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Research Paper

A COORDINATED OPTIMIZATION OF DG CAPACITY, LOCATION WITH OPTIMAL USE OF DISTRIBUTION NETWORK USING GA

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There is increase in the integration of Distributed Generation (DG) into the distribution network to meet ever increasing demand. Many studies suggested that with proper integration of DG will improves the voltage profile; reduce the losses of the network. However without any modifications in the distribution network the DG integrating capacity is restricted due to the voltage limit violation, fault levels and power flow constraints. So this paper aims to address the new approach of coordinated optimization of the DG capacity with optimal use of the distribution network. Genetic Algorithm (GA) is used to optimize the DG capacity and to find the best radial path that is the feeder reconfiguration is done by using GA. Comprehensive case studies are illustrated in this paper to explain the proposed method.

Keywords: Distributed generation, Network reconfiguration, Genetic algorithm

INTRODUCTION

Distribution networks are normally configured as radial in nature. Two types of the switches are found in the network one is sectionalizing switches (normally closed), second is tie switches (normally opened) (Chiradeja and Ramakumar, 2004). There is a need for the steady power supply with less interruption this can be achieved by changing the status of the both switches the configuration of the network varied and it must be a radial network. This configuration is in such a way that must reduce the losses of the system. This is called feeder reconfiguration or network reconfiguration.

Now a days, there is increasing the demand for electricity, which is more than the generation. So to meet the demand a small scale generation is introduced which are nearer to the load centres. And those are mainly uses the renewable resources as the fuel. This small scale generation is termed as Distributed Generation (DG) or the dispersed

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generation. These DGs are generating the power at distribution voltage level. Recent developments in the DG technologies are wind, solar and biomass generations have drawn an attention for the utilities to accommodate the DG units into their system. Most of the algorithms are heuristic approaches. This paper also used Genetic algorithm to optimize the DG capacity and location, and also for the feeder reconfiguration. GA is used for Distributed generation capacity optimization with feeder reconfiguration (Dugan, 2008) which reduces the losses. In this paper the effectiveness of the methodology is demonstrated by using 33 and 14 bus systems. Totally this paper discusses about four problems.

- DLF (distribution load flow).
- Optimization of the DG capacity for existing radial network.
- Feeder reconfiguration.
- Coordinated optimization of the Dg capacity and location with optimal use of distribution network, i.e., feeder reconfiguration.

PROBLEM FORMULATION

Case 1: DLF Distribution Load Flow Procedure

Actually present distribution network is radial network. Here our aim is to find the loss of the actual system. So here vector based distribution load flow is used. The loss vectors are calculated as

$$P_{eff} = P_{load}(i) + P_{load}(i+1) + P_{loss}(i+1) \quad ...(1)$$

$$Q_{eff} = Q_{load}(i) + Q_{load}(i+1) + Q_{loss}(i+1) \quad ...(2)$$

$P_{load}(i)$ = Active power load at i^{th} bus

$Q_{load}(i)$ = Reactive power load at i^{th} bus

$P_{load}(i+1)$ = Active power loss at $i+1$ bus

$Q_{load}(i+1)$ = Reactive power loss at $i+1$ bus

$P_{loss}(i+1)$, $Q_{loss}(i+1)$ are the active power and reactive power loss at $i+1$ bus

i is the bus number

Algorithm

Step 1: Read system data R, X, sending end and receiving end p_{load}, q_{load}.

Step 2: Initialize loss vectors p_{loss} and q_{loss} as 0.

Step 3: Calculate the effective vectors of P and Q from the above Equations (1 and 2).

Step 4: Calculate the loss vectors.

$$p_l = p_{loss}(i) + p_{eff}(i)$$

$$Q_l = Q_{loss}(i) + Q_{eff}(i)$$

Step 5: Calculate the voltages at each bus.

Results to the 33 Bus System

Active power loss is 202.34 KW Reactive power loss is 134.8 KW

Case 2: Optimization of DG Capacity and Location Using GA

Here our aim is to optimize the DG capacity. So in GA optimization technique the objective function is to maximization of DG capacity (Sheng-Yi Su *et al.*, 2011).

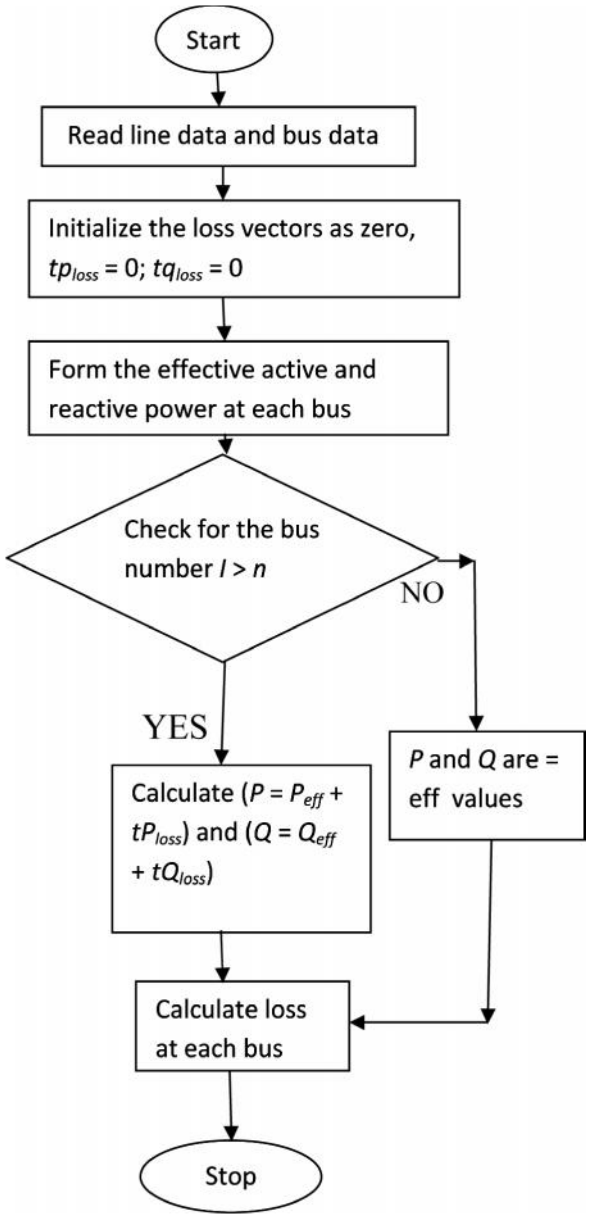
Objective function is

$$F_n = \max S_{DGi}$$

Subjected to

$$\sum S_{pk}^{v}(u) \le S_{p}^{\max} \text{ for all } p \in N_T \;\; k \in K_{out}$$

Figure 1: DLF Flow Chart



$$S_j^v(u) \le S_j^{max} \quad j = N_L$$

$$V_i^{min} \le V_i^v(u) \le V_i^{max} \quad i \in N_N$$

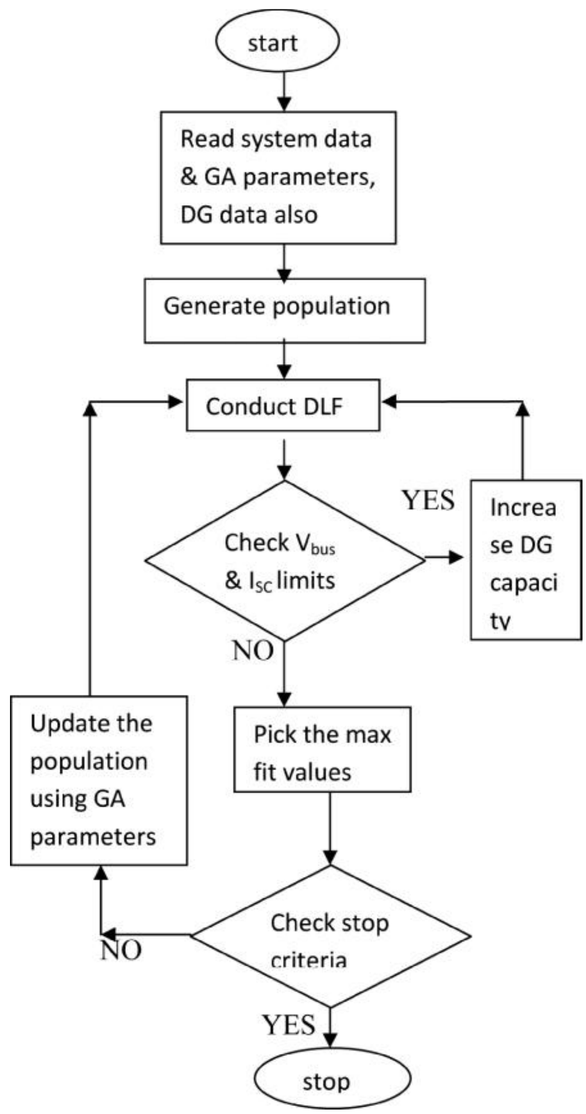
$$S_{DGi}^v(u) \le S_{DG}^{max}$$

$$I_{Scp}(u) \le I_{SCp}^{max} \quad p \in N_T$$

where S_{DGi} is the DG capacity S_{pk}^v is the power transferred to the feeder k from transformer p at v loading condition. S_p^{max} is the maximum power handled by the transformer p. S_j^v is capacity of feeder j at v loading condition. S_j^{max} is the maximum capacity of the feeder j. S_{DGi}^v is DG capacity at ith bus at v loading condition. V_i^v is the voltage of feeder j at v loading condition. I_{scp} is the short circuit current capacity of transformer p.

First read the system data and also integrate means introduce the DG at particular

Figure 2: Flow Chart to the DG Optimization Using GA



location with some capacity. Later optimize the capacity and location of Distributed generation using genetic algorithm. The flow chart is shown in Figure 2.

Case 3: Feeder Reconfiguration

Most distribution networks use sectionalizing-switches that are normally closed and tie-switches that are normally opened. From time to time, modifying the radial structure of the feeders by changing the on/off status of the sectionalizing and tie switches to transfer loads form one feeder to another may significantly improve the operating conditions of the overall system.

In this method, all the possible switching options obtained from the combination of the Tie switch and its two neighbours are selected and the infeasible combinations in the selection are omitted. The minimum loss configuration in the selected combinations is identified. Finally, an extensive search is carried out by changing the switching status one at a time, by either moving to the left of the open branch in the configuration obtained, and the configuration with maximum loss reduction is determined (Prabhakar Karthikeyan *et al.*, 2011).

Algorithm

Step 1: Read the system data.

Step 2: Give the line coding to the normally closed and normally opened branches as 1, 0 respectively.

Step 3: Initially the line code is checked for 0 that is for tie line. If line code is 0 then go to step 4.

Step 4: The corresponding RC (Right connect) and LC (Left connect) of the line are determined.

Step 5: Find losses of RC, LC and ZC.

Step 6: If losses of RC>LC and RC>ZC then RC is added to the Max_Loss matrix else go to step 7.

Step 7: If LC>RC and LC>ZC then LC is added to Max_Loss matrix else ZC is added.

Step 8: Checking is done whether any of the tie lines are left.

Step 9: If yes go to step 4 else go to next step.

Step 10: Find max in the Max_Loss matrix.

Step 11: Open the max line and close the corresponding tie line.

Case 4: Coordinated Operation of the DG Optimization with Optimal Use of Distribution Network (Feeder Reconfiguration)

This paper emphasizes the advantage of network reconfiguration to the distribution system in the presence of DG units for loss reduction and bus voltage improvement. The application of a genetic algorithm is applied to determine the optimal on/off patterns of the switches to minimize the system loss subject to system constraints (Nattachote Rugthaicharoencheep *et al.*, 2010). The effectiveness of the methodology is demonstrated by a practical sized distribution system consisting of 14 buses and 33 bus system. Figure 4 represents the flow chart for the coordinated optimization of the DG capacity with the feeder reconfiguration.

NUMERICAL RESULTS

MATLAB programming results are presented in this paper. This 33 bus test system results are approximately getting as the results in Nattachote Rugthaicharoencheep *et al.* (2010).

Table 1: 33 Bus Test System

No. of DGs	DG Optimization Without FDR	DG Optimization with FDR
One	2.54 MW at 2nd bus loss = 146.21 KW	5.4 MW at 2nd bus loss = 121.1 KW
Two	DG1 = 0.983231 MW at 2nd bus DG2 = 0.983235 MW at 6th bus loss of the system = 139.11 KW	DG1 = 1.51 MW at 6th bus DG2 = 1.24 MW at 2nd bus loss = 101.1 KW
Three	DG1 = 0.75947 MW at 2nd bus DG2 = 0.75947 MW at 15th bus DG3 = 0.759472 MW at 32 bus loss = 128.11 KW	DG1 = 0.9 MW at 15th bus DG2 = 0.95 MW at 32 bus DG3 = 1.000 MW at 2nd bus Loss = 97.23 KW

Figure 3: Coordinated Optimization of DG Capacity with Feeder Reconfiguration

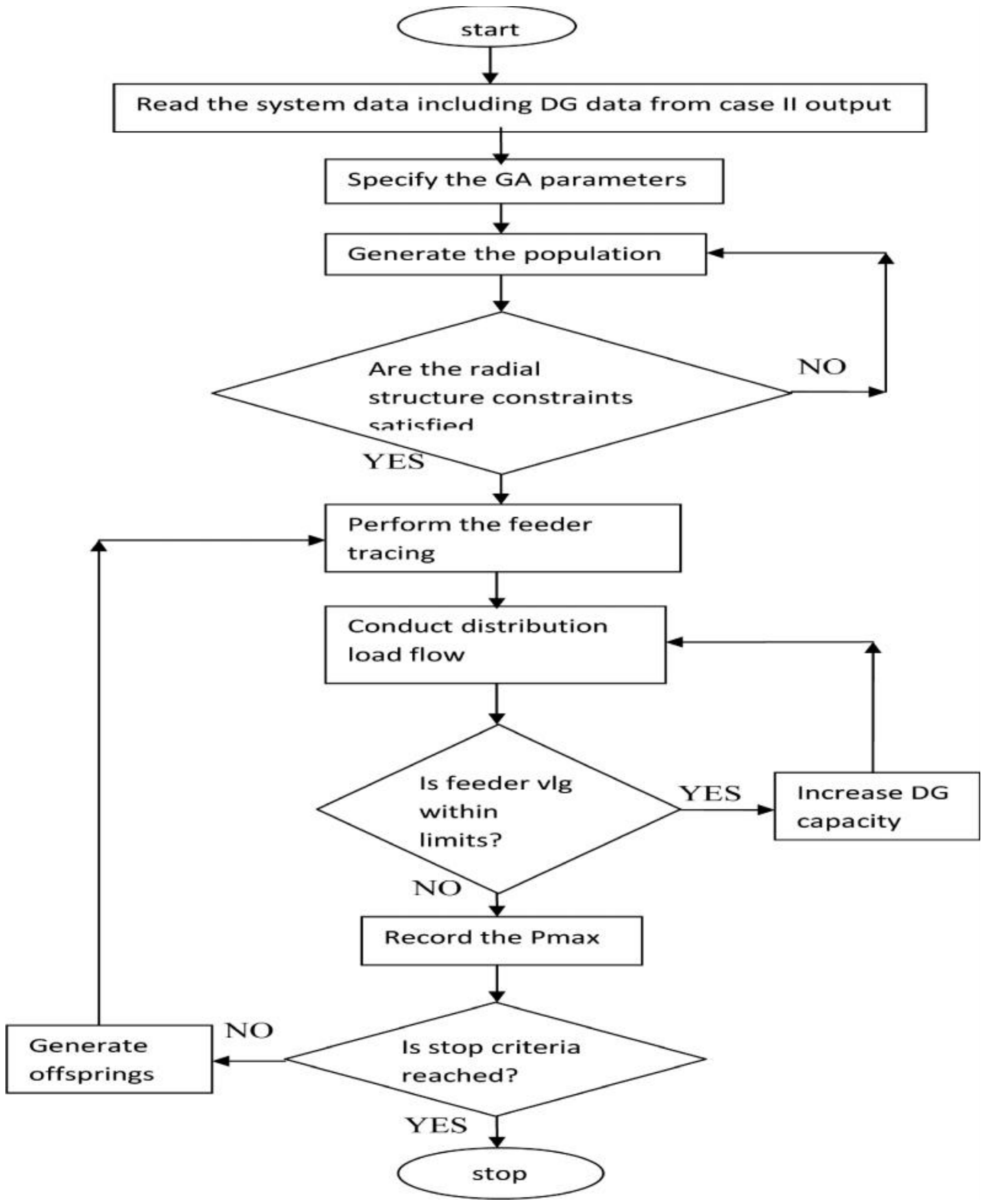


Table 2: 14 Bus Test System Results

No. of DGs	DG Optimization Without FDR	DG Optimization with FDR
One	10.34 MW at 2nd bus loss = 30.10 KW	13.34 MW at 2nd bus loss = 23.6 KW
Two	DG1 = 10.983231 MW at 2nd bus DG2 = 11.983235 MW at 6th bus loss = 14.234 KW	DG1 = 14.68831 MW at 6th bus DG2 = 14.8808 MW at 2nd bus loss = 13.9 KW
Three	DG1 = 2.75947 MW at 2nd bus DG2 = 3.75947 MW at 6th bus DG3 = 5.759472 MW at 13 bus loss = 3.3321 KW	DG1 = 7.1669 MW at 15th bus DG2 = 7.577 MW at 13 bus DG3 = 7.5788 MW at 2nd bus loss = 03.033 KW

It is noticed that from the results the loss of the actual system is 202.344 KW. With introducing the DG into the system loss of the system is reduced. When 3 DGs are introduced into the system the loss is 128.11 KW. And including feeder reconfiguration the loss is reduced to 97.23 KW. So the minimum loss is observed in case IV that is coordinated optimization of DG capacity with feeder reconfiguration.

CONCLUSION

Genetic algorithm optimization technique is presented in this paper to find out the efficient radial topology with integration of the distributed generation. In this paper 33 bus distribution system and 14 bus distribution systems are used to demonstrate the effectiveness of the proposed algorithm up to 3 DGs are introduced into the distribution system. Although the integration of DG contributes to reduce the system losses and congestion but there is small violation of voltage constraints are observed. So such a problem is remedied by feeder reconfiguration. The results shown that with coordinated optimization of the distributed generation capacity and location with optimal use of the distribution network gives the better results such as reduced loss and voltages are within the voltage constraints.

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APPENDIX

14 Bus Test System

From	To	R(pu)	X(pu)
1.0000	2.0000	0.0750	0.1000
1.0000	3.0000	0.1100	0.1100
1.0000	4.0000	0.1100	0.1100
2.0000	5.0000	0.0800	0.1100
2.0000	6.0000	0.0900	0.1800
3.0000	8.0000	0.1100	0.1100
3.0000	9.0000	0.0800	0.1100
4.0000	12.0000	0.0900	0.1200
4.0000	13.0000	0.0800	0.1100
6.0000	7.0000	0.0400	0.0400
9.0000	11.0000	0.0800	0.1100
9.0000	10.0000	0.0800	0.1100
3.0000	14.0000	0.0400	0.0400

Bus No	P_{load}	Q_{load}
1	2.0	1.6
2	4.0	2.7
3	1.0	0.9
4	3.0	1.5
5	0	0
6	2.0	0.8
7	1.5	1.2
8	0	0
9	5.0	3.0
10	4.5	2.0
11	1.0	0.7
12	1.0	0.9
13	2.1	1.0
14	0	0

IEEE 33 Bus Test System

From	To	R(pu)	X(pu)
1	2	0.0922	0.0477
2	3	0.4930	0.2511
3	4	0.3660	0.1864
4	5	0.3811	0.1941
5	6	0.8190	0.7070
6	7	0.1872	0.6188
7	8	0.7114	0.2351
8	9	1.0300	0.7400
9	10	1.0400	0.7400
10	11	0.1966	0.0650
11	12	0.3744	0.1238
12	13	1.4680	1.1550
13	14	0.5416	0.7129
14	15	0.5910	0.5260
15	16	0.7463	0.5450
16	17	1.2890	1.7210
17	18	0.7320	0.5740
18	19	0.001021	0.000974
19	20	1.5042	1.3554
20	21	0.4095	0.4784
21	22	0.7089	0.9373
22	23	0.4512	0.3083
23	24	0.8980	0.7091
24	25	0.8960	0.7011
25	26	0.2030	0.1034
26	27	0.2842	0.1447
27	28	0.006594	0.005814
28	29	0.8042	0.7006
30	31	0.006067	0.005996
30	31	0.9744	0.9630
31	32	0.3105	0.3619
32	33	0.3410	0.5302

Tie Line Data

8	21	0.0001332	0.0001332
9	15	0.0001332	0.0001332
12	22	0.0001332	0.0001332
18	33	0.00003325	0.00003325
25	29	0.00003345	0.00002235

P_{gen}	Q_{gen}	p_{load}	Q_{load}
0	0	0	0

APPENDIX (CONT.)

0	0	100	60
0	0	90	40
0	0	120	80
0	0	60	30
0	0	60	20
0	0	200	100
0	0	200	100
0	0	60	20
0	0	60	20
0	0	45	30
0	0	60	35
0	0	60	35
0	0	120	80
0	0	46.0	10
0	0	60	20
0	0	24	20
0	0	90	40
0	0	90	40
0	0	90	40
0	0	90	40
0	0	90	40
0	0	90	50
0	0	420	200
0	0	420	200
0	0	60	25
0	0	60	25
0	0	60	20
0	0	120	70
0	0	200	600
0	0	150	70
0	0	210	100
0	0	60	40