Enhancing Voltage Profile and Power Loss Reduction Considering Distributed Generation (DG) Resources

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Abstract-In recent years, Distributed Generation (DG) has received attention due to its benefits on the distribution network. In this paper, the influence of DG along with several techniques for mitigating the detrimental impact on voltage profile and power losses was examined. The test system of 132 KV residential test feeder was selected, examined, and modeled in the Electrical Transient Analyzer Program (ETAP). Various tests were carried out to determine the influence of DG on the distribution network. Results were compared with, and with-out DG, taking into account the voltage profile. When injecting DG with unity power factor at different buses in a radial test system, it was discovered that when the right DG size and type is injected at the ideal position, the voltage profile improves while the power losses are reduced. When an un-deterministic DG is injected at multiple points on the test feeder, no improvement in voltage profile was observed. When the cross sectional area of conductors is increased and a DG is injected at optimal locations, a positive impact on voltage profile is observed while a detrimental impact on power losses were also analyzed. These findings may be useful for many distribution firms regarding the future expansion of the power systems and the proliferation of DG.

Keywords-distributed generation; voltage level; power losses; synchronous and induction generator

I. INTRODUCTION

Electricity consumption is quickly expanding in all the sectors of global economy. Currently, a number of factors are creating significant challenges to the power supply, including pollution, depletion of local energy supplies, and the need to improve the energy infrastructure. Promoting the broad use of Distributed Generation (DG) is a strategy to fulfil the continually expanding demand for power [1]. The government's energy policy aims of reducing emissions, ensuring a dependable energy supply, and promoting competitive markets will all benefit from increased deployment of DG technologies.

DG may work as a single construction, such as a home or a firm, or it can be part of a small grid (that is also linked to the larger power distribution network), e.g. at a huge industrial site, military base, or college campus [2, 3]. DG can support the distribution of clean, dependable power to additional consumers while also reduces power losses along the distribution and transmission lines when inserted to the electric utility's lesser voltage distribution lines. Some of the benefits of installing DG include increased electric system reliability, improved power quality, reduced system energy loss, and improved voltage profile. DG can work both as conventional energy sources (non-renewable) and non-conventional energy sources (renewable) [4]. Wind energy, PV energy, and small hydro energy are the most capable renewable energy resources in DG, while coal, petroleum, and natural gas are all non-renewable energy sources [5].

Nowadays the need for electricity is rapidly rising, while one of the most significant challenges for power and electrical engineers is to produce power from non-conventional energy sources in order to meet the rising demand while minimizing the environmental impact of power generation. However, whenever a new generation is linked with the power distribution system, issues come up because traditional distribution systems were built to run radially, without taking into account the new generation's future integration [6, 7]. Using DG is necessary to assure reliable power generation and dropping power losses, while, on the other hand, extensive use of these technologies brings additional challenges to power systems such as voltage regulation, optimal location, and power loss issues [8]. The installation of DG may destabilize the system voltage and create over-voltage and volatility. If management is not appropriately achieved, the inserting of DG may raise the system losses in the distribution network, depending on the network structure, the penetration level, and the nature of DG technology [9, 10].

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In this research paper, various cases are considered in order to see their effect on voltage level and power losses. Six-bus bar distribution systems were considered as test cases. They were designed and examined in the Electrical Transient Analyzer Program (ETAP). Firstly, results were obtained without the injection of a DG unit. This case is used as a model for the other cases. In the second case, a DG unit (synchronous generator) is injected at busbar-3 and in the third case a DG unit (synchronous generator) is injected at busbar-6. In the fourth case, a DG unit (induction generator/wind generator) is injected at busbar-3 and in the fifth case a DG unit (induction generator/wind generator) is injected at busbar-6. Moreover, two more cases were considered as " injecting un-deterministic DG in a distribution system" and "increasing a cross sectional area of the transmission cable". The results were compared in order to determine the best DG size and location.

II. THE IMPACT OF DISTRIBUTION GENERATION

The term "Distributed Generation" (DG) refers to energy generation close to the point of consumption. Because of its good impact on the electrical distribution system, DG has received a lot of attention. DG has the potential to improve grid dependability by lowering transmission losses, providing greater voltage support, and enhancing power quality. Because DG uses renewable energy resources, it has lower initial cost and reduces greenhouse gas emissions, resulting in more clean and efficient energy [11]. Tiny combustion and micro turbines, micro steam turbines, battery storage, comparatively tiny hydro dams, photovoltaic (PV) panels, wind turbines, power storage systems, and other power generation technologies are being developed or are now in use [12]. Distributed Resources (DRs) can reduce T&D system losses, enhance service performance and stability, improve voltage strength, and reduce T&D system crowding [13]. The connection of DG may vary the voltage level along a feeder by varying the direction and amplitude of actual and reactive power flows. Furthermore, the effect of DG on voltage parameters might be positive or negative depending on the distribution network, the distributed generator features, and the DG site. Due to the immense injection of active and reactive power, overvoltage may occur when DG units are installed along with power distribution feeders [14, 15]. DG is the best option to satisfy the increasing requirements of power and improve voltage profile. This is dependent on the DG injection site and the kind of DG that is to be inserted in the power system or grid. If a DG is inserted into the power system in an ad hoc manner, voltage profiles may vary [16].

DG has a big impact on power losses as well. DG must be properly coordinated with the distribution system in order to have a positive impact. Because DG and its effect on the system are proportional to feeder requirements and ability, the injection of DG into the system should be precisely enhanced to avoid this kind of problems [17]. The DG is a significant standard that has to be examined in order to be able to get a better consistency of the system with reduced losses. DG has negative impact as well: if not injected in a proper way, it may result in power losses [8].

III. MATHEMATICAL MODELING

Because of the slow changing nature of power networks, steady state analysis is used. In the steady state, disruption-induced transients are supposed to be unchanged. The operational technique for the steady state analysis is called power flow analysis. The voltage magnitude and phase angle, as well as the flow of active and reactive power across the network at all buses, may all be found using load flow analysis. The Newton-Raphson method is discussed below as one of the approaches for solving the power flow equations. The approach begins by solving the issue with only two equations and two variables. After that, the study will be extended to the solution of the load flow equation. Consider the following equation for a two-variable function Z_A and Z_B equal to a constant C_A as:

$$\mathrm{F_A}(Z_A, Z_B) = C_A \quad (1)$$

$$\mathrm{F_B}(Z_A, Z_B) = C_B \quad (2)$$

$$\mathrm{C_A} = \mathrm{F_A}(Z_A, Z_B) = \mathrm{F_A}\left(Z_A^{(0)} + \Delta Z_A^{(0)}, Z_B + Z_B^{(0)}\right) \quad (3)$$

$$\mathrm{C_B} = \mathrm{F_B}(Z_A, Z_B) = \mathrm{F_B}\left(Z_A^{(0)} + \Delta Z_A^{(0)}, Z_B + Z_B^{(0)}\right) \quad (4)$$

Expanding (3) and (4) in Taylor’s series we have:

$$\mathrm{C_A} = \mathrm{F_A}\left(Z_A^{(0)} + Z_B^{(0)}\right) + \Delta Z_A^{(0)} \frac{\partial F_1}{\partial Z_1}\Big|^{(0)} + \Delta Z_B{}^{(0)} \frac{\partial F_1}{\partial Z_2}\Big|^{(0)} + \ldots (5)$$

$$\mathrm{C_B} = \mathrm{F_B}\left(Z_A^{(0)} + Z_B^{(0)}\right) + \Delta Z_A^{(0)} \frac{\partial F_2}{\partial Z_1}\Big|^{(0)} + \Delta Z_B{}^{(0)} \frac{\partial F_2}{\partial Z_2}\Big|^{(0)} + \ldots (6)$$

$$\begin{bmatrix} \mathrm{C_A} - \mathrm{F_A}\left(Z_A^{(0)}, Z_B^{(0)}\right) \\ \mathrm{C_B} - \mathrm{F_B}\left(Z_A^{(0)}, Z_B^{(0)}\right) \end{bmatrix} = \begin{bmatrix} \frac{\partial F_1}{\partial Z_1} & \frac{\partial F_1}{\partial Z_2} \\ \frac{\partial F_2}{\partial Z_2} & \frac{\partial F_2}{\partial Z_2} \end{bmatrix} \begin{bmatrix} \Delta Z_A^{(0)} \\ \Delta Z_B^{(0)} \end{bmatrix} \quad (7)$$

$$\begin{bmatrix} \Delta C_A^{(0)} \\ \Delta C_B^{(0)} \end{bmatrix} = \mathrm{J}^{(0)} \begin{bmatrix} \Delta Z_A^{(0)} \\ \Delta Z_B^{(0)} \end{bmatrix} \quad (8)$$

For a total of *N* buses, the intended voltage at any bus A and P_1 and Q_1 are given as:

$$V_A = \frac{1}{Y_{AA}} \left[\frac{P_1 - jQ_1}{V_{A^*}} - \sum_{n=1}^{N} Y_{An} V_n \right] \quad (9)$$

$$P_1 - jQ_1 = \left(Y_{AA}\, V_A + \sum_{n=1}^{N} Y_{An} V_n\right) \quad (10)$$

$$P_1 - jQ_1 = V_A{}^{*} \sum_{n=1}^{N} Y_{An V_n} \quad (11)$$

$$P_{1=} V_A{}^{*} \sum_{n=1}^{N} Y_{An}\, V_n \quad (12)$$

$$Q_{1=} - Img\,\{V_A{}^{*} \sum_{n=1}^{N} Y_{An} V_n\} \quad (13)$$

The Voltage at bus and line entries in polar form is:

$$V_{A=} |V_A| < \delta_A;\; V_n = |V_n| < \delta_n; Y_{an} = |Ykn| < \theta_{An}$$

By exchanging these in (11):

$$P_1 - jQ_1 = \sum_{n=1}^{N} Y_{An} V_n < \theta_{An} + \delta_n - \delta_A \quad (14)$$

$$P_{1=} \sum_{n=1}^{N} Y_{An} V_n\, Cos(\theta_{An} + \delta_n - \delta_A) \quad (15)$$

and:

$$Q_{1\,=} - \sum_{n=1}^{N} Y_{An} V_n\, sin(\theta_{An} + \delta_n - \delta_A) \quad (16)$$

Now by relating (8) with the power system we have:

$$\Delta C_A{}^{(0)} = \Delta P_1 = P_{1Spec} - Q_{1Calc}$$

$$\Delta C_B{}^{(0)} = \Delta Q_1 = Q_{1Spec} - Q_{1Calc}$$

$$\Delta Z_A{}^{(0)} = \Delta \delta_A{}^{(0)}$$

$$\Delta Z_B = \left|V_A{}^{(0)}\right|$$

The partial derivative of real and reactive power is contained in the Jacobian "J." The following is the fundamental iterative procedure:

- Start with the previous case's outcome.
- Calculate the dispersion and stop when the acceptance value's bound exceeds it.
- Calculate the Jacobian's power flow, update the value, and return to the previous step.

IV. METHODOLOGY

In this research, different cases were analyzed/investigated. In the first case, the power flow was tested on the test scheme without injecting a DG unit. Voltage profile and power losses on each bus bar were monitored. Furthermore, synchronous generator and induction generator were injected on two optimum points which were selected by the hit and trial method, which resulted to finding that Bus bar 3 and Bus bar 6 were suitable for the installation of DG. Furthermore, an un-deterministic DG was injected and voltage level and power losses were monitored. As a result, disturbance occurred in the overall network. Finally, the conductor's cross sectional area was raised, and the influence on voltage profile and power losses was noted.

V. TEST CASES

A. *Case-1: Without DG Unit Injection*

The load flow evaluation of the radial distribution system in Case 1 is illustrated in Figure 1.

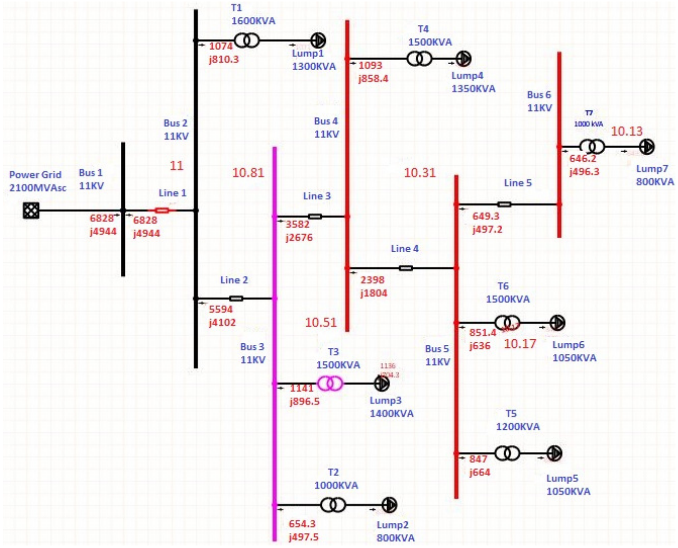

Fig. 1. Without inserting a DG unit.

In this case, there is no injecting DG unit and the load demand is met by the electricity grid. This situation is used as a model for future cases. The voltage profile at various buses is displayed. The red color demonstrates critical situation of buses. We can see that Bus bars 4, 5, and 6 are in critical situation. Table I shows the power losses at various points of the distribution system. The entire active power losses in this situation are 542.7KW, whereas the total reactive power losses are 1048.6KVAR.

TABLE I. TOTAL POWER LOSSES WITHOUT DG INJECTION

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	158.9	31.7
Line-2	217.9	32.1
Line-3	95.8	14.1
Line-4	44.7	6.6
Line-5	3.4	0.5
T1	3.3	146.5
T2	2.1	92.4
T3	4.3	192.2
T4	4.1	183.4
T5	3.1	141.1
T6	2.8	110.1
T7	2.4	97.8
Total	542.7	1048.6

B. *Case-2: Synchronous Generator Inserted at Bus-3*

Power flow analysis of case-2 is illustrated in Figure 2. During this case, a DG unit is inserted at Bus bar 3. A DG unit (synchronous generator) of 2.5MW is attached in the system at Bus bar 3 and the load demand is achieved by the electricity grid. The voltage level is enhanced at various buses when linked to the previous case, as illustrated in Figure 2. In this case, Bus bar 5 and Bus bar 6 are in critical state. Table II shows the power losses at various points of the distribution system. The entire active system losses are 376.8KW, whereas the overall reactive system losses are 1025.4KVAR. When compared to the previous case the power losses are reduced.

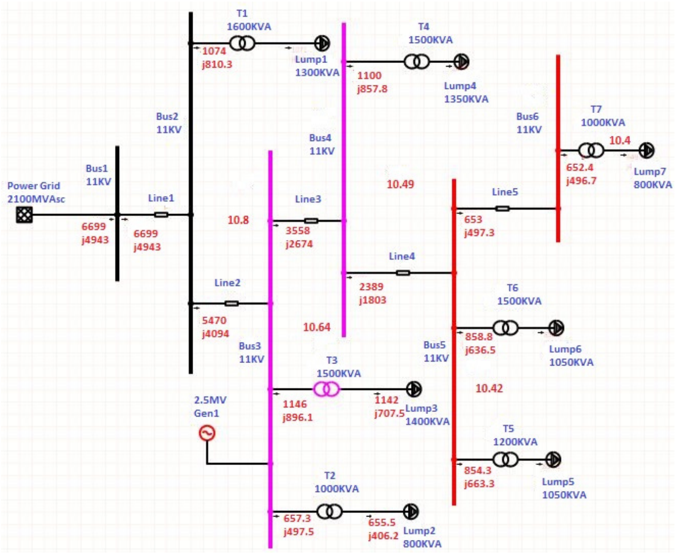

Fig. 2. A DG unit (synchronous generator) is inserted at Bus-3.

TABLE II. POWER LOSSES WHEN A SYNCHRONOUS GENERATOR IS INSERTED AT BUS BAR 3

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	155.0	39.2
Line-2	108.2	27.4
Line-3	68.5	13.0
Line-4	22.0	5.6
Line-5	1.7	0.4
T1	3.3	146.6
T2	2.0	90.7
T3	4.2	188.4
T4	4.0	178.3
T5	3.0	135.8
T6	2.7	106.1
T7	2.3	93.9
Total	376.8	1025.4

C. Case-3. Synchronous Generator inserted at Bus-6

The power flow study of Case 3 is illustrated in Figure 3. A DG unit (synchronous generator) of 2.5MW is inserted in the network at Bus bar 6 and the load demand is met by the power grid.

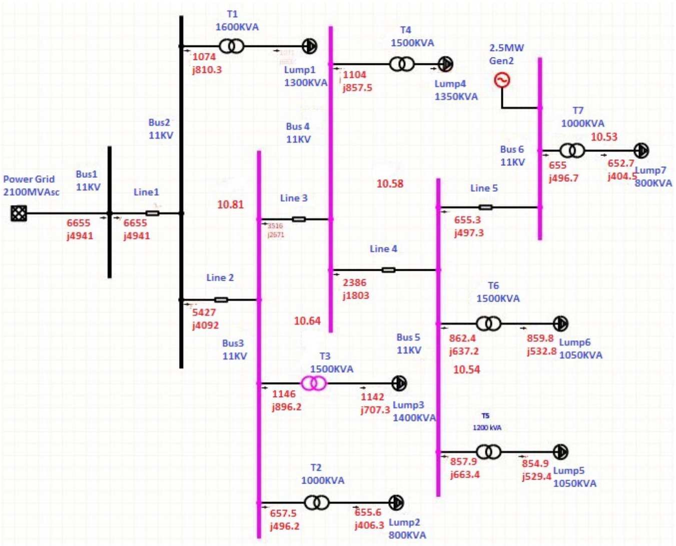

Fig. 3. A DG unit (synchronous generator) is inserted at Bus 6.

TABLE III. POWER LOSSES WHEN A SYNCHRONOUS GENERATOR IS INSERTED AT BUS BAR 6

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	153.6	38.9
Line-2	107.1	27.1
Line-3	26.7	11.2
Line-4	10.1	5.0
Line-5	0.8	0.4
T1	3.3	146.5
T2	2.0	90.7
T3	4.2	188.4
T4	3.9	176.1
T5	3.0	133.4
T6	2.6	104.4
T7	2.3	92.2
Total	319.5	1014.2

In this situation, the DG source and the power grid work together to meet the load requirements. The voltage level is enhanced at various buses when compared to the previous case. Table III shows the overall power losses in the distribution network at various locations. The entire active power losses when a synchronous generator unit is inserted at Bus bar-6 are 319.5KW, whereas the entire reactive power losses are 1014.2KVAR. These losses are decreased when compared to DG unit placed at Bus Bar-3.

D. Case-4: Induction/Wind Generator inserted at Bus-3

The load flow study of case 4 is shown in Figure 4. A DG unit (induction/wind generator) of 2.5MW is linked with the network at Bus bar 3 and the load demand is met by the grid. The electricity grid and the DG source work together to meet the load requirements. In this case Bus bars 4, 5, and 6 are in critical state. Table IV shows the overall power losses in the distribution network at various locations. The entire active power losses are 621.7KW when the 2.5MW induction generator unit is linked at Bus 3, whereas the total reactive power losses are 1046.9KVAR. Compared to the prior examples, the losses are increased.

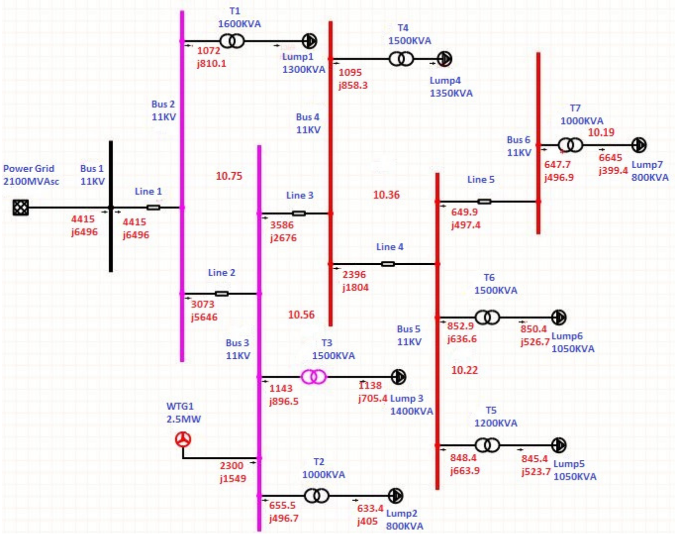

Fig. 4. A DG unit (induction/wind generator) is inserted at Bus 3.

TABLE IV. POWER LOSSES WHEN INDUCTION/WIND GENERATOR IS INSERTED AT BUS BAR 3

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	296.6	39.8
Line-2	189.2	27.9
Line-3	95.0	14.0
Line-4	44.3	6.5
Line-5	1.7	0.4
T1	3.3	147.8
T2	2.0	91.8
T3	4.2	190.8
T4	4.0	181.9
T5	3.1	140.0
T6	2.7	109.2
T7	2.4	96.8
Total	621.7	1046.9

E. Case-5: Induction/Wind Generator inserted at Bus-6

The load flow examination of case 5 is illustrated in Figure 5. A 2.5MW DG unit (induction/wind generator) is attached to the network at Bus bar 6 and the electricity grid and the DG source work together to meet the load demand. Table V shows the overall power losses in the distribution network at various locations. The entire active system losses are 445.0KW, whereas the entire reactive system losses are 1012.8KVAR. These losses are improved when compared to case 4.

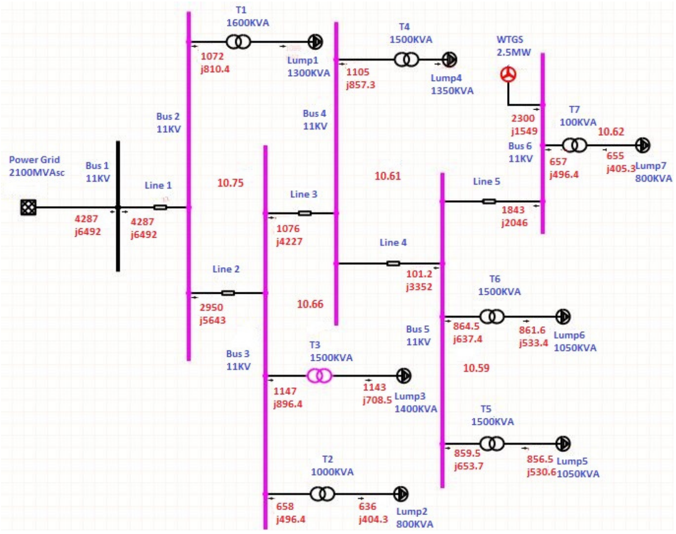

Fig. 5. A DG unit (induction/wind generator) inserted at Bus 6.

TABLE V. POWER LOSSES WHEN INDUCTION/WIND GENERATOR IS INSERTED AT BUS BAR 6

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	264.5	39.0
Line-2	68.7	22.8
Line-3	45.3	11.5
Line-4	27.1	6.9
Line-5	18.2	4.6
T1	3.3	147.6
T2	2.0	90.4
T3	4.2	187.8
T4	3.9	175.2
T5	2.9	132.4
T6	2.6	103.6
T7	2.3	90.9
Total	445.0	1012.8

F. Case-6: Inserting a Small Un-Deterministic DG Unit

In this situation, a small DG is inserted in the system and its effect on voltage level and power losses are examined. The power flow analysis for this situation is shown in Figure 6. The red color indicates the critical state of buses. Bus bars 4, 5, and 6 are in critical state. Table VI shows the overall power losses in the distribution network at various locations. The entire active power losses in this situation are 518.7KW, while the entire reactive power losses are 1031.5KVAR.

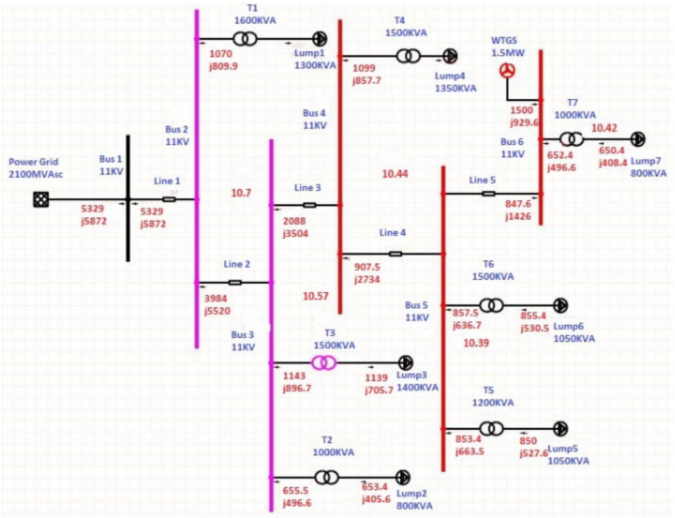

Fig. 6. Load flow analysis when inserting un-deterministic DG in the distribution system.

TABLE VI. INJECTION OF UN-DETERMINISTIC DG IN THE DISTRIBUTION SYSTEM

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	274.8	40.5
Line-2	97.0	24.6
Line-3	82.1	12.1
Line-4	29.8	5.7
Line-5	13.4	2.0
T1	3.3	148.6
T2	2.0	91.6
T3	4.2	190.3
T4	4.0	179.6
T5	3.0	136.4
T6	2.7	106.6
T7	2.3	93.6
Total	518.7	1031.5

G. Case-7: Increasing the Cross Sectional Area of the Conductor

In this case, the Cross Sectional Area (CSA) of the transmission cable is increased in order to analyze the effect of voltage profile and power losses. By considering the CSA of the conductor, its resistance is equal to:

$$R=\rho\, L/A$$

where ρ is the resistivity, L the length, and A the CSA.

The above equation shows that CSA A is inversely proportional to the resistance R and by increasing the CSA, the R will be decreased and maximum current will flow. Figure 7 illustrates the findings of the load flow analysis. The power grid and the un-deterministic DG unit meet the load requirements. Table VII shows the overall power losses in the distribution network at various locations. The overall active power losses are 426.7KW and the total reactive power losses are 1019.7KVAR. Comparing with the power losses from the previous situation, we see that the power losses are much improved.

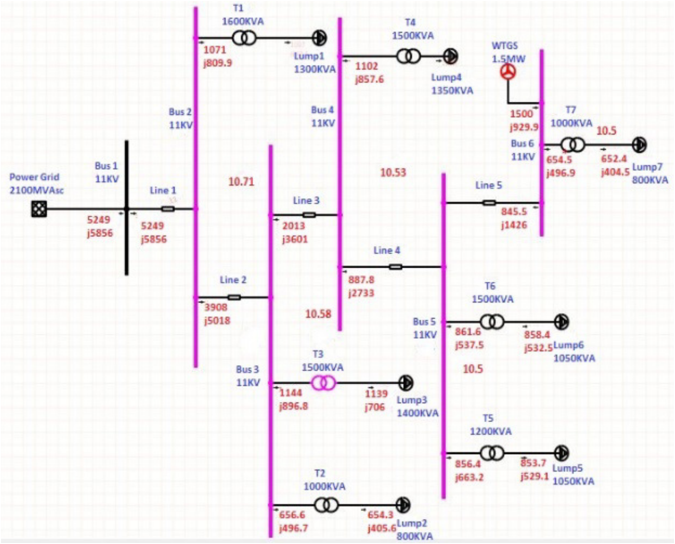

Fig. 7. Total power losses of the system by increasing the CSA of the conductor.

TABLE VII. INCREASING THE CSA OF THE ONDUCTOR

Branch/Circuit ID	Losses	
	KW	KVAR
Line-1	270.5	40.0
Line-2	95.5	24.2
Line-3	23.5	9.9
Line-4	11.5	4.8
Line-5	3.9	1.6
T1	3.3	148.5
T2	2.0	91.5
T3	4.2	190.2
T4	3.9	177.4
T5	3.0	134.2
T6	2.6	105.0
T7	2.3	92.5
Total	426.7	1019.7

VI. RESULT ANALYSIS AND DISCUSSION

In this section, the obtained results and Voltage profile analysis and power losses analysis from different cases are discussed in detail.

A. *Voltage Profile Analysis*

When various kinds of DG units are inserted to the radial distribution network, they have various impacts on the voltage level. The entire results are illustrated in Table VIII.

TABLE VIII. RADIAL FEEDER VOLTAGE ARRANGEMENT

Bus bar no	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)	Case (7)
1	11	11	11	11	11	11	11
2	10.81	10.8	10.81	10.75	10.75	10.7	10.71
3	10.51	10.64	10.64	10.56	10.66	10.57	10.58
4	10.31	10.49	10.58	10.36	10.61	10.44	10.53
5	10.17	10.42	10.54	10.22	10.59	10.39	10.5
6	10.13	10.4	10.53	10.19	10.62	10.42	10.5

1) *Voltage Level without DG Injection*

In this case, no DG is inserted. Figure 8 illustrates the radial fall in voltage level from the source to the load. The decrease in voltage profile is caused by the impedance of the line.

2) *Effect on Voltage Profile when a DG (Synchronous Generator) is Inserted at Bus-3 and Bus-6*

Figure 9 shows the voltage level at different Bus Bars when a synchronous generator is injected at Buses 3 and 6. It can be seen that the voltage profile improves when the synchronous generator is injected at Bus-6.

3) *Effect on Voltage Level when a DG (Induction/Wind Generator) is Inserted at Bus-3 and Bus-6*

Here, the voltage comparison is made at different Bus bars when an induction generator is injected at Bus-3 and Bus-6. It is shown in Figure 10 that the voltage profile is improved when the induction generator is injected at Bus-3 and Bus-6 as compared to the base case, but when compared to the previous case, the synchronous generator injected at Bus 6 gives the best result.

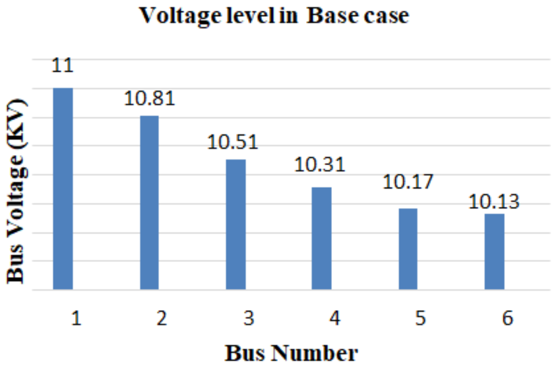

Fig. 8. Voltage level when no DG is injected.

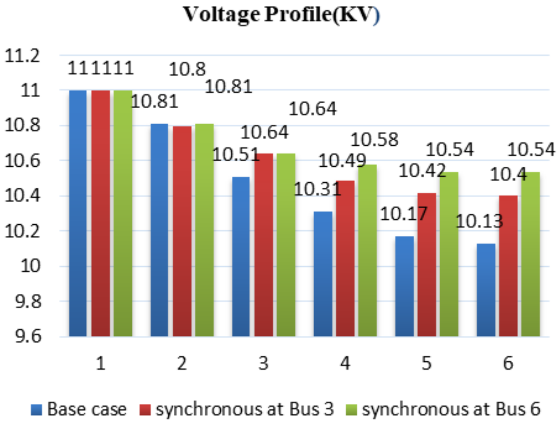

Fig. 9. Voltage profile when a synchronous generator is inserted at Bus 3 and Bus 6.

4) *Effect on Voltage Level when Injecting an Un-Deterministic DG Unit and Increasing the Conductor's CSA*

In this case an undeterministic DG unit is injected and the CSA of the conductor is increased and its impact on the voltage level is observed. It is shown that Voltage level is improved when the CSA of the conductor is increased. The result obtained is shown in Figure 11.

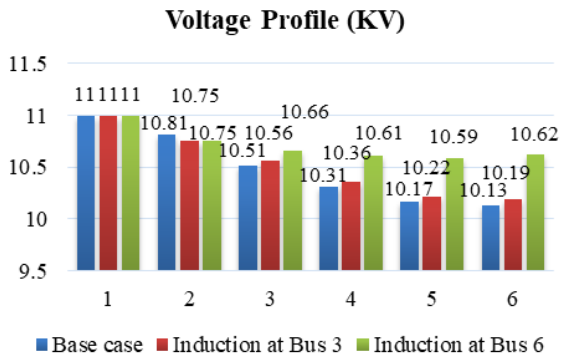

Fig. 10. Voltage profile when an induction generator is inserted at Bus 3 and Bus 6.

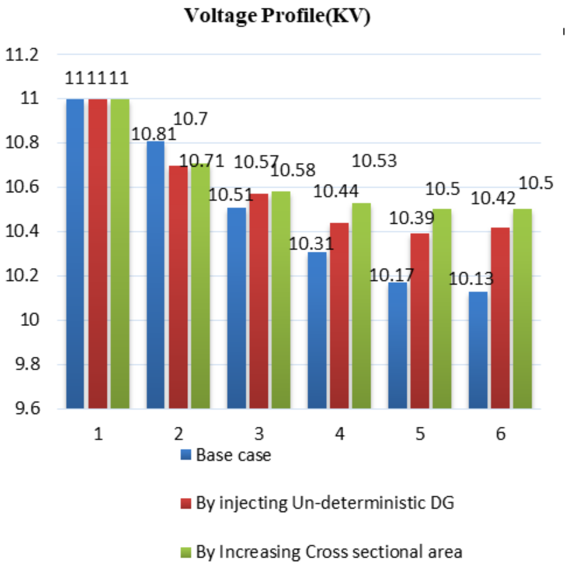

Fig. 11. Voltage profile when an un-deterministic DG is inserted and the CSA of the conductor is increased.

B. Power Losses Analysis

When various kinds of DG units are linked to the radial distribution system, different effects on power losses occur.

1) Total Power Losses in the Base Case

In this case, the power losses are observed without injecting a DG unit. The total losses are shown in Figure 12. Impedances in the lines cause these losses. No DG unit is inserted and all power is supplied by the electrical grid. Each cable carries current from the grid to the customer locations, resulting in significant power losses.

2) Power Losses when a DG (Synchronous Generator) is Inserted at Bus 3 and Bus 6

Figure 13 shows the total power losses in KW when a synchronous generator is inserted at Bus 3 and Bus 6. It is seen that the power losses are reduced when the generator is injected at Bus 6.

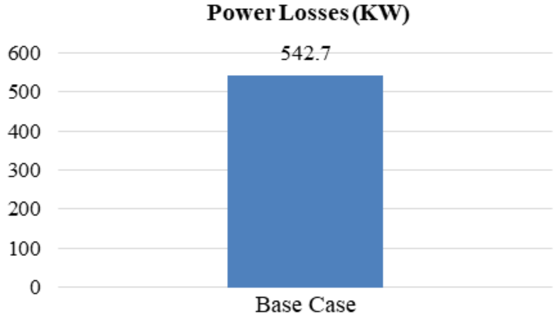

Fig. 12. Total power losses of the base case.

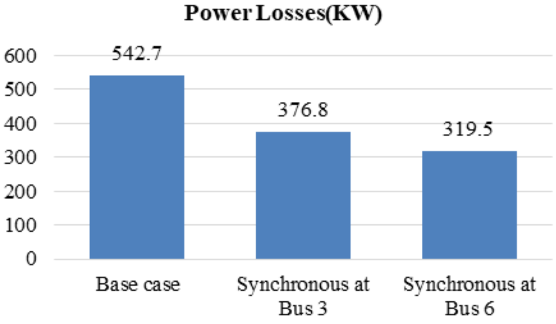

Fig. 13. Total power losses when a synchronous generator is inserted at Bus 3 and Bus 6.

3) Power Losses when a DG Unit (Induction/Wind Generator) is Inserted at Bus Bars 3 and 6

Figure 14 shows the total power losses when an induction generator is injected at Buses 3 and 6. It is seen that the injection caused increase in power losses due to the absorption of reactive power by the induction generator.

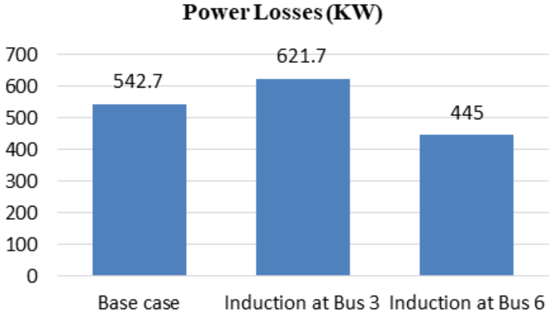

Fig. 14. Total power losses when an induction generator is injected at Buses 3 and 6.

Inserting a synchronous generator at Bus 6 has an outstanding result in comparison with the other cases. As a result, injecting a DG unit at an optimal position, such as Bus bar 6, and a DG type, such as the synchronous generator, will have positive impact on power losses.

4) Power Losses when an Un-Deterministic DG is Inserted in the Distribution System and the Conductor CSA is Increased

In this case, an un-deterministic DG unit is injected and the CSA of the conductor is increased and the impact on power losses is observed. It is seen that the power losses will be reduced when the CSA of the conductor is increased. The entire power losses are shown in Figure 15.

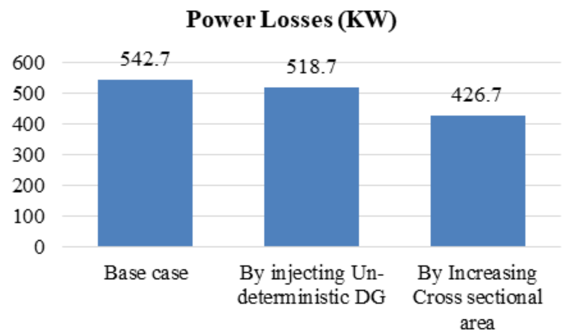

Fig. 15. Total power losses when an un-deterministic DG is injected and the CSA of the conductor is increased.

The novelty of this research work is that a real test system of 132KV residential test feeder is modeled in ETAP. Various tests were carried out to determine the influence of DG on the distribution network. Various researchers work on IEEE built-in systems and very limited work has been conducted by taking or selecting a real test system. DG was injected at multiple points on the test feeder, and improvement in voltage profile and reduction in power losses were observed. These findings will be useful to many distribution firms around the world, and specifically in Pakistan, in the future expansion of the power systems and the proliferation of DG.

VII. CONCLUSION AND FUTURE WORK

In this research paper, the effect of DG on voltage level and system losses in a radial test system was observed and different cases were considered. It was concluded that by connecting a synchronous generator at Bus 6, the voltage level improved and power losses were reduced the most. Attaching an induction/wind generator considering as DG unit close to a load improves the voltage profile, but, due to the immersion of reactive power by the induction generator, the power losses will be increased. Moreover, it was concluded that when an un-deterministic DG unit is inserted in the distribution system, it will cause disturbance in the whole system. Inserting un-deterministic DGs has negative effect on the voltage level and power losses. Furthermore, it was concluded that by increasing the CSA of the conductor, the voltage level can be elevated and power losses can be reduced. The effects of various conventional and non-conventional DG units can be examined more in the future, considering harmonics and reliability.

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