross over operator cannot explore the whole search space because there is no new information introduced. Mutation introduced the new element by chaging 0 to 1(or) 1 to 0 which increases the search space.

In this paper the following GA parameters has been considered,

Population Size	:	20
Scaling Function	:	RANK
Selection Function	:	Stochastic Uniform
Mutation Function	:	Constraint Dependent
Crossover Function	:	Scattered
Crossover Fraction	:	0.8
Generations	:	100
Initial Penalty	:	10
Penalty Factor	:	100

RESULT AND DISCUSSION

To analysis the effect of DG on the Distribution system, the 33Bus system has been considered here. The effect of DG with different load models has been shown in Fig. 4. From the fig it was clear that the optimal size of DG is 0.14MW for reduced loss and the optimal location has been selected by using VSI, Which is at location 18. The same test system has been tested with Matlab GA tool box. The test result shown in Fig.5, From the fig.5 it was found that the best location is 32 for minimizing power loss at 209.8kW the corresponding DG size is 0.2MW. Table 2. gives the information about the comparative analysis of power loss reduction. The Base case load solution given in Table.3.From the table it was found the lowest voltage at the node 18, which was already found by using VSI

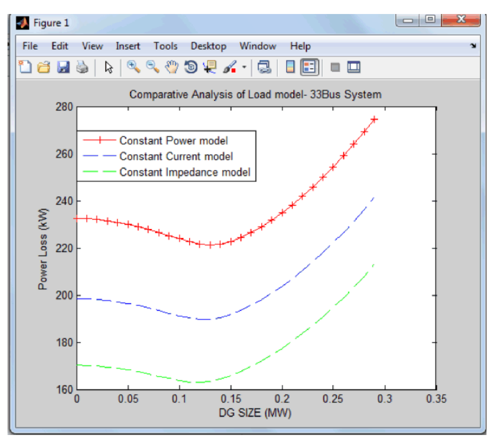

Fig. 4: Comparative Analysis of Load model- 33Bus System

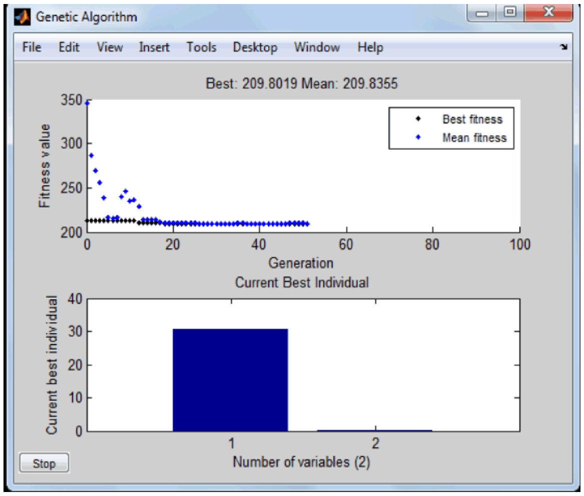

Fig. 5: Output of Genetic Algorithm- 33Bus System

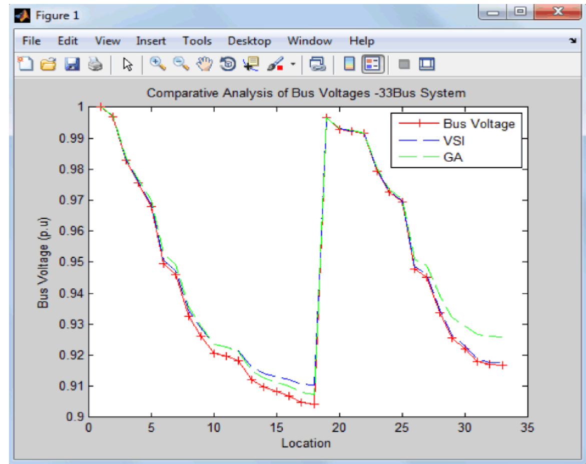

Fig. 6: Comparative Analysis of Bus Voltages- 33Bus System

Table 1: Voltage Stability Index for 33Bus System

Bus. No	VSI
1	1
2	0.9952
3	0.9721
4	0.9569
5	0.9434
6	0.9103
7	0.897
8	0.8411
9	0.8288
10	0.81
11	0.8086
12	0.8033
13	0.7814
14	0.7744
15	0.7715
16	0.7668
17	0.7591
18	0.7576
19	0.9929
20	0.9746
21	0.9751
22	0.9715
23	0.9582
24	0.9217
25	0.9094
26	0.9045
27	0.8951
28	0.8535
29	0.8241
30	0.8097
31	0.797
32	0.7965
33	0.7969

Table 2: Comparative Analysis of Power Loss Reduction

Test case	33 bus system	
Approach	VSI	GA
Optimal location	18	32
Optimal Size of DG in MW	0.14	0.2
Loss in kW	221.2841	209.8355

Table 3: Load flow solution of 33-bus RDS

Bus no	Voltage (pu)	Angle (degree)
1	1	0
2	0.997	0.0136
3	0.9829	0.0958
4	0.9754	0.1619
5	0.968	0.229
6	0.9495	0.1349
7	0.946	-0.0967
8	0.9323	-0.2501
9	0.926	-0.3246
10	0.9201	-0.3888
11	0.9193	-0.3814
12	0.9178	-0.3697
13	0.9116	-0.4628
14	0.9093	-0.543
15	0.9079	-0.5815
16	0.9065	-0.6052
17	0.9044	-0.684
18	0.9038	-0.6938
19	0.9965	0.0028
20	0.9929	-0.0642
21	0.9922	-0.0836
22	0.9916	-0.1039
23	0.9793	0.0648
24	0.9726	-0.0239
25	0.9693	-0.0676
26	0.9476	0.1744
27	0.945	0.2305
28	0.9336	0.3135
29	0.9253	0.3914
30	0.9218	0.4967
31	0.9176	0.4123
32	0.9167	0.3892
33	0.9164	0.3815

The effect on Bus Voltages by the Placement of DG for the test system has been shown in Fig. 5. From the Fig. 6. it has been found that GA gives the better voltage profile improvement compare to VSI and Base case.

CONCLUSION

In this paper the optimal location of DG is obtained using VSI and the size of the DG is obtained by trial and error method to minimize the real losses. GA. is used simultaneously to find the location and size both to minimize the losses. Even through the size of DG obtained by GA is high, for this size the loss obtained by VSI method is greater than the loss obtained by GA, so GA gives better performance when compared to other method.

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