Investigation and Enhancement of Distribution System Loadability using DG Units Considering Random Behavior of Loads

Mostafa Alimohamadi[1], Ali Asghar Ghadimi[2]
[1]Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Arak-Iran;
Mostafa.alimohamadi65@gmail.com, (Corresponding Author)
[2]Department of Electrical Engineering, Faculty of Engineering, Arak University, Arak-Iran; a-ghadimi@araku.ac.ir

Received February 2015 Revised March 2015 Accepted March 2015

ABSTRACT:
Considering that nowadays has occurred to a widely application of distributed generation in distribution systems, it is necessary to investigation of problems and issues that may arise the distribution system. In this paper the main issue is to investigate the effect of random load behavior of distribution system on enhancement of system loadability in presence of DG units. The results show that random load behavior how and how much will affect on improved system loadability. To do these investigations, at first the optimized place for installing DG has been specified in certain load condition using Genetic Algorithm, and its effect on loadability is investigated. Then network loads has taken randomly and the results are obtained and investigated for this case too. Moreover, in certain load condition, effect of number of DG and type of generation capability of real and reactive power (due to the fact that some types of DG can only generate and inject real power) has been studied and best one is specified.

KEYWORDS: Distribution System, Loadability, Distributed Generation, Random Load Behavior.

1. INTRODUCTION

Generally due to power systems development, methods for delivery of electricity to consumers, because of voltage variation, are a very important issue that power plants are following the rules and criteria. A good solution for improved transmission and distribution of electric power that most consumers prefer is to generate energy near the loads. Very small units that are connected to the distribution system directly, is called decentralized or distributed generation. Restructuring of the electricity industry and the development of renewable energies are the most important factors in the development of this type of electricity generation. Today, DG has a key role in the electrical distribution system. For example, improved reliability index, improved stability index and loss reduction in power system can be obtained by using DG. One of key issues in use of DG is the placement of these resources in distribution networks. Loadability of distribution system and its enhancement has an effective role in the operation of power system.

In the recent years there has been a great concern in integration of distributed generation units at distribution level. DGs are able to provide cost-effective, environmentally friendly, higher power quality and more reliable energy solutions than conventional generation. Loadability enhancement is another benefit that DG can add to distribution system, if optimally placed and sized. This paper presents a study for placement of DG considering system loadability and random behavior of loads.

Optimal distributed generation allocation and sizing in distribution systems can be used in order to minimize the electrical network losses and to guarantee acceptable reliability level and voltage profile through combination of genetic algorithms (GA) techniques with methods to evaluate DG impacts in system reliability, losses and voltage profile.[1] In Ref. [1] The fitness evaluation function that drives the GA to the solution is the relation between the benefit obtained by the installation of DG units and the investment and operational costs incurred in their installation. Ref. [2] has introduced a simple methodology for placing a distributed generation with the view of increasing loadability and voltage stability of distribution system. Effectiveness of the proposed placement technique is demonstrated in a practical distribution system. Distributed generation can be integrated into distribution systems to meet the increasing load demand while expansion and reinforcement of these systems are faced by economical and environmental difficulties. In Ref. [3] an efficient methodology for integration of DG power into distribution systems, in order to maximize the voltage limit loadability is presented.

The main aim of Ref. [4] is the investigation of the impact of DG on the loadability of medium voltage distribution networks. The loadability is evaluated in two aspects, the maximum loading according to the voltage limit (VL) and the maximum loading according to the voltage stability limit (VSL). The impact of the reactive power injection from DG on the system losses is also investigated. The Continuation Power Flow method is used to evaluate the loadability with respect to the two aspects. Loadability enhancement is investigated through using two main types of DG units - synchronous machine and induction machine in Ref. [5], the proposed methodology is based on the concept of reactive power margin. Buses have been ranked based on the reactive power margin and grouped as strong and weak buses for finding suitable location of DG units.

Ref. [6] presents a methodology for optimal placement of DG units in distribution networks to guarantee the enhancement of voltage profile and reduce distribution system losses. The methodology aims to find the configuration, among a set of system components, which meets the desired system reliability requirements, taking into account the stability limits. DG is applied for micro-grid (MG) planning in a primary distribution system. In Ref. [7] the optimal region for micro-grid is identified by the loss sensitivity factor, then, a Pareto-based non-dominated sorting genetic algorithm II (NSGA-II) is proposed to determine locations and sizes of a specified number of distributed generator units (DGs) within MG. With ever-increasing demand of electricity consumption and increasing open access particularly in restructured environment, transmission line congestion is quite frequent. For maximum benefit and mitigation of congestion, proper sizing and position of distributed generators are ardently necessary. Ref. [8] presents a simple method for optimal sizing and optimal placement of generators. A simple conventional iterative search technique along with Newton Raphson method of load flow study is used. Numerical programming methods are used for optimal placement of controlled thyristor phase angle regulator to promote loadability of power system [9]. In Ref. [10] a novel combined genetic algorithm (GA)/particle swarm optimization (PSO) is presented for optimal location and sizing of DG on distribution systems. The objective is to minimize network power losses, better voltage regulation and improve the voltage stability within the frame-work of system operation and security constraints in radial distribution systems. Ref. [11] uses tangent vectors for ranking buses and chooses best place only for one type of DG for example synchronous generator with fixation of its size. Ref [12] optimizes both of place and size but considers DG as a real power resource without notice at its capability of reactive power. Loss minimization is the most objective of studied papers. Several methodology are applied for distribution network loss minimization through DG sizing and placing, such as analytical method, genetic algorithm [13], ant colony [14], evolution programming (EP) [15] and dynamic programming [16].

The scope of Ref. [17] is the optimal sitting and sizing of distributed generation within a power distribution network considering uncertainties. A probabilistic power flow (PPF)-embedded genetic algorithm (GA)-based approach is proposed in order to solve the optimization problem that is modeled mathematically under a chance constrained programming framework. The uncertainties considered include: (i) the future load growth in the power distribution system, (ii) the wind generation, (iii) the output power of photovoltaics, (iv) the fuel costs and (v) the electricity prices. Ref. [18] proposes a hybrid possibilistic-probabilistic evaluation tool for analyzing the effect of uncertain power production of distributed generations (DG) on active losses of distribution networks. The considered DG technologies are Gas and wind turbines. This tool is useful for Distribution Network Operators (DNOs) when they are faced with uncertainties which some of them can be modeled probabilistically and some of them are described possibilistically. The generation pattern of DG units change the flow of lines and this will cause in change of active losses which DNO is responsible for compensating it. In Ref. [19] an optimality criterion is investigated to minimize losses by including load uncertainty, different DG penetration levels and reactive power of multiple-DG concept. Due to the complexity of the multiple-DG concept, artificial neural network based optimal DG placement and size method is developed.

However, placement of DG sources in order to enhance the distribution system loadability index has been noticed less, in this paper we show that DG optimal placement increases system loadability significantly. Also, since the network loads are assumed to be constant in all papers, but in this paper random behavior of loads is considered and its effect on loadability is investigated.

2. THE IMPACT OF VARIOUS DG TECHNOLOGIES

2.1. DG with synchronous generator (SG)

Synchronous generators have this capability of both generating and absorbing reactive power. The local reactive power generation reduces its import from the substation, thus reduces the losses of network lines, and improves the voltage profile. As a logical result, the voltage security is also improved. An immediate conclusion to be drawn here is that the installation of a distributed generation will most likely enhance the voltage stability of the network as long as the DG rating is smaller than twice of the local loading level. The utilization of self-commutated converters for interfacing DG units with network allows fast and precise control of magnitude and phase of the output voltage. Therefore, reactive power can be either generated or absorbed, depending on the control mode. Since normally the power factor of such a converter is close to unity, no reactive power is injected into the network however, the overall impact of the distributed generator on the voltage stability is positive. This is due to the improved voltage profiles as well as decreased reactive power losses, as following equation suggests:

$$Q_{loss} = \frac{(P_{load}-P_{DG})^2+(Q_{load}-Q_{DG})^2}{V^2} X_{line} \qquad (1)$$

Where P_{load}, Q_{load}, P_{DG} and Q_{DG} are the active and reactive power of the load and DG, respectively and X_{line} is the aggregate reactance of the line connecting the load to the feeding substation. [21].

2.2. DG with induction generator (IG)

An induction generator possesses a number of features that make it very suitable for DG. Some of these features are: relatively inexpensive prices, insignificant maintenance requirements, in addition these motors are robust. On the other hand, when directly connected to the network, this type of DG will always consume reactive power thus contributing to the factors increasing the probability of encountering voltage stability problems. The reactive power consumption of induction generators is normally compensated by shunt capacitor banks. This however is only a partial solution to the voltage stability problem, since a voltage reduction will decrease the amount of reactive power generated by the capacitor banks, while increasing the reactive power consumption of the induction generator. Therefore, there is a risk that instead of supporting the network at an under voltage situation the induction generator will further depress the system voltage [21].

3. PROBLEM FORMULATION AND SUGGESTED INDICES

In order to assess and quantify the distributed generation advantages, appropriate mathematical models must be applied along with distribution system models and power flow calculations to reach indices of these advantages. Between several advantages we have got three essential ones.

3.1. Network Loss Reduction Index (NLRI)

One of the advantages which can be obtained is reduction of electrical losses of network. With DG installation, line currents would reduce, hence it leads to network loss reduction.

The real power loss in a system is given by (2). This is popularly referred to as ‘‘exact loss’’ formula [20].

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iQ_j\right)\right] \qquad (2)$$

Where, $\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j)$, $\beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$ and $r_{ij} + jx_{ij} = Z_{ij}$ are the ijth element of [Zbus] matrix.

The suggested network line loss reduction index is described as follow:

$$NLRI = \frac{NL_{W\,DG}}{NL_{Wo\,DG}} \qquad (3)$$

Where NL_{WDG} and NL_{WoDG} are total network loss after DG integration and before DG integration respectively.

Network loss (NL) can be presented as:

$$NL = 3\sum_{i=1}^{M} I_i^2 R_i D_i \qquad (4)$$

I_i, D_i and R_i are the per unit line current in distribution line i, the line resistance (pu/km) and distribution line length (km) respectively, and M is the number of lines in the system.

This index can be used to specify the best place of DG in order to maximize network loss reduction. The minimum value of NLRI corresponds to the best DG place in terms of network loss reduction.

3.2. Voltage Profile Enhancement Index (VPEI)

Given the above issues, use of the DG, will yield improved voltage in various buses. As already has been mentioned, one of the most significant problems in the distribution network is inappropriate voltage profile. The impact of distributed generation on voltage regulation can be positive or negative, and this depends on the distribution system, specifications of distributed generation and where they are installed. Since the voltage is one of the most important criteria in terms of the power quality in services provided by electricity companies, Therefore in recent years, with the presence of distributed generation in distribution networks, more attention has been performed to investigate the effect of these units on voltage [22], [23].

Voltage profile enhancement index (VPEI) quantifies voltage profile improvement in presence of DG [24], which is explained as following:

$$VPEI = \frac{VP_{W\,DG}}{VP_{Wo\,DG}} \qquad (5)$$

The general expression for VP is given as:

$$\mathrm{VP} = \sum_{i=1}^{N} V_i L_i K_i \qquad (6)$$

Where, $\sum_{i=1}^{N} K_i = 1$, V_i is the voltage magnitude at bus i in per-unit, Li is the load represented as complex bus power at bus i in per-unit, K_i is the weighting factor for bus i, and N is the total number of buses in the distribution system. The weighting factors are chosen based on the importance of different loads.

3.3. Network Loadability Improvement Index

Reduction of transmitted real and reactive power is one of the most important advantages of DG integration, which results lines capacity increment and prevents the construction and development of new lines and other facilities such as: transmission and distribution substations and therefore reduce related costs. Network transmission apparent power improvement or network loadability improvement index is expressed as follow:

$$\mathbf{LTAPII} = \frac{\mathbf{LTAP_{W\ DG}}}{\mathbf{LTAP_{Wo\ DG}}} \quad (7)$$

Where, $LTAP_{WDG}$ and $LTAP_{WoDG}$ are the total line transmission apparent power with DG and without DG respectively.

$$\mathbf{LTAP} = \sum_{i=1}^{M} \mathbf{I_i}.\mathbf{V_j} \quad (8)$$

V_j is the voltage magnitude at bus j in per units, I_i is the per unit line current in distribution line I with DG and without DG. Based on this Description, there is following aspects:

NLII>1, DG is not beneficial,

NLII=1, DG has no impact on system transmission active and reactive powers,

NLII<1, DG has improved transmission active and reactive powers.

4. SUGGESTED METHOD: USING DG INTEGRATION TO ENHANCE LOADABILITY

As mentioned, installation of DG can improve various parameters of line, that loadability is one of the most important one. For this propose, place of DG must be in the best buses. In this paper a GA method is employed to DG allocation.

4.1. Objective function selection

The proposed approach focuses on the minimization of a combined objective function which has been designed to reduce power losses, improve voltage profile and increase the efficiency of system loadability through optimal placement of distributed generations simultaneously. The main objective function can be formulated as:

$$OF = -\left((BW_{VPE}).(VPEI) + \left(\frac{BW_{NLR}}{NLRI}\right) + (BW_{NLI}).(NLII)\right) \quad (9)$$

$$BW_{VPE} + BW_{NLR} + BW_{NLI} = 1 \quad (10)$$

BW_{VPE}, BW_{NLR} and BW_{NLI} are weighting factors of corresponding indices.

4.2. Problem Constraints

4.2.1. Buses Voltage Limitation

If bus voltage comes more or less than an acceptable value, it cause to reduce power quality and might damage consumers. Hence, various buses voltage of network must be in the normal range.

$V_{imin} < V_i < V_{imax}$

4.2.2. Real and Reactive Power Generation Limitation

Another constraint that must be considered is the real and reactive power of power plant, which are expressed as following:

$PG_{i\ max} < PG_i < PG_{i\ min}$

$QG_{i\ max} < QG_i < QG_{i\ min}$

4.2.3. Line Passing Flow Limitation

In designing of distribution system, the lines between buses have a certain capacity. S_{ij} is the power flow between buses i and j, which must not exceed the maximum power flow between buses i and j.

$S_{Gij} < S_{ijmax}$

4.3. DG Allocation Using Genetic Algorithm

In the mentioned method, optimization is used according to natural selection and genetic rules. In several cases genetic algorithm is different from conventional optimization methods such as gradient methods, linear programming Genetic algorithm.

1- Works with a set of encoded parameters.

2- Starts from a parallel set of points instead of one point and the probability of reaching to the false optimum point is low.

3- Uses the original data of the objective function.

Employing GA for DG allocation that related flowchart is shown in Fig. 1 needs to determine 6 steps, as following:

- For DG allocation, the initial population is the primary proposed locations.
- In the selection stage certain number of the chromosomes that have lower costs (better chromosomes) should be selected to generate their offspring. (In this paper half of chromosomes).
- In combination stage parent combination has been done to generate offspring. At this stage, for each of two selected parents we will have two children.
- In this stage, new created population that includes parents and children are mutated. At this stage designs that have a lower cost comparing to initial chromosomes, may be created.
- In displacement stage, chromosomes with the lowest cost are selected as best chromosomes. This is the same chromosome that mutation operation is not occurred on it.
- In continue the convergence of the answers will be checked out .The number of iterations in each step is checked in order to show that we have got the same answers or not? If we're not reaching; algorithm will return in the second stage otherwise the algorithm ends [25].
-

5. LOAD RANDOM BEHAVIOR MODELING

The increasing utilization of renewable energy sources, as well as the unbundling of formerly integrated utilities poses new challenges to grid operation. At the same time as power flow patterns get less predictable, the necessity for an operation of the grid closer to its limits leads to the need of more appropriate approaches for dealing with uncertainties in grid usage. The classical deterministic load flow calculation techniques are not able to cope with uncertainties and can only be used within tight limits.

For networks with constant configuration and line parameters and given set of probable values of node loads, the problem is to find the set of corresponding values of branch flows. The necessity of dealing with such a problem stems from the uncertainty of load data. The uncertainty can be due, for example, to: Measurement error or forecast inaccuracy, the load is known or assumed within certain limits, unscheduled outage.

As a reaction to this shortcoming the field of Probabilistic Load Flow (PLF) evolved. The main aim of PLF is to calculate the probability of operational grid states from the probability of a certain grid usage profile. In general two main types of PLF algorithms can be distinguished. The first type makes use of classical load flow calculation for a selected set of grid usage profiles. The calculated grid state is associated with the overall probability of the used grid usage profile. Due to the computational complexity Monte-Carlo approaches are used to find an approximate result for load flow probabilities in a reasonable amount of time. The second type bases on an analysis of the underlying grid in order to find a model allowing for the usage of convolution techniques. Most of these methods use a linearization of the Load Flow equation at a certain expansion point [26].

For the above and other reasons the load is not known exactly but instead a range of values are given together with frequency of occurrence. Traditional method of load flow solution requires specific value of loads, and any change in load will require a new solution. A practical way to overcome the difficulties is by selection of a limited number of loads variations [27].

In the presented method, the effect of changes in bus loads over time by using a stochastic simulation approach is included. Different types of distributions can be chosen. The uncertainty of hourly bus loads can be modeled by normal distributions with respective means and standard deviations to indicate the level of variations [28].

Fig. 2 shows the process of suggested stochastic simulation. For each feeder configuration, bus injection data required for one hundred load flow simulations (i=1~100) are randomly selected from their respective distributions for each bus and each hour (h=1~24). The number of the simulated operation conditions (i) can be increased to cover more operation conditions. But in the simulation it was found that selected operation conditions are proper and acceptable.

6. NUMERICAL RESULTS AND DISCUSSIONS

6.1. Test System

The distribution system used in this paper is depicted in Fig. 3. It is a balanced three-phase loop system that consists of 30 nodes and 32 segments, operating at 6.5 kV voltage level. It is assumed that all the loads are fed from the substation located at node 1. The loads belonging to one segment are placed at the end of each segment. The system has 30 loads totaling 4.43 MW and 2.72 MVAR, real and reactive power loads respectively. [19]

$V_{base} = 6.5KV$, $S_{base} = 10MVA$

6.2. Simulation and discussion

According to Section 4.3, the initial population, mutation rate and the number of iteration of genetic algorithm are considered 20, 0.1 and 100 respectively. In the simulation, it was observed that the suggested values are appropriate. To analyze the efficiency of the proposed approach on loadability, two scenarios are considered, all programmed in MATLAB.

6.2.1. First scenario (Certain load condition)

In the first scenario, buses loads are certain and unchanged and has been investigated in 3 cases:

1- Using one IG (injects only real power).

2- Using one SG (injects both real and reactive power).

3- Using three SG.

In this case, IG capacity is 3 MW, SG capacity is 3 MW and 1.5 MVAR, and when 3 SG is used, capacity of each SG is 1.25 MW and 0.75 MVAR. Location of DG is bus 21, and when 3 DG is used, buses 8, 19 and 24 are obtained.

As illustrated in Figures 4 and 5, it is observable that when DG is integrated in distribution system, has been got satiable results. Figure 5 shows the comparison of lines current in several cases of using DG and without DG. Based on this figure, when DG is integrated, the lines current have decreased so much, and SG impact is more than IG impact. And it is obvious that when 3 SG is used, this impact is more.

Figure 4 illustrates voltage profile in different cases of using DG, that we can observe improvement in network voltage profile. Simulation results of other studied values such as real and reactive power losses, loadability index (LTAPII) and voltage regulation are presented in Table 1. As it is specific, all studied values have improved more after integrating three SG.

6.2.2. Second scenario (Random load condition)

In the second scenario, the network load consumption changes during different hours, furthermore, buses loads vary randomly. And loadability has been studied in terms of the above, there are two cases:

1- Using one SG.

2- Using three SG.

From simulation results of certain load condition in section 6.2.1, we have got that SG has stronger impact on system parameters improvement, thus, in this section IG has not been used and only SG is applied.

As mentioned in section 5, in random load condition, in addition of random variation of buses load, consumption load of network also changes during the time. The hourly load profile is shown in figure 6.

In figures 7-9, transmission apparent power, voltage regulation and amount of loss reduction are respectively illustrated when one DG is integrated, and figures 10-12 shows named parameters when three DG are connected, totally in random load condition. As it is observable in these figures, in all hours voltage regulation has improved, about transmission apparent power and real and reactive power loss reduction, except a few hours which network consumption power is very low, in other hours results have improved as certain load condition. It means impact of DG integration on loadability and other studied parameters has been positive. Unless in a few hours that total load of network is low and losses have increased.

The reason for higher losses can be explained by the fact that the distribution system was initially designed such that power flows from the sending end (source substation) to the load and conductor sizes are gradually decreased from the substation to consumer point. Thus without reinforcement of the system, the use of high capacity DG will lead to excessive power flow through small-sized conductors and hence results in higher losses.

7. CONCLUSION

Simulation results for certain load condition show that installing DG has a positive impact on loadability improvement of distribution system. Also, it has a positive and acceptable effect in random load condition. Other results that have been obtained from simulations are:

- Application of DG in distribution system reduces transmission power in distribution lines.
- DG can enhance the voltage profile, reduce electrical losses of lines and thus increase the load ability.
- In order to optimal use of DG resources is essential that both the size and location of DG should be carefully considered.
- According to the simulation results, using DG at several locations relative to one location shows better results in terms of load ability.
- According to the simulation results, using DG with capability of generating both real and reactive power (SG) would improve load ability more than using DG with capability of generating real power (IG).
- At random load condition and using the suggested method, if more than one DG is installed, the desired result is achieved more.

REFERENCES

[1] B. Carmen L.T., Djalma M. Falcao, **"Optimal distributed generation allocation for reliability, losses, and voltage improvement"**, *Elsevier, Electrical Power and Energy Systems*, Vol. 28, Issue 6, pp. 413–420, 2006.

[2] A. Lomi, N. Cong Hien, N. Mithulananthan, "**Application of Distributed Generation to Enhance Loadability of Distribution System, A Case Study"** *Sustainable Alternative Energy (SAE), 2009 IEEE PES/IAS Conference on*, pp.1-7, 2009.

[3] N.G.A. Hemdan , M. Kurrat **"Efficient integration of distributed generation for meeting the increased load demand"** *Elsevier, Electrical Power and Energy Systems*, Vol. 33, Issue 9, pp. 1572–1583, 2011.

[4] N.G.A. Hemdan, M. Kurrat, **"Loadability Aspects For Medium Voltage Distribution Networks With Integration Of Decentralized Generation"** *International Journal of Distributed Energy Resources*, Vol. 5, Issue 3, pp. 187 – 200, 2009.

[5] T. Aziz, T. K. Saha, N. Mithulananthan, **"Distributed Generators Placement for Loadability Enhancement based on Reactive Power Margin"** *9th International Power and Energy Conference*, IPEC 2010, pp. 740 – 745, 2010.

[6] K. Nagaraju, S. Sivanagaraju, T. Ramana, V. Ganesh, **"Enhancement of Voltage Stability in Distribution Systems by Optimal Placement of Distribution Generator",** *Distributed Generation & Alternative Energy Journal*, Vol. 27, No. 2, pp. 25-41, 2012.

[7] K. Buayai, W. Ongsakul, N. Mithulananthan, **"Multi-objective micro-grid planning by NSGA-II in primary distribution system"**, *European Transactions On Electrical Power*, Vol. 22, Issue 2, pp. 170-187, 2012.

[8] Sudipta Ghosh, S.P. Ghoshal, Saradindu Ghosh "**Optimal sizing and placement of distributed generation in a network system"**, *Elsevier, International Journal of Electrical Power and Energy Systems*, Vol. 32, Issue 8, pp. 849-856, 2010.

[9] A. Kumar, S. Parida, S.c Srivastava and S.N. Singh, **"Enhancement of Power System Loadability with Optimal Location of TCPAR in Competitive Electricity Market Using MILP"**, *International Conference on Power System*, Kathmandu, Nepal, pp. 705-710, 2004.

[10] M. H. Moradi, M. Abedini, **"A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems"**, *Elsevier, International Journal of Electrical Power and Energy Systems*, Vol. 34, Issue 7, pp. 66- 74, 2012.

[11] N. Mithulananthan and T. Oo, **"Distributed Generator Placement to Maximize the Loadability of Distribution System",** *International Journal of*

Electrical Engineering Education, Vol. 43, No. 2, pp. 107-118, 2006.

[12] N. Acharya, P. Mahat, and N. Mithulananthan, **"An analytical approach for DG allocation in primary distribution network"**, *International Journal of Electrical Power & Energy Systems*, vol. 28, pp. 669-678, 2006.

[13] E. Haesen, M. Espinoza, B. Pluymers, I. Goethals, V. Thong, J. Driesen, "**Optimal placement and sizing of distributed generator units using genetic optimization algorithms"**, *Electrical Power Quality Utility Journal*, pp.97–104, 2005.

[14] FS. Abu-Mouti, ME. El-Hawary, "**Modified artificial bee colony algorithm for optimal distributed generation sizing and allocation in distribution systems"**, *IEEE Electrical Power & Energy Conference (EPEC). Montreal (QC)*; pp. 1–9, 2009.

[15] SGB. Dasan, S. Ramalakshmi, R. Devi, **"Optimal siting and sizing of hybrid distributed generation using EP"**, *International conference on power systems*, 2009 ICPS'09. Kharagpur: IEEE; pp. 1–6, 2009.

[16] N. Khalesi, N. Rezaei, M-R. Haghifam, "**DG allocation with application of dynamic programming for loss reduction and reliability improvement"**, *International Journal of Electric Power & Energy System*, Vol. 33, pp. 88–95, 2011.

[17] V.A. Evangelopoulos, P.S. Georgilakis, **"Optimal distributed generation placement under uncertainties based on point estimate method embedded genetic algorithm"**, *IET Generation, Transmission & Distribution*, Vol. 8, Issue 3, pp. 389 – 400, 2014.

[18] A. Soroudi, M. Ehsan, "**A possibilistic-probabilistic tool for evaluating the impact of stochastic renewable and controllable power generation on energy losses in distribution networks- A case study"**, *Elsevier, Renewable and Sustainable Energy Reviews*, Vol. 15, Issue 1, pp. 794-800, 2011.

[19] F. Ugranlı, E. Karatepe, **"Multiple-distributed Generation Planning Under Load Uncertainty and Different Penetration Levels"**, *Elsevier, International Journal of Electrical Power & Energy Systems*, Vol. 46, pp. 132-144, 2013.

[20] N. Acharya, P. Mahat, and N. Mithulananthan, **"An analytical approach for DG allocation in primary distribution network"**, *Elsevier, International Journal of Electrical Power & Energy Systems*, Vol. 28, Issue 10, pp. 669-678, 2006.

[21] H. Hedayati, S.A. Nabaviniaki and A. Akbarimajd, **"A Method for Placement of DG Units in Distribution Networks"**, *Power Delivery, IEEE Transactions on*, Vol. 23, Issue 3, pp. 1620-1628, 2008.

[22] Kojovic, **"Impact of DG on Voltage Regulation"**, *IEEE/Power Engineering Society Summer Meeting*, Vol. 1, pp. 97-102, July 21-25, 2002.

[23] P.P. Barker and R.W. de Mello, **"Determining the Impact of Distributed Generation on Power Systems: Part 1-Radial Distribution Systems"**, *IEEE/Power Engineering Society Summer Meeting*, Vol. 3, pp. 1645-1656, July 16-20, 2000.

[24] T. Ackermann, G. Andersson and L. Soder, "**Distributed Generation: a Definition"**, *Elsevier, Electric Power System Research*, Vol. 57, Issue 3, pp. 195-204, 2001.

[25] M. javadi, 2008, Genetic Algorithm, MS thesis, Imam Hossein University, Tehran, Iran.

[26] J. Schwippe, O. Krause, C. Rehtanz, **"Probabilistic Load Flow Calculation Based on an Enhanced Convolution Technique"**, *IEEE Bucharest Power Tech Conference*, 2009.

[27] B. Borkowska, "Probabilistic Load Flow", *Power Apparatus and Systems, IEEE Transactions on*, Vol. 93, pp. 752-759, 1974.

[28] Sheng-Yi Su, CN. Lu, RF. Chang and G. Gutierrez, "**Distributed Generation Interconnection Planning: A Wind Power Case Study"**, *Smart Grid, IEEE Transactions on*, Vol. 2, No.1, pp. 181-189, 2011.

Tables

Table1. Studied Values of Network in Certain Load Condition

Case Study	DG Location	Active Loss (KW)	Reactive Loss (KVAR)	NLII	VR%
Without DG	-	170.9	247.3	1	25.9
One IG	21	62	76.3	0.5393	11.2
One SG	21	27.8	17.5	0.2564	4.8
Three SG	8-19-24	5.1	1.6	0.0874	2.02

Figures

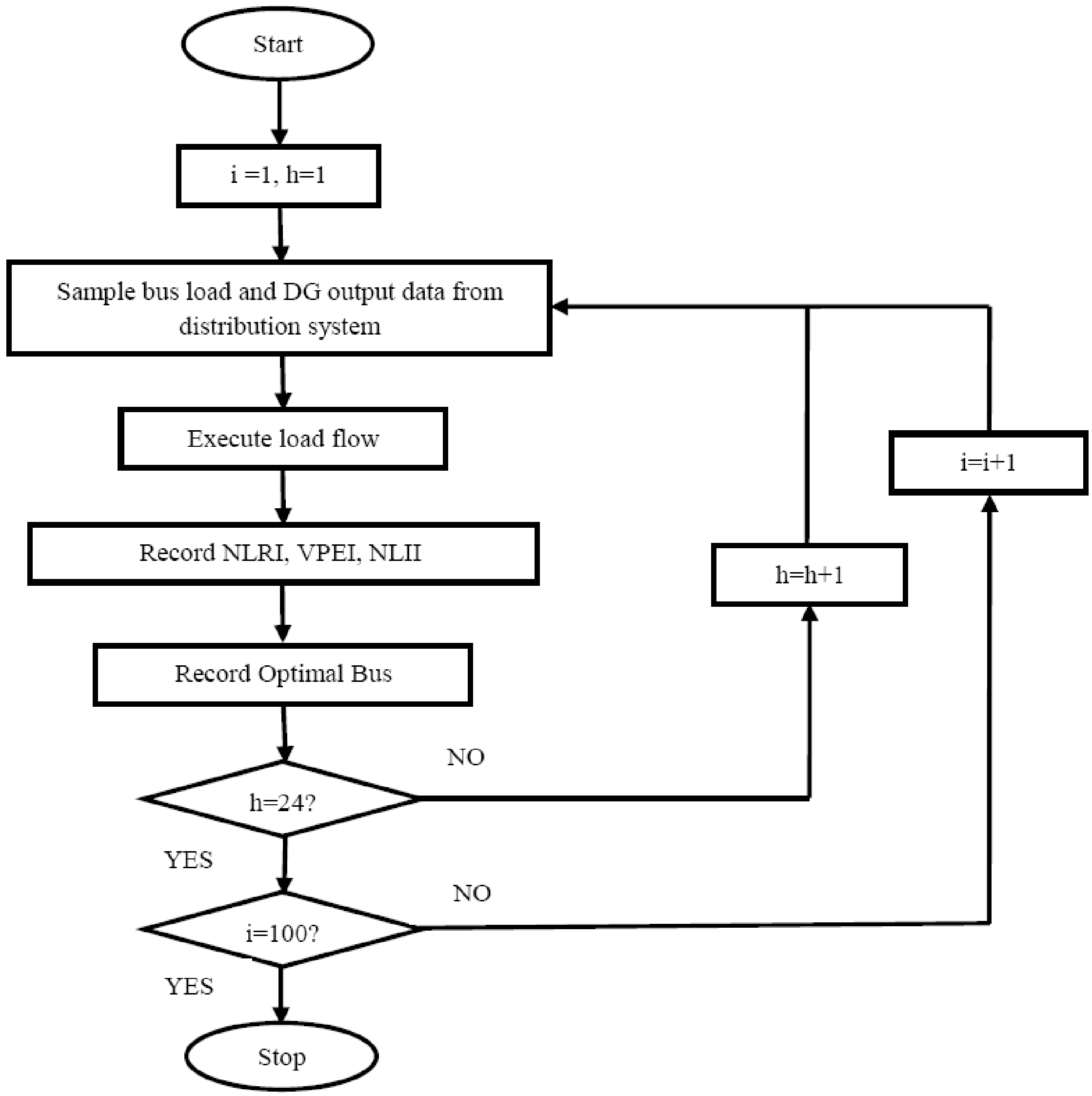

Fig.2. Stochastic Load Flow

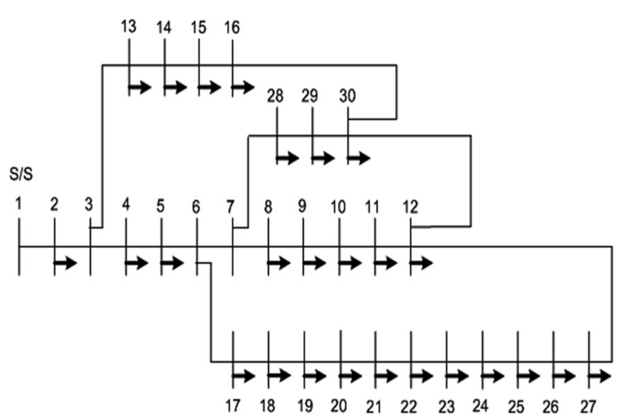

Fig.3. Single Line Diagram of the Test Distribution System

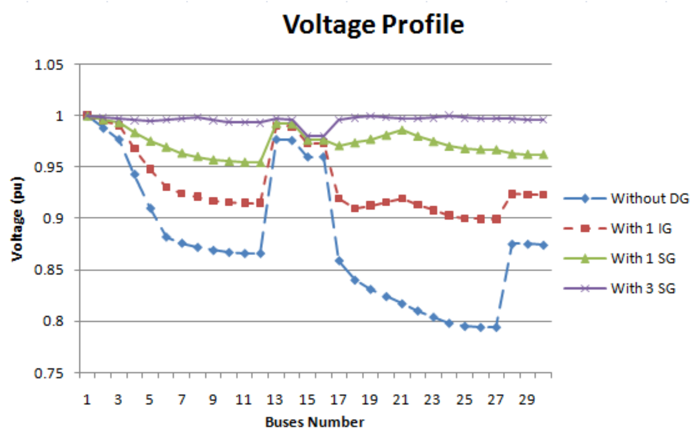

Fig. 4. Improvement of network VP in certain load condition

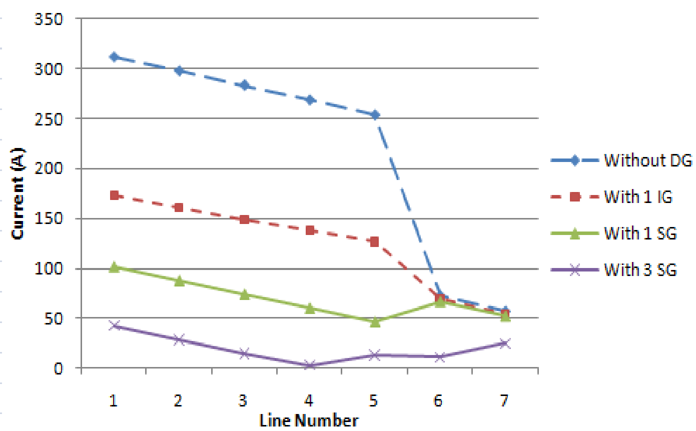

Fig.5. Line Current Graph (1-7) in Certain Load Condition

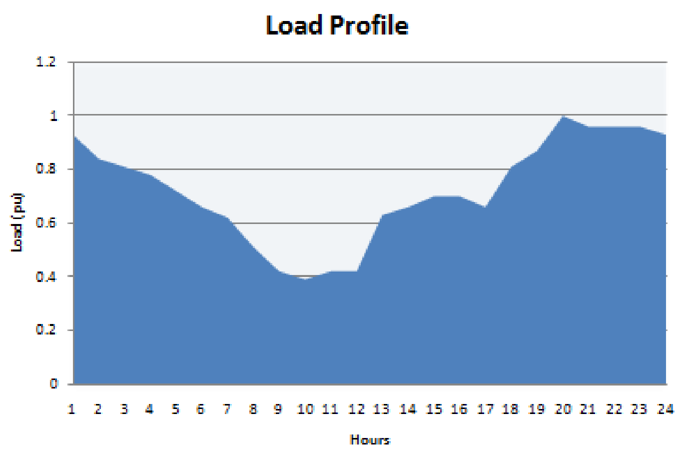

Fig.6. Hourly Load Profile of Network

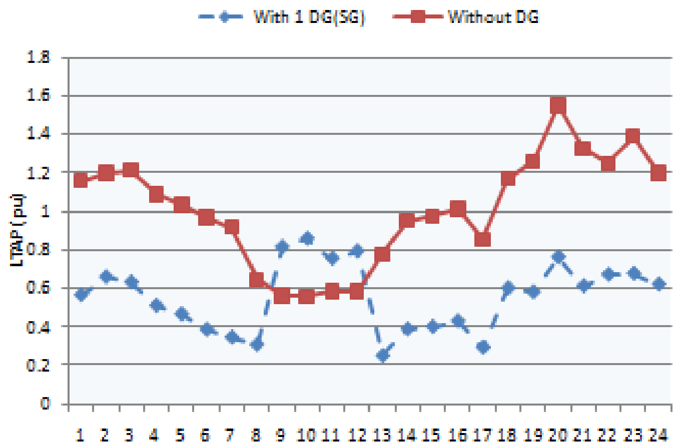

Fig.7. Line Transmission Apparent Power in Random Load Condition and Using 1 DG

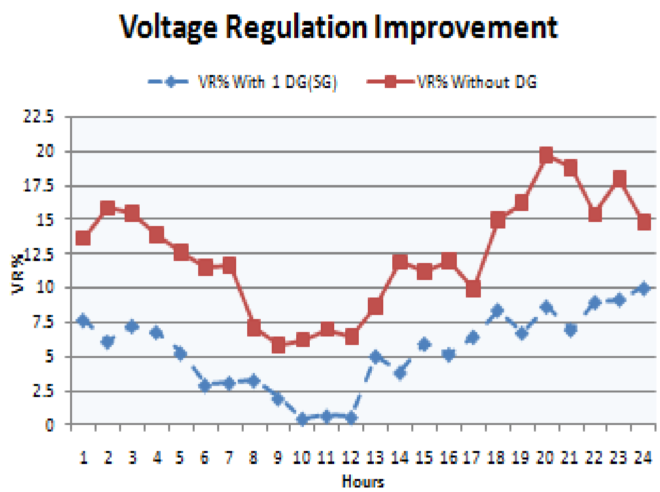

Fig.8. Voltage Regulation in Random Load Condition and Using 1 DG

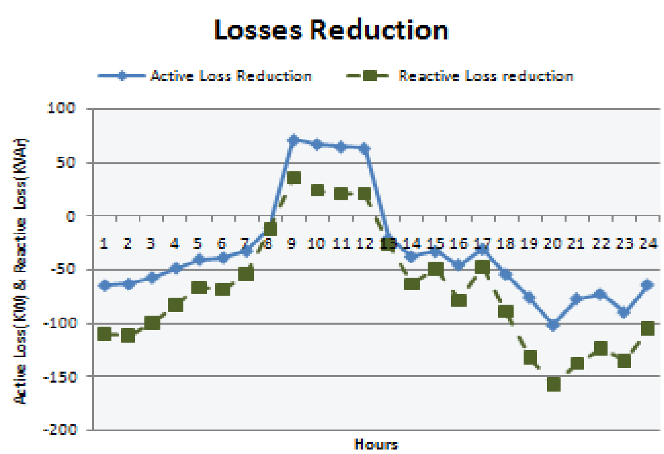

Fig.9. Amount of Loss Reduction in Random Load Condition and Using 1 DG

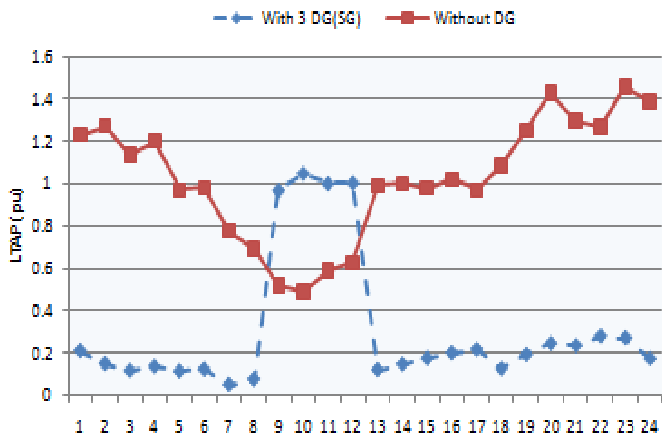

Fig.10. Line Transmission Apparent Power in Random Load Condition and Using 3 DG

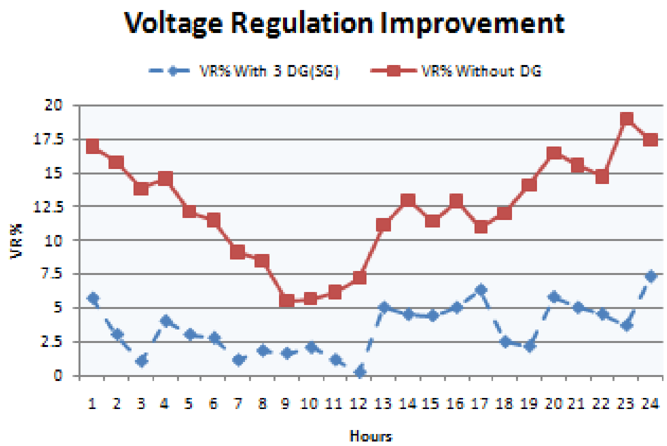

Fig.11. Voltage Regulation in Random Load Condition and Using 3 DG

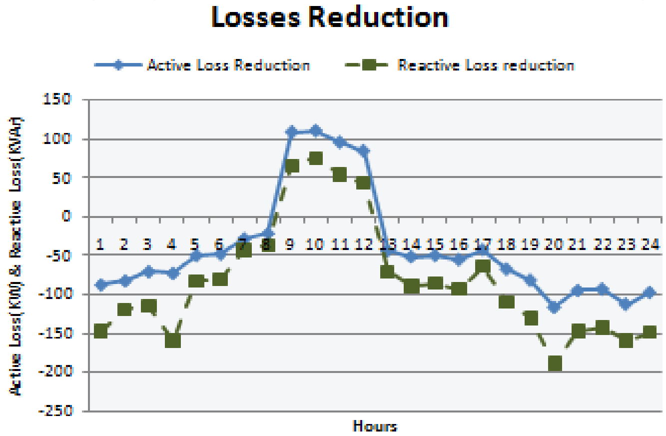

Fig.12. Amount of Loss Reduction in Random Load Condition and Using 3 DG