International Journal of Advanced Research in Engineering and Technology (IJARET)
Volume 10, Issue 6, November-December 2019, pp. 884-895, Article ID: IJARET_10_06_090
Available online at https://iaeme.com/Home/issue/IJARET?Volume=10&Issue=6
ISSN Print: 0976-6480 and ISSN Online: 0976-6499
Impact Factor (2019): 10.22 (Based on Google Scholar Citation)
DOI: https://doi.org/10.34218/IJARET_10_06_090

OPTIMAL PLANNING FOR DG INTEGRATION WITH DISTRIBUTION NETWORK TO EXTEND LOADABILITY LIMIT AND IMPROVE NETWORK PERFORMANCE USING CPF BASED VOLTAGE STABILITY INDICES

Pravin Danger
M.E. Student, Electrical Engineering Department,
Shantilal Shah Engineering College, Bhavnagar, Gujarat, India

Jaydeepsinh Sarvaiya
Assistant Professor, Electrical Engineering Department,
Shantilal Shah Engineering College, Bhavnagar, Gujarat, India

ABSTRACT

Voltage stability becomes an important parameter looking to the contornos demand growth over existing network in last few years. Power distribution network required proper planning and analysis to maintain consistent good efficient and fulfil various power quality constraints. Moreover, distributed generation connected near to load end requires deep planning and analysis to improve performance of the network. In this paper voltage stability analysis has been done based on continuous power flow method where buses weak buses have been identified. The main objective of is to analysis the influence of DGs on voltage stability of radial distribution network. Distributed generators planned to deployed on these weak buses to strengthen the network considering future load growth. Optimal sizing of DGs has been done using Genetical Algorithm. Proposed analysis has been done using IEEE-33 bus system.

Keywords: School-Going Children, Public Transport, and Bus Rapid Transit

Cite this Article: Pravin Danger and Jaydeepsinh Sarvaiya, Optimal Planning for Dg Integration with Distribution Network to Extend Loadability Limit and Improve Network Performance Using CPF Based Voltage Stability Indices, International Journal of Advanced Research in Engineering and Technology (IJARET), 10(6), 2019, pp. 884-895.
https://iaeme.com/MasterAdmin/Journal_uploads/IJARET/VOLUME_10_ISSUE_6/IJARET_10_06_090.pdf

1. INTRODUCTION

The distribution systems are transitioning from passive to active due to various distributed generation (DG) across the network. In recent years, the diffusion of DG into distribution networks has been rising worldwide. The primary reasons behind this trend are the restructuring of the power industry, environmental concerns, and the development of technologies for small-scale power generation[1]. There are several terminologies used for DG, such as “dispersed generation”, “embedded generation”, or “decentralized generation”. The essential meaning of DG is a small-scale power generation instead a conventional or large central power plant[3-5].

In the future of the smart grid trend, if DGs are correctly located and have a suitable size, they could have a role in system security, reliability, and quality[6]. Where the inappropriate allocation of DG units may lead to a voltage rise and increase the losses, it also negatively influences reliability and power quality, further implying a reduction in the payback return of specific investments in terms of DG. Therefore, systematic studies and scheduling are required to locate and operate the DGs well. The significant technical and economic benefits of DG are comprised in Table-1.1.

Table 1 Technical and Economic Benefits of DG

Sr No	Technical Benefits	Economic Benefits
1	Improve Distribution Efficiency	Lowering operating cost due to peak power reduction.
2	Reduce line losses	Increase security of critical load
3	Improve voltage profile of Network	Reduce cost of reserve and associated cost for convectional plants
4	Reduce transmission line congestion	Reduce healthcare cost due to pollution free energy conversion.
5	Improve power quality	Reduce fuel cost
6	Improve distribution system reliability	Enhanced productivity

Due to economic advancement and the increase in population, the load demand of the distribution system is rising at a higher rate. Hence, the distribution system operates near the voltage decline point or instability. Therefore, it is essential to incorporate steady-state voltage stability while optimal DG planning is carried out in the distribution network. Optimal allocation of distributed resources is a complex, non-linear and mix-integer problem, and it cannot be solved using traditional classical methods used for optimization.

Voltage magnitude itself may not be a good indicator of the voltage stability of the system7. Therefore, the voltage stability of the system is assessed using Voltage Stability Indices (VSIs). These VSIs indicate how far the system operates from the voltage collapse point. Awareness of voltage instability helps the operators to manage the power system securely and reliably.

2. LITERATURE REVIEW

During the past two decades, with new DG technologies and the restructuring of power industries, researchers have contributed more attention to integrating DG units into medium or low-voltage networks. Integrating DGs with proper location and appropriate size will help in future innovative grid trends. In the literature, it is found that the techniques which are generally used to address the DG optimal allocation problem of transmission networks are failures for power distribution networks. It is because the distribution network has a wide range of X/R ratios, a large number of nodes and radial type structure[8–10].

In 2000, Das and Chakravorty proposed a voltage stability index for radial distribution networks to recognize the node most sensitive to voltage decline[9]. This SI-related literature shows the DG placement effect on voltage stability of distribution networks consisting of one distribution network as four feeder forms[11]. Most of the studies incorporate SI as one of the objective parameters in the objective function, which is to be minimized by the suitable optimization algorithm. In [12] introduced optimal sizing and siting of DG units for voltage stability improvement with load has been taken constant and neglected the constraints of total capacity of DG unit. In [13], objective function developed for optimal location and sizing of DG unit, which considers three parts: voltage stability index, voltage regulation and power losses. Different overall voltage stability indexes (OVSI) used for stability enhancement of the network. This OVSI are used to evaluate the stability of different buses and they also incorporate load variation and DG's operating with different power factor. In addition, fitness function which is further optimized through GA. The finest size and location of Wind Turbine in radial distribution network with different diffusion levels and at different P.F. are analyzed using SI2.

M.M. Aman et. al. had proposed PSI (Power Stability Index) to find prime location for DG placement in a distribution system[14]. In which an i-j line having the value of PSI is near to one, the DG should be placed at j-bus. The PSI is used to envisage the impact of DG on voltage profile, system losses and voltage stability[15]. Another approach was Tangent Vector of power flow Jacobian is used as index[8]. In which the absolute values of tangent vector components corresponding to the bus voltage magnitude indicate sensitivity of bus.

In the modal analysis (MO), a steady state system model is computes and the eigenvalues of reduced Jacobian accompanying with a mode of V/Q variation provide a good measure of proximity to voltage uncertainty[16]. Bus participation factor derives from model analysis and it observes as load increases, the eigenvalues start decreasing and least eigenvalues for most stressed conditions[17]. In [18] proposed modified modal analysis, which is to eliminate the MA drawback like neglecting the effect of active power variation. Instead of V-Q sensitivity

Looking to the future load growth, the result may differ for different loading condition across the distribution network. So, the Continuous Power Flow method (CPF) is used. In CPF, solutions starting at some base load and foremost to the nose point of the system[19]. the predictor-corrector step is used to solve the PV or λ-V curve. The voltage stability index using tangent vector is stated that most sensitive bus to voltage decline is that, which has expansive proportion of differential change in voltage in a differential change in load. Using this index, In [20] author identifies the sensitive bus for IEEE 24-bus Reliability Test System (RTS). In[21] author presents CPF method for finding of most sensitive buses to voltage decline and they analyzed power transfer capacity (PTC) of the distribution network, maximum loading(λmax) and Voltage Stability Margin(VSM) for a typical 34-bus test system. author used CPF to find the maximum loadability (λmax) as a fitness function for its proposed algorithm[22]. Author stated that bus sensitivities are nothing but the components of tangent vector themselves[23]. In [17] author derived voltage sensitivity index from the continuous power flow.

Continuous power flow and Modal analysis both are used to analyze DG placement impact on radial distribution network[6,24].

3. RESEARCH METHODOLOGY

DG integration with the existing network change the network power flow and it also have higher influence onto the network performance parameters i.e. losses and voltage profile. Improper DGs location may increase the losses and reduce the bus voltage of various distribution nods. In present analysis voltage stability analysis based on continues power flow has been used to identify various critical buses which are more prone to voltage collapse considering future load growth.

3.1. Critical Point identification based on CPF:

Usually the traditional power flow methods can be invoked to provide solutions right up to the nose point. Where continuation methods become necessary only if solutions exactly at the nose point or past of nose point are required. Therefore, CPF is used to evaluate the system state variables at extreme loading condition when the system operating at near to the voltage decline point. In CPF, the predictor-corrector scheme is used to solve the PV or nose curve [23].

The curve tracing process shown in Fig. 1, In which Jacobian matrix becomes the singular at nose point (i.e. point G) and it causes trouble either in the prediction or in the correction step. This means that the present continuation parameter has become ill-suited. One way of overcoming ill-suit condition at nose points is to parameterize the curve by arc length. The augmented Jacobian can be non-singular throughout the tracing process[23]

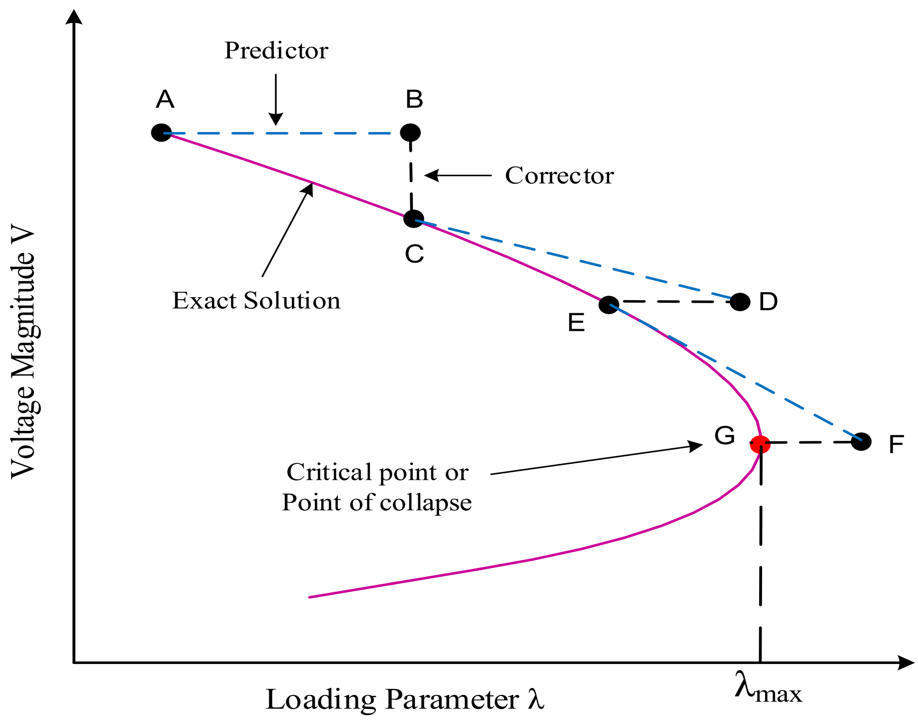

Figure 1 Predictor-Corrector Scheme of CPF

To determine the stopping criterion for the CPF, we must find whether the critical point has been reached. The critical point itself indicates the maximum loading (λ_{max}) occurs before decreasing. For this reason, at the critical point, the tangent vector component corresponding

to λ (which is dλ) is zero and becomes negative once it passes the critical point. Thus, the sign of the dλ component tells us whether the critical point has been passed or not[23].

In the curve tracing process, relation between base load and target load are indicated in equation 1.

$$P_{operating} = P_{base} + \lambda\,[P_{target} - P_{base}] \qquad (1)$$

Where, $P_{target} = KP_{base}$

Suppose, the CPF is carried out by assuming base case loading equal to zero and target load is set as given base case data, then load parameter λ indicates $\lambda_{critical}$. But here, analysis for all three cases is carried out based on base case as given data and target case is set as the constant of changing rate in load.

3.2. VSI based on the tangent vector of the continuous Power Flow Jacobian

For performing CPF, in predictor step tangent vector are calculated using equation(2) as below

$$TV = \begin{bmatrix} d\delta \\ dV \\ d\lambda \end{bmatrix} = \begin{bmatrix} F_\delta & F_V & F_\lambda \\ & e_k & \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ \pm 1 \end{bmatrix} \qquad (2)$$

At the nose point, the tangent vector components consequent to λ (which is dλ) is zero and becomes negative once it reaches the nose point. Thus, the sign of the dλ component informs us whether the nose point has been reached or not.

The absolute values of tangent vector components consequent to the bus voltage magnitude indicate sensitivity of the bus. This component of the tangent vector is treated as VSI.

3.3. Indices for Performance Evaluation of test Systems

Voltage Stability Margin (VSM)

The VSM is the separation from current working point to the point of voltage decline. Higher estimation of VSM guarantee that the system is equipped for conveying more loading without losing its stability.

Penetration Level of DG

The net demand from the source is reduced due to the addition of DG unit at any node in a distribution network and it affects the performance of distribution network. The fraction of real power generated by DG to total real power demand is defined as penetration level of DG in a distribution network.

$$\%\,penetration\ level = \frac{P_{DG}}{P_{load}} \times 100\% \qquad (3)$$

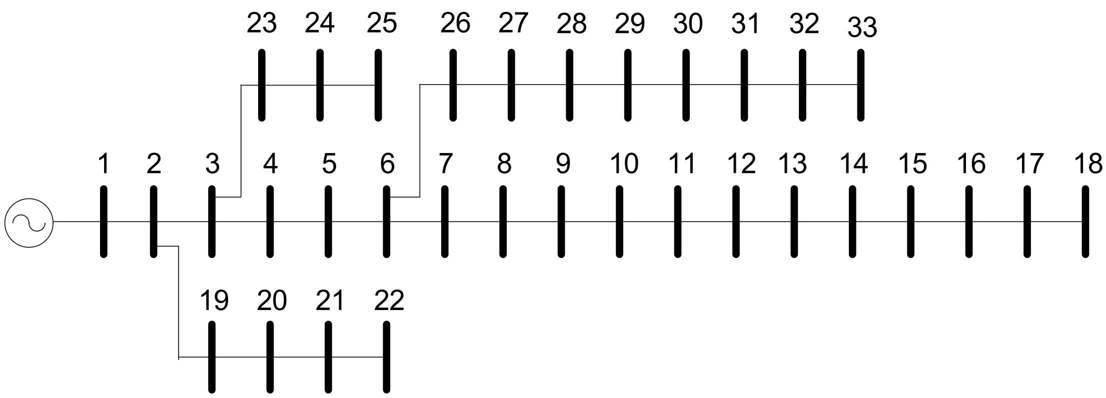

Figure 2 IEEE-33 BUS configuration

Fig.(3)shows algorithm steps for the proposed strategy. Algorithm starts with the identification of week buses using CPF method. Tangent Vector has been find using CPF method for each distribution nods. Critical buses has been finds for consideration of DG placement. GA has been applied to identify optimal size of renewable based DGs. Fitness function has been evaluated in each generation. Objective function yield line losses of the IEEE-33 bus system. As per the termination criteria GA gives optimal value of objective function.

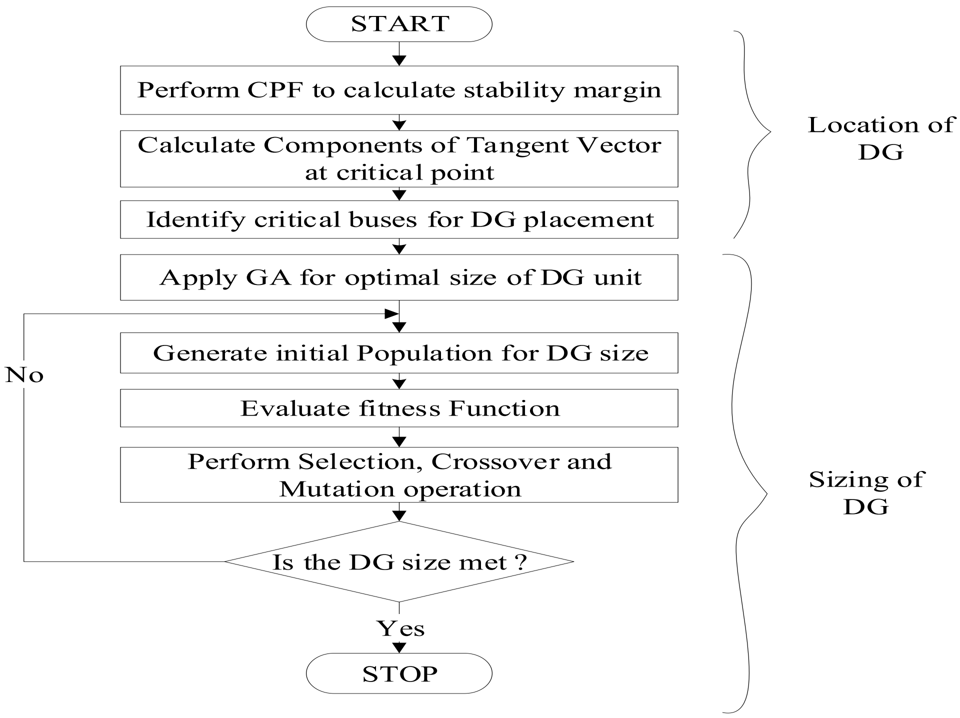

Figure 3 Algorithm steps of proposed strategy

4. RESULT AND DISCUSSION:-

The results of CPF have been presented. Formulation of λ-V curve is done using the method of continuation. The objective is to determine critical bus using sensitivity analysis. The superior the bus sensitivity value, the weaker the bus is and stability margin is poor for weaker bus. The second stage is to find the perfect size of DG units at candidate bus with the help of Genetic Algorithm. The third stage is DGs are placed properly with appropriately sized and to analyzed DG penetration impact on voltage stability in a given radial distribution system.

4.1. Determination of optimal location for DG unit

The CPF is carried out for different cases at different loading conditions by target loading equal to 110%, 120%, and 130% of base case. By performing CPF it is assuming that the real and reactive power load are increased with constant P.F. till the voltage decline. Penetration level of DG unit taken as 45% for all three case.

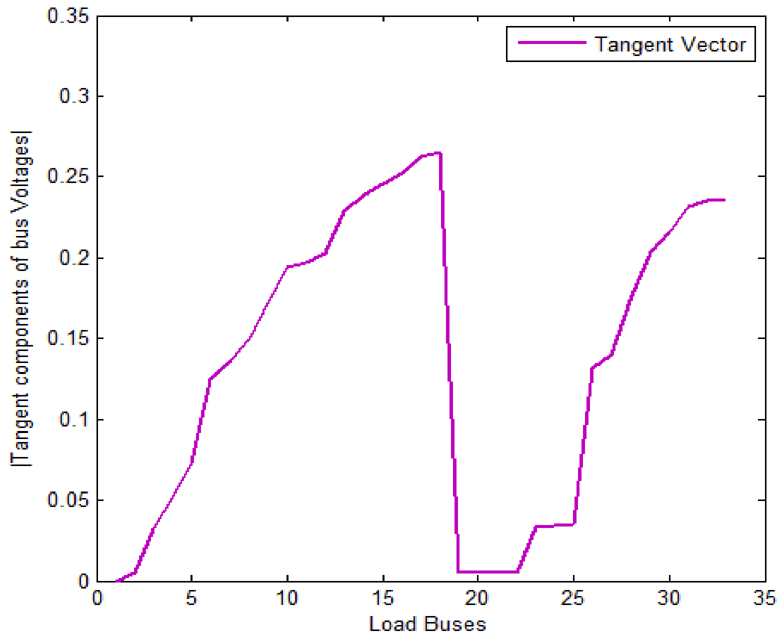

Figure 4 Tangent vectors of 33 bus radial distribution system

Using the value of tangent components of bus voltages according to 120% loading Fig. 6.2 is to be plotted. Figure(4) shows the bus 18 and bus 33 has highest value of TV and corresponding values are 0.2746 and 0.2445. So, these two buses are selected as candidate bus for DG location. Where, Fig. (5) indicate nose curve for candidate buses. In which, the steady state stability limit (nose point) at 120% loading is obtained as a multiplier 13.1109 p.u. for bus 18 and 33.

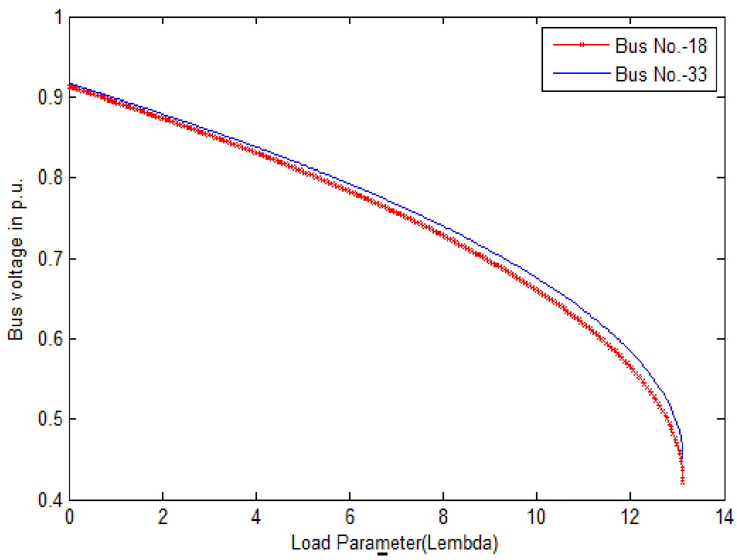

Figure 5 λ -V curve for IEEE-33 bus system

Table 2 Optimal location of DG

Type of Bus system	DG location (Bus No.)
33 bus	18
	33

4.2. Determination of optimal size of DG using GA

The bound variables are selected based on 45% PL. Figure (6) presents convergence graph of objective function for 33 bus system. It shows that best individual at bus 18 and 33 are 0.679 and 0.835 p.u. respectively. So that, DG size 679kW and 835kW are put into bus 18 and 33 correspondingly. Table 3 shows various algorithm specific parameters of GA and Table 4 shows optimal size of each DG units corrupting to optimal location.

Table 3 Algorithm Specific Parameters for GA

Sr. No.	Component of GA	Method / Value
1	No. of Population	20
2	No. of Generation	50
3	Objective Function	Minimization
4	Selection Method	Stochastic uniform
5	Cross over method	Single point
6	Mutation method	Constraint dependent
7	Bound of variables	[0 0] to [0.835 0.835] for 33 bus [0 0] to [0.855 0.855] for 69 bus [0 0] to [5.1095 5.1095] for 119 bus

Table 4 Optimal Size and Location of IEEE-33 Bus system

Type of Bus system	DG location (Bus No.)	DG size in kW
33 bus	18	679
	33	835

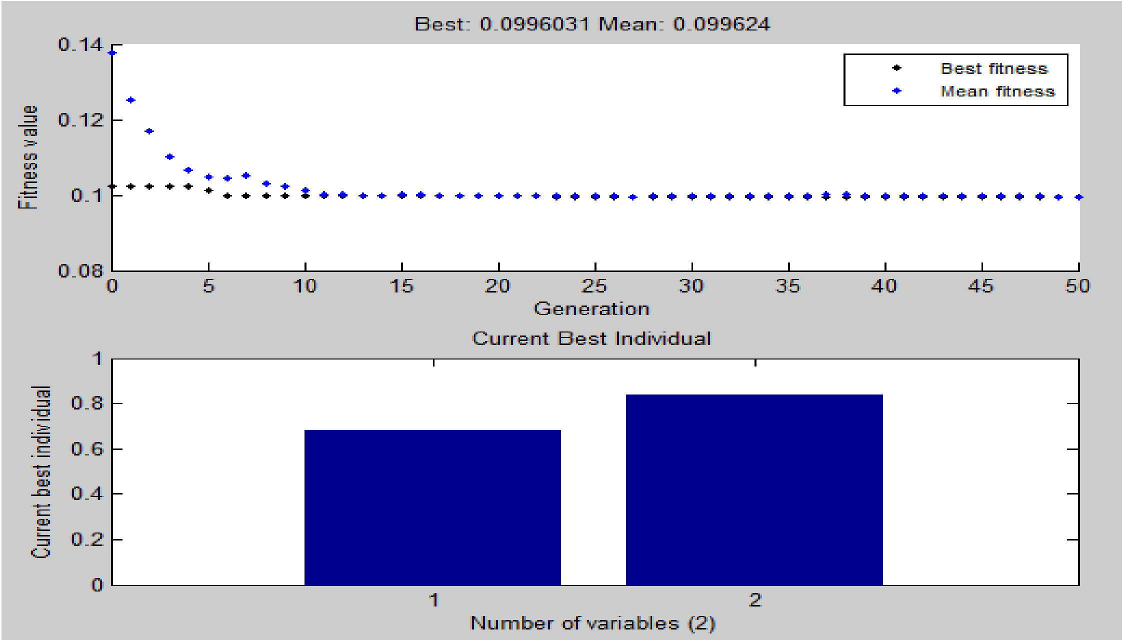

Figure 6 Convergence curve of GA

4.3. impact of DG integration into Distribution system

The integration of DGs at bus 18 with 679kW and bus 33 with 835 kW. Now, DG integration impact are observed as enhancement of voltage stability margin, improvement in voltage profile and reduction of line losses in Fig. (7), Fig. (8) and Fig. (9) respectively. Table 5 shows comparison of network active and reactive losses before and after implementation of proposed strategy.

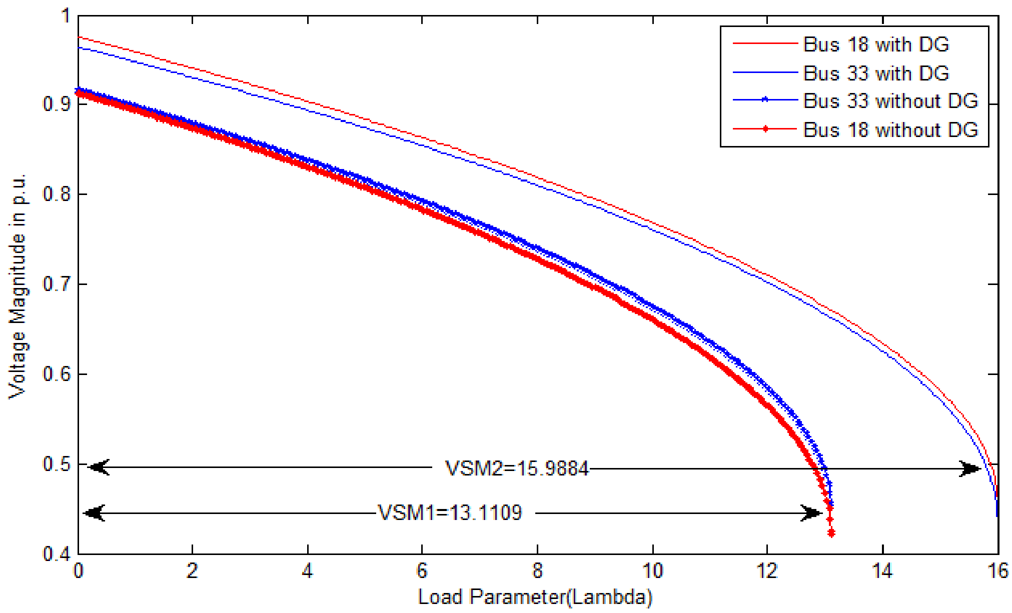

Figure 7 Impact of DG unit on maximum loadability for 33 bus system

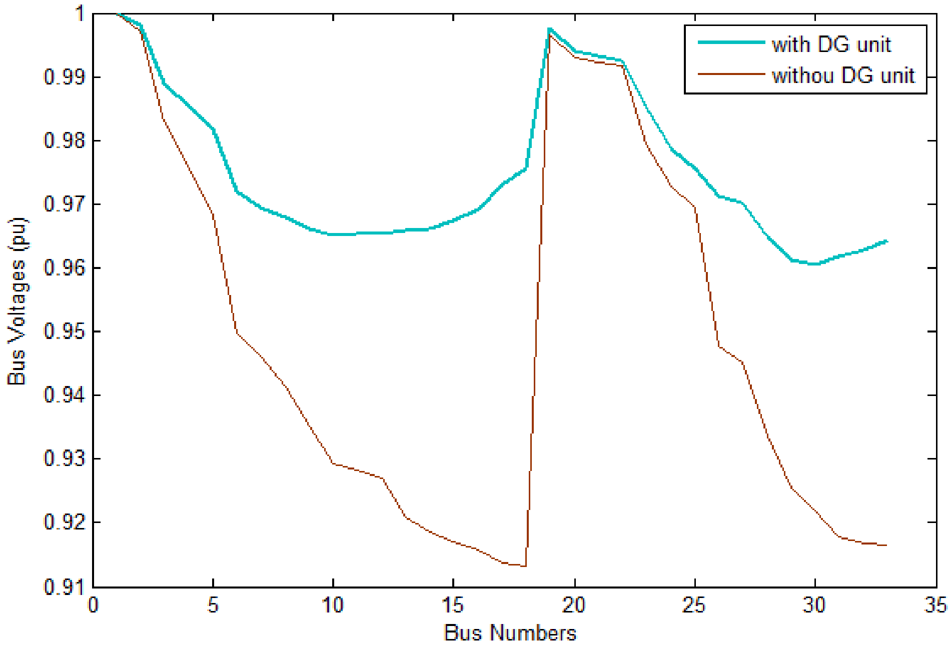

Figure 8 Voltage profile comparison of IEEE-33 bus system

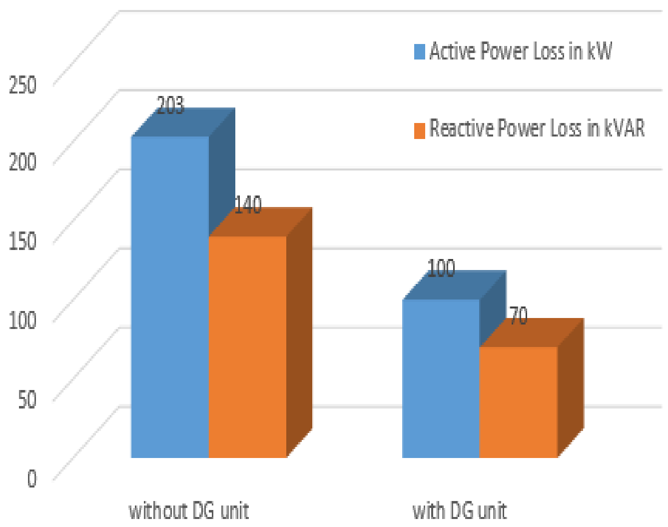

Figure 9 Power loss comparison chart

Table 5 Comparison of VSI and Losses

<table>
<tr><th>Configuration</th><th>Type of Bus system</th><th colspan="2">Without DG Unit</th><th colspan="2">With DG Unit</th></tr>
<tr><td>Voltage stability margin</td><td>33 bus system</td><td colspan="2">13.1109</td><td colspan="2">15.9884</td></tr>
<tr><td>Loss value in kW and kVAR</td><td>33 bus system</td><td>203</td><td>140</td><td>100</td><td>70</td></tr>
</table>

5. CONCLUSION

This effort presents; voltage stability analysis based on continuous power flow method. The analysis is carried out on IEEE 33-bus test system. Voltage stability index based on the tangent vector of continuous power flow Jacobian is used to find critical buses of the system. Appropriate size of DG unit is deciding using GA. Finally, it is observed that the impact of DG integration is, to enhanced the stability margin, to improve the voltage profile and reduce the line losses. Result demonstrate considerable improvement has been gain in terms of Bus voltage stability margin, voltage profile of the network and active /reactive losses. Present analysis has been carried out with constant load model. It may further extended with different types of variable load model for achieving realistic greater accuracy.

REFERENCES

[1] Hill, D. Definition and Classification of Power System Stability. **19**, 1387–1401 (2004).

[2] Mahmoud, G. A. E., Saeed, E. & Oda, S. Investigation of Connecting Wind Turbine to Radial Distribution System on Voltage Stability Using SI Index and λ -V Curves. 16–45 (2016).

[3] Hung, D. Q., Mithulananthan, N., Bansal, R. C. & Member, S. Analytical Expressions for DG Allocation in Primary Distribution Networks. **25**, 814–820 (2010)

[4] Al Abri, R. S., El-Saadany, E. F. & Atwa, Y. M. Optimal placement and sizing method to improve the voltage stability margin in a distribution system using distributed generation. *IEEE Trans. Power Syst.* **28**, 326–334 (2013)

[5] Salama, M. M. A. Distributed generation technologies , definitions and benefits. **71**, 119–128 (2004)

[6] Ettehadi, M., Member, S., Ghasemi, H., Member, S. & Member, S. Voltage Stability-Based DG Placement in Distribution Networks. 1–8 (2012).

[7] Haque, M. H. Use of Local information to determine the distance to voltage collapse. in *2007 International Power Engineering Conference (IPEC 2007)* 407–412 (2007)

[8] N, V. A. A New Voltage Stability Index based on the Tangent Vector of the Power Flow Jacobian. 1–6 (2013).

[9] Chakravorty, M. & Das, D. Voltage stability analysis of radial distribution networks. **23**, 129–135 (2001)

[10] Gözel, T. & Hocaoglu, M. H. An analytical method for the sizing and siting of distributed generators in radial systems. 79, 912–918 (2009)

[11] Hemdan, N. G. A. & Kurrat, M. Distributed generation location and capacity effect on voltage stability of distribution networks. *2008 Annu. IEEE Student Pap. Conf. AISPC* **25**, 1–5 (2008)

[12] Sriramulu, M. & Rahul, M. R. Optimal placing and sizing of DG in a distribution system for voltage stability improvement. *Int. Conf. Electr. Electron. Optim. Tech. ICEEOT 2016* 1469–1475 (2016). doi:10.1109/ICEEOT.2016.7754926

[13] Saad, M. A., Abd, H. A. & Azmy, A. M. Optimal DG Deployment to Improve Voltage Stability Margin Considering Load Variation. 19–21 (2017)

[14] Aman, M. M., Jasmon, G. B., Mokhlis, H. & Bakar, A. H. A. Electrical Power and Energy Systems Optimal placement and sizing of a DG based on a new power stability index and line losses. *Int. J. Electr. Power Energy Syst.* **43**, 1296–1304 (2012)

[15] Rambabu, T. & Prasad, P. V. Optimal Placement and Sizing of DG Based on Power Stability Index in Radial Distribution System. (2014)

[16] Ieee, P. K. F. Voltage stability evaluation using modal analysis b. **7**, (1992)

[17] Mehta, P., Bhatt, P. & Pandya, V. Optimal selection of distributed generating units and its placement for voltage stability enhancement and energy loss minimization. *Ain Shams Eng. J.* **9**, 187–201 (2018)

[18] Jalali, A. Modified Modal Analysis Approach for Distribution Power Systems

[19] Eady, S. I., Voltage, S. & Analysis, S. THE CONTINUATION POWER FLOW A TOOL FOR. **7**, 416–423 (1992)

[20] Arief, A. & Nappu, M. B. DG placement and size with continuation power flow method. *Proc. - 5th Int. Conf. Electr. Eng. Informatics Bridg. Knowl. between Acad. Ind. Community, ICEEI 2015* 579–584 (2015). doi:10.1109/ICEEI.2015.7352566

[21] Hedayati, H., Nabaviniaki, S. A. & Akbarimajd, A. A new method for placement of DG units in distribution networks. *2006 IEEE PES Power Syst. Conf. Expo. PSCE 2006 - Proc.* **23**, 1904–1909 (2006)

[22] Aman, M. M., Jasmon, G. B., Bakar, A. H. A. & Mokhlis, H. Electrical Power and Energy Systems Optimum network reconfiguration based on maximization of system loadability using continuation power flow theorem. *Int. J. Electr. POWER ENERGY Syst.* **54**, 123–133 (2014)

[23] Pai, M. A. & Stankovic, A. *Computational Techniques for Voltage Stability Assessment and Control Series Editors*

[24] Shukla, A. & Siddiqui, S. A. Voltage Stability Improvement of Distribution N etworks by Enhancing DGs Impacts 1 2 ,. 1–6 (2016)

[25] Zimmerman, R. D., Murillo-sánchez, C. E., Thomas, R. J., Fellow, L. & Atpower, A. M. Steady-State Operations , Systems Research and Education. **26**, 12–19 (2011)

[26] Wu, F. F. Network reconfiguration in distribution systems for loss reduction and load balancing. **4**, 1401–1407 (1989)

[27] Das, D. Optimal placement of capacitors in radial distribution system using a Fuzzy-GA method. **30**, 361–367 (2008)

[28] Ghasemi, S. & Moshtagh, J. Radial distribution systems reconfiguration considering power losses cost and damage cost due to power supply interruption of consumers. **5**, 297–315 (2013)

Citation: Pravin Danger and Jaydeepsinh Sarvaiya, Optimal Planning for Dg Integration with Distribution Network to Extend Loadability Limit and Improve Network Performance Using CPF Based Voltage Stability Indices, International Journal of Advanced Research in Engineering and Technology (IJARET), 10(6), 2019, pp. 884-895.

Article Link:
https://iaeme.com/MasterAdmin/Journal_uploads/IJARET/VOLUME_10_ISSUE_6/IJARET_10_06_090.pdf

Abstract Link: https://iaeme.com/Home/article_id/IJARET_10_06_090

✉ **editor@iaeme.com**