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Placement of Distributed Generation Unit and Capacitor Allocation in Distribution Networks In Order To Reduce Losses and Develop Voltage Profile Using Genetic Algorithm

Mehrdad Movahed Poor, Saeed Boyerahmadi

Technical & Vocational University, Iran

ABSTRACT

This paper is aimed at investigating optimal placement of DG and capacitor in radial distribution systems in order to reduce losses and enhance voltage profile. Simulation is done using genetic algorithm to minimize loss of active power, loss of reactive power and to enhance voltage profile and multipurpose optimization. In this study, at first the effect of placement of DG and capacitor is evaluated separately and then it is investigated synchronously. With regard to synchronic placement two conditions are examined: 1) all equipments are embedded on a same bus. 2) Equipments are placed on different buses. Load flow is done according to Raphson-Newton method. Simulation conducted on the two standard networks 33 and 69 bus IEEE is tested. Results indicate that losses are reduced significantly and voltage profile is enhancing also.
KEYWORDS: optimal placement of DG, capacitor allocation, genetic algorithm, losses, voltage profile, Raphson-Newton.

INTRODUCTION

With regard to the fact that power equipments are designed for special voltages therefore if the voltage is violated from its rated voltage it may harms the system equipments and causes aging effect on them. Therefore, regulation of bus voltage is mandatory. Series capacitors are used in transmission and distribution networks to regulate reactance and shunt capacitors are used to correct power coefficient, regulate voltage and transmittal reactive power [9,11]. Losses are existed at all levels of power system including generation, transmission and distribution. The most loss is of the distributed system and therefore main focus is on the loss reduction of distribution systems. With regard to competition and renewal of structure of power systems, it is expected that small generation units (distributed generation) play the most important role in the future of systems [10]. Placement of DG is a vital process such that installing DG units in non-optimal places can have negative effects on network loss and leads to higher costs, unpleasant effects on system reliability such as lack of coordination between fuse-recloser [7]. Therefore, to find the optimal place for DG, genetic algorithms used [1, 8, 9, and 11]. There are multiple reasons to use distributed generation plants:

1- *Reduction of system harmonics*
2- *Improvement of reliability of systems*
3- *Improvement of voltage profile*
4- *Removing cost needs for preparing infrastructures related to generation, distribution and transmission networks.*

By placing distributed power unit, it is possible to reduce the cost of repairmen and maintenance of power systems and to diminish voltage loss and to develop voltage of system [9,10] .

GENETIC ALGORITHM FOR OPTIMAL PLACEMENT OF DG AND CAPACITORS

Genetic algorithm works with a set of coded parameters. Instead of a single point, it begins searching from a set of poits parallely. Therefore, it is less likeley to reach a pesudo-optimal low point. Genetic algorithm uses the main information og objective function. It dosen't need auxilliary data such as derivative of objective function. This algorithm hase been produces according to evolution and genetic mechanisms. It includes three operators: generation of elite population, crossover and mutation.

1-2- selection: this operator imitates mechanism of nature survive i.e. it grants more chance to better creature and less chance to worse one. In each stage, two creatures are considered as parents using two selections.

2-2- crossover: this operator generates offsprings from parents. In this stage, two chromosomes of parents are selected accidentally.

The genes located before the cut point are directly transmitted to offspring 1 from prent 1 and to offspring 2 from parent 2. Cutting is done by the possibility of $\mathbf{P_{cross}}$ ($0 \leq P_{cross} \leq 1$). If the cut stage is eliminated, all genes are transmitted to offspring 1 from parent 1 and to offspring 2 from parent 2. In the most cases, $\mathbf{P_{cross}}$ ranges from 0 to 0.8. in this experiment $\mathbf{P_{cross}}$ =0.8.

2-3- mutation: if this operator is regulated correctly then if prevents the answer to approach local optimal point instead of central optimal one. In each chromosome, mutation is done by the possibility of $P_{mutation.}$ In this stage, one gene is selected from chromosome randomly and then the selected gene will be changed. For example in binary chromosomes, one of the selected genes will be changed to 1 if it is 0 and will be changed to 0 if it is 1. This method allows us to work with whole research space. $P_{mutation}$ ranges from 0.01 to 0.1 which is considered as 0.1here.

Corresponding Author: Saeed Boyerahmadi, Technical & Vocational University, Iran

DETERMINATION OF OBJECTIVE FUNCTION

multi-purpose function composes of multiple function which is determined according to defined indices and their weights:

$$MVAsys=[(P_{intake} + p_{DG})^2 + (Q_{intake} + Q_C)^2]^{0.5} \qquad (1)$$

Where:
P_{intake}: intake active power of Distribution Company
P_{DG}: active power of distributed generation unit
Q_C: reactive power of capacitor
Q_{intake}: intake reactive power

1- *below indices are presented to explain charge model:*
a) *loss of active and reactive power indices*
b) *LPI=*$\frac{P_{LDG}}{P_L}$ *(2)*
c) *LQI=*$\frac{Q_{LDG}}{Q_L}$ *(3)*

Q_{LDG}, P_{LDG} are total active and reactive loss power of distribution system after DG enters. P_L and Q_L are total active and reactive system power losses without DG in the Distribution system .

b) voltage profile index (VPI): the mentioned index indicates the pair (magnitude-place) with a deviation higher then nominal level (V1 = 1pu). Therefore, index near zero increases network efficiency. VPI is small and placed in permitted range.

$$VPI=\max_{i=2}^{n}\left(\frac{|\overline{v_1}|-|\overline{v_i}|}{|\overline{v_1}|}\right) \qquad (4)$$

DETERMINATION OF OBJECTIVE FUNCTION ACCORDING TO THE MENTIONED INDICES AND ADMINISTRATING GENETIC ALGORITHM

Objective function is presented as FF. optimization of GA for finding the best answer uses optimization algorithm for FF. if the structure of the network is constant and all branches are determined among bus, evaluation of objective function depends loation, magnitude of DG and capacitor.

Administrating GA using random population leads to possible initial answers. A DG place and a bus capacitor are specified for each answer. A pair of magnitude-place remains till total power loss of system is selected randomly for DG penetration level and optimal capacitor. Genetic operators are exploited to generate new population. If one of the requirements is not satisfied or the location or magnitude of DG is out of permitted range, therefore the answer will be pulled out and the algorithm will repeat again. Objective function is determined according to the presented indices and their weights.

$$FF=(\omega_1.LPI + \omega_2.LQI + \omega_3.VPI) \qquad (5)$$

$$\sum_{p=1}^{3}\omega_p = 1 \qquad \omega_p\epsilon[0,1]$$

ω_ρS are weight coefficients. These coefficients give us the specified importance of each index for DG penetration using charge models which depends on required analysis. Normalized weight indices are considered as component of objective function whose weights are calculated according to their effect on the function. Their values are given in the below table:

Table1: weight coefficient of indices

Weight coefficient	Index
0.35	PLI
0.35	QLI
0.30	VPI

2- Multi-purpose function (5) is minimized according to operational constraints. These constraints are:
1) Power keeping range: algebraic summation over inputs and outputs including loss of distribution network and power generated of DG unit must equal to zero:

$$2)\quad P_{Gi} + P_{DGi} - P_{Di} = 0 \qquad (6)$$

$$3)\quad Q_{Gi} - Q_{Di} = 0 \qquad (7)$$

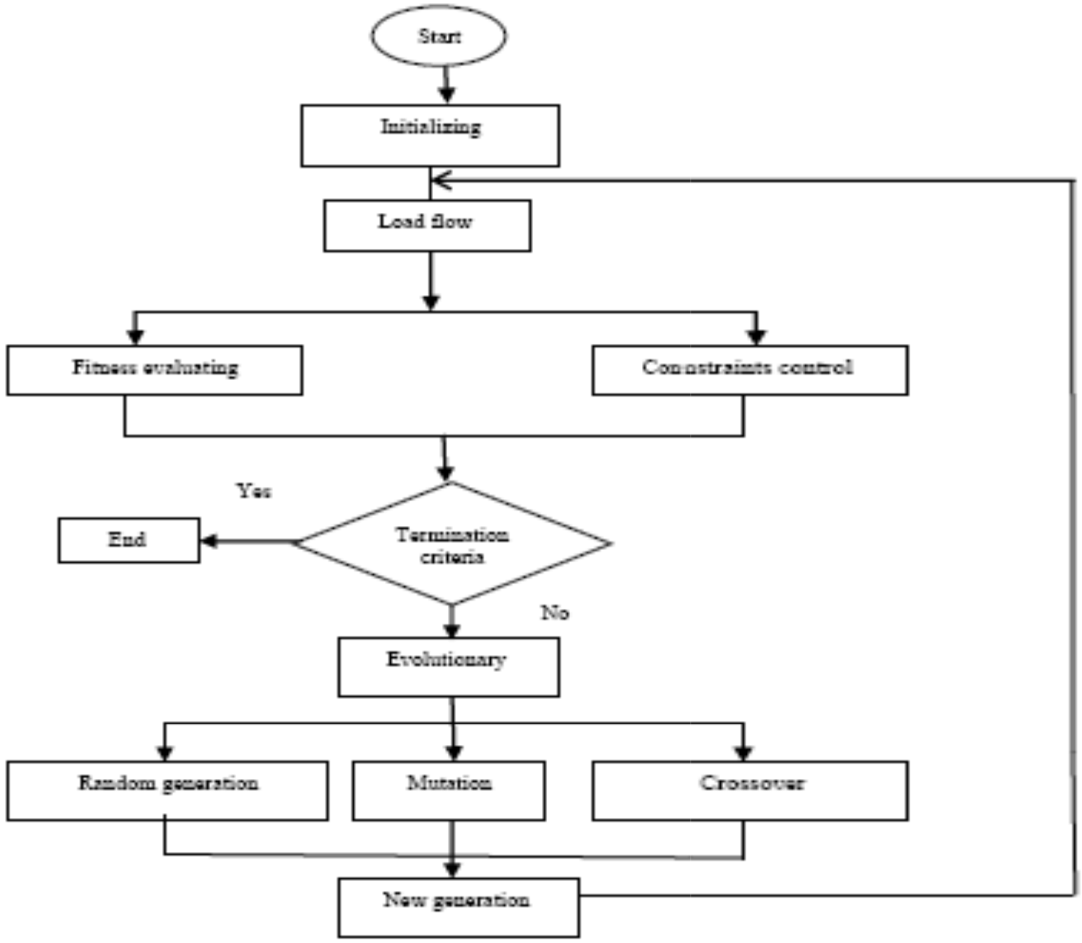
P_D means power demand.
2) range of distribution line capacity: charge spreading must determine heat capacity of lines.

$$S_{(i,j)} \leq S_{(i,j)\,\max} \qquad (8)$$

4) Specified range of voltage

$$V_{min} < V < V_{max} \qquad (9)$$

3- *The flowchart of optimization of installing distributed plants and capacitors using genetic algorithm is given in the figure (1).*



Figure(1): flochart of administrating genetic algorithm

Numerical investigations and results of simulation conducted on sample systems:
In this section, numerical investigation conducted on the two networks (33- and 69-bus systems) having high loss and unsuitable voltage profile is presented. It is assumed that capacitors are single-step ones and the power of each one is 0.1 of whole reactive power in the peak level. Also, active power of distributed resource equals to 0.4 of active power in the peak level. Power coefficient of distributed generation resource is considered as 1. At first, the effects of separately placing DG avd capacitor is evaluated and then synchronplacement is investigated. Simulation of sample systems is tested. The variables in this condition are:
Finding the place of installing distributed generation resource, finding the place of installing capacitors, determining generative power of distributed generation resource.
2-5- in this thesis, two standard network (33- and 69-bus networks) are used. In the following, the mentioned networks are defined.
1-2-5 presenting 33-bus network: this system is a radial network. Figure (2) represents the mentioned network. Voltage profile of this network is seen in figure (3).

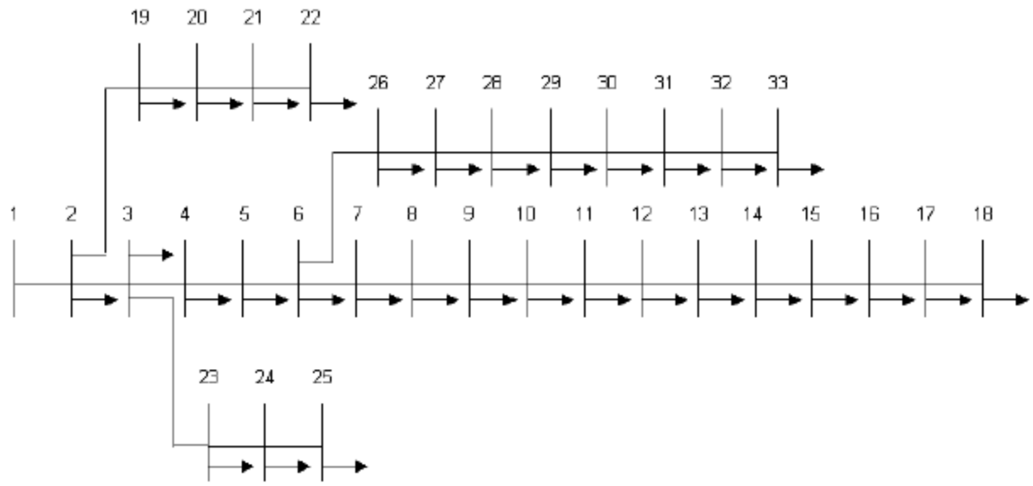


Figure (2): radial 33-bus network

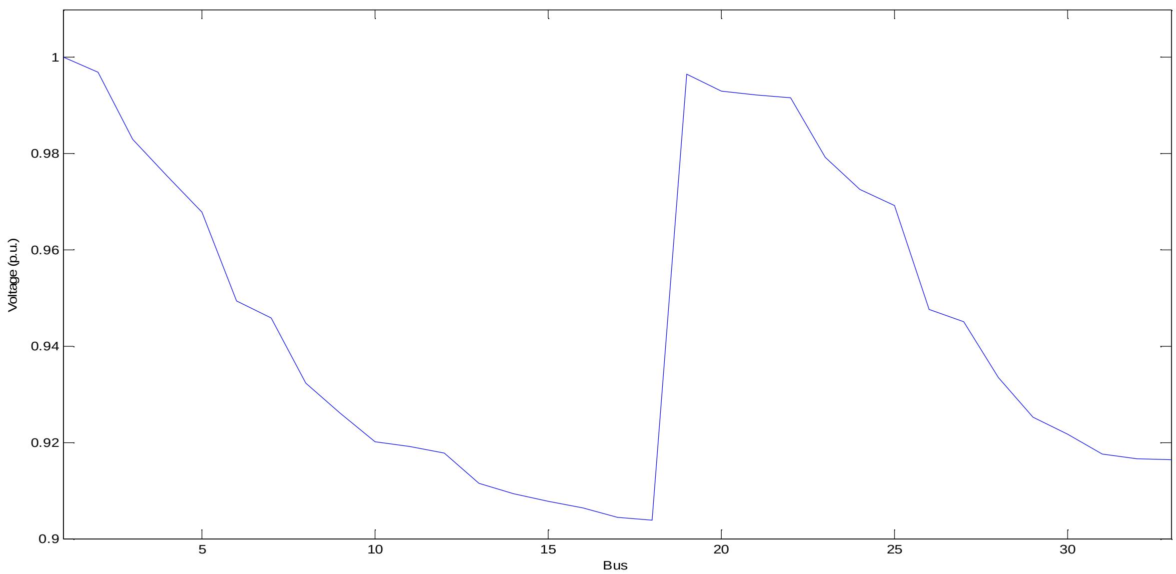


Figure (3): voltage profile of 33-bus network

Table (2): active, reactive and minimum loss and voltage for ground state of 33-bus network

	Active loss	Reactive loss	Minimum loss of voltage
Value (perionite)	0.2110	0.1430	0.9037

2-2-5- presenting 69-bus network:

This network is a radial one which is represented in figure (4). Voltage profile of the mentioned network is shown in figure (5).

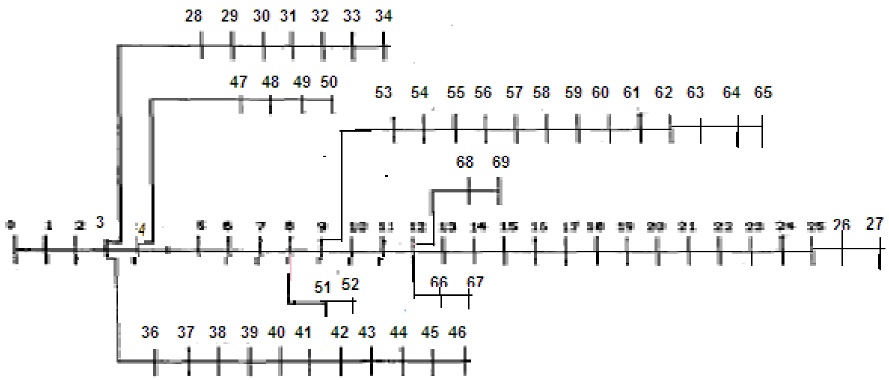


Figure (4): radial 69-bus network

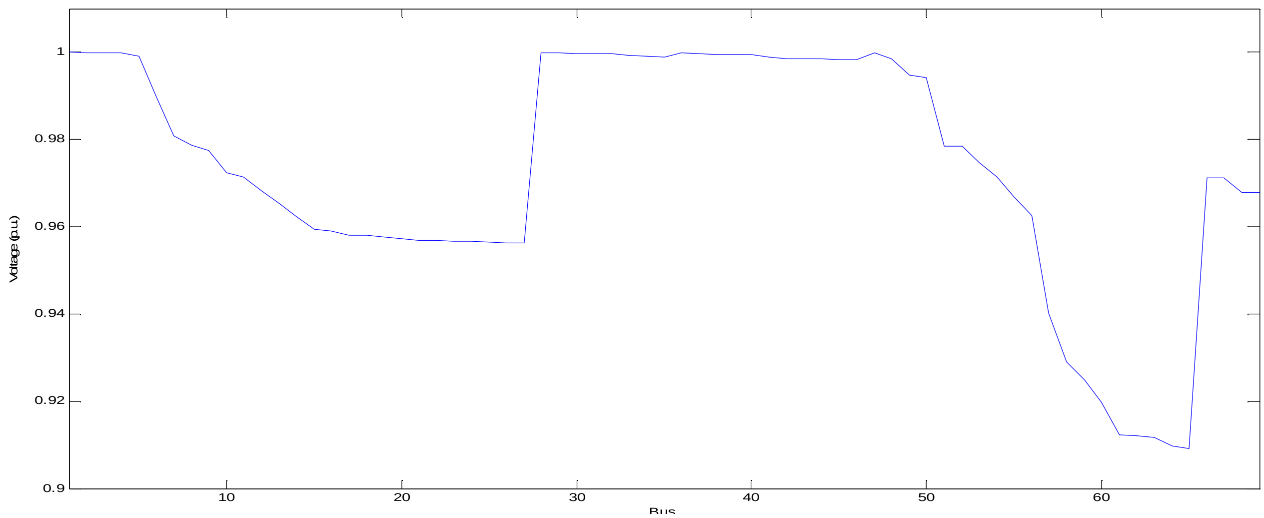


Figure (5): voltage profile of 69-bus network

Table (3): active, reactive and minimum loss of voltage for ground state of 69-bus network

	Active loss	Reactive loss	Minimum loss of voltage
value	0.2250	0.1022	0.9092 (bus 65)

1-3-5- in this section, numerical studies are conducted on 33- and 69-bus systems. At first, placement of placement of two distributed generation units is evaluated and then placement of a 4 capacitors is tested and the results are presented in tables (4) and (5).

Table (4): a) results of placing one and two distributed generation units conducted on 33-bus system

	Installing one distributed generation unit	Installing two distributed generation units	Promotion percent
Objective value	0.8276	0.3013	63.59
Number of the bus for installing distributed generation unit and capacitors	9	30 and 12	………………
Value of generative power of distributed generation unit	0.4	0.4 and 0.27	……………….
LPI	0.5763	0.4140	28.16
LQI	0.5826	0.4179	28.26
VPI	0.0612	0.0339	44.60
Active loss after installing equipments (KW)	121.6	87.3	28.20
Reactive loss after installing equipment (KVAR)	83.3	59.8	28.21
Total deviation of minimum voltage (V)	511.46	0.0000	100

Table (4): b) results of placing one to four capacitors conducted on 33-bus system

	Installing one capacitor	**Installing two capacitors**	**Installing three capacitors**	**Installing four capacitors**
Objective value	5.0514	3.9468	3.0438	2.3135
Number of the bus for installing distributed generation unit and capacitors	18	17 and 18	17 and 17 and 18	15 and 16 and 17 and 18
Value of generative power of distributed generation unit	……………..	……………	…………	……………..
LPI	0.9234	0.8935	0.8963	0.8967
LQI	0.9227	0.9006	0.9170	0.9182
VPI	0.0812	0.0792	0.0776	0.0761
Active loss after installing equipments (KW)	194.8	188.5	189.1	189.2
Reactive loss after installing equipment (KVAR)	132	128.8	131.2	131.3
Total deviation of minimum voltage (V)	5546	4160	3020	2095

Table (5): a) results of placing one and two distributed generation units conducted on 69-bus system

	Installing one distributed generation unit	**Installing two distributed generation units**	**Promotion percent**
Objective value	0.2935	0.2492	15.09
Number of the bus for installing distributed generation unit and capacitors	61	12 and 61	……………….
Value of generative power of distributed generation unit	0.4	0.4 and 0.4	……………..
LPI	0.3896	0.3292	15.5
LQI	0.4200	0.3589	14.45
VPI	0.0338	0.0279	17.45
Active loss after installing equipments (KW)	87.7	74.1	15.5
Reactive loss after installing equipment (KVAR)	42.9	36.7	14.45
Total deviation of minimum voltage (V)	0	0	0

Table (5): b) results of placing one to four capacitors conducted on 69-bus system

	Installing one capacitor	**Installing two capacitors**	**Installing three capacitors**	**Installing four capacitors**
Objective value	3.0465	2.6427	2.3071	2.0312
Number of the bus for installing distributed generation unit and capacitors	65	64 and 65	64 and 64 and 65	61 and 64 and 64 and 65
Value of generative power of distributed generation unit	……………….	………………….	……………..	…………….
LPI	0.8804	0.8000	0.7499	0.7149
LQI	0.8881	0.8128	0.7659	0.7319
VPI	0.0847	0.0799	0.0757	0.0726
Active loss after installing equipments (KW)	198.1	180	168.7	160.8
Reactive loss after installing equipment (KVAR)	90.7	83	78.2	74.8
Total deviation of minimum voltage (V)	3040	2600	2220	1902

According to results of the given tables, it is obvious that optimal replacement of distributed generation plant reduces loss and promotes voltage profile. By adding another distributed generation unit, better results are obtained. Adding a more capacitor has positive effect on objective function.

2-3-5- placement of DG and capacitor synchronously:

Studies are divided into two parts:

1- *Finding optimal location when all resources of distributed generation plant and capacitors are embedded in one bus*
2- *Finding optimal place when all resources of distributed generation plant and capacitors are embedded in multiple buses*

1-2-3-5- simulation for 33-bus network in presence of DG and capacitor synchronously:

1-1-2-3-5- installing resource of distributed generation plant and capacitor on one bus:

Results of table (6) indicates that, when all equipments (capacitors and distributed generation resources) are embedded on one bus of 33-bus network, the values of LPI, LQI and VPI are not the same as the values of the objective function. The reason is the fine due to placing bus voltage in the range of 0.95 perionite to 1.05 perionite. Algorithm couldn’t find an answer for installing the units in which bus voltages are not placed in the mentioned range. On the other hand, there is no solution to meet the problem constraints. Accordingly, the best solutions are presented but they don’t meet the problem requirements.

Table (6): results of installing distributed generation unit and capacitor on a bus of 33-bus system

	Minimizing LPI	Minimizing LQI	Minimizing VPI	Multi-purpose
Objective value	0.5122	0.5244	0.1459	0.4066
Number of the bus for installing distributed generation unit and capacitors	8	8	8	8
Value of generative power of distributed generation unit	0.4	0.4	0.4	0.4
LPI	0.4199	0.4199	0.4199	0.4199
LQI	0.4321	0.4321	0.4321	0.4321
VPI	0.0536	0.0536	0.0536	0.0536
Active loss after installing equipments (KW)	0.0886	0.0886	0.0886	0.0886
Reactive loss after installing equipment (KVAR)	0.0618	0.0618	0.0618	0.0618
Total deviation of minimum voltage (V)	0.0092	0.0092	0.0092	0.0092

2-1-2-3-5- installing distributed generation plant and capacitors on multiple buses:

Results of installing distributed generation unit and capacitors on multiple buses are shown in table (7). By comparing these results and the results of placing all equipments on a same bus, it is obvious that results are more satisfactory. Replacing distributed generation plant and capacitors on multiple buses instead of a same bus leads to better values for objective function.

Table (7): results of installing distributed generation unit and capacitors of multiple buses of 33-bus network

	Minimizing LPI	Minimizing LQI	Minimizing VPI	Multi-purpose
Objective value	0.3354	0.3405	0.0346	0.2494
Number of the bus for installing distributed generation unit	8	8	29	8
Number of bus for installing first capacitor	30	14	17	32
Number of bus for installing second capacitor	30	30	13	14
Number of bus for installing third capacitor	32	32	14	30
Number of bus for installing fourth capacitor	15	30	15	30
Value of generative power of distributed generation unit	0.4	0.4	0.4	0.4
LPI	0.3354	0.3361	0.4685	0.3356
LQI	0.3403	0.3405	0.5092	0.3402
VPI	0.0426	0.0435	0.0346	0.0428
Active loss after installing equipments (KW)	0.0708	0.0709	0.0988	0.0708
Reactive loss after installing equipment (KVAR)	0.0478	0.0478	0.0728	0.0487

2-2-3-5-simulation for 69-bus network:

In this section, simulation is done for two conditions:

1- *Finding location when all resources of distributed generation and capacitors are embedded in a same bus*
2- *Finding location when all resources of distributed generation and capacitors are embedded in multiple buses*

1-2-2-3-5- installing distributed generation resource and capacitors on the same bus:

With regard to the results of table (8) and comparing them with the previous characteristics of test network, it is obvious that installing distributed generation unit and capacitors reduces system loss significantly and it promotes voltage profile too.

Table (8): results of installing distributed generation unit and capacitors on the same bus of 69-bus system

	Minimizing LPI	Minimizing LQI	Minimizing VPI	Multi-purpose
Objective value	0.1391	0.1819	0.0305	0.1215
Number of bus for installing distributed generation unit and capacitor	61	61	61	61
Value of generative power of distributed generation unit	0.4	0.4	0.4	0.4
LPI	0.1391	0.1391	0.1391	0.1391
LQI	0.1819	0.1819	0.1819	0.1819
VPI	0.0305	0.0305	0.0305	0.0305
Active loss after installing equipments (KW)	0.0313	0.0313	0.0313	0.0313
reactive loss after installing equipments (KW)	0.0186	0.0186	0.0186	0.0186

2-2-2-3-5- installing distributed generation resource and capacitors on various buses:

The results of installing distributed generation resource and capacitors on various buses are shown in table (9).

Table (9: the results of installing distributed generation unit and capacitors on various buses for 69-bus network

	Minimizing LPI	Minimizing LQI	Minimizing VPI	Multi-purpose
Objective value	0.1379	0.1806	0.0237	0.1213
Number of the bus for installing distributed generation unit	61	61	61	61
Number of bus for installing first capacitor	61	61	21	61
Number of bus for installing second capacitor	61	61	62	61
Number of bus for installing third capacitor	61	61	25	61
Number of bus for installing fourth capacitor	64	64	65	63
Value of generative power of distributed generation unit	0.4	0.4	0.4	0.4
LPI	0.1379	0.1379	0.1983	0.1388
LQI	0.1806	0.1806	0.2334	0.1816
VPI	0.0305	0.0305	0.0237	0.0305
Active loss after installing equipments (KW)	0.0310	0.0310	0.0446	0.0312
Reactive loss after installing equipment (KVAR)	0.0184	0.0184	0.0238	0.0185

According to the comparison between results of tables (8) and (9), it is seen that installing distributed generation units and capacitors on various buses plays a more significant role in reducing loss and promoting voltage profile.

CONCLUSION

This study is conducted based on genetic algorithm for optimal placement of distributed generation plants and series capacitors. Charge load flow is done according to Raphson-Newton method. Genetic algorithm allows us to found the best solutions as soon as possible. DG presence and capacitors embedded in distribution systems with various arrangements reduce loss and promote voltage profile. Results indicate that the best solution is obtained when DG and capacitors are embedded on various bus. Also, it is proved that the best location for installing DG and capacitors is bus. Located near the load. When DG and capacitors are located on various buses, the outcome is better than the situation in which equipments are embedded on the same bus.

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