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A Combined Approach to place Solar DGs in Distribution Network

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Abstract

Demand of energy is increased drastically in recent times. In other way fossil fuel availability is declined. So, it is important to connect the renewable energy sources in an optimum way in distribution network (DN) is required. This article presents a method to place solar distributed generators (DG) in DN. Also, a combined method of voltage stability index (VSI) and flower pollination algorithm (FPA) is utilized to solve above mentioned problem. Further, the main objective of this to reduce the losses and increase of VSI of the DN to maximum extent. Also, the method is tested on IEEE 118 bus system. Finally, various cases are considered for the analysis and significant findings are tabulated. From these findings the presented method shows its superiority in view of improving loss reduction and VSI of DN.

Keywords: Solar DG, Distribution Network, Voltage Stability, Flower Pollination Algorithm, Power loss

1.Introduction

Demand of energy is escalated very fast in last two decades. Due to these engineers simultaneously increases the generation to satisfies the demand. But, in opposite to this conventional source like coal, diesel is declined drastically. So, immediate attention is required to generate power using renewable sources. Also, environmental problem is a prominent issue in recent times. Finally, to fulfil these requirements power generation by solar and wind is the solution. But, power output from these sources is nature dependent. Also, a suitable methodology is required to generate the power and fulfil the requirement. So, integration of these sources to existing DN poses other problems such as increasing power loss, reducing quality and efficiency of the system [1].

Further, losses in DN is very high because of high R/X ratio. Also, integration of these sources in appropriate manner increases these further, but optimal integration of these sources gives positive results. Finally, placement of solar based DGs to DN reduces the losses to maximum extent. So, a suitable methodology is presented to solve solar DG placement problem (DGPP) in DN.

In the literature different authors solved this problem and producing promising results. In [2-3] authors solved DGPP using analytical approach with objective of loss reduction of DN. In

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[4] authors solved DGPP using numerical approaches. Next, authors solved the same problem using heuristic approaches. In [5] GA/PSO method is considered for solving DGPP in DN. Further, loss reduction is the primary objective. In [6] authors solved DGPP using SA method. In [7] authors solved DGPP using BSOA. Further, various types of DGs are taken in the analysis. In [8] authors considered BA for solving DGPP in DN. Further, various load models are taken for the analysis. In [9] authors solved DGPP using PSO. Further, in this paper various DGs like and solar and wind are considered for the placement. In [10] OKHA is considered for solving DGPP in DN. Also, different test systems are considered for the analysis. In [11] TLBO approach is considered for solving DGPP in DN. In [12] authors used different optimization techniques for solving PV placement problem in DN. In [13] authors solved DGPP using ALO. Further, different types of RESs are considered for the analysis. In [14] authors considered hybrid approach to solve DGPP in DN. Most of the authors solved DGPP using various approaches but they considered small scale system. This article proposes a technique of FPA and VSI to figure out solar DGPP in DN. Further, various cases are considered for the analysis. Finally, it is implemented on 118 bus system.

The rest of the paper is as follows: Formulation of problem with objectives is given in section 2. Locations of DGs using VSI is given in section 3. FPA for calculating DGs sizes are represented in section 4. In section 5 important findings of the manuscript is given. Finally, conclusion is explained in section 6.

2. Problem formulation

A suitable approach is presented to place solar DGPP in DN. Further, reduction of power loss and VSI to maximum extent.

2.1 Objective

In this article a prominent method is presented to minimize DN power loss. The formula for power loss is given by Eq. (1)

$$P_{DG,\mathrm{Tloss}} = \sum_{k=1}^{b} P_{DG,loss}(\mathrm{l},\mathrm{l}+1) \tag{1}$$

2.2 Constraints

Solar DG Constraint

$$P_{SDGT}^{\min} \le P_{DGT} \le P_{DGT}^{\max} \tag{2}$$

Voltage Constraint

$$\left|V_1 - V_l\right| \le \Delta V_{\max} \tag{3}$$

Power balance Constraint

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$$\sum_{l=2}^{m} P_{DG,l} \leq \sum_{l=2}^{m} P_l + \sum_{l=1}^{b} P_{lossl,l+1} \tag{4}$$

Thermal Constraint

$$\left|J_{l,l+1}\right| \leq \left|J_{l,l+1,\max}\right| \tag{5}$$

3. Solar DG location using VSI

VSI is the very important metric to assess the weak buses in a DN. Further, run the basic distribution load flow and calculate VSI and place the DGs where VSI is less. Finally, the formulae for VSI is calculated by [15].

$$VSI_l = |V_m|^4 - 4[P_l r_{lm} + Q_l x_{lm}]|V_m|^2 - 4[P_l x_{lm} - Q_l r_{lm}]^2 \tag{6}$$

The VSI of 118 bus is calculated and the same is represented in Fig.1. The buses with weak VSI are considered (Only 15% of total number of buses).

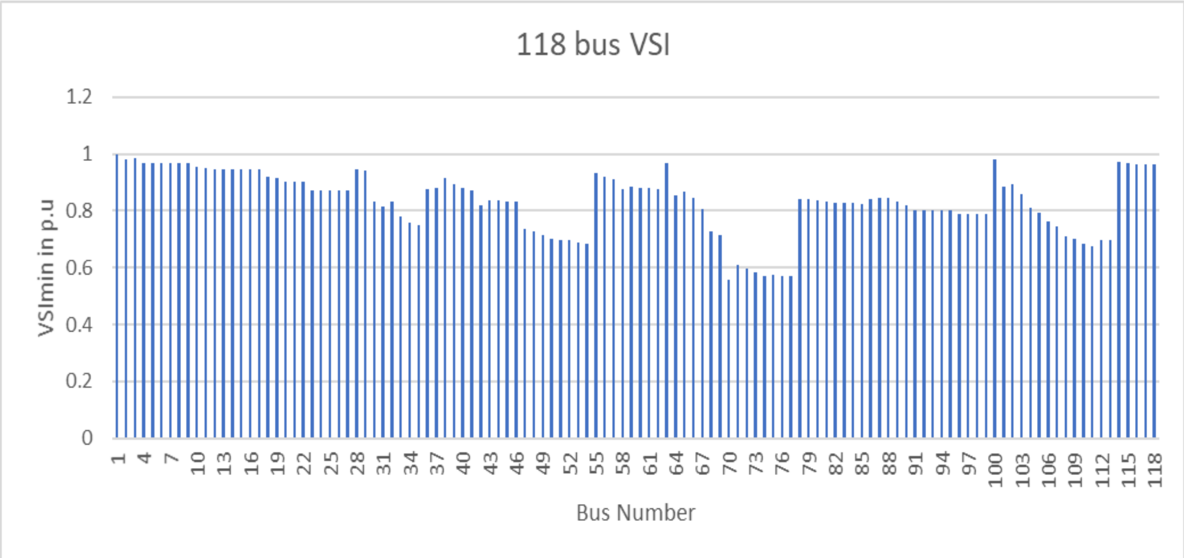

Fig.1 VSI of 118 bus DN

4. Flower pollination Algorithm

FPA was implemented by Yang [16]. Also, the algorithm is developed based on pollination process. Finally, this was developed based on four prominent rules [16].

4.1 Steps to solve Solar DGPP

1. Read the data of 118 bus system

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2. parameters of FPA was initialized [16].

3. Locations of DGs are calculated using VSI.

4. Further, those are given as input to FPA.

5. if rand>p the sizes of solar DGs are calculated by global pollination

6. Else the sizes of solar DGs are calculated by local pollination

7. Revise the current gbest

8. Illustrated the sizes and calculate power los. If values found are good stop the process else ways repeat from step 5.

5. Results and Discussions

Developed approach is implemented using MATLAB. First run the load flow and calculate VSI and found the weak buses to place solar DGs. The buses for placement of solar DGs are 70, 77, 76,74, 75,73,72,71,11,54,110,53,52,51,113. Out of 118 buses only 15% of buses are considered. Next, FPA finds the best sizes of solar DGs at these locations. Finally, the method is implemented on large scale test system that is 118 bus DN. The data of this test system considered from [17]. Various cases are considered for the analysis and the same is represented in Table 1.

Base case
Case 1: 1 Solar DG
Case 2: 2 Solar DGs
Case 3: 3 Solar DGs
Case 4: 4 Solar DGs

In base case before allocation of solar DGs in DN the loss is 1291.1 kW and V_{min} is 0.8688 p.u. After allocation of 1 solar DG the P_{loss} is reduced to 1014 kW and the V_{min} is upgraded to 0.9068 p.u. Comparative to base case loss reduction percentage is improved to 21.46% and voltage profile improved percentage is 4.19%. Next in case2, two solar DGs are considered for placement and the P_{loss} is reduced to 816.81 kW and the V_{min} is enhanced to 0.9095 p.u. Next, the P_{loss} reduction as compared to base case is 36.73% and the voltage profile improved percentage is 4.47%. In case, 3 solar DGs are taken and the P_{loss} after allocation is 711.83 kW and V_{min} is enhanced to 0.9466 p.u

In view of percentage comparison, the loss reduction is improved in percentage is 44.86% and the voltage profile percentage as compared to base case is 8.21%. Finally, in case 4, 4 solar DGs are considered and the power loss after allocation is 699.68 kW and voltage profile are enhanced up to 0.9467 p.u. In view of percentage loss reduction, it is 45.81% and V_{min} improved percentage is 8.23%. From the overall analysis, it is clear that penetration levels of solar DGs allocated in the system increases it reduces the losses to maximum extent. Also, voltage profile for different cases are illustrated in Fig.2 and 3. From the graph V_{min} at all buses enhanced

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significantly. Finally, VSI with various cases are considered and the same are illustrated in Fig.4 and Fig.5.

Table 1 Simulation results of 118 bus DN

Particulars	DG location	DG size (kW)	P_{loss} (kW)	%P_{loss} Reduction	V_{min} (p.u)	VSI_{min} (p.u)
Base Case	…..	…..	1291.1	NA	0.8689	0.5589
Case 1	70	3047.9	1014	21.46	0.9068	0.6768
Case 2	70 111	3047.9 2655.4	816.81	36.73	0.9095	0.6833
Case 3	70 111 54	3047.8 2655.4 1934.6	711.84	44.86	0.9466	0.8077
Case 4	54 70 77 111	1934.3 2203.8 819.6 2655	699.68	45.80	0.9467	0.8077

Fig.2. Voltage profile of 118 bus system (Base case, Case 1, Case 2)

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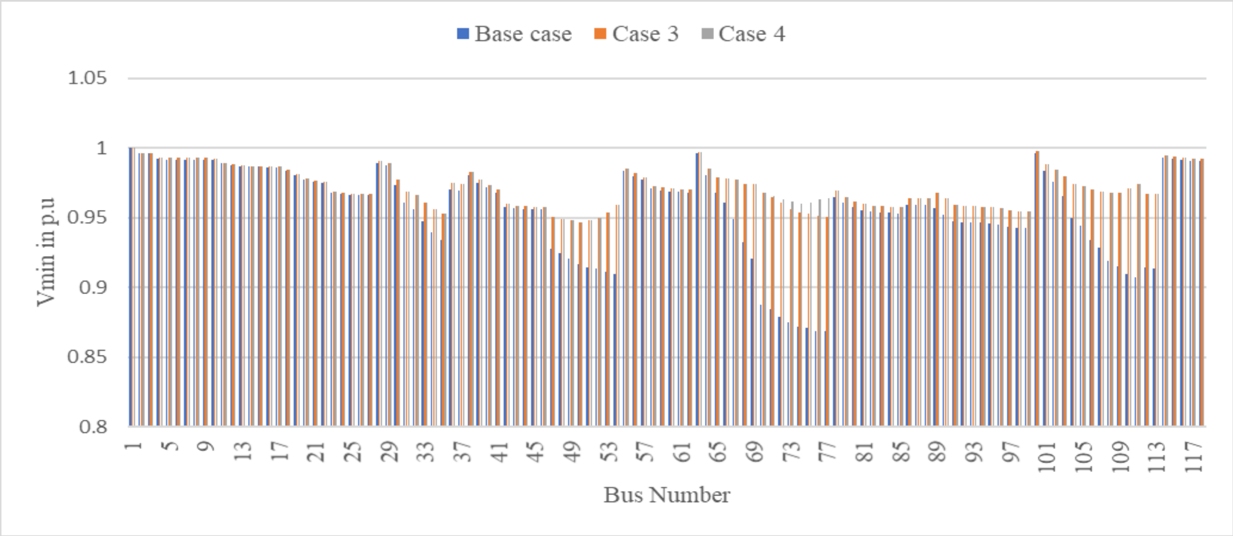

Fig.3. Voltage profile of 118 bus system (Base case, Case 3 , Case 4)

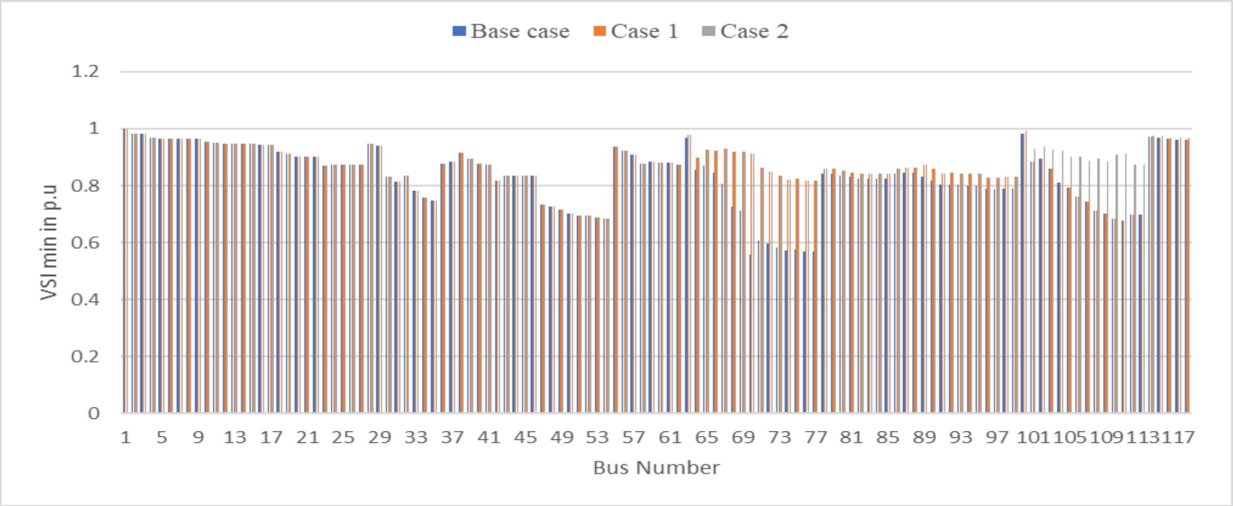

Fig.4. VSI of 118 bus system (Base case, Case 1, Case 2)

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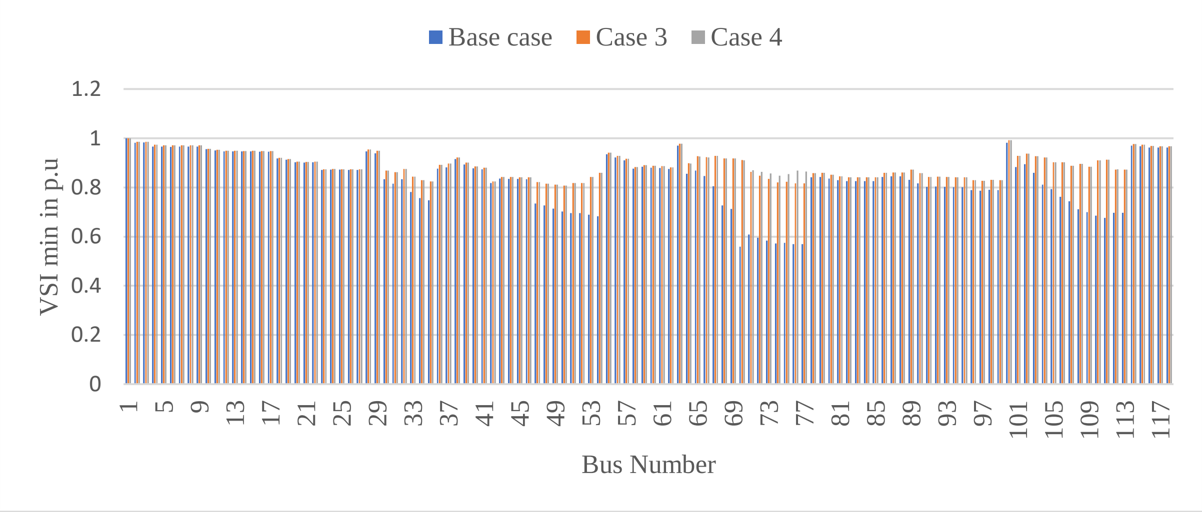

Fig.5. VSI of 118 bus system (Base case, Case 3, Case 4)

6.Conclusion

In this article a significant approach is described to solve solar DGPP in DN. Also, a combined approach based on FPA and VSI is utilized to solve location and sizing problem. Further, 118 bus is considered for analysis. Various cases such as 1 solar DG, 2 solar DGs, 3 solar DGs and 4 solar DGs are considered. Further, power loss reduction is improved in all cases as compared to base case. Also, VSI and voltage profile is improved to maximum extent in case 4 because a greater number of solar DGs placed at suitable locations with appropriate sizes. Finally, in overall analysis maximum loss reduction is achieved with maximum allocation of DGs. But, keeping on increases DGs locations again power loss is increased. So, finally it can be concluded that the presented method reduces the losses to maximum extent. Also, this method is efficient to solve soar DG problem in DN.

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