Optimal Placement and Sizing of Distributed Generation Sources in Distribution Networks Using SPEA Algorithm

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Abstract: Distribution grids are being transformed from passive to active networks by integrating distributed generation (DG). In this paper, a Strength Pareto Evolutionary Algorithm (SPEA) has been used to estimate the best type of DGs and their optimal capacity and location in a 33-node radial distribution network. In order to improve the voltage stability, expressed by its index, and to reduce the active and reactive power losses, multiple scenarios have been proposed and compared. The backward/forward sweep method of distribution load flow was used to evaluate the three objective functions. The same distribution network has been also used to show the effect of the capacity and location of the DGs on the objective functions.

Keywords: distributed generation (DG), optimal distributed generation placement, Voltage Stability Index, Genetic algorithm, Strength Pareto Evolutionary Algorithms (SPEA).

1. Introduction

The increase in electricity demand, technological advancements in the grid integration of renewable energy sources, environmental concerns and the restructuring of electricity market have significantly motivated the network integration of DG units. Moreover, DGs are available in modular units, and are characterized by ease of finding sites for smaller generators, shorter construction times, and lower capital costs. Distributed Generation (DG) is defined as “an electric power source connected directly to the distribution network or on the customer site of the meter” [1]. DGs should be strategically placed in distribution networks for grid reinforcement, reducing power losses and on-peak operating costs, and improving voltage profiles and load factors [2],[3]. DGs also affect power quality, stability, reliability, and protection. Since DG units have a small capacity compared to central power plants, the impacts are minor if the penetration level is low (1%–5%). However, if the penetration level of DG units increases to the anticipated level of 20%–30%, the impact of DG units will be profound [4],[5]. The planning of the electric system with the presence of DGs requires defining several factors including the best technology to be used, the size, location and capacity of each unit, the interconnection method, etc. [6],[7].

Optimal location, size, type and number are the design variables which are alternatively computed for each DG. The authors in [8], [9] introduce a review about several investigations on this subject. The selection of the best places for installation and the size of the DG units in large distribution system is a complex combinatorial optimization problem [10]. The optimal installation of DGs into existing distribution networks is subjected to electrical network operating constraints, DG operation constraints and investment constraints. The distribution network must be kept within operational and design limits at all times to provide good-quality energy and avoid damage to the equipment.

Different methods have been used to keep the network within operational limits and to optimize the steady state impacts of DGs integration. These methods can be classified into three types: analytical, numerical and heuristic. Analytical methods have been used in [11], [12] to

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Numerical Methods such as Linear Programming used in [13] and Nonlinear Programming used in [14] have been proposed to solve the optimal DG placement. Heuristic Methods such as Genetic Algorithm (GA) and Artificial Bee Colony (ABC) are required for optimization problems that try to satisfy either one or several objectives with discrete or continuous decisions variables. The Genetic Algorithm (GA) presents the advantage to explore the space of the feasible solutions from a set of solutions created in a random manner. GA have been used to solve multi-objective Optimal DG placement problem in [15], [16], [17]. It is also used in [18] to minimize power loss cost. In [19], a non dominated sorting GA (NSGA) is used to maximize the distributed wind power integration.

The voltage stability phenomenon has been well recognized in distribution systems. Radial distribution systems having a high resistance to reactance ratio cause a high power loss so that the radial distribution system is one of the power systems which may suffer from voltage instability [20]. In certain industrial areas, it has been observed that under certain critical loading conditions, the distribution system experience voltage collapse. Voltage collapse is a local phenomenon. It occurs at a node within the area with high loads and low voltage profile [21]. It is more practical using DGs to solve the most critical problems, especially with the development of their technologies including photovoltaic, wind turbine, fuel cells, small and micro-sized turbine packages, internal combustion engine generators, and reciprocating engine generators [22].

A literature survey shows that a lot of work has been conducted on the optimization of design variables (number, type, location and size) in distributed networks in order to improve proposed objective functions (min power loss, min cost, max profit, max DG capacity, max benefit/cost ratio, voltage stability). To the knowledge of the authors, none of precedent works has combined voltage stability and active and reactive power loss that are considered as very important objective functions.

In this paper a multi-objective GA, strength pare to evolutionary algorithms (SPEA), has been used to find the optimal DG location and size considering the type and number of installed DGs in a radial distribution system. The problem is solved to improve the voltage stability, reducing active power loss and reactive power loss. A comparison between optimal design variables of two different load states has been conducted in order to demonstrate the effect of the load state on the optimization process. A comparison between integrating a single DG and a multiple DGs with the same power injection in a distributed network has also been conducted. The effect of DG capacity and location on the objective functions has been analyzed. A steady state voltage stability index is used to assess the network stability.

2. Types of DGs

In this study four major types of DG have been considered. DG classification is based on their terminal characteristics in terms of real and reactive power delivering capability; Different types of the DG's can be characterized as [6]:

Type1: DG capable of injecting both real and reactive power, e.g. synchronous machines.

Type2: DG capable of injecting real but consuming reactive power, e.g. induction generators used in the wind farms.

Type3: DG capable of injecting real power only, e.g. photovoltaic panels.

Type4: DG capable of injecting reactive power only, e.g. kvar compensator, synchronous compensator, capacitors etc.

To have an idea about the effect of distributed generators capacity of each type on the system behavior, the active Penetration Level (APL) and the reactive Penetration Level (RPL) parameters are respectively defined as the ratio of the total active power and reactive power generation from DGs ($\sum P_{dg}$, $\sum Q_{dg}$) to the active and reactive power peak load demand ($\sum P_{peak}$), ($\sum Q_{peak}$).

They can be calculated as:

$$APL = \frac{\sum P_{dg}}{\sum P_{peak}} * 100 \quad RPL = \frac{\sum Q_{dg}}{\sum Q_{peak}} * 100\%$$

3. Problem formulation

The optimization problem is formulated to improve the distribution network stability while reducing power loss by optimally selecting the location, number and size of different types of DGs using a Genetic Algorithm, Strength Pareto Evolutionary Algorithm (SPEA). The backward/ forward sweep method of distribution load flow [23] has been used to evaluate the desired objective. The constraints of the proposed problem include voltage limits at each bus, and the feeder and DG capacity limits.

A. Objective Function

A.1. Voltage Stability Index

A steady state voltage stability index is proposed by M. Charkravorty et.al in [24] and has been used in [21] and [25] for identifying the node which is most sensitive to voltage collapse. Figure 1 shows the electrical equivalent of a radial distribution system.

Figure 1. Electrical equivalent of two-node system [21]

$$SI(i+1) = \{ |V(i)|^4 \} - 4.0 \{ P(i+1)x(j) - Q(i+1)r(j) \}^2 - 4.0 \{ P(i+1)r(j) + Q(i+1)x(j) \} / |V(i)|^2$$

Where

SI (i+1) = voltage stability index of node i+1.

j = branch number,

i = sending end node,

i+1 = receiving end node,

I(j) = current of branch j,

V(i) = voltage of node i,

V (i+1) = voltage of node i+1,

P (i+1) = total real power load fed through node i+1,

Q (i+1) = total reactive power load fed through node i+1.

For stable operation of the radial distribution networks, SI (i+1) must be ≥ 0 .

The node at which the value of the stability index is minimum is more sensitive to the voltage collapse. The minimum SI is considered as an objective function in this investigation.

A.2. Minimizing the total active and reactive power losses

Minimise

$$\{ P_L = \sum_{k=1}^n |I_k|^2 R_k \}$$

Minimise

$$\{ Q_L = \sum_{k=1}^n |I_k|^2 X_k \}$$

Where:

$$n = n_{bus} - 1$$

B. Constraints

B.1. Voltage limits on each bus

Make sure that the voltages $|v_i|$ along the feeder are well within the tolerable range, $\pm 5\%$ of the nominal value [26].

$$0.95 \leq |v_i| \leq 1.05 \quad i = 1, 2, \dots, nbus$$

B.2. Feeder capacity limits:

$$0 \leq I_{ij} \leq I_{ijmax} \quad \forall i, j$$

B.3. DG Power Limits:

$$p_{DG,i}^p \leq p_{DG,i}^{MAX}, Q_{DG,i}^p \leq Q_{DG,i}^{MAX}$$

Where $p_{DG,i}^{MAX}$ and $Q_{DG,i}^{MAX}$ are the allowable maximum active and reactive powers for the i th DG unit.

4. Strengthpare to evolutionary algorithms

This approach has been proposed par Zitzler[27]; it is implemented with the help of genetic algorithm and is based on the maintenance of elitism in the population by the constitution of an external set of non-dominated solutions. The elitism techniques try to keep the non-dominated solutions along the procedure of research of the solutions.

To every generation, the set is actualized according to the new non-dominated solutions. The algorithm starts with a population of size N generated in an uncertain manner with an empty external set. To every t generation, the set is filled and actualized by the non-dominated solutions gotten from the current population.

The notion of dominance permits us to identify the optimal Pareto solutions forming the border of Pareto. For a problem of minimization, a solution x_i dominates a solution x_j if and only if:

$$\forall m \in [1, n], \quad f_m(x_i) \leq f_m(x_j) \text{ et } \exists m \in [1, n], f_m(x_i) < f_m(x_j)$$

f_m is an objective function.

The Algorithm of SPEA [28]:

Step 1: initialization: an initial population P_t will be created as well as an empty external set $\bar{P}_t$. ($t = 0$; N =Population size). The initial population is randomly generated (The set of candidate buses and DGs size are limited).

Step 2: updating of the external set: All individuals of P_t whose decision vectors are no dominated will be copied into a current version of the external set $\bar{P}$. Individuals that become weakly dominated will be removed. Finally, the new external set can be defined as $\bar{P}_{t+1} = \bar{P}$

Step 3: fitness assignment: to all the individuals of the external set $i \in \bar{P}_t$, the strength value will be assigned firstly: $(i) \in [0, 1]$. The strength is measured by the number of dominated solutions, divided by the population size $N + 1$, and thus proportional to the population size (n_i number of solutions dominated by i):

$$S_i = \frac{n_i}{N + 1}$$

Once the strength values (i) are defined, the fitness values can be calculated. For the external set the fitness value of i is equal to the strength value: $(i) = (i)$. For $j \in P_t$ the fitness is the sum of all strength values of the dominated items in the external set, plus one, to ensure that the external set is having a lower value than the population:

$$(j) = 1 + \sum_{i \in \bar{P}_t} (i) \text{ (} i \text{ dominate } j \text{)}$$

Step 4: selection: for this, two random individuals of both sets are chosen $(i, j) \in \bar{P}_t + P_t$ and compared. The one with the lower fitness value will be included in the next generation.

Step 5 & 6: recombination and mutation: the individuals inside the population will be modified depending on recombination and mutation probability parameters. The recombination recombines two individuals into new solutions, while the mutation is flipping genes randomly.

Step 7: constraints check: the new individuals will be checked against the constraints. In this work, it have been proposed to replace those genes randomly by others surviving the constraint.

Step 8: termination criterion: if stopping criteria are satisfied (fixed number of iteration), the algorithm will stop here: The best solutions are stored in the external set. Otherwise, the algorithm continues on to Step 2 with the next generation.

5. Results and analysis

The simulations have been carried out in MATLAB environment.

A. Effect of active and reactive power injection on objective functions

The Effect of active and reactive power injection on objective functions are evaluated in the test 33-bus radial distribution network; a constant power load model has been used in the simulation. The detailed data for this system is given in table 1 in the Appendix [29]. Figure 2 illustrates the network structure of the system.

Figure 2. 33-bus test distribution system [29]

A mesh plot have been used to evaluate the stability index, the total active power losses and the total reactive power losses in the 33-bus distributed network versus the location and size of both active and reactive power injection. Figure. 3 shows that the active power injection affect the stability index more than the reactive power injection and the improvement level increase as the penetration level increase. However, the constraints –see section III.B- limit the penetration level of DGs. The location and the size have the principal effect on the objective functions. Figure. 4 and Figure. 5 show the total active and reactive power losses of the system for different locations and sizes of the DG units.

It can be observed that the highest reduction in power losses does not take the same location and size where the highest improvement in system stability. If the system face a critical problem of stability, it is better to consider only one objective function to prevent the voltage collapse. If the interests are to enhance different parameters such as stability and power losses, the SPEA can find the optimal solution.

Figure 3. Effect of capacity and location of DG on Stability Index

Figure 4. Effect of capacity and location of DG on active power losses

Figure 5. Effect of capacity and location of DG on Reactive power losses

A. SPEA investigation progress for two objective functions

The SPEA investigation progress for two objective functions has been tested for 12-bus radial distribution network; a summary of system data is presented in Table 2 in the Appendix[30]. Figure 6 illustrates the network structure of the system.

Figure 6. 12-bus and 11 branches system

Figure 7 represents SPEA progress on the 12 Bus system, to select optimal location and size of one DG type 1 to minimize the total active power loss and maximize the stability index.

In order to show clearly the progress of population selection, a minimization problem has been taken. In this test, two objective functions have been used, the total active power loss and the parameter $\frac{1}{1+SI}$ instead of the SI (the stability index). It is observed from Figure 7- that the no dominated solution has been selected among the total population. It is also noted that the search for the solution does not sweep all the area because of the constraints that have been taken in consideration.

Figure 7. SPEA progress in selecting optimal location and size of DG type 1

B. Selecting optimal location and size of different types of DGs using SPEA algorithm

The parameters of the genetic algorithm, SPEA, selected for optimization are: Population size ($N=10$), recombination probability ($Pr=0.8$) and mutation probability ($Pm=0.03$). The GA is set to stop when 150 iterations are evaluated.

In this study, after validation of the program, three cases have been analyzed depending on the number and type of DGs to be installed. The first case considers only one connected DG type. The second case, four different connected DG are considered to be installed optimally. For the two cases, the algorithm is applied on a modified 33-bus distribution system. This system works at the nominal voltage of 12.66 kV and the base apparent power is 10 MVA. In addition, the maximum currents limit of the system branches is selected to be 255 A[31].

The third case considers two connected DGs to a 119-bus network. This system functions at 11 kV nominal voltage. The detailed data for this system is given in table 3 in the Appendix [29].

Validation of the program:

In order to validate the implementation of the SPEA algorithm in our MATLAB program, a comparison with the results presented on Figure 3 where only the voltage stability index is considered as objective function. The case of one DG of type 3, active power injection, and type 4, reactive power injection, is used for validation purposes.

The SPEA algorithm is meant to find the optimal placement and size for this case. From table 1, it can be noted that the optimal location and size presented by the algorithm are the parameters presenting the highest voltage stability index among all other locations and sizes.

Table 1. Optimal location and sizes of DG using SPEA algorithm.

DG	Optimal location	Optimal size		Stability Index
		(APL%)	(RPL%)	
type 3	8	99.89	0	0.92
type 4	9	0	99.50	0.79

Case-I: One DG is connected Considering two load states of the 33-bus distribution system, SPEA algorithm was used to find the optimal location and size for type 1, type3 and type 4 independently. The maximum penetration of DG in the network is limited: APL max=30%, RPL max =30%. The optimal size and locations obtained for each type in the first and second load state are given in Table 2 and Table 3.

The objective functions without DG integration:

First load state: Stability index=0.71, Active power loss=493.07 kW, Reactive power loss=328.178kvar. Second load state: Stability index=0.68, Active power loss=579.18 kW, Reactive power loss=391.42 kvar.

Table 2. Optimal location and sizes of DG in the first load state.

DG type	Optimal location	Optimal size		Stability Index	Power loss	
		(APL%)	(RPL%)		(KW)	(KVAR)
type 1	10	27.44	29.49	0.81	227.09	150.61
type 3	11	29.90	0	0.80	268.95	178.94
type 4	13	0	29.94	0.76	440.65	293.42

Table 2 and 3 show that the SPEA algorithm can find the optimal location and size of each DG type integration, and The network stability and energy losses depend on the network load state. It can be noted that the stability index is improved and the system power losses are reduced in each load state after the integration of DG especially for type 1. It can be observed that when a DG unit of type 1 is considered, the stability index is improved over 10%, and the active and

reactive power losses are reduced over 55% in the two load states. The optimal placement and size at the first state is not the same as the second. Therefore, to benefit more from DGs integration, the optimal location and size should be investigated according to different load variations data during one year.

Table 3. Optimal location and sizes of DG in the second load state.

DG type	Optimal location	Optimal size		Stability Index	Power loss	
		(APL%)	(RPL%)		(KW)	(KVAR)
type 1	30	29.77	28.54	0.79	203.90	139.58
type 3	31	29.439	0	0.77	259.01	174.37
type 4	31	0	29.41	0.73	507.96	343.35

Figure 8 show the impact of DG on voltage profile considering only one type optimally installed. It can be observed that the greatest improvement on voltage profile is achieved when the DG units of type 1 is integrated.

Figure 8. Voltage profile before and after integrating of DGS in the first load state

Case-II: four DGs are connected: in order to compare with the first case, the total active and reactive penetration of DGs are limited to 30 %. (The first load state has been used in the investigation).

In this case, three scenarios have been investigated to show the effect of DGs number on the voltage stability and the power losses.

Scenario1: four DG units of type 3 have been installed. Maximum penetration of each unit is $APL_{max}=(30/4)\%$, $RPL_{max}=(30/4)\%$. The optimal sizes and locations obtained are given in Table 4.

Scenario2: four DG units of type 4 have been installed. Maximum penetration of each unit is $APL_{max}=(30/4)\%$, $RPL_{max}=(30/4)\%$. The optimal sizes and locations obtained are given in Table 5.

Scenario3: two DG units of type 3 with two DG units of type 4 have been installed. Maximum penetration of each unit is $APL_{max}=(30/2)\%$, $RPL_{max}=(30/2)\%$. The optimal sizes and locations obtained are given in Table 6.

Table 4. Optimal locations and sizes of the four DG units of type 3.

Optimal location				Optimal size			
DG unit 1	DG unit 2	DG unit 3	DG unit 4	DG unit 1 (APL%)	DG unit 2 (APL%)	DG unit 3 (APL%)	DG unit 4 (APL%)
31	29	18	13	7.50	7.49	7.46	7.50
Stability Index				Power loss			
				(KW)		(KVAR)	
0.84				212.11		138.62	

Table 5. Optimal locations and sizes of the four DG units of type 4.

Optimal location				Optimal size			
DG unit 1	DG unit 2	DG unit 3	DG unit 4	DG unit 1 (RPL%)	DG unit 2 (RPL%)	DG unit 3 (RPL%)	DG unit 4 (RPL%)
29	13	18	31	7.50	7.50	7.50	7.50
Stability Index				Power loss			
				(KW)	(KVAR)		
0.795				410.24	273.33		

Table 6. Optimal locations and sizes of the four DG units of type 3 and 4.

Optimal location				Optimal size			
DG unit 1 (Type 3)	DG unit 2 (Type 3)	DG unit 3 (Type 4)	DG unit 4 (Type 4)	DG unit 1 (APL%)	DG unit 2 (APL%)	DG unit 3 (RPL%)	DG unit 4 (RPL%)
15	31	30	18	14.22	13.83	12.88	13.15
Stability Index				Power loss			
				(KW)	(KVAR)		
0.87				164.34	106.29		

The optimal location and size of each DG unit for different scenarios are shown in table 4 to 6. Comparing with the first case, table 4 and 5 show that the number of DGs affects significantly the stability and the power losses. It is observed from there sults that four optimally installed DGs present better voltage stability and less power losses than one installed DG with the same total size. It is also observed from the results in table 6 that when DGs of different types are installed optimally, a higher loss reduction and stability improvement can be achieved.

A comparison between the voltage stability index obtained by integration of one DG type1 and the one obtained in the scenario 3 is illustrated in Figure 9.

Figure 9. Voltage stability index before and after integrating of DGS

It is noted from the results given in case-I and case-II that an optimal integration of several small DGs with deferent types improves the stability of the network and reduce the energy loss more than the use of one DG of important size. Moreover, the reliability of the power injection is increased.

Case III: Two different DGs are connected to the modified IEEE 119-node test feeder (Figure 10) [29]. The first one is a type 3 DG with a maximum capacity of 1,9 MW and the second one is considered as a set of reactive compensators (type 4 DG) of 0.2MVA. This test system is an 11 kV distribution system.

Figure 10. The modified 119-bus test system[29]

Table 7. Optimal locations and size of the two DG units of type 3 and 4.

Optimal location		Optimal size	
DG type 3	DG type 4	DG type 3 (APL%)	DG type4(RPL%)
79	80	9.985	35.794
Stability Index		Power loss	
		(KW)	(KVAR)
0.7954		1577.7	1206

Figure 11. Voltage stability index before and after integrating DGs

The optimal locations and size of the two DGs are presented in table 7. Results show that the optimal placement is situated at a node within the area with high loads and that the optimal size of DGs is their full capacity. The voltage stability index of all buses before and after integrating DGs is presented in Figure 11 it can be noticed that only the feeder of buses 66 to 104 had it stability index effected by the integration of DGs. This can be explained by the fact that the DGs are present only on this feeder branch and that the different feeders are separated. Under these circumstances, the effects of the DGs are limited to this feeder branch.

It can also be noticed that the integration of the type 4 DG didn't improve much the stability index of the affected set of buses while a great improvement of the index occurred with integration of a type 3 DG. It is worth mention that our algorithm operates normally with large systems.

6. Conclusion

In this paper, SPEA algorithm has been used to investigate the optimal DG placement and size in a distributed network. The optimization problem has been formulated in order to improve voltage stability and minimize total active and reactive power losses for integration of different DG types. Penetration level of DG, voltage and current limit are considered as the constraints in

the optimization process. A steady state voltage stability index has been used to assess the stability at each node. A 33-node distribution network has been used for the simulation. Illustrative mesh plots were given in this paper to show the impacts of DGs locations and sizes on the voltage stability and power losses. The proposed algorithm has been used in different scenarios to show the effect of the type and the number of DGs integration on the distributed network. The location, size and type of DGs significantly affect the voltage stability and the power losses. The algorithm proposed in this paper can find a compromise between different objective functions providing useful information for optimal DGs integration.

7. References

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8. Appendix

Line #	Node i	Node j	R (Ω)	X (Ω)	Load at node j		Line #	Node i	Node j	R (Ω)	X (Ω)	Load at node i	
					P (kw)	Q (kvar)						P (kw)	Q (kw)
1	1	2	0.0922	0.047	100	60	20	20	21	0.4095	0.4784	90	40
2	2	3	0.493	0.2512	90	40	21	21	22	0.7089	0.9373	90	40
3	3	4	0.3661	0.1864	120	80	22	3	23	0.4512	0.3084	90	50
4	4	5	0.3811	0.1941	60	30	23	24	25	0.8980	0.7091	420	200
5	5	6	0.8190	0.7070	60	20	24	24	25	0.8980	0.7071	420	200
6	6	7	0.1872	0.6188	200	100	25	6	26	0.2031	0.1034	60	25
7	7	8	0.7115	0.2351	200	100	26	26	27	0.2842	0.1474	60	25
8	8	9	1.0299	0.7400	60	20	27	27	28	1.0589	0.9338	60	20
9	9	10	1.044	0.7400	60	20	28	28	29	0.8043	0.7006	120	70
10	10	11	0.1967	0.0651	45	30	29	29	30	.5074	0.2585	200	100
11	11	12	0.3744	0.1298	60	35	30	30	31	0.9745	0.9629	150	70
12	12	13	1.4680	1.1549	60	35	31	31	32	0.3105	0.3619	210	100
13	13	14	0.5416	0.7129	120	80	32	32	33	0.3411	0.5302	60	40
14	14	15	0.5909	0.5260	60	10	-	-	-	-	-	-	-
15	15	16	0.7462	0.5449	60	20	-	-	-	-	-	-	-
16	16	17	1.2889	1.7210	60	20	-	-	-	-	-	-	-
17	17	18	0.7320	0.5739	90	40	-	-	-	-	-	-	-
18	2	19	0.1640	0.1565	90	40	-	-	-	-	-	-	-
19	19	20	1.5042	1.3555	90	40	-	-	-	-	-	-	-

Table 2. System data of 12 buses and 11 branches system

Branch no.	Sending end	Receiving end	R (ohms)	X (ohms)	Load at node i	
					PL (kW)	QL (kVAR)
1	1	2	1.093	0.455	0	0
2	2	3	1.184	0.494	60	60
3	3	4	2.095	0.873	40	30
4	4	5	3.188	1.329	55	55
5	5	6	1.093	0.455	30	30
6	6	7	1.002	0.417	20	15
7	7	8	4.403	1.215	55	55
8	8	9	5.642	1.597	45	45
9	9	10	2.89	0.818	40	40
10	10	11	1.514	0.428	35	30
11	11	12	1.238	0.351	40	30
					15	15

Table 3. System data for modified 119-bus distribution network

Line #	Node i	Node j	R (Ω)	X (Ω)	Load at node j		Line #	Node i	Node j	R (Ω)	X (Ω)	Load at node i	
					P (kw)	Q (kvar)						P (kw)	Q (kw)
1	1	2	0.036	0.01296	101.14	0.12	60	60	61	0.207	0.0747	90.758	0.69
2	2	3	0.033	0.01188	11.292	0.11	61	61	62	0.247	0.8922	47.7	0.823
3	2	4	0.045	0.0162	21.845	0.15	62	31	63	0.187	0.261	369.7	0.623
4	4	5	0.015	0.054	63.602	0.05	63	63	64	0.133	0.099	321.64	0.443
5	5	6	0.015	0.054	68.604	0.05	64	64	65	0.070	0.044	150.64	0.223
6	6	7	0.015	0.0125	61.725	0.05	65	1	66	0.028	0.0418	463.74	0.093
7	7	8	0.018	0.014	11.503	0.06	66	66	67	0.117	0.2016	52.006	0.39
8	8	9	0.021	0.063	51.073	0.07	67	67	68	0.255	0.0918	100.34	0.85
9	2	10	0.166	0.1344	106.77	0.553	68	68	69	0.21	0.0759	193.5	0.7
10	10	11	0.112	0.0789	75.99	0.373	69	69	70	0.383	0.138	26.713	1.277
11	11	12	0.187	0.313	18.687	0.623	70	70	71	0.504	0.3303	25.257	1.68
12	12	13	0.142	0.1512	23.22	0.473	71	71	72	0.4	0.1461	38.713	1.353
13	13	14	0.18	0.118	117.5	0.6	72	72	73	0.962	0.761	395.14	3.207
14	14	15	0.15	0.045	28.79	0.5	73	73	74	0.165	0.06	239.74	0.55
15	15	16	0.16	0.18	26.45	0.533	74	74	75	0.303	0.1092	84.363	1.01
16	16	17	0.157	0.171	25.23	0.523	75	75	76	0.303	0.1092	22.482	1.01
17	11	18	0.218	0.285	11.906	0.727	76	76	77	0.206	0.144	1614.775	110.687
18	18	19	0.118	0.185	78.523	0.393	77	77	78	0.233	0.084	129.817	110.777
19	19	20	0.16	0.196	351.4	0.533	78	78	79	0.591	0.1773	1122.43	111.97
20	20	21	0.12	0.189	164.2	0.4	79	79	80	0.126	0.0453	145.37	110.42
21	21	22	0.12	0.0789	54.594	0.4	80	67	81	0.559	0.3687	223.22	1.863
22	22	23	1.41	0.723	39.65	4.7	81	81	82	0.186	0.1227	162.47	0.62
23	23	24	0.293	0.1348	95.178	0.977	82	82	83	0.186	0.1227	437.92	0.62
24	24	25	0.133	0.104	150.22	0.443	83	83	84	0.26	0.139	183.03	0.867
25	25	26	0.178	0.134	24.62	0.593	84	84	85	0.154	0.148	183.03	0.513
26	26	27	0.178	0.134	24.62	0.593	85	85	86	0.23	0.128	119.29	0.767
27	27	28	0.1866	0.127	53.336	0.622	86	86	87	0.252	0.106	27.96	0.84
28	4	29	0.015	0.0296	522.62	0.05	87	87	88	0.18	0.148	26.515	0.6
29	29	30	0.012	0.0276	59.117	0.04	88	82	89	0.16	0.182	257.16	0.533
30	30	31	0.12	0.2766	99.554	0.4	89	89	90	0.2	0.23	20.6	0.667
31	31	32	0.21	0.243	318.5	0.7	90	90	91	0.16	0.393	11.806	0.533
32	32	33	0.12	0.054	456.14	0.4	91	91	92	0.16	0.393	11.806	0.533
33	33	34	0.178	0.234	136.79	0.593	92	68	93	0.669	0.2412	42.96	2.23
34	34	35	0.178	0.234	83.302	0.593	93	93	94	0.266	0.1227	34.93	0.887
35	35	36	0.154	0.162	93.082	0.513	94	94	95	0.266	0.1227	66.79	0.887
36	36	37	0.21	0.1383	42.361	0.7	95	95	96	0.266	0.1227	81.748	0.887
37	37	38	0.12	0.0789	51.653	0.4	96	96	97	0.266	0.1227	66.526	0.887
38	38	39	0.15	0.0987	57.965	0.5	97	97	98	0.233	0.115	15.96	0.777
39	39	40	0.15	0.0987	1205.1	0.5	98	98	99	0.496	0.138	60.48	1.653
40	40	41	0.24	0.1581	146.66	0.8	99	95	100	0.196	0.18	224.85	0.653
41	41	42	0.12	0.0789	56.608	0.4	100	100	101	0.196	0.18	367.42	0.653
42	42	43	0.405	0.1458	40.184	1.35	101	101	102	0.1866	0.122	11.7	0.622
43	43	44	0.405	0.1458	283.41	1.35	102	102	103	0.0746	0.318	30.392	0.249
44	44	45	0.405	0.1458	283.41	1.35	103	103	104	0.0746	0.318	30.392	0.249
45	30	46	0.33	0.194	55.134	1.1	104	1	105	0.0625	0.0265	47.572	0.208
46	46	47	0.31	0.194	38.998	1.033	105	105	106	0.1501	0.234	350.3	0.5
47	47	48	0.13	0.194	342.6	0.433	106	106	107	0.1347	0.0888	449.29	0.449
48	48	49	0.28	0.15	278.56	0.933	107	107	108	0.2307	0.1203	168.46	0.769
49	49	50	1.18	0.85	240.24	3.933	108	108	109	0.447	0.1608	134.25	1.49
50	50	51	0.42	0.2436	66.562	1.4	109	109	110	0.1632	0.0588	66.024	0.544
51	51	52	0.27	0.0972	39.76	0.9	110	110	111	0.33	0.099	83.647	1.1
52	52	53	0.339	0.1221	31.964	1.13	111	111	112	0.156	0.0561	419.34	0.52
53	53	54	0.27	0.1779	20.758	0.9	112	112	113	0.3819	0.1374	135.88	1.273
54	30	55	0.391	0.141	26.86	1.303	113	113	114	0.1626	0.0585	387.21	0.542
55	55	56	0.406	0.1461	88.38	1.353	114	114	115	0.3819	0.1374	173.46	1.273
56	56	57	0.406	0.1461	55.436	1.353	115	115	116	0.2445	0.0879	898.55	0.815

57	57	58	0.706	0.5461	332.4	2.353	116	116	117	0.2088	0.0753	215.37	0.696
58	58	59	0.338	0.1218	16.83	1.127	117	117	118	0.2301	0.0828	40.97	0.767
59	59	60	0.338	6	49.156	1.127	118	105	119	0.6102	0.2196	192.9	2.034

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