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MODEL APPORTIONMENT OF DISTRIBUTED RESOURCES DELIBERATING INCREASING VOLTAGE STABILITY INDEX FOR POWER DISTRIBUTION NETWORK USING TLBO

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ABSTRACT

The development of various distributed resources will bring new challenges to the traditional power distribution network. Traditional power generation has been slowly shifted to small distributed generation at load end to reduce carbon emission and improve the performance of the power system. In restructured environment distribution utility continuously increases penetration of various distributed resources which need to be analyzed through various aspects for getting a cost-effective solution. The size and location of various types of Distributed generators and Reactive power compensator devices across distribution network plays a significant role in loss minimization, voltage profile and stability improvement. Thus distribution utility is required to address placement problems to get the most economical solution for a specific investment. Enhancement of voltage stability is also an equally important aspect considering future load growth. This paper presents a novel approach to address Distributed Generators and Reactive power compensators placement problems across distribution networks considering different objectives. A multi-objective function is created to look after loss minimization, investment-cost minimization, and voltage stability enhancement. The proposed technique has been applied to the IEEE-33 bus radial distribution network. A meta heuristic-based TLBO algorithm is used to find an optimal solutions. Analysis has been extended for different cases with three different load level data to demonstrate the effectiveness of the proposed method.

Keywords: Distributed Generation, Voltage Stability, Loss Minimization, Cumulative voltage stability index.

1. INTRODUCTION

Looking to the cautiously increasing demand every utility tends to enhance penetration of various distributed resources across the distribution network without interfering with traditional transmission and generation system. Moreover, deployment of DG is also beneficial in order to reduce active losses, improve voltage profile, enhance voltage stability, improve reliability and reduce transmission congestion.

The selection of appropriate location and capacity of Distributed resources requires deep planning and analysis. Improper placement may yield increased investment costs and reduced revenue returns. To increase the significance of various Distributed generators and Reactive power compensator devices, multi-objective planning is required which gives a cost-effective solution while satisfying all different set criteria (i.e. voltage profile, active power loss, voltage stability).

Since the deployment of Distributed resources across distribution networks is a nondifferentiable, complex, multi-objective constraint optimization problem, many researchers proposed different approaches to find economical solutions [1-7]. Acharya et al.[1]proposed an analytical approach to finding the most economical size and location of DG units with an objective of power loss reduction. Mistry and Ranjit[2] used PSO to deploy multiple DGs to cater to the incremental load on the distribution system with an objective of minimization of active power loss. Baran and Wu[3] presents an optimal allocation of a capacitor across a network for minimization of loss. R.ShrinivasaRao et al.[4]used the Harmony Search Algorithm for optimal reconfiguration of a network in the presence of DGs to minimize loss. The algorithm is tested on 33 bus distribution network. Sudipta Ghosh et al [5] present a new methodology for DG placement to gain economic benefit effectively. Sneha and Roy [6] used a teaching Learning Based Optimization algorithm for optimal placement of the capacitor to reduce cost and losses across a distribution network. F.S. Abu-Mouti et al.[7]apply the artificial Bee colony Algorithm to solve the DG placement problem for a distribution system. In addition to loss minimization and cost reduction, voltage stability is also an important factor to be considered for analysis. Looking to the continuously increasing demand it is highly required to identify critical bus prone to voltage collapse based on voltage stability indices. Many researchers consider different voltage stability indices for identifying the effective location of various Distributed resources [8]– [11]. M.M.Aman et al. [12]proposed a new approach for DG placement based on new power stability index and line losses. M.Moghavvemi, M.O Faruque[13] present voltage stability analysis to predict voltage collapse considering future load growth for the radial distribution network. Amaresh and Sudipta[14] introduce a new combined voltage stability index to identify the effective location of DGs with the objectives of minimization of power loss and voltage profile improvement. M.H.Moradi and M.Abedini[15] present a new approach consisting of GA and PSO to address DG siting and sizing problems. MohmedImram A and Kowsalyam M[16] applied BFOA to address DGs and capacitors placement problems to minimize active power losses of the IEEE 33 bus network.

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This paper presents a methodology for the deployment of DGs and RPC devices across a distribution networks. Loss sensitivity analysis and voltage stability analysis have been used to identify the potential location of DGs and RPC device respectively. A multi-objective function is developed to maximize benefits in terms of minimization of active loss, voltage profile improvement and investment cost minimization. Objective function also incorporate voltage stability enhancement as it needs to be
analyzed looking to the future load growth.

2. SENSITIVITY ANALYSIS FOR RPC PLACEMENT

Sensitivity analysis[16] has been carried out to identify potential location of RPC device across network. It helps to reduce the search space for the optimization procedure.

Consider line section of distribution network having impedance $R_n + jX_n$ and a load $P_{Ln,eff} + j\,Q_{Ln,eff}$ is connected between n and n+1 buses as shown below,

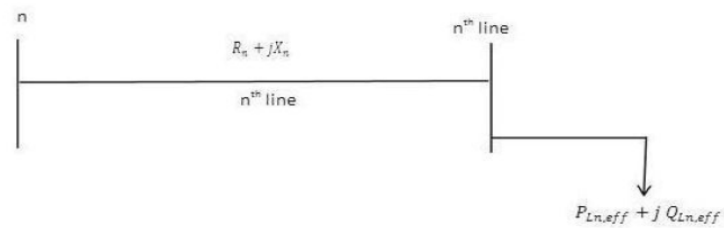

Figure 1 Two bus network

$$P_{Loss\,n,n+1} = R_{n,n+1} * \frac{P^2_{n+1,eff} + Q^2_{n+1,eff}}{|V_{n+1}|^2} \quad (1)$$

Based on line loss equation Loss sensitivity factor can be calculated with equation,

$$\frac{\partial P_{Loss\,n,n+1}}{\partial Q_{n+1,eff}} = \frac{2 * Q_{n+1,eff} * R_{n,n+1}}{|V_{n+1}|^2} \quad (2)$$

$$\frac{\partial P_{Loss\,n,n+1}}{\partial P_{n+1,eff}} = \frac{2 * P_{n+1,eff} * R_{n,n+1}}{|V_{n+1}|^2} \quad (3)$$

Using (2) the loss sensitivity factor can be computed. These values are arranged in descending order for all in IEEE 33 bus system. Buses having a higher value of LSF are considered for the placement of RPC devices. In this paper first four buses having higher LSF are select for RPC placement. After the selection of candidate location, size of RPC device is calculated using the optimization algorithm.

3. VOLTAGE STABILITY ANALYSIS FOR DEPLOYMENT OF DG Voltage magnitudes of buses reduces with continuously incremental demand. It may result in a voltage collapse. Bus

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voltage mainly improves by reducing the voltage drop component (IZ). Voltage stability index based DG location is proposed by [14], [17]. VSI is used to find critical buses w.r.t. voltage level which are more critical to voltage collapse looking to the future load growth. Placement of DG at these weak buses not only reduces losses but also improves voltage stability of the whole distribution network.

Consider two bus system of distribution network given in Fig-2,

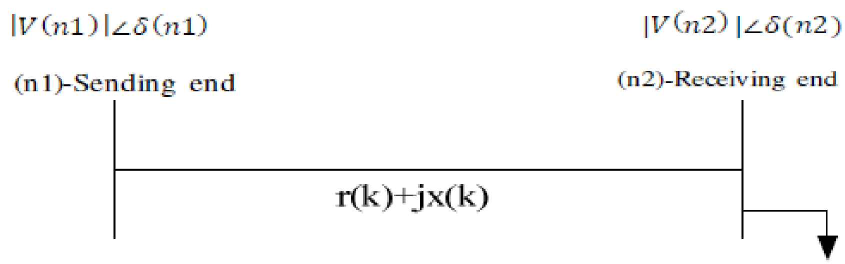

Figure 2 Two bus network

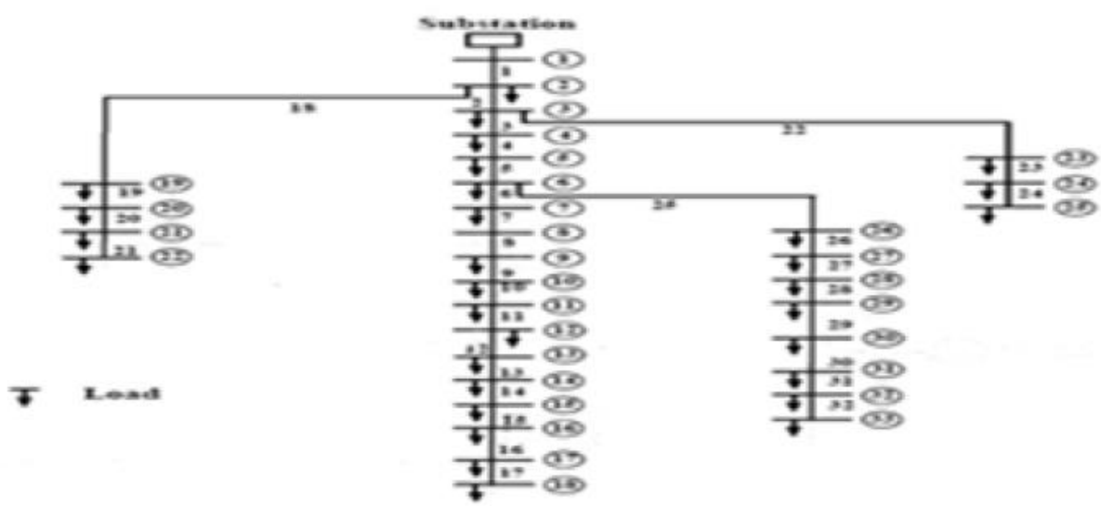

Figure 3 IEEE-33 bus network.

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$S_L = V_R I_R^*$ (4)

$S_L = P_L - jQ_L$ (5)

$\overrightarrow{V_R} = \overrightarrow{V_S} - \overrightarrow{I_R Z}$ (6)

Where $\boldsymbol{I_R}$is the current at receiving end (n2)

$$\overrightarrow{I_R} = \frac{P_L - jQ_L}{V_R^*} \quad (7)$$

Considering real and reactive power support at load end by injecting proper type of DG , (7) can be written as ,

$$\overrightarrow{I_R} = \frac{(P_L - P_G) - j(Q_L - Q_G)}{V_R^*} (8)$$

As for two bus network shown in fig (4),

$$\overrightarrow{V(n_2)} = \overrightarrow{V(n_1)} - \overrightarrow{IZ} \ (9)$$

Substituting value of $\overrightarrow{\boldsymbol{I_r}}$ from (8) in (9) and Rearranging gives a quadratic equation,

$$|V_R|^2 - \frac{|V_S||V_R|\cos(\emptyset - \delta_s + \delta_r)}{\cos(\emptyset)} + \frac{Z(P_L - P_G)}{\cos(\emptyset)} = 0 \ (10)$$

For stable node voltages, (10) should have real roots, i.e. Discriminant b2-4ac ≥ 0.

$$\frac{\boldsymbol{V_S^2 \cos^2(\emptyset - \delta_s + \delta_r)}}{\boldsymbol{\cos^2\emptyset}} - \frac{\boldsymbol{4Z(P_L - P_G)}}{\boldsymbol{\cos\emptyset}} \geq \boldsymbol{0} \ \ (\boldsymbol{11})$$

The voltage stability index can be derived by simplifying above equation(11), which gives the lines and the subsequent nods which are weak and most critical to voltage collapse. These weak buses are consider an effective location for placement of small capacity DG.

$$\boldsymbol{VSI} = \frac{4x(i)(P_L - P_G)}{[|V_{n1}|\cos(\emptyset_i - \delta_{n1} + \delta_{n2})]^2} \leq 1 \ (12)$$

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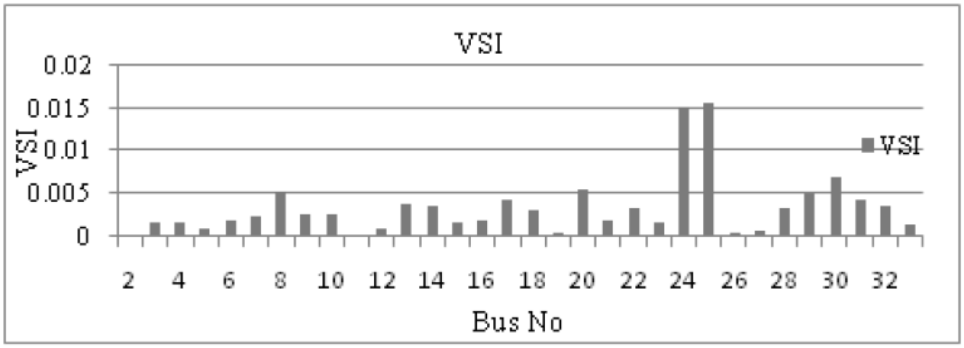

Figure 4 VSI values of different buses

VSI values for all buses arranged in descending order. In addition to the voltage stability index values of all buses in present paper a new Cumulative voltage stability index introduced to indicate the state of stability of whole network ,

$$\textbf{CVSI} = \sqrt{\frac{\sum_{i=1}^{n}(VSI_i - VSI_0)^2}{n}} \quad (13)$$

Placement of DG and RPC across distribution network improves CVSI and it approaches to 1. In present paper CVSI incorporate with objective function to ensure stability improvement with fulfillment of other objectives.

4. FORMULATION OF MULTI OBJECTIVE FUNCTION

The proposed objective function (F) of the problem yield minimization of active loss, minimization of cost of investment in terms of DG and RPC, enhancement of CVSI of distribution network.

$$Min\ F = k_1 \times \frac{P_{Loss}}{P_{Loss_B}} + k_2 \times \frac{\sum cost_{DG}}{cost_{DG^{max}}} + k_3 \times \frac{\sum cost_{RPC}}{cost_{RPC^{max}}} + k_4 \times \frac{CVSI}{CVSI_B} \quad (14)$$

F= Multi objective function to be optimized.

K1, K2, K3,K4 = Weighted Factors.

$\boldsymbol{P_{Loss}}$=Active power loss of IEEE-33 bus network after DG and RPC placement.

$\boldsymbol{P_{Loss_B}}$= Base case Active power loss without DG and RPC placement.

$\sum \boldsymbol{cost_{DG}}$= Investment cost of DG to be placed.

$\boldsymbol{cost_{DG^{max}}}$= Maximum investment of DG to be placed with full capacity as per constrain.

$\sum \boldsymbol{cost_{RPC}}$ = Investment cost of RPC to be placed.

$\boldsymbol{cost_{RPC^{max}}}$= Maximum investment of RPC to be placed with full capacity as per constrain.

$\boldsymbol{CVSI}$ = Cumulative Voltage Stability index value.

5. RESULTS AND DISCUSSION

The proposed technique has been applied to the IEEE 33 bus network. The maximum nos of DG and RPC devices installed for the given network are limited to four as the rate of improvement reduce with the potential location is more. In this analysis different scenarios are considered to demonstrate the effectiveness of the proposed technique.

6. CONCLUSION

In present paper a new methodology has been proposed to install DG and RPC across power distribution network. A new CVSI is formed to describe stability of whole network, in addition to this a multi objective function is formed to reduce losses as well as cost of investment and improve CVSI. It has been tested on IEEE 33 bus network and AI based TLBO used to optimize multi objective function. Simulation results shows that this approach helps not only to reduce losses and cost of investment but also to improve CVSI considerably.

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