ISSN 2278-3083
Volume 9, No.3, May – June 2020
International Journal of Science and Applied Information Technology
Available Online at http://www.warse.org/ijsait/static/pdf/file/ijsait01932020.pdf
https://doi.org/10.30534/ijsait/2019/01932020

Optimal Location of Distributed Generation Photovoltaic (DGPV) for Total Loss Minimization

Abdul Fattah Abdul Mazed[1], Nurzanariah Roslan[2], Karmila Kamil[3], Sharifah AzwaShaaya[4]
[1]Department of Electrical and Electronics Engineering, College of Engineering, Universiti Tenaga Nasional, Malaysia, fattahlyon@gmail.com
[2]Department of Electrical and Electronics Engineering, College of Engineering, Universiti Tenaga Nasional, Malaysia, nurzanariah@uniten.edu.my
[3]Department of Electrical and Electronics Engineering, College of Engineering, Universiti Tenaga Nasional, Malaysia, karmila@uniten.edu.my
[4]Department of Electrical and Electronics Engineering, College of Engineering, Universiti Tenaga Nasional, Malaysia, shazwa@uniten.edu.my

ABSTRACT

This paper presents the application of two types of Evolutionary Programming (EP) technique which are Original Evolutionary Programming (OEP) and Modified Evolutionary Programming (MEP). The performance of these two techniques was observed in this study. Two cases have been introduced while solving the optimal DGPV installation problem. It is found that OEP and MEP have successfully resolved the problem by providing the same solution. However, compared to the non-optimal solution, both techniques managed to reduce the total real power loss by more than 60 %.

Key words : Distributed generation installation, photovoltaic, Evolutionary Programming, optimization.

1. INTRODUCTION

In recent years, an upturn in power demand has led to the restructuring of the energy system by many researchers. Distributed Generations (DGs) are in favour of many to be installed in a power system based on its high efficiency and environmentally cleaner power output. This is important to take care of, as the Earth is at risk with negative environmental impacts, such as overuse of oil and coal [1]. With the installation of DGs, the environmental damage problem can be reduced while at the same time providing power support. Renewable sources of energy must therefore be seen as a substitute for fossil fuels[2].

However, the decision to install the DGs is not based solely on its cleaner environmental impact. It was discussed in[3]that the DG Units provide a wide range of choices between cost and reliability. DG units are found to be easier to install on a smaller site, which means that they only need a short amount of time during the installation process. The possibility of bringing DGs closer to the customer has resulted in a reduction in the costs of transmission and distribution. As a result, the risks of facilities considered to be low among investors.

Many advantages are derived from the installation of DGs in power systems, such as increased voltage support, efficiency and reliability[4]. Besides that, emission, cost of electricity and system energy losses are also reduced. However, there are few important issues and challenges that need to be addressed when installing DGs in the system. Below are the issues and challenges of the installation of DGs:

A. Optimal Location

Many techniques can be used to achieve various objectives, such as the optimal location of DGs. However, the optimal locations of DGs achieved by the techniques are only applicable to a system that does not change. With the system growing over the years, where load requirements may increase in many different areas, the optimal locations of the DGs will no longer be the same.

B. Power Quality

Power quality issues vary between the different types of DGs used. A large single DG, such as a wind turbine, often causes a great deal of power quality problems in a weak network system. The wind turbine requires a large number of power electronic devices, which could lead to many problems with the power quality.

C. Commercial Issues

Development needs to be as persuasive as possible of the benefits it can achieve. Contracts for companies supported in connecting DGs for future rewards are very important[4]. As mentioned in [5],for the problems in China when installing DGs, long-term load stability is not guaranteed and this is a concern for the business and the economy. With several lack of awareness of the maintenance of DGs facilities, where efficiency may decrease and a lack of professional guidance may lead to a risky investment.

With regard to non-renewable sources which are declining and the risk of not being able to supply demand for future expansion of the power system, consideration is given to risk options and problems. Critical and detailed solutions are needed to avoid problems when installing DGs on the network.

Malaysia has considered the implementation of Distributed Generation Photovoltaic (DGPV) in the next few years. DGPV is not only known for its renewable energy sources, but also for its carbon-free generation of electricity[6]. As set out in the Low Carbon Society Blueprint for Iskandar Malaysia 2025, the DGPV system is one of the recommendations for sustainable and clean energy generation technologies in the energy system[7]. With an increase in population, technological and economic progress, demand for electricity and consumption have also increased. It requires investment and alternative sources of demand to be met, as the supply of non-renewable environmental resources is becoming shorter[8]. There are several benefits gained from the installation of the DGPV in the systems, such as loss reduction, reduced environmental impacts, peak shaving, and increased overall energy efficiency[9].

By simply installing the DGPV, it does not provide an optimum solution. There are other key factors, such as the size and location of DGPV when installing it in the system. By identifying the optimum location and size, major problems can be avoided, such as a drop in power quality, unbalanced demand for supply under fault conditions, increased power losses and a decrease in reliability[3]. It is important to note that oversizing of DGPV may lead to problems such as an increase in power losses where there is a possibility of more power losses than in the system[10].

In order to obtain an optimum location and size of the DGPV in the system tested, various forms of optimization techniques may be used. This paper proposed the use of two types of Evolutionary Programming (EP) techniques, the original EP and the modified EP. EP is a popular optimization technique used to solve various power system optimization problems. In addition to solving the problem of the DG installation, this paper also examines the performance of these two EP techniques. These two EP techniques (OEP and MEP) have been found to have successfully resolved the DG installation problem by producing a similar solution. The solution produced by OEP and MEP are much better than the non-optimal solution (load flow solution).

2. METHODOLOGY

Two types of Evolutionary Programming (EP) techniques are used to achieve the optimum installation of DGPV units, which are Original Evolutionary Programming (OEP) and Modified Evolutionary Programming (MEP). Three DGPV units are optimally installed in the IEEE 30-bus Reliability Test System (RTS) using OEP and MEP. The size of DGs is fixed at specified values in [11]. However, the EP algorithms will find the optimal size of 3 DGPV units in this paper. The sizes of the 3 DG units are randomly generated between 5MW and 150MW.

With different types of buses present in the IEEE 30-Bus RTS, it is important to identify which type of bus is suitable for the installation of the DGPV units. As stated in [11], DGPV units may be installed in PQ buses or may also be referred to as load buses. PV buses, which are generator buses, are excluded when searching for optimal locations. Busses 2, 5, 8, 11 and 13 are PV buses which are excluded from the search.

The generators' power output shall not exceed their maximum limit together with the output voltage of the DGPV units[12]. It can cause a real loss of power in the PV system and damage to low voltage electronic equipment[13].

Using the IEEE 30-bus RTS, a loading case will be performed by increasing the load on the weakest bus[14]. When the reactive load at the weakest bus is increased, it is expected that the optimum location of the DGPV units will be injected closer to the consumer, which in this case is the weakest bus, in order to achieve better quality of service[15].

The objective of this optimization process is to minimize the total real power loss of the power system. The total real power loss is calculated using (1).

$$P_{loss} = \sum_{k=1}^{l} g_k[V_i^2 + V_j^2 - 2V_iV_j cos(\delta_i - \delta_j)], \quad k \in \{1,2,\dots,l\} \tag{1}$$

Where:
g_k is the conductance of k^{th} line,
V_i and δ_i are the voltage magnitude and angle of bus i, respectively,
V_j and δ_j are the voltage magnitude and angle of bus j, respectively, and
l is the number of lines in the system.

General EP algorithm is shown in Figure 1. The processes in EP algorithm are as follows:

A. Step 1: Initialization

First, this step will initialize the population of 20 individuals. The population contains control variables which are the locations and sizes of the DGPV units generated randomly on the basis of their limits. The population is known as the parent population.

B. Step 2: Mutation

The parent population is mutated through a Gaussian mutation process that resulted in another 20 new individuals named the offspring. The new individuals are then used to calculate a new fitness value, which is the total real power loss. Equation (2) is the Gaussian mutation equation used to generate the offspring population.

$$x_{i+m,j} = x_{i,j} + N\left(0, \beta(x_{j,max} - x_{j,min}\left(\frac{f_i}{f_{max}}\right)\right) \qquad (2)$$

Where;
$x_{i+m,j}$ is mutated parent (offspring),
$x_{i,j}$ is parents,
N is Gaussian random variable with mean, μ and variance, γ^2,
β is mutation scale/step size,
$x_{j,max}$ is maximum random number for every variable,
$x_{j,min}$ is minimum random number for every variable,
f_i is fitness for the i^{th} random number, and
f_{max} is maximum fitness

C. Step 3: Combination

The parent and offspring populations are combined to make up a population of the size of 40. Subsequently, this big population will undergo the selection process.

D. Step 4: Selection

By observing the fitness values, the best 20 individuals will be selected by selecting individuals with lower fitness values. This means selecting the lowest total real power loss.

E. Step 5: Convergence Test

To check whether the algorithm has converged, a stop criterion is established that the difference in fitness values between the first and the twentieth must be equal to or less than 0.0001. If the criterion is met, the optimization process will end as the optimal solution has already been found.

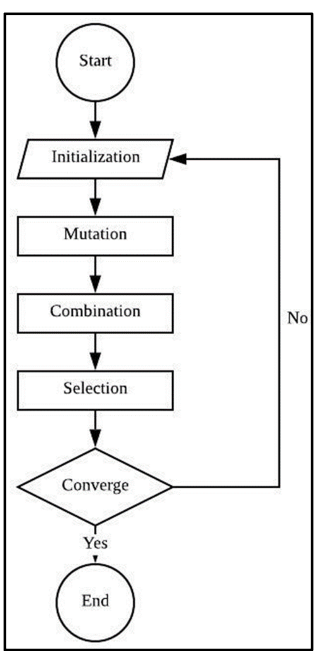

Figure 1: General flow chart of EP

As mentioned previously, two types of EP are used to solve the optimal DG installation problem with the aim of minimizing total real power loss. It begins with the OEP, followed by the MEP. The initial value of β, which is the step size in the Gaussian mutation, is fixed at 0.0005 in the OEP. While the value of β is randomized in the MEP.

As stated in[16], if the step size is small, there will be a very small improvement if offspring individuals. However, if the step size is too large, it may exceed the minimum and the chance of improvement will be extremely small. The optimum step size is between the small values. As for this paper, the value of β is randomized from 0 to 0.00009.

There are 2 cases for each EP algorithm, which are base case and loaded case. The base case is where there are no changes to the IEEE 30-Bus RTS loads. Total real power loss are observed with the locations and sizes of the 3 DG units obtained.

For the loaded case, there are 3 conditions under which the reactive power load will be added to the weakest bus in the system. The weakest bus was identified by reference to the study conducted in[17], and the weakest bus in the IEEE 30-Bus RTS is bus 30. Initially, the reactive load at bus 30 is 1.9 MVAR. As for the loading conditions, the reactive loads to be added are 10 MVAR, 20 MVAR and 30 MVAR. The new reactive load of bus 30 is therefore 10.9 MVAR, 20.9 MVAR and 30.9 MVAR respectively.

3. RESULTS AND DISCUSSION

It is important to find the optimal location and size of the DGPV system in order to minimize the total real power loss. In this paper, 3 DGPV units were installed in the IEEE 30-Bus RTS with the aim of minimizing total real power loss using OEP and MEP. The capacity of the three DGPV units is shown in Table 1. The three DGPV units were optimally installed on the load buses, excluding generator buses. This section discusses the results of optimal installation of DGPV units using OEP and MEP and comparison between them.

Table 1: Lower and upper limits of DGPV units

	Capacity (MW)	
DG units	Lower Limit	Upper Limit
DG1	5	150
DG2	5	150
DG3	5	150

3.1 Results of Optimal Installation of DGPV Units using OEP

For this type of EP technique, the value of β is fixed at 0.00005 in the mutation process.

A. Base Case

Starting with the base case, where there is no change to the system data. Table 2 shows the 10 runs of the original OEP algorithm to solve the optimal DGPV installation problem. The locations of *DG1*, *DG2* and *DG3* for all runs are bus 12, bus 9 and bus 7 with the corresponding sizes of 87.89 MW, 121.35 MW and 9.79 MW. The total real power loss for all the 10 runs is 5.49 MW.

Table 2: Result for base case(OEP) for 10 runs

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	***DG2***	***DG3***	***DG1***	***DG2***	***DG3***	
1	12	9	7	87.89	121.35	9.79	5.49
2	12	9	7	87.89	121.35	9.79	5.49
3	12	9	7	87.89	121.35	9.79	5.49
4	12	9	7	87.89	121.35	9.79	5.49
5	12	9	7	87.89	121.35	9.79	5.49
6	12	9	7	87.89	121.35	9.79	5.49
7	12	9	7	87.89	121.35	9.79	5.49
8	12	9	7	87.89	121.35	9.79	5.49
9	12	9	7	87.89	121.35	9.79	5.49
10	12	9	7	87.89	121.35	9.79	5.49

B. Loaded Case

1. <u>10 MVAR added to the weakest bus</u>

For this loaded case, 10 MVAR has been added to the load at bus 30, where the new reactive power value is 11.9 MVAR. Again, 10 runs were performed on the OEP algorithm to solve the optimal DGPV installation problem. The results for this condition is tabulated in Table 3. For all 10 runs, the locations of *DG1*, *DG2* and *DG3* are on buses 12, 9 and 7 with the sizes of 87.89 MW, 121.35 MW and 9.79 MW, respectively. The total real power loss is 6.05 MW, the majority of which was observed. Total real power loss is higher in this case due to higher reactive power when 10 MVAR were added to the weakest bus.

2. <u>20 MVAR added to the weakest bus</u>

Table 4 shows the results for loaded case (20 MVAR added to the weakest bus). Similar to the first loaded case, 10 runs were carried out on the OEP algorithm to solve the optimum installation problem of DGPV. For all 10 runs, OEP consistently gives locations of *DG1*, *DG2* and *DG3* at buses 22, 4 and 28, respectively. The sizes of the three DGPV units are 44.54 MW, 68.28 MW and 116.14 MW, respectively. The total real power loss, with a majority of 7.56 MW, is observed. The total real power loss is higher than the previous cases due to higher reactive power loaded at the weakest bus.

Table 3: Result for loaded case (10 MVAR added to the weakest bus) for 10 runs -OEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	***DG2***	***DG3***	***DG1***	***DG2***	***DG3***	
1	12	9	7	87.89	121.35	9.79	6.05
2	12	9	7	87.89	121.35	9.79	6.05
3	12	9	7	87.89	121.35	9.79	6.05
4	12	9	7	87.89	121.35	9.79	6.05
5	12	9	7	87.89	121.35	9.79	6.05
6	12	9	7	87.89	121.35	9.79	6.05
7	12	9	7	87.89	121.35	9.79	6.05
8	12	9	7	87.89	121.35	9.79	6.05
9	12	9	7	87.89	121.35	9.79	6.05
10	12	9	7	87.89	121.35	9.79	6.05

Table 4: Result for loaded case (20 MVAR added to the weakest bus) for 10 runs - OEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	***DG2***	***DG3***	***DG1***	***DG2***	***DG3***	
1	22	4	28	44.54	68.28	116.14	7.56
2	22	4	28	44.54	68.28	116.14	7.56
3	22	4	28	44.54	68.28	116.14	7.56
4	22	4	28	44.54	68.28	116.14	7.56
5	22	4	28	44.54	68.28	116.14	7.56
6	22	4	28	44.54	68.28	116.14	7.56
7	22	4	28	44.54	68.28	116.14	7.56
8	22	4	28	44.54	68.28	116.14	7.56
9	22	4	28	44.54	68.28	116.14	7.56
10	22	4	28	44.54	68.28	116.14	7.56

3. <u>30 MVAR added to the weakest bus</u>

For the last condition of the loaded case, 30 MVAR has been added to the load at bus 30, where the new reactive power value is 31.9 MVAR. The results for this 10-run condition are shown in Table 5. For all 10 runs, the locations of *DG1*, *DG2* and *DG3* are at buses 30, 7 and 9 with corresponding sizes of 51.29 MW, 96.24 MW and 23.37 MW. The total real power loss is 8.08 MW for all 10 runs. The total real power loss is observed to be the highest compares to the two loaded conditions.

Table 5: Result for loaded case (30 MVAR added to the weakest bus) for 10 runs - OEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	*DG2*	*DG3*	*DG1*	*DG2*	*DG3*	
1	30	7	9	51.29	96.24	23.37	8.08
2	30	7	9	51.29	96.24	23.37	8.08
3	30	7	9	51.29	96.24	23.37	8.08
4	30	7	9	51.29	96.24	23.37	8.08
5	30	7	9	51.29	96.24	23.37	8.08
6	30	7	9	51.29	96.24	23.37	8.08
7	30	7	9	51.29	96.24	23.37	8.08
8	30	7	9	51.29	96.24	23.37	8.08
9	30	7	9	51.29	96.24	23.37	8.08
10	30	7	9	51.29	96.24	23.37	8.08

3.2Results of Optimal Installation of DGPV Units using Modified EP (MEP)

For this MEP, the value of β is randomized between 0 and 0.00009. Changes in location and size of the DGPV units are observed in MEP while solving the problem of DGPV installation with two cases: base case and loaded case.

A. Base Case

Similar to OEP, for MEP, it starts with the base case where there is no modification of the system data. Table 6 shows the 10 runs of the MEP algorithm to solve the optimal DGPV installation problem. The locations of *DG1*, *DG2* and *DG3* for all runs are buses 12, 9 and 7 with the sizes of 87.89 MW, 121.35 MW and 9.79 MW, respectively. The total real power loss obtained is 5.49 MW.

B. Loaded Case

1. 10 MVAR added to the weakest bus

Figure 7 shows the results for loaded case (10 MVAR added to the weakest bus) for 10 runs solved using MEP. For this loaded case, 10 MVAR has been added to the load at bus 30, where the new reactive power value is 11.9 MVAR. Again, 10 runs were carried out on the MEP algorithm to solve the optimal DGPV installation problem. For all 10 runs, the locations of *DG1*, *DG2* and *DG3* are buses 12, 9 and 7 with the corresponding sizes of 87.89 MW, 121.35 MW and 9.79 MW. The total real power loss obtained by MEP is 6.05 MW.

Table 6: Result for Base Case(MEP) after 10 runs

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	*DG2*	*DG3*	*DG1*	*DG2*	*DG3*	
1	12	9	7	87.89	121.35	9.79	5.49
2	12	9	7	87.89	121.35	9.79	5.49
3	12	9	7	87.89	121.35	9.79	5.49
4	12	9	7	87.89	121.35	9.79	5.49
5	12	9	7	87.89	121.35	9.79	5.49
6	12	9	7	87.89	121.35	9.79	5.49
7	12	9	7	87.89	121.35	9.79	5.49
8	12	9	7	87.89	121.35	9.79	5.49
9	12	9	7	87.89	121.35	9.79	5.49
10	12	9	7	87.89	121.35	9.79	5.49

Table 7: Result for loaded case (10 MVAR added to the weakest bus) for 10 runs - MEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	DG2	DG3	DG1	DG2	DG3	
1	12	9	7	87.89	121.35	9.79	6.05
2	12	9	7	87.89	121.35	9.79	6.05
3	12	9	7	87.89	121.35	9.79	6.05
4	12	9	7	87.89	121.35	9.79	6.05
5	12	9	7	87.89	121.35	9.79	6.05
6	12	9	7	87.89	121.35	9.79	6.05
7	12	9	7	87.89	121.35	9.79	6.05
8	12	9	7	87.89	121.35	9.79	6.05
9	12	9	7	87.89	121.35	9.79	6.05
10	12	9	7	87.89	121.35	9.79	6.05

2. 20 MVAR added to the weakest bus

For this loaded case, 20 MVAR has been added to the load at bus 30, where the new reactive power value is 21.9 MVAR. The results for this condition can be seen in Table 8. 10 runs were carried out on the MEP algorithm. For all 10 runs, the locations of *DG1*, *DG2* and *DG3* are at buses 22, 4 and 28 with the sizes of 44.54 MW, 68.28 MW and 116.13 MW, respectively. The total real power loss of 7.56 MW is observed for all 10 runs. Total real power loss is higher for this condition compared to 10 MVAR loaded case.

3. 30 MVAR added to the weakest bus

Finally, for this loaded case, 30 MVAR has been added to the load at bus 30. 10 runs were carried out on the MEP algorithm to solve the optimal DGPV installation problem as shown in Table 9. The locations of *DG1*, *DG2* and *DG3*that found by MEP for this condition are buses 30, 7 and 9 with corresponding sizes of 51.29 MW, 96.24 MW and 23.37 MW. The total real power loss minimized by MEP is 8.08 MW for all 10 runs. The total real power loss is the highest in this case due to the highest reactive power added to the weakest bus.

Table 8: Result for loaded case (20 MVAR added to the weakest bus) for 10 runs - MEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	DG2	DG3	DG1	DG2	DG3	
1	22	4	28	44.54	68.28	116.13	7.56
2	22	4	28	44.54	68.28	116.13	7.56
3	22	4	28	44.54	68.28	116.13	7.56
4	22	4	28	44.54	68.28	116.13	7.56
5	22	4	28	44.54	68.28	116.13	7.56
6	22	4	28	44.54	68.28	116.13	7.56
7	22	4	28	44.54	68.28	116.13	7.56
8	22	4	28	44.54	68.28	116.13	7.56
9	22	4	28	44.54	68.28	116.13	7.56
10	22	4	28	44.54	68.28	116.13	7.56

Table 9: Result for loaded case (30 MVAR added to the weakest bus) for 10 runs - MEP

No of Runs	DG Location (Bus Number)			DG Size (MW)			Total Real Power Loss (MW)
	DG1	DG2	DG3	DG1	DG2	DG3	
1	30	7	9	51.29	96.24	23.37	8.08
2	30	7	9	51.29	96.24	23.37	8.08
3	30	7	9	51.29	96.24	23.37	8.08
4	30	7	9	51.29	96.24	23.37	8.08
5	30	7	9	51.29	96.24	23.37	8.08
6	30	7	9	51.29	96.24	23.37	8.08
7	30	7	9	51.29	96.24	23.37	8.08
8	30	7	9	51.29	96.24	23.37	8.08
9	30	7	9	51.29	96.24	23.37	8.08
10	30	7	9	51.29	96.24	23.37	8.08

3.3Comparison Between OEP and MEP

Two different types of EP were used to solve the optimal DGPV installation problem in the IEEE 30-Bus RTS. For the both EP techniques, there were 2 cases introduced with 10 runs each. The results showed different types of results for their location and size of DGPV units when different reactive loads were added to the weakest bus. As noted in both OEP and MEP, total real power loss produced is the same. This may be due to the small step size difference as indicated in [16].

In Table 10, a comparison is made between the non-optimal solution and the optimal solution (OEP and MEP) for their total real power loss. Non-optimal solution is a condition in which no optimization technique has been applied. The total real power loss is extracted from the load flow solution without involving any optimization process. The load flow is carried out through the bus data, where the guides can be followed in[18]. Using optimization techniques, that is, the OEP and the MEP, where the total real power loss between the two are the same. It can be noted that the total real power loss has decreased by more than 60% in all cases and conditions as compared to the non-optimal solution.

Table 10: Results comparison between non-optimal solution, OEP ad MEP

Case		Total Real Power Loss (MW)			Percentage Decrease (%)
		Non-Optimal Solution (Load Flow)	Original EP	Modified EP	
Base Case		17.6	5.49	5.49	68.81
Loaded Case	10 MVAR	18.35	6.05	6.05	66.98
	20 MVAR	20.28	7.56	7.56	62.72
	30 MVAR	26.06	8.08	8.08	68.99

4. CONCLUSION

Two types of Evolutionary Programming (EP) techniques have been applied to the IEEE 30-Bus RTS. Both the Original Evolutionary Programming (OEP) and the Modified Evolutionary Programming (MEP) have achieved the optimal location and size of the DGPV units in the IEEE 30-Bus RTS. Thus, both algorithms have shown a significant decrease in total real power loss.

With the given techniques presented in this paper, a hybrid technique can be introduced in applying the Multiple-Objective Immune Evolutionary Programming (MOIEP) along with a Distributionally Robust Reactive Power Optimization Model in the future to give better solution. MOICEP has the capability to solve the optimization problem with multiple objectives such as emission minimization and voltage stability improvement.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Universiti Tenaga Nasional (UNITEN)for the financial support of this project. This research is supported by UNITEN under the UNITEN Internal Research Grant (UNIIG2018)with project code: J510050629

REFERENCES

1. O. M. Toledo, D. Oliveira Filho, and A. S. A. C. Diniz.**Distributed photovoltaic generation and energy storage systems: A review**, *Renew. Sustain. Energy Rev.*, vol. 14, no. 1, pp. 506–511, 2010.
2. S. Wang, S. Chen, L. Ge, and L. Wu.**Distributed Generation Hosting Capacity Evaluation for Distribution Systems Considering the Robust Optimal Operation of OLTC and SVC**, *IEEE Trans. Sustain. Energy*, vol. 7, no. 3, pp. 1111–1123, 2016.
3. M. R. Aghaebrahimi, M. Amiri, and S. H. Zahiri.**An immune-based optimization method for distributed generation placement in order to minimize power losses**, *2009 Int. Conf. Sustain. Power Gener. Supply*, pp. 1–6, 2009.
4. S. Singh, J. Østergaard, and N. Jain.**Distributed generation in power Systems: An overview and key issues**, in *24th Indian Engineering Congress, NIT Surathkal, Kerala*, 2009, no. January, p. 8.
5. H. Yu, B. Hong, W. Luan, B. Huang, Y. K. Semero, and A. T. Eseye.**Study on business models of distributed generation in China**, *Glob. Energy Interconnect.*, vol. 1, no. 2, pp. 162–171, 2018.
6. M. H. Alham, M. Elshahed, D. K. Ibrahim, and E. E. D. Abo El Zahab.**A dynamic economic emission dispatch considering wind power uncertainty incorporating energy storage system and demand side management**, *Renew. Energy*, vol. 96, pp. 800–811, 2016.
7. M. H. Mansor, I. Musirin, M. M. Othman, S. A. Shaaya, and S. A. S. Mustaffa.**Application of Immune Log-Normal Evolutionary Programming in Distributed Generation Installation**, *Indones. J. Electr. Eng. Comput. Sci.*, vol. 6, no. 3, pp. 730–736, 2017.
8 T. B. Garlet, J. L. D. Ribeiro, F. de Souza Savian, and J. C. Mairesse Siluk.**Paths and barriers to the diffusion of distributed generation of photovoltaic energy in southern Brazil**, *Renew. Sustain. Energy Rev.*, vol. 111, no. October 2018, pp. 157–169, 2019.
9. P. Chiradeja.**Benefit of distributed generation: A line loss reduction analysis**,*Proc. IEEE Power Eng. Soc. Transm. Distrib. Conf.*, vol. 2005, pp. 1–5, 2005.
10. M. Jamil and A. S. Anees.**Optimal sizing and location of SPV (solar photovoltaic) based MLDG (multiple location distributed generator) in distribution system for loss reduction, voltage profile improvement with economical benefits**, *Energy*, vol. 103, pp. 231–239, 2016.
11. S. A. S. Mustaffa, I. Musirin, M. M. Othman, and N. H. Rosli.**Multi DGPV installation in transmission system for loss minimization**, *2017 4th Int. Conf. Ind. Eng. Appl. ICIEA 2017*, no. October, pp. 350–354, 2017.
12. W. Ongsakul and D. Vo Ngoc.***Artificial Intelligence in Power System Optimization***, CRC Press, 2013.
13. R. Albarracin and M. Alonso.**Photovoltaic reactive power limits**, *12th Int. Conf. Environ. Electr. Eng. EEEIC 2013*, pp. 13–18, 2013.
14. M. Amroune, A. Bourzami, and T. Bouktir.**Weakest Buses Identification and Ranking in Large Power Transmission Network by Optimal Location of Reactive Power Supports**, *TELKOMNIKA Indones. J. Electr. Eng.*, vol. 12, no. 10, pp. 7123–7130, 2014.
15. S. A. Shaaya, I. Musirin, S. I. Sulaiman, and M. H. Mansor.**Immunized-Evolutionary Algorithm Based Technique for Loss Control in Transmission System with Multi- Load Increment**, *Indones. J. Electr. Eng. Comput. Sci.*, vol. 6, no. 3, pp. 737–748, 2017.
16. M. A. Schumer and K. Steiglitz.**Adaptive Step Size Random Search**, *IEEE Trans. Automat. Contr.*, vol. 13, no. 3, pp. 270–276, 1968.
17. M. Pesaran H.A, P. D. Huy, and V. K. Ramachandaramurthy.**A review of the optimal allocation of distributed generation: Objectives, constraints, methods, and algorithms**,*Renew. Sustain. Energy Rev.*, no. October, pp. 1–20, 2016.
18. H. Saadat.***Power System Analysis 3rd Edition***, PSA Publishing, 2010.