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Distributed generation's integration planning involving growth load models by means of genetic algorithm

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Abstract: The growth in the system load accompanied by an increase of power loss in the distribution system. Distributed generation (DG) is an important identity in the electric power sector that substantially overcomes power loss and voltage drop problems when it is coordinated with a location and size properly. In this study, the DG integration into the network is optimally distributed by considering the load conditions in different load models used to surmount the impact of load growth. There are five load models tested namely constant, residential, industrial, commercial and mixed loads. The growth of the electrical load is modeled for the base year up to the fifth year as a short-term plan. Minimization of system power loss is taken as the main objective function considering voltage limits. Determination of the location and size of DG is optimally done by using the breeder genetic algorithm (BGA). The proposed studies were applied to the IEEE 30 radial distribution system with single and multiple placement DG scenarios. The results indicated that installing an optimal location and size DG could have a strong potential to reduce power loss and to secure future energy demand of load models. Also, commercial load requires the largest DG active injection power to maintain the voltage value within tolerable limits up to five years.

Key words: distributed generation, genetic algorithm, load models, power loss, load growth

1. Introduction

In rapid economic developments, rising population growth and increased investment in the industrial sector have contributed to the remarkable increase in Southeast Asian energy consumption in recent years. Power demand in this region has increased 2.5 times in the last 20 years [1]. By 2040, Southeast Asias energy demand will increase to almost 1100 MTOe (the increase by 80%). The expansion of transmission and distribution networks and the addition of the number of plants is a solution to the growing demand for energy. In any case, the expansion of the distribution network is also followed by the increasing power losses. The power losses in the distribution network, today come mostly from the distribution network and amount to 13% [2]. Some of the power loss reduction techniques that have been tested in previous researches include changes in the size of the conductor, the reconfiguration of the network and the addition of a reactive power compensation device to a distributed network.

However, the DG integration of the distribution network brings a challenge with the technical and operational issues that must be faced with a new approach [3]. The existence of the dispersed generation units affect the operational aspects of the power flow distribution network and may cause power quality problems [4]. On the other hand, the positive points derived from the integration of distributed generation are power loss reduction and voltage improvement [5–7], stability improvement [8], reliability improvement [9, 10] and CO_2 emission reductions [11]. To maximize the benefits obtained, proper planning and consideration are required for the placement of such units. This last approach is known as optimal distributed generation placement (ODGP). The ODGP has attracted much attention over the past two decades for efficient DG penetration planning for interested parties. Optimization the determination of the size and location of the DG is the result of objective function manipulation that is assimilated by various heuristic methods. Particle swarm optimization (PSO) has also managed to determine the optimal size based on the minimum loss of power [10, 12]. Some other heuristic techniques such as a cuckoo search [13], tabu search [14], and firefly algorithm [15] are also found in the literature. References [16–18] present a GA method to obtain an optimal DG allocation and size based on the minimum power loss configuration. In these references, the load is taken into account. The load model is also represented by the peak load to represent load behavior so it is inaccurate when implemented in practical conditions [19, 20]. The study [21] shows that the load model has a real and reactive power loss contribution to the distribution system. Different load models, namely residential, commercial, industrial and mixed are used in references [22–24] for the optimal size determination and location of the DG. As previously described, the integration of the DG into the power system is a solution for load growth and energy demand. However, DG integration into the distribution system requires proper planning. DG allocation is expected to provide optimal benefits within a certain period. The effect of load growth on DG placement taking into account the load growth has been studied in the constant load model [25, 26].

In this paper, the contribution given is the assessment of a load model in determining the size and location of the DG considering precise load growth. To address this contribution, an increase load scenario consists of five different load models, which have been tested up to five years and it refers to a short-term system planning period. The goal of this study was to identify the optimal size and location of the DG for minimal power loss. The optimization method is carried out by the use of a breeder genetic algorithm (BGA) and considering the different scenarios of single and multiple. This method has been carried out for the IEEE 30 radial system bus test to prove its effectiveness. The rest of the paper is structured as follows: section 2 explicates load modeling and impact of load growth on the distribution system, section 3 comprises objective function formulation and various technical constraints, section 4 explains the implementation of the proposed BGA and simulation results, section 5 contains conclusions.

2. Load growth

In the power flow study, load characteristics determine the results of the analysis and the convergence. Real power requirements and reactive power of the load will affect the value of voltage and frequency of the system. Therefore, in this paper consider the voltage-dependent load model quoted from IEEE task force [27], which is expressed in Eq. (1) and Eq. (2).

$$P_L(i) = P_{Lo}(i)V_L(i)^{\alpha}, \tag{1}$$

$$Q_L(i) = Q_{Lo}(i)V_L(i)^{\beta}, \tag{2}$$

where, $P_L(i)$ and $Q_L(i)$ represent the real and reactive power at bus i, (Vi) is the voltage at bus i, α and β are the exponents of the voltage-dependent load model. The exponential values of α and β for each load model are given in Table 1.

Table 1. Load model exponent constants [27]

Load type	α	β
Constant	0	0
Industrial	0.18	6.0
Residential	0.92	4.04
Commercial	1.51	3.40

2.1. Load models

The effect of voltage dependent load models is analyzed by making several different planning scenarios. The load model scenarios consist of a constant, a residential, an industrial, and a commercial load [23, 24]. In fact, the load connected to the distribution network is not purely a reference to the type of loads previously mentioned. The load consists of a combination of load models called as mixed loads. Referring to the results of the study [28] model in Eq. (3) and Eq. (4).

$$P_L = \sum_{i=1}^{\rho} P_{L0}V^{\alpha} + \sum_{i=1}^{\sigma} P_{L0}V^{\alpha} + \sum_{i=1}^{\tau} P_{L0}V^{\alpha}, \tag{3}$$

$$Q_L = \sum_{i=1}^{\rho} Q_{L0}V^{\beta} + \sum_{i=1}^{\sigma} Q_{L0}V^{\beta} + \sum_{i=1}^{\tau} Q_{L0}V^{\beta}, \tag{4}$$

where ρ, σ, and τ are the bus numbers classified in randomly generated industrial, residential and commercial loads. In this simulation the values of ρ, σ and τ are respectively 50%, 20% and 30% of the total number of the buses tested.

2.2. Load growth effect on power system

The addition of new loads increases a nominal load on the feeder. This affect the change of the real and reactive power that change the power loss value, the voltage stability index and the voltage deviation. The effects of load growth were tested using the IEEE 30 standard radial distribution system and the results illustrate significant influences in real systems and reactive power losses, system voltage profiles, and repeater loading capabilities [26]. To see the effect of load increases on DG integration, the trend of load growth every year is calculated by the annually statistic.

$$P_L(k) = P_L(0)(1+g)^k, \tag{5}$$

$$Q_L(k) = Q_L(0)(1+g)^k. \tag{6}$$

The load growth (g) gets annually a rate of 8.6% [29] of value of each load model that is scenario over k year according to Eq. (5) and Eq. (6) [30]. The k value is the number of years, which in this paper uses the growth of the load for five years ($k = 5$).

3. Proposed intelligent approach to allocate DG

The use of a GA to solve optimization problems has been widely applied to engineering problems. In the GA, chromosomes (individuals) are a potential population of solutions. These chromosomes evolve to get the best solution by using genetic operators called selection operators, crossovers, and mutations. In the initial stage, each chromosome is rated for its fitness, based on several criteria.

Relative chromosomal selection occurs in the reproductive process. In a new individual reproduction process it is made using a crossover and mutation operators. The selection method in the genetic algorithm is done randomly, so it is possible that the good chromosome can not survive in a new generation because it does not pass the selection. It is necessary to preserve the best chromosome so that the good chromosome can pass the selection.

Breeder genetic algorithm (BGA) uses the parameter r, which denotes the best chromosome. This chromosome will be maintained in the next generation by replacing randomly as many r chromosomes in that generation, as it is possible. Chromosome to be replaced are determined randomly concerning Eq. (7).

$$p = r_i < r, \tag{7}$$

where r_i denotes the random numbers generated for each chromosome and r is the probability of best chromosome preservation.

3.1. Proposed algorithm

The best fitness value is represented as the optimum solution to the problem. Step by step a computational program to find the solution of the DG placement using a BGA is given below and depicted in Figure 1.

Step (1): read and input system data include data bus, line data, generator data, load data, etc.

Step (2): run power flow IEEE 30 bus without DG for five load models at base year (initial condition).

Step (3): initialize BGA parameters (population, mutation rate, cross over, breeder probability, iteration maximum, etc).

Step (4): update the variables by selection, mutation, and crossover.

Step (5): find the optimal size and location of DG based on fitness function considering constraint for three scenarios (DG1, DG2, DG3).

Step (6): run power flow of test system with DG for each scenario including five load models.

Step (7): repeat this procedure up to maximum iterations.

Step (8): save all the output simulations.

Step (9): test result of record by step (2) for the *k*-th year.

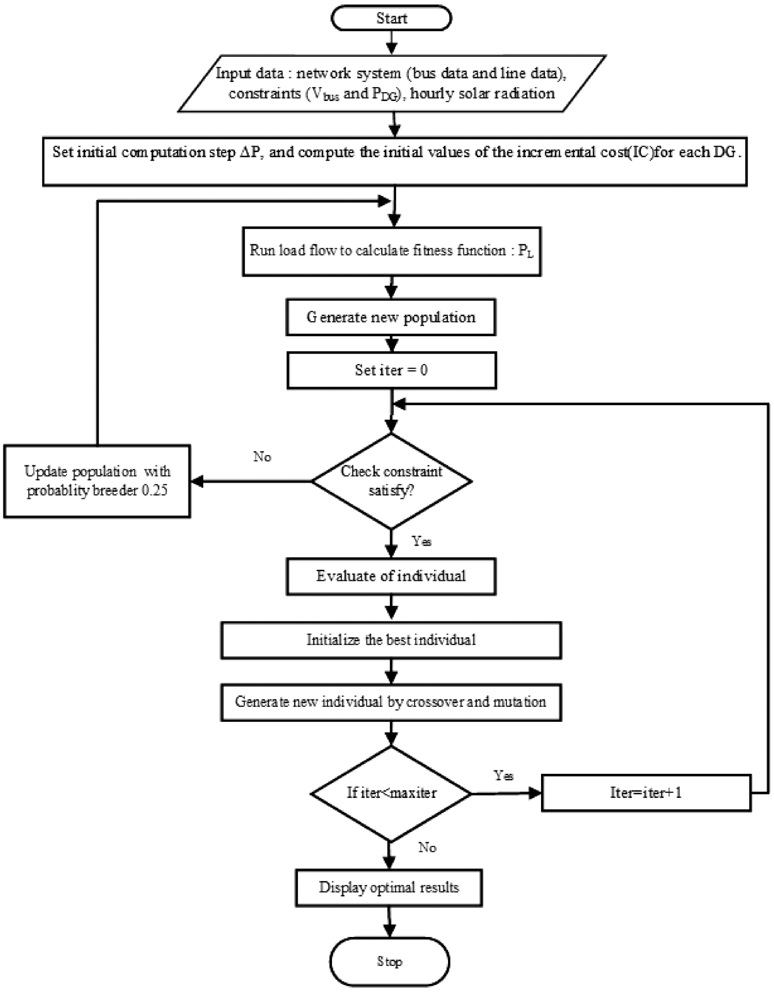


Fig. 1. Computational flowchart of optimal placement DG

3.2. Objective function

Transmission and distribution losses are unavoidable as they relate to the impedance and current values of the conductor. The power loss in this distribution system contributes to a considerable portion of the total loss of power to the system. Although it cannot be eliminated, the value of this power loss can be decreased. Related to DG function was to minimize power losses, optimization function is formulated based on the power loss calculated from the power flow analysis. The objective function is written as a fitness function in Eq. (8).

$$F = \min \sum_{i=1}^{N_{\mathrm{DG}}} f(p_{\mathrm{DG}\,i}), \tag{8}$$

where F is the optimal total loss of the system, $f(P_{\mathrm{DG}\,i})$ is the total loss in consequence of the injected i-th DG in the system, N_{DG} is the total number of DG dispersed in the network.

3.3. Technical constraint

Minimization of objective functions is limited to constraint functions, bus voltage and DG power. Constraint's value was controlled based on Eq. (9) and Eq. (10).

Voltage bus constraint:

$$|V_{\min}| < |V_i| < |V_{\max}|, \tag{9}$$

where $|V_i|$ is the magnitude of the voltage at any bus i, $|V_{\min}|$ and $|V_{\max}|$ are the magnitudes of the minimum and maximum voltage limits taken as 0.9 per unit and 1.05 per unit, respectively.

DG power constraint:

$$P_{\mathrm{DG,min}} \le \sum_{j=1}^{n\mathrm{DG}} P_{\mathrm{DG}}(y)_j \le P_{\mathrm{DG,max}}\,, \tag{10}$$

where the maximum value of active power ($P_{\mathrm{DG,max}}$) and reactive power ($Q_{\mathrm{DG,max}}$) is limited by Eq. (11) and Eq. (12):

$$P_{\mathrm{DG,max}} = \sum_{i=2}^{N} P_{\mathrm{load}}(0)_{(i)}\,, \tag{11}$$

$$Q_{\mathrm{DG,max}} = \sum_{i=2}^{N} Q_{\mathrm{load}}(0)_{(i)}\,. \tag{12}$$

In any year y, the maximum active power generation limit is given by Eq. (11). $P_{\mathrm{DG,min}}$ and $P_{\mathrm{DG,max}}$ are the minimum and maximum value of DG size, taken as 50 KW and 25 MW, respectively. It is real power generated by j-th DG at the year y. $P_{\mathrm{load}}(0)_{(i)}$ and $Q_{\mathrm{load}}(0)_{(t)}$ are the real load and reactive load at bus i in the base year (year 0), respectively; n is the number of DG units which dispersed in the distribution network. N is the total number of buses in the distribution network.

3.4. Intermittent factor of renewable energy

In this paper, the type of DG used is Photovoltaic (PV). PV is renewable energy that utilizes sunlight to generate electricity directly. This produces active power which included DG type one. In this paper, PV array technology is chosen to generate electricity in the distribution system. The output power of the PV array depends on solar radiation and can be calculated according to the following Eq. (13).

$$P_{\mathrm{PV}} = N_m * P_{m\mathrm{PV}} * G_t/1000, \tag{13}$$

where P_{PV} is the output power of the PV array (W), $\mathrm{P}_{m\mathrm{PV}}$ is the average power of each array under conditions $G_t = 1000$, G_t is the global irradiance incident on the titled plane (W/m^2) and N_m is the number of modules [31].

The intermittent nature of renewable energy sources leads to different uncertainties in forecasting the PV array's output power. Therefore, for PV integration planning properly, uncertainty should be considered in DG optimization. To calculate uncertainty, the solar radiation profile should be predicted at an early step. In this study, the solar radiation profile refers to the daily solar irradiation curve model that has been proposed in the previous research [32], which is depicted in Figure 6. Then, the PV unit output power can be determined based on Eq. (13). In the prediction process, there are deviations between the approximate value and the actual ones. Eq. (14) in this paper is used to accommodate these deviations [33].

$$dP_{\mathrm{PV}} = 0.7 * \sqrt{P_{\mathrm{PV}}}. \tag{14}$$

PV output power variations are obtained by multiplying Eq. (14) with the random number, which is generated by the Matlab function [34].

4. Result and discussion

This study used a standardized IEEE 30 bus radial distribution system, which has a total real load and reactive load of 283.40 MW and 126.20 MVAR, respectively [27]. These values become the reference as the load on the base year (year 0). Optimization of DG allocation is solved by using a GA and performed in MATLAB. The values of the various parameters used in GA are taken as follows: $n = 150$, itermax = 100, breeder probability 0.25.

There are five load models used in this study. Mixed load include the residential load (bus 3, 5, 10, 18), industry load (bus 4, 7, 16, 17, 19, 20, 29), and commercial load (bus 8, 12, 14, 15, 21, 23, 24, 26, 30). This paper is divided into five cases based on load models to achieve the research objectives within a given approach. In this research we have used DG type 1, a practical field represented by photovoltaic (PV). The use of distributed PV generation has been proven to reduce the loss of power in the distribution network [34]. The number of DG units dispersed into the system reached a maximum of 10% from the total bus. Each case consists of five scenarios representing the load model. The optimization results obtained in the base year (Y0), were tested for the load model up to the fifth year growth (Y1, Y2, Y3, Y4, Y5).

4.1. Load growth on each load models

Load models change load parameters on the IEEE 30 bus test system. Assuming the conditions in the base year, the ratio the active and reactive power consumption absorbed by the load, are shown in Figure 2. The ratio of reactive power demand to active power demand is significantly lower for residential (0.48) and commercial loads (0.47) than for industrial loads (0.51). The proportion percentage of the real and reactive power consumption for each load model is described below.

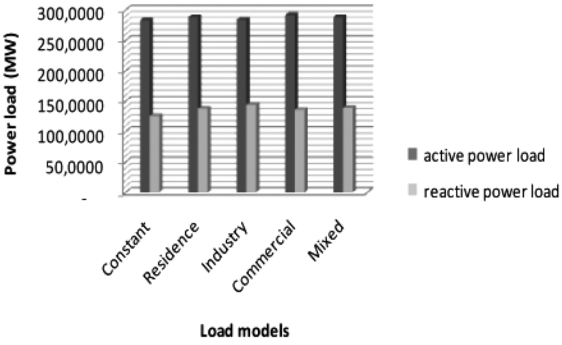


Fig. 2. Real and reactive power load ratio of each load model

Active and reactive power usage of the constant load is 69.19% and 30.81% respectively, as illustrated in Figure 3. However, in a practical case, this can not be used as a basis in planning generation integration.

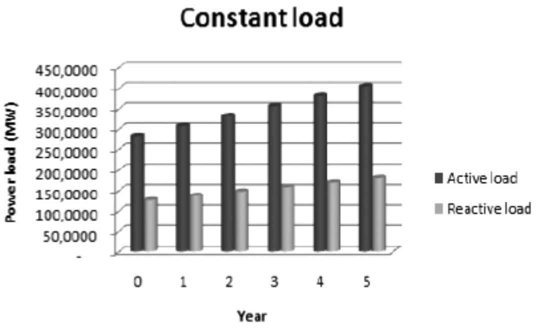
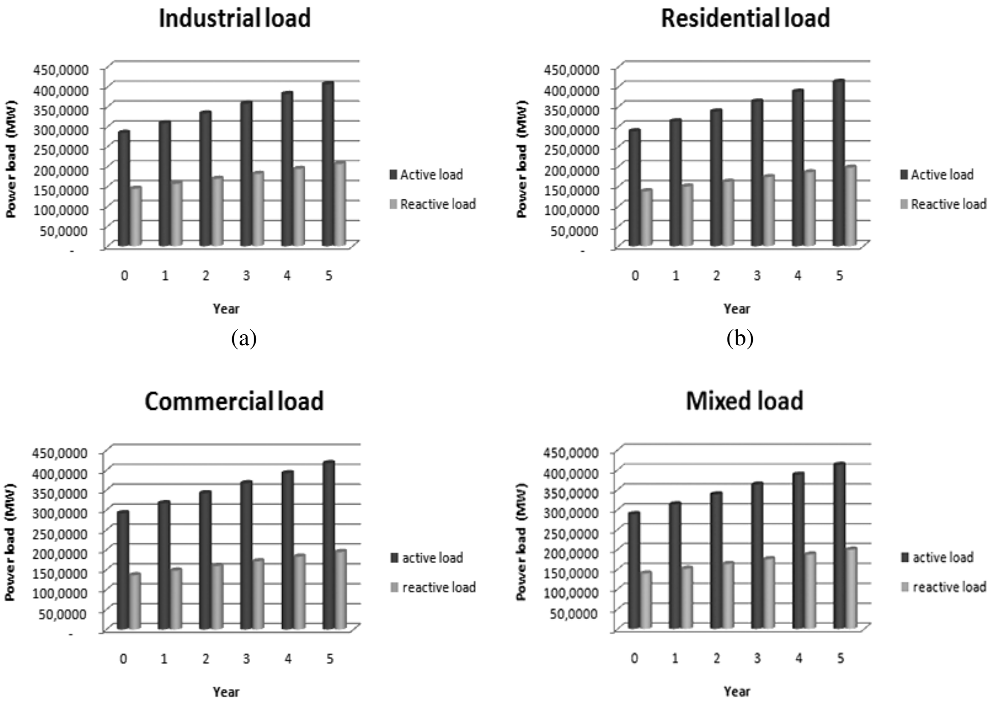


Fig. 3. Power usage of constant load model

At the resident load, 67.64% of total power is used for real load, and 32.36% for a reactive load. For an industrial load, the active and reactive power usage is 66.33% and 33.67%, respectively.

Commercial load expenses absorb an active power and reactive power of 68.21% and 31.79% respectively. For mixed loads, 67.41% of power is absorbed by the real load and 32.59% is absorbed by the reactive load. The active power consumption is mostly absorbed by a commercial load model of 291.81 MW. The reactive power consumption is mostly absorbed by an industrial load sector of 144.36 MW. This corresponds to the distribution system in practice. Commercial expenses are dominated by facility services such as lighting which requires real power, while industrial customers are associated with the use of motors that requires the reactive power. Since the load growth uses an annual rate, the consumption of the real and reactive power for load models also increases constantly as presented in Figure 4.



(a) (b)

(c) (d)

Fig. 4. Power load increase due to load growth: industrial load model (a); residential load model (b); commercial load model (c); mixed load model (d)

The distribution system in conditions without DG, is load growth impact on bus voltage condition. For the constant load model, the minimum voltage is still within the limit of tolerance up to the third year load increase. In the fourth year, the minimum voltage reaches 0.918 pu. This also applies to other load models. Critical voltage limits also occur in the fourth year of residential and industrial loads of 0.913 pu and 0.908 pu, respectively. For commercial and mixed loads, the voltage level is still awake in the level conditions of 0.924 pu and 0.923 pu, respectively.

Load growth until the fifth year has the effect of decreasing the minimum voltage limit exceeding the –90% tolerance limit of almost all loads. In the fifth year, the minimum voltage limit for constant loads is 0.899 pu. Likewise, the minimum voltage at the residential and industrial loads also decreases to 0.891 pu and 0.887 pu, respectively, while at the commercial and mixed loads, the minimum voltage reaches the level of 0.899 pu and 0.898 pu.

4.2. Effect of load models on power loss

The increase in power loss follows the load growth in the distribution system. In the first year, the maximum power losses 22.902 MW occurs in the industrial load. In the second year, the power loss at the resident load attained 27.418 MW, it is the highest loss of power compared to other load models. In the third and fourth, maximum power loss take place on commercial loads of 32.759 MW and 38.18 MW, respectively. A maximum power loss of 44.85 MW occurs in the fifth year for the residential load.

DG integration in the distribution system is expected to contribute to minimizing power loss. In Figure 5, it can be seen the maximum power loss within five years for five load models.

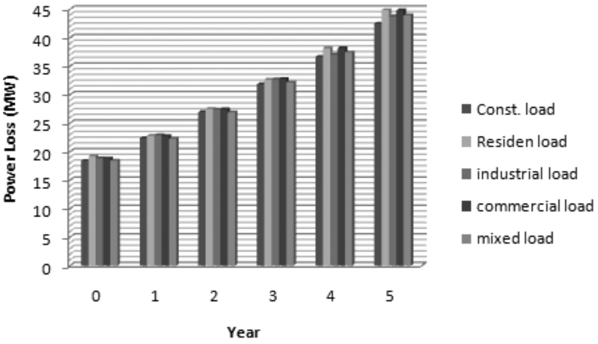


Fig. 5. The power loss of load models due to load growth

4.3. Impact of DG placement on power loss

To show the effect of DG placement, the DG is modeled as a constant real (P) power generating source. In a real application, an example of DG type 1 is PV. The intermittent of the PV output power is modeled according to the method proposed in section 3. To more reflection, the daily solar irradiation curve is showed in Figure 6. This becomes the basic DG size provided in the constraint function of the DG size and location optimization process.

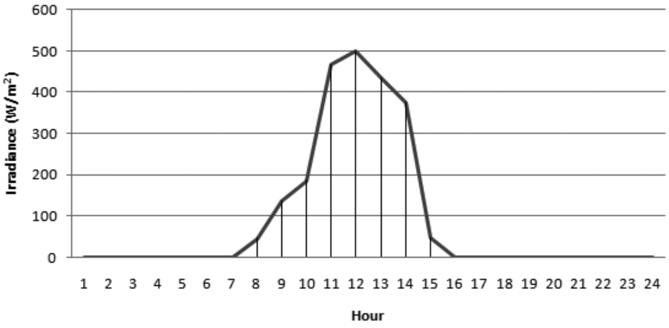


Fig. 6. Solar irradiation curve

All the results for the proposed methodology are implemented in Matlab 2016. In this study, determination of the location and the size of DG uses the base year data for each load model. Each year, the DG placement is divided into three scenarios based on the number of DG units integrated into the system: DG1, DG2, DG3. The results obtained are then tested on each load model in subsequent years with an annual incremental load up to five years. Table 2 shows the detailed result of DG allocation for different types of load models and also power loss due to load growth of each load models.

Table 2. Result of DG placement due to load growth

Load model	**Placement DG**		**Power Losses (MW)**					
	DG	**Location, size (MW)**	**Base year**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Constant	0		18.40	22.35	26.95	31.85	36.62	42.45
	1	26(15.30)	16.46	20.50	24.50	29.29	35.47	40.13
	2	10(16.2); 14(15.3)	16.21	19.65	22.37	28.35	34.66	39.02
	3	26(15.8); 10(16.1); 27(16.2)	14.86	18.38	22.18	26.67	30.04	37.07
Industrial	0		18.83	22.90	27.41	32.69	37.06	43.77
	1	26(15.60)	17.12	20.78	25.15	28.83	35.13	41.63
	2	15(15.40); 25(16.50)	16.54	19.78	24.03	28.56	33.77	39.52
	3	4(16.1); 15(15.5); 24(16)	15.55	18.66	22.77	27.16	32.22	37.81
Residential	0		19.18	22.78	27.50	32.64	38.17	44.85
	1	9(15.6)	15.67	18.13	21.16	26.10	30.69	36.55
	2	15(15.40); 25(16.50)	14.55	17.01	20.38	24.74	29.45	34.89
	3	15(15.6); 24(15.9); 26(16.2)	13.87	15.75	19.07	23.27	27.68	33.02
Commercial	0		18.79	22.74	27.43	32.76	38.18	44.81
	1	6 (16.5)	17.57	21.57	26.04	31.28	36.53	42.92
	2	19(16.2); 29(16.4)	17.00	20.23	24.54	29.16	34.65	40.83
	3	15(16); 18(16.2); 24(16.8)	15.69	18.93	22.81	27.50	32.78	38.17
Mixed	0		18.42	22.29	26.89	32.12	37.43	43.93
	1	12(16.3)	17.20	20.89	25.22	30.30	35.42	41.56
	2	7(15.2); 22(15.4)	16.44	20.06	24.32	28.89	34.32	40.44
	3	14(16.4); 15(15.2); 25(15.8)	15.17	18.70	22.54	27.20	32.34	37.84

Constant load

In the base year, the amount of the active and reactive power system loads is 307.77 MW + 137.05 Mvar. In the initial condition, without DG, the active power loss reached 18.403 MW. For the first scenario, the DG1 placement is resulting in a reduction 7.34% of power loss. Integration of DG 2 and DG 3 decreases the power loss 11.89% and 19.23%, respectively. In the first year the load increase, location assumptions and the same DG size in the base year, showed DG's ability to reduce power loss for DG1, DG2 and DG3 by 8.27%, 13.7%, and 17.7%, respectively.

Industrial load

A power loss of 18.83 MW is experienced in the base year system with a load of 308.84 MW + 156.77 Mvar. DG placement in the first year can reduce power loss by 19.24% for placement scenario of three DG units. DG integration canreduce power loss until the fifth year reaches 13.6%.

Residential load

The active and reactive power load of the system under the base year conditions is 313.28 MW + 149.87 Mvar. The active power loss reached 19.198 MW since no DG integration. The maximum reduction of power losses occurs in the third scenario with the addition of three DG units that reduce the power loss up to 27.7%.

Commercial load

The load in the base year is 291.81 MW + 136.02 Mvar. Power loss on commercial loads is significant compared to residential and industrial load models. A DG placement of 40.3 MW is capable of reducing 3.04% of the power loss. Addition of DG 3 by about 49 MW can reduce power loss by 17.4%.

Mixed load

In this study, the majority of the mixed load consists of industrial loads with a total load of 288.41 MW + 139.42 Mvar. The effect of power loss due to maximum DG integration occurs when placement DG is 47.4 MW. DG placement can reduce power loss by 13.9% of an initial power loss amount 18.422 MW.

To validate the proposed method, it is compared with the result in existing reference [35] under the same load conditions and the same objective function. The comparison of the results in a pair size-location of DG units and real power losses is also listed in Table 3. The results tabulated in Table 3 show that the proposed method is capable of determining the proper placement of the DG. The reduction in power loss can be better than the result in the existing reference.

Table 3. Comparison of the result of DG placement

Load model	**Method**	**Placement DG**		**Power loss (MW)**
		Location	**Size (MW)**	
Constant	Proposed method	26	15.30	16.463
Constant	PSO [35]	15	13.5788	16.572

In this study, there are three placement scenarios in each year. The maximum DG capacity is achieved when placing three DG units. With the constant load, a maximum reduction of power loss amount equal to 19.24% was achieved at 283.40 MW load due to a level penetration of about 15.2%. For the resident load, the penetration DG at level 15.1% was reduced by 27.76% of power loss, when the load achieved at 288.47 MW. At industrial loads, a maximum decrease of power lossby about 38.6% occurs when penetration the DG level achieved 15% to serve 288.34 MW load systems. For the commercial loads, the 15.5% of DG penetration causes the reduction of power loss by 16.83%. For the mixed load, power loss is reduced by 17.64% as the impact integration DG is about 14.98%. The results obtained are supported by the existing reference [36] that studies the impact of high PV penetration on the grid by considering short-term transient radiation due to clouds. The study shows that a 'break-even cost was achieved if the penetration of PV reached 10% or more. The level of commercial and mixed loads amounted to 342 MW and 288.41 MW, respectively. The ratio of $P_{DG,\max}$ to the maximum loss percentage loss in each load model is shown in Figure 7.

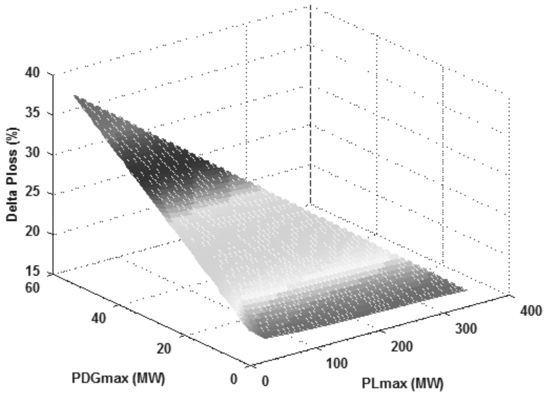


Fig. 7. Effect of power load on DG size and power loss

4.4. Withstand DG due to load growth

The optimal size and location of the DG has been presented in Table 2. This result is obtained from DG optimization using a BGA based on the smallest power loss which did not violate the constraint limits that have been set. In a proper planning, integration DG should be able to maintain the performance of the distribution system over a period of time [37]. Percentage of power loss reduction points generally indicates that single and multiple DG integration on the distribution system is capable of effectively reducing power losses until the fifth year on each load model. However, measuring by minimum voltage values for each year, DG integration has been effective in maintaining the voltage level within tolerable limits (1.06 pu − 0.9 pu). This condition was depicted in Figure 8.

DG capability was tested in the fifth year, where there has been a 43% load increase from the base load. At a constant load of 405.26 MW + 180.47 Mvar, the system voltage condition has exceeded the tolerance limit of 0.899 pu. The existence of DG placement can improve the profile of the voltage of 1.67%. At the resident load, in the fifth year the load reaches 406.66 MW + 206.44 Mvar. In this condition, the system voltage has exceeded the tolerance limit, which is 0.891 pu. The presence of DG placement can improve the profile voltage to 0.904 pu. At an industrial load of 412.52 MW + 197.35 Mvar, the system voltage condition reaches the most extreme minimum value compared to other load models, which is 0.887 pu. DG placement is capable of fixing a voltage of 2.02% and maintaining a voltage profile in the tolerance level of 0.905 pu. At a commercial load of 417.29 MW + 194.51 Mvar, the system voltage condition

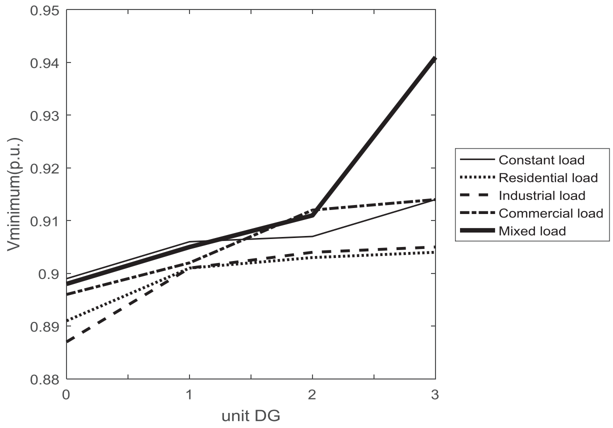


Fig. 8. The minimum voltage load models after placement DG in 5-th year

also exceeds the tolerance limit of 0.899 pu. The existence of DG placement can improve the profile voltage of 4.67%. In the fifth year, the nominal mixed load of 412.43 MW + 199.37 Mvar resulted in a voltage drop outside the tolerance limit of 0.898 pu. DG placement can improve the voltage profile to be 0.914 pu.

5. Conclusion

In this paper, detailed investigations have been tested to get an optimal size and location of DG for five load model, namely constant, residential, industrial, commercial, and mixed load. The contribution in this study was DG placement, considering a five year load growth factor as short-term planning.

A BGA is proposed to find a solution for power loss reduction based on the location and size of DG determination. Analyses were conducted on an IEEE 30 bus system using a MATLAB toolbox. The results have shown a significant improvement of power system distribution performance using the proposed algorithm to load growth for five years. A future work needs to consider the technical and non-technical indicators that include a stability system and costs in determining the optimal pair size-location of the DG.

References

[1] Birol D.F., *Southeast Energy Asia Outlook*, Directorate of Global Energy Economics, International Energy Agency, France (2015).

[2] Lopes N.H.J.P., Mutale J., Djapic P., Jenkins N., *Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities*, Electric Power Systems Research, vol. 77, pp. 1189–1203 (2007).

[3] Pesaran M.H.A., Huy P.D., Ramachandaramurthy V.K., *A review of the optimal allocation of distributed generation: Objectives, constraints, methods, and algorithms*, Renewable and Sustainable Energy Reviews, vol. 75, pp. 293–312 (2017).

[4] Sultana S., Roy P.K., *Multi-objective quasi-oppositional teaching learning based optimization for optimal location of distributed generator in radial distribution systems*, International Journal of Electrical Power & Energy Systems, vol. 63, pp. 534–545 (2014).

[5] Rao R.S., Ravindra K., Satish K., Narasimham S., *Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation*, IEEE Transactions on Power Systems, vol. 28, pp. 317–325 (2013).

[6] Othman M., El-Khattam W., Hegazy Y.G., Abdelaziz A.Y., *Optimal placement and sizing of distributed generators in unbalanced distribution systems using supervised big bang-big crunch method*, IEEE Transactions on Power Systems, vol. 30, pp. 911–919 (2015).

[7] Kang Q., Zhou M., An J., Wu Q., *Swarm intelligence approaches to optimal power flow problem with distributed generator failures in power networks*, IEEE Transactions on Automation Science and Engineering, vol. 10, pp. 343–353 (2013).

[8] Seifi A.R., Jangjoo M.A., *Real time voltage stabilization in microgrid*, Archives of Electrical Engineering, vol. 63, pp. 273–293 (2014).

[9] Al-Muhaini M., Heydt G.T., *Evaluating future power distribution system reliability including distributed generation*, IEEE Transactions on Power Delivery, vol. 28, pp. 2264–2272 (2013).

[10] Baghipour R., Hosseini S.M., *Placement of DG and capacitor for loss reduction, reliability and voltage improvement in distribution networks using BPSO*, International Journal of Intelligent Systems and Applications, vol. 4, p. 57 (2012).

[11] Ogunjuyigbe A., Ayodele T., Akinola O., *Optimal allocation and sizing of PV/Wind/Split-diesel/Battery hybrid energy system for minimizing life cycle cost, carbon emission and dump energy of remote residential building*, Applied Energy, vol. 171, pp. 153–171 (2016).

[12] Bagheri A., Habibzadeh A., Alizadeh S., *Comparison of the effect of combination of different DG types on loss reduction using APSO algorithm*, Canadian Journal on Electrical and Electronics Engineering, vol. 2, pp. 468–474 (2011).

[13] Poornazaryan B., Karimyan P., Gharehpetian G.B., Abedi M., *Optimal allocation and sizing of DG units considering voltage stability, losses and load variations*, International Journal of Electrical Power & Energy Systems, vol. 79, pp. 42–52 (2016).

[14] Mohammadi M., Nafar M., *Optimal placement of multitypes DG as independent private sector under pool/hybrid power market using GA-based Tabu Search method*, International Journal of Electrical Power & Energy Systems, vol. 51, pp. 43–53 (2013).

[15] Balachennaiah P., Suryakalavathi M., Nagendra P., *Firefly algorithm based solution to minimize the real power loss in a power system*, Ain Shams Engineering Journal (2015).

[16] Bhattacharyya B., Rani S., Vais Ram I., Bharti Indradeo P., *GA based optimal planning of VAR sources using Fast Voltage Stability Index method*, in Archives of Electrical Engineering, vol. 65, ed, p. 789 (2016).

[17] Abou El-Ela A.A., Allam S.M., Shatla M.M., *Maximal optimal benefits of distributed generation using genetic algorithms*, Electric Power Systems Research, vol. 80, pp. 869–877 (2010).

[18] Yusran, *Electrical network power quality improvement through distributed generation optimum placement based on Breeder Genetic Algorithm method*, Makassar International Conference on Electrical Engineering and Informatics (MICEEI), pp. 20–22, 26–30 (2014).

[19] Abdelaziz A.Y., Hegazy Y.G., El-Khattam W., Othman M.M., *Optimal planning of distributed generators in distribution networks using modified firefly method*, Electric Power Components and Systems, vol. 43, pp. 320–333 (2015).

[20] Soroudi A., Afrasiab M., *Binary PSO-based dynamic multi-objective model for distributed generation planning under uncertainty*, IET Renewable Power Generation, vol. 6, pp. 67–78 (2012).

[21] Ameli A., Bahrami S., Khazaeli F., Haghifam M.-R., *A multiobjective particle swarm optimization for sizing and placement of DGs from DG owner's and distribution company's viewpoints*, IEEE Transactions on Power Delivery, vol. 29, pp. 1831–1840 (2014).

[22] Hien N.C., Mithulananthan N., Bansal R.C., *Location and sizing of distributed generation units for loadabilty enhancement in primary feeder*, IEEE Systems Journal, vol. 7, p. 10 (2013).

[23] Bohre A.K., Agnihotri G., Dubey M., Kalambe S., *Impacts of the load models on optimal planning of distributed generation in distribution system*, Advances in Artificial Intelligence, vol. 2015, p. 6 (2015).

[24] Bohre A.K., Agnihotri G., Dubey M., *Optimal sizing and sitting of DG with load models using soft computing techniques in practical distribution system*, IET Generation, Transmission & Distribution, vol. 10, pp. 2606–2621 (2016).

[25] Prabha D.R., Jayabarathi T., *Optimal placement and sizing of multiple distributed generating units in distribution networks by invasive weed optimization algorithm*, Ain. Shams. Engineering Journal, vol. 7, pp. 683–694 (2016).

[26] Rajendran A., Narayanan K., *Optimal installation of different DG types in radial distribution system considering load growth*, Electric Power Components and Systems, vol. 13 (2017).

[27] Price W., Casper S., Nwankpa C., Bradish R., Chiang H., Concordia C. *et al.*, *Bibliography on load models for power flow and dynamic performance simulation*, IEEE Power Engineering Review, vol. 15, p. 70 (1995).

[28] Tanwar S.S., Khatod D.K., *Techno-economic and environmental approach for optimal placement and sizing of renewable DGs in distribution system*, Energy, vol. 127, pp. 52–67 (2017).

[29] Power Supply Business Plan (RUPTL) PT PLN (PERSERO) 2017–2026 (2017).

[30] Roy R., Mistry K.D., *Enhancement of loading capacity of distribution system through distributed generator placement considering techno-economic benefits with load growth*, International Journal of Electrical Power & Energy Systems, vol. 54, pp. 505–515 (2014).

[31] Markvart T., *Solar Electricity*, 2nd Edition (2000).

[32] Kathiravan R., Devi R.P.K., *Optimal power flow model incorporating wind, solar, and bundled solar-thermal power in the restructured Indian power system*, International Journal of Green Energy, vol. 14, pp. 934–950 (2017).

[33] Shinji T., Sekine T., Kashiwagi T., Akisawa A., Fujita G., Matsubara M., *Discussion on reduction of power fluctuation by distributed generation in micro grid*, IEEJ Transactions on Power and Energy, vol. 126 (2006).

[34] Rahman Y.A., Manjang S., Yusran, Ilham A.A., *Evaluating the effect placement capacitor and distributed photovoltaic generation for power system losses minimization in radial distribution system*, Engineering International Conference (EIC2017), vol. 1941, p. 6 (2018).

[35] Haidar A.M.A., *Optimal Location of Distributed Generation Using Intelligent Optimization*, in 2011 IEEE 23rd International Conference on Tools with Artificial Intelligence, pp. 891–893 (2011).

[36] Asano H., Yajima K., Kaya Y., *Influence of photovoltaic power generation on required capacity for load frequency control*, IEEE Transactions on Energy Conversion, vol. 11, pp. 188–193 (1996).

[37] Yusran, Mochamad A., Soeprijanto A., *Optimization scheme of distributed generation installation growth considering network power quality*, Journal of Theoretical and Applied Information Technology, vol. 53, no. 1, pp. 30–39 (2013).