Optimal Placement of SPV based DG using Heuristic Search Strategies for Loss Less Distribution

U. Ravi Kumar, G. Surya Chandra & K V S Ramachandra Murthy

Abstract: In this paper, Heuristic Search Strategies is implemented to determine the optimal sizes of SPV based Distributed Generators (DGs) and optimal locations such that maximum possible reduction in real power loss is obtained. SPV based DG inject active power. The objective of this paper is to apply heuristic search strategies to determine the node for the appropriate placement of DG. In heuristic approach, a critical node, called sensitive node is selected based upon maximum power losses caused for installing DG system .This method ensures that voltage constraints are met. This paper is tested on 34 bus and 69 Bus Radial Distribution Systems. The loss reduction obtained in this paper for the 34 bus and 69 Bus Power factor of the DG is considered in this study is 0.85.

On 34 bus system, without placement of DGs the loss is 221.16 kW whereas after placement it is 129.15 kW. On 69 bus system, without placement of DGs the loss is 225 kW whereas after placement it is 84.5 kW.

It is implemented using MATLAB/Simulink.

Keywords: DG placement, Distribution Systems, heuristic search strategies, SPV system, loss reduction.

I. INTRODUCTION

Optimal capacitor placement is implemented for improving the voltage profile and reducing the power loss. Optimal SPV based DG placement is implemented for reduction of active power loss, voltage profile and to improve the reliability of the system. Very few papers have addressed the concept of minimizing the active loss by placing both DGs and Capacitors [4-6] at their optimal locations. This concept works well for the developing countries like India, where the 11KV rural distribution feeders are too long. The voltages at the far end of many such feeders are very low with very poor voltage regulation.

The distributed generators (DGs) are small production units based either on renewable energy sources (such as wind and solar photovoltaic) or conventional energy (such as small gas engines or diesel generators) that are connected to the distribution network. It can be from the renewable sources like solar photovoltaic, wind etc. or from the conventional sources like small gas engines, diesel generators etc. These DG sources are normally placed close to load and generally they are added to the distribution system.

Although in practice, distribution engineers will present some limitations in determining DG location, the existence of an index based on technical impacts indicates where DG could be more beneficial for the distribution network (i.e. for the electric utility, helping distribution engineers take decisions and even shape the nature of the contract that might be established between the network operator and the distributed generator owner [3]).

Distributed generation is well-suited to the use of renewable energy technologies, because they can be located close to the user and can be installed in small increments to match the load requirement of the customer. One of such renewable energy is the solar photovoltaic, solar energy reduces the cost of investment in grid transmission extension, which carries both an economic cost and a time element associated with capital investment and planning approvals. Solar Photovoltaic systems can be placed in the distribution system in small sizes as per load requirement. The Positive point with solar energy is that it is environmental friendly with respect to coal and nuclear, running cost is very low. It also produces peak power at day when power requirement is generally high. Many approaches dealing with the placement of distributed generation systems in distribution network have been proposed in literature [1].

The technical merits of DG implementation include voltage support, energy-loss reduction, release of system capacity, and improve utility system reliability [7]. By supplying power during peak load periods DG can best serve as a price hedging mechanism. Numerous techniques are proposed so far to address the viability of DGs in power system. Besides, several optimization tools, including artificial intelligence techniques, such as genetic algorithm (GA), Tabu search, etc., are also proposed for achieving the optimal placement of DG. An optimization approach using GA for minimizing the cost of network investment and losses for a defined planning horizon is presented in [8]. The method for optimal placement of DG for minimizing real power losses in power distribution system using GA is proposed in [9].

The gradient and second order methods to determine the optimal location for the minimization of losses is employed in [10]. An iterative method that provides an approximation for the optimal placement of DG for loss minimization is demonstrated in [11]. Analytical methods for determining optimal location of DG with the aim of minimizing power loss are proposed in [12]. Optimal placement of DG with Langrangian based approach using traditional pool based Optimal Power Flow and voltage stability constrained Optimal Power Flow formulations is proposed in [13].

Carpinelli et al. implemented [14] non-linear programming technique for capacitor placement on three phase unbalanced system. Wang et al. implemented [15] integer programming technique, and Tabu search was used by Huang et al. [16] for optimal capacitor placement. Grainger implemented equal area criterion [17] and genetic algorithm applied to capacitor placement by Dlfanti [18] for determining optimal sizes of capacitors. Das applied Fuzzy-GA method for capacitor placement problem [19]. Sydulu and Reddy applied Index Vector to capacitor placement problem [20], Prakash and Sydulu applied particle swarm optimization for optimal capacitor placement problem [21]. Safigianni and Salis presented optimum VAr control of radial primary power distribution networks by shunt capacitor installation [22]. Das implemented genetic algorithm [23], Hsiao implemented Fuzzy-genetic algorithm for [24] for optimal capacitor placement problem. Huang applied immune multi objective algorithm for capacitor placement problem [25]. Kannana et al. applied Fuzzy-Differential Algorithm [26], Srinivasa Rao et al. applied plant growth algorithm for optimal capacitor placement problem [27].

In this paper a heuristic method is presented in which only critical node, named sensitive node, is selected for installing DG in order to achieve a large overall loss reduction in the system. This is based on the idea that the number of sensitive nodes is relatively small compared to the total number of nodes, which will considerably reduce the size of the problem. The sensitive nodes are prime locations for installing DGs. The sensitive nodes are selected based on the power loss caused in the system by the active components of the load (bus) currents. Also, the variations of the load during the day are taken into consideration for the purpose of achieving a higher reduction of the overall losses during the year..

The Heuristic search strategies implemented, with a possible expert interaction yields optimal locations with suitable sizes of DGs, results in minimum active power loss. In this paper is implemented on 34 Bus and 69 Bus Standard Test Systems. 69 Bus data is available in [29]. SPV based DG injects active power into the system as mentioned in [1].

This paper is organized as follows: Identification of optimal DG location is presented in section II. In Section III implementation of heuristic approach is discussed. Results are discussed in Section IV. A conclusion followed by the references is presented in Section V.

II. IDENTIFICATION OF OPTIMAL DG LOCATION

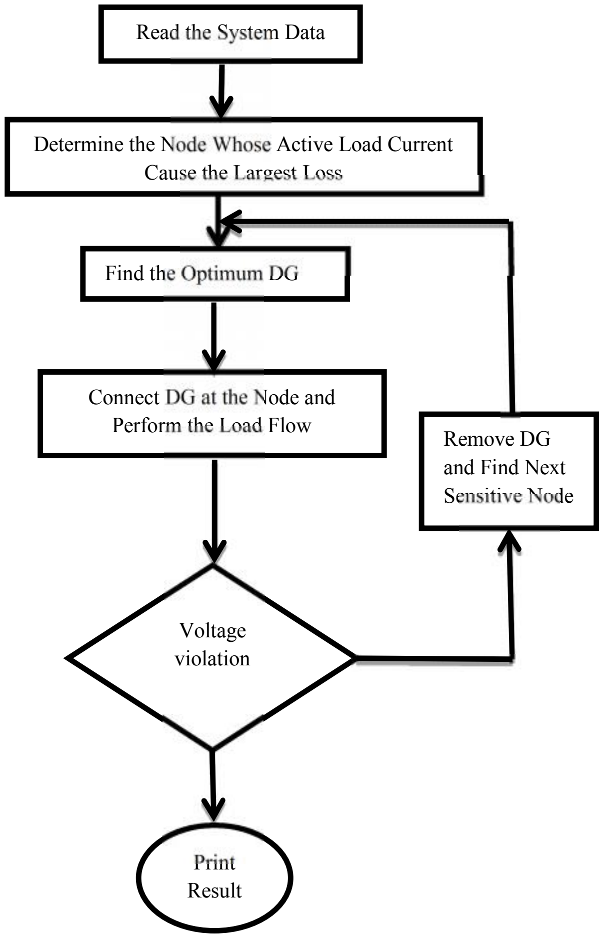
Determination of a solution to the SPV based DG problem using heuristic rules involves searching through a set of possible solutions. As the losses due to the reactive components of the load currents cannot be affected by the placement of DG, the search will focus only on the losses due to the active currents. The objective of this search is to determine the optimal locations, sizes, and number of standard capacitor banks to be placed in the distribution network. The method outlined below effectively implements heuristic approaches for solving this problem, while accounting for the voltage constraints along the feeder.

The DG unit can be placed on the nodes where the active load currents are causing the highest power losses. The problem of DG unit placement consists of determining the size, location and number of DG units to be installed in a distribution system such that maximum benefits are achieved while operational constraints at different loading levels are satisfied. The branch current has two components, active component and reactive component. For a given configuration of a single source radial distribution network, the losses associated with the active component of branch current cannot be minimized because all the active power must be supplied by the source at the root bus. This is not true if DG units are to be placed at different locations for loss reduction that is real power can be supplied locally by using DG units of optimum size to minimize active power loss associated with the active component of branch current. The method for obtaining the optimal DG size and location is outlined as follows Fig. 1.

Step 1: The peak power losses caused by the active load currents that flow through the feeder are computed by first, a load flow program calculates the power loss reduction by compensating the total active load current at every node of the distribution system. The loss reductions are then linearly normalized into a (0 - 1) range called as power loss reduction index (PLRI) with the largest loss reduction having a value of 1 and the smallest one having a value of 0. The node whose active load current has the largest impact on the power loss in the system is then selected for compensation and is called a sensitive node. Suppose this node is 'k'.

Step 2: Secondly, the optimal size of the compensating DG to be placed at node 'k' has to be determined. The idea is to place a DG unit with a proper size and location such that the system loss reduction is maximized. For system loss reduction to be maximum the DG unit must be placed at node 'k', such that the rate of change of losses with respect to the injected bus power becomes zero [28].

$$\partial P_l/\partial P_k = 0 \quad (1)$$



Step 3: A load flow is performed in order to get the new values of the load currents and to check if the voltage constraints are met. If there is any violation of the voltage constraints, the DG is removed and the next largest loss node is selected as the next sensitive node and the procedure is repeated starting from Step 2.

III. IMPLEMENTATION OF HEURISTIC APPROACH

The described method is applied to a 34-bus and 69-bus three-phase radial feeder with lateral branches, shown in Fig. 2.and Fig. 3. Details of the feeder and the load characteristics are given in [1][29].The software implementation of the procedure has been done using the MATLAB environment for the ease of operating with complex numbers. All the calculations have been carried out in the per-unit system.

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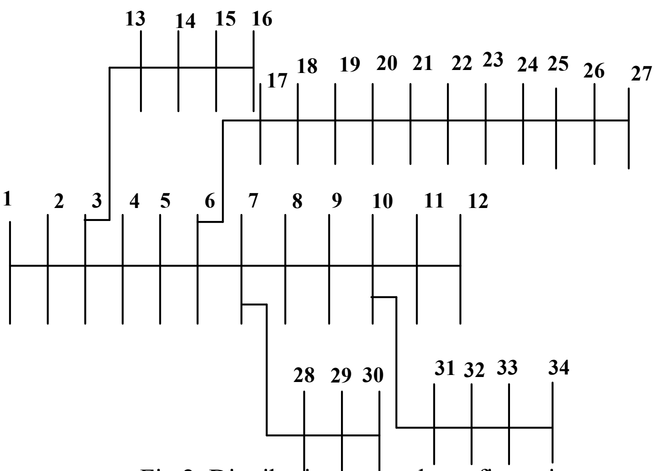


Fig.2. Distribution network configuration

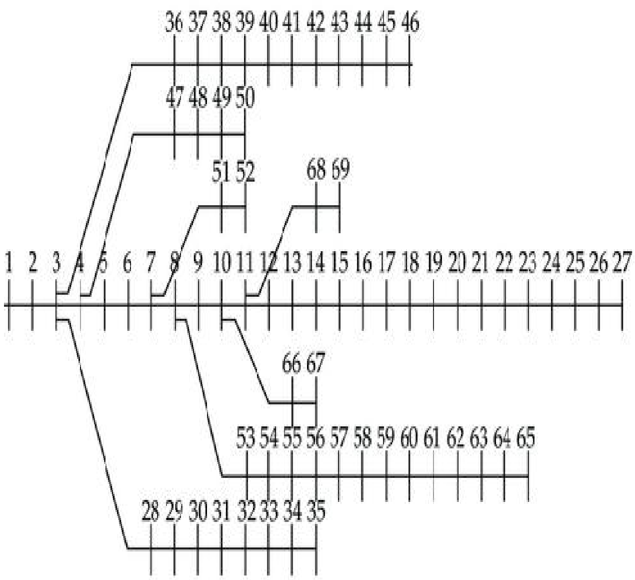


Fig.3. Distribution network configuration

IV. RESULTS

34-BUS RESULTS

The initial power loss in the system is 221.16 kW. The losses due to active component of current in the system are 163.99 kW and the losses due to reactive component of current in system are 57.17 kW. The application of the proposed method to the system yields the following results. Fig 4 shows the normalized power loss reduction index after compensating the total active power at every node of the distribution system, it is clear from Fig 4 that the node 25 is causing the highest losses in the system and it is identified as the most sensitive node for the placement of DG.

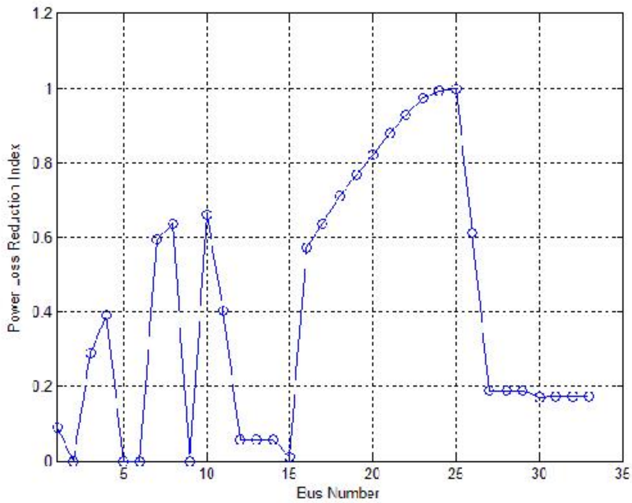
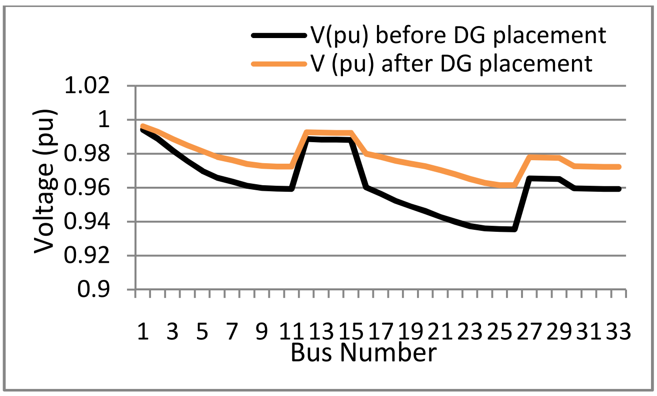


Fig.4. Power Loss Reduction Index at different buses

The optimal SPV type DG size which supplies only the active power is found to be 2.4692 MW which gives the maximum loss reduction at this particular node. The total active power losses in the system after placement of DG at node 26 is 128.43 kW and the losses due to the active component of current are 66.63 kW and the losses due to reactive component of the current is 61.49 kW. Fig. 5 shows the voltage profile of the system before and after placement of the DG at node 25 and it is seen in the figure that placement of DG also significantly improves the system profile.



69-BUS RESULTS

The initial power loss in the system is 225.0 kW. The losses due to active component of current in the system are 153.14 kW and the losses due to reactive component of current in system are 71.86 kW. The application of the proposed method to the system yields the following results. Fig 6 shows the normalized power loss reduction index after compensating the total active power at every node of the distribution system, it is clear from Fig 6 that the node 60 is causing the highest losses in the system and it is identified as the most sensitive node for the placement of DG.

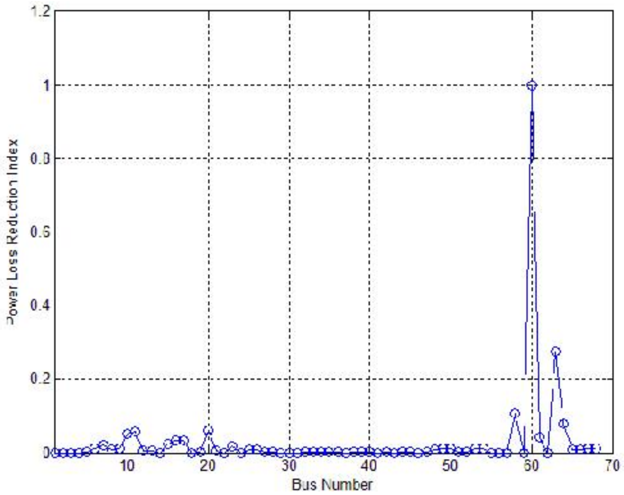
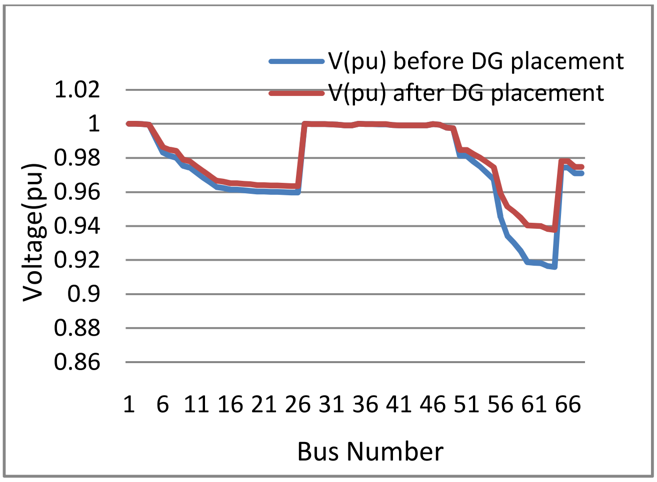


Fig.6. Power loss reduction index at different buses

The optimal SPV type DG size which supplies only the active power is found to be 1.6692 MW which gives the maximum loss reduction at this particular node. The total active power losses in the system after placement of DG at node 61 is 218.48 kW and the losses due to the active component of current are 146.76 kW and the losses due to reactive component of the current is 71.62 kW. Fig. 7 shows the voltage profile of the system before and after placement of the DG at node 60 and it is seen in the figure that placement of DG also significantly improves the system profile.



V. CONCLUSIONS

In this paper Heuristic Search Strategies is implemented to determine the optimal sizes of Distributed Generators (DGs) with their optimal locations in 34 Bus and 69 Bus Radial Distribution System so that maximum possible reduction in real power loss is obtained. The optimal sizes of SPV based DG are chosen to be standard sizes i.e., discrete sizes of DG are considered. This is achieved in this paper by examining the solution at a critical node named sensitive node. The sensitive node is selected based on the losses caused in the system by the active components of the load currents. This method is easy to be implemented and faster for the given accuracy than analytical methods. It is proved that the proposed method can save huge amount of power and achieve significant improvement in voltage profile. This makes this method very attractive when dealing with large distribution systems. Further, this method requires less computation time compared to other analytical methods.

On 34 bus system, without placement of DGs the loss is 221.16 kW whereas after placement it is 129.15 kW. On 69 bus system, without placement of DGs the loss is 225 kW whereas after placement it is 84.69 kW.

REFERENCES

[1] Sheeraz Kirmani, Majid Jamil and M. Rizwan “Optimal Placement of SPV based DG System for Loss Reduction in Radial Distribution Network Using Heuristic Search Strategies”

[2] Yann Riffonneau, Seddik Bacha, Franck Barruel, and Stephane Ploix,“Optimal Power Flow Management for Grid Connected PV Systems With Batteries”, IEEE Transactions on Sustainable Energy, vol. 2, no.3, pp. 309-320, 2011.

[3] Luis F. Ochoa, Antonio Padilha-Feltrin and Gareth P.Harrison,“Evaluating Distributed Generation Impacts With a Multiobjective Index”, IEEE Transaction on Power Delivery, vol. 21, no. 3, pp 1452-1458 , 2006.

[4] Mamta Karayat, G. V. Srihara Rao, K. Ravi Kumar & K V S Ramachandra Murthy, “Optimal Capacitor and Type -2 DG Placement using Modified KVS – Direct Search Algorithm for Loss Less Distribution”, International Journal of Emerging Trends in Electrical and Electronics, May, 2013.

[5] T. S. Sirish, G. V. Srihara Rao & K V S Ramachandra Murthy, “Optimal Capacitor and DG Placement for Loss Less Distribution on 69- Bus System using KVS – Direct search Algorithm”, International Journal of Emerging Trends in Electrical and Electronics, May, 2013.

[6] K. V. S. Ramachandra Murthy, Mamta Karayat, G. V. Srihara Rao, P. K. Das and A. Ravi Shankar, Loss Less Distribution using Optimal Capacitor and Type-3 DG Placement on Radial Distribution System, International Journal of Emerging Trends in Electrical and Electronics, May, 2013.

[7] P.P. Barker, Determining the impact of distributed generation on power systems: Part 1 -radial distribution systems, in: Proceedings of IEEE Power Engineering Society Summer Meeting, 2000, pp. 1645–1656.

[8] G. Celli, F. Pilo, Optimal distributed generation allocation in MV distribution networks, in: 22nd IEEE PES International Conference on Power Industry Computer Applications PICA 2001, Sydney, Australia, May 2001, pp. 81–86.

[9] N. Mithulananthan, Than Oo, LeVan Phu, Distributed generator placement technique in power distribution system

using genetic algorithm to reduce losses, Thammasat Int. J. Sci. Tech. 9 (September (3)) (2004) 56–62.

[10] N.S. Rau,Y.H.Wan, Optimum location of resources in distributed planning, IEEE Trans. Power Syst. 9 (4) (1994) 2014–2020.

[11] T. Griffin, K. Tomsovic, D. Secrest, A. Law, Placement of dispersed generations systems for reduced losses, in: Proceedings of the 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[12] C.Wang, M. Hashem Nehrir, Analytical approaches for optimal placement of distributed generation sources in power systems, IEEE Trans. Power Syst. 19; November (4); 2004; 2068–2076.

[13] W. Rosehart, Optimal placement of distributed generation, in: Nowicki (Ed.), 14th PSCC, Sevilla, 24–28 June 2002.

[14] Carpinelli G, Varilone P, Di Vito V, Abur A. Capacitor placement in three-phase distribution systems with nonlinear and unbalanced loads. IEE Proc Generation Transmission Distribution 2005;152(1):47–52.

[15] Wang J, Chiang H, Nanminu K, Darling G. Capacitor placement and real time control in large-scale un-balanced distribution systems: Part I and II. IEEE Trans Power Delivery 1997;12:953–64.

[16] Huang YC, Yang HT, Huang CL. Solving the capacitor placement problem in a radial distribution system using Tabu search application. IEEE Trans Power System 1996; 11:1868–73.

[17] Grainger JJ, Lee SH. Optimum size and location of shunt capacitors for reduction of losses on distribution feeders. IEEE Trans Power App System 1981;100:1105–18.

[18] Dlfanti M, Granelli GP, Maranninio P. Optimal capacitor placement using deterministic and genetic algorithm. IEEE Trans Power System 2000;15: 1041–6.

[19] Das D. Optimal placement of capacitors in radial distribution system using Fuzzy-GA method. J Electr Power Energy Syst 2008;30: 361–7.

[20] Sydulu M, Reddy VVK. Index and GA based optimal location and sizing of distribution system capacitors. In: Power engineering society general meeting, Tampa, FL; 2007. p. 1–4.

[21] Prakash K, Sydulu M. Particle swarm optimization based capacitor placement on radial distribution systems. Power Eng Soc Gen Meet 2007: 1–5.

[22] Safigianni AS, Salis GJ. Optimum VAr control of radial primary power distribution networks by shunt capacitor installation. Electrical Power Energy System 2001;23:389–401.

[23] Das D. Reactive power compensation for radial distribution networks using genetic algorithm. Electr Power Energy System 2002;24:573–81.

[24] Hsiao Ying-Tung, Chen Chia-Hong, Chien Cheng-Chih. Optimal capacitor placement in distribution systems using a combination Fuzzy-GA method. Electr Power Energy Syst 2004;26(7):501–8.

[25] Huang Tsong-Liang, Hsiao Ying-Tung, Chang Chih-Han, Jiang Joe-Air. Optimal placement of capacitors in distribution systems using an immune multi objective algorithm. Electrical Power Energy Syst 2008;30:184–92.

[26] Kannana SM, Renugab P, Kalyania S, Muthukumarana E. Optimal capacitor placement and sizing using Fuzzy-DE and Fuzzy-MAPSO methods. Appl Soft Comput 2011.

[27] Srinivasa Rao R, Narasimham SVL, Ramalingaraju M. Optimal capacitor placement in a radial distribution system using plant growth simulation algorithm. Electr Power Energy Syst 2011;33:1133–9.

[28] Naresh Acharya, Pukar Mahat and N. Mithulananthan, “An analytical approach for DG allocation in primary distribution network”, Electric Power and Energy Systems, vol. 28, pp.669-678, 2006.

[29] D. Das, Optimal placement of capacitors in radial distribution system using a Fuzzy-GA method, International Journal of Electrical Power and Energy Systems 30 (2008) 361–367

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