International Journal of Applied Power Engineering (IJAPE)
Vol. 2, No. 2, August 2013, pp. 71~78
ISSN: 2252-8792

Distributed Generation Allocation to Improve Steady State Voltage Stability of Distribution Networks using Imperialist Competitive Algorithm

Navid Ghaffarzadeh[1], Masoud Akbari[1], Amir Khanjanzadeh[2]
[1] Faculty of Technical and Engineering, Imam Khomeini International University, Qazvin, Iran
[2] Department of Engineering, Islamic Azad University, Chalous Branch

Article Info

Article history:

Received Jan 2, 2013
Revised Apr 17, 2013
Accepted May 6, 2013

Keyword:

Distributed Generation Allocation
Distribution Networks
Imperialist Competitive Algorithm
Voltage Stability

ABSTRACT

In this paper, a new method is proposed to optimal distributed generation allocation for stability enhancement in radial distribution networks. Voltage stability is related with stable load and acceptable voltage in all buses of system. According to the time spectrum of the incident of the phenomena the instability is divided into steady state and transient voltage instability. The analysis is accomplished using a steady state voltage stability index which can be evaluated at each node of the distribution system. Different optimal locations and capacities are used to check this effect. The location of DG is more important in comparison with the capacities and has the main effect on the network voltage stability. Effects of capacity and location on increasing steady state voltage stability in radial distribution networks are evaluated through Imperialist Competitive Algorithm (ICA) and at the end the results are compared to particle swarm optimization and genetic algorithm on the terms of speed, accuracy and convergence.

Corresponding Author:

Navid Ghaffarzadeh,
Assistant Professor, Faculty of Technical and Engineering,
Imam Khomeini International University,
Qazvin, Iran.
Email: ghaffarzadeh@ikiu.ac.ir

1. INTRODUCTION

Concurrent with the extension of national economy and people's life, demand of load in distribution system are strongly increasing. Similar totransmission system, the operation conditions of distribution system are more and more close to the voltage stability boundaries. The decrease of voltage stability level is one of most important parameter which restricts the increase of load served by distribution companies[1].During the planning and operation of distribution system, the problems related to voltage now have become a great concern, since theconsiderable amount of failures which is thought that have been caused by voltage instability. In 1997, a voltage instability problem in a distribution system, which was widespread to a corresponding transmission system, caused a major blackout in the Brazilian system [2]. So, we think it seems necessary to consider voltage stability constraints for planning and operation of power system.

At the sametime, the distributed generations have increased in the distribution system due to rapidchanges intechnology, economic and environmentalissues. In recent years, the use of distributed generations has increased as a clean renewable energy alternative generation and its advantage due to the global warming and exhaustion fossil fuels problems [3] and also technological innovations and a changing economic and regulatory environment have resulted in a renewed interest for distributed generation [4]. This topic confirmed by the [5], who lists five important parameters that contribute to this evolution, i.e. developments in distributed generation technologies, constraints on the construction of new transmission lines, increased in demand of customer for highly reliable electricity, the electricity market liberalization and concerns about climate change.

A general definition was suggested in [6], which are now widely accepted as follows: ‘‘Distributed Generation is an electric power source connected directly to the distribution network or on the customer site of the meter’’. From distribution network planning point of view, DG is a feasible alternative for new capacity, particularly in the competitive electricity market environment, and has immense advantages such as short lead time and low investment risk since it is built in modules, small-capacity modules that can track load variation more closely, small physical size that can be installed at load centers and does not need government approval or search for utility territory and land availability, and existence of a widespread range of DG technologies [7]. The advantages of distributed generationdepend on the location and the size of distributed generation.

Advantages of distributed generation are [3]:

1. Reduce power flow inside the transmission system thus improve the system voltage profile
2. Reduce power losses at distribution system by supplying some load demand at the distribution
3. Reduce thermal stresses caused by loaded substations, transformers and feeders thus improve reliability and efficiency of the power system
4. Defer upgrades for an existing infrastructure since they provide distribution and transmission capacity release
5. Decrease related costs to transmission and distribution
6. Help in “peak load shaving” and load management programs
7. Provide local load reliability which can be used as on-site standby to supply power during emergency and system outages
8. Supply the required spinning reserve thus maintain power system stability
9. Renewable distributed generations can eliminate or reduce emission.

The planning of the distribution network with the presence of DG requires the definition of several parameters, such as: the best technology to be used, the number and the capacity of the DGs, the best location of DGs, the type of network connection, etc. The impact of DG in system operating characteristics, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated [8]. The problem of DG allocation and sizing is great importance. The installation of DG in non-optimal location can increase the losses of system, increase costs and result inan adverse effectondesirable. Thus, the use of an optimization method capable of showing the best solution for a given network can be very useful for the system planning engineer. The selection of the best places for installation and the preferable size of the DG units in large distribution systems is a complex combinatorial optimization problem. The optimal location and sizing of DG on the power system has been continuously studied in order to attain various goals. The objective can be the minimization of the active losses of the feeder [9],[10]; or the minimization of the total network supply costs, which includes generators operation and losses compensation [11]-[14]; or even the best utilization of the available generation capacity [15].

Voltage stability is related with stable load and acceptable voltage in all buses of system. Accurate voltage stability contingency analysis could be accomplished by performing a PV (active load powervoltagemagnitude) curve study [16]. Some other methods presentingvarious stability indices have also been introducedand compared in [17].The instability is derived into steady state and transient voltage instability as for the time spectrum of the incident of the phenomena.

In the case of instability voltage, when the disturbance occursin the power system, an uncontrollable progressive reduction will arise .Voltage stability analysis often requires examination of system state losses and a lot of other related scenarios [18]. According to this, the established rationale based on steady state analysis is more feasible and it can create an overall prediction about voltage reaction problems as well.

Voltage stability phenomenon is fully known in distribution systems. In radial distribution system resistance to reluctance ratio is high that causes a lot of power loss, hence radial distribution systems are kinds of power systems which are threatened by voltage instability.

2. VOLTAGE STABILITY

As mentioned in the previous section, in this paper, thesteady-statevoltage stability is evaluated. Forthis purpose anewsteady statevoltage stabilityindexin [19] is presented, which is most sensitive to voltage collapse. In order toformulatetheindex, one method load flow for radial distribution systems was presented by Das et al in [20].According to Equation (1) the steady state voltage stability index for each bus is:

$$SI(m2) = |V(m1)|^4 - 4.0\{P(m2)x(jj) - Q(m2)r(jj)\}^2 - 4.0\{P(m2)r(jj) - Q(m2)x(jj)\}|V(m1)|^2 \quad (1)$$

Where [19]:
SI (m2) =voltage stability index of node m2 (m2=2,3, … , NB).
NB =the total number of nodes.
jj =branch number.
r(jj), x(jj) = resistance and reactance of branch jj.
V(m1) = voltage of node m1.
V(m2) = voltage of node m2.
P(m2) =total real power load fed through node m2.
Q(m2) = total reactive power load fed through node m2.

Steady state voltage stability index is derived for the two node equivalent system shown in Fig. (1).

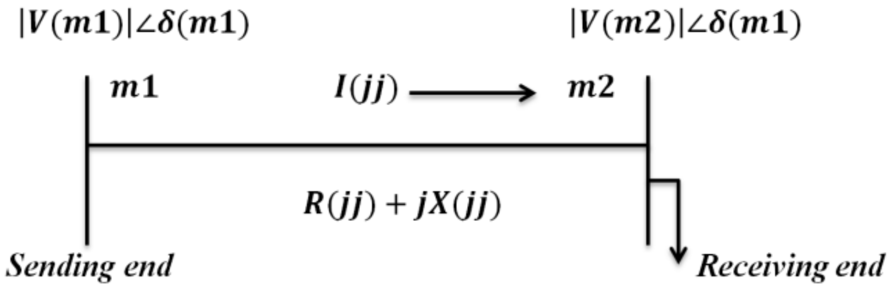

Figure 1. Equivalent system of feeder

Actually,
$P(m2)$ =sum of the real power loads of all the nodes beyond node m2 plus the real power load of node m2 itself plus the sum of the real power losses of all the branches beyond node m2.
$Q(m2)$ =sum of the reactive power loads of all the nodes beyond node m2 plus the reactive power load of node m2 itself plus the sum of the reactive power losses of all the branches beyond node m2. For all of the network buses, the following Fitness function is defined:

$$\text{Fitness Function}=\sum \text{SI(mi)}, mi = 2,3, \dots, NB \quad (2)$$

3. CASE STUDY

To evaluate theproposedalgorithm, a system was selected from one part of Tehran distribution network. Single line diagram of the network is shown in Fig. 2. That is MV feeder with 13 buses from 63/20 kV substation (Khoda-Bande-Loo substation).

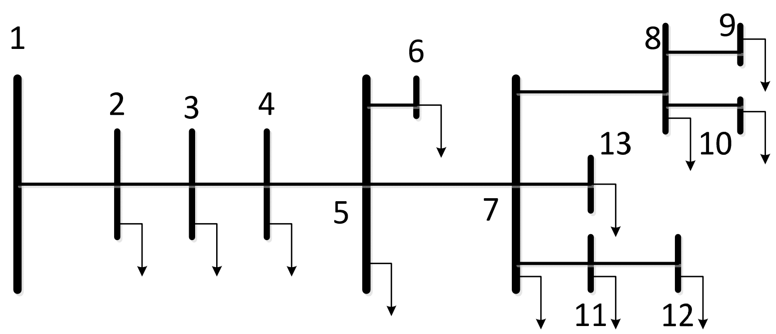

Figure 2. Single Line Diagram of feeder

This network is chosen because of its practically. Table 1 and Table 2, illustrate line and bus information. Initially, a load flow was run for the case study without installation of DG. Result of power flow without DG shown in Table 3.

Table1. Lines Data

From	To	R(ohm)	X(ohm)
1	2	0.176	0.138
2	3	0.176	0.138
3	4	0.045	0.035
4	5	0.089	0.069
5	6	0.045	0.035
5	7	0.116	0.091
7	8	0.073	0.073
8	9	0.074	0.058
8	10	0.093	0.093
7	11	0.063	0.05
11	12	0.068	0.053
7	13	0.062	0.053

Table 2. Buses Data

Bus Number	P(kw)	Q(kvar)
1	0	0
2	890	468
3	628	470
4	1112	764
5	636	378
6	474	344
7	1342	1078
8	920	292
9	766	498
10	662	480
11	690	186
12	1292	554
13	1124	480

Table 3. Result of power flow without DG

Bus Number	Stability Index
2	0.9729
3	0.9486
4	0.9429
5	0.9332
6	0.9329
7	0.9221
8	0.9199
9	0.9191
10	0.9181
11	0.9174
12	0.9198
13	0.9198

4. IMPERIALIST COMPETITIVE ALGORITHM

Imperialist Competitive Algorithm (ICA) is a new socio-politically motivated global search strategy that has recently been introduced for dealing with different optimization tasks.

In [21] descripted ICA as follow:

This algorithm starts with an initial population. Each population in ICA is called country. Countries are divided in two groups: imperialists and colonies. In this algorithm the more powerful imperialist, have the more colonies. When the competition starts, imperialists attempt to achieve more colonies and the colonies start to move toward their imperialists. So during the competition the powerful imperialists will be improved and the weak ones will be collapsed. At the end just one imperialist will remain. In this stage the position of imperialist and its colonies will be the same. The flowchart of this algorithm is shown in Fig. 3 [22]. More details about this algorithm are presented in [22].

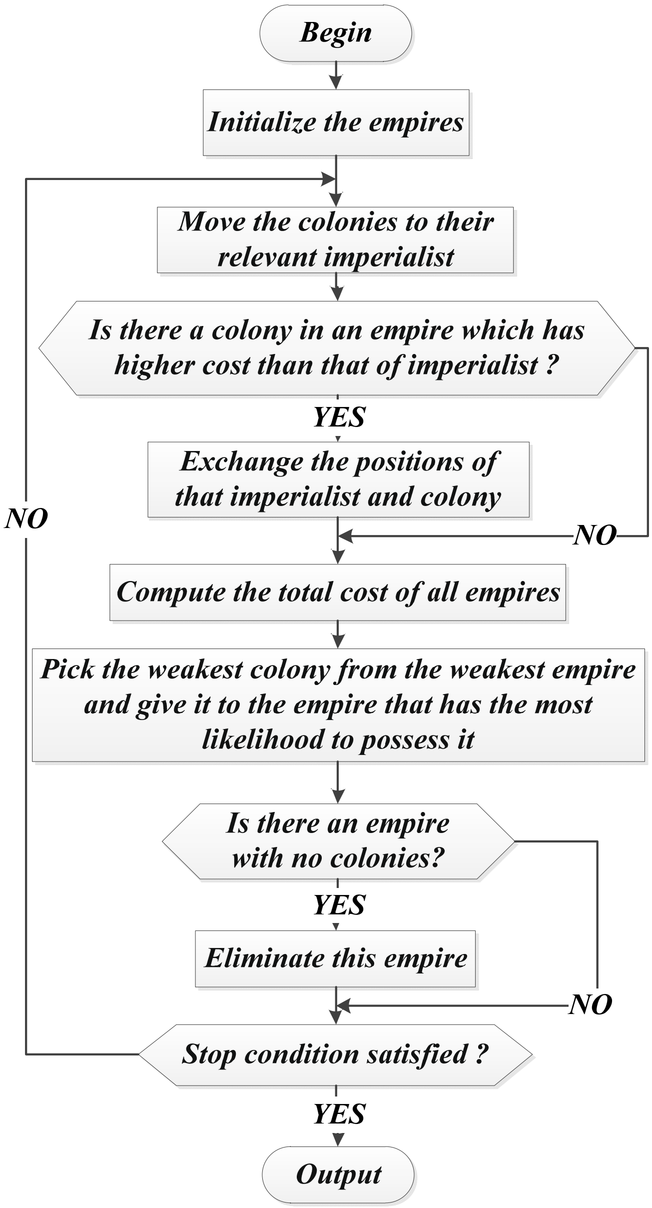

Figure 3. Flowchart of the ICA.

5. RESULTS AND DISCUSSIONS

Reference [23] gave us a method synthesizing optimal power flow and Particle Swarm Optimization (PSO) to find the best combination of sites within a distribution network for connecting DGs. Reference [24] performed same method by genetic algorithm(GA). In [18],[25],[26]voltage stability and location of DGs optimized by PSO , CSA and HSA were presented. result of PSO, GA and ICA presented in this section. The results are calculated for integration of 3 DG into the distribution network. These results are obtained while assuming that all the generators operate at a power factor of 0.9.

In this paper voltage stability index presented by three method of optimization algorithm that is PSO, GA and ICA.

Assessment of value of steady state voltage stability index done with analysis of this system. Newton-Raphson load flow method is performed first for load flow solution for this system. P(m2) and Q(m2) at each node accepted by results of the load ,Finally the SI index has been app raised.

The results of optimal location and capacity of DG and impact of installing 3 DGs in the case study network by PSO, GA and ICA are illustrated in Table 4. Comparing the results in table 3 with those of table 5, we can conclude that with installing 3 DGs, the voltage instability is improved.

Table 4. Optimal Location and Capacity with different optimization algorithm

Solution	Bus NO	DG Capacity	Cost Function
By PSO[19]	4 8 12	4.0573 4.6701 2.8894	0.0834177
By GA[19]	11 8 5	3.4455 3.8218 3.8149	0.0834505
By ICA	4 13 11	4.3499 4.5070 3.6147	0.08480

Table 5. Result of Power Flow with DG in different optimization algorithm

Bus Number	Stability index by PSO[18]	Stability index by GA[18]	Stability index by ICA
2	0.9986	0.9974	0.9932
3	0.9994	0.9970	0.9869
4	1.0000	0.9974	0.9854
5	0.9983	0.9996	0.9829
6	0.9980	0.9992	0.9828
7	0.9978	0.9986	0.9800
8	1.0000	1.0000	0.9794
9	0.9991	0.9991	0.9791
10	0.9981	0.9981	0.9791
11	0.9996	1.0000	0.9796
12	1.0000	0.9988	0.9793
13	0.9990	0.9979	0.9798

Fig 4 shows voltage instability of the case study network without and with 3 optimal DGs. In this paper we compare GA, PSO and ICA methods on the terms of speed, accuracy and convergence.

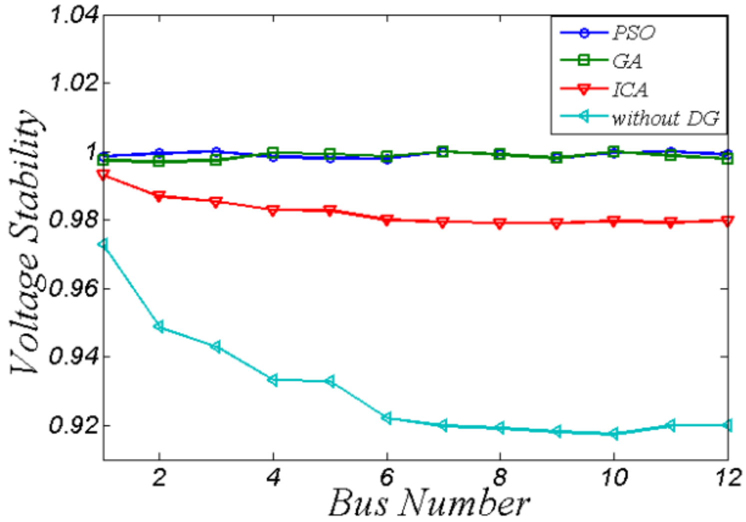

Figure 4. Voltage Stability Index of the case study system without and with three optimal DGs in different optimization algorithm

6. CONCLUSION

In this paper, a novel approach is proposed to optimal distributed generation allocation for stability enhancement in radial distribution networks. The method is based on ICA algorithm and the result of applying ICA algorithm for DG allocation in distribution system has been presented. The effectiveness of the proposed algorithm in solving DG allocation problem was demonstrated through a numerical example.The result of algorithm showed that the better solution quality of the PSO and GA in comparison with the ICA but in the speed, ICA was better than both of them.

ACKNOWLEDGEMENTS

The study was supported by the Imam Khomeini International University, Qazvin, Iran, under grant no.388041-92.

REFERENCES

[1] M. J. SheebaJeba, J. A. Jaleel. "Impact of Distributed Generation on Voltage Stability: a Review", *ICTT Electrical Engineering*, 2011.

[2] R. B. Prada, L. J. Souza. "Voltage stability and thermal limit: constraints on the maximum loading of electrical energy distribution feeders", *IEE Proceedings-Generation, Transmission and Distribution*, Vol/Issue: 145(5). Pp. 573–577, 1998.

[3] A. Arief, M.B. Nappu, A. Nizar, Z.Y. Dong. "Determination of DG Allocation with Modal Participation Factor to Enhance Voltage Stability", *8th International Conference on Advances in Power System Control, Operation and Management*. Pp. 331-337, 2009.

[4] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans, W. D'haeseleer. "Distributed generation: definition, benefits and issues", *Energy Policy*, Vol. 33. Pp. 787–798, 2005.

[5] "Distributed Generation in Liberalised Electricity Markets", *IEA. Paris*. Pp. 128, 2002.

[6] T. Ackermann, G. Andersson, L. Söder. "Distributed generation: a definition", *Electric Power Systems Research*, Vol. 57. Pp.195–204, 2000.

[7] M. Gandomkar, M. Vakilian, M. Ehsan. "A combination of genetic algorithm and simulated annealing for optimal DG allocation in distribution networks", *IEEE CCECE/CCGEI, Saskatoon*. Pp. 645-648, 2005.

[8] M. Sedighizadeh, and A. Rezazadeh. "Using Genetic Algorithm for Distributed Generation Allocation to Reduce Losses and Improve Voltage Profile", *World Academy of Science, Engineering and Technology*, Vol. 37, 2008.

[9] K. Nara, Y. Hayashi, K. Ikeda,and T. Ashizawa. "Application of tabu search to optimal placement of distributed generators", in *Proc. 2001 IEEE Power Engineering Society Winter Meeting*. Pp. 918-923, 2001.

[10] T. K. A. Rahman, S. R. A. Rahim, and I. Musirin. "Optimal allocation and sizing of embedded generators", in *Proc. 2004 National Power and Energy Conference*. Pp. 288-294, 2004.

[11] G. Celli, and F. Pilo. "Optimal distributed generation allocation in MV distribution networks", in *Proc.2001 IEEE PICA Conference.* Pp. 81-86, 2001.

[12] W. El-Khattam, K. Bhattacharya, Y. Hegazy, and M. M. A. Salama. "Optimal investment planning for distributed generation in a competitive electricity market", *IEEE Trans. Power Systems*, Vol. 19. Pp. 1674-1684, 2004.

[13] W. El-Khattam, Y. G. Hegazy, and M. M. A. Salama. "An integrated distributed generation optimization model for distribution system planning", *IEEE Trans. Power Systems*, Vol. 20. Pp. 1158-1165, 2005.

[14] M. Gandomkar, M. Vakilian, M. Ehsan. "A combination of genetic algorithm and simulated annealing for optimal DG allocation in distribution networks", *IEEE CCECE/CCGEI, Saskatoon*. Pp.645-648, 2005.

[15] A. Keane, and M. O'Malley. "Optimal allocation of embedded generation on distribution networks", *IEEE Trans. Power Systems*, Vol. 20. Pp. 1640-1646, 2005.

[16] M. Nafar. "Optimal Placement of DGs in Distribution Systems Considering Voltage Stability and Short Circuit Level Improvement Using GA", *Journal of Basic and Applied Scientific Research*, Vol/Issue: 2(1). Pp. 368-375, 2012.

[17] H. Zareipour, K .Bhattacharya and C. A. Canizares. "Distributed Generation: Current Status and Challenges", *IEE Proceeding of NAPS 2004*, 2004.

[18] A. Khanjanzadeh, M. Arabi, M. Sedighizadeh, A. Rezazadeh. "Distributed Generation Allocation to Improve Steady State Voltage Stability of Distribution Networks Using Particle Swarm Optimization and Genetic Algorithm", *Canadian Journal on Electrical and Electronics Engineering*, Vol/Issue: 2(6), 2011.

[19] M. Charkravorty and D. Das. "Voltage stability analysis of radialistribution networks", *International Journal of Electrical Power &Energy Systems*, Vol/Issue: 23(2). Pp. 129-135, 2001.

[20] D. Das, D. P. Kothari, and A. Kalam. "Simple and efficient method for load flow solution of radial distribution networks", *Electrical Power & Energy Systems*, Vol/Issue: 17(5). Pp. 335-346, 1995.

[21] C. Lucas, Z. Nasiri-Gheidari, F. Tootoonchian. "Application of an imperialistcompetitive algorithm to the design of a linear induction motor", *Energy Conversion and Management*, Vol. 51. Pp. 1407–1411, 2010.

[22] E. Atashpaz-Gargari, C. Lucas. "Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition", In: *IEEE conference CEC*, 2007.

[23] Y. Alinejad-Beromi, and M. Sedighizadeh, and M. Sadighi. "A particle swarm optimization for sitting and sizing of Distributed Generation in distribution network to improve voltage profile and reduce THD and losses," *43rd International Universities Power Engineering Conference, UPEC 2008*, 2008.

[24] M. Sedighizadeh, A.Rezazadeh. "Using Genetic Algorithm for Distributed Generation Allocation to Reduce Losses and Improve Voltage Profile", *Proceedings of World Academy of Science, Engineering and Technology (CESSE2008), Cairo, Egypt*, Vol. 27. Pp.251-256, 2008.

[25] M. Sedighizadeh , A. Rezazadeh , D. Dehghani , M. Mohammadi. "Distributed generation allocation to improve steady state voltage stability of distribution networks using clonal selection algorithm", *International Journal of Engineering & Applied Sciences (IJEAS)*, Vol/Issue: 3(2). Pp. 52-60, 2011.

[26] H. Piarehzadeh, A. Khanjanzadeh and R. Pejmanfer. "Comparison of Harmony Search Algorithm and Particle Swarm Optimization for Distributed Generation Allocation to Improve Steady State Voltage Stability of

Distribution Networks", *Research Journal of Applied Sciences, Engineering and Technology*, Vol/Issue: 4(15). Pp. 2310-2315, 2012.

BIOGRAPHIES OF AUTHORS

Navid Ghaffarzadeh is an assistant professor of electrical engineering at Imam Khomeini Internatial University (IKIU).
His special fields of interest include power systems protection, transient in power systems and power quality. He is the author and the coauthor of over 50 technical papers.
Email: ghaffarzadeh@ikiu.ac.ir