A review on impact of distributed generation penetration in deregulated electricity market having renewable energy sources in India

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Abstract. Nowadays it is seen that, distributed generation (DG) system based on conventional energy sources and renewable energy sources (RESs), specially using solar energy, is playing an important role to match load demand across India. Energy policies are promoting renewable energy resources and in the coming time to increase the energy efficiency, DGs installation and RESs scheme will play a vital role. It can be observed that India's load rate is increasing rapidly day by day. Unplanned management made without planning can adversely affect the grid and put a serious load demand on the power grid. Distributed generation systems can be very useful to avoid such problems, especially if we use renewable energy. In this paper, we have mentioned about how we can manage the load demand and how to meet the power supply of the people using the distributed generation. In this review, strength, stability and reliability of distributed generation (DG) system is discussed with different aspects including different scenarios. This analysis shows a major action on the power system planning and working of the grid system. Recent works are included in this review. Different steps have also been taken for the integration of DGs with various scenarios in electric power systems. The main objective of this review is, how to achieve better integration of flexible demand and demand response, so that demand side Management (DSM) with the help of distributed generation can be fulfilled and create grid proficiency. Different challenge in DG system has also been mention in this research.

Keywords: Regulation, Renewable Energy Sources, Distributed Generations, Penetration, Congestion, Electricity market

1. INTRODUCTION

It was seen that a comprehensive reform and change had begun in the entire world in electricity supply industry (ESI). Deregulation is the reduction or elimination of government power in a particular industry, usually enacted to create more competition within the industry. DGs are any small electric power system, independent of traditional utility grid which is located on the user side to meet end users demand. This period was the starting time of the 1990s, when liberalization started with lips and bound in the power supply industries and it moved away from the integrated monopoly of industry. In transmission and distribution, liberalization played a very important role which led restructuring of the electricity sector from traditional vertical utilities into new different participants devoted to specific activities such as generation and retailing. Due to deregulation in electricity supply system, new structure and new relation set up between the participants to enhance progressive decoupling such as the flow of money and flow electricity power. This leads to unbundling of
conventional tariffs schemes and creates special type of tariffs to compensate providers for their cost in transmission network. At that time tariffs establishes using robust methods, leading transparency in the system and by which transmission efficiency can be improved and it may send economical signal to the grid users [1].

There is much challenge in the electricity market as per rules of operation of restructured power system that liberalized market faces number of challenges like security and reliable operation of transmission line, competitive bid prices and conflicts of interest between multiple service providers such as GENCO(Generating Companies), TRANSCO (transmission company) and DISCOM (distribution company) [2]. In the deregulated electricity market, companies want maximum benefits as well as security from cheaper source. Such situation creates extra burden on supply system in term of overloading and congestions of a particular corridors by which the transmission network is affected. Excessive use may violate line flow, which would be a dangerous practice leading to voltage instability and thus further weakening system security. Therefore, the system can be adequately exploited and their available transfer needs to be determined, so that available transfer capabilities ensure the reliability of the system can be maintained. Serving a wide range of bilateral and multilateral transactions, adequate transmission corridors are needed from the system to the whole sale energy markets. Due to liberalization, It is believed that market rules and laws in various national markets exhibit different characteristics from which different design concepts are evolved [3]. The policy of liberalization of electricity markets has two main approaches which are the market organization can be distinguished as bilateral trade of electricity and centralized electricity trade. Sufficient transmission corridors are needed to energy market for reliable power transfer to consumers end. Bilateral trade enhances the bilateral transaction and multilateral transaction model in between GENCO and DISCO without involvement of any third party.

In this type of multi-seller/buyer system individual buyer or sellers make a deal to exchange a power at prices and under the conditions they agree to. Bilateral trading participants in the electricity market, arrange the power transaction independently among themselves so that they become enable for own financial terms. Bilateral transactions have a different importance. Trade of electricity in the electricity market which includes bilateral promotes economic efficiency to maximize the uses of expensive generators [4]. The bilateral approach gives excellent opportunities in decentralized electricity market to make free decision for benefit of consumers as well as producers. We can also promote this in the electricity market by the concept of free market competition, aiming to provide customers with “direct access” to the producers of choice between consumers and producers [5]. As we know that in the centralized business model, a common market for energy business is established in which there are many types of business models. This centralized business model includes the following market model such as spot market, pool market and power exchange etc.

1.1 Centralized electricity markets:

Centralized markets implement central unit commitment. In some ways Markets mimic vertically integrated operations, and have inherited some processes from national monopolies and regional power pools that previously existed before deregulation. According to economic terms, electricity is a commodity which can be used in real time market. The electricity market works as a 'spot' market, where power supply and demand is matched instantaneously. The systems balance supply with demand in real time and free to sell or buy for immediate delivery [6]. Select which generators are dispatched, determine the spot price, and in doing so, facilitate the financial settlement of the physical market. Deregulation improves the economic efficiency of the production and use of electricity. In spot market, the price of electricity fluctuates and assets are bought or sold on commodity exchanges contracted for immediate payment and delivery [7].

Another centralized trading approach is the Pool market, where the bidding process is done on the basis of unit commitment, in which total cost of power generation can be minimize, and all energy transaction are carried out though pool dispatch function [7,8]. In pool market bidding process also follows the same guidelines as in case of spot market but in these market operators are also responsible for use and operation of electrical network. An electricity pool market facilitates competition between generators and the calculation of the price, paid for electricity by buyers. All the market participants, GENCOS, TRANSUCOS and DISCOS and even system operator, market.
Operator, suppliers, etc., are signatories to a pooling agreement that guide the operations of the pool market.

1.2 Centralized power exchange trading:

Power exchange trading model in deregulated electricity markets differ from the spot market and pool markets as they cater to short-term energy trading, but do not include economic unit commitment [9]. This involves power exchange operators not having operations and network access, as there is competition among a lot of players in the deregulated market, which includes power products, transmission and power distribution. In deregulated electricity market, trading of electricity is treated as commodity for economical model. Within a restructured electricity market congestion of network and losses plays a big cause inters of market inefficiency. Many distributed generation options are playing important and fast growing role to become economical viable in deregulated electricity market due to introduction of advanced technologies. Actually DGs are small and new expansion of power capacity in electricity market utilities which is a big cause of boosting economy of system with immense benefits. As in conventional and non-conventional power generation systems, DG includes both small and modular size at door end of transmission and distributions which provides needed electricity to the users. Distributed generations (DGs) may be due to conventional resources such as Diesel engine, gas turbine, thermal power and hydro or due to renewable energy sources. Now a day’s renewable energy distribution generations are rapidly increasing in deregulated market and playing an important role by giving economical benefits for both producers and consumers also more viable economically [10].

2. PROBLEMS FACED:

The exchange-based electricity market is being restructured. An ultimate goal is to cater to a wider range of destinations. Key points include intensifying personal speculation, driving liquidity and productivity forward. It is beneficial to use distributed generation in electricity market to overcome the overloading of conventional utility distribution systems and enhance the efficiency [11]. DGs are more preferred because of low investment cost and reduced capital risk as it is robust and more modulated. In deregulated electricity market, DGs are of different size. The diesel engine, gas turbine plant and biogas and fuel cell generated electricity are considered as small DGs these are easily set up and time of construction is less. Due to advancement and innovation in technology, the deregulated electricity markets has given opened environment to used DGs by using small scale energy resource and connect it to grid for better utilization. Here there are dispersed energy resources available to generate electricity by DGs. From long time traditionally electricity generation is done at large scale by using Nuclear, thermal and hydro power plants. These traditionally power generating stations are located at far distance from the load centre, due to this a long transmission line system needed to set up which is more costly and uneconomical as transmitted from power generating station to load centre and further at consumer end.

Due to increased demand of electricity, new plants are needed to install which take more money and time. DGs are also environment friendly suitable for electricity utility market and consumers. DGs are directly setup near the load centre and demand of electricity can be fulfilled without suffering overloading of transmission system. Now a days, integration of DGs are done with conventional power system at large scale fast to fulfill the demand. IEA listed five major cause that reflect the need of distributed generation after changing regulatory environment and technological innovation [12, 13]. Due to these factors, such as market liberalization, increased customer demand, development of new technologies, constraints without effecting new transmission line and changing climate, resulted a new interest in distribution generations. Here is the DGs and RESs roles in potential market of electricity are shown in figure1.
In certain locality and region, different DGs options can be planned according to the reliability and quality of electricity supply. There are open options for market players to select suitable DG technology in changing market condition by the flexible ways. Due to enhancement and innovation of technology, flexible DG has more options in liberalized electricity market. Changing economic environment also boost the flexible DGs market. As there is small size and less period of construction of DG, it leads more viable and acceptable as compared to large central power plant. As shown in the figure1, different DGs generating plants G1, G2,…… are connected to generation companies and D1,D2……… represented the distribution companies connected a reliable system operator. As DGs are important because it can be connected near the load and it can operate in sequence with system grid. DGs can work independently and supply power to load which is considered as micro grid [14]. This autonomous mode of DGs imbedded with other DGs units. Such system can operate as grid connected entity and autonomous mode.

3. RENEWABLE SOURCE DGs:

One of the major developments in present electricity market scenario is the distributed generation with the help of renewable energy sources (RESs) [15]. DGs in deregulated market have been enhanced with the help of renewable energy distribution generation. In India ample of different renewable energy sources are available which can be utilized. Distributed Generation (DG) employs smaller-size generators using RESs, usually generated by wind energy, solar PV or solar thermal, micro hydro, tidal wave, geothermal, fuel cells and micro turbines etc. These are distributed through the power system but are concentrated mainly closer to the loads. In distributed type solar photovoltaic generation, electricity is generated near the end users and directly distributed to users and the surplus or deficit energy is regulated by the grid. In this PV system is connected to the grid and injects power to grid. RESs based DGs integration with electric utility system is one of the transition step in deregulated electricity market. As renewable energy and DG are complementary to each other because renewable energy transition into generation creates less centralized environment and promotes integrated approach towards renewable technology [16]. Figure 2 shows a renewable source DGs units adopted by grid to maximize system utilization.
4. DGS DEPENDABILITY WITH POWER SYSTEM

In deregulated electricity market, the system operator must have accurate knowledge about customer and theirs expectations so as to ensure the performance of the power system in the competitive market with acceptable reliability. The electric utility industry is moving towards competitive market in which it is supposed to ensures customer expectations and system reliability instead of generation and transmission on which focused from few decades. It is widely considered that inadequacy of generation and transmission system put a great impact on both its society and its environment. For the measurement of system reliability, electric utility gave several performance measurement parameters. These reliability parameters may be the measurement of frequency during outages, duration of outage, system availability and response time measurement. To improve system reliability by DGs capabilities creating intentional islands has been discussed in [17] during service restoration. Service can be restored using the network combination and with intentional islanding for DGs units, has been discussed in this paper [10]. To improve system reliability, there is an optimal siting and sizing method to place DGs units in distribution network [18]. Microgrid can improve system reliability and power quality of load centre. Introduction of microgrid in system can reduce frequency of outages, decreases duration in which level of energy not supplied and rate of interruption and hence improving network reliability [18].

In distributed system, evaluation of reliability of DGs units, based on the intermittent energy sources including solar energy generation or wind energy generation were suggested in various literatures. Impact of DGs on system reliability for distribution network has been examined by the various studies, such as evaluation of fixed or dispatchable DG in conventional distribution system [19]. Gradient projection method for distribution systems in terms of optimal realization index has been presented [20]. Primal dual interior point algorithm method suggested in [21], to gain optimal reliability design in electrical distribution system. Modified genetic algorithm is used to obtain optimum failure rates and repair times in each segments of distribution system [22]. For reliability optimization in radial distribution network, particle swarm optimization method was used in [23]. In [24], an optimal operating strategies for distributed generation was developed, which is based on hourly reliability worth. Effect of microgrids on distribution system, to assess reliability using various
modeling aspects was obtained in [25]. There is a market mechanism which can be used to calculate reliability option in distributed generation systems, was presented in [26]. Such mechanism provides an alternative of distribution system operators to increase investment in new distribution schemes.

4.1 Integration issues associated with DGs:

Due to possible three trends in the electricity market, DGs are extensively introduced such as the utility industries restructured, increase in system capacity and enhancement in technology. Because of attractiveness for manufacturers, policy makers, electricity market operators and regulators it provides an option to reduce transmission and increase investment in power distribution system in a way to reduce the losses in our system [25, 26]. Both DG and DSM can play an important role to demonstrate the more economic behavior with further boosting technology, throughout the wholesale and retail market thereby reducing the cost of supply during peak demand and minimizing the system loss. Retail market opening in the electricity market can creates a huge numbers of competitors with great competition; the other is an economic stimulus from a real pricing to a sophisticated market system, which is very beneficial for DG.

Site scenario, usability and customers are the things that affect the cost of DGs, and the system operator prepares plans for development and planning in electric power systems that ensure the operation and safety of the electricity market. The challenge for the system operator to maintain high quality of power supply to the consumer at the time of volatility in supply and fuel prices by integrating new energy sources regardless of the shrinking and scarcity of energy resources.

4.2 Technical Issues with DGs:

Large variable generation variable generating units create a technical challenge when these are connected to electric utility system. Management of these connected DGs are challenge across a globe to maintain quality of grid and continuous supply to the customers. Various Dg technologies based on common characteristics may be categorized according to: type of energy source or turbine used availability of unit size, feasibility and modularity.

DGs technologies can be classified as how much the unit is operating under emission free condition, type of local/central dispatch and intermittent power output. During the connection of DG units to the present transmission or distribution system, such strict technical rules and regulation needs to be followed. These technical criteria ensure that quality of electric supply should be maintained and no other operational security issues arise in the network.

For power system reliability, power should flow unidirectional but power may flow in bidirectional in utility because of large increased DGS units injects enormous power in system. This induces power flow from the low level voltage to high level. To mitigate this situation we need to put protection schemes at both end of utility system. At the time of outage, customers living in ‘Islanding’ situation must be ensured that quality of supply is maintained and safety of utility will be considered. Resynchronization must also be ensured after distribution grid is back into the system for operation.

Reactive power is one of the important components in power flow which is not produced by mostly asynchronous generators in DGs units. However, DG units while interfaced by modern power electronics devices, provides reactive power at some instant and deliver it into system. But DGs units having fuel cells, PV cells etc, produces DC supply. These DGs units’ needs to synchronize with grid carefully with the help of DC-AC interface which is one of the technical issue. DGs units interface with DC-AC techniques, produces harmonics when fed into system and creates another problem. This requires special technology to nullify it.

DGs units’ allocation should be appropriate in the electric utility system show that the flow of power from distribution network can be maintained economically. DGs units distribution network may cause flow of power in both direction from substation to load or load to substation if proper allocation is not chosen. However, DGs installation may have positive effects by feeding reactive component in distribution system as reactive compensation may reduce losses in system and hence controlling of voltage profile. Generally, the DGs are installed by independent producers or at consumer’s end hence it is difficult to absolute control of the DGs installation by the electric energy utility. However, using technological aspects and methodology, utility can allocate DGs installation for optimal use and for the benefit of society at great instant[27].
4.3 Environmental issues with DGs:
DGs are generated from different energy sources including fossil fuelled which emits harmful gases like CO2, Nox SO2 etc and harm the environment. These emitted gases from DGs units; damage ozone layer of troposphere and causes climate change, global warming and acidification in our environment [28]. This also creates bad impact on air quality, many health and ecological problems. However DGs are beneficial for electric utility and play an important role in DSM. By using technologies and strong emission control technique, these problems can mitigate.

4.4 Economical Issues with DGs:
DGs units are generated near the load centre; however it requires the additional transmission and distribution system to connect it with present electric utility system. For this, underground cables or overhead lines need to be set up which count additional charges. There is another concern to meet power quality and reliability levels of electric utility. According to electric utility condition, extra requirement for grid operator and connections are needed to match cost in present competitive environment. Generating units should be set up in such a way that cost of installation and connection to grid by cables, busbar etc, minimizes [29]. If energy resources are located in remote area, then cost of connection through grid is an important economic constraint investment depends on per unit generated cost by the system. Generally, capital cost for DGs units requires more investment as compared to conventional energy project for the same capacity of installation. Price of DGs units depend on the many factors such as type of technologies used, time of generation and the quality of generation. These factors also allow customers to support in investment in utility company. It is up to the policy makers to understand the fundamental economics of DGs and act according for the growth in future.

5. MANAGEMENT OF CONGESTION:
Now a day’s electricity demand is increasing in the market and to fulfill these requirements, a lot of DGs units have been put on the existing transmission system in deregulated electricity market. This causes congestion in transmission line and creates big challenges for electric utility systems. Due to scarcity of adequate transmission line and to fulfill such demand of customers, the cost of electric supply got increased. This increased power price, in the electricity market is unable to make equilibrium with its competitors, which makes it difficult to do free and fair electricity sells or buy in deregulated market, and hence affect the quality and reliability operation of electric supply [30].

Congestion management is a big challenge in deregulated electricity market. To overcome these issues in network, a lot of methods are suggested and proposed time to time. Some viable approach has developed to minimize the price of electricity due to congestion such as spot price methodology for electricity pool market.

5.1 Various methods based on generation
Cluster-based method has been also proposed for congestion management in which it is checked that how much system users are operating and what constraints are they are affecting of transmission system [31]. To minimize congestion demand side management (DSM) control may more effective instead of rescheduling the generating units. Now a day’s DGs units has been involved in the industry and providing load services which are being set up throughout the transmission and distribution system. To reduce the transaction from system, willingness- to-pay methodology has been given [32]. There is methodology of marginal cost signals, suggested for generators, can be used [33]. Distributed resources used for DGs put a great impact to manage congestion is discussed [34]. Congestion issue in deregulated power markets for optimal power dispatch was suggested [35].

Power electronics devices like flexible ac transmission system (FACTS) play a very important role in utilization of transmission systems in better way and help in congestion management. FACTS devices compensate reactive component in transmission system whenever required and hence transmission system can be manage in efficient way. These FACTS devices are installed at proper location in transmission system to increase the efficiency and relieve the congestion. Particle swarm optimization technique has been also used for minimization of congestion and the power system operational cost which is a complex non-linear optimization method used in [36]. To manage
congestion in transmission network, construction of new network or their expansion and setting new power plant can be implemented which take long span of time[36,37]. Available Transfer Capability (ATC) analysis determines the maximum incremental MW transfer possible between two parts of a power system without violating any specified limits

6. FUTURE CHALLENGES AND RESEARCH SCOPE:

Demand of electricity is increasing by the users and sequentially contingencies and congestion in system has also increased. In these circumstances, contingencies and congestions need to be eliminated from the system by ESI and require expanding generation, transmission and distribution system vastly. One of the alternate ways is to increase distribution generation which may provide a solution for electricity industries in developing infrastructures. There are many benefits of DGs integration with electric utility system. To increase the potential and credit of DG installation, some benefits should be accurately evaluated, analyzed and quantized. Some terms which decide the benefit criteria of DG penetration in the system are energy value, saving of energy cost capacity, quantization of voltage profile improvement, reduction of line loss and mitigation of environment impact. These benefit criteria of evaluation and quantization put attention of researchers towards penetration of DG in system. There are various research papers in which planning for optimization and reliable operation of DGs have been mentioned [37, 38]. But there is loop hole in research works as load-ability voltage security criteria are not considered. The allocation of the DG presented in the literature is not considered DG, based on the needs of the utility and customer approach. In deregulated electricity market, scope of studies of outages cases can be extended in DG allocation based on RESs.

6.1 DG Integration challenge based on RESs:

Planning and utilization of renewable energy sources (RESs) play a vital role in deregulated electricity market, which provides system reliability and adequate energy along with environmental concern. RESs based DG units can be allocated in power system, has been mentioned in various research paper [39, 40]. Some research works shows adequate study of DGs integration in restructured electricity market based on RESs. RESss based DGs units such as wind energy, solar PV or solar thermal, micro hydro, tidal wave, geothermal, fuel cells and micro turbines etc, do not generate continuous electrical energy and generally depends on the circumstances of atmospheric conditions. Integration of such units with electric utility system may have a great challenge. As storage capacity of RESs based generated electrical energy have big challenge which may be utilized during peak hours. However, RESs based energy is neat and clean which create less environmental effect and maximize system utilization.

6.2 Security challenge:

Trading of electricity is got commoditized in a restructured electricity industry as economical model. Trading of electrical energy with controllable frequency and improved voltage profile, it is ESI which is responsible to manage quality of supply by creating competitive environment. Different outages and security challenges in system create a barrier for achieving healthy electricity market. Here commercialization gap need to be addressed so that physical reality can be known. To focus on this gap is necessary because different utilities companies adopted integrated market for providing energy services in all over the world. Electricity market efficiency may be affected by congestion and losses in network and these effects are considered as most important limitation of deregulated electricity market [41]. Various researchers have mentioned and written about congestion management in network in their research work [50, 52]. But literature review shows that some few researchers put their attention toward congestion management by the integration of DGs in system.

7. CONCLUSION

This paper shows a comprehensive review about renewable energy based DGs integration with existing electricity utility and its impact on deregulated electricity market. Various researchers mentioned different path following developments about DGs integration, which is shown since decades. DGs integration depends upon the operational condition, reliability issues and many others
parameters which are mentioned in this paper. Now days in electricity industry, there is open access transmission network and a good competitive environment in which utility industry can generate and transmit electricity in free and fair way and trade economically without any discrimination. Customer’s benefits are also ensured in deregulated electricity market with minimization of environmental effect & maximization of power quality. This paper interprets about healthy environment of DGs integration with minimum interference of environment and transmission network quality. This paper also predict about the improvement of gap between generation and demand, occurred due to large population growth demand for electricity. With proper technique and planning, such generation and demand gap can be compensated by injecting DGs units at the level of sub-transmission and distribution. Work in this review paper explain about tremendous research work has been done by different researchers in DG allocations and various technique used for power flow analysis in system. This review show a path to achieve better integration with flexible demand and demand response, so that demand side Management (DSM) with the help of distributed generation can be achieved.

REFERENCES
[1] Price DL. Distributed generation in general and micro turbines. In: Proceedings of the 33rd energy information dissemination program. Oklahoma State Univ. Stillwater, OK; 2002.
[2] Loh Poh Chiang, Zhang Lei, Gao Feng. Compact integrated energy systems for distributed generation. IEEE Trans Ind Electron 2013; 60(4):1492–502.
[3] Dondi P, Bayoumi D, Haederli C, Julian D, Suter M. Network integration of distributed power generation. J Power Sources 2002; 106:1–9.
[4] Abbate AL, Fulli G, Starr F, Peteves SD. Distributed power generation in Europe: technical issues for further integration. EUR 23234 EN-2007. Brussels: European Commission; 2007.
[5] Rao RS, Ravindra K, Satish K, Narasimham S VL. Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation. IEEE Trans Power Syst 2013; 28(1):317–25.
[6] Ackermann T. Distributed resources and re-regulated electricity markets. Elect Pwr Syst Res 2007; 77:1148–59.
[7] Federico M. Continuous Newton’s method for power flow analysis. IEEE Trans Power Syst 2009:24.
[8] Greene N, Hammerschlag R. Small and clean is beautiful: exploring the emissions of distributed generation and pollution prevention policies. Electr J 2000;13:50–60.
[9] Huang Shyh-Jier, Hsieh Chi-Wei, Wan Hsing-Ho. Confirming the permissible capacity of distributed generation for grid-connected distribution feeders. IEEE Trans Power Syst 2015;30(1):540–1.
[10] US EPA. Latest findings on national air quality: status and trends. EPA-454/K-03-001. Washington, [70] Kim Sung-Yul, Kim Wook-Won, Kim Jin-o. Determining the optimal capacity of renewable distributed generation using restoration methods. IEEE Trans Power Syst 2014;29(5):2001–13. DC: US Environmental Protection Agency; 2003.
[11] Distributed IEA. Generation in liberalised electricity markets. Paris; 2002. p. 128.
[12] Auer H, Stadler M, Resch G, Huber C, Schuster T, Taus H et al. Cost and technical constraints of RES-E grid integration. Pushing a least cost integration of green electricity into the European grid. ienna; 2004.
[13] Zieneldin HH, El-Saadany EF, Salama MMA. Impact of DG interface control on islanding detection and nondetection zones. IEEE Trans Power Del 2006;21:1515–23.
[14] Singh SN, David AK. Optimal location of FACTS devices for congestion management. Elect Pwr Syst Res 2001; 58:71–9.
[15] Swider DJ. Compressed air energy storage in an electricity system with significant wind power generation. EEE Trans Energy Convers 2007;22:95–102.
[16] Hazra J, Sinha AK. Congestion management using multi objective particle swarm optimization. IEEE Trans- Power Syst 2007;22(4):1726–34.
[17] Martinez JA, Guerria G. A parallel Monte Carlo method for optimum allocation of distributed generation. IEEE Trans Power Syst 2014; 29(6):2926–33.
[18] Dale L. Distributed generation transmission. In: Proceedings of the IEEE power engineering society winter meeting; 2002. p. 132–4.
[19] Acharya N, Mahat P, Mithulananthan N. An analytical approach for DG allocation in primary distribution network. Int J Elect Power Energy Syst 2006;28:669–78.
[20] Friedman R. Microturbine power generation: technology development needs and challenges. In: Proceedings of the environmental electric energy opportunities for the next century, IEEE/EPRI Vision-21. Washington, DC; 1998.
[21] Shrestha GB, Fonseka PAJ. Congestion-driven transmission expansion in competitive power markets. IEEE Trans Power Syst 2004; 19:1658–65.
[22] Del Monaco JL. Current status of distributed generation technologies. In: 31st energy information dissemination program. Oklahoma State Univ. Stillwater, OK; 2000.
[23] Hamoud G. Assessment of available transfer capability of transmission systems. IEEE Trans Power Syst 2000; 15:27–32.
[24] Ramakumar R. Technology and economic market integration of DG. In: Proceedings of the 2001 frontiers of power conference; 2001. p. 1–14.
[25] Federico M. Continuous Newton's method for power flow analysis. IEEE Trans Power Syst 2009;24.
[26] Price DL. Distributed generation in general and micro turbines. In: Proceedings of the 33rd energy information dissemination program. Oklahoma State Univ. Stillwater, OK; 2002.
[27] Ejebe GC, Wright JG, Santos-Nieto M, Timney WF. Fast calculation of linear available transfer capability. IEEE Trans Power Syst 2000;15:1112–6.
[28] Bae IS, Kim JO, Kim JC, Singh C. Optimal operating strategy for distributed generation considering hourly reliability worth. IEEE Trans Power Syst 2004; 19:287–92.
[29] Chiradeja P, Ramakumar R. An approach to quantify the technical benefits of distributed generation. IEEE Trans Energy Convers 2004;19(4):764–73.
[30] Castronuovo ED, Lopes JAP. On the optimization of the daily operation of a wind-hydro power plant. IEEE Trans Power Syst 2004; 19:1599–606.
[31] El-Khattam W, Salama MMA. Distributed generation technologies, definitions and benefits. Electr Power Syst Res 2004; 71:119–28.
[32] Hadjsaid N, Canard JF, Dumas F. Dispersed generation Impact on distribution networks. IEEE Comput Appl Power 1999; 12:22–8.
[33] Zhang Xianjun, Karady GG, Ariaratnam ST. Optimal allocation of CHP-based distributed generation on urban energy distribution networks. IEEE Trans Sustain Energy 2014; 5(1):246–53.
[34] Paulo MC, Manuel AM. Assessing the contribution of microgrids to the reliability of distribution networks. Electr Power Syst Res 2009;79:382–9.
[35] Barker PP. determining the impact of distributed generation on power systems: Part I-radial distributed systems. In: Proceedings of the IEEE power engineering society summer meeting; 2000. p. 1645–56.
[36] Huang HS, Chiang CT. Reliability worth assessment of distribution system with large wind farm considering wake effect. In: Proceedings of the power India conference -IEEE; April 2006.
[37] Pereira BR, Costa GRMD, Contreras J. Optimal distributed generation and reactive power allocation in electrical distribution systems. IEEE Trans Sustain Energy 2016;7(3):1–10.
[38] Dale, L. Distributed generation transmission. In: Proceedings of the IEEE power engineering society winter meeting; 2002. p. 132–4.
[39] Agarwal RK. Renewable energy programmes in India: status and future prospects IC 077; 2010. p. 1–25.
[40] Ding F, Loparo KA. Feeder recon_guration for unbalanced distribution systems with distributed generation a hierarchical decentralized approach. IEEE Trans
[41] Caisheng W, Nehrir MH. Analytical approaches for optimal placement of distributed generation sources in power systems. IEEE Trans Power Syst 2004;19:2068–76.
[42] Trebolle D, Gomez T, Cossent R, Frias P. Distribution planning with reliability options for distributed generation. Electr Power Syst Res 2009;80:222–9.
[43] Munoz-Delgado G, Contreras J, Arroyo JM. Joint expansion planning of distributed generation and distribution networks. IEEE Trans Power Syst 2015;30(5):2579–90.
[44] Hadjsaid N, Canard JF, Dumas F. Dispersed generation impact on distribution networks. IEEE Comput Appl Power 1999; 12:22–8.
[45] Duttagupta SS, Singh C. A reliability assessment methodology for distribution system with distributed generation. In: Proceedings of the 9th international conference on probabilistic methods applied to power systems. Stockholm –Sweden; 2006.
[46] Braga A, Saraiva JT. Long term marginal prices–solving the revenue reconciliation problem of transmission providers. In: Proceedings of 15th PSCC. Liege; 2005.
[47] Celli G, Pilo F. Penetration level assessment of distributed generation by means of genetic algorithms. In: IEEE Proceedings of power system conference. Clemson, SC; 2002.
[48] Hogan WW. Contract networks for electric power transmission. J Regul Econ 1992; 4:211–42.
[49] Rao RS, Ravindra K, Satish K, Narasimham SVL. Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation. IEEE Trans Power Syst 2013; 28(1):317–25.
[50] Fang RS, David AK. Transmission congestion management in an electricity market. IEEE Trans Power Syst 1999; 4:877–83.
[51] Rosehart W. Optimal placement of distributed generation. In: Proceedings of the 14th PSCC. Sevilla; 2002, p. 24–8.
[52] Rahmani-Andebili M. Distributed generation placement planning modeling feeder’s failure rate and customer's load type. IEEE Trans Ind Electron 2016;63(3):1598–606.
[53] Christie RD, Wollenberg BF, Wagensteen I. Transmission management in the deregulated environment. Proc IEEE 2000;88:170–95.
[54] Agnew S, Dargusch P. Effect of residential solar and storage on centralized electricity supply systems. Nat Clim Change 2015;5:315–8.
[55] Kashem M, Ledwich G. Multiple distributed generators for distribution feeder voltage support. IEEE Trans Power Syst 2005;20:676–84.