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INTEGRATING DISTRIBUTED GENERATIONS (DGS) INTO PESHAWAR ELECTRIC SUPPLY COMPANY (PESCO) DISTRIBUTION NETWORK: ISSUES AND CHALLENGES

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Abstract

Currently, the demand of electricity is increasing enormously and the major challenge for power engineers is to produce electricity from sources of renewable energy to resolve the increasing energy usage with reduced environmental impact of power generation. This research study is an attempt to utilize the sources of renewable energy to overcome the increasing demand of electricity by integrating photovoltaic system as a Distributed Generations (DGs) into Peshawar Electric Supply Company (PESCO) Distribution Network and the issues and challenges which are arising due to integration of such (DGs). The researcher uses simulation model to study and predict its performance in the real world. This simulation model has two main phases: the first phase was distribution network has been analyzed without the integration of Photovoltaic cell. The result indicates that the overall power system losses without the integration of distributed generations. In the second phase the researcher analyzed the distribution system by integrating Photovoltaic cell (DG) to mitigate the loss of power in distribution system. The result shows that while integrating (DG) into power distribution network the overall power losses has reduced due to designed optimum location.

INTRODUCTION

Due to increasing population and industrial development the higher demand of electricity is putting great pressure on power industry to enhance the capability of power generation [1]. To overcome the growing demand of electricity, fossil fuels are mostly used for power generation causing environmental deterioration [2]. Consequently, the existing power generation system can be modified by adding new generation capacities which keep the emission of carbon dioxide (CO_2) at the lowest rate [3]. This can be achieved through using renewable sources for the power generation. [4]

The Distributed Generation means the energy in the form of electricity that is generated to the load side and is connected with the main grid to supply energy to the end users [5]. This process usually minimizes the losses in the circuit. The Distributed Generation is usually called a Micro grid. Distributed generation has two levels: Which are the distributed generation at local level and distributed generation at end point level. The power plants in local level are place specific and consist of renewable energy sources technologies while energy plants in the end-point level is associated with various technologies which are given below having the same effects. The distributed generators include various types of power generators, including fuel cells, micro turbines, renewable energy sources such as wind, sun, and tide scales, synchronous generators, induction generators and combustion gas turbines. These small new distributed systems fed in the excess energy, linking the DG to the load side and reducing the cost of installation. Due to increasing energy demands, renewable energy generation is very competitive and effective. [6]

Motivation and Objectives

In the modern days, power systems are very complicated and expanded in nature which covers thousands of buses [7]. Analyzing a system having too much nodes is beyond human capabilities, and consequently highly sophisticated computer programs are required for analyzing, developing and operating advanced power systems. The raising energy demands could be met by integrating renewable energy sources in to current energy networks [8]. Moreover, introducing unconventional energy sources like wind, solar, hydro and geothermal etc. creates technical problems of stability and reliability measures because of unsystematic nature of the renewable sources and distributed nature of power generation [9]. There have been increasing interests in distributed generation (DG) systems that is an electrical energy source being attached with a power generation system so close to a point or near to the customer's side, very little as compare to centralized power plants. The evolution of Distributed Generation provides an enhanced management system that has the efficiency to balance electrical loads from varied situations and random generation sources. The national grid integration of renewable energy like wind energy system and solar system and will solve many issues like voltage fluctuations, frequency variations and harmonics. Efficiently developed distributed generators would be good in operation if islanded, which gives customers and distribution system an extensive outages ability. Utility system effectiveness and reliability can be improved by distributed resources through powering the grid vital protective functions although it fails in supplying its own power.

It is pertinent to simulate the real-world phenomena that impact the power systems and analyze the potential problems in order to figure out best possible solutions for power systems before its physical realization. Figuring out best possible solutions in the presence of these obstacles demand simulation of multiple scenarios that can take place, and apply the solution that best suits the particular situations. Currently, there are a wide range of commercial as well as open-source computational tools to select from; consequently, majority have been developed for particular purposes. There is limited comparative knowledge available about the effectiveness of such tools in different scenarios.

In this research, we will carry out the load flow analysis of Peshawar Electric Supply Company (PESCO) grid feeder stations in Electrical Transient Analyzer Program (ETAP) with and without the integration of DG at different Buses. The ETAP power station has special quadratic convergence attribute. As compared to other load flow calculation techniques its convergence speed is very high.

Modern Power Systems Overview

A normal electrical power system comprises of three integral parts: to generate, to transmit and to distribute the electrical power as given in figure 1. The generation stations, normally, nuclear and thermal hydro generators have levels of voltage 11KV – 25KV and thus step up transformers are used to rise level of voltage for long transmission distances. The distribution network could be distributed into primary and secondary levels to lower the voltage levels with step down transformers.

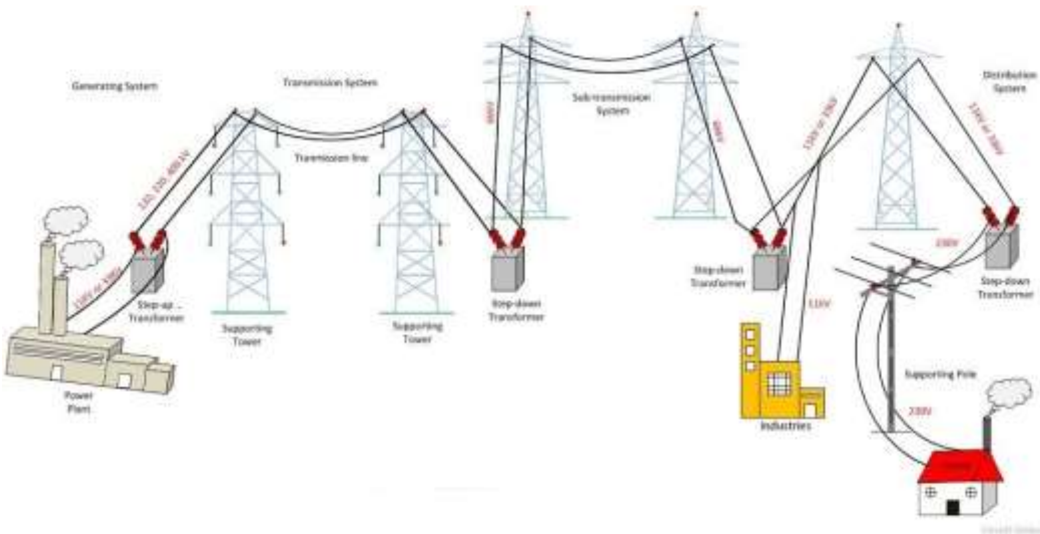

Figure 1 Typical Electrical Power System

In recent years' integration of (DG) like renewable sources of energy to electrical distribution network has become economical. The arising micro grid concept that enables renewable energy integration in a distribution network's integral part is distributed generation. Growing electrical demands and difficult conventional energy sources alternative renewable energy sources (RES) including photovoltaic (PV) systems, fuel cells, wind energy systems and micro turbines have been incorporated to electric power systems. These RESs are attached to the distribution network through distribution generations (DGs) as given in figure 2

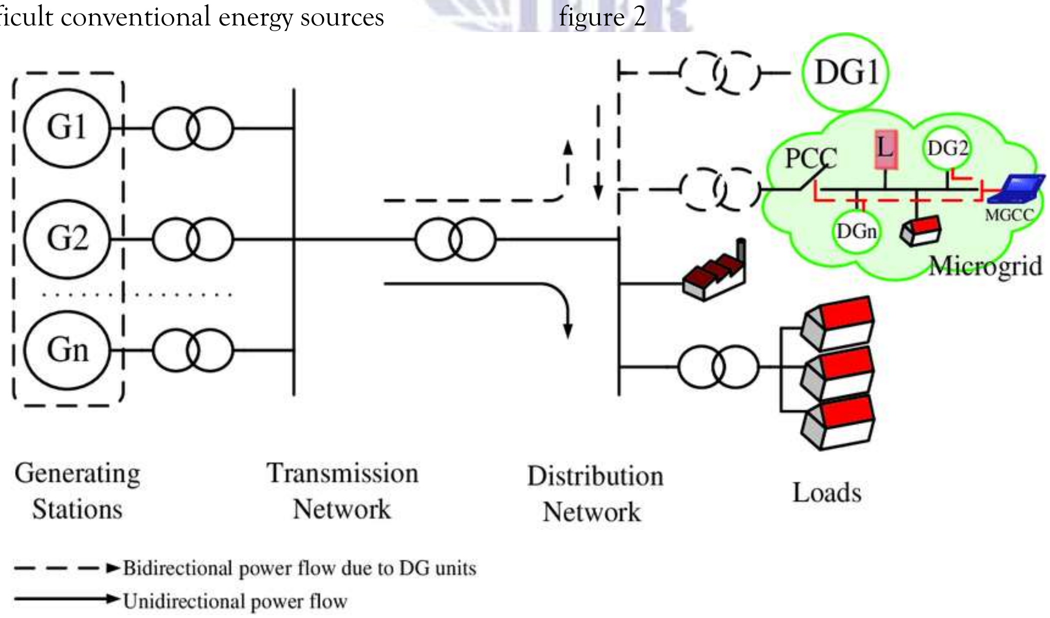

Figure 1 Modern Electrical Power System

The power plants in distributed Generation are attached to low voltage side or to medium voltage side having output power in between a few watts to hundred megawatts. Some DG sources rates. Per module production ranges are given below:

- Small hydropower system: 1 – 100 MW

- Micro Turbines generator: 25 kW – 1000 KW (1MW)
- Wind Turbines generator: 200 W – 3000 KW (3MW)
- Solar system arrays: 20 W – 100 KW
- Geothermal energy system: 5 – 100 MW
- Ocean thermal energy system: 100 kW – 5000KW (5MW)

A lot of work has been done regarding integration of different DGs into the distributed network. DG units which are not located at optimal locations can cause power losses. To maximize efficiency of overall system DGs the most desirable location of DGs in power network is crucial.

To investigate the effects of the distributed generations on grid and optimal location for reduction in loss the optimization techniques is used in the above method. In ETAP software the load flow analysis has been applied which indicates reduced active power losses after Distributed generator is being installed. There are a number of challenges that we will face while simulating the results practically which are given below

- Voltage fluctuation
- Thermal Capacity Congestion

Apart from the above issues, there are some features in distributed generation which traditional centralized systems lacks:

- Power loss Reduction
- Energy balancing and Reactive power control
- Close proximity to the consumer location
- Relatively small generated power
- Improving power quality and providing better voltage support.

One of the power systems new trends is distribution Generation (DG) used to support the increasing electrical demands. DG has many definitions therefore includes numerous new applications and technologies. Several notations used for DGs in many countries such as embedded generation (EG) etc. In addition, IEEE, CIGRE etc. organizations also proposed different definitions which are causing confusion. Following definition is accepted in this thesis: DG is defined as an electrical energy source attached to the power network, near the customer's side, that is very small as compared to the main power plants. [10].

A lot of work has been done regarding the challenges of integrating DGs into the distributed network. There are a number of researchers who uses different procedures to solve these problems. Some of the related works are described as under.

This study covers an outline of the issue regarding the connecting of distribution generation which are being focused in modern days. The major factors behind the integration of DG are such as renewable type also used in several countries. A synopsis of the major issues which should be solved in the process is given and emphasis. This study also analyzes the reflection in power transmission system operation and expansion resulting by integrating large numbers of DG of various systems of energy conversion concentrating on problems concerning effects in steady state condition, contingency analysis, and protection along with dynamic behavior analysis. [11]

In this study, load flow studies of 11kv test feeder distribution network or substation in Electrical Transient Analyzer Program (ETAP) with and without the injection of Distribution Generation has been discussed and simulations have been carried out in ETAP software. A detailed load flow study is analyzed to reduce the losses that arise due to integration of DG in the network. [17]

With the passage of time demand of power is raising, therefore substantial rise in the penetration of DG to fulfill the end user's requirements. DG integration has impact on the existing distribution system and on the system and the biggest issues is with the power system protection. The change in the distribution systems short circuit power will also change the state and cause change in short circuit power by disconnecting various generators in the distribution systems. This will delay the fault clearing time by disconnecting equipment's in the distribution network. This study analyzed the effect of distributed generation integration in a distribution network on the short circuit level with wind energy turbine and gas generators. [12].

Proposed Methodology

Load flow is essential tool utilized for planning by engineers and calculating the load flow analysis, to obtain better operation for a power system and sharing of power between utility companies. it is pertinent to explore efficient suitable method for load flow analysis of the system for the sake of efficient operating power system. Load flow measurement aim is to identify the power systems steady state operating qualities for the given generator real power, loads and voltage. Due to changes in power demands and generations a power flow technique could take too long thus giving inaccurate results to a power flow solution. There are some numerical approaches to solve or analysis the problems in load flow like Gauss-Seider, Newton-Raphson etc. We are adopting Newton-Raphson approach to measure the unknown quantities of our power system and simulate the results in ETAP software. Newton–Raphson is the more credible method due to the smaller number of iterations and converges faster.

Inputs and outputs of Load Flow Analysis

Minimum input data for power flow analysis is listed as:

- Bus Data
  - For Slack Bus
    - Voltage magnitude (usually 1 per unit).
    - Voltage angle (specified to be 0).
  - For PV Bus
    - Real power (generation and demand)
    - Reactive power (demand).
    - Voltage magnitudes.
  - For PQ Bus
    - Real Power (generation and demand).
    - Reactive power (generation and demand).
- Line Data:
  - Transmission lines
    - Resistance
    - Reactance
  - Transformers
    - Winding Resistances
    - Leakage resistance

Active and Reactive Power Calculations

Before finding the load flow analysis, let's formulate the active and reactive power entering a bus.

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

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

The Newton-Raphson load flow approach is same as solving a system of nonlinear equations employing the Newton-Raphson approach: Jacobian matrix is formed at each iteration and solved for the correctness of an equation. The equation for the load flow is given as

$$J\begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \\ \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_{1+n_p}|}{|V_{1+n_p}|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_{1+n_p} \end{bmatrix}$$

The Newton- raphson procedure for load flow algorithm, is given as:

Step 1: Select Voltage magnitudes initial values $|V|(0)$ for all the np load buses and n-1 angles $\delta(k)$ of the voltages of all the buses except the slack bus.

Step-2: Take the estimated $|V|(k)$ and $\delta(k)$ to measure a total n-1 number of injected real power Pcalc (k) and equal number of real power mismatch P(k).

Step-3: Utilize the estimated $|V|(k)$ and $\delta(k)$ to measure a total np number of injected reactive power Qcalc(k) and equal number of reactive power mismatch ΔQ(k).

Step-4: Utilize the estimated $|V|(k)$ and $\delta(k)$ to formulate the Jacobian matrix J(k).

Step-5: Solve

$$J\begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \\ \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_{1+n_p}|}{|V_{1+n_p}|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_{1+n_p} \end{bmatrix}$$

for $\Delta\delta(k)$ and $\Delta|V|(k) \div |V|(k)$

Step-6: Take the updates from

$$\delta(1) = \delta(0) + \Delta\delta(0) \quad (1)$$

$$|V|(k+1) = |V|(k)[1 + \Delta|V|(k) / |V|(k)] \quad (2)$$

Step-7: If the conditions are satisfied, then terminate the process if not then return to step-1 to initiate the next iteration with the updates given by (1) and (2).

The Newton-Raphson approach depends on the bus voltage initial value. It is highly recommended that bus voltage initial values should be carefully selected.

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Results And Conclusion

Simulation Results Phase 1:

Power System simulation without DG installation:

Utility power grid with rating of 900 MVA is attached to nominal voltage Bus - 1 of 220 KV system as given in the figure below. Our designed power system composed of 11 Buses, 1st one is the swing bus and all other buses up to Bus-10 are 11 KV load buses. Total 9 loads are connected and the transformer connected is 400 MVA step down transformer 220Kv – to – 11 KV connected between Bus - 1 and Bus - 2. Another 3 – phase delta – star transformer is connected after Bus -10. This transformer is 11Kv – to – 220V step down, 50 MVA transformer and a load of 15 KW is connected to Bus - 11. Different lengths of transmission lines are connected between the buses for transfer of power flow from main utility to the end customers. High voltage circuit breakers are used at different locations while a low circuit breaker is used before the Bus – 11 for voltage safety towards the end customers. The detailed simulation of one line diagram is shown in figure 3.

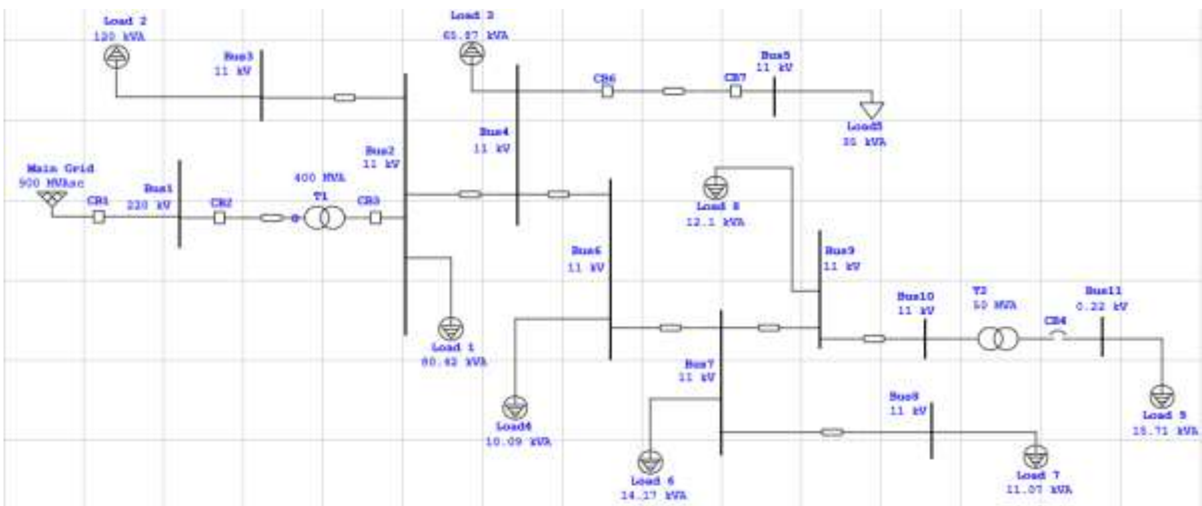

Figure 3: one Line Diagram of Power System

The main power grid is supplying 500 MW to the whole network and is connected at 220Kv swing bus. The transformer T1 is connected between Bus -1 and Bus-2 to step down the voltage from 220Kv to 11Kv and its power rating is 400 MVA.

Noload is directly attached to Swing Bus – 1 and Bus – 10 while all other busses are being loaded. The total connected loads on all buses is 348 KW as presented in the table 1.

Table 1: Buses Load of the given power system

us No.	oad (KW)
us - 1	o Load
us – 2	3
us -3	08
us – 4	5

us – 5	5
us – 6	0
us – 7	4
us – 8	1
us – 9	2
us - 10	o Load
us - 11	5

In optimization and testing stage, the load flow analysis of the power system was executed without installing any Distributed Generation (DG) system so that to research the effect of losses without distributed generation DG. The transmission lines also affect the behavior of power losses in the system. The length and type of transmission lines used in the design of PESCO power network is listed in the table 2.

Table 2: Transmission Line Length between the Buses

From	To	Length (km)
Bus – 1	Bus – 2	100
Bus -2	Bus -3	55
Bus -3	Bus – 4	60
Bus – 4	Bus – 5	30
Bus - 4	Bus – 6	50
Bus – 6	Bus – 7	50
Bus – 7	Bus -8	45
Bus -7	Bus – 9	40.8
Bus – 9	Bus – 10	36

The power flow analysis of power system without (DG) is shown in figure 4. The load flow analysis shows the input and output power in KW and voltage in KV across each bus and the loads in KVA.

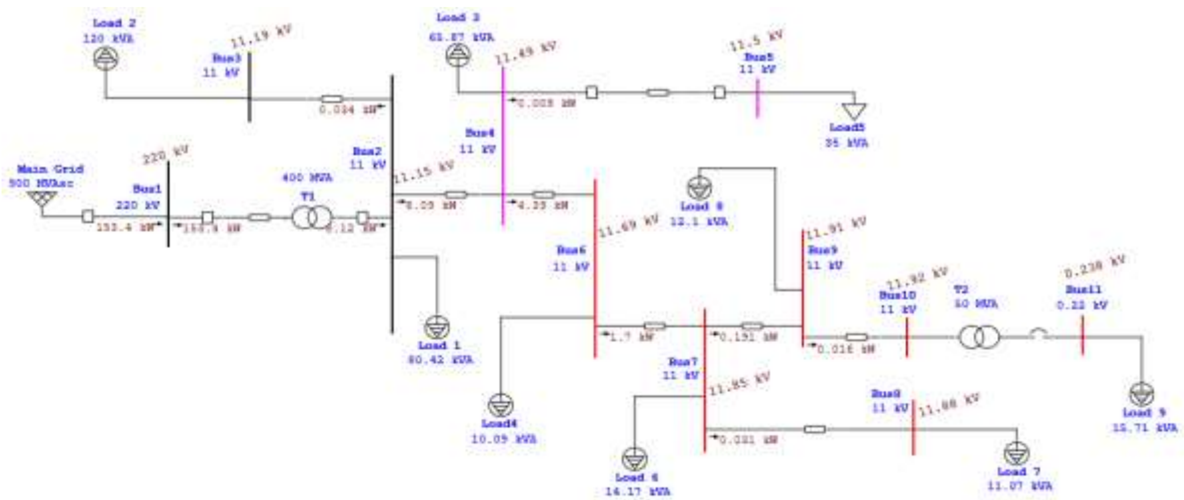

Figure 4: Load Flow Analysis of Power System

The buses with pink color shows the buses are under voltage as their voltage is below the required limits. If we draw the contour map of the load flow analysis, the under voltage and over voltage buses can be clearly observed from their colors as shown in the figure 5.

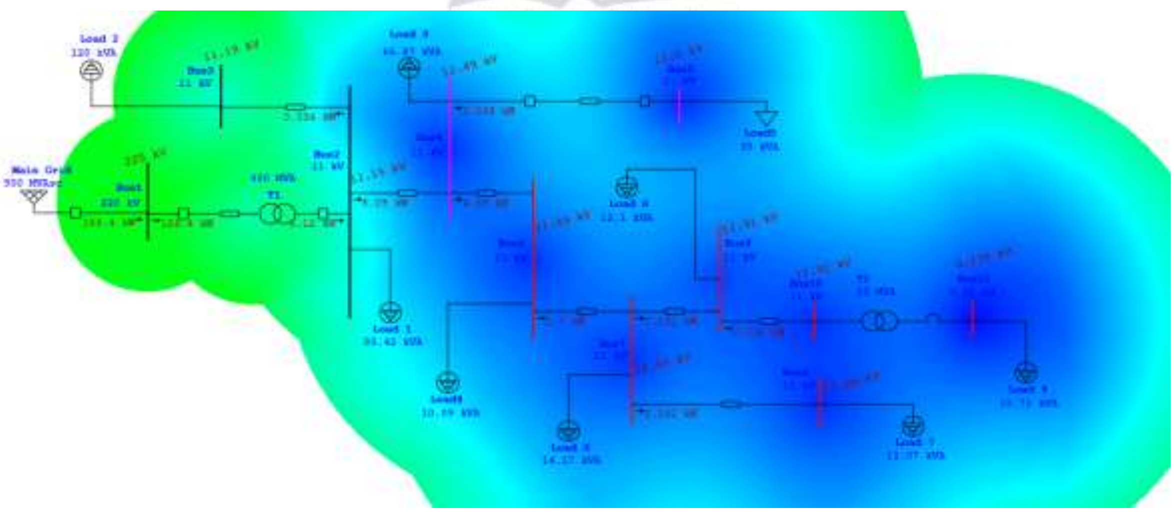

Figure 5: Enable Contouring in Load Flow Analysis

The contour map shows that the load of our designed power system network is not balance. The pink color shows the buses voltages are marginally over voltage, while red color indicates the buses are critically overvoltage more than as required. After executing and observing of the load flow study, the overall losses in the system in the absences of Distributed Generation (DG) is 153.4 KW and 22275.1 Kvar.

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd
	MW	Mvar	MW	Mvar	kW	kvar	From	To	% Drop in Vmag
100 KM	-0.008	0.169	0.153	-22.275	145.3	-22106.4	101.4	100.0	1.40
T1	0.008	-0.169	-0.008	0.169	0.0	0.0	101.4	101.4	0.00
55 KM	0.000	-0.026	0.000	0.000	0.0	-25.9	101.4	101.7	0.29
60 KM	0.008	-0.143	-0.004	0.118	3.7	-25.1	101.4	104.4	3.02
30 KM	0.000	-0.014	0.000	0.000	0.0	-14.1	104.4	104.5	0.09
50 KM	0.004	-0.104	-0.002	0.081	2.7	-22.1	104.4	106.3	1.89
50KM	0.002	-0.081	0.000	0.058	1.5	-23.7	106.3	107.8	1.44
40.8 KM	0.000	-0.036	0.000	0.017	0.2	-19.3	107.8	108.2	0.48
45 KM	0.000	-0.021	0.000	0.000	0.0	-21.3	107.8	108.0	0.21
36 KM	0.000	-0.017	0.000	0.000	0.0	-17.2	108.2	108.4	0.14
T2	0.000	0.000	0.000	0.000			108.4	108.4	
					153.4	-22275.1			

Figure 6: Branch Losses Summary Report

Simulation Results Phase 2:
Power System with DG

Now we have to insert DG to overcome the losses. The DG we are using in this network is a Solar panel based DG having power of DC 100 KW, 24 V. In each solar panel array, 10 panels are connected in series while 50 are in parallel. An integrated inverter is used along PV panel array whose rating is 90 KVA and 11 KV. The inverter will automatically convert DC power to AC and we will input its power to Buses to check the proper placement of DG system. To know about the impact of DG on the entire system the distributed generation (DG) PV array having capacity of 100 KW of unity power factor is being in contact with the power system. The main grid is connected to Bus – 1 so its voltage is 220 KV while other buses except bus – 11 are rated as 11 KV. The Bus – 11 is 220 V bus.

DG at Bus – 2:

First, we have to check our designed DG setup at Bus-2. After connecting the DG at Bus-2, we have to find the power flow analysis including voltage and power i.e. the reactive and real power across every bus as given in figure 7.

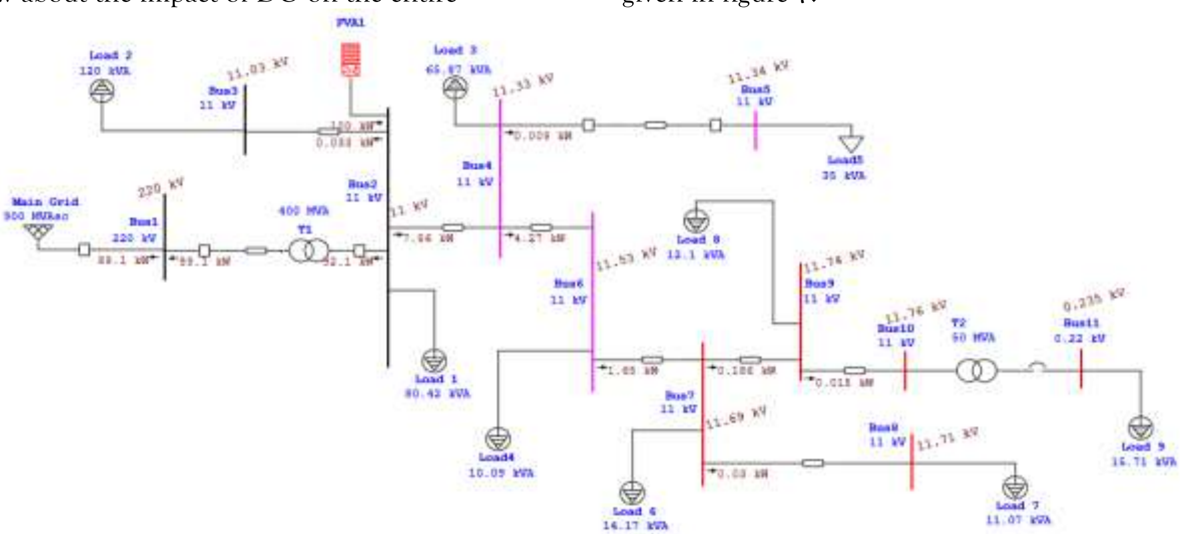

Figure 7: Load Flow Analysis after connecting DG at Bus

– 2

As we can see in the load flow analysis diagram, the buses which are over voltages have no effect due to DG installation as those buses are away from the DG. We have to use that design which can control the voltages at buses also along with power losses reduction. The overall losses are indicate in the figure 8. Its indicates that our real power losses have been diminished from 153.4 KW to 11.9 KW (i.e., reduced to 92.24 %) and reactive power is reduced up to 129Kvar.

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
100 KM	0.092	-9.252	-0.088	-12.752	3.6	-22003.4	100.2	100.0	0.23
T1	-0.092	9.252	0.092	-9.231	0.4	21.3	100.2	100.0	0.23
55 KM	0.000	-0.025	0.000	0.000	0.0	-25.2	100.0	100.3	0.29
60 KM	0.008	-0.139	-0.004	0.115	3.6	-24.4	100.0	103.0	2.98
30 KM	0.000	-0.014	0.000	0.000	0.0	-13.7	103.0	103.1	0.09
50 KM	0.004	-0.101	-0.002	0.079	2.6	-21.5	103.0	104.8	1.86
50KM	0.002	-0.079	0.000	0.056	1.4	-23.0	104.8	106.3	1.42
40.8 KM	0.000	-0.035	0.000	0.017	0.2	-18.7	106.3	106.7	0.47
45 KM	0.000	-0.021	0.000	0.000	0.0	-20.7	106.3	106.5	0.21
36 KM	0.000	-0.017	0.000	0.000	0.0	-16.7	106.7	106.9	0.13
T2	0.000	0.000	0.000	0.000			106.9	106.9	
					11.9	-22146.1			

Figure 8: Branch Losses after connecting DG at Bus - 2

DG at Bus – 4:

After connection of DG system to Bus – 4, the bus voltages, active power and loads are shown in figure 9. The total losses across each bus and transmission lines are also shown in figure 10.

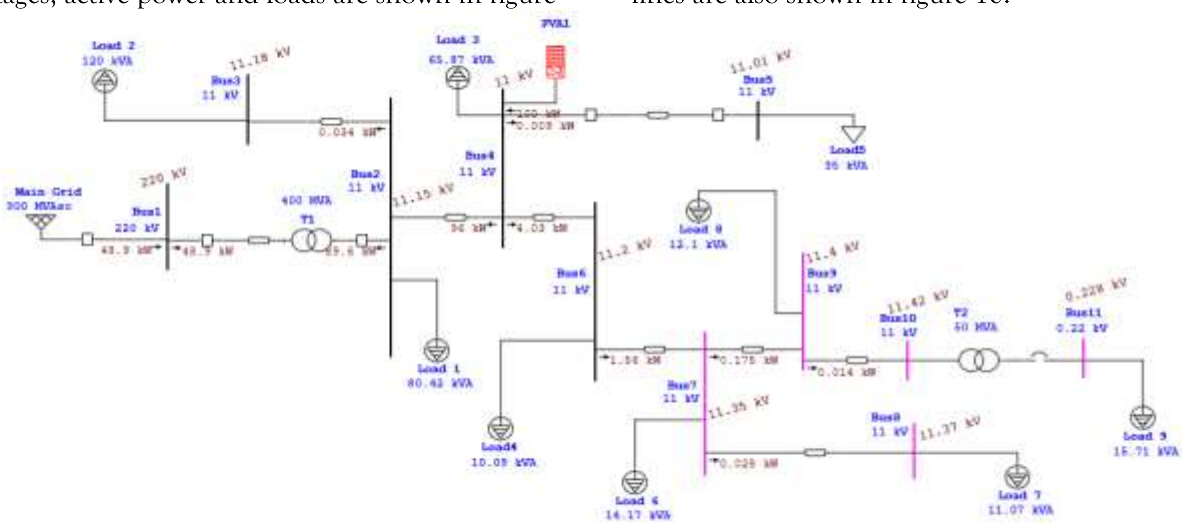

Figure 9: Load Flow Analysis after DG connection at Bus - 4

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
100 KM	0.094	0.028	0.048	-22.137	141.8	-22109.1	101.4	100.0	1.39
T1	-0.094	-0.028	0.094	0.028	0.0	0.0	101.4	101.4	0.00
55 KM	0.000	-0.026	0.000	0.000	0.0	-25.9	101.4	101.7	0.29
60 KM	-0.094	-0.002	0.096	-0.025	2.0	-26.6	101.4	103.2	1.83
30 KM	0.000	-0.014	0.000	0.000	0.0	-13.8	103.2	103.3	0.09
50 KM	0.004	-0.101	-0.002	0.080	2.6	-21.6	103.2	105.1	1.87
50KM	0.002	-0.080	0.000	0.056	1.4	-23.2	105.1	106.5	1.43
40.8 KM	0.000	-0.036	0.000	0.017	0.2	-18.8	106.5	107.0	0.47
45 KM	0.000	-0.021	0.000	0.000	0.0	-20.8	106.5	106.7	0.21
36 KM	0.000	-0.017	0.000	0.000	0.0	-16.8	107.0	107.1	0.13
T2	0.000	0.000	0.000	0.000			107.1	107.1	
					148.1	-22276.6			

Figure 10: Branch Losses after DG connection at Bus - 4

At this stage, when the DG was in connection with bus-4, the power system losses were 148.1 KW (i.e., 3.46 %) as compared to when DG was not connected. So the DG is not very effective while connecting to Bus-4.

DG at Bus – 6:

After connecting the DG to Bus – 6, the bus voltages, active power and loads are shown in figure 11.

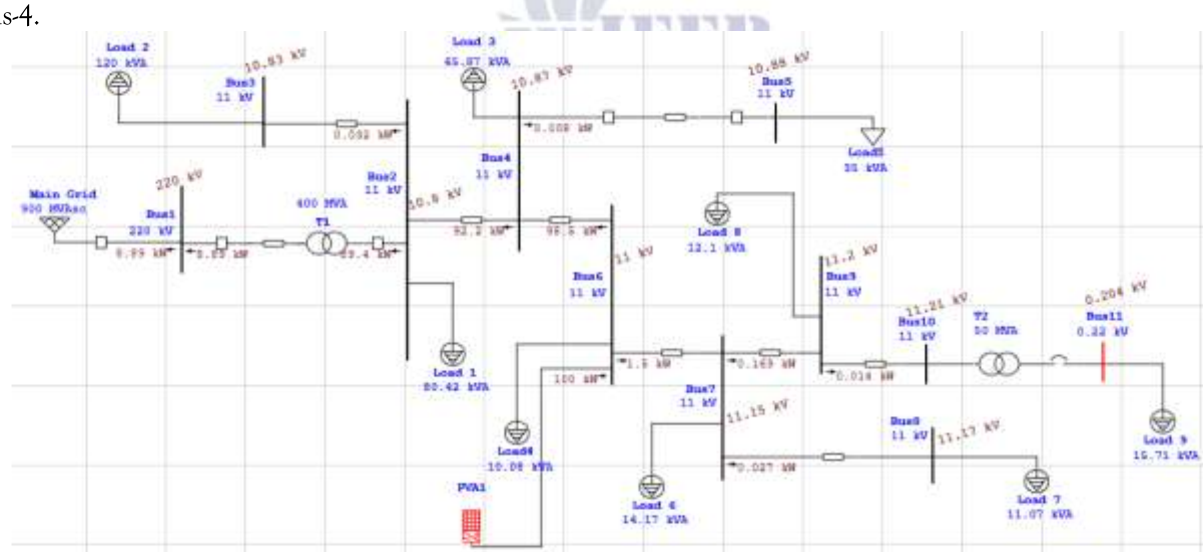

Figure 11: Load Flow Analysis after connecting DG at Bus – 6

As we can see, after connecting DG at bus – 6, it also maintains the voltages of buses in its vicinity and the total losses at each branch are shown in figure 12.

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
100 KM	0.089	-0.024	-0.009	-18.361	80.5	-18385.6	101.0	100.0	0.96
T1	-0.089	0.024	0.089	-0.024	0.0	0.0	101.0	98.2	0.00
55 KM	0.000	-0.024	0.000	0.000	0.0	-24.3	98.2	98.5	0.28
60 KM	-0.089	0.048	0.092	-0.072	2.8	-23.6	98.2	98.8	0.58
30 KM	0.000	-0.013	0.000	0.000	0.0	-12.6	98.8	98.9	0.09
50 KM	-0.092	0.085	0.098	-0.102	6.2	-17.2	98.8	100.0	1.21
50KM	0.002	-0.072	0.000	0.051	1.3	-21.0	100.0	101.4	1.36
40.8 KM	0.000	-0.032	0.000	0.015	0.2	-17.1	101.4	101.8	0.45
45 KM	0.000	-0.019	0.000	0.000	0.0	-18.9	101.4	101.6	0.20
36 KM	0.000	-0.015	0.000	0.000	0.0	-15.2	101.8	101.9	0.13
T2	0.000	0.000	0.000	0.000			101.9	92.7	
					91.1	-18535.4			

Figure 12: Branch Losses after connecting DG at Bus – 6

The overall power losses of the system were now decreased from 153.4 KW to 91.1 KW (i.e., 40.61%). Connecting DG at this bus is not very effective but it also maintains the voltages of those buses whose voltages were above the required range.

DG at Bus – 7:

When we connect DG at Bus-7, the load KVA, voltages and real power at every bus is given in figure 13. All the buses voltages are under the required range.

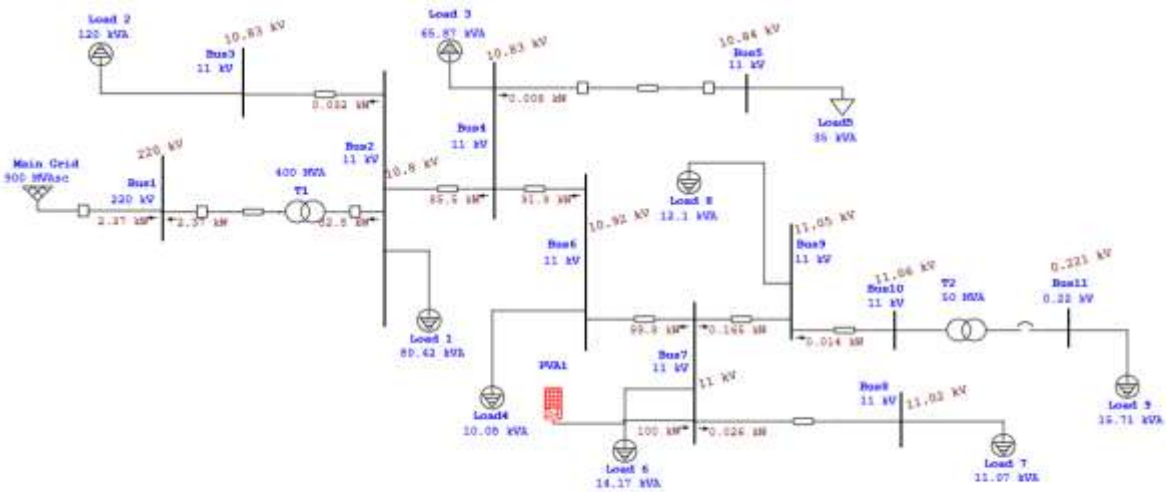

Figure 13: Load Flow Analysis after connecting DG at Bus-7

The overall branch real and reactive power losses summary is listed below in the figure 14.

Branch Losses Summary Report

Branch ID	From-To Bus Flow MW	From-To Bus Flow Mvar	To-From Bus Flow MW	To-From Bus Flow Mvar	Losses kW	Losses kvar	% Bus Voltage From	% Bus Voltage To	Vd % Drop in Vmag
100 KM	0.083	-0.031	-0.002	-18.355	80.4	-18385.5	101.0	100.0	0.96
T1	-0.083	0.031	0.083	-0.031	0.0	0.0	101.0	98.2	0.00
55 KM	0.000	-0.024	0.000	0.000	0.0	-24.3	98.2	98.5	0.28
60 KM	-0.083	0.055	0.086	-0.079	2.7	-23.6	98.2	98.5	0.26
30 KM	0.000	-0.013	0.000	0.000	0.0	-12.5	98.5	98.5	0.09
50 KM	-0.086	0.091	0.092	-0.108	6.3	-16.9	98.5	99.3	0.84
50KM	-0.092	0.108	0.100	-0.124	7.9	-16.2	99.3	100.0	0.70
40.8 KM	0.000	-0.031	0.000	0.015	0.2	-16.6	100.0	100.4	0.44
45 KM	0.000	-0.018	0.000	0.000	0.0	-18.4	100.0	100.2	0.20
36 KM	0.000	-0.015	0.000	0.000	0.0	-14.8	100.4	100.6	0.13
T2	0.000	0.000	0.000	0.000			100.6	91.4	
					97.6	-18528.8			

Figure 14: Branch Losses after connecting DG at Bus – 7

The real power losses are reduced from 153.4KW to 97.6KW (i.e., 36.37%) and reactive power is increased up to 3746.3 KVAR. The voltages are also maintained at all the buses.

DG at Bus – 8:

When we connect DG at bus – 8, the load KVA, transformers MVA, voltages and real power at each bus is shown in figure 15. All the buses voltages are under the required range.

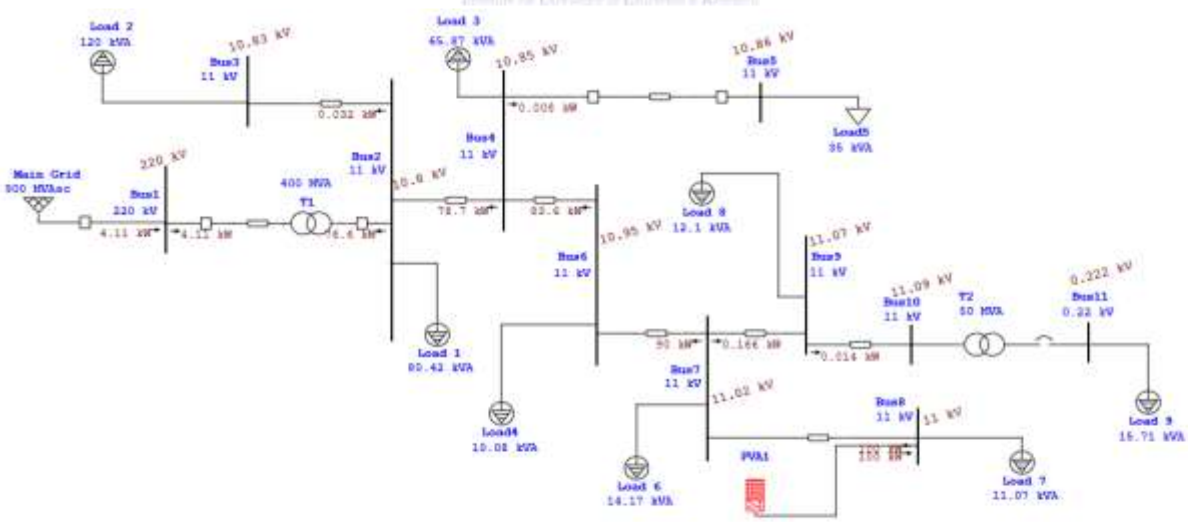

Figure 15: Load Flow Analysis after connecting DG at Bus – 8

The overall branch losses summary is listed below in the figure 16.

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
100 KM	0.077	-0.016	0.004	-18.369	80.7	-18385.3	101.0	100.0	0.96
T1	-0.077	0.016	0.077	-0.016	0.0	0.0	101.0	98.2	0.00
55 KM	0.000	-0.024	0.000	0.000	0.0	-24.3	98.2	98.5	0.28
60 KM	-0.077	0.040	0.079	-0.065	2.1	-24.3	98.2	98.7	0.47
30 KM	0.000	-0.013	0.000	0.000	0.0	-12.6	98.7	98.8	0.09
50 KM	-0.079	0.077	0.084	-0.095	5.0	-17.9	98.7	99.6	0.88
50KM	-0.084	0.095	0.090	-0.113	6.4	-17.3	99.6	100.2	0.67
40.8 KM	0.000	-0.032	0.000	0.015	0.2	-16.7	100.2	100.7	0.44
45 KM	-0.090	0.144	0.100	-0.156	9.8	-11.7	100.2	100.0	0.22
36 KM	0.000	-0.015	0.000	0.000	0.0	-14.9	100.7	100.8	0.13
T2	0.000	0.000	0.000	0.000			100.8	91.6	
					104.1	-18525.1			

Figure 16: Branch Losses after connecting DG at Bus – 8

The overall power systems losses are also different as in the previous system. The power losses are now decreased from 153.4 KW to 91.1 KW (i.e., 32.14%). Connecting DG at this bus is not very effective but it also maintains the voltages of those buses whose voltages were above the required range.

Conclusion

The simulations result showed the impact of DG system on the power system, losses and reduction of power losses. First the results were noted down without connecting DG and then DG was connected at different buses step by step to calculate the power differences. Above all the results, we came to the conclusion that while connecting DG system at Bus – 2, the overall real power losses were least recorded which is 141.5 KW as compared to the other buses. Consequently, the Bus – 2 is the optimal location for our designed DG system because at this location, the overall losses are drastically minimized. The whole results are sum up in the table 3.

Table 3: DG based Power Losses Summary

DG Location	Power Losses (KW)	Power Losses Reduction in KW	Power Losses (KVAR)
No DG	153.4	0	22275.1
At Bus – 2	11.9	141.5	22146.1
At Bus – 4	148.1	5.3	22276.6
At Bus – 6	91.1	62.3	18535.4
At Bus – 7	97.6	55.8	18528.8
At Bus – 8	104.1	49.3	18525.1

The table 3 is the summary of our proposed power system network. The best location to connect DG is Bus – 2 as its real power is maximally reduced but the reactive power is slightly reduced. If we need to reduce the reactive power losses, then the optimal locations are Bus-6 and Bus-7. Another benefit of connecting DG at Bus-6 and Bus-7 is the voltage variation is minimized at all the buses.

So from the above discussions, we came to the conclusion that for decreasing the real power losses, best location of DG is Bus – 2 but for reducing voltage variations and reactive power losses, the best locations for installing the DG are Bus – 6 and Bus – 7.

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