ARTICLE
JOURNAL`S UNIVERSITY OF BABYLON FOR ENGINEERING SCIENCES (JUBES)
مـــجلــة جـــــامعة بـــــــابــل للعلـــــوم الهندسية
Vol. 32, No. 3. \ 2024 ISSN: 2616 - 9916

A Review on Distributed Generation Effects on Electrical Power Systems

Karrar M. Al-Anabry[1] **Hayder Hussein Kadhum**[2]

1, 2 Department of Electrical Engineering, University of Babylon, Babylon, Iraq

Karrar.ajeel@uobabylon.edu.iq eng.hayder.kadhum@uobabylon.edu.iq

Received: 6/3/2024 **Accepted:** 7/5/2024 **Published:** 10/6/2024

Abstract

Distributed generation (DG) is used to describe a small-scale production of electrical power through integrating different energy technologies. In fact, integration of DG into distribution systems might result in various technical, operational, and economic impacts on distribution systems that can contribute to the enhancement of the security and reliability of the grid. These benefits include decreasing the operation cost, improving the voltage profile and the voltage stability, reducing the losses in the lines as well as eliminating the upgrades of the existing electric networks. In fact, DG units that located close to loads can significantly reduce energy losses in distribution systems. However, DG units need to be allocated correctly and optimally in order to avoid negative effects on electric networks in terms of power losses and voltage profile for the whole network. This paper presents an overview regarding distributed generation effects of electrical networks in terms of technical, environmental and economic benefits.

Keywords: Distributed generation, Power losses, Economic benefits, Technical benefits.

1. Introduction

Renewable energy resources such as solar, wind, hydropower and other renewable technologies have emerged as safe, clean and economic resources, which can be used to reduce the dependency on fossil fuels through the correct integration of these sources with the traditional ones. In fact, a significant number of countries aim to increase the penetration of renewable energy resources into the current conventional networks in order to reduce the emissions from the electrical power that produced from the fissile fuel sources where these countries placed goals for increasing renewable energy penetration. Renewable energy resources such as solar, wind and geothermal as well as the storage technologies emerged as alternative and sustainable ways for producing electrical power globally. Recently, the normal electrical grids are experiencing high penetration of these resources for the purpose of generating safe and clean energy as well as for making the current grid more resilient, reliable and efficient [1]. The integration of storage technologies and renewable energy resources into the power grids could be achieved in the form of small units called distributed generation (DG) [2]. The consumption of energy has decreased significantly, where the majority of energy consumption relies on using fossil fuels. In fact, the total energy that consumed worldwide increased significantly from 6106 Mtoe to 13371 Mtoe between the period of 1973 and 2012 where the share of gas, oil and coal is about 81% of the total energy consumed in 2012 [3]. Additionally, the worldwide consumption of energy is 10 Terawatts (TW) per a year and it is expected to be 30 TW by 2050 [4]. In order to stabilize the amount of CO_2 emissions in the atmosphere, the world require adopting around 20 TW of non-destructive energy, which is not associated with CO_2 emissions [4].

2. Distributed generation overview

Generally, Distributed generation can be defined as an electrical power source that connected directly to the distribution network or to the customer [5]. However, there are many definitions for the concept of distributed generation in terms of sizing, capacity and location. For example, The Electric Power Research Institute has defined distributed generation in terms of generation from a few kilowatts to 50 Megawatt [6]. Therefore, it can be seen that the definitions of distributed generation varied with respect to its size depends on the applications and the area and that used for. In addition, different types of distributed generation units with their ratings presented in Table (1) [7-10]. Distributed generation units include several technologies such as wind, solar, fuel cells, geothermal and energy storage technologies which can be connected together or separately to make an network islanded or connected to the main grid as shown in Figure (1) [11].

Table (1): The ratings of distributed generation units [7-10]

DG Technology	Rated Size of DG Technology
Combined cycle gas	34 MW – 400 MW [7]
Micro-Turbines	34 kW – 1 MW [7]
Internal combustion engines	4 kW – 10 MW [7]
Combustion turbine	1 MW – 250 MW [8]
Wind turbine	250 W – 3 MW [8]
Small hydro	1MW – 100 MW [9]
Photovoltaic arrays	10 W – 100 kW [9]
Micro hydro	20 kW – 1 MW [9]
Solar thermal, Lutz system	15 MW – 80 MW [7]
Solar thermal, central receiver	1 MW – 10 MW [7]
Geothermal	5 MW – 100 MW [7]
Biomass	100 kW – 20 MW [8]
Fuel cells, proton exchange	1 kW – 250 kW [10]
Fuel cells, phocid	200 kW – 2 MW [10]
Fuel cells, solid oxide	250 kW–5 MW [10]
Fuel cells, molten carbonate	250 kW – 2 MW [10]
Stirling engine	2 KW – 10 kW [8]
Ocean energy	100 kW – 1 MW [7]
Battery storage	500 kW – 5 MW [10]

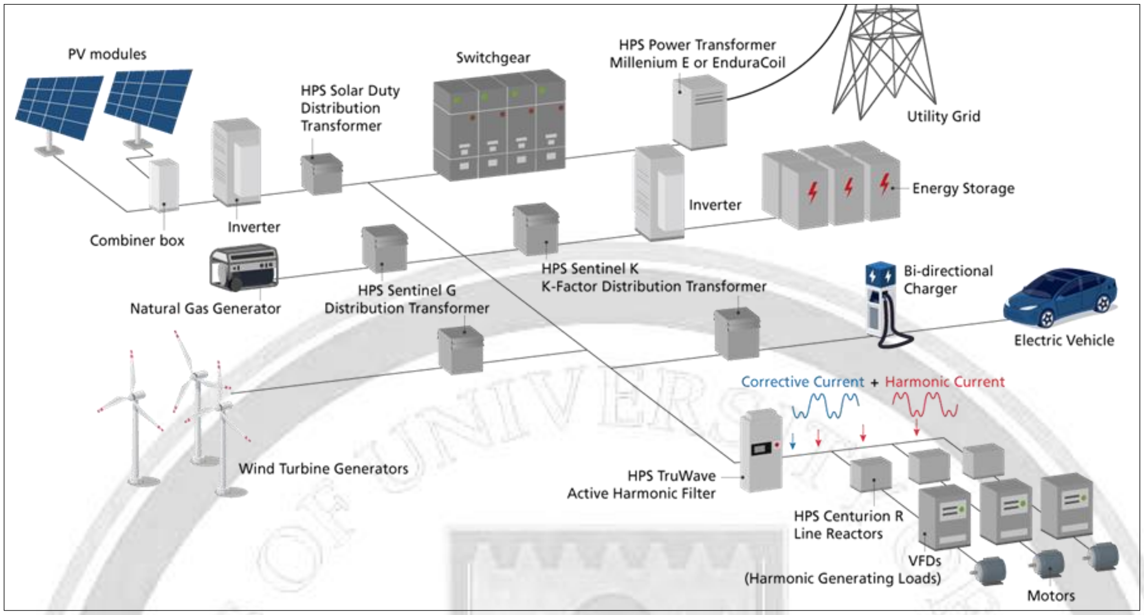

Figure (1): Integration of different distributed generation units into electric grid [11].

Typically, an electrical power source is connected to the electrical network through a point, which named point of common connection (PCC) which linked through an interfacing technology. In fact, there are various methods that can be used to interface distributed technologies with the current electric network such as full and partial power electronic coupling as shown in Figure (2) where different approaches are illustrated [12].

Energy source type	Source of energy	Electrical generator	Power electronics
Wind power	Wind	SG, PMSG, IG, DFIG	Optional, AC/AC
Hydropower	Water	SG	N/A
Fuel cell (CHP)	Hydrogen	N/A	DC/AC
Biomass (CHP)	Biomass	SG, IG	N/A
Microturbines (CHP)	Diesel or gas	SG, IG	Optional, AC/AC
Photovoltaic (solar power)	Sun	N/A	DC/AC
Solar thermal (solar power)	Sun	IG	N/A
Wave power	Ocean	LSG	AC/AC
Flow of river (small hydro)	Rivers	PMSG	AC/AC
Geothermal	Earth temperature	SG, IG	No

Figure (3): Interfacing approaches of different distributed generation technologies [12].

Additionally, Distributed generation units have a significant number of benefits, which can be classified into three categories, which are technical, economic and environmental benefits. In fact, DG units can play an important role in providing ancillary services such as frequency control, voltage regulation, spinning reserve and reactive power support [13, 14]. Indeed, the DG units also contribute to reduce the gas emissions, which consequently reduce the impacts of global warming and climate change as well as provide clean and safe energy to the consumers [15, 16]. However, the integration of such these technologies into the power grids is considered as a major challenge because of the inappropriate allocation and sizing of these units might lead to power losses maximization, voltage profile deterioration and reliability reduction and therefore, these the optimal planning of DG units is sorely needed [17].

3. Distributed Generation Benefits

Distributed generation units have a significant number of benefits, which can be classified into three categories, which are technical, economic and environmental benefits. In fact, distributed generation units can play an important role in providing ancillary services such as voltage regulation, frequency control, spinning reserve and the support of reactive power. However, inadequate operation and planning of DG resources might lead to low stability of the grid, voltage rise and higher losses as a consequence of adverse power flow. Therefore, the appropriate accommodation of DG resources is sorely needed. In addition, the planning of DG resources should consider different technical, environmental and economic constraints in order to bring a variety range of benefits to the grid and consequently the consumers.

3.1 Technical Benefits

The DG technology has s considerable number of technical benefits in terms of enhancing voltage profile, reducing energy losses, improving the grid reliability and removing some issues of electrical power quality.

3.1.1 Energy losses

The electrical power distribution system is associated with considerable voltage drops as the ratio of R/X of the distribution system is significantly high that results in considerable power losses in the grid. In fact, the losses of distribution system are higher than the losses of transmission system. For instance, a study demonstrated that the distribution system losses are about 6% - 8% while the transmission losses are about 2.5%-7.5% in the American electric grid [18]. Consequently, more research in terms of reducing distribution losses is sorely needed, as it is a challenging task.

In fact, the planning methods of DG units for the aim of loss reduction can be divided into two types, which are minimising energy and power losses. The optimal sizing and allocation of DG units for power loss reduction in the electric distribution system have attracted the researchers' interest. A significant number of studies have supposed that distribution generation units are working as dispatchable units with peak load [18]. For example, numerical methods have been used in [19, 20], analytical approaches have been presented in [21].

In addition, different methods based on heuristic algorithms have also used such as Genetic Algorithms (GA) [22], Harmony Search Algorithms (HSA) [19] as well as Particle Swarm Optimization (PSO) [23]. However, these conventional approaches might not consider the renewable energy resources as well as time changing characteristics of the load. Additionally, some researchers have recently used two main methods based on probabilistic and time series models in order to assess the energy losses and consider renewable resources.

Indeed, a few research has done regarding time changing characteristics of loads with renewable sources for the aim of reducing energy losses. For instance, optimal sizing of DG units based on wind turbine have been investigated using Optimal Power Flow (OPF) in [25] and also through using Genetic Algorithm method (GA) in [24]. However, these methods did not consider the optimal location of wind turbines.

Additionally, optimal sizing and location of solar PV and wind turbine based distributed generation units were studied in [26] through using evolutionary programming based method with considering the probability of generation and demand. Finally, the conventional planning approaches for optimal sizing and locating of DG units provide less accurate results in comparison with probabilistic and time varying methods.

3.1.2 Voltage stability

Typically, the voltage instability happens due to the lack support of reactive power with strongly loaded electric system, which might lead to voltage breakdown. In fact, the voltage instability at the distribution levels have been investigated through several studies and reports. A study in [27] have reported that distribution system on a specific industrial region was subjected to voltage collapse due to heavy demand conditions. Indeed, voltage stability need extensive research in recent network due to the increased penetration of intermittent resources such solar PV and wind power and fluctuations of loads.

In addition, optimal allocation and sizing of distributed generation units for the aim of improving voltage stability has attracted the interest of researchers where various approaches have been used to solve this matter. For example, various conventional methods have been used such as numerical approach in [28], Continuous power flow (CPF) based method in [29], Particle Swarm Optimization (PSO) in [30,31] and Genetic Algorithm based approach in [32]. However, these approaches did not consider intermittent energy resources as well as time changing properties of various demands.

A probabilistic method for allocation of renewable resources based DG units was proposed in [33] for the aim of improving voltage stability where both generation and varied demand were considered through applying sensitive technique to find candidate buses. However, a study in [34] have reported that sensitivity approaches might be infective for choosing candidates buses. Additionally, a study based on voltage stability algorithm in [35] was proposed for enhancing voltage stability through using CPF and Modal analysis to find candidate buses. Finally, using sensitive analysis approaches might limit the penetration levels of distributed generation units into a specific distribution system.

3.1.3 Network upgrade deferral

The network upgrade deferral can be defined as the capability to postpone a specific investment regarding transformers and feeders in electric network due to the connection of distributed generation units. In fact, network upgrade deferral can play an important role in meeting the growing demand [36]. Typically, the studies of optimal sizing and location of DG units for the aim of postponing the investments of distribution grid are associated with economical and technical benefits based methods. For instance, various methods were used for the aim of increasing the advantages of network upgrade deferral such as hybrid GA and Optimal Power Flow (OPF) in [37], hybrid heuristic method based on immune system and GA [38] and a dynamic method based on OPF in [39] for the aim of decreasing capital costs for upgrading the electric grid.

3.1.4 Reliability

The main purpose of electrical power grids is to supply customers at different stages with a reliable and efficient electrical power. Reliability of the electric networks is one of the major characteristics of the electrical networks that need to be furtherly investigated. In fact, the installation of DG units plays an important role in enhancing the reliability of the electric grids. A study of optimal sizing and location of DG units in [40] based on system segmentation method was proposed for the aim of maximizing the reliability of electrical power system. In addition, a multi-objective study for optimal location and sizing of DG units based on ε-constraint and Genetic Algorithm (GA) approaches for improving the electric grid reliability [41]. However, all the previous work was based on utilizing traditional dispatchable distributed generation units.

3.1.5 Voltage profile

The voltage profile is related to the quality of supplied power where voltage profile is attracting the interest of researchers due to the increased penetration levels of renewable energy resources. In fact, there are a considerable research regarding voltage profile at the electric distribution system. For instance, a multi criteria index based method was proposed for optimal allocation and sizing of DG units in order to enhance voltage profile, optimize the DG quantity as well as reduce power losses [42].

However, the limitation with the previous work is that the demand was supposed to be constant not a time varying demand. In addition, a multi objective method for optimal sizing and location of DG units based on Genetic Algorithm (GA) was presented in [23] for the purpose of improving voltage profile and enhancing MVA capacity of the electric system. Various load models were considered in the previous study, which showed that considerable difference in the size, and location of DG units is achieved with changing load models.

Similarly, a multi-criteria approach based on PSO algorithm technique was presented in [43] in order to enhance voltage profile, decrease power losses as well as maximizing voltage stability where various load models and non-unity power factor were also considered. However, both studies in [43] have a limitation where the distributed generation units were supposed to be dispatchable resources and located at peak demand.

3.2 Environmental Benefits

Conventional (centralized) electrical power plants emit a great amount of poisonous gases such as nitrogen dioxide (NOx) and carbon dioxide (CO2) because of burning fossil fuels, which have destructive impacts on the environment. In fact, various international agreements and policies have intended to decrease the amount of these emissions such as Kyoto Protocol through increase the penetration of renewable DG resources well as decrease the dependence on the centralized power plants [44]. A significant number of studies have assured that the widespread adoption and utilization of DG units can considerably decrease emissions. For example, the Danish electrical power system have reported that the adoption of DG technology reduced the emissions by 30% between 1998 and 2001 [45]. Another example includes British power system where the use of local combined heat and power technology lead to the reduction of CO2 emissions by 41% in 1991 [45]. This confirm the positive effects of DG technology in terms of reducing the impacts of climate change.

Indeed, renewable DG technologies such as solar PV, biomass and wind are associated with no or little emissions in comparison with the conventional technology such natural gas turbines and thermal plants. Other environmental benefits include lower emission and noise as well as more green power. Additionally, various methods and approaches have been proposed for the aim of optimal sizing and allocation of DG units for the aim of maximization emission mitigation as well as associated with economical and technical advantages. For instance, a modified honeybee mating optimization algorithm was proposed to reduce the emissions and minimize the operation and installation costs as well as energy losses of DG units [46]. In addition, a multi objective study that based on Immune Genetic Algorithm (IGA) method is proposed to reduce the poisonous emissions while minimizing the installation and operation costs of DG units [47]. Similarly, a multi attribute approach was proposed to decrease both the emissions and the costs of operation and installation of DG units [48].

Moreover, a probabilistic multi objective method that based on nonlinear programming computation was proposed in order to accomplish a trade-off between minimizing the emissions and minimizing the financial costs [49]. However, all these methods and studies have a limitation where the DG units were supposed to be operated as dispatchable units without paying attention to the uncertainties of these resources. Furthermore, a multi-criteria optimization method based on Genetic Algorithm (GA) was developed for a wind-based distribution generation with considering uncertainties of wind power. Indeed, the purpose of this study is to enhance the reliability of wind DG, decrease losses and costs as well as minimize the serious impacts on the environment [50]. Finally, environmental impacts of DG technology are an important topic that attracts a significant number of academics and researchers to investigate more and propose approaches that are more efficient in order to reduce emissions.

3.3 Economic Benefits

Distributed generation technology has various financial advantages in terms of reducing the operation, maintenance and installation costs, decreasing fuel costs, reducing the prices of electricity and deferring investments for improving the grid facilities. In addition, the technical and environmental advantages from DG units have monetary impacts that need to be considered. In fact, a considerable research has done regarding DG planning but the majority of these works investigated the cost analysis. In fact, all the proposed methods from [51] have considered the analysis of the DG units cost only. Additionally, a multi criteria method based on mixed integer nonlinear programming (MINLP) was proposed for the aim of minimizing the line losses as well as minimizing the cost of fuel in the hybrid electrical power market [51].

A framework was proposed based on the integration of Geographical Information Systems (GISs) simulation modules and mathematical optimization for the purpose of reducing the total cost of investment, maintenance, operation and the cost of energy from the conventional resources [52]. Similarly, a study was presented in [53] based on heuristic planning model through using mathematical model and modified software tools, which are MATLAB and GAMS, for the aim of decreasing total cost of DG planning, maintenance and reducing the energy losses. Similarly, a study based on incorporating both Particle Swarm Optimization (PSO) and constriction factor for the objective of minimizing the operation and investment cost as well as decreasing energy losses and the imported power [54]. In addition, a proposed method was presented in [55] that based on a techno-economic assessment for biomass power plant where the economic optimal size was calculated and examined.

However, a few studies were proposed for the aim of planning DG investment in terms of energy sales benefits from distributed generation units. For example, a heuristic approach was presented to size and allocate DG units for the purpose of maximizing the profit of the utility in terms of energy sales as well as minimizing the operation and investment costs [56]. Moreover, a research in [57] was presented that based on Genetic Algorithm (GA) to locate DG units for the aim of maximizing energy sales and consequently, the profit of the providers as well as reducing the energy losses. Finally, a wide range of economic advantages in terms of maximizing energy sales and provider profits as well as minimizing energy prices, energy losses and investment and operation costs.

4. Conclusion

In conclusion, a brief overview regarding electrical power distribution system, the principle of distributed generation and the main technologies of distributed generation was clearly presented. In addition, this review presents the main advantages and disadvantages of distributed generation in terms of technical, economic and environmental constraints where different case studies and scenarios were thoroughly presented. In fact, the benefits of DG units outweigh the disadvantages of these technologies, which can refer to a promising future for this principle around the world. Additionally, DG units require appropriate planning to be integrated into the conventional resources in order to minimize the negative consequences such as voltage collapse and unreliable networks as well as maximize the positive one such as adequate ancillary services. Additionally, different interfacing approaches between the electrical grid and the distributed generation units were also illustrated in this review in order to show how to implement the harmonization between the produced energy and the requirements of electrical networks.

References

[1] J. Casazza, J. Casazza, and F. Delea, *Understanding electric power systems: an overview of the technology and the marketplace* vol. 13: John Wiley & Sons, 2003.

[2] I. Committee, "IEEE standard for interconnecting distributed resources with electric power systems," *New York, NY: Institute of Electrical and Electronics Engineers*, 2003.

[3] "Key World Energy Statistics," International Energy Agency" 2014.

[4] T. Razykov, C. Ferekides, D. Morel, E. Stefanakos, H. Ullal, and H. Upadhyaya, "Solar photovoltaic electricity: current status and future prospects," *Solar Energy*, vol. 85, pp. 1580-1608, 2011.

[5] Njuguna, Chege Simon. Optimization of Placement and Sizing of Distributed Generation and Capacitors for Voltage Stability Improvement. Diss. JKUAT-COHRED, 2021.

[6] 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.

[7] A. Keane and M. O'Malley, "Optimal allocation of embedded generation on distribution networks," *Power Systems, IEEE Transactions on*, vol. 20, pp. 1640-1646, 2005.

[8] Ackermann, Thomas, Göran Andersson, and Lennart Söder. "Distributed generation: a definition." Electric power systems research 57.3 (2001): 195-204.

[9] International Energy Agency, Enhancing the Market Deployment of Energy Technology: a Survey of Eight Technologies, Paris, 1997.

[10] Duffie, John A., William A. Beckman, and Nathan Blair. Solar engineering of thermal processes, photovoltaics and wind. John Wiley & Sons, 2020.

[11] Mahmud, Khizir, et al. "An internet of energy framework with distributed energy resources, prosumers and small-scale virtual power plants: An overview." Renewable and Sustainable Energy Reviews 127 (2020): 109840.

[12] Husin, H., and M. Zaki. "A critical review of the integration of renewable energy sources with various technologies." Protection and control of modern power systems 6.1 (2021): 1-18.

[13] N. Khalesi, N. Rezaei, and M.-R. Haghifam, "DG allocation with application of dynamic programming for loss reduction and reliability improvement," *International Journal of Electrical Power & Energy Systems,* vol. 33, pp. 288-295, 2011.

[14] Sambaiah, Kola Sampangi, and T. Jayabarathi. "Optimal reconfiguration and renewable distributed generation allocation in electric distribution systems." International Journal of Ambient Energy 42.9 (2021): 1018-1031.

[15] Valencia, Alejandro, Ricardo A. Hincapie, and Ramón A. Gallego. "Optimal location, selection, and operation of battery energy storage systems and renewable distributed generation in medium–low voltage distribution networks." Journal of Energy Storage 34 (2021): 102158.

[16] Pandey, Ravi Shankar, and S. R. Awasthi. "A multi-objective hybrid algorithm for optimal planning of distributed generation." Arabian Journal for Science and Engineering 45.4 (2020): 3035-3054.

[17] L. I. DULAU, M. ABRUDEAN, and B. Dorin, "SCADA simulation of a distributed generation system with power losses," *Scientific Bulletin of the" Petru Maior" University of Targu Mures,* vol. 11, p. 25, 2014.

[18] A. Nourai, V. Kogan, and C. M. Schafer, "Load leveling reduces T&D line losses," *Power Delivery, IEEE Transactions on,* vol. 23, pp. 2168-2173, 2008.

[19] Dini, Anoosh, et al. "A flexible-reliable operation optimization model of the networked energy hubs with distributed generations, energy storage systems and demand response." Energy 239 (2022): 121923.

[20] Grisales-Noreña, Luis F., Oscar Danilo Montoya, and Carlos Andrés Ramos-Paja. "An energy management system for optimal operation of BSS in DC distributed generation environments based on a parallel PSO algorithm." Journal of Energy Storage 29 (2020): 101488.

[21] L. F. Ochoa and G. P. Harrison, "Minimizing energy losses: Optimal accommodation and smart operation of renewable distributed generation," *Power Systems, IEEE Transactions on,* vol. 26, pp. 198-205, 2011.

[22] Abdelkader, Mohamed A., Zeinab H. Osman, and Mostafa A. Elshahed. "New analytical approach for simultaneous feeder reconfiguration and DG hosting allocation in radial distribution networks." Ain Shams Engineering Journal 12.2 (2021): 1823-1837.

[23] Taha, Haitham A., M. H. Alham, and Hosam KM Youssef. "Multi-objective optimization for optimal allocation and coordination of wind and solar DGs, BESSs and capacitors in presence of demand response." IEEE Access 10 (2022): 16225-16241.

[24] R. S. Rao, K. Ravindra, K. Satish, and S. Narasimham, "Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation," *Power Systems, IEEE Transactions on,* vol. 28, pp. 317-325, 2013.

Vol. 32, No. 3. \ 2024 ISSN: 2616 - 9916

[25] F. Ugranlı and E. Karatepe, "Optimal wind turbine sizing to minimize energy loss," *International Journal of Electrical Power & Energy Systems,* vol. 53, pp. 656-663, 2013.

[26] D. K. Khatod, V. Pant, and J. Sharma, "Evolutionary programming based optimal placement of renewable distributed generators," *Power Systems, IEEE Transactions on,* vol. 28, pp. 683-695, 2013.

[27] M. Chakravorty and D. Das, "Voltage stability analysis of radial distribution networks," *International Journal of Electrical Power & Energy Systems,* vol. 23, pp. 129-135, 2001.

[28] M. Esmaili, "Placement of minimum distributed generation units observing power losses and voltage stability with network constraints," *Generation, Transmission & Distribution, IET,* vol. 7, pp. 813-821, 2013.

[29] H. Hedayati, S. Nabaviniaki, Akbarimajd, and A. Akbarimajd, "A method for placement of DG units in distribution networks," *Power Delivery, IEEE Transactions on,* vol. 23, pp. 1620-1628, 2008.

[30] M. Aman, G. Jasmon, A. Bakar, and H. Mokhlis, "A new approach for optimum DG placement and sizing based on voltage stability maximization and minimization of power losses," *Energy Conversion and Management,* vol. 70, pp. 202-210, 2013.

[31] P. Kayal and C. Chanda, "Placement of wind and solar based DGs in distribution system for power loss minimization and voltage stability improvement," *International Journal of Electrical Power & Energy Systems,* vol. 53, pp. 795-809, 2013.

[32] S. K. Injeti and N. P. Kumar, "A novel approach to identify optimal access point and capacity of multiple DGs in a small, medium and large scale radial distribution systems," *International Journal of Electrical Power & Energy Systems,* vol. 45, pp. 142-151, 2013.

[33] R. Al Abri, E. F. El-Saadany, and Y. M. Atwa, "Optimal placement and sizing method to improve the voltage stability margin in a distribution system using distributed generation," *Power Systems, IEEE Transactions on,* vol. 28, pp. 326-334, 2013.

[34] R. Kollu, S. R. Rayapudi, and V. L. N. Sadhu, "A novel method for optimal placement of distributed generation in distribution systems using HSDO," *International Transactions on Electrical Energy Systems,* vol. 24, pp. 547-561, 2014.

[35] M. Ettehadi, H. Ghasemi, and S. Vaez-Zadeh, "Voltage stability-based DG placement in distribution networks," *Power Delivery, IEEE Transactions on,* vol. 28, pp. 171-178, 2013.

[36] S. Favuzza, G. Graditi, M. G. Ippolito, and E. R. Sanseverino, "Optimal electrical distribution systems reinforcement planning using gas micro turbines by dynamic ant colony search algorithm," *Power Systems, IEEE Transactions on,* vol. 22, pp. 580-587, 2007.

[37] G. P. Harrison, A. Piccolo, P. Siano, and A. R. Wallace, "Hybrid GA and OPF evaluation of network capacity for distributed generation connections," *Electric Power Systems Research,* vol. 78, pp. 392-398, 2008.

[38] A. Soroudi and M. Ehsan, "Efficient immune-GA method for DNOs in sizing and placement of distributed generation units," *European Transactions on Electrical Power,* vol. 21, pp. 1361-1375, 2011.

[39] E. Naderi, H. Seifi, and M. S. Sepasian, "A dynamic approach for distribution system planning considering distributed generation," *Power Delivery, IEEE Transactions on,* vol. 27, pp. 1313-1322, 2012.

[40] Y. Attwa and E. El-Saadany, "Reliability based analysis for optimum allocation of DG," in *Electrical Power Conference, 2007. EPC 2007. IEEE Canada*, 2007, pp. 25-30.

[41] G. Celli, E. Ghiani, S. Mocci, and F. Pilo, "A multiobjective evolutionary algorithm for the sizing and siting of distributed generation," *Power Systems, IEEE Transactions on,* vol. 20, pp. 750-757, 2005.

[42] W. S. Tan, M. Y. Hassan, H. A. Rahman, M. P. Abdullah, and F. Hussin, "Multi-distributed generation planning using hybrid particle swarm optimisation-gravitational search algorithm including voltage rise issue," *Generation, Transmission & Distribution, IET*, vol. 7, pp. 929-942, 2013.

[43] A. El-Zonkoly, "Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation," *Generation, Transmission & Distribution, IET,* vol. 5, pp. 760-771, 2011.

[44] A. Tsikalakis and N. Hatziargyriou, "Environmental benefits of distributed generation with and without emissions trading," *Energy Policy*, vol. 35, pp. 3395-3409, 2007.

[45] R. Viral and D. Khatod, "Optimal planning of distributed generation systems in distribution system: A review," *Renewable and Sustainable Energy Reviews*, vol. 16, pp. 5146-5165, 2012.

[46] T. Niknam, S. I. Taheri, J. Aghaei, S. Tabatabaei, and M. Nayeripour, "A modified honey bee mating optimization algorithm for multiobjective placement of renewable energy resources," *Applied Energy*, vol. 88, pp. 4817-4830, 2011.

[47] A. Soroudi, M. Ehsan, and H. Zareipour, "A practical eco-environmental distribution network planning model including fuel cells and non-renewable distributed energy resources," *Renewable Energy*, vol. 36, pp. 179-188, 2011.

[48] A. D. Alarcon-Rodriguez, R. Currie, G. W. Ault, and J. R. McDonald, "Planning highly distributed power systems: effective techniques and tools," *International Journal of Distributed Energy Resources*, vol. 4, pp. 35-53, 2008.

[49] V. Vahidinasab, "Optimal distributed energy resources planning in a competitive electricity market: Multiobjective optimization and probabilistic design," *Renewable Energy*, vol. 66, pp. 354-363, 2014.

[50] T. Jin, Y. Tian, C. W. Zhang, and D. W. Coit, "Multicriteria planning for distributed wind generation under strategic maintenance," *Power Delivery, IEEE Transactions on*, vol. 28, pp. 357-367, 2013.

[51] A. Kumar and W. Gao, "Optimal distributed generation location using mixed integer non-linear programming in hybrid electricity markets," *Generation, Transmission & Distribution, IET,* vol. 4, pp. 281-298, 2010.

[52] S. Kucuksari, A. M. Khaleghi, M. Hamidi, Y. Zhang, F. Szidarovszky, G. Bayraksan, *et al.*, "An Integrated GIS, optimization and simulation framework for optimal PV size and location in campus area environments," *Applied Energy*, vol. 113, pp. 1601-1613, 2014.

[53] S. Porkar, P. Poure, A. Abbaspour-Tehrani-fard, and S. Saadate, "A novel optimal distribution system planning framework implementing distributed generation in a deregulated electricity market," *Electric Power Systems Research*, vol. 80, pp. 828-837, 2010.

[54] K. D. Mistry and R. Roy, "Enhancement of loading capacity of distribution system through distributed generator placement considering techno-economic benefits with load growth," *International Journal of Electrical Power & Energy Systems*, vol. 54, pp. 505-515, 2014.

[55] S. L. Payyala and T. C. Green, "Sizing of distributed generation plant through techno-economic feasibility assessment," in *Power Engineering Society General Meeting, 2006. IEEE*, 2006, p. 8 pp.

[56] W. El-Khattam, K. Bhattacharya, Y. Hegazy, and M. Salama, "Optimal investment planning for distributed generation in a competitive electricity market," *Power Systems, IEEE Transactions on*, vol. 19, pp. 1674-1684, 2004.

[57] M. F. Akorede, H. Hizam, I. Aris, and M. Ab Kadir, "Effective method for optimal allocation of distributed generation units in meshed electric power systems," *Generation, Transmission & Distribution, IET*, vol. 5, pp. 276-287, 2011.

ARTICLE
JOURNAL`S UNIVERSITY OF BABYLON FOR ENGINEERING SCIENCES (JUBES)
مـــجلــة جـــامعة بـــــابـل للعلـــــوم الهندسية
Vol. 32, No. 3. \ 2024 ISSN: 2616 - 9916

مراجعة عن تأثير وحدات التوزيع على انظمة القدره الكهربائية

كرار محسن عجيل[1] حيدر حسين كاظم[2]

1, 2 قسم الهندسة الكهربائية، جامعة بابل، بابل، العراق

eng.hayder.kadhum@uobabylon.edu.iq Karrar.ajeel@uobabylon.edu.iq

الخلاصة

يستخدم التوليد الموزع (DG) لوصف إنتاج الطاقة الكهربائية على نطاق صغير من خلال دمج تقنيات الطاقة المختلفة. في الواقع، قد يؤدي دمج الحكم الديمقراطي في أنظمة التوزيع إلى تأثيرات فنية وتشغيلية واقتصادية مختلفة على أنظمة التوزيع التي يمكن أن تساهم في تعزيز أمن وموثوقية الشبكة، وتحسين ملف الجهد واستقرار الجهد، وتقليل الخسائر في الخطوط، فضلاً عن التخلص من ترقيات الشبكات الكهربائية الحالية. ومع ذلك، لا يمكن تعظيم وتعزيز كل هذه الفوائد المذكورة سابقًا ما لم يتم تحديد الحجم والموقع الأمثل لوحدات التوليد الموزعة بعناية ودقة. في الواقع، يمكن لوحدات التوزيع المباشر التي تقع بالقرب من الأحمال أن تقلل بشكل كبير من فقدان الطاقة في أنظمة التوزيع. ومع ذلك، يجب تخصيص وحدات DG على النحو الأمثل وبشكل صحيح لتجنب النتائج السلبية على الشبكات الكهربائية من حيث فقدان الطاقة وملف الجهد للشبكة بأكملها. تقدم هذه الورقة لمحة عامة عن وحدات التوليد الموزعة من حيث الفوائد الفنية والبيئية والاقتصادية.

الكلمات الدالة:- التوليد الموزع، فاقد الطاقة، فوائد اقتصادية، فوائد تقنية.