

Original Research Article

Reliability/Security of Distribution System Network under Supporting by Distributed Generation

Ali M. Eltamaly¹, Yehia Sayed Mohamed², Abou-Hashema M. El-Sayed², Amer Nasr A. Elghaffar^{2*}

¹ Electrical Engineering Department, Mansoura University, Mansoura, Egypt

² Electrical Engineering Department, Minia University, Minia, Egypt

*Corresponding Author: amernasr70@yahoo.com

ABSTRACT

This paper discusses the impact of Distributed Generator (DG) on the power system for enhancing the power system quality by improving the voltage profile and power losses reduction. With the increasing on the demand power and the power system extension, the distributed renewable energy technologies are becoming increasingly important in the energy supply systems of many countries. DGs units can be defined as a small-units that generate electric power near to the location of customers based on the renewable energy techniques, including wind energy, solar energy, and geothermal energy. Interconnecting DG to an existing distribution system provides various benefits to several entities as for example the owner, utility and the final user. DG provides an enhanced power quality, higher reliability of the distribution system and can peak shaves and fill valleys. However, the integration of DG into existing networks has associated several technical, economic and regulatory questions. Also, this paper uses the power system IEEE-12 busses for an example to illustrate the voltage control and decreases the active and reactive power losses by adding the wind generation DGs with the distribution network.

KEYWORDS: Power quality, Renewable energy, Distributed Generator, Voltage control and power losses reduction.

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1. Introduction

With the increasing on the demand power, the power system should be increased to meet the required value to prevent the system disturbance or black out. The power system extension by new areas needs to add new power plants with a new transmission system to link with the main grid. But this new extension will lead to some unrequited conditions in the power system as voltage dip, under frequency, low power factor, power losses increase and so on. The Distributed Generation (DG) is predicted to play an increasing role in the electric power system of the near future. DG is by definition that which is of limited size (roughly 10 MW or less) and interconnected at the substation, distribution feeder or customer load levels.

Statistics show that most of the power outages are caused by the failure of distribution system, so the reliability evaluation of distribution system has been widely concerned^[1]. In recent years, distributed generations are more and more connected to the distribution system for its flexible and friendly-environment features, which changes the structure and operation mode of traditional distribution system and brings significant impact to the reliability evaluation of the distribution

system^[2]. At present, some researches have been made on the reliability evaluation of distribution system with DG. The island partition model is established according to the importance of load, based on which, the reliability evaluation model of distribution system with constant DG is proposed, but the impact of intermittent DG is not considered^[3]. However, the variation range of intermittent DG output is large and three states can't accurately reflect the DG's actual state. In reference^[4], multi-state output power model of wind turbine is researched and the reliability of distribution system is assessed using the minimal cut set method, which does not consider the effect of different types of DG on distribution system^[5].

The power network has been intrinsically radial. Introduction of DG makes it bidirectional as energy can flow from DG as well as the main utility grid^[6]. This causes numerous complications in regard to the system voltage profile, power quality, adequacy, security, power flow control, energy management, frequency control and protection. System protection, in the presence of DG, has been a conspicuous issue in recent years and needs immediate consideration^[7]. Examples of renewable energy sources are wind turbines, photovoltaic systems, biomass, fuel cells and small hydro power plants^[8]. In particular, small hydro power plants have obtained increasing interest due to their acceptable prices for generating electrical power without producing harmful pollution and green-house gases and their relatively low environmental impact compared to large hydro power plants. However, the connection of the DG has both benefits and drawbacks of the technical, economic and environmental aspects^[9].

A high DG penetration level may influence the whole system operation and control, leading to technical impacts that must be identified^[10]. Figure 1 shows the renewable energy links with the power system. Therefore, this paper will summarize the impacts of integrating distributed generation into distribution network including voltage stability and power losses. Based on the literature review discussed above, it has been observed that the different issues in the field of distributed generation are covered which are based on optimal location and sizing of DG, loss minimization, voltage stability enhancement and reconfiguration of distribution network after the integration of DG resources. This paper is mainly focused on voltage control techniques and power losses reduction by using distributed generating units. The impact of DG operating in a voltage regulation mode has been analyzed and simulated in this paper for IEEE-12 bus using for the voltage stability enhancement.

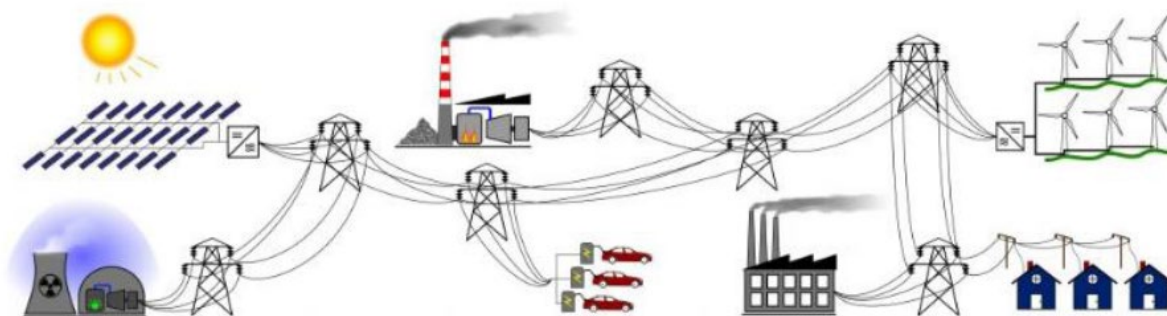


Figure 1. Renewable energy with the power system

2. Impact of DG on the power system voltage stability

Distributed generation technology is not only clean, environmental protective, economic and efficient, but also can look up the stability and flexibility of the whole power system. In recent years, distributed generation technologies have developed rapidly, and that implement the parallel operation^[10]. The segments of electricity generation, transmission, distribution and supply were integrated within individual electric utilities. This made the operation of the grid less complicated because the system operator had full knowledge of the grid status and total control over it. Liberalization and deregulation of the industry led to the introduction of competition in the segments of generation and supply^[11]. In transmission and distribution, the natural monopoly element has been maintained subject to network regulation.

Electricity exhibits a combination of attributes that make it distinct from other products: non-storability (in economic terms), real time variations in demand, low demand elasticity, random real time failures of generation and transmission, and the need to meet the physical constraints on reliable network operations. One of the consequences of liberalization is the new way in which the now separated entities interact with each other. In order to ensure instantaneous balancing of supply and demand, real-time markets are run as centralized markets, even in fully deregulated systems. The system operator acts as a single buyer and is responsible for upward and/or downward regulation, which may be done via regulating bids under an ex-change or pool approach. Economic decisions are made individually by market participants and system-wide reliability is achieved through coordination among parties belonging to different companies. So, the connection of generators to distribution networks modifies the radial design and structure

of these networks, in which the flow is in a single direction, from the substation to the loads. Changing the flows changes the voltage profile [12]. Voltage stability of electrical power system can be defined as the ability of this system to retrieve its normal operating condition after being subjected to severe interruptions such as faults. There are a significant number of approaches that are used to improve the stability of power systems such as using FACTS devices, shunt reactors, and capacitors as well as DG units. Indeed, DG units can play an important role in improving the stability of power system by increasing the maximum load penetration as well as increasing the margins of voltage stability. In addition, DG units inject real power to the electrical grids which support the ability of the loads and the network regarding voltage fluctuation due to sudden changes in load as well as disturbances. Accordingly, DG technologies are grouped in the following manner [12,13].

2.1 Type 1: DG capable of injecting both active power (P) and reactive power (Q)

DG units that are based on synchronous machine for small hydro, geothermal, and combined cycles fall in Type 1 category. The DG with the synchronous generators may be modeled either with constant terminal voltage control (voltage control mode) or with constant power factor control (power factor control). The DGs with the voltage control mode are considered as PV nodes and DGs with the power factor control mode are considered as PQ nodes [14]. In this work, the DG with synchronous generator of Type 1 category is modeled as PV nodes.

2.2 Type 2: DG capable of injecting active power (P) only

Photovoltaic (PV), micro turbines, fuel cells, which are integrated to the main grid with the help of converters/inverters [15] are the examples of Type 2 category. In this work, it is assumed that DG units in this category neither absorb nor deliver reactive power to system and operate with unity power factor only.

2.3 Type 3: DG capable of injecting reactive power (Q) only

The DG units equipped with synchronous compensator are considered as Type 3 category.

2.4 Type 4: DG capable of injecting active power (P), but consuming reactive power (Q)

Fixed speed squirrel cage induction generator (SQIG) used for wind turbine generating (WTG) system falls under this category. SQIG in super-synchronous mode is capable of injecting real power in the system whereas it demands reactive power from the system. Thus, it is worthwhile to note that the type of DG technology adopted will have a significant bearing on the performance of distribution network [12-15]. The installation of synchronous machine-based DG units that are close to the loads can lead to beneficial impact on system voltage stability margin; on another end, the case with an induction generator may have detrimental impact on the system stability margin. Therefore, it is an utmost requirement to analyse the effect of different types of DG technologies on the voltage stability to enjoy the system wide benefits.

3. Custom power device with DG

The conventional sources for power generation are fossil fuels, nuclear energy, hydro, etc. Due to the use of these energy sources, the environment has been seriously affected. And the fossil fuels cost will increase evidently, which will be exhausted in near future^[16]. Flexible AC Transmission System (FACTS) devices can be used for reactive compensation^[17]. The FACTS components consider an electronic device based on the types of the volt-ages or power level either, it's a Gate Turn-Off thyristors (GTO) or Insulated Gate Bipolar Transistor (IGBT)^[18]. Static Synchronous Compensator (STATCOM) module can be operated with the power system by the fed or absorb the reactive power^[19].

Due to technology innovation and cost reduction, renewable wind energy is enjoying a rapid growth globally to become an important green electricity source to replace the fossil fuels that are polluting and trending to be exhausted^[20]. The integration of distributed energy sources is expected to increase significantly in the near future^[21]. Grid-connected renewable wind-photovoltaic systems increased significantly in the last years and are expected to grow significantly until 2015 if governments keep the actual incentives^[22]. The integration of embedded power generation systems to existing power systems influences the power quality, and causes voltage quality, over-voltage, reactive power, and safety issues^[23]. The widely popular generation resources are wind and the photovoltaic^[24]. This can be operated in isolated or grid-connected mode depending upon the requirements^[25].

Due to technical issues and uncertainties in power generation from wind and PV systems, these resources need to be integrated along with energy storing devices like batteries, super power capacitors, etc. to enhance the power quality and reliability of the power supply^[26]. The efficient and proper operation of a wind energy system depends upon many factors that include the variable wind velocity, power fluctuations, integration to grid challenges, power quality issues, different types of wind turbines, level of penetration of wind power to grid, etc. ^[27] Renewable energy sources are rapidly gaining popularity for sustainable power generation: less polluting and using readily available resources. The development and control of Custom Power Device (CPD), due to the penetration of renewable energy, the poor power quality arises and these power quality problems have a bad effect on electric systems connected together^[28].

4. Active and reactive power flow analysis

The formulation of the active and reactive power entering a bus, it's needs to define the following quantities^[29]. The nodal analysis equations for the power system can be used to driven the OPF basic equations^[30].

Equation (1) the matrix for N -buses system.

$$\begin{bmatrix} I_1 \\ \vdots \\ I_N \end{bmatrix} = \begin{bmatrix} Y_{11} & \dots & Y_{1N} \\ \dots & \dots & \dots \\ Y_{N1} & \dots & Y_{NN} \end{bmatrix} \begin{bmatrix} V_1 \\ \vdots \\ V_N \end{bmatrix} \quad (1)$$

Y_{ij} : Elements of the bus admittance matrix

V_i : Buses voltages

I_i : Currents value at each node

So, Equation (2) followed to node at bus i.

$$I_i = \sum_{j=1}^n Y_{ij} V_j \quad (2)$$

Per-unit value at Bus i for active and reactive power and current injected into the system at that bus:

$$S_i = V_i I_i^* = P_i + jQ_i \quad (3)$$

V_i : per-unit voltage at the bus

I_i^* : complex conjugate of the per-unit current injected at the bus

P_i and Q_i : per-unit real and reactive powers.

$$I_i = \frac{I_i^* = \frac{(P_i + jQ_i)}{(P_i - jQ_i) V_i}}{V_i^*} = \frac{(P_i - jQ_i)}{V_i^*} = V_i^* \sum_{j=1}^n Y_{ij} V_j = \sum_{j=1}^n Y_{ij} V_j V_i^* \quad (4)$$

Can be simulate as:

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij}, \text{ and } V_i = |V_i| \angle \delta_i$$

$$(P_i - jQ_i) = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \angle (\theta_{ij} + \delta_j - \delta_i) \quad (5)$$

$$P_i = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \quad (6)$$

$$Q_i = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \quad (7)$$

So, 4 variables are required to compute the power flow parameters P, Q, V.

5. Renewable energy sources (RESs)

In distribution systems that use DGs, the active and reactive powers of the DGs are typically scheduled for the purposes of a specific objective, such as loss minimization, and this schedule is based on forecast data. The time intervals of the forecast data are typically tens of minutes or an hour. In this section, we describe the optimization algorithm used to determine the scheduled re-active power of each RES at a given time. Solar photo-voltaic modules can be defined as solid-state devices that transform the self-contained energy of photons into DC electricity. The fundamental principle of PV modules operation dates back up to 150 years ago.

However, the significant advancement of PV modules started the sub-sequent invention of silicon cell by Bell Labs in the mid of the twentieth century^[31]. It is worth mentioning that solar technology has numerous advantages such as free emissions, long-life services, and noiseless operation. Not only this, it does not require high maintenance and fuel expenses^[32]. Furthermore, solar energy is regarded as redundant and infinite. Conversely, it has some disadvantages including, weather dependency intermittency and unavailability during the night. Also, high penetration level of PV coupled with load demand variations causes power fluctuations along with unpredicted voltage escalation, voltage stability problems, and higher power losses in the power distribution networks.

Wind energy is not a novel form; it has been utilized for several decades. Wind turbines comprised of a generator, rotor, blades, drive device, shaft and the nacelle that. Contemporary turbines provide green electricity to wind farms or individuals^[33,34]. They can be categorized into two kinds such as Vertical Axis Wind Turbine (VAWT) and Horizontal Axis Wind Turbine (HAWT), the output power of wind turbine DG (WT) depends on the wind speed as well as the parameters of the power performance curve as shown in figure (2). This type of energy is characterized by free emissions and no fuel requirements. It is also known that wind power is considered as an endless and redundant source. However, the main issues related to wind generation are intermittency nature, high initial investment costs. Moreover, some problem may occur as a result of extreme wind generation simultaneously with off-demand such as voltage rise, voltage instability, and high-power losses in the power distribution networks^[35-37].

The hybrid wind solar system is the combination of solar photovoltaic and wind, which has the advantage that these two sources complement each other since the peak functioning times take place during different times of the day and year. Evidently, the power generation of such a system is constant and tends to fluctuate less than the two subsystems separately^[38]. In this paper, Hybrid wind–solar system is utilized to comprehend the impact of combination between these sources on the voltage stability of IEEE-12 bus system. In this case, power generated from solar and wind energy is injected into the weak buses in this particular system.

6. Optimum DG installation based on voltage stability

There is more researchers focus on the renewable energy especially solar generation and wind generation that considered friendlier with the environment. Due to considerable costs, the DGs must be allocated suitably with optimal size to improve the system performance such as to reduce the system loss, improve the voltage profile while maintaining the system stability^[39]. The problem of DG planning has recently received much attention by power system researchers. Selecting the best places for installing DG units and their preferable sizes in large distribution systems is a complex combinatorial optimization problem. Different formulations have been used based on calculus-based methods, search-based methods and combinations of various approaches^[40], such as, gradient and second-order algorithms^[41], Here-ford Ranch algorithm^[42], heuristic iterative search method^[43], analytical method^[44], hybrid fuzzy-Genetic Algorithm (GA) method^[45].

The placement of different types of DG in distribution network greatly affects the voltage profile at the different buses and power flow in feeders, thus alters the active and reactive power losses in a system. The variation in voltage profile and losses in a system also varies with the different types of DG technologies discussed in Section 2. Hence, the attention must be paid not only to decide the location for DG placement but the types of DG technologies need to be considered. In this work, voltage stability enhancement is considered to be the major criteria for the DG placement to ensure the stable operation of the system with acceptable voltage levels at the consumer nodes^[46,47]. The procedure adopted to find out the optimal locations for DG placement along with selection of different types of DG technologies in a given test system is shown in Figure 3.

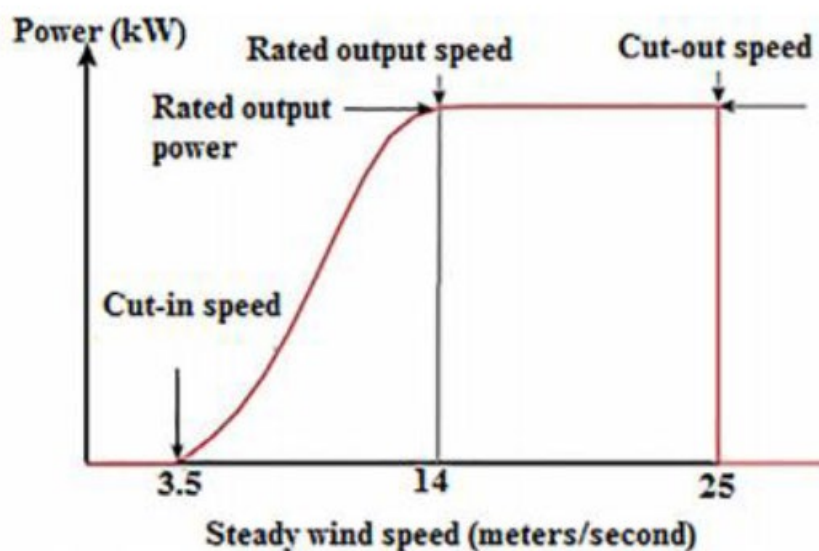


Figure 2. Wind turbine power output with steady wind speed.

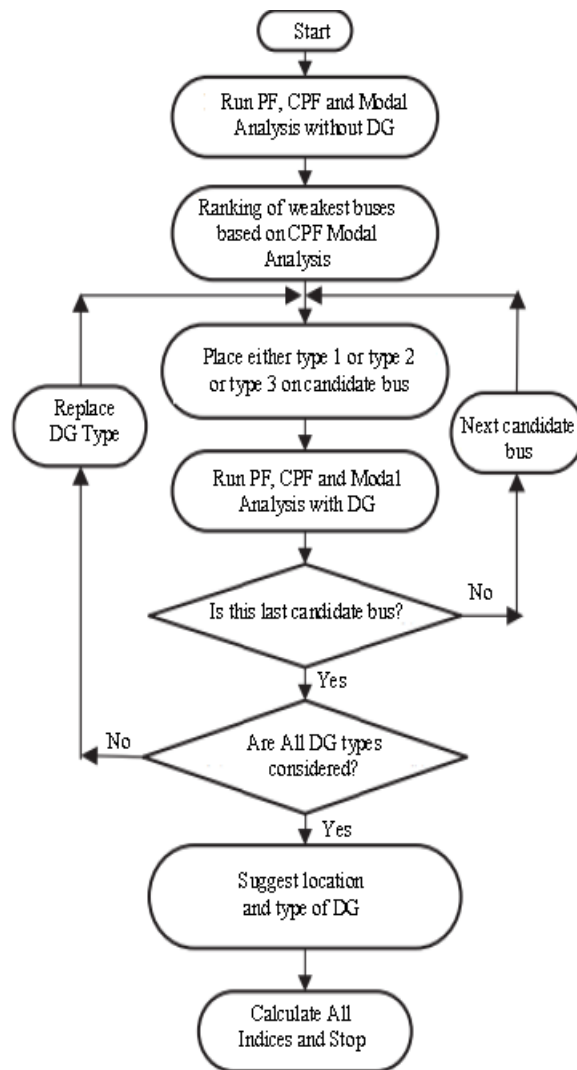


Figure 3. Flowchart for selection of DG type and location for voltage stability

7. Simulation and discussion

IEEE-12 bus system as shown in Figure 4 has been used for voltage stability study. This system comprises five generators including one slack bus and 11 load buses as well as 17 transmission lines, the system full data has been illustrated in Table 1 and Table 2. Modal analysis method has applied to the 12-IEEE bus system to evaluate the voltage stability and the losses reduction of the above-mentioned system. All generators values are calculated in order to identify the weakest bus in the system. This study has been implanted based on power world simulator software. Table 3 shows the active and reactive power losses in the branches. After adding the wind generation DG with bus-8, it found the voltage improved as shown in Table 4. The comparison between the busses voltage without DG and with DG is illustrated in Figure 5. Also, his branches losses have been decreased as shown in Table 5. Figure 6 and Figure 7 are shown the comparison between active power and reactive power losses respectively without adding the DG and with adding the wind generation DG. Finally, after adding the DG with the distribution network, the voltage will be improving and the losses will reduce.

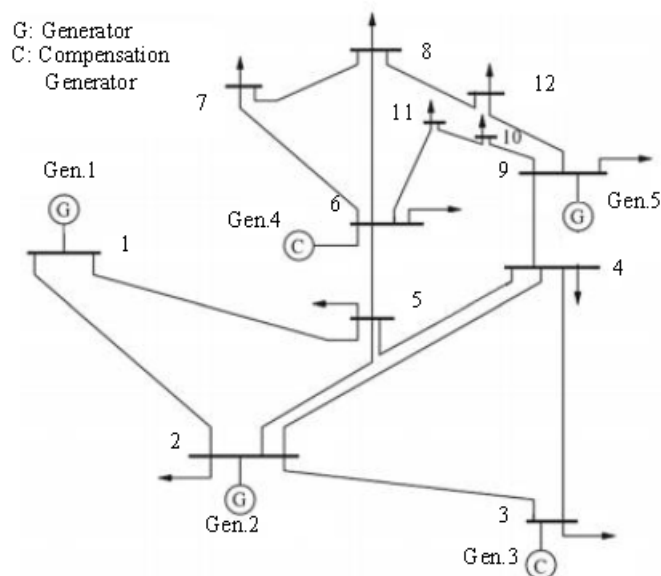


Figure 4. IEEE-12 buses system distribution network

Bus No.	Nom. Voltage	Voltage (kV)	Nom PU	Kv	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	22	22.000	1.00000		-18.16	50.30	18.50	75.16	44.03
2	22	22.000	1.00000		-15.26	18.00	12.58	31.01	77.20
3	22	22.000	1.00000		0.36	37.00	11.00	274.61	21.55
4	22	21.227	0.96485		-19.72	25.00	10.00	-	-
5	22	21.038	0.95625		-24.52	33.25	11.00	-	-
6	22	21.522	0.97826		-37.74	30.31	19.42	20.00	100.00
7	22	20.897	0.94989		-39.01	48.24	26.79	-	-
8	22	20.607	0.93670		-39.74	33.58	19.21	-	-
9	22	22.000	1.00001		-31.23	18.04	5.00	50.00	93.81
10	22	21.006	0.95480		-40.68	59.95	10.00	-	-
11	22	20.894	0.94973		-41.90	44.85	11.59	-	-
12	22	20.747	0.94306		-37.83	35.18	19.76	-	-

Table 1. Operation system data without DG with distribution network

Link No.	Branch From Bus	Branch To Bus	Branch R	Branch X	Branch Lim MVA A
1	1	2	0.00000	0.18000	120.0
2	1	5	0.00000	0.20000	120.0
3	2	3	0.05000	0.21000	180.0
4	2	4	0.00000	0.20000	120.0
5	5	2	0.08000	0.24000	120.0
6	3	4	0.02000	0.30000	190.0
7	5	4	0.01000	0.30000	120.0
8	9	4	0.01000	0.20000	150.0
9	5	6	0.00000	0.20000	150.0
10	7	6	0.02000	0.05000	120.0
11	8	6	0.02000	0.30000	120.0
12	6	11	0.02000	0.23000	120.0
13	8	7	0.02000	0.22000	120.0
14	8	12	0.01100	0.18000	120.0
15	10	9	0.00200	0.21000	120.0
16	9	12	0.00100	0.21000	120.0
17	11	10	0.00100	0.13000	120.0

Table 2. Initial data for the branches to link the system

Link No.	Branch From Bus	Branch To Bus	Branch MW Loss	Branch Mvar Loss	Branch MVA (Max)	% of Limit
1	1	2	0.00	1.42	23.4	
2	1	5	0.00	6.85	48.8	
3	2	3	7.93	33.29	35.0	
4	2	4	0.00	3.54	69.9	
5	5	2	3.36	5.29	60.3	
6	3	4	3.21	37.40	21.7	
7	5	4	0.17	2.09	72.9	
8	9	4	1.00	19.98	54.0	
9	5	6	0.00	25.01	26.7	
10	7	6	0.96	1.99	53.8	
11	8	6	0.06	0.85	13.9	
12	6	11	0.21	2.45	6.4	
13	8	7	0.01	0.05	14.4	
14	8	12	0.03	0.57	66.6	
15	10	9	0.13	13.22	49.8	
16	9	12	0.04	7.49	66.3	
17	11	10	0.0	0.24	12.8	

Table 3. Active and reactive power losses through the 17 branches system without DG

Bus No.	Nom. Voltage (kV)	Voltage (kV)	Nom PU	Kv	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	22	22.000	1.00000		-13.35	50.30	18.50	75.16	34.29
2	22	22.000	1.00000		-11.31	18.00	12.58	31.01	51.60
3	22	22.000	1.00000		0.36	37.00	11.00	217.79	11.17
4	22	21.489	0.97679		-14.99	25.00	10.00	-	-
5	22	21.411	0.97323		-18.61	33.25	11.00	-	-
6	22	22.000	1.00000		-28.07	30.31	19.42	20.00	65.85
7	22	21.663	0.98469		-28.95	48.24	26.79	-	-
8	22	22.277	1.01259		-27.58	33.58	19.21	50.00	50.00
9	22	22.000	1.00000		-23.48	18.04	5.00	50.00	54.89
10	22	21.210	0.96407		-32.12	59.95	10.00	-	-
11	22	21.188	0.96308		-32.85	44.85	11.59	-	-
12	22	21.690	0.98592		-27.62	35.18	19.76	-	-

Table 4. IEEE-12 busses operation System data after adding the wind energy DG with bus 8

Link No.	Branch From Bus	Branch To Bus	Branch MW Loss	Branch Mvar Loss	Branch MVA (Max)	% of Limit
1	1	2	0.00	0.70	16.5	
2	1	5	0.00	4.46	39.4	
3	2	3	0.00	2.29	28.2	
4	2	4	4.43	18.62	52.3	
5	5	2	2.15	21.37	46.5	
6	3	4	0.14	1.17	16.8	
7	5	4	0.00	13.60	55.0	
8	9	4	2.06	1.32	42.5	
9	5	6	0.30	3.46	32.4	
10	7	6	0.42	0.61	33.5	
11	8	6	0.02	0.39	12.5	
12	6	11	0.06	0.51	14.0	
13	8	7	0.01	-0.02	4.3	
14	8	12	0.55	10.95	49.3	
15	10	9	0.01	2.54	29.0	
16	9	12	0.10	10.93	60.4	
17	11	10	0.00	0.02	7.6	

Table 5. Branch losses after adding DG with the distribution network

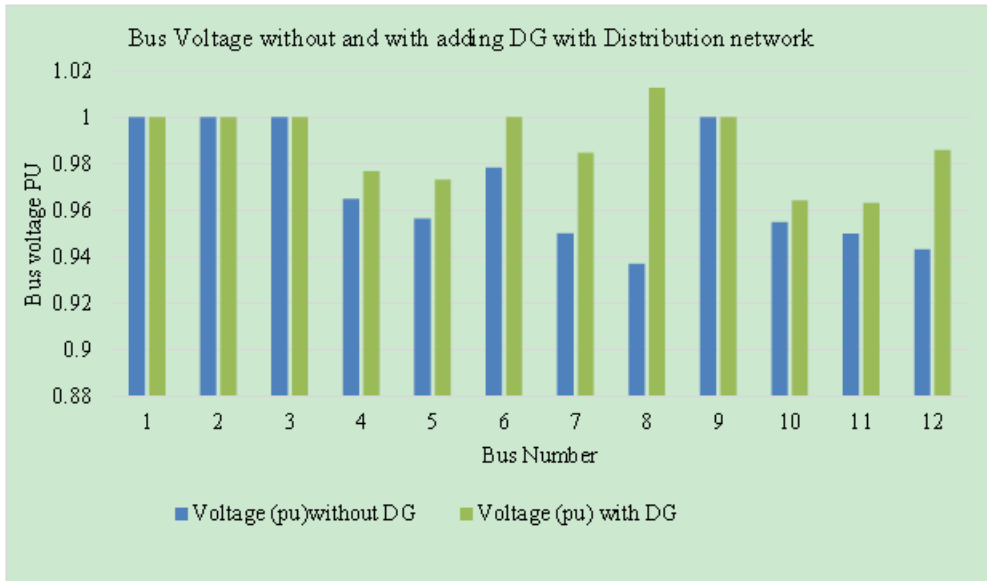


Figure 5. Bus Voltage without and with adding DG with Distribution network

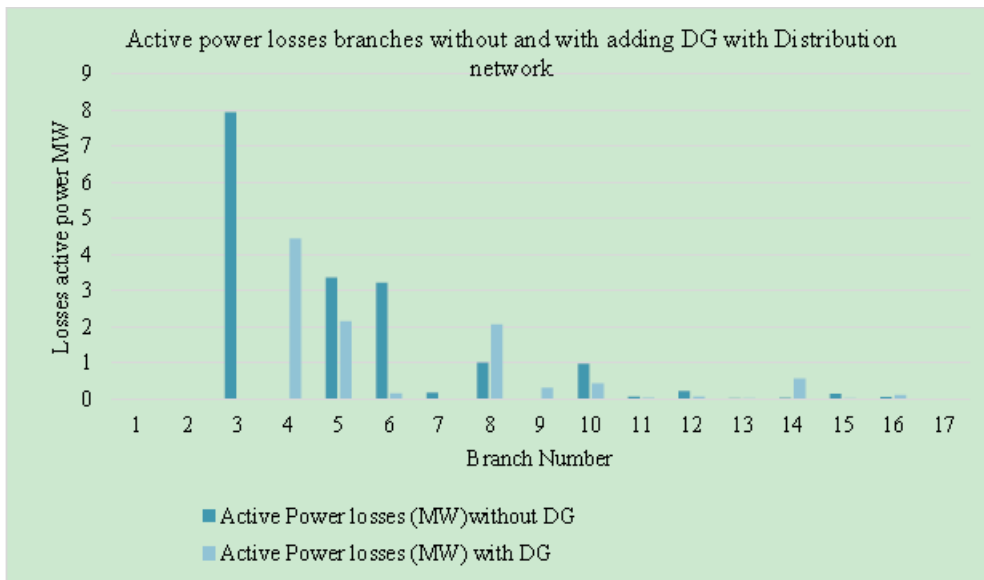


Figure 6. Active power losses without and with adding DG with Distribution network

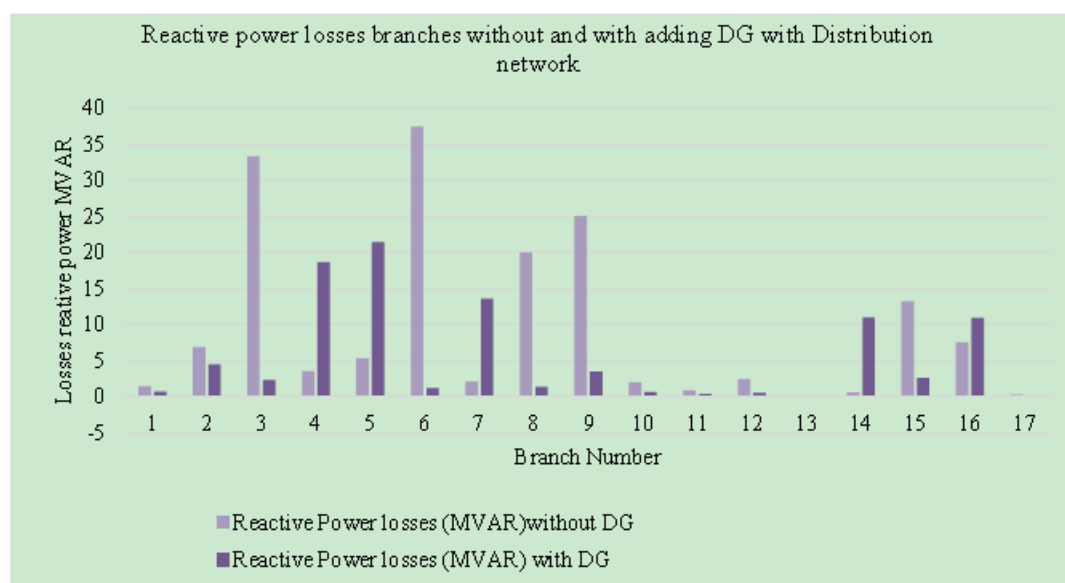


Figure 7. Reactive power losses branches without and with adding DG with Distribution network

8. Conclusion

There is no doubt that the electrical system became the main world drive economy. Due to the world industry grows, the electrical system should extend with adding new power plants, and this new extension is translated to increasing cost. Using the new renewable energy near the load can enhance the power system quality. The small-scale renewable generation is considered Distributed Generation (DG). In recent times, the DG has become a trend in power engineering. This goes well in close association with the society's common growth, where responses to a lot of quandaries are regarded by minute scale solutions and proximity. In this paper, a discussion has been proposed for investigating impacts of the DG which focuses on the wind generation on distribution network reliability. The simulation studied in this paper for IEEE-12 buses system as a distribution system network 22kV. From the study, it found the voltage has been improved to reach 1 put in bus 6 and bus 8 also its improved in another busses. Also, the total active power losses have been decreased to reach 10.25 MW which is 17.11 MW before adding the WIND DG and the reactive power has been decreased to reach 92.92 MVAR which is 161.73 MVAR. Finally, from this paper is important to recommend to the power system designer to consider the wind DGs for enhancing the power system quality.

References

1. Jingxu Yang, Gengyin Li, Dawei Wu, Zhiwen Suo. The Impact of Distributed Wind Power Generation on Voltage Stability in Distribution Systems. IEEE 2013
2. Kang L, Guo H, Wu J and Chen S 2010 Characteristics of distributed generation system and related re-search issues caused by connecting it to power system Power System Technology 34(11):43-47
3. Liu C and Yan Z 2007 Distribution network reliability considering distribution generation Automation of Electric Power Systems 31(22):46-49
4. Fotuhi-Firuzabad M and RajabiGhahnavie A 2005 An analytical method to consider DG impacts on distribution system reliability Transmission & Distribution Conf. & Exhibition: Asia and Pacific pp(a) 6.
5. Xu Y and Wu Y. 2011 Reliability evaluation for distribution system connected with wind turbine generators Power System Technology 35(4):154-158
6. Ali M. Eltamaly, Amer Nasr A. Elghaffar: Power Flow Control for Distribution Generator in Egypt Using Facts Devices.
7. Shahzad, U. (2015) The Need for Renewable Energy Sources. International Journal of Information Technology and Electrical Engineering, 4, 16-19.
8. Ali M. Eltamaly, Amer Nasr A. Elghaffar: Tech-no-Economical Study of Using Nuclear Power Plants for Supporting Electrical Grid in Arabian Gulf. 12/2017; 2(1), DOI:10.1007/s40866-017-0031-8

9. V. V. Thong, J. Driesen, R. Belmans, "Benefits and Impact of Using Small Generators for Network Support", in Proc. 2007 IEEE Power Engineering Society General Meeting, pp 1-7.
10. Amer Nasr A. Elghaffar, Adel A. Elbaset: Treatment EMF on The Protection IEDs in HV Substations. 2017 Nineteenth International Middle East Power Systems Conference (Mepcon), Cairo-Egypt; 12/2017, DOI:10.1109/MEPCON.2017.8301245
11. N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac, "Embedded. Generation", 1st ed. London, U.K.: Inst. Elect. Eng., 2000.
12. Freitas Walmir, Vieira Jose CM, Morelato Andre. Influence of excitation system control modes on the allowable penetration level of distributed synchro-nous generators. IEEE Trans Energy Convers 2005;20(2):474–80.
13. Pankita Mehta, Praghnes Bhatt and Vivek Pandya.(2015). Optimal selection of distributed generating units and its placement for voltage stability enhancement and energy loss minimization. Ain Shams Engineering Journal (2018) 9, PP: 187–201, <http://dx.doi.org/10.1016/j.asej.2015.10.009>
14. Puttgen HB, MacGregor PR, Lambert FC. Distributed generation: semantic hype or the dawn of a new era? IEEE Trans Power Energy Manage 2003;1(1):22–9.
15. Blaabjerg F, Teodorescu R, Liserre M, Timbus AV. Overview of control and grid synchronization for distributed power generation systems. IEEE Trans Ind Electron October 2006;53(5):1398–409.
16. C. Chompoonwai, C. Yingvivanapong, K Methaprayoon, and W. J. Lec, "Reactive compensation techniques to improve the ride through capability of wind turbine during disturbance", IEEE Trans. Ind. Appl., vol. 41, no. 3, pp. 666–672, 2005.
17. Ali M. Eltamaly, Amer Nasr A. Elghaffar: Enhancement of Power System Quality Using Static Synchronous Compensation (STATCOM). International Journal of Electrical and Computer Engineering 10/2018; 30(8):3966-3975.
18. Ali M. Eltamaly, Amer Nasr A. Elghaffar: MultiControl Module Static VAR Compensation Techniques for Enhancement of Power System Quality. Annals of Faculty Engineering Journal, Aug.2018.
19. Ali M. Eltamaly, Amer Nasr A. Elghaffar, Yehia Sayed Mohamed, AbouHashema M. El-Sayed: Enhancement of Power System Quality Using PI Control Technique with DVR for Mitigation Voltage Sag. 2018 Twentieth International Middle East Power Systems Conference (MEPCON), Cairo, Egypt; 12/2018.
20. DOE and NREL. Wind power today and tomorrow: An overview of the wind and hydropower technologies program. (2004). [Online]. Available: <http://www.nrel.gov/wind>
21. I. I. E. Agency, Trends in Photovoltaic Applications—Survey Report of Selected IEA Countries Between 1992 and 2007, 2008.
22. T. Ackermann, Wind Power in Power Systems, Chichester: Wiley, 2005.
23. S.-K. Kim, J.-H. Jeon, C.-H. Cho, J.-B. Ahn, and S.-H. Kwon, "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer," IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1677–1688, Apr. 2008.
24. P. K. Ray, S. R. Mohanty, and N. Kishor, "Proportional integral controller based small-signal analysis of hybrid distributed generation systems," Energy Convers. Manage., vol. 52, pp. 1943–1954, Jan. 2011.
25. Ali M. Eltamaly, Amer Nasr Abd Elghaffar: Modeling of distance protection logic for out-of-step condition in power system. Electrical Engineering 11/2017;, DOI:10.1007/s00202-017-0667-3
26. Ali M Eltamaly, Yehia Sayed, Abou-Hashema M El-Sayed, Amer Nasr A. Elghaffar: Mitigation Voltage Sag Using DVR with Power Distribution Networks for Enhancing the Power System Quality. IJEEAS Journal. Vol.1 No.2. Oct. 2018.
27. Zhe Chen, Josep M. Guerrero and Frede Blaabjerg.(2009). A Review of the State of the Art of Power Electronics for Wind Turbines. IEEE transactions on power electronics, Vol. 24, No. 8, august 2009.
28. Ali M. Eltamaly, Amer Nasr A. Elghaffar: A Survey: Hvdc System Operation and Fault Analysis. Annals of Faculty Engineering Journal. 2017.
29. Ali M Eltamaly, Amer Nasr A. Elghaffar: Load Flow Analysis by Gauss-Seidel Method; A Survey. International Journal of Mechatronics, Electrical and Computer Technology (IJMEC). 2017.
30. Ali M. Eltamaly, Amer Nasr A. Elghaffar, Yehia Sayed Mohamed, Abou-Hashema M. El-Sayed: Optimum Power Flow Analysis by Newton Raphson Method, A Case Study. Annals of Faculty Engineering Journal, 2018.
31. Esmaili M, Firozjaee EC, Shayanfar HA (2014) optimal placement of distributed generations considering voltage stability and power losses with observing voltage-related constraints. Appl Energy 113:1252–1260
32. Poullikkas A (2007) Implementation of distributed generation technologies in isolated power systems. Renew Sustain Energy Rev 11(1):30–56
33. Herzog AV, Lipman TE, Kammen DM (2001) Renewable energy sources. Encyclopedia of life support systems (EOLSS). Forerunner Volume- 'Perspectives and overview of life support systems and sustainable development
34. Sarabia AF (2011) Impact of distributed generation on distribution system. Aalborg University, Aalborg

35. Albadi MH, ElSaadany EF (2010) Overview of wind power intermittency impacts on power systems. *Electr Power Syst Res* 80(6):627–632
36. Gao B, Morison GK, Kundur P (1992) Voltage stability evaluation using modal analysis. *IEEE Trans Power Syst* 7(4):1529–1542
37. Reis C, Andrade A, Maciel FP (2009) Line stability indices for voltage collapse prediction. In: 2009 International conference on power engineering, energy and electrical drives, pp 239–243
38. Zaid H. Al-Tameemi, et al. Voltage stability enhancement based on DG units. *Electrical Engineering journal*, 2018, <https://doi.org/10.1007/s00202-018-0737-1>.
39. Suresh Kumar Sudabattula, Kowsalya M. Optimal allocation of solar based distributed generators in distribution system using Bat algorithm. *Perspectives in Science* (2016) 8, 270–272, <http://dx.doi.org/10.1016/j.pisc.2016.04.048>
40. R V S Lakshmi Kumari, G V Nagesh Kumar, S Siva Nagaraju and M. Babita. (2017). Optimal Sizing of Distributed Generation using Particle Swarm Optimization. 2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)
41. Rau N.S., Wan Y., “Optimal location of resources in distributed planning,” *IEEE Trans. Power Syst.*, Vol.9, No.4, pp. 2014–2020, 1994.
42. Kim JO, Nam SW, Park SK, Singh C., “Dispersed generation planning using improved Hereford ranch algorithm,” *Electrical Power System Research*, Vol.47, No.11,1998.
43. Griffin, T., Tomsovic, K., Secrest, D. et al.: ‘Placement of dispersed generation systems for reduced losses. *Proc. 33rd Int. Conf. System Sciences*, Hawaii, pp. 1446–1454, 4–7 January 2000.
44. Willis, H.L., “Analytical methods and rules of thumb for modeling DG distribution interaction,” *Proc. IEEE Power Engineering Society Summer Meeting*, Seattle, USA, pp. 1643–1644, 16–20 July 2000.
45. Nara, K., Hayashi, Y., Ikeda, K. et al., “Application of tab search to optimal placement of distributed generators,” *Proc. IEEE Power Engineering Society Winter Meeting*, Columbus, USA, pp. 918–923, 28 January–1 February 2001
46. Kim K.-H., Lee Y.-J., Rhee S.-B., Lee S.-K., You S.-K., “Dispersed generator placement using fuzzy-GA in distribution systems,” *Proc. IEEE Power Engineering Society Summer Meeting*, Chicago, IL, USA, Vol. 3, pp. 1148–1153, 2002.
47. Teng, J.-H., Luor, T.-S., and Liu, Y.-H., “Strategic distributed generator placements for service reliability improvement,” *Proc. IEEE Power Engineering Society Summer Meeting*, Chicago, USA, pp. 719–724, 21–25 July 2002.