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Optimize the position of the distributed generator and capacitor bank in the distributed grid to minimize the generation cost

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ABSTRACT

In this paper, we focus on determining the optimal position and size of multi-distributed generators and capacitor banks to minimize the generation cost of a distributed grid. The optimal position and size of distributed generators and capacitor banks are determined using a hybrid of conventional loss sensitivity factor and an improved one. The proposed algorithm has two stages. For each distributed generator, we prioritize its position and size. After that, we find the optimal position and size of the capacitor banks corresponding to this distributed generator installation to minimize the power loss. After considering all distributed generators, the optimal number, position, and size of the distributed generators and capacitor banks are determined based on the minimum generation cost value. This idea is developed in MATLAB and verified via sample distributed grids, including the IEEE-69 bus and IEEE-85 bus. The verifying results are evaluated and analyzed. By comparing those results to those of other methods, the performance of the newly introduced method is proven.

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1. INTRODUCTION

With the development of renewable energies, such as wind and solar, distributed generators have become more popular in power systems, especially in distributed grids. These distributed generators can impact operational indices, such as power loss, generation cost, and so on. These indices can become worse if DG's position is not suitable. Therefore, the determination of distributed generators (DG) optimal placement is important.

Until now, there have been many proposed methods to tackle the power loss issue [1]-[15]. Some authors focused on using DG solely [1]-[3] or a capacitor bank (CB) solely [4]. The combination of DG and other methods was also introduced. In the references [5], [6], DGs are associated with grid reconfiguration; the disadvantage of this combination is that it requires a high investigation to reconfigure, or this combination can not apply to a tie-distributed grid. The combination of reactive power compensation equipment and DG is quite popular [7]-[15]. The result [15], a STATCOM was suggested, while in [7]-[14], CBs or shunt capacitors were used. Generally, STATCOM can be very efficient in voltage quality support but is more expensive than a CB of the same size. Therefore, the combination of DG and CB is quite popular.

Many algorithms were suggested to determine the position of DG and CB [7]-[13]. Generally, these algorithms are divided into three groups, including the conventional algorithms [16], the heuristic-based algorithms [8], [9], and the hybrid algorithms [10], [14], [17]. These algorithms can apply to two classes of objective functions: single and multi-cost functions. Concerning the cost function, the reduction of power loss or energy loss was the main and popular objective. Still, some researchers considered other objectives such as voltage index, benefit, and so on [17]. Depending on the applied algorithm, the results may be different, no matter the cost function. The percentage of power reduction is normally used to compare algorithms together. Normally, if the installed power of DG and CB is high, the power loss may be low, and hence, the percentage of power reduction is higher. However, when we install a DG and CB combination with a higher capacity, the annual operation cost will be higher. Therefore, the higher power loss does not mean that we can obtain benefits.

In this research, we suggest an algorithm to identify the best location and capacity of DGs and CBs. The optimization goal focuses on minimizing the generation cost, but we still achieve lower losses within the distribution network. The proposed algorithm is developed from the loss sensitivity factor (LSF). Unlike many previous works that focus mainly on power loss or voltage profile, our research emphasizes generation cost, including both DG and CB investment, using an efficient step-wise analytical approach. We utilize the MATLAB scripting environment to execute the algorithm, and we employ the IEEE-69 bus and IEEE-85 bus power systems for verification. The findings are evaluated and juxtaposed with other existing methods.

2. PROBLEM STATEMENT AND LOSS SENSITIVITY FACTOR

In this study, we do not mainly focus on the power loss minimization, but we focus on minimizing the generation cost in the distribution system. This cost includes the energy cost from both DGs and the grid, and the investment in CBs. Compared to many previous studies that only minimize power loss, this objective better reflects the economic performance of the system. To obtain this goal, we use an analytical method, which is named the improved loss sensitivity factor (ILSF), to determine the optimal installation site and rating of DGs and CBs. This method does not require population-based or heuristic algorithms, so it is faster and easier to implement. To our knowledge, this optimal problem and solution method have not been used in similar works.

2.1. Generation cost

The generation cost is defined as the cost to supply electricity to loads per hour. This cost is computed from the investment and the energy selling costs from electrical sources in the grid. With an existing grid, the investment cost is almost constant. Hence, the generation cost is only reliant on the energy quantity received from sources, the new components' cost. Hence, the generation cost is simplified as (1)-(4) [17].

$$Cost = C_{EDG} + C_{Cap} + C_{EG} \tag{1}$$

$$C_{EDG} = C_{DG} P_{DG} \tag{2}$$

$$C_{Cap} = \frac{n_c e_i + K_C \times Q_c}{T_C} \tag{3}$$

$$C_{EG} = C_{grid} \times P_{grid} \tag{4}$$

Where, C_{DG} is the price of a kWh from DG; e_i, T_C, and K_C are constant cost, lifetime, and investment of a kVAr of CB; n_c is the number of nodes where the CB is installed; C_{grid} is the selling price of 1 kWh from the grid; P_{grid} is the power supplied from the grid; and P_{DG} and Q_C are the DG power generation and CB capacity.

2.2. Optimization problem

The objective is to minimize the generation cost of the grid. Accordingly, the optimization problem is defined as:

$$Cost = C_{EDG} + C_{Cap} + C_{EG} \to min \tag{5}$$

$$V_{min} \leq V_i \leq V_{max} \tag{6}$$

$$i_k \leq I_{kmax} \tag{7}$$

$$0.8 \leq pf_{DG} \leq 1 \tag{8}$$

$$0 \leq \sum_{d=1}^{d_{max}} P_{DG,d} \leq P_{demand} \tag{9}$$

$$0 \leq \sum_{c=1}^{c_{max}} Q_{CB,c} \leq Q_{demand} - \sum_{d=1}^{d_{max}} Q_{DG,d} \tag{10}$$

$$\Delta P_{iter} \leq \Delta P_{iter-1} \tag{11}$$

where, i_k is the current on the k^{th}line; $V_i$is the voltage at the i^{th}node; P_{demand} and Q_{demand} are active and reactive power demands in the grid; P_{DG}, Q_{DG}, and pf_{DG} are active, reactive power, and power factor of DG; ΔP_{iter} is the power loss at the $iter^{th}$iteration; V_{min}, V_{max}, and I_{kmax} are the bounded values of node voltage and current on the k^{th} line; d_{max} and c_{max} are the maximum number of DG and CB, respectively. Noted that:

$$V_{min,iter} = \min\left(V_{min,iter-1}, 0.95\right) \tag{12}$$

2.3. Loss sensitivity factor

2.3.1. Conventional LSF method

We consider the simplified tree-structured grid in Figure 1, where $\dot{S}_i$ is the total apparent power of loads in branches connected to the i^{th}node and $\dot{S}_{i\Sigma}$ is the apparent power injected into the i^{th}node. The power loss from the source to the i^{th}node caused by the power $\dot{S}_{i\Sigma}$ can be simplified as (13).

$$\Delta P_i = S_{i\Sigma}^2 \sum_{k=2}^{i} \frac{R_{k-1}}{V_k^2} = (P_{i\Sigma}^2 + Q_{i\Sigma}^2) \sum_{k=2}^{i} \frac{R_{k-1}}{V_k^2} \tag{13}$$

Where, R_{k-1} is the resistance of the line from the $(k-1)^{th}$node to the k^{th}node and V_k is the k^{th}node's voltage. The LSF value at the i^{th}node versus active power ($LSF_{i,P}$) and versus reactive power ($LSF_{i,Q}$) is computed as (14) and (15).

$$LSF_{i,P} = 2P_{i\Sigma} \sum_{k=2}^{i} \frac{R_k}{V_k^2} \tag{14}$$

$$LSF_{i,Q} = 2Q_{i\Sigma} \sum_{k=2}^{i} \frac{R_k}{V_k^2} \tag{15}$$

To obtain ΔP_i in (13) equal to zero, we should install DG at the i^{th}node such that:

$$P_{i,DG} = P_{i\Sigma} \tag{16}$$

$$Q_{i,DG} = Q_{i\Sigma}. \tag{17}$$

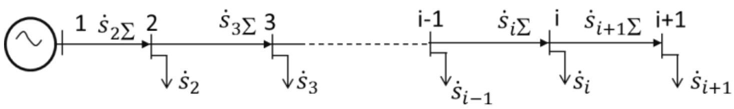


Figure 1. A sample of the distributed grid

2.3.2. Improvement of LSF method

The improvement of LSF (ILSF) was developed from LSF, and the ILSF detail was described in [18]. The ILSF value of active power and reactive power at the i^{th} node is computed as (18) and (19).

$$ILSF_{i,P} = 2 \sum_{k=2}^{i} \frac{P_{k\Sigma}}{V_k^2} R_{k-1} \tag{18}$$

$$ILSF_{i,Q} = 2 \sum_{k=2}^{i} \frac{Q_{k\Sigma}}{V_k^2} R_{k-1} \tag{19}$$

The optimal active and reactive power of DG at the i^{th}node to minimize the power loss is defined as (20) and (21).

$$P_{i,DG} = \sum_{k=2}^{i} \frac{P_{k\Sigma}}{V_k^2} R_{k-1} \left(\sum_{k=2}^{i} \frac{R_{k-1}}{V_i^2}\right)^{-1} \tag{20}$$

$$Q_{i,DG} = \sum_{k=2}^{i} \frac{Q_{i\Sigma}}{V_i^2} R_{k-1} \left(\sum_{k=2}^{i} \frac{R_{k-1}}{V_k^2}\right)^{-1}. \tag{21}$$

3. PROPOSED ALGORITHM

Unlike simultaneous optimization approaches as BSA [7] and SSA [8], the proposed method applies a step-wise optimization method that first determines the optimal placement and size of DGs, followed by that of CBs. This approach is motivated by the following considerations. Firstly, DGs and CBs affect the distribution network in fundamentally different ways. While DGs can supply both active and reactive power, CBs only provide reactive compensation. If both are optimized simultaneously, the algorithm may install large capacitors without fully utilizing the DGs' reactive power capability, leading to inefficiency. Secondly, our method uses a deterministic analytical approach by using ILSF, rather than metaheuristic algorithms. This helps avoid the need to set up a population, adjust parameters, or evaluate fitness many times, making the method simpler and faster to run. Therefore, although simultaneous optimization using metaheuristic algorithms may work well in other studies, the step-wise method used in this paper is reasonable and takes advantage of the specific strengths of the ILSF approach.

To ensure minimal generation cost in the grid, an algorithm is proposed in Figure 2. In this algorithm, the calculation of each DG's optimal position and size is always prioritized over that of CBs to utilize the reactive power supported by DG. It means after determining the d^{th} DG, we start to determine the optimal installation site and rating of CBs to obtain the lowest generation cost, and then move to the next DG. The CB number, position, and size of CBs are dependent on the installed DG number. Here, we compare the result of the LSF method to the ILSF method to identify the best position and power rating of DG or CB. This algorithm is shown in Figure 2.

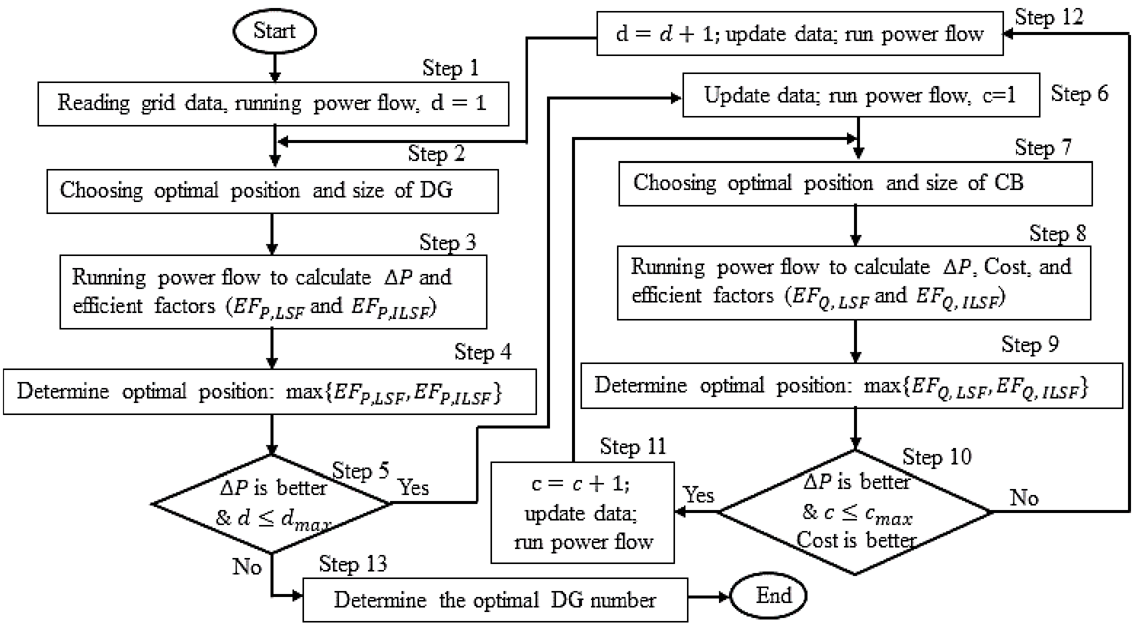


Figure 2. Algorithm to determine the optimal position and size of both DG and CB

Step 1: Reading data, including the grid parameters, $Data$; costs of DG, CB, and the connected grid; and run the power flow. We start the first DG, d=1. Step 2: Calculating LSF_P (14) and $ILSF_P$ (18) at all nodes. We chose the best position for the d^{th} DG based on $ILSF_P$ and LSF_P, and we determine DG's size (P_{LSF}, Q_{LSF} from (16), (17), and P_{ILSF}, Q_{ILSF} from (20), (21)) at these nodes. Due to the limitation of reactive power from DG, the optimal reactive power of DG is determined by the allowable power factor as (22).

$$Q_{DG,opt} = min\ (Q_{DG}, P_{DG} tan\varphi_{max}) \tag{22}$$

Step 3: Running power flow with the existence of this DG to obtain the power loss, ΔP_{LSF} and ΔP_{ILSF}, corresponding to the LSF method and ILSF method, respectively. The efficiency factor of DG installation is:

$$EF_{P,LSF} = \frac{\Delta P_{d-1} - \Delta P_{LSF}}{P_{LSF}} \text{ and } EF_{P,ILSF} = \frac{\Delta P_{d-1} - \Delta P_{ILSF}}{P_{ILSF}} \tag{23}$$

where, ΔP_{d-1} is the power loss before installing the d^{th}DG for each method.

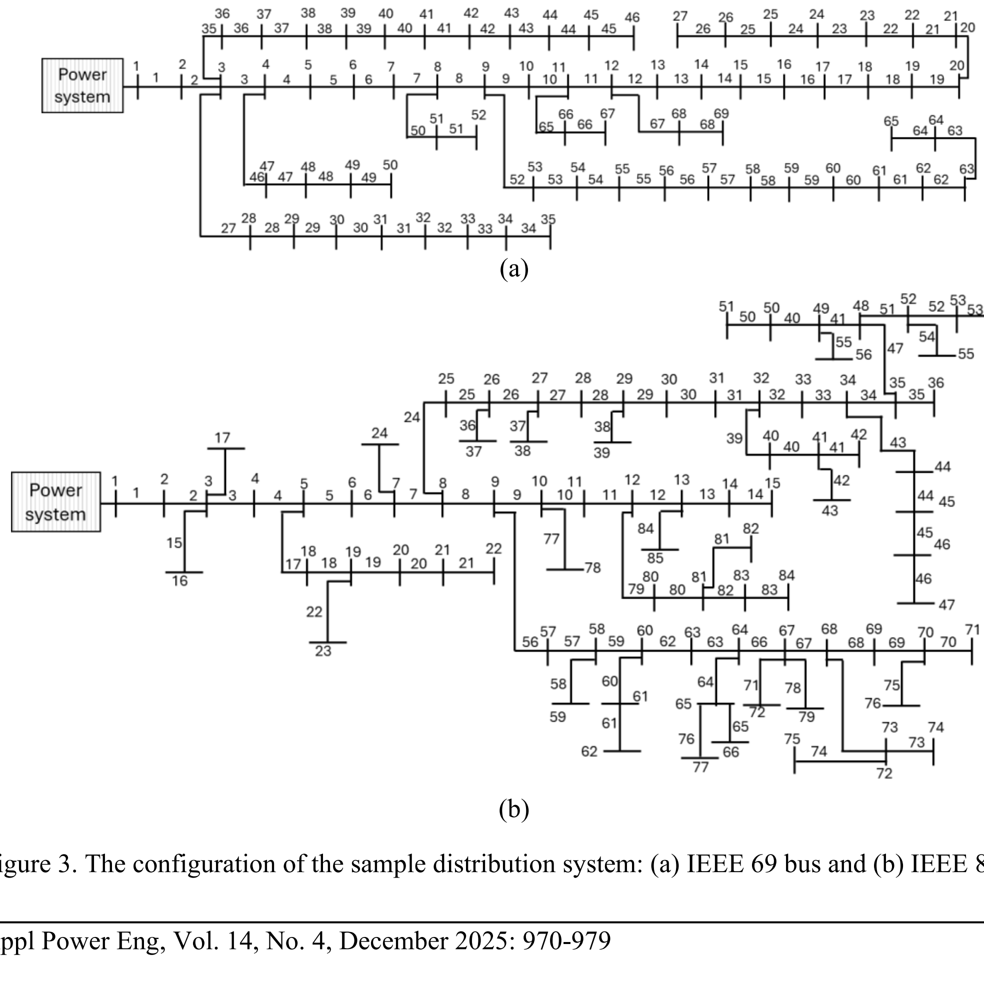
Step 4: Deriving the optimal installation site and size of DG. If $EF_{P,LSF} > EF_{P,ILSF}$, the best installation site and size of DG come from the LSF method; otherwise, they come from the ILSF method. We store the position and rating of DG in the set $\aleph_d$ and we use the power loss, $\Delta P_{\boldsymbol{d}}$, corresponding to this case in the next steps. Step 5: Testing the stop condition. If $\Delta P_{\boldsymbol{d}} \leq \Delta P_{d-1}, and\ d \leq d_{max}$, Step 6 is used; otherwise, Step 13 is done. Step 6: Updating the grid data by adding the d^{th}DG in $Data$. We start the first CB, $c = 1$, and we set $\Delta P_{c-1} = \Delta P_{\boldsymbol{d-1}}$, $Cost_{\boldsymbol{c-1}} = Cost_{\boldsymbol{d-1}}$, $CData_c = Data$, and run power flow. Step 7: Calculating LSF_Q (15) and $ILSF_Q$ (19) at all nodes. We choose the best node to install CB and its size for the LSF method, Q_{LSF} (17) and the ILSF method, Q_{ILSF} (21). Step 8: Running power flow after adding this CB for each method to obtain the power loss, ΔP_{LSF} and ΔP_{ILSF}. We compute the efficient factor as (24), where ΔP_{c-1} is a power loss before installing the c^{th} CB.

$$EF_{Q,LSF} = \frac{\Delta P_{c-1} - \Delta P_{LSF}}{Q_{LSF}} \text{ and } EF_{Q,ILSF} = \frac{\Delta P_{c-1} - \Delta P_{ILSF}}{Q_{ILSF}} \quad (24)$$

Step 9: Deriving the optimal position and size of CB. If $EF_{Q,LSF} \geq EF_{Q,ILSF}$, the optimal position and size of this CB come from the LSF method; otherwise, we use the ILSF method. We use the power loss, $\Delta P_{\boldsymbol{c}}$, corresponding to this case in the next steps.
Step 10: If $\Delta P_{\boldsymbol{c}} \leq \Delta P_{c-1}$, $c \leq c_{max}$, $Cost_{\boldsymbol{c}} \leq Cost_{c-1}$, Step 11 is done; otherwise, we move to Step 12.
Step 11: Updating the c^{th}CB in $CData_c$ then run the power flow. We set c=c+1, and then Step 7 is returned.
Step 12: We set $DCCost_d = Cost_{c-1}$, d=d+1, use $Data$ to run the power flow, and then execute Step 2 again.
Step 13: Deriving the optimal DG and CB numbers from min $\{DCCost_1, DCCost_2, \dots, DCCost_{d-1}\}$.

4. RESULTS AND DISCUSSION

To verify the proposed algorithm, we use the IEEE 69 bus and IEEE-85 bus distributed system as shown in Figure 3. The total load in the IEEE-69 bus grid is 3801.9 kW and 2694.1 kVAr, while in the IEEE-85 bus grid, it is 2570.3 kW and 2622.1 kVAr. These grids' data are listed in [19], [20]. We suppose that the energy price from the grid and DG are 49 $/MWh and 51.45 $/MWh, respectively; the CB investment and its constant are 0.35$/kVAr/year and 100$/year.



(b)

Figure 3. The configuration of the sample distribution system: (a) IEEE 69 bus and (b) IEEE 85 bus

4.1. IEEE-69 bus distributed grid

With the IEEE-69 bus system, if the maximum DG number is 4, we obtain the results in Table 1 and Figure 4. Clearly, with the proposed algorithm, we only install 1 DG at the 61st node (1562 kW) and 3 CBs at the 16th, 64th, and 17th nodes (with 225, 204, and 195 kVAr, respectively). With this installation, the power loss and the generation cost are reduced significantly, and the minimum node voltage in this network is elevated. A notable power loss reduction is observed, from 225 kW to 20.45 kW, and the generation cost is cut from 197.3 $/h to 191.196 $/h. The voltage at nodes from the 50th node to the 69th node is over 98%, and the minimum voltage in the grid is around 98% at the 27th node, while in the base case, the minimum voltage is 91.02% at the 65th node.

Table 1. Results of applying the proposed algorithm to the IEEE-69 bus

Case	DG size (node) (kW)	pf (%)	CB size (node) (kVAr)	ΔP (kW)	$V_{i,min}$ (%)	Cost ($/h)
Base				225	91.02	197.3
Proposed method	1562(61)	81	195(17) 204(64) 225(16)	20.45	97.73	191.196

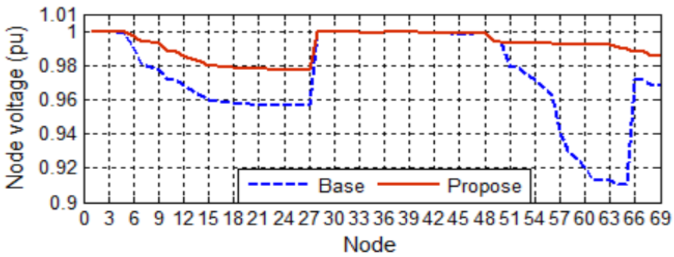
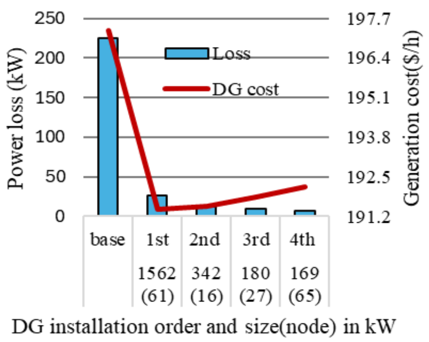
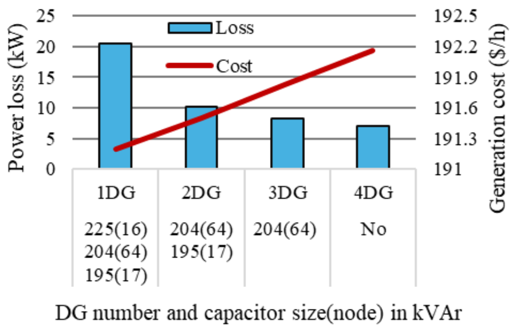


Figure 4. The voltage at nodes in the IEEE-69 bus after installing DG and CBs

To clarify the above results, the results of all cases are shown in Figure 5. Figure 5(a) indicates the power lost and the generation cost when we install 4 DGs step by step. Obviously, after installing the 1st DG, the power loss is reduced from 225 kW to 26.737 kW, and its efficiency is around $0.056\ \%/kW$ while after installing the 4th DG, the power loss is 7.017 kW and the efficiency is around $0.043\%/kW$. Concerning the generation cost, after installing the 1st DG, the generation cost is the lowest, 191.435 $/h. By adding more DGs, the generation cost increases. Figure 5(b) indicates the results in the case of both DG and CB installation. From this figure, when the DG number is higher, the CB number is lower, and in the case of 4 DGs, none CB are suggested. Obviously, by adding CB, both power loss and generation cost are lower than those in Figure 5(a). However, the higher the DG number, the higher the generation cost. This increase comes from the increase in the DG cost. Therefore, we should install a DG and 3 CB as Table 1 to obtain the lowest generation cost.



(a)



(b)

Figure 5. Power loss and generation cost after installing DG and CB: (a) Only DG and (b) both CB and DG

To compare to other research, two cases of power factor (pf_{min} = 100% and pf_{min} = 80%) and two cases of the DG number ($d = 1$ *and* $d = 3$) are used. The comparison results are shown in Table 2 [7]-[9], [21], [22]. Clearly, with our algorithm, the power loss cannot be compared to others because the total capacity of DG and CB in the proposed algorithm is lower than that of others. However, the investment effectiveness of the introduced scheme surpasses others. For example, in the case of 3 DGs with $pf_{min} = 100\%$, in [22], after installing 2547 kW of DG and 1797 kVAr of CB, the system loss is as low as 4.263 kW, but the generation cost is 192.883 $/h, which is higher than our algorithm. Likely, in the case of 1DG with $pf_{min} = 80\%$, with the proposed algorithm, the power loss and generation cost are 20.45 kW and 191.196 $/h, while with the ABC algorithm, the data is 18.551 kW and 191.817 $/h. This means that my algorithm is more efficient.

Table 2. Comparison between the proposed method and other methods

Method	DG size in kW (node/pf)	CB size in kVAr (node)	ΔP in kW	Cost in $/h
ABC [21]	1870(61/0.85)	300(18)	18.551	191.817
Propose	1562(61/0.81)	225(16) 204(64) 195(17)	20.45	191.196
BSA [7]	294(19/0.866) 219(22/0.866) 1768(61/0.866)	450(7) 300(2) 150(3)	7.604	192.344
SSA [8]	358(19/NA) 518(10/NA) 1673.5(61/NA)	600(11) 600(48) 200(60)	4.853	192.952
Propose	1562(61/0.81) 342(16/0.83) 180(27/0.96)	204(64)	8.256	191.831
ABC [21]	1800(61/1)	1350(61)	23.282	191.937
Propose	1562(61/1)	1116(61) 225(16) 204(64) 195(17)	20.446	191.271
WCA [9]	540.8(17/1) 2000(61/1) 1159.2(69/1)	1187.9(2) 1237.3(62) 269.7(69)	33.339	197.184
Ref.[22]	504(11/1) 376(17/1) 1667(61/1)	1193(61) 367(11) 237(20)	4.2632	192.883
Propose	1562(61/1) 342(16/1) 180(27/1)	1115(61) 225(16) 204(64)	8.747	191.954

4.2. IEEE-85 bus distributed grid

By applying the proposed algorithm to the IEEE-85 bus grid, we can get results in Table 3 and Figure 6. Obviously, with 2 DGs and 6 CBs as Table 3, both the power loss and the generation cost are reduced significantly, and the nodes' voltage in the grid becomes flat. A considerable drop in power losses is observed, from 314.537 kW to 45.760 kW, and the generation cost is cut down by about 10 $/h. The nodes' voltage is from 97.71% to 1.01%.

Table 3. Results as applying the proposed algorithm to the IEEE-85 bus grid

Case	DG size (node) (kW)	pf (%)	CB size (node) (kVAr)	ΔP (kW)	$V_{i,min}$ (%)	Cost ($/h)
Base				314.537	87.43	141.357
Proposed method	794(54) 617(76)	86 82	1167(8) 99(84) 48(47) 62(15) 66(22) 59(21)	45.760	97.71	131.798

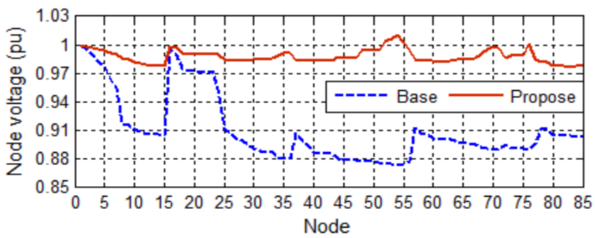


Figure 6. Voltage at nodes in the IEEE-85 bus grid

To clarify the above result, the case of $d_{max} = 4$ is used and the detailed results are shown in Figure 7, in which Figure 7(a) represents the case of DG without CB and Figure 7(b) represents the case of DG with CBs. Figure 7(a) shows that the power loss and the generation cost are reduced with the increase in the DG number. Obviously, after installing the 4th DG (794 kW, 617 kW, 348 kW, and 187 kW at the 54th, 76th, 84th, and 62nd nodes, respectively), the system loss is decreased significantly from 314.537 kW to 54.363 kW, and the generation cost is cut down from 141.357 $/h to 133.376 $/h. Figure 7(b) indicates that the combination of DG and CBs will reduce the power loss, but the generation cost increases again when we use more than 2 DGs. For example, with 3 DGs (794 kW at the 54th node, 617 kW at the 76th node, 348 kW at the 84th node) and 5 CBs (906 kVAr, 65 kVAr, 56 kVAr, 73 kVAr, and 89 kVAr at the 8th, 47th, 43rd, 22nd, and 20th nodes, respectively), the power loss is 36.264 kW but the generation cost is 132.156 $/h which is higher than the data in Table 3. Therefore, the optimal result is the case of 2 DGs and 6 CBs, as Table 3.

To compare the proposed algorithm and others, here we use the case of DG with unity power factor; the value of d_{max} and c_{max} are set based on the compared references, and we relax the condition of generation cost (step 13 in Figure 2). Comparison results are shown in Table 4 [23]-[25]. From Table 4, in the case of sole DG, with the proposed algorithm, the power loss may be higher than others, but the generation cost is always lower than others. Take the SA algorithm [24] with $d_{max} = 2$ for example, the power loss is 170 kW lower than 177.637 kW of the proposed algorithm, but the generation cost is 139.637 $/h, higher than 138.103 $/h of the proposed algorithm. This is explained by the lower DG size in the proposed algorithm. In the case of DG and CB, the power loss and the generation cost are always lower than those of others. Obviously, with $d_{max} = c_{max} = 3$, the data with the introduced scheme is 49.570 kW and 132.864 $/h, which are lower than 73.24 kW and 135.027 $/h of the GABC scheme [25]. This proves that the proposed algorithm is more efficient than others.

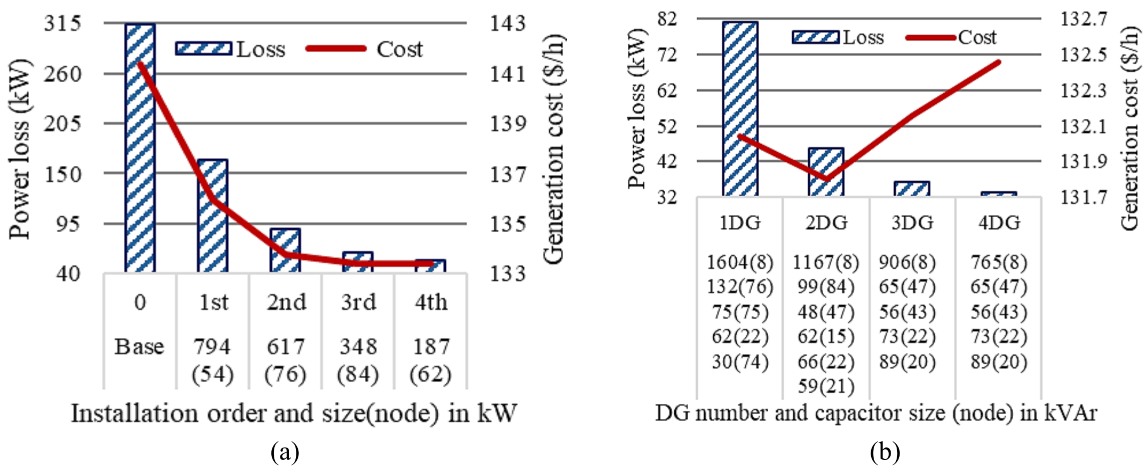


Figure 7. Power loss and generation cost as: (a) only DG and (b) combination of CB and DG

Table 4. Comparing the proposed algorithm to others in the case of the unity power factor

d_{max} & c_{ma}	Method	DG size in kW (node)	CB size in kVAr (node)	ΔP in kW	Cost in $/h
1&0	WOA [23]	946.3(55)		224.049	139.241
	Propose	794(54)		220.279	138.683
2&0	SA [24]	591.2 (36) 1597.5(9)		170	139.637
	Propose	794(54) 617(76)		177.637	138.103
3&0	SA [24]	321.1(69) 851.2 (33) 744.3(9)		166.44	138.795
	Propose	794(54) 617(76) 348(84)		165.595	138.363
1&1	GABC [25]	1801(36)	900(53)	118.26	136.214
	Propose	794(54)	2070(8)	100.919	132.964
2&2	GABC [25]	851(36) 1349(56)	600(53) 450(46)	86.34	135.648
	Propose	794(54) 617(76)	2068(8) 612(30)	58.465	132.439
3&3	GABC [25]	574(36) 1204(56) 426(54)	300(53) 450(46) 300(54)	73.24	135.027
	Propose	794(54) 617(76) 348(84)	2068(8) 612(30) 33(22)	49.570	132.864

5. CONCLUSION

This paper proposed an algorithm to minimize the generation cost and reduce the power loss in the grid by determining the optimal position, size, and power factor of DGs and the optimal position and size of CBs. The algorithm is developed from the loss sensitivity factor. By applying this algorithm to the IEEE-69 bus and IEEE-85 bus distributed grid, the optimal position, size, and power factor of DGs and CBs in each grid are determined, the power loss in the grid is reduced significantly, and the generation cost is minimal. Compared to other research, with the proposed algorithm, the generation cost is always lower than others. This is the efficiency of the proposed algorithm. In the future, this method can be extended to apply to renewable sources with uncertainty, such as wind generators, solar systems, or combined with other techniques to solve more complex problems.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ngoc An Luu	✓	✓	✓	✓	✓			✓	✓	✓				
Dinh Chung Phan		✓	✓					✓	✓	✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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