International Journal of Electronics and Electrical Engineering

Volume 2 | Issue 3 Article 10

January 2014

DISTRIBUTED GENERATION IMPACT ON DISTRIBUTION NETWORKS: A REVIEW

GOPIYA NAIK. S
Alternate Hydro Energy Centre, IIT Roorkee, Roorkee-247667, India., gopiya.naik94@gmail.com

D. K. KHATOD
Alternate Hydro Energy Centre, IIT Roorkee, Roorkee-247667, India., d.k.khatod@gmail.com

M. P. SHARMA
Alternate Hydro Energy Centre, IIT Roorkee, Roorkee-247667, India., mpsharma@gmail.com

Recommended Citation

NAIK. S, GOPIYA; KHATOD, D. K.; and SHARMA, M. P. (2014) "DISTRIBUTED GENERATION IMPACT ON DISTRIBUTION NETWORKS: A REVIEW," *International Journal of Electronics and Electrical Engineering*: Vol. 2 : Iss. 3 , Article 10.
DOI: 10.47893/IJEEE.2014.1096
Available at: https://www.interscience.in/ijeee/vol2/iss3/10

DISTRIBUTED GENERATION IMPACT ON DISTRIBUTION NETWORKS: A REVIEW

GOPIYA NAIK. S [1], D. K. KHATOD [2] & M. P. SHARMA [3]

[1,2&3] Alternate Hydro Energy Centre, IIT Roorkee, Roorkee-247667, India.
E-mail: gopiya.naik94@gmail.com

Abstract: The concept of traditional distribution networks with unidirectional power flow is weakening due to large penetration of Distributed Generation (DG). The penetration of DG may impact the operation of a distribution network in both beneficial and detrimental ways. Some of the positive impacts of DG are voltage support, power loss reduction, support of ancillary services and improved reliability, whereas negative ones include protection coordination, dynamic stability and islanding. Therefore, proper planning methods that evaluate the composite impacts, i.e. technical, economical and environmental impacts of DG integration to existing distribution networks are very much essential. This paper presents a critical review of various impacts of DG on power distribution system. For ease of reference and to facilitate better understanding this literature is categorized and discussed under five major headings.

Keywords*: Distributed Generation, Renewable energy resources, Distribution network, DG impacts.*

1. INTRODUCTION

Electrical power generation systems are in transition stages from large centralized generation plants connected to the transmission network to decentralized system with smaller generating units connected directly to the distribution networks near demand centre. The later type of generation unit is known as Distributed Generation (DG) which is an electric power source connected directly to the distribution network or on the customer site of the meter [1-2]. DG can be powered by both renewable and non-renewable. Examples of renewable sources include PV solar, wind, geothermal, mini-hydro, biomass while reciprocating engines, fuel cell, gas turbines and micro turbines belong to the non-renewable category. The fast depleting fossil fuel has necessitated the exploitation of natural resources and the increasing environmental concerns have rapidly increased the appearance of DG in the electricity supply systems [3].

The benefits of DG include reduction of power flow in lines when it is located close to load centers and electricity production coincides with the load demand. The reduced power flow results in an improvement of voltage profile and reduction in line losses [4]. Other benefits include: deferred network investment [6], improvement in network reliability and can be operated in islanded mode while connected to radial networks. In contrast, DG with variable output like wind generators or DG connected to radial networks and not allowed to operate in islanded mode does not increase the reliability of the network [4]. These technical aspects yield economic benefits for the Distribution System Operator (DSO) or for the customer. The DG developer can maximize the energy traded while keeping the system operation within technical limits is a paramount.

The distribution networks are designed to be radial for operational simplicity, economical benefits and to lower protection cost [5]. The distribution networks have been designed deterministically for unidirectional power flows from higher to lower voltages, instead of accommodating large penetrations of DG. The improperly located DG whose generation production is not coincident with demand or the DG capacity largely exceeds the capacity of the network, has negative effects such as reverse power flows, increments in line losses and voltage rise. DG located close to fault points is reported to contribute to the fault currents [3]. Other impacts of improper location of DG are the degradation of voltage quality, creation of power electronic harmonics and an increase in network instability due to low inertia of DG [7].

The distribution networks must be kept within operational and design limits at all times to provide good quality energy and avoid damage to the equipment. The technical impacts of DG can limit the installation of DG and reduce the economic and environmental benefits. Location of large number of renewable energy based DG in weak rural networks results in rise in voltage [8] and thermal capacity of line that limiting the integration of DG. On the other hand, location of large numbers of micro-combined heat and power (CHP) DG units in meshed urban networks suffer from thermal limits and fault levels as the most common constraints [3].

Appropriate multi-objective planning methods [9] can support a suitable model of stochastic DG and active networks; can give a deep insight into the advantages and drawbacks of DG. This study presents a review of the work by various researchers to study the technical, economical, and environmental and also their composite impacts resulting by the DG integration to distribution network. It is mentioned that DG can be considered as one of the possible solutions to the energy and environmental crisis of today.

2. IMPACTS OF DG

The impacts of DG integration on the distribution networks are categorized into the following five types, viz. technical, economical, techno-economical, techno-environmental and econ-environmental. Further, the objective may be either single or multiple: a single objective planning approach is often practical from a distributed energy resource (DER) developer or distribution system operator's (DSO) point of view, whereas, multi-objective approaches can be formulated based on different objectives, like DER developer, DSO and civil society. Though the multi-objective (MO) approaches are conflicting but have to satisfy all stake holders in the way of compromised solution.

2.1. Technical impacts

These DG impacts affect the peak load shaving, voltage profile, system losses, reliability, power quality, line loading, stability and protection. Optimal allocation of DG in distribution network for loss minimization were discussed in references [10,11,23,31] by employing different approaches like analytical, genetic algorithm (GA). Further, optimal allocation of DG for annual energy loss minimization were dealt in [15, 16, and 17] by using techniques such as optimal power flow and mixed integer non-linear programming. Loss minimization and voltage profile improvement by optimal DG planning were discussed in [13, 21, 30, 35] with the use of methods like power flow continuation, analytical and performance index analysis. Planning of DG in distribution system for reliability improvement using probabilistic approach was presented in [38]. An operational scheme using distribution network reconfiguration with DG for loss reduction, voltage profile improvement and load balancing were discussed in [37, 39, and 40] with the help of different techniques.

It has been concluded that proper placement and size of DG units can have a significant impact on the system loss reduction. Other benefits are better voltage profile, higher reliability; better power quality and capacity saving. Proper placement and sizing of DG is crucial to accommodate their increasing penetration level on distribution network. Optimal placement combined with adequate power factor settings can harvest significant loss reduction. Higher loss reduction is possible when DG units are more dispersed along network feeders. The DG units with reactive power control are found to provide better voltage profile and lower losses. Optimal selection of DG improves reliability and brings investment deferral profit to the utility. Network reconfiguration at the power distribution systems with DG has positive effects on loss reduction and voltage profile improvement. Beside, better load balancing may be attained by DGs installation in distribution system. Table 1, summarizes the technical impact of DG. Due to the brevity of space other impacts of DG like protection, stability and islanding are not discussed here.

2.2. Economical Impacts

These DG impacts affects world fuel saving, transmission and distribution cost and electricity price. Minimization of planning cost were discussed in references [19, 26, 28, 29, 33, 36, 37] by employing different techniques such as mathematical modeling, binary decision variable, cost-benefit analysis, GA and e-constrained, evolutionary algorithm and weight method and successive elimination method.

It can be concluded that DG increases the feeder's life time by reducing the load and make the existing distribution network fit is for any further load growth without the need of feeder's upgrading. Also, improves the power quality and minimizes the DISCO'S total planning cost and reduces customer's bills. Significant reduction in losses for different penetration level of DG will take place. Therefore DG is an alternative to distribution networks reinforcement and for innovative financial rewards. Table 2, summarizes the economical impacts of DG on distribution system.

2.3. Techno-economical Impacts

These impacts affect both technical and economical impacts resulting due to DG inclusion into distribution system. Minimization of planning cost and power loss, improvement in voltage profile were discussed in [18, 20, 22, 24, 25, 32, 42] by using different techniques such as Newton Raphson load flow method, nodal pricing, Bellman Zadeh algorithm and fuzzy approach, particle swarm optimization, linear programming and genetic algorithm.

It can be concluded that multiple small capacity optimally located DGs can offer more profit than a single large capacity DG that is not optimally located. Minimization of the total installation and operational costs along with improvement in reliability, loss reduction and voltage profile improvement are the positive impact of DG. The techno-economical impacts of DG on distribution system are summarized in the table 3.

2.4. Techno-Environmental

These DG impacts include both technical and environment. Chiradeja and Ramkumar [12] discussed a general approach with set of indices to assess and quantify the technical benefits of DG in terms of voltage profile improvement, line loss reduction and environmental impact reduction and found that the DG placement in the network has improved system voltage profile, reduced electrical line losses and emission of pollutants. The impacts of DG on techno-environmental is summarized in Table 4.

2.5. Econ-environmental impacts

These DG impacts include both economical and-

Table 1. Technical impacts of DG

Objective		Refere nces	Remarks
Single	**Multiple**		**% reduction**
Loss minimization		[10]	NA
Loss minimization		[11]	80.72%
	Line loss reduction and increase in voltage stability margin	[13]	38.8% and 72%
Maximization of Generation		[14]	NA
Minimization of Energy losses		[15]	77%(firm) and 40%(variable)
Minimization of annual energy loss		[16]	615.71 MWhr (W-B-S)
Minimization of annual energy loss		[17]	NA
	Voltage drop and loss reduction	[21]	76.58% and 93.43%
Loss reduction		[23]	89% (3-DG Scenario)
	Cost of loss reduction and voltage profile improvement	[27]	55.84% (peakload) and 36%.
	Voltage profile improvement and line loss reduction	[30]	NA
Loss reduction		[31}	87.6% (30-Bus system)
	Voltage profile improvement, line loss reduction and increase in line loading.	[35]	NA
Reliability improvement		[38]	NA
Loss reduction		[39]	43.7%
	Loss reduction and load balancing	[40]	9.8
Loss reduction		[41]	31.4%

environment. Suroudi et al. [43] proposed a long term multi-objective planning model for distribution network expansion in order to optimize two objectives, namely cost and emission and determined the optimal schemes of sizing, placement and specially the dynamics (i.e. timing) of investments on DG and network reinforcements over the planning period using power flow, operating limits of DG, capacity limit of feeders as the constraints. Muis et al.[44] developed an optimization model based on mixed integer linear programming (MILP) using general algebraic modeling system (GAMS) for optimal planning of electricity generation scheme to minimize the cost of electricity generation and simultaneously fulfill the forecasted electricity demand and targeted CO_2 emission using mix of fossil fuel as well as renewable energy. The constraints were: annual energy demand, plant capacity and CO_2 emission target. The impacts of DG on econ-environmental are summarized in Table 5.

3.0. DISCUSSIONS

Different impacts of DG integration on the existing power distribution networks were reviewed in this study.

4.0. CONCLUSIONS

This paper has presented a critical review of the various impacts, viz., technical, economical, and environmental and also their composite impacts resulting by the DG integration on power distribution system. It was identified that all the impacts are grouped and discussed into five different sub categories, viz. technical, economical, techno-economical, techno-environmental and econ-environmental. The use of DG has been considered as one of the possible solutions to today’s energy and environmental challenges. The optimal integration of DG in distribution networks is essential to guarantee the best of resource, i.e. maximize their benefits, such as reduction of carbon emissions, reduction of network energy losses, minimization of total planning cost and to minimize the negative impacts, which can affect the network quality, cause network sterilization and increase investment and operation costs. Despite of proposing different research studies for proper DG placement, the systematic principle for this issue is still an unsolved problem. In practice, the main problem is the complexity of this process. Indeed, a lot of constraints should be considered simultaneously such as power loss, reliability, load factors, voltage profile (quality), operational cost, emission of green house gas, the related capacity and so on. That’s why the most of researchers have been divided the problem into limited parts along with imposed constraints and then they were tried to propose their solutions.

REFERENCES

[1] Energy white paper: meeting the energy challenge. Department of Trade and Industry, UK (DTI); 2007.

[2] Ackermann T, Andersson G, Soder L, “Distributed generation: a definition”, Electric Power Systems Research, 2001;57 (April (3)):195–204.
[3] Frias. P, Gomez. T, Cossent R, Rivier J, “Improvement in current European network regulation to facilitate the integration of distributed generation”, Electric power energy system: (31) 2009, pp. 445-451.
[4] Jenkins N, Allan R, Crossley P, Kirschen D, Strbac G, “Embedded generation”, London: Institution of Electrical Engineers; 2000.
[5] Gonen. T, Ramirez. R.I.J, “Review of distribution system planning models; a model for optimal multi-stage planning”, IEEE Proc. C 133(7), 397-408 (1086).
[6] Mendez VH, Rivier J, De la Fuente JI, Gomez T, Arceluz J, Marin J, et al., “Impact of distributed generation on distribution investment deferral”, International Journal of Electrical Power and Energy Systems 2006;28(May (4)):244–252.
[7] Thong V.V, “Impact of Distributed Generation on Power System Operation and Control”, PhD thesis. Katholieke University, Leuven, Leuven, Belgium; May 2006.
[8] Pepermans G, Driesen J, Haeseldonckxc D, Belmans R, D’haeseleer W, “Distributed generation: definition, benefits and issues”, Energy Policy 2005;33(April (6)):787–98.
[9] Arturo Alarcon-Rodriguez, Graham Ault, Stuart Galloway “Multiobjective planning of distributed energy resources: A review of the state-of-the-art”, Renewable and sustainable energy review, Vol.14, 2010, pp 1353-1366.
[10] Caisheng Wang, M. Hashhem Nehir, “Analytical approaches for optimal placement of distributed generation sources in power system”, IEEE Transactions on power system, vol.19, no.4, 2004, pp. 2068-2076.
[11] N. Mithulanathan, Than Oo, Lee Van phu, “Distributed generator placement in power distribution system using Genetic Algorithm to reduce losses”, Thammasat Int. J. Sc.Tech., vol.9, no.3, 2004, pp. 55-62.
[12] P. Chiradeja, R. Ramkumar, “An approach to quantify the technical benefits of distributed generation”, IEEE Trans. on energy conversion, Vol.19, no.4, December 2004, pp. 764-773.
[13] Hasan Hedayati, S.A. Nabaviniaki, Adel Akbarimazd, “A method for placement of DG units in distribution network”, IEEE Transactions on power delivery, vol.23, no.3, July 2008, pp. 1620-1628.
[14] Keane and Mark O’ Malley, “Optimal allocation of embedded generation on distribution networks”, IEEE Trans. on power systems, vol.20, no.3, August 2005, pp. 1640-1646.
[15] L. F. Ochoa, G.P. Harrison, “Minimizing energy losses: Optimal accommodation and Smart operation of renewable DG”, IEEE Trans. on Power systems, vol.26, no.1, February 2011, pp. 198-205.
[16] Y.M. Atwa, E.F. EI-Saadany, M.M.A. Salama, R. Seethaparhy, “Optimal renewable resource mix for distribution system energy loss minimization”, IEEE Trans. on Power System, vol.25, no.1, February 2010, pp. 360-370.
[17] V.H. Mendez Quezeda, Jua-Rivier Abbad, T. Gomez, “Assessment of energy distribution losses for increasing penetration of DG”, IEEE Transactions on Power System, vol.21, no.2, May 2006, pp. 533-540.
[18] Sudiptha Ghosh, S.P. Ghoshal, Suradindu Ghosh, “Optimal sizing and placement of DG in network system”, Electrical power and energy systems, vol.32, 2010, pp. 849-856.
[19] Porkar, P. Poure, A. Abbaspour-Tehrani-fard, S.Sadate, “A novel distribution system planning framework implementing DG in a deregulated electricity market”, Electric power system research, vol.80, 2010, pp. 828-837.
[20] R.K. Singh, S.K. Goswami, “Optimal allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage profile improvement including voltage rise issue”, Electric power and energy systems, 32 (2010), pp. 637-634.
[21] Hasham Khan, M.A. Choudhry, “Implementation of distributed generation algorithm for performance enhancement of distribution feeder under extreme load growth”, Electrical power and energy systems”, 32 (2010), pp. 985-997.
[22] W. Ouyang, H. Cheng, X. Zhang, L. Yao, “Distribution network planning method considering distributed generation for peak cutting”, Energy conversion and management, 51 (2010) 2394-2401.
[23] D.Q. hung, N. Mithulanathan, R.C. Bansal, “Multiple distributed generators placement in primary distribution networks for loss reduction”, IEEE Transactions on industrial electronics, vol. , issue. 99, 2010.
[24] M.C.A. Herault, D.P.R. Caire, B. Raison, N. HadjSaid, W. Bienia, “A novel Hybrid architecture to increase DG insertion in electrical distribution systems”, IEEE transactions on power systems, vol. 26, no.2, May 2011.
[25] Alexandre Barin, Luis F, Pozatti, Luciane N. Canha, “Multi-objective analysis of impacts of DG placement on the operational characteristics of networks for distribution system planning”, Electrical power and energy systems, 2010.
[26] Suroudi, M. Eshan, “A distribution system expansion planning model considering DG options and techo-economical issues”, Energy vol.35, 2010, pp.1364-1374.
[27] Ziari, G. Ledwich, A. Ghosh, “Optimal allocation and sizing of DGs in distribution networks”, IEEE Power and energy society general meeting, 25-27 July 2010, Minneapolis, Minnesota.
[28] W. EI-Khattam, Y.G. Hagazy, M.M.A. Salama, “An integrated distributed generation optimization model for distribution system planning”, IEEE trans. on power systems, vol. 20, no.2, May 2005, pp. 1158-1165.
[29] W.EI-Khattam, K. Bhattacharya, Y.G. Hagazy, M.M.A. Salama, “Optimal investment planning for distributed generation in a competitive electricity market”, IEEE trans. On power systems, vol. 19, no.3, August 2004, pp. 1674-1684.
[30] Deepedra Singh, Devendra Singh, K.S. Verma, “Multi-objective optimization for DG planning with load models”, IEEE transactions on power systems, vol. 24, no.1, February 2009, pp. 427-436.
[31] R.M. Kamel and B. Karmanshahi, “Optimal size and location of DGs for minimizing power losses in a primary distribution network”, Trans. on CS and EEE, vol.16, no.2, December 2009, pp. 137-144.
[32] .Ganguly, N.C.Sahoo, D.Das, “A novel multi–objective PSO technique for electric distribution system planning incorporating distributed generation”, IEEE Trans. on Energy System, vol.1, 2010, pp. 291-237.
[33] Giani Celli, Emilio Ghiani, Susanna Mocci, Fabrizio Pilo, “A multi-objective evolutionary Algorithm for siting and sizing of distributed generation”, IEEE Trans. on power systems, Vol. 20, no.2, may 2005, pp. 750-757.
[34] M.A. Golkar, S. Hassienzadeh, A.Hajizadeh, “Optimal multi-objective planning of distribution System with DG”, Journal of Iranian association of electrical and electronics, Vol.5, no.2, 2008, pp. 37-44.
[35] L.F. Achoa, A.P.Felrtin, G.P. Harrison,“ Evaluating distributed generation (DG) impacts with multi- objective index”, IEEE Trans. On power delivery, vol. 21, no.3, July 2006, pp. 1452-1458.
[36] Antonio Piccolo, Pierluigi Siano, “Evaluating the impact of network investment deferral on DG Expansion”, IEEE Trans. on power systems, vol.24, no.3, Aug 2009, pp. 1559-1567.
[37] W.T.C. Wang, Luis F. Ochoa, G.P. Harrison, “DG impact on investment deferral: Network planning and security of supply”, IEEE Trans. on Power System, vol.25, no.2, May 2010, pp. 1134-1141.
[38] Chowdhury, Sudhir Kumar Agarwal, Don O. Koval, “Reliability modeling of distributed generation in conventional distribution systems planning and analysis”, IEEE Trans. on industry applications, vol. 39, no.3, October 2003, pp. 1493-1498.
[39] J. H. Choi and J. C. Kim, “Network reconfiguration at the power distribution system with dispersed generations for

loss reduction", in Proc. IEEE Power Engineering Society Winter Meeting, 2000, vol. 4, pp. 2363–2367.

[40] Y.K. Wu, Ching- Yu Lee, Le- Chang Liu, Shao-Hong Tsai, " Study of reconfiguration for the distribution system with DG", IEEE Trans. on Power Delivery ,vol.25,no.3, July 2010, pp. 1678-1684.

[41] Viswanadha Raju. G.K, Bijwe P.R, "An efficient algorithm for minimum loss reconfiguration of distribution system based on sensitivity and heuristics", IEEE Trans. on power systems, vol. 21, no.3, February 2008, pp. 1280-1287.

[42] A.A. Abou EI-Ela, S.M. Allam, M.M. Shatla, "Maximal optimal benefits of distributed generation using genetic algorithm", Electric power system research, 80 (2010), pp. 869-877.

[43] Aliereza Suroudi, Mehdi Ehsan, Hamidreza Zareipour, "A practical eco-environmental distribution network planning model including fuel cells and non-renewable distributed energy resources", Renewable energy, xxx (2010) 1-10.

[44] Z.A. Muis, H. Hashim, Z.A. Manan, F.M. Taha, P.L. Douglas, "Optimal planning of renewable energy-integrated electricity generation schemes with CO2 reduction target", Renewable energy, 35 (2010), pp. 2562-2570.

Objective	References	Remarks
Multiple		
Minimization of cost of DG investment and O&M, cost of power purchased from the grid, cost of power loss	[19]	NA
Minimization of cost of energy purchased from grid, cost of DG, and network reinforcement.	[26]	NA
Minimization of DG investment and cost of O&M and loss compensation.	[28]	12% 19.9%
Minimization of capacity investment and O&M cost, payment for loss compensation.	[29]	NA
Minimization of Cost of network upgrading, energy not supplied and power loss.	[33]	39% 34.7%
Minimization of Cost of energy not supplied and power loss.	[34]	NA
Minimization of T&D investment cost, DG installation and O&M cost	[36]	30%
Investment deferral cost	[37]	NA

Table 2. Economical impacts of inclusion of DG

Objective	Reference	Remark
Multiple		
Voltage profile improvement, line loss reduction and emission reduction.	[12]	NA

Table 4. Techno-environmental Impacts of DG

Objective	Remarks	References
Mutiple		
Cost minimization and loss reduction.	NA	[18]
Revenue maximization, loss reduction and voltage profile improvement.	12.91% US$/year	[20]
Minimization of feeder cost, cost of loss, DG investment and O&M cost.	10%	[22]
Minimization of global cost and, reliability improvement.	NA	[24]
Voltage profile improvement, loss reduction at minimum DG cost.	NA	[25]
DG installation and O&M cost minimization, Reliability improvement, voltage profile improvement, loss reduction.	C_r=41% V_P=0.87%	[32]
Voltage profile improvement, line loss reduction, power flow reduction and peak capacity increase.	NA	[42]

Table 3. Techno-economical impacts of DG

Objective	Remarks	References
Multiple		
Minimization of emission	50%	[44]
Minimization of cost and emission	17.69% 15%	[43]

Table 5. Econ-environmental Impacts

◈◈◈