Strategic Placement of Distributed Generation in Distribution Networks

A. YOUNES Y.G. HEGAZY S. TAG ELDIN M. EL-METWALLY

Electrical Engineering R & D, Pegesco, Cairo, EGYPT

Electric Power and Machines Dept. Faculty of Engineering, Ain Shams University, Abbasia, Cairo, EGYPT

Electric Power and Machines Dept. Faculty of Engineering, Cairo University , Cairo, EGYPT

Abstract: -This paper proposes an algorithm for the strategic placement of distributed generation in distribution networks for single, two or three DG units. The most effective busses are selected to minimize the total power losses in each case and to improve the voltage profile. The proposed algorithm is implemented on the IEEE 44 bus large industrial power system that is used in the IEEE brown book, several case studies are analyzed and the results are presented.

Key-Words: - Distributed Generation, Distribution systems, Planning, Cost analysis.

1 Introduction

It is becoming widely accepted that distributed generation (DG) resources can provide benefits to distribution and transmission networks. DG affects the flow of power and voltage conditions at customers and utility equipment. These impacts may manifest themselves either positively or negatively depending on the distribution system operating characteristics and the DG characteristics.

DG must be reliable, dispatchable of the proper size and strategically placed to give the following system benefits: grid reinforcement, voltage support and improved power quality, loss reductions, transmission and distribution capacity release, improved utility system reliability [1]-[6]. DG capacity shall not exceed 25% of the total system capacity while connected to grid to maintain over all system stability [7].

As distribution network with DG are no longer passive, all questions about planning, maintenance and operation become more interesting and demand reassessment. Power injections from the DG change magnitude and even direction of network power flows. This causes an impact on network operation and planning practices of distribution companies with both technical and economic implications [8]-[13]. The main issues include where to locate and how to operate DGs to minimize the impact on distribution management. Additionally, it will be necessary to investigate whether DG capability and placement could be used to enhance distribution network planning and operation [14].

The selection of the best location for installation of DG units in large distribution systems is a complex problem. Lagrangian based approaches are used to determine optimal locations for placing DG, considering economic limits and stability limits [15].

Recently, optimization methods are applied to the optimization problems in power systems. A genetic algorithms (GA) based DG allocation method is presented where the power losses in an existing network is minimized [16]-[18]. In references [19], [20] the process of DG allocation is presented similar to capacitor allocation to minimize losses. Moreover, analytical approaches to determine the optimal location for placing DG in both radial and networked systems to minimize power losses are proposed which are not iterative algorithms, like power flow programs [21].

It is clear from the above, that the problem of DG allocation is very important and the installation of DG units at the best location can result in a decrease in system losses which leads to decrease in costs. For that reason, the use of an algorithm for strategic placement of DG can be very useful.

This paper proposes an algorithm for the strategic placement of distributed Generation in a distribution network for single, two or three DG units. The most effective busses are selected to minimize the total power losses in each case and to improve the voltage profile.

2 Strategic placement algorithm of DG

The proposed algorithm begins with traditional tasks as identifying the area of the distribution network under study. The main components for the DG connected distribution system are number of buses, type of buses, voltage level, transformers, reactors, lines, cables and the DG units.

The system components are simulated and the load flow is preformed for the system without installing DG units. The flow chart shown in fig. 1 and the step-by-step procedure is discussed as follows for single, two and three DG units' cases:

1. The single, two and three DG units' capacity shall be chosen as 25% of the total swing bus capacity. The reactive power range shall be identified (+/- Q_{max}) to support the DG power factor range for each case.
2. List the DG buses which support the DG power factor range.
3. Rotate the DG units' on the previous listed buses and perform the load flow study for each case.
4. Calculate the reactive power for each case.

The power factor of the DG is calculated and if the DG power factor is within the specified range then list the accepted buses which the DG are connected; while if the DG power factor is out of the specified range then these buses are rejected. Check the bus if one of its combinations is accepted then list these buses if not then reject the bus

3 Case Study

3. 1 System Composition

The proposed system under study is a "44 bus systems with total load of 6.2 MVA shown in Fig. 2 which is a typical composite single-line diagram for a large industrial power system that is used in IEEE brown book [22]. The main components for the system (buses, transformers, lines, cables and the DG units connected to the DG bus through a cable…..etc.) are modeled with all of its detailed parameters using ETAP program. The system data is presented in Appendix A. The proposed algorithm has been implemented on the system and the obtained results are listed in table 1.

Table 1: Listed buses in each DG case

Case	Listed buses combinations	Listed buses
Single DG unit	26 out of 41	26 out of 41
Two DG units	153 out of 171	17 out of 41
Three DG units	643 out of 969	17 out of 41

3.2 Analysis and Results

The buses combinations which support the DG power factor ≥ 85% in single, two and three DG cases are employed according to the algorithm presented in Fig. 1 to calculate the losses and voltage profile.

A. Calculation of losses

The overall P_{Losses} for the system is calculated in the following cases:

- Without installing DG units.
- Single, two and three DG units.

The most sensitive buses and not rejected in the two DG case were found to be Bus 18, Bus 16, Bus 30, Bus 37 and Bus 5. The overall P_{Losses} for the above buses are summarized as follows which shows the best bus location of the DGs to give the minimum P_{Losses}:

- Bus 18

- The single DG is placed at Bus 18.
- The two DGs are placed at Buses 18 and 37.
- The three DGs are placed at Buses 18, 37 and 18.

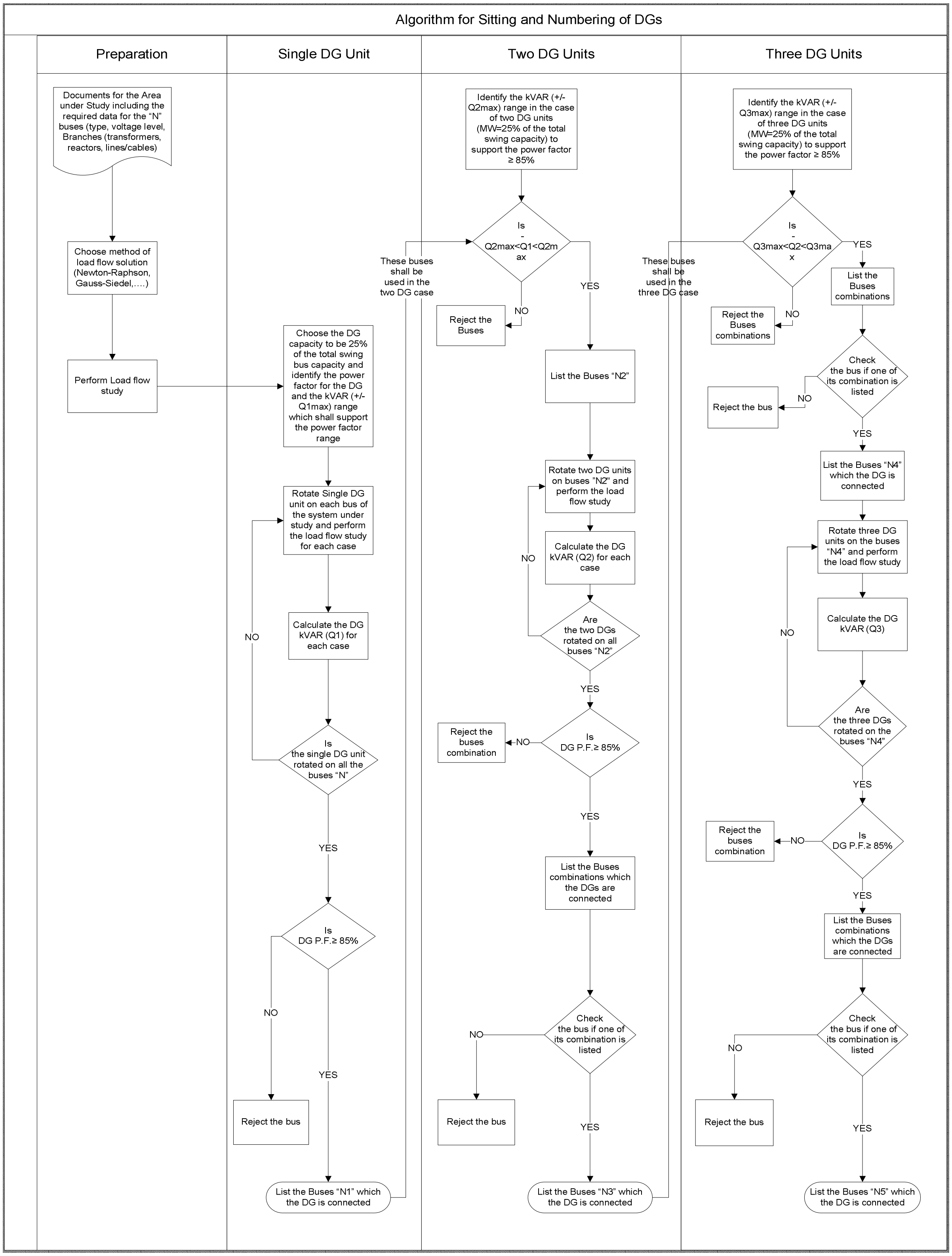

Fig. 1- Sitting and Number of DGs Algorithm

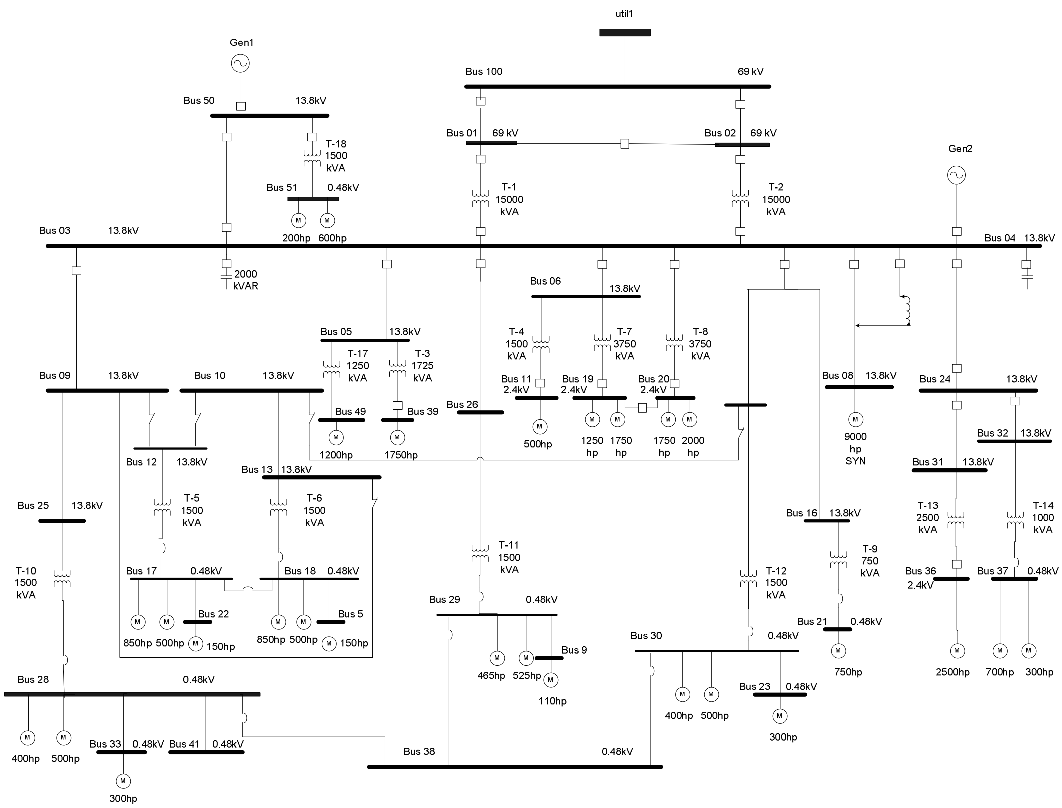

Fig.2:- The system composition

The strategic placement of the DGs in the system was concluded from the load flow studies on the combination of DG locations on bus 18 for single, two and three DG cases.

Figure 3 shows that the strategic location of the three DG case gives the least P_{Losses} for the system from the without, single and two DG cases. In case of locating the DGs in the locations shown above, 13% reduction in the P_{Losses} for the three DG case while it showed 9.7% for the single DG case and 11.8% for the two DG case.

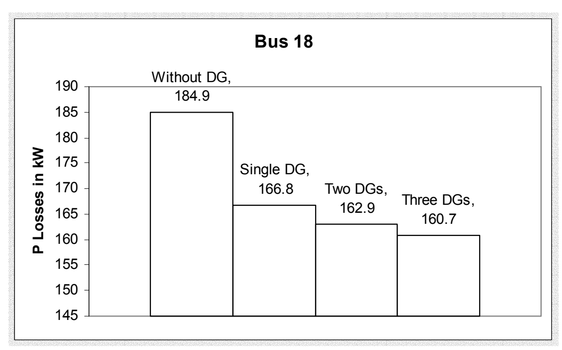

Fig. 3- Overall P_{Losses} without and with DG at Bus 18

- Bus 16

- The single DG is placed at Bus 16.
- The Bus is rejected in the two and three DG cases.

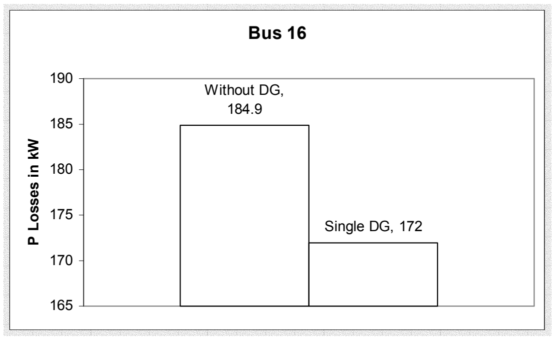

Fig. 4- Overall P_{Losses} without and with DG at Bus 16

Figure 4 shows that the strategic location of the single DG case gives the least P_{Losses} for the system from the without DG cases.

In case of locating the DGs in the locations shown above, 6.9% reduction in the P_{Losses} for the single DG case is presented.

- Bus 30
  - The single DG is placed at Bus 30.
  - The two DGs are placed at Buses 30 and 18.
  - The three DGs are placed at Buses 30, 37 and 21.

The strategic placement of the DGs in the system was concluded from the load flow studies on the combination of DG locations on bus 30 for single, two and three DG cases. Figure 5 shows that the strategic location of the three DG case gives the least P_{Losses} for the system from the without, single and two DG cases. In case of locating the DGs in the locations shown above, 13.7% reduction in the P_{Losses} for the three DG case while it showed 6.8% for the single DG case and 10.8% for the two DG case.

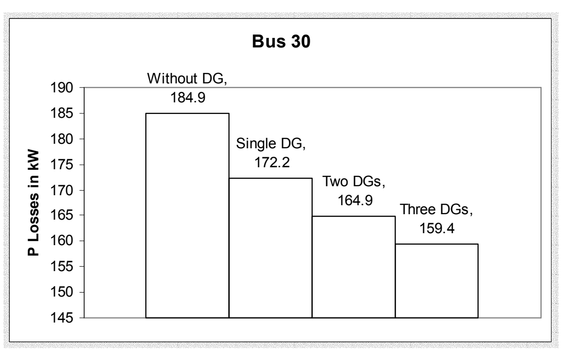

Fig. 5- Overall P_{Losses} without and with DG at Bus 30

- Bus 37
  - The single DG is placed at Bus 37.
  - The two DGs are placed at Buses 37 and 18.
  - The three DGs are placed at Buses 37, 21 and 5.

The best location for the DGs in the system was concluded from the load flow studies on the combination of DG locations on bus 37 for single, two and three DG cases.

Figure 6 shows that the strategic location of the three DG case gives the least P_{Losses} for the system from the without, single and two DG cases. In case of locating the DGs in the locations shown above, 14.3% reduction in the P_{Losses} for the three DG case while it showed 5.4% for the single DG case and 11.8% for the two DG case.

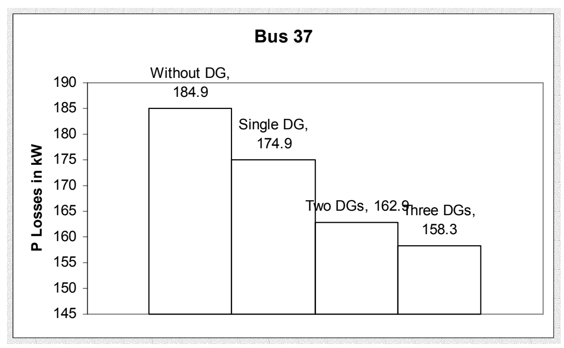

Fig. 6- Overall P_{Losses} without and with DG at Bus 37

- Bus 5
  - The single DG is placed at Bus 5.
  - The two DGs are placed at Buses 5 and 37.
  - The three DGs are placed at Buses 5, 37 and 21.

The best location for the DGs in the system was concluded from the load flow studies on the combination of DG locations on bus 5 for single, two and three DG cases.

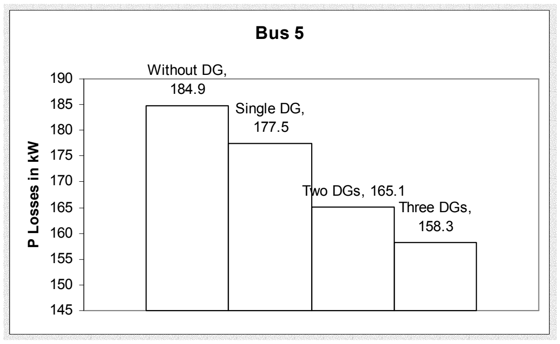

Fig. 7- Overall P_{Losses} without and with DG at Bus 5

Figure 7 shows that the strategic location of the three DG case gives the least P_{Losses} for the system from the without, single and two DG cases. In case of locating the DGs in the locations shown above, 14.3% reduction in the P_{Losses} for the three DG case while it showed 4% for the single DG case and 10.7% for the two DG case.

B. Voltage impact on the bus connected to the DG

The voltage magnitude is taken from the load flow study for the single, two and three DG cases. It was found that installing the same DGs at the same bus shall give different voltage magnitude levels and this due to combining identical generators which produce different reactances and reactive power.

It was also, found that installing the DGs at the same bus shall give the best voltage magnitude but the maximum voltage magnitude is in the single DG case and it is summarized in the following charts:

- Bus 18

Figure 8 shows that the strategic location of the single DG case gives the best voltage magnitude for bus 18 from the without, two and three DG cases.

In case of locating the DGs in the locations shown above, 2.46% increase in the voltage magnitude for the single DG case while it showed 2.3% for the two DG case and 2.27% for the three DG case.

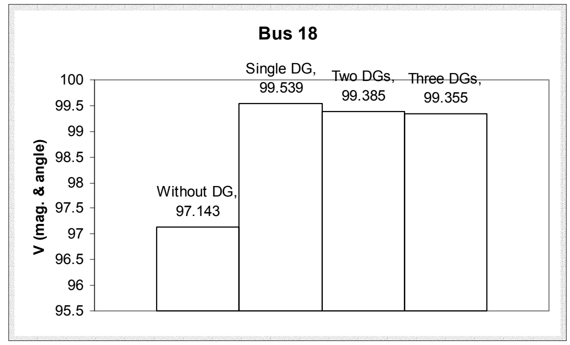

Fig. 8- Voltage magnitude without and with DG at Bus 18

- Bus 16

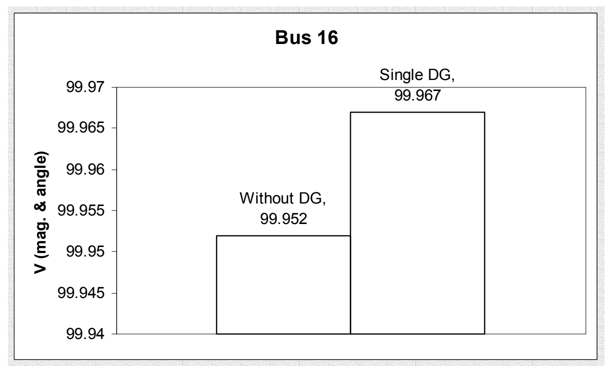

Fig. 9- Voltage magnitude without and with DG at Bus 16

Figure 9 shows that the strategic location of the single DG case gives the best voltage magnitude for bus 16 from the without DG case.

In case of locating the DGs in the locations shown above, 0.015% increase in the voltage magnitude for the single DG case.

- Bus 30

Figure 10 shows that the strategic location of the single DG case gives the best voltage magnitude for bus 30 from the without, two and three DG cases.

In case of locating the DGs in the locations shown above, 2.5% increase in the voltage magnitude for the single DG case while it showed 2.33% for the two DG case and 2.35% for the three DG case.

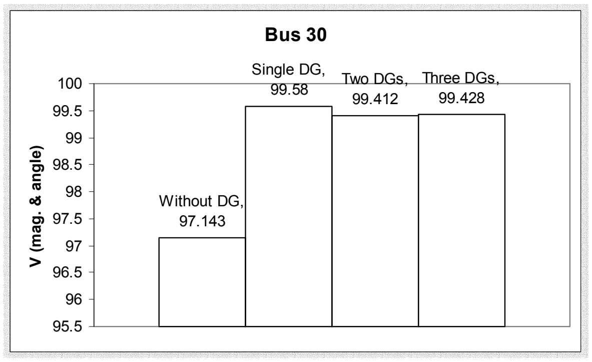

Fig. 10- Voltage magnitude without and with DG at Bus 30

-Bus 37

Figure 11 shows that the strategic location of the single DG case gives the best voltage magnitude for bus 37 from the without, two and three DG cases. In case of locating the DGs in the locations shown above, 2.65% increase in the voltage magnitude for the single DG case while it showed 2.47% for the two DG case and 2.51% for the three DG case.

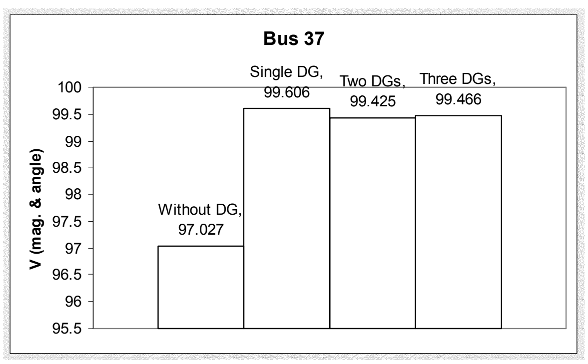

Fig. 11- Voltage magnitude without and with DG at Bus 37

4 Conclusions

A novel algorithm for the strategic placement of distributed generation units in electrical distribution system is presented in this paper.

The algorithm is implemented on the IEEE 44 bus large industrial power system that is used in the IEEE brown book, the strategic locations of a single DG, two DGs and three DGs are obtained and the performance of the system is measured with respect to the change in the system power loss and the voltage profile.

The system overall performance for the three DG case is shown to be superior over both the two DGs and the single DG.

References

[1] T. GOZEL , M.Hakan , U.EMINOGLU, A. BALIKCI " Optimal Placement and sizing of distributed Generation on Radial Feeder with Different static load models " , stake planning organization of turkey (project No : 2003 k 120530).

[2] N.S. Rau and Y.H. Wan, " Optimum location of resources in distributed planning," IEEE Trans. Power Syst., vol. 9, pp. 2014-2020, Nov. 1994.

[3] K.-H. Kim, Y.-J.Lee, S.-B.Rhee, S.-K.Lee and S.-K.You,'Dispersed generator placement using fuzzy-GA in distribution systems," in Proc. 2002 IEEE Power Engineering Soc. Summer meeting, vol.3, Chicago, IL, July 2002, pp. 1148-1153.

[4] N. Hadjsaid, J.F. Canard, and F. Dumas," Dispersed generation impact on distribution networks," IEEE Comput. Appl. Power, vol. 12, pp.22-28, Apr. 1999.

[5] T. Griffin, K. Tomsovic, D. Secrest, and A. Law, " Placement of dispersed generation systems for reduced losses," in Proc 33rd Annu. Hawaii Int. Conf. Systems Sciences, Maui, HI, 2000.

[6] M.H. Nehrir, C. Wang, and V. Gerez, " Impact of wind power distributed generation on distribution systems," in Proc. 17th Int. Conf. Electricity Distribution (CIRED), Barcelona, Span, May 2003.

[7] www.distributed-generation.com

[8] T. Ackermann and V. knyazkin, "Interaction between distributed generation and the distribution network: Operation aspects" in Proc. Second Int. Symp. Distributed Generation: Power System Market Aspects, Stockholm, Sweden, 2002.

[9] G. Joos, B-T.Ooi, D.Mc Gillis, F.D. Galiana and R. Marceau, "The potential of distribution generation to provide ancillary services", in Proc. IEEE Power Eng. Soc. Summer Meeting, Seattle, WA, 2000.

[10] T. Hoff, H.J.Wenger, and B.K.Farmer, "The value of grid-support photovoltaics in providing distribution system voltage support", in Proc.

American Solar Energy Society Annual Conf. San Jose, CA, 1994.
[11] M.I. Marei, E.F. El-Saadany, amd M.M.A. Salama, “A novel control algorithm for the DG interface to mitigate power quality problems,” IEEE Trans. Power Del., vol.19, no. 3, pp. 1384-1392, Jul. 2004.
[12] N. Jankins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac, Embedded Generation. London, U.K.: Inst. Elec. Eng., 2000.
[13] H.L. Willis and W.g. Scott, Distributed Power Generation. Planning and Evaluation, 1st ed. New York: Marcel Dekker 2000.
[14] Luis .F.Ochoa, Antonio Padilha- Feltrin, Garethp,Harrison “ Evaluating Distributed Generation impacts with a multiobjective lndex “ IEEE transactions on power delivery, 2006.
[15] Rosehart W, Nowicki E,”Optimal placement of distributed generation,” Proceedings of 14th power systems computation conference, section 11, paper 2, Servilla; 2002, p.1-5.
[16] Celli G, Pilo F, “Optimal distributed Generation allocation in MV distribution networks,” Proceedings of IEEE PES conference on power industry computer applications-PICA 2001, Australia; 2001, p.81-6.
[17] Carmen L.T. Borges, Djalma M. Falcao, ”Optimal distributed generation allocation for reliability, losses, and voltage improvement,” Electrical Power and Energy Systems 28 (2006) 413-420, 2006.
[18] Goldberg D. Gentic, “Genetic algorithms in search, optimization and machine learning, Reading, MA: Addison-Wesley; 1989.
[19] Alvarado FL.,” Locational aspects of distributed generation. Proceedings of IEEE PES winter meeting, Ohio, vol.3; 2001, p.140.
[20] H.L. Willis, “ Analytical methods and rules of thumb for modeling DG- distribution interaction, “ in Proc. 2000 IEEE Power Engineering Society Summer Meeting, vol.3, Seattle, WA, July 2000, pp.1643-1644.
[21] Caisheng Wang, M. Hashem Nehrir, “ Analytical approaches for optimal placement of distributed generation sources in power systems, “ IEEE Trans. Power Syst., vol. 19, pp. 2068-2076, Nov. 2004.
[22] American National Standard (ANSI) Recognized as an IEEE Std 399-1997 “IEEE Recommended Practice for Industrial and commercial Power Systems Analysis” (Brown Book).