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Optimal Dispatchable DG Location and Sizing with an Analytical Method, based on a New Voltage Stability Index

Mohammad Aryanfar[1,*]

[1] *Tehran Electrical Distribution Company, Tehran, Iran*

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ABSTRACT

With the high penetration of DGS in the distribution network and its impact on the power loss and voltage profile of the network, the choice of location and the optimal size of the DG has become a challenge for utility companies. In this paper, a method for determining the optimal location and size of dispatchable DG at different load levels for optimal utilization of the distribution network is presented. The goal is to reduce active power losses and improve voltage profiles for stable system performance. The average daily load demand is considered as the load demand profile. The optimal location of DG is determined by sensitivity analysis based on a new voltage stability index. The voltage stability index is based on the voltage breakdown feature and provides an overview of the network voltage stability so that it can show the effect of DG installation location on network voltage stability. DG provides loads at different levels, then by selecting the appropriate bus from the most important buses in terms of index, the optimal size of DG is determined using a search algorithm and based on the lowest active power losses for different load levels. The proposed method on IEEE 33 bus network has been tested using MATLAB software, and its results have been compared with other available methods. The results show the effectiveness of the proposed method in reducing active power losses and improving the voltage profile compared to other available methods.

1. Introduction

With the expansion of Renewable energy resources, the issue of investment in the Distributed Production Resources (DG) sector has attracted the attention of many distribution companies. Considering renewable sources such as solar wind energy and micro-turbines, the use of DG can be an excellent solution for reducing greenhouse gas emissions, including CO2. Therefore, the development of DGs has been on the agenda of many countries, including the UK, [1], and examining the barriers, challenges, and opportunities of these resources is one of the most pressing topics in electrical engineering.

However, the use of DG, despite its advantages such as clean energy production, has requirements that must be considered when designing the networks containing DGs. By placing DGs in distribution networks, the network changes from inactive to an active network, and therefore issues related to voltage stability and system reliability in the network must be reconsidered. If the implementation of DGs is not considered carefully, not only does it not help network indices, but it may also weaken indices such as voltage stability and system reliability index. So weneed ways to take advantage of DG while preventing new problems.

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* Corresponding author
E-mail address: mohamad.aryanfar324@gmail.com
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The issue of DG sizing and allocation has been discussed in numerous papers. These studies are generally divided into two types. The first type is papers that use optimization methods to calculate an objective function and try to maximize or minimize variables. These variables can be the cost of energy production, lost power, or other indicators. The second category is methods that analyze the sensitivity of the buses to one or more indicators and then decide whether or not to place the DG on a bus. DG sizing is also achieved in these methods by considering various indices.

Methods that use the optimization algorithms include genetic optimization (GA) and particle rhythm (PSO) ant colonies (AC) Bee Colonies (BC) and various other heuristic and none heuristic methods. For example, in [2], an ant colony algorithm (AC) is used to find the optimal location of DGs, considering the reliability of the system .In [3], the genetic algorithm and PSO are used together to find the optimal location and size of DGs in the distribution network.

In [4], the method using craziness-based particle swarm optimization (CRPSO) algorithm based on the game-theoretical formulation strategy is used for optimal placement of DG units. In this method, the authors' goal is to reduce the cost of power supply, and the objective function is composed of the cost of buying power, power loss, communication, and load shedding. A two-step coordinate method has been used in [5] to locate heterogeneous DG in a micro-energy microgrid. In this method, uncertainties related to renewable resources are considered, and in addition to optimizing the location and capacity of DG units, to maximize the Net Present Value index, investment costs and type of DGs are also considered.

In [6], a new method called Harris Hawks optimization has been used to optimally locate and determine the capacity of distributed generation units in the radial distribution network. In this method, the authors aim to minimize lost power, and they compare the performance of this method with similar methods of heuristic optimization. There are many papers in the literature that use indices to locate and determine the size of DG units. For example, [7] suggests an analytical method that locates DG units. In this method, the goal is to minimize power loss, which has been investigated in two types of networks: the distribution network and transmission network.

In [8], an indicator was used for power loss sensitivity based on two matrices, the Bus-Injection to Branch-Current (BIBC) and Branch-Current to Bus-Voltage (BCBV) matrix to Calculates the power of the injected average .Using this index, the size and the location of DGs are determined. In [9], the authors used the loss sensitivity index to optimize capacity and extract power loss equations. The DG's optimal location is also calculated based on power loss. They also used an analytical approach based on sensitivity to the lost real power to obtain the optimal location and capacity of the DGs in the distribution network and minimize the wasted power.

A method for allocating distributed generation has been proposed in [10]. The authors use an index called Power Stability Index (PSI), which analyses the voltage of a stable node. The algorithm is used to visualize the impact of DG placement on system loss. Three deferent indices have been proposed in [11], which are used to determine the optimal location and size of DGs in the radial distribution network. These methods are then compared, and their pros and cons have been demonstrated. Authors in [12] use a proposed index to determine the system reliability and to minimize power loss. Also, an optimization method named the Imperialistic Competitive Algorithm (ICA) has been used to compare and evaluate the results. In[13], optimal multi-objective allocation of DG units to achieve more power loss reduction and reliability betterment is carried out by co-evolutionary multi-swarm particle swarm optimization (CMPSO) algorithm. In[14], a novel analytical algorithm is proposed to distinguish the optimal location and size of DGs in radial distribution networks based on a new combined index (CI) to reduce active power losses and improve system voltage profiles. [

A new probabilistic index is defined in [16] that measures the controllability of voltages and currents in the buses and lines of distribution systems. This index is then used to determine the location of Different types of DG in the distribution network. Authors in [17] use the protection coordination index (PCI) to determine the optimal location of DGs in the distribution network. The impact of fault current limiters on this index is also discussed in this paper.

In [18], a stability index-based technique is proposed for determining the optimal location and size of different types of DG units in the distribution systems to reduce line losses, improve voltage profile, and decrease pollution level. Authors in [19] used a planning approach based on Voltage stability index (VSI) with improved loss minimization (LM) formulation. They employed these methods to determine DG location and size in a loop test distribution network (LDN). There are a variety of analytical methods available to solve the DG sizing and placement problem, one of which is shown in [20], where authors have proposed an iterative analytical method to find the optimal size and location of distributed generation units in radial distribution networks with the objective of minimizing network loss.

This paper presents a method for optimal utilization of the distribution network by determining the optimal location and size of DG, to reduce annual energy losses and improve voltage profiles. The optimal DG location is determined by a new voltage stability index. This indicator is based on the characteristic of voltage collapse in power systems, which can show the positive effect of DG on network voltage stability. The characteristic of voltage collapse is not used in other papers in this field. The optimal DG size is also determined by a search algorithm based on minimizing active power losses.

The structure of the paper is as follows. In Section 2, the modeling load is presented.In Section 3, the formulation of the problem is presented.In Section 4, the proposed methods is presented. In Section 5, the discussion and simulation results are reviewed, and, finally, in Section 4, the paper’s overall conclusion is discussed.

2. Modeling Load

In this section, the network load is modeled for 1 year (8760 hours). The network load is first modeled for 1 day and then generalized to 365 days of the year [21]. The amount of load per hour varies from 0.4 to 1 per unit. The daily load model is shown in Fig.1, which varies from 0.4 to 1 per unit. Then, this pattern is considered for 1 year. Table 1 shows the average daily and annual load demand.

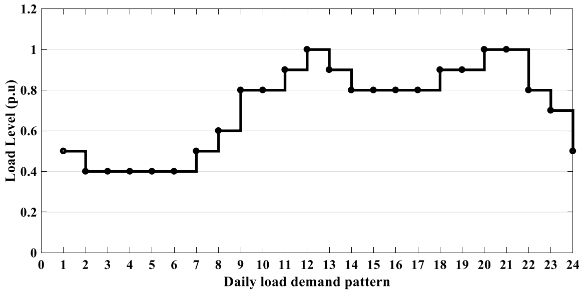

Fig.1. Daily load model pattern

Table I. Average hourly daily load model

Time	Load Level (p.u)	hours	T_{Time}(Hours/year)
1	0.5	1	365
2-6	0.4	5	1825
7	0.5	1	365
8	0.6	1	365
9-10	0.8	2	730
11	0.9	1	365
12	1	1	365
13	0.9	1	365
14-17	0.8	4	1460
18-19	0.9	2	730
20-21	1	2	730
22	0.8	1	365
23	0.7	1	365
24	0.5	1	365

3. Problem Formulation

3.1. Voltage stability index for optimal DG location

In this section, the proposed voltage stability index is modeled to determine the optimal DG location. This index is obtained using the active power bus equation for the receiver bus. Thus, the derivative of the voltage to the power of the receiver bass at the point of voltage instability is zero. According to Fig2, the power of the receiver bus is obtained by the following equation:

$$P_R = P_L - P_{DG} = \frac{V_S V_R \cos(\theta-\delta)}{Z} - \frac{V_R^2 \cos(\theta)}{Z} \tag{1}$$

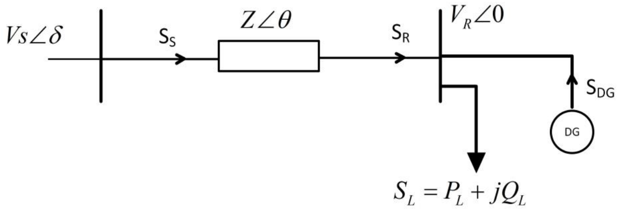

Fig.2. Study network

By rewriting the equation (1) based on the voltage of the receiver, the equation (2) is obtained as follows:

$$V_R^2 - \frac{V_S V_R \cos(\theta-\delta)}{\cos(\theta)} + \frac{P_R Z}{\cos(\theta)} = 0 \tag{2}$$

By deriving the equation (2) we have:

$$\frac{dV}{dP_R} = \frac{Z}{V_S \cos(\theta-\delta) - 2V_R \cos(\theta)} \tag{3}$$

The $\frac{dV}{dP_R} < \circ$ must always be true voltage stability, therefore:

$$V_S \cos(\theta-\delta) - 2V_R \cos(\theta) < \circ \tag{4}$$

According to equation (4), the following relation must always be true for voltage stability:

$$\frac{2V_R \cos(\theta)}{V_S \cos(\theta-\delta)} > 1 \tag{5}$$

According to equation (5), the voltage stability evaluation index for a network with l transmission lines, it is defined as follows:

$$VSI_l = 2 - \frac{2V_R \cos(\theta)}{V_S \cos(\theta-\delta)} \tag{6}$$

Equation (6) shows the stability of network lines. The following is a general main equation for the OVSI (Overall voltage stability index):

$$OVSI = \sum_{l=1}^{n-1} VSI_l \tag{7}$$

Where n is the number of network studied buses and l is the number of lines.

3.2. DG size optimization

In this section, the optimal DG measurement for active power loss is determined. After determining the appropriate location for the DG installation, by changing the DG size, from 0 to 100% of the total network active load, the ratio of active loss changes to the DG size is obtained. Then, by holding the permitted constraints of voltage, the DG size is selected so that the active network losses are minimized. It is important to note that, given that the DG power loss diagram is as large as the DG size, the step size of the DG changes is very important in choosing the optimal DG size. In this paper, the step size at each stage is considered to be 1% of the total active load.

For determining the optimal DG size, the following constraints must be held:

- Voltage constraints:

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{8}$$

- Power Balance Constraint:

$$P + P_{DG} = P_{load} + \sum RI^2 \tag{9}$$

$$Q + Q_{DG} = Q_{load} + \sum XI^2 \tag{10}$$

- DG Size constraint:

$$\begin{cases} P_{DG} \le P_{load} \\ Q_{DG} \le Q_{load} \end{cases} \tag{11}$$

4. Proposed Methods

In this section, a general algorithm for selecting the optimal location, and the optimal size of dispatchable DG is provided. To determine the right place to install DG, first, calculate the different OVSI load levels. The receiving bus of a line, which has the highest OVSI value for different load levels, is selected as the candidate bus for DG installation. By selecting a candidate bus, the optimal DG size for different load levels over 24 hours is obtained by holding the operating constraints following Section 2.3 to reduce losses. The flowchart of the proposed method for determining the optimal location and size of DG is shown in Fig.3.

By determining the optimal location and size of DG by the proposed method, the annual cost of energy losses and operating costs of DG are calculated as follows:

- Cost of energy losses:

By determining the optimal location and size of DG, the cost of energy losses is reduced. The cost of annual energy losses is as follows [11]:

$$C_{Losses} = (\text{Total Real Power Loss})_{Time} * K_P * T_{Time} \tag{12}$$

Where $K_P = 0.06(\frac{\$}{kwh})$.

- Operating costs of DG:

The DG cost function is according to Equation (13) [22]:

$$C(P_{DG}) = a * P_{DG}^2 + b * P_{DG} + c \tag{13}$$

Where $a = 0$, $b = 15$ and $c = 0.002$.

The reactive power cost function is obtained based on the trigonometric relations between active and reactive power as follows [23]:

$$C(Q_{DG}) = a'' * Q_{DG}^2 + b'' * Q_{DG} + c'' \tag{14}$$

Where the coefficients of the cost function are calculated as follows:

$$a'' = a * \sin^2(\theta)$$

$$b'' = b * \sin(\theta)$$

$$c'' = c$$

$$\theta = \cos(PF)^{-1}$$

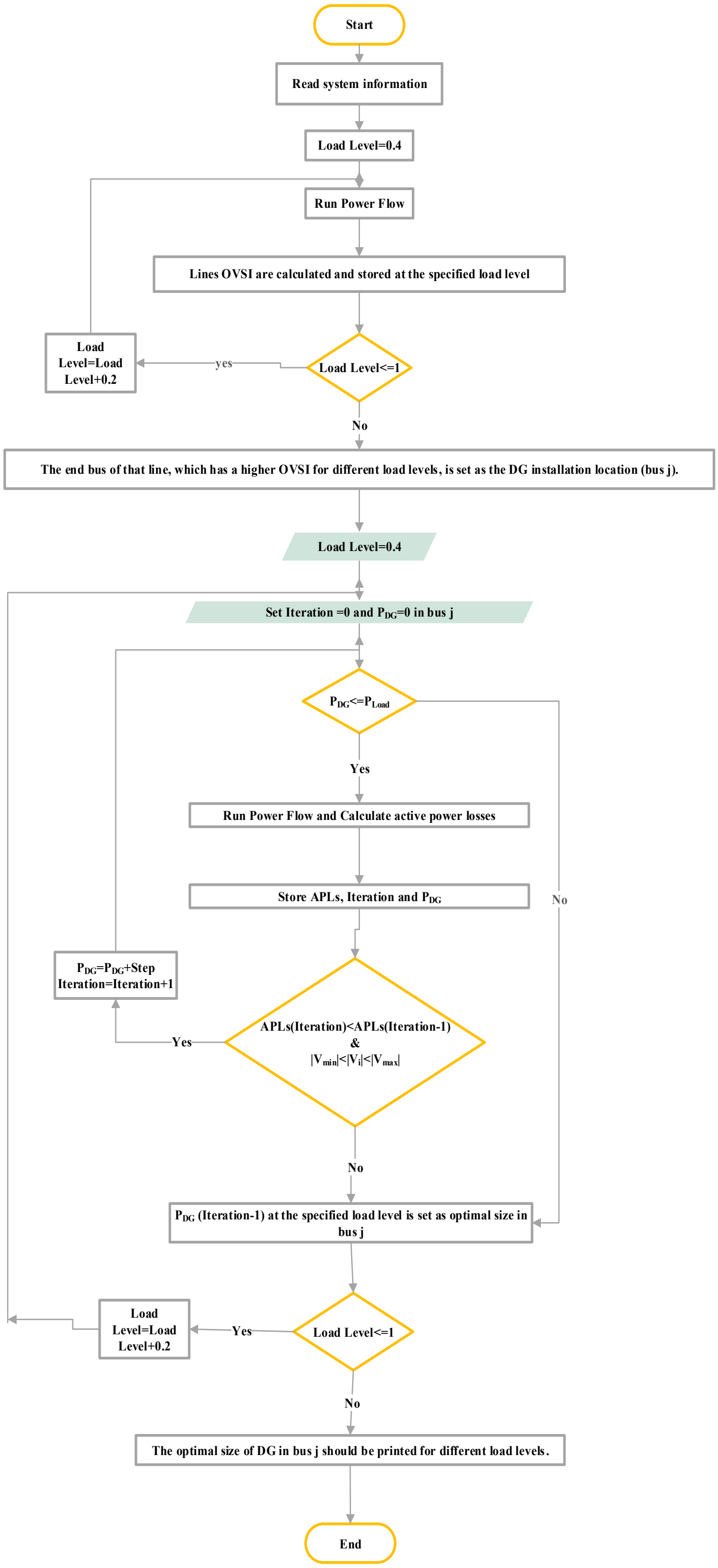

Fig.3. Flowchart of the proposed method algorithm

5. Results of simulation and discussion

To implement and examine the proposed method for optimal and sustainable utilization of the distribution network, the 33-bus IEEE [24] bus, has been selected as the study network. The 33-bus network has 3715 kW of active load and 2300 kW of the reactive load. In this simulation, the base voltage and the base apparent power are considered to be 12.66 kV and 100 MVA, respectively. The 33-bus network studied is shown in Fig3. The proposed model is implemented in MATLAB software.The model has been executed in a PC with Intel Core i7 CPU @3.20 CPU and 4 GBs of RAM.

In this section, according to the proposed algorithm, first, the optimal location of the dispatchable DG is determined, then the optimal DG size for different load levels is calculated in 24 hours with a unit power factor, 0.9 lag, and the optimal power factor. Then, the results obtained for the different power factors and load level 1 are compared with the Index vector (IV) method [25], voltage stability index (VSI) methods [11] and Voltage sensitivity index (VSI) methods [26].

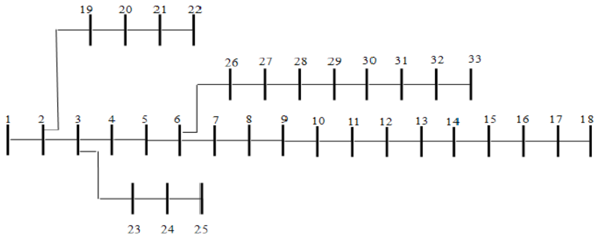

Fig.4 33-bus network

5.1. Dispatch able DG with unit power factor

In this section, the optimal location and size of the DG are selected for the unit power factor. According to the algorithm, the optimal place of DG is obtained first. Fig.5 shows the value of the VSI index for different load levels. The examination of Fig.4 shows that line 7 has the largest VSI value for different load levels. Therefore, Bus 8 at the end of Line 7 is the most suitable bus for installing DG.

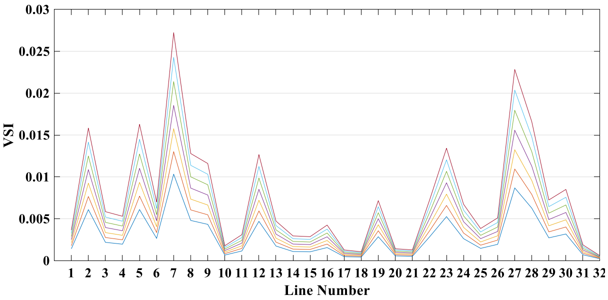

Fig.5. VSI index value for IEEE 33 bus network lines

By installing a dispatchable DG on Bus 8, the optimal DG size for different load levels over 24 hours is obtained according to the flowchart in Fig.3. Table 2 shows the dispatchable DG optimal size, total active and reactive losses without DG installation and with DG, minimum voltage, the annual cost of active power losses for DG installation mode without DG installation, and the annual cost of DG operation for different load levels. Give. The results of **Table.II** show that with the dispatchable DG installation, the Bus 33 voltage has the lowest voltage level in 24 hours. The minimum voltage measurement for the average daily load is shown in **Fig.6**. **Fig.7** shows a 33-volt mains voltage for a 0.8 per unit load level, without DG installation and with DG installation. Optimal DG installation increases the stability margin and network load. The P-V graph of bus 30 at the load level of 0.8 per unit is presented in **Fig.8** that confirms the results. With the presence of DG, the load and voltage stability margin of the network has increased.

As mentioned, choosing the optimal DG size for different levels of the load over a year reduces the resulting losses and costs. The cost of annual energy losses for 0.8 per unit load is higher than other load levels. Also, the installation of DG has reduced the cost of annual energy losses by $ 8678 for 0.8 per unit level load, which is the highest decrease compared to other load levels. The total cost of annual energy losses for different levels of the load before installing DG is $ 55,134, which has been reduced to $ 31,164 with DG installation.

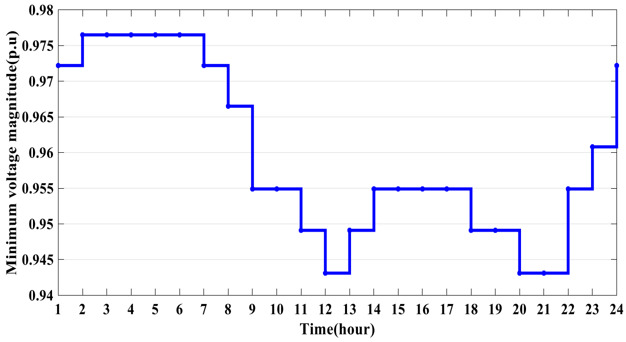

Fig.6. Minimum voltage measurement for average daily load by installing DG with unit power factor

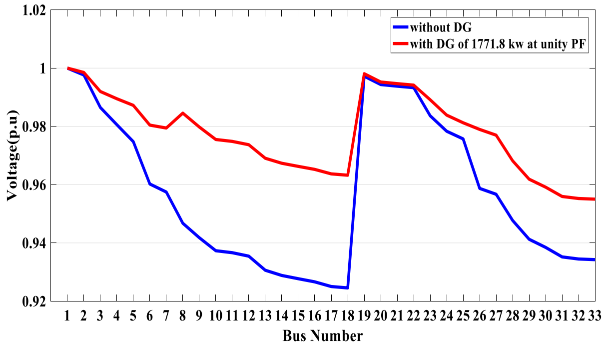

Fig. 7. 33 bus network voltage at 0.8 per unit load level without DG installation and with DG installation

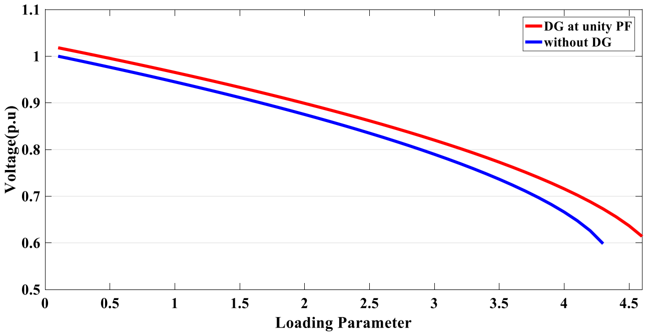

Fig.8. The effect of DG installation with unit power factor on increasing load and network voltage stability

Table II. Results for DG operating at the unit power factor

		Load Level						
Items		0.4	0.5	0.6	0.7	0.8	0.9	1
DG location bus		8	8	8	8	8	8	8
DG size in kVA		1486	1744.8	1756.6	1765.1	1771.8	1780.2	1788.18
Active power losses(kw)	**Without DG**	30.7186	48.6947	71.1646	98.3433	130.4654	167.7864	210.5861
	With DG	18.0680	28.0499	40.7663	56.0104	73.8571	94.3852	117.6781
Reactive power losses(kVAr)	**Without DG**	20.8229	33.0170	48.2656	66.7177	88.5355	113.8963	142.9942
	With DG	12.4102	19.6662	28.6045	39.320	51.867	66.313	82.817
Minimum voltage (Bus)		0.9765 (33)	0.9722 (33)	0.9665 (33)	0.9608 (33)	0.9549 (33)	0.9491 (33)	0.9431 (33)
Cost of energy losses ($/h)	**Without DG**	3363.7	3199.2	1558.5	2153.7	20000	11023	13836
	With DG	1974.4	1842.9	892.78	1226.6	11322	6201.1	7731.5
Net savings ($)		1385.3	1356.3	665.72	927.1	8678	4821.9	6104.5
Cost of P_{DG}($)		40686	28663	9618.8	9665.4	67914	38992	29375

5.2. Dispatchable DG with a power factor of 0.9 lag

According to the previous section, the optimal location for the dispatchable DG installation with a power factor of 0.9 lag at different load levels was bus 8, obtained according to the proposed algorithm. Therefore, the dispatchable DG is installed in Bus 8, and according to the search algorithm and by reducing the active power losses, the optimal DG size for different load levels during 24 hours period is obtained. **Table.III** shows the optimal DG measurement for 24 hours, active and reactive power losses for with and without DG modes, minimum voltage for different load levels, and the annual cost of active power losses for both DG-free and DG-mode modes, and annual DG utilization costs. The results of **Table.III** show similar to the DG installation mode with a unit power factor, in this case, for different load levels, and within 24 hours, bus 33 voltage has a minimum value. Bus 33 voltage levels are shown in **Fig.9** for 24 hours. **Fig.10** shows the network voltage profile of 33 buses for 0.8 per unit loads in two modes without DG installation and with DG installation. In mode without DG installation, bus 18 has the lowest voltage, and with the installation of DG in bus 8 causes bus 33 to have the lowest voltage, and therefore the network voltage level is optimal. A comparison of minimal voltage in DG installation mode with a unit power factor and a 0.9 lag shows the effect of reactive power on improving voltage profile. Also, the P-V diagram of bus 30 for the 0.8 per unit load level in **Fig.11** shows that the installation of DG with a power factor of 0.9 lag has a greater effect on increasing the voltage stability margin and increasing the network stability level. Therefore, in using DG, the optimum power factor should be considered. An examination of **Table.III** shows a good reduction in the cost of annual active power losses with DG installation. The cost of annual active power losses for the 0.8 per unit load level is higher than other load levels, which is reduced by $ 11863.9 with the installation of DG. The cost of annual active power loss for all load levels before installation is $ 55134, which is reduced to $24010 by installing DG. Their results show that the installation of DG with a power factor of 0.9 lag of 56.52% reduction in the cost of annual active power loss has been created.

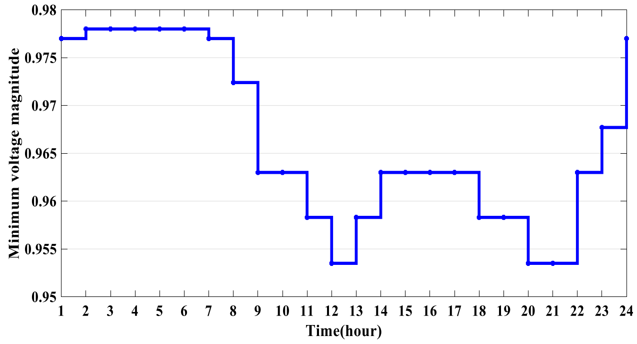

Fig.9. Minimum voltage for average daily load with the installation of DG with 0.9 lag

Table.III. Results for DG operating at 0.9 power factor lag

		Load Level						
Items		0.4	0.5	0.6	0.7	0.8	0.9	1
DG location bus		8	8	8	8	8	8	8
DG size in kVA		1651.1	2063.9	2077.4	2086.1	2100	2109.6	2120.2
Active power losses(kw)	**Without DG**	30.7186	48.6947	71.1646	98.3433	130.4654	167.7864	210.5861
	With DG	14.2483	20.3299	29.6444	40.3667	53.0729	67.6178	84.0419
Reactive power losses(kVAr)	**Without DG**	20.8229	33.0170	48.2656	66.7177	88.5355	113.8963	142.9942
	With DG	9.7753	14.9545	21.7020	29.7495	39.1643	49.9321	62.1113
Minimum voltage (Bus)		0.9780 (33)	0.9770 (33)	0.9724 (33)	0.9677 (33)	0.9630 (33)	0.9583 (33)	0.9535 (33)
Cost of energy losses ($)	**Without DG**	3363.7	3199.2	1558.5	2153.7	20000	11023	13836
	With DG	1559.8	1335.7	649.2	884.0	8136.1	5923.3	5521.6
Net savings ($)		1083.9	1863.5	909.3	1269.7	11863.9	5099.7	8314.4
Cost of P_{DG}($)		40686	30512	10238	10281.1	72444	41583	31346
Cost of Q_{DG} ($)		8591.8	6444.3	2161.8	2017.5	15297	8781.4	6618.5

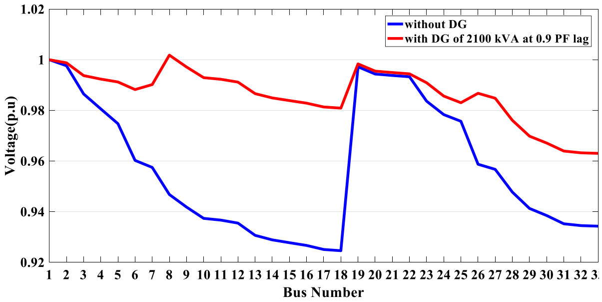

Fig.10. 33 bus network voltage at 0.8 per unit load level without DG installation and with

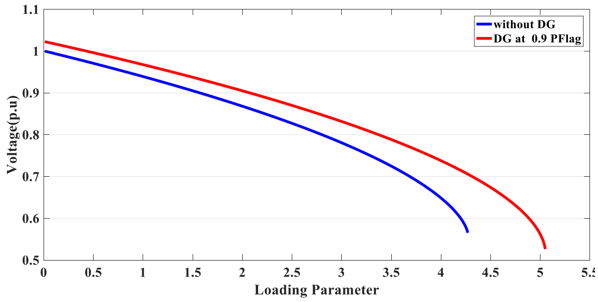

Fig.11. The effect of DG installation with 0.9 lag power factor on increasing the loading and network voltage stability

5.3. Dispatchable DG with optimal power factor

Given the importance of reactive power in minimizing losses and improving voltage profiles, the optimal DG power factor is very important. To minimize losses, $P_{DG} = P_{Load}$ must be true [27]. The optimum power factor for the 33-bus network is 0.85 lag. **Table.IV** shows results with the installation of DG with an optimal power factor. Examination of the results shows that, like installing DG with a unit power factor and 0.9 lag, in this case, bus 33 has a minimum voltage for different load levels. **Fig.12** shows the minimum network voltage profile for 24 hours. **Table.IV** shows that for the load level of 0.8 per unit, the optimal DG size is 2114.4 kVA, and **Fig.13** shows its effect on the voltage profile compared to the without DG mode. In the following, to investigate the effect of DG installation with optimal power factor on increasing voltage stability margin, the P-V diagram for Bus 30 at 0.8 load level in **Fig.14** is shown. The maximum load factor, in this case, is 5.06, and it is 5.05 in the case of results with a power factor of 0.9 lag, which are close to each other.

The results in **Table.IV** show the annual reduction in the cost of active power losses with the installation of DG. Before the installation of DG, the annual cost of active power losses was $ 55,134, and with the installation of DG, it reached $ 23,455 and decreased by $ 31,679. Active power losses for DG mode with unit power factor, DG with 0.9 lag power factor, and also DG with optimal power factor are shown in **Fig.15**. Examining **Fig.15** shows the effect of reactive power on reducing active power losses and highlights the importance of optimal power factor.

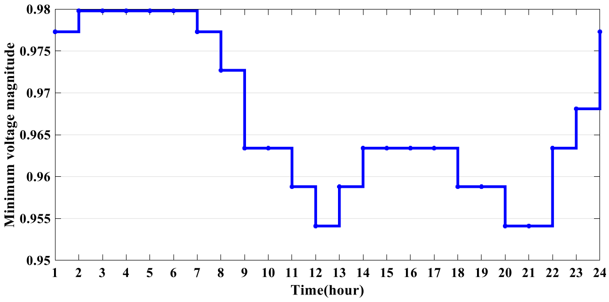

Fig.12. Minimum voltage measurement for average daily load by installing DG with optimal power factor

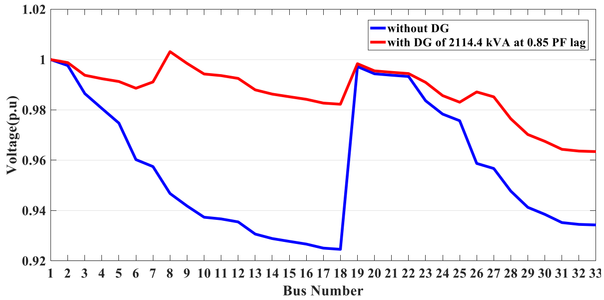

Fig.13. 33 bus voltage at 0.8 per unit load level without DG installation and with DG installation

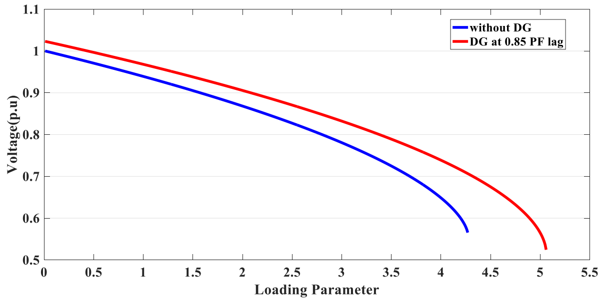

Fig. 14. The effect of DG installation with 0.85 lag power factor on increasing the loading and network voltage stability

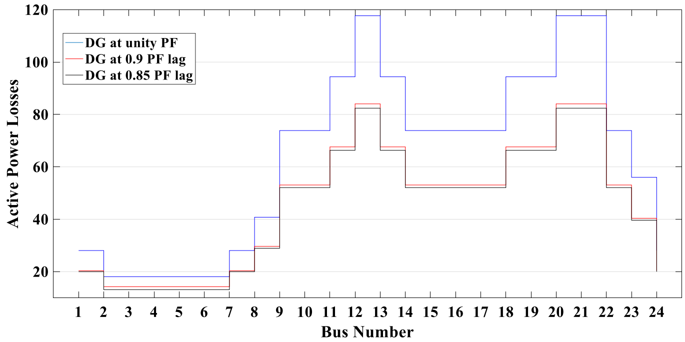

Fig.15. Active power losses for different power coefficients

Table.IV. Results for DG operating at 0.85 power factor lag

		Load Level						
Items		0.4	0.5	0.6	0.7	0.8	0.9	1
DG location bus		8	8	8	8	8	8	8
DG size in kVA		1748.2	2081.3	2091.1	2104.2	2114.4	2125.3	2137.8
Active power losses(kw)	**Without DG**	30.7186	48.6947	71.1646	98.3433	130.4654	167.7864	210.5861
	With DG	13.118	19.9619	28.9237	39.6151	52.0697	66.3219	82.4072
Reactive power losses(kVAr)	**Without DG**	20.8229	33.0170	48.2656	66.7177	88.5355	113.8963	142.9942
	With DG	9.2789	14.7799	21.4317	29.3902	38.6618	49.2859	61.3060
Minimum voltage (Bus)		0.9798 (33)	0.9773 (33)	0.9727 (33)	0.9681 (33)	0.9634 (33)	0.9588 (33)	0.9541 (33)
Cost of energy losses ($)	**Without DG**	3363.7	3199.2	1558.5	2153.7	20000	11023	13836
	With DG	1436.4	1311.5	633.4	867.5	7982.3	5809.8	5414.2
Net savings ($)		1927.3	1887.7	925.1	1286.2	12017.7	52013.2	8421.8
Cost of P_{DG} ($)		40686	29062	9732.9	9793.9	68889	29676	29851
Cost of Q_{DG} ($)		13285	6326.2	3178	3197.9	22494	12920	9746.8

5.4. Comparison of results with other available methods

In this section, for validation of the proposed method, its results are compared with IV, VSI, and VSI methods. A comparison of the results for the 33-bus network at level 1 and the installation of DG with a power factor of 0.9 lag is shown in **Table.V**. Examining the results of the proper performance of the proposed method in selecting the location and optimal size of DG and therefore shows the reduction of losses and improvement of the voltage profile.

Table.V. Comparison of results with DG at 0.9 PF lag for 33 bus system

Items	IV method[24]	VSI method[26]	VSI method[11]	Proposed method
DG location bus	30	16	33	8
DG size in kVA	1950	1200	1570.8	2120.2
Active power losses(k)	78.4	112.8	96.6	84.04
Reactive power losses(kVAr)	58.9	77.4	77.26	62.11
Minimum voltage(p.u)	0.9391	0.9378	0.9322	0.9535

6. Conclusion

In this paper, a new method is proposed to locate and determine the optimal dispatchable DG size. The average hourly load demand during the day is considered as the load profile. A new voltage stability index is provided to determine the optimal location for DG installation. The voltage stability index, obtained using the voltage collapse feature of power systems, has determined the appropriate location of the DG installation based on the analysis of the impact of DG installation on improving the voltage stability of the distribution network. Then, the optimal DG size for 24 hours a day, and different load levels are determined by the search algorithm to reduce active power losses. Optimal DG placement and dispatch has been performed for different load levels and three types of DG with a single "power" coefficient, 0.9 lag power factor, and optimal power factor.

In this paper, the proposed method is tested on the IEEE 33 bus network, and its results are analyzed. The use of the proposed method for optimal DG placement and dispatch for different hours of the day and different load levels on the IEEE 33 bus network has improved voltage profiles and voltage stability margins, as well as minimizing active power losses and costs. The proposed method for load levels of 1 per unit and DG with a power factor of 0.9 lag has been compared and validated with IV, VSI, and CPLS methods. A comparison of the obtained results shows the effectiveness of the proposed method in locating and determining the optimal DG size to reduce active power losses and improve voltage profiles. In general, it can be concluded that the proposed method is suitable for the deployment of dispatchable DG for optimal operation of distribution networks with stable performance.

In future work, in addition to power losses and voltage profile improvements, the reliability of the distribution system can also be considered.

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