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Optimal DG Allocation based New Approach of Voltage Stability Index and Genetic Algorithm

SAYED MIR SHAH DANISH[1*], HASHMATULLAH ZEERAK[2], MOHAMAD AMIN AMIN[3] & ABDULLELAH RASOOLI[4]

[1]Electrical Power Engineering Department, Kabul Polytechnic University, 5th District, Kabul-Afghanistan.
Email: sayedmir.danish@gmail.com

[2]Electrical Power Engineering Department, Kabul Polytechnic University, 5th District, Kabul-Afghanistan.
Email: hashmat.zeerakf@gmail.com

[3]Electrical Power Engineering Department, Kabul Polytechnic University, 5th District, Kabul-Afghanistan.
Email: aminsharif.amin2@gmail.com

[4]Electrical Power Engineering Department, Kabul Polytechnic University, 5th District, Kabul-Afghanistan.
Email: abrasooli.kpu@gmail.com

Abstract

Electrical distribution networks often face energy losses, voltage instability, lack of capacity and problems in energy transmission. Distributed generation (DG) in optimal and appropriate locations in power grids as a desirable solution can significantly boost the reliability and stability of the mentioned system by reducing energy loss and improving voltage stability. The rise of global environmental concerns and the significant reduction of fossil fuels, especially in the last few decades, have necessitated using and integrating renewable energy-based generation in power systems to meet the increasing electrical energy demand. Meanwhile, another challenge is to determine the optimal location and exact size of renewable generators in the distribution network, which is important from the view of technical and economic standpoints. In this paper, a usable and adaptable approach using the new voltage stability index (VSI) method and genetic algorithm (GA) weighting factors-based is proposed for the optimal size and location of DGs in medium and large distribution networks. The objective function is adapted to enhance the overall system voltage stability, minimize power loss, and to achieve significant improvement in distribution network operation. The proposed methodology is tested on medium and large scale IEEE test systems (34-bus and 69-bus). The simulation results obtained in this research are compared with previously performed methodologies and it is a clear proof of the efficiency and superiority of the proposed algorithm.

Keywords: Distributed generation, Genetic algorithm, Network loss reduction, Voltage profile improvement, Voltage stability index.

* Corresponding Author

1. Introduction

Among the stages of the electric energy division, the power distribution network is the final stage in the delivery of electric power, which connects the transmission system to individual consumers. Main features such as low voltage and high current of distribution systems, lead to high power losses compared to the transmission systems. On the other hand, the problem of voltage drop may arise when using radial feeders, especially at long distances. Therefore, considering this problem and finding a desirable solution for this problem becomes crucial.

Distributed generation (DG) renewable energy-based has been considered as a reasonable solution to the environmental challenges caused by conventional power plants. Renewable energy-based DG as a clean and harmless energy is the best alternative to fossil fuel consumption that minimizes harmful carbon emissions. Meanwhile, the use of green energy also causes the reduction of energy losses in electrical networks, for this reason, this process rapidly expanded all over the world in recent years [1]. The installation of DG has significant impacts on system operations and the expansion of existing networks is possible by integrating DG renewable based [2]. Among many scientific researchers that have ascertained and implemented these benefits are the authors in [3] who discuss the technical and economic benefits, and different active and reactive power control strategies for grid-connected photovoltaic (PV) systems in Germany. These strategies effectively control the voltage rise in the presence of high local PV connection and hence allow additional capacity to be connected to the main supply. Static phenomena, including grid operation improvement, voltage drop issues, and power loss at high levels of grid-connected PV were analyzed in [4]. A new adaptive optimization method for DG placement and solving related problems to minimize power losses and stay voltage within the standard and statutory range is proposed in [5]. In [6] authors have examined the integration of renewable energy sources in European power systems along with the benefits, shortcomings, challenges, solutions, and overall possible and practical solutions for power system operation. Similarly, there are many studies and investigations that testify significant effects of renewable energy integration on distribution network improvement. It is noteworthy that the integration of renewable energy boosts energy level and makes electrical networks more stable, on the other hand, it reduces greenhouse-gases and minimizes global concerns regarding environmental issues.

Since optimal placement and size of DG allocation is a complex combinatorial optimization problem, several methods and methodologies were proposed in the recent years. Authors in [7] proposed the Whale Optimization Algorithm (WOA) for solving multi objectives, active power loss minimization and voltage profile enhancement. Particle Swarm Optimization algorithm (PSO) is handled in [8] for multi DGs assignment in distribution network with the objective of loss reduction. By using this methodology, the DGs have been moved to suitable and desirable places, and it has shown its beneficial effects in reducing electrical energy losses. Authors in [9] proposed a new method using Harmony Search Algorithm (HSA) with differential operators for optimal placement of DG in distribution networks with the objective of reducing active power losses and improving voltage characteristics. Differential evolution algorithm is used to find the optimal size and placement of DG considering total real power loss and improve the

voltage profile within the framework of system operation and security constraints [10]. A methodology is reported for optimal size and locating of DGs in [11] to improve voltage stability and minimize the losses all over the network simultaneously. In this approach, vulnerable buses are determined using the bifurcation analysis as the best locations to locate the DG, and the required size of DG is defined through employ the dynamic programming search method.
However, mentioned methodologies reflect good results, but most of them could not contribute effective and efficient due to the luck of Hosting Capacity (HC) consideration [12]. Moreover, some methods considering restrictions and constraints imposed does not predicate the required DG size. The lack of DG required size prevents the acceptable reduction of system losses, which itself indicates the problem of a methodology. Hence, maintaining stable operation and reliable power system supply requires an effective methodology of optimal size and location of DGs.

1.1. Contribution and paper organization

Manifestly, the effective integration of DGs in distribution systems relies on their optimal size and location, and their better performance lies in their accurate selection. This paper provides a new Voltage Stability Index (VSI) that able to predicate the optimal DGs location based on renewable energy in radial distribution systems. Genetic Algorithm (GA) is used to determine the optimal size of DG for voltage deviation control and loss reduction purposes.
The main contribution of this article will be presented as follows:

i. To propose new VSI for optimal DG placement (vulnerable bus prediction)
ii. Using Genetic Algorithm (GA) for optimal DG size
iii. Optimizing objective function with respect to reducing power loss and voltage deviation
iv. The importance of dealing with voltage improvements and loss reduction considering weight factors
v. Application of the proposed method in medium and large systems to show its validation

The rest of this paper is organized as follows. Section *II* illustrates methodology including voltage stability index, objective function and application of optimization technique. In section *III*, the simulation results and discussion are presented. Finally, this paper closes with a brief conclusion in section *IV*.

2. Methodology

2.1. Voltage Stability Index (VSI) for optimal DG placement

The schematic model in (Figure 1) shows the desired concept for deriving the VSI mathematical model: as shown, the source and load are placed on both sides, respectively. To extract the mathematical model of the voltage stability index, we proceed as follows:

I_{12} is the branch current that is presented as follows:

$$I_{12} = \left[\frac{P_2 + jQ_2}{V_2 \angle \delta}\right]^* \quad (1)$$

The voltage at the end bus for consumers:

$$V_2\angle\delta = V_1\angle 0 - (R + jX)I_{12} \quad (2)$$

Substituting Equation (1) within Equation (2), can simplify as follows:

$$V_2\angle\delta = V_1\angle 0 - (R + jX)\left[\frac{P_2 + jQ_2}{V_2\angle\delta}\right]^* \quad (3)$$

$$\left\{V_2\angle\delta = V_1\angle 0 - (R + jX)\left[\frac{P_2 - jQ_2}{V_2\angle -\delta}\right]\right\}\ (V_2\angle -\delta) \quad (4)$$

$$V_2{}^2 = V_1V_2\angle -\delta - (R + jX)(P_2 - jQ_2) \quad (5)$$

$$V_2{}^2 = V_1V_2cos\delta - jV_1V_2sin\delta - (R + jX)(P_2 - jQ_2) \quad (6)$$

$$V_2{}^2 + P_2R + Q_2X + j(P_2X - Q_2R) = V_1V_2cos\delta - jV_1V_2sin\delta \quad (7)$$

The delta (δ), which describes the phase difference between voltage and electric current, is due to the impedance contained therein. Meantime, δ change at any time has simultaneous impact on the active and imaginary parts. Delta variation (δ<0, δ=0 or δ>0) changes both parts at the same time, hence, δ is assumed to be zero to obtain the simple form of the final index.

Now in Equation (7) calculated the real and imaginary parts for the value δ=0:

Real part:

$$V_2{}^2 + P_2R + Q_2X = V_1V_2cos\delta, \text{for } \delta = 0, V_2{}^2 + P_2R + Q_2X = V_1V_2 \quad (8)$$

Imaginary part:

$$P_2X - Q_2R = -jV_1V_2\ sin\delta, \text{for } \delta = 0, P_2X - Q_2R = 0, R = \frac{P_2X}{Q_2} \quad (9)$$

Equation (9) can be substituted within Equation (8):

$$V_2{}^2 + P_2\frac{P_2X}{Q_2} + Q_2X = V_1V_2 \quad (10)$$

$$V_2{}^2 - V_1V_2 + \left(\frac{P_2^2}{Q_2} + Q_2\right)X = 0 \quad (11)$$

$$\mathrm{ax}^2 + \mathrm{bx} + \mathrm{c} = 0 \quad (12)$$

Equation (11) has the form of a quadratic equation (12), as such;

$\mathrm{a} = 1$, $\mathrm{b} = -V_1$ and $\mathrm{c} = \left(\frac{P_2^2}{Q_2} + Q_2\right)X$.

Evidently, for stable bus voltages $b^2 - 4ac \geq 0$, hence VSI is defined as Equation (16):

$$b^2 - 4ac \geq 0 \quad (13)$$

$$V_1^2 - 4\left(\frac{P_2^2}{Q_2} + Q_2\right)X \geq 0 \quad (14)$$

$$1 \geq \frac{4X}{V_1^2}\left(\frac{P_2^2}{Q_2} + Q_2\right) \quad (15)$$

$$VSI = \frac{4X}{V_1^2}\left(\frac{P_2^2}{Q_2} + Q_2\right) \leq 1 \quad (16)$$

A closer look reveals that VSI reports three conditions as follows: (*i*) normal operating conditions when VSI is less than one, (*ii*) higher stability when VSI is close to zero, (*iii*) higher instability and vulnerability when the VSI is a high value. With this logic, the DG should target the bus with high VSI values.

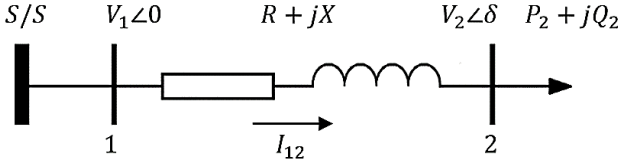


Figure 1: Simple radial distribution system.

2.2. Objective function

The selection of the objective function is a serious and important matter to obtain the desired results through the optimization process, and it will essentially affect the performance of optimization behavior. Therefore, it should be attentively selected based on the network condition. In this study, the objective function considered as power loss and voltage improvement. The allocation of DG in the distribution network must satisfy two main tasks: firstly, to minimize power losses, and secondly to place the system's overall voltage profile within statutory limits. Therefore, the required size of the DG placed on the vulnerable bus should have beneficial effects on the voltage deviation (VD) and active power loss (PL). These demands are introduced to the MATLAB program using an objective function, and MATLAB performs the simulation in accordance with the objective function, and as a result, presents the best and most effective results for the electrical network in the form of tables and figures. In order to determine the optimum DG size, the following function is optimized:

$$Minimize\ F(P_{DG}) = w_1 \times \frac{VD_{DG}}{VD_{BC}} + w_2 \times \frac{PL_{DG}}{PL_{BC}} \quad (17)$$

where F represents the weighted objective function; VD_{BC} and PL_{BC} express voltage deviation and power losses at baseline case (without DGs); w_1 and w_2 illustrate weighting factors for voltage deviation and power losses, respectively; VD_{DG} and PL_{DG} explain voltage deviation and power losses as function of P_{DG}, respectively.

Along with objectives of loss reduction and voltage improvement, various simulated cases provide an analysis that assesses the importance of voltage regulation and loss reduction as weight factors. Weight factors enable the optimization tool to contribute proportionally to the importance and adjustment of weight factor values in reducing

energy loss and improving voltage profile.
To achieve this goal, the following three different weight factors will be considered in the simulation:

i. The weighting factors are equal.
ii. The weighting factor for power loss is lower than the voltage deviation factor.
iii. The weighting factor for power loss is higher than the voltage deviation index.

Equations (18-20) illustrate the mathematical representation of these objectives:

$$w_1 + w_2 = 1 \tag{18}$$

$$VD = \sum_1^N (V_i - 1)^2 \tag{19}$$

$$PL = \sum_{k=1}^{NB} real[Z_K * I_k^2] \tag{20}$$

where VD, V_i, N, PL, NB, Z_K and I_k are the voltage deviation index, voltage at i^{th} bus, bus number, power losses, brunch number, *K* brunch's impedance and *K* brunch's current, respectively.

The constraints are considered as follows:

$$V_{min} \leq V_i \leq V_{max} \tag{21}$$

$$P_{sub} + \sum P_{DG} = P_{load} + P_{loss} \tag{22}$$

$$Q_{sub} + \sum Q_{DG} = Q_{load} + Q_{loss} \tag{23}$$

$$P_{DG_{min}} \leq P_{DG_i} \leq P_{DG_{max}} \tag{24}$$

$$Q_{DG_{min}} \leq Q_{DG_i} \leq Q_{DG_{max}} \tag{25}$$

2.3. Application of optimization technique and power flow analysis

Genetic Algorithm (GA) is a well-known method for solving optimization problems involving constrained and unconstrained parameters [13] - [15]. In this article, it is used as optimization technique to obtain the optimal and required sizes of DGs in distribution networks. The Newton Raphson power flow is selected to conduct the load flow and to determine the influence of DG's on the network [16]. To analyze the power flow, the distribution network is considered a steady-state model. Comprehensively, the flowchart in (Figure 2) shows the different stages of the proposed method (VSI and GA).

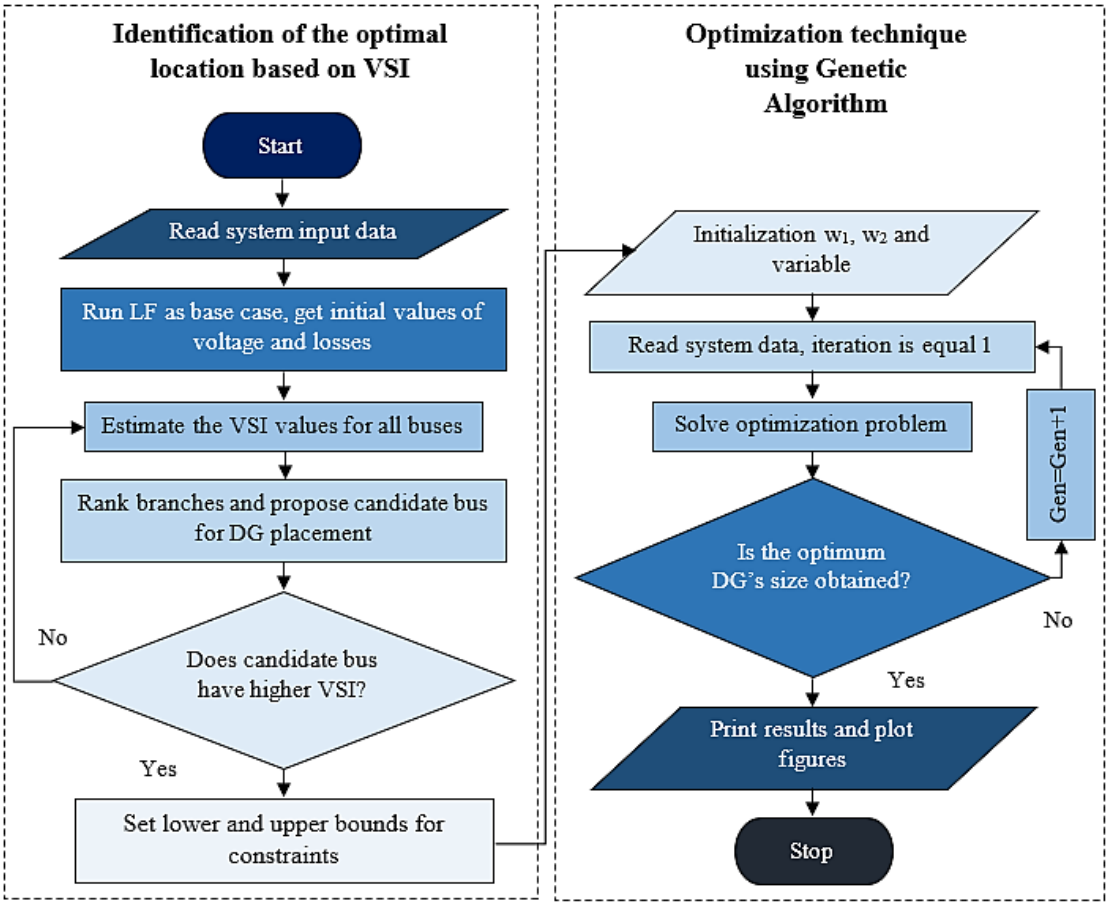


Figure 2: Flowchart of optimal DG allocation and genetic algorithm.

Algorithm steps:

Step 1: Get system bus and line data, and run load flow as baseline case.

Step 2: Calculate the VSI profile for all buses (Equation 16).

Step 3: Rank the branches and identify candidate buses with high VSI for DG placement.

Step 4: Does the candidate bus have higher VSI?

No; Repeat steps 2 and 4.

Yes; Go to step 5.

Step 5: Set constraints; and initialize w_1, w_2 and variables for genetic algorithm.

Step 6: Run GA to solve the optimization problem (Equation 17).

Step 7: Is the optimum DG's size achieved?

No; Repeat steps 6 (GA calculates new generation in next iteration).

Yes; Go to step 8.

Step 8: Print results and plot figures.

3. Simulation results and discussion

The proposed algorithm is implemented in the MATLAB environment and for better comparison with previous methods, DGs optimal size and location have been obtained through the mentioned algorithm in test systems (IEEE 34-bus and IEEE 69-bus). For both systems, considering various values of w_1 and w_2, and to show how GA can achieve optimal DG size and improve system efficiency according to required DG integration, four cases are presented below:

i. **Baseline Case:** In this case, without DG the technical parameters of distribution networks such as voltage profile and power losses are estimated.

ii. **Case 1:** In this case, equality is considered between the weight factors (i.e., w_1=0.5, w_2=0.5).

iii. **Case 2:** In this case, the weighting factors are different, as the power loss factor is lower than the voltage index (i.e. w_1=0.8, w_2=0.2).

iv. **Case 3:** In this case, the weighting factors are different too, as the power loss factor is higher than the voltage index (i.e. w_1=0.2, w_2=0.8).

To validate the proposed method, it is compared with the results of other classical methods such as Cuckoo Search Optimization (CSA) [17], Imperialistic Competitive Algorithm (ICA) [18], Ant Colony Search Algorithm (ACSA) [19] and Whale Optimization Algorithms (WOA) [20].

3.1. IEEE 34-Bus test system

This test system has a main feeder and 4 lateral feeders, which can be seen in (Figure 3). load data and related line parameters are acquired from [21], that the active and reactive loads of this network are 4636.5 kW and 2873.5 kVAr, respectively.

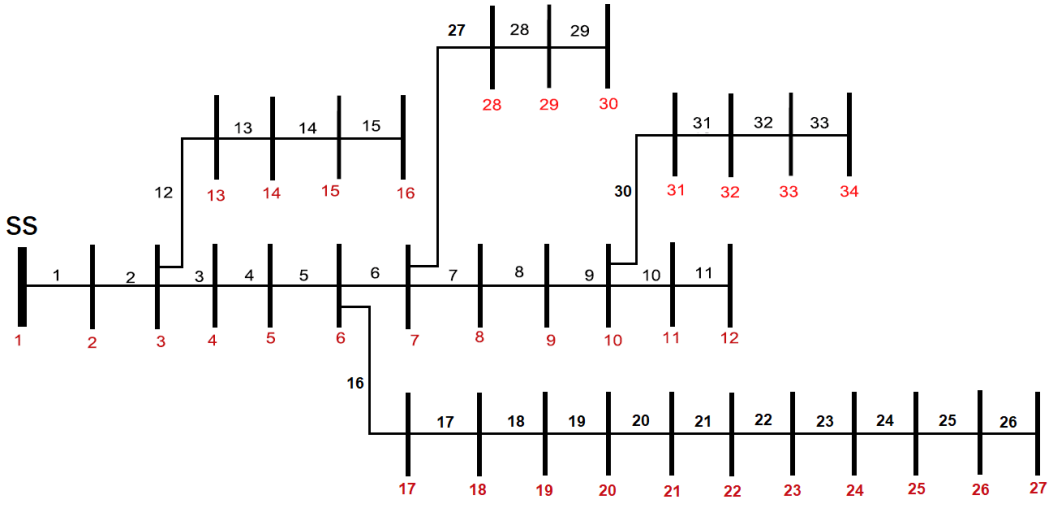


Figure 3: IEEE 34-bus distribution system [21].

Based on equation (16) VSI calculated for all buses. (Figure 4) shows the voltage stability index for the IEEE 34-bus network, where buses number 8 and 23 with the highest VSI can be select as candidate buses for optimal DG allocation.

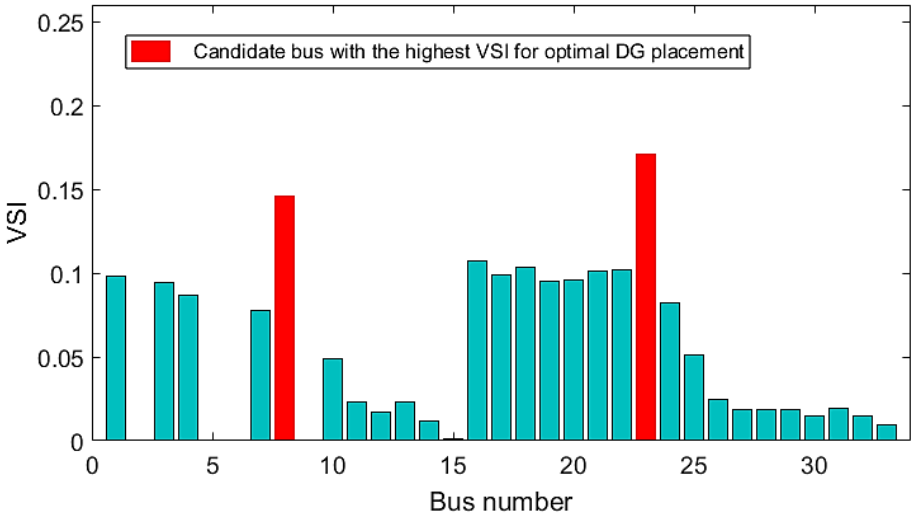


Figure 4: VSI profile for IEEE 34-bus distribution network.

After organizing the data and initial parameters of all buses and lines, imposing restrictions, and inaugurating the relation within the objective function and the decision variables regarding DG number and size, the MATLAB program has implemented the GA optimization technique. (Table 1) shows the comprehensive simulation results for IEEE 34-bus.

Table 1: Comprehensive simulation results for IEEE 34-bus.

	Baseline case	Case 1	Case 2	Case 3
Weighting factor: w_1, w_2	-	w_1=0.5, w_2=0.5	w_1=0.8, w_2=0.2	w_1=0.2, w_2=0.8
Number of Installed DGs	-	2	2	2
P_{DG} in MW (location)	-	1.737(8) & 1.740(23)	1.135(8) & 1.305(23)	1.738(8) & 1.817(23)
Q_{DG} in MVAr (location)	-	1.064(8) & 1.127(23)	0.639(8) & 0.775(23)	1.067(8) & 1.147(23)
Daily real power loss (MW)	0.2208	0.0198	0.0402	0.0194
Stored power (MW)	-	0.2010	0.1806	0.2014
Reactive power loss (MVAr)	0.0655	0.0045	0.0119	0.0042
Stored power (MVAr)	-	0.0610	0.0536	0.0613
Peak minimum voltage (pu)	0.9484	1.0018	0.9874	1.0034
Voltage rise (%)	-	5.6305	4.1122	5.7992

The voltage profile for all buses before and after DG integration is illustrated in (Figure 5). At the baseline case, the minimum voltage is 0.9484 pu. For Case 1 (weighting factors are equal), the overall voltage profile improves to the acceptable limit. By integrating DG (1.737+j1.064 & 1.740+j1.127) MVA, the minimum voltage increases from 0.9484 pu to 1.0018 pu which shows 5.6305% rise (Table 1). In case 2 with different weighting factor (losses weighting factor is lower than the voltage index), the voltage increased from 0.9484 pu to 0.9874 pu with smaller DG size integration (1.135+j0.639 & 1.305+j0.775) MVA. In case 3, where the coefficients are also different (the losses weighting factor is higher than the voltage index), the optimal DG size is higher than the other cases, hence, it improves the voltage more and greatly reduces the power loss. The voltage profile for case 3 shows that the bus with minimum voltage increased from 0.9484 pu to 1.0034 pu, a change of 5.7992%.

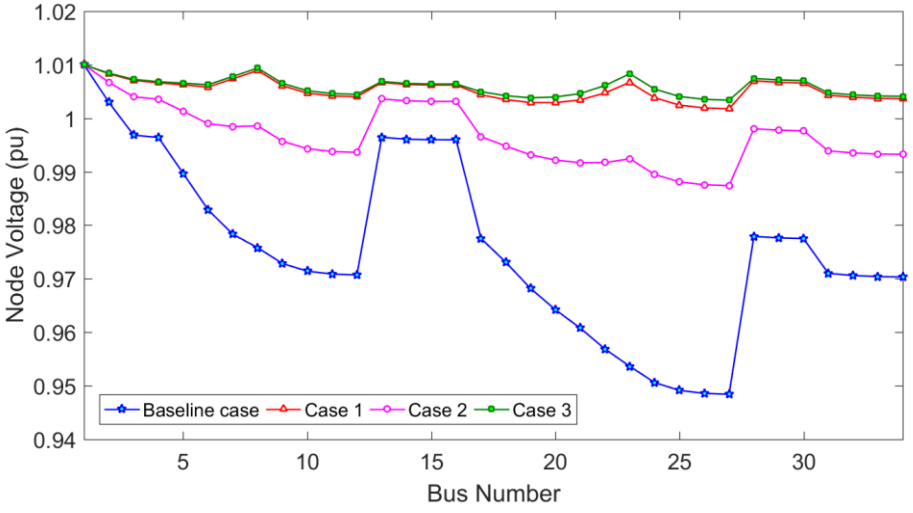


Figure 5: IEEE 34-bus voltage profile before and after DG integration.

As illustrated in (Table 1), integrating DGs in this test system caused to store the power by (0.201+j0.061) MVA, (0.1806+j0.0536) MVA and (0.2014+j0.0613) MVA for Case 1, Case 2 and Case 3, respectively. After comparing the cases for the 34-bus system, it is clear that the best-case scenario is case 1 (equal weighting factors); The optimal DG size has effectively improved the voltage profile and significantly reduced the line losses.
The results of proposed approach using VSI and GA are compared with classical methods such as Cuckoo Search Optimization (CSA) [17], Imperialistic Competitive Algorithm (ICA) [18] and Ant Colony Search Algorithm (ACSA) [19], and shown in (Table 2). Undeniably, the proposed approach serves maximum loss reduction with (0.201+j0.061) MVA of stored power, and indicates a significant reduction in power loss compared to other methods. Meantime, this method has been able to provide high values of DGs for the network. As high integration of renewable energy causes problems such as Hosting Capacity (HC), voltage deviation and so on, the proposed optimization algorithm with respect to the objective function (voltage fluctuation is a major part) offers the optimal DG size. As shown in voltage profile in (Figure 5), DG size obtained for different cases are in accordance with operating standards and there is no problem with HC. It is noteworthy, comparison of different methods result proves better voltage improvement for the proposed method (Table 2).

Table 2: Comparison of different methods results for the IEEE 34-bus system.

Points of comparison	Without DG (Baseline case)	With DG			
		ACSA [19]	ICA [18]	CSA [17]	Proposed method (Case 1)
P_{DG} in MW (location)	-	0.1(9), 0.25(18), 0.3(22) & 0.5(27)	2.999(27)	2.328(23)	1.737(8) & 1.740(23)
Q_{DG} in MVAr (location)	-	0.05(9), 0.1(18), 0.15(22) & 0.2(27)	1.821(27)	NA	1.064(8) & 1.127(23)
V_{min} (pu)	0.9484	0.9668	0.981	0.9740	1.0018
Voltage rise (%)	-	1.9401	3.4374	2.6992	5.6305
P_{TLoss} (MW)	0.2208	0.1937	0.0489	0.0984	0.0198
Stored power (MW)	-	0.0271	0.1719	0.1224	0.2010
Q_{TLoss} (MVAr)	0.0655	NA	0.0113	NA	0.0045
Stored power (MVAr)	-	NA	0.0542	NA	0.0610

3.2. IEEE 69-Bus test system

The system includes 69 buses, 7 laterals, and 68 branches represented in (Figure 6). The data for this network is acquired from [22]. Total active and reactive power loads are 3.801 kW and 2.695 kVAr, respectively, with rated voltage of 12.66 kV. (Figure 7) shows the voltage stability index for the IEEE 69-bus network, with buses 9, 48, and 59 having the highest VSI. Hence, mentioned buses are selected as candidate buses for optimal DG placement.

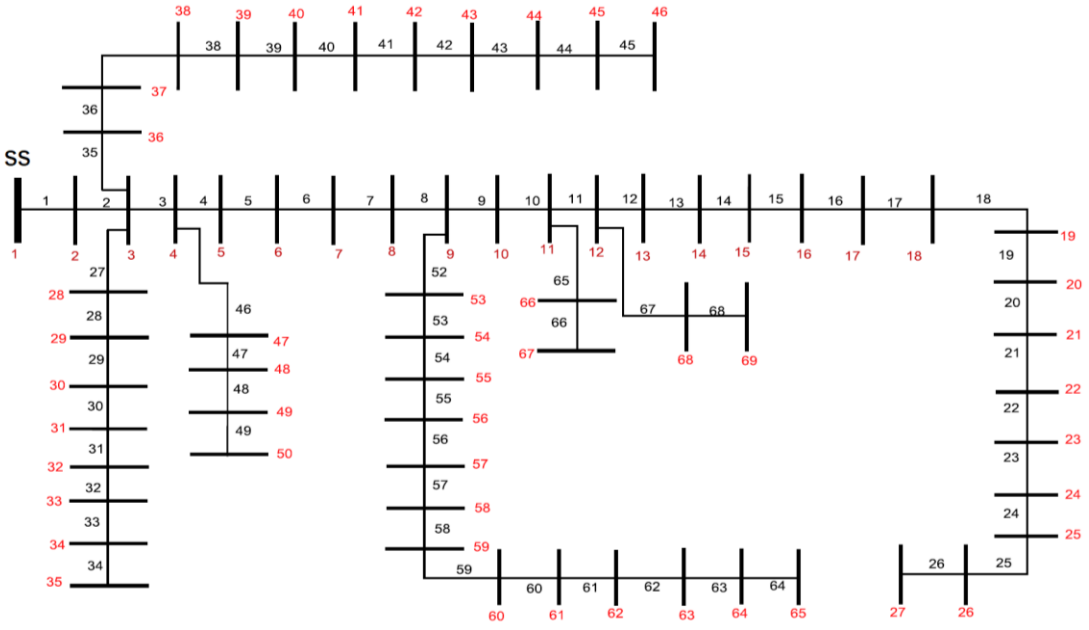


Figure 6: IEEE 69-bus distribution system [22].

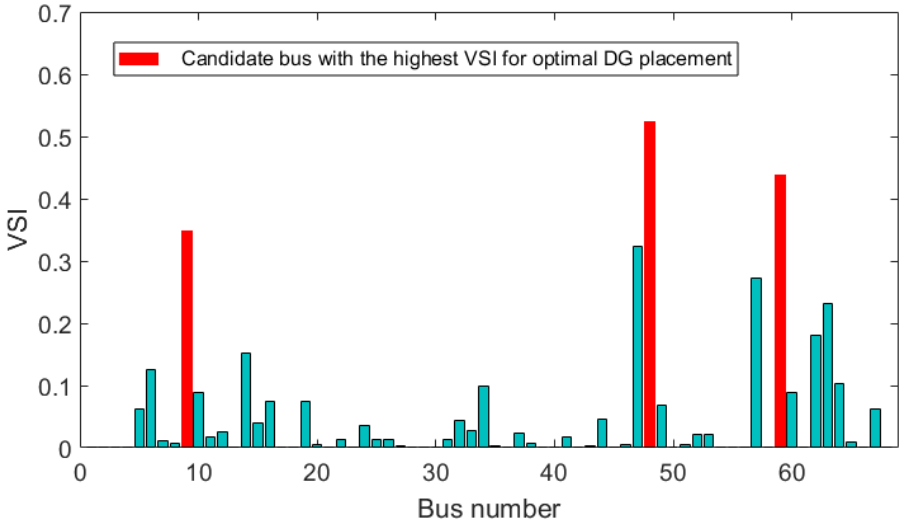


Figure 7: VSI profile for IEEE 69-bus distribution network.

After organizing the data for all buses and lines, and performing the simulation, the comprehensive results for IEEE 69-bus are illustrated in (Table 3). The voltage profile for various cases is shown in (Figure 8). As shown in (Table 3) and (Figure 8), the integration of DGs in this test network shows significant improvement in voltage profile for all three cases.

Table 3: Comprehensive simulation results for IEEE 69-bus.

	Baseline case	Case 1	Case 2	Case 3
Weighting factor: w_1, w_2	-	w_1=0.5, w_2=0.5	w_1=0.8, w_2=0.2	w_1=0.2, w_2=0.8
Number of Installed DGs	-	3	3	3
P_{DG} in MW (location)	-	1.471(9), 0.819(48) & 1.705(59)	1.593(9), 0.622(48) & 1.405(59)	1.178(9), 0.819(48) & 1.708(59)
Q_{DG} in MVAr (location)	-	0.937(9), 0.615(48) & 1.208(59)	1.043(9), 0.428(48) & 0.921(59)	0.782(9), 0.599(48) & 1.208(59)
Daily real power loss (MW)	0.3480	0.0362	0.0406	0.0340
Stored power (MW)		0.3118	0.3074	0.3140
Reactive power loss (MVAr)	0.1518	0.0142	0.0157	0.0130
Stored power (MVAr)		0.1376	0.1361	0.1388
Peak minimum voltage (pu)	0.8832	0.9945	0.9918	0.9910
Voltage rise (%)	-	12.602	12.2962	12.206

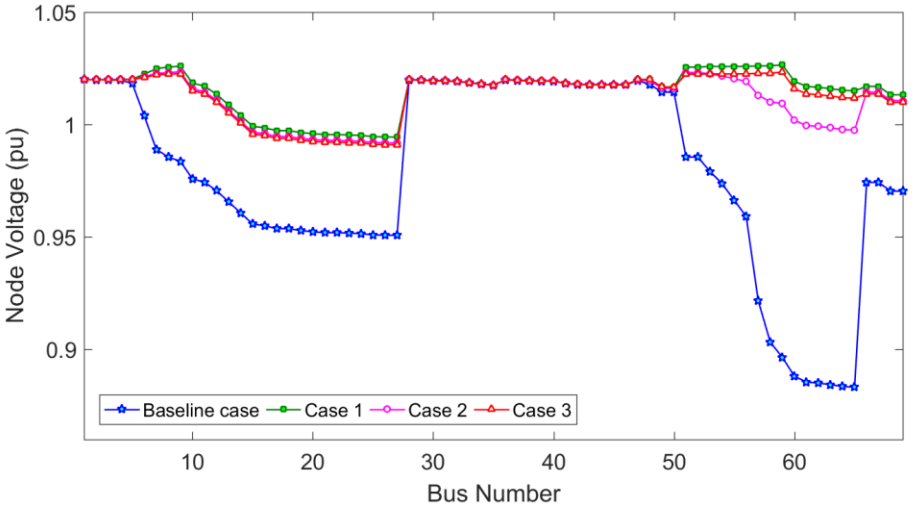


Figure 8: IEEE 69-bus voltage profile before and after DG integration.

In Case 1 (weighting factors are equal) by integrating DGs (1.471+j0.937, 0.819+j0,615

& 1.705+j1.208) MVA the minimum voltage increases from 0.8832 pu to 0.9945 pu which shows 12.602% rise. In case 2 (losses weighting factor is lower than the voltage index), the minimum voltage is improved from 0.8832 pu to 0.9918 pu, which integrated DGs sizes are (1.593+j1.043, 0.622+j0,428 & 1.405+j0.921) MVA. For Case 3 the voltage profile denotes that the voltage has been increased from 0.8832 pu to 0.991 pu, a change of 12.206%. As is illustrated in (Table 3), due to the integration of DGs in the network, active power loss reduction represents (0.3118+j0.1376, 0.3074+j0.1361 & 0.314+j0.1388) MVA of the stored power for case 1, case 2, and case 3, respectively. The best-case scenario for IEEE 69-bus system is case 3. The optimal DG size has effectively been able to maintain voltage deviations within the statutory range and significantly reduce system losses.

(Table 4) compares the results of the proposed method using VSI and GA with other classical methods such as Cuckoo Search Optimization (CSA) [17], Imperialistic Competitive Algorithm (ICA) [18] and Whale Optimization Algorithms (WOA) [20]. In this test system, a significant power loss reduction is visible compared to other methods as well. The proposed method minimizes loss reduction with (0.3140+j0.1388) MVA of stored power. Since the direct effect of DGs integration on voltage profile improvement is indubitable, the integration of DGs in this test network could contribute significant improvement in voltage profile. As such, according to (Table 4), the values of voltage increase for the proposed approach and three other methods are 12.206%, 9.6241%, 10.111% and 9.7373%, respectively, that 12.206% voltage rise indicates the effectiveness and superiority of the proposed method.

Table 4: Comparison of different methods results for the IEEE 69-bus system.

Points of comparison	Without DG (Baseline case)	With DG			
		WOA [20]	ICA [18]	CSA [17]	Proposed method (Case 3)
P_{DG} in MW (location)	-	1.8728 (61)	1.8364 (65)	1.8727 (61)	1.178(9), 0.819(48) & 1.708(59)
Q_{DG} in MVAr (location)	-	NA	1.3047 (65)	NA	0.782(9), 0.599(48) & 1.208(59)
V_{min} (pu)	0.8832	0.9692	0.9725	0.9682	0.991
Voltage rise (%)	-	9.7373	10.111	9.6241	12.206
P_{TLoss} (MW)	0.348	0.0832	0.0423	0.0832	0.0340
Stored power (MW)	-	0.2648	0.3057	0.2648	0.3140
Q_{TLoss} (MVAr)	0.1518	0.0405	0.0144	NA	0.0130
Stored power (MVAr)	-	0.1113	0.1374	NA	0.1388

4. Conclusion

The main focus of this article is on the optimal DGs size and placement in distribution networks. And to meet this demand, an effective approach including Voltage Stability Index (VSI) and Genetic Algorithm (GA) is proposed. Simultaneously, to show the better capability and reliability of this method, several cases based on different weighting factors are also discussed. This proposed method has been applied on medium and large scale test systems in order to better comparison of this method's performance with other previous methods. The simulations carried out in the MATLAB environment prove that the nodes' low voltage problem is eliminated, so that the minimum voltage increases from 0.9484 pu to 1.0018 pu, which shows 5.6305% rise (IEEE 34-bus). The voltage profile for (IEEE 69-bus) shows that the minimum voltage has been increased from 0.8832 pu to 0.991 pu, a change of 12.206%. Meantime, the proposed methodology brings a significant energy loss reduction and allows the network to increase its storage capacity. Integrating DGs in IEEE 34-bus and IEEE 69-bus test systems caused to store the power by (0.201+j0.061) MVA and (0.314+j0.1388) MVA, respectively. The three simulated cases, regarding the weighting factors, provide an analysis that accurately predicts the importance of voltage regulation and loss reduction. The results indicate that this method can effectively identify the optimal location and required size of DG in the network, and reduce network problems caused by large energy losses and voltage instability.

Future Scope: Along with extension of this article as future work we will adapt the proposed methodology, using voltage stability index (VSI) and genetic algorithm (GA) for Afghanistan’s real networks. Moreover, including economic calculations for integrated DGs PV-base are another task. Hence, we will illustrate the proposed algorithm's effectiveness from technical and economic standpoints in real distribution systems.

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Authors Profile



Sayed Mir Shah Danish received his BSc in Electrical Power Engineering from Kabul Polytechnic University in 2012, and MSc in Electrical and Electronics Engineering from the University of the Ryukyus, Okinawa-Japan in 2020. From 2012 to date, He worked with various companies (VEC, ZTE, TTTA, etc.) as a Power Engineer, Senior Engineer, and Lecturer (full-time & part-time) for more than 8 years. He is currently working as a lecturer (Assistant Professor) in the Electrical Power Engineering Department, at Kabul Polytechnic University (KPU), Kabul-Afghanistan. His activities have been met with admiration and appreciation, Appreciation Certificates, Merit Certificates, and recently the University of the Ryukyus President Award in 2020 on his record. He has nearly 15 peer-reviewed publications and his research interests include Sustainable Energy Development, Renewable Energy Resources, Energy Storage Systems, and Smart Grid.



Hashmatullah Zeerak graduated and received his BSc in Electrical Power Engineering from Kabul Polytechnic University in 2014, and MSc in Electrical Power Engineering from the University of the University Technology Malaysia (UTM) in 2023. From 2014 to the present, He worked with many organizations (DABS, IARCSC, NEXA, etc.) as a power system protection designer engineer, senior engineer, and lecturer (full-time & part-time) for more than 6 years. He is currently working as a lecturer (Assistant Professor) in the Electrical Power Engineering Department, at Kabul Polytechnic University (KPU), Kabul-Afghanistan.



Mohammad Amin Amin received his BSc in Electrical Power Engineering from Kabul Polytechnic University (KPU) in 2008, and his MSc in Electric Power Systems from the University of Brighton in 2013. He has been an academic member of the Electrical Power Engineering Department, at KPU since 2008. He is a member of the External Peer Review team for Institutional Accreditation, Quality Assurance, and Accreditation Directorate (QAAD) Ministry of Higher Education. He has worked in several other positions such as Head of the Electrical Power Engineering Department, and Dean of the Electromechanics Faculty, at KPU. He has 7 peer-reviewed publications in national and international journals and conference proceedings. His research interests include; Electric Power Systems, Power Electronics, and Renewable Energy deployment.



Prof. Abdullelah Rasooli earned his BSc and MSc in Electrical Power Engineering from Kabul Polytechnic University (KPU) and currently serves as a professor in the Electrical Power Engineering Department. With over 36 years of experience, he has fulfilled various roles, including project guide, project consultant, Head of the Power Engineering Department, Manager of the KPU Press Center, and Managerial Director of the KPU academic journal, Science and Technology. He has authored more than 21 peer-reviewed publications, and his research focuses on energy, climate change, and power system planning.