ISSN 2229-5518

Comparative Analysis of 132kV Grid Stations from Distributed Generation Perspective

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Abstract—Pakistan is facing severe power crisis where power demand is greater than the total generated power. Distributed generation (DG) is a preferred scheme to improve system efficiency and to meet the power demand for domestic and commercial applications. This paper investigates those areas where DG installation is necessary to overcome power crisis. Comparative analysis of all 132kV grid stations of Peshawar has been carried out on the basis of overloaded transmission lines, MWh energy losses, line losses, and duration of load shedding. Statistical analysis of the data collected for more than fifteen grid stations shows the locations where DG is necessary to be installed to meet power demand and to avoid load shedding. The newly introduced type of DG renewable energy sources are more suitable in the selected areas of Peshawar based upon different weather conditions.

Index Terms—distributed generation, energy crisis, grids, line losses, load shedding, power demand, renewable energy

1 Introduction

Energy crisis is one of the major issue in Pakistan these days. During summer season (May-Sep) electric power demand becomes much greater than the generated capacity of the system. There are more than fifteen 132kV grid stations in Peshawar region which are being not capable of delivering sufficient power during summer. This problem is due to overloaded transmission lines linking these grids and excessive losses due to more current than its rated capacity. Thus with an increase in losses the transmission line efficiency becomes lower and the line voltages drop significantly. This results in voltage and overall system instability.

Distributed generation (DG) is considered as a solution to meet the power demands. With current initiatives on smart grids and sustainable energy resources, DG schemes are going to play vital role in the emerging electric power systems [1]. Various DG schemes relieves transmission and distribution congestion, voltage support, reduces line losses, and deferred investments to upgrade existing generation, transmission, and distribution systems [1-2].

Comparison of the 132kV grid stations inside Peshawar region from DG perspective is provided here by the statistical data analysis of grids. The grids are investigated for the DG most optimal and suitable location, its size or capacity, and type of DG like photovoltaic (PV), wind or other type depends on atmospheric conditions. The comparison is based on the transmission line overloading, "MW" demand on grids or generating unit, "MWh" losses, line losses and duration of load shedding during summer from April, 2014 onwards.

Challenges in integration of the DG technologies to the existing utilities are the best optimal location, size, and capacity of DG. However, unlike large central power plants, DG can be installed at grid or near to the load [3]. The suitable size of DG for efficient and reliable supply is also a major concern. However, the size of the DG depends on the several factors such as availability of input energy, space, economic and environmental concerns [4].

Some of the popular DG technologies are as mentioned below:

1. Reciprocating Diesel or Natural Gas Engines [5]
2. Micro-Turbines [6]
3. Combustion Gas Turbines [7]
4. Fuel Cells [8]
5. Photovoltaic (PV) system [9]
6. Wind Turbines [10]

A lot of work has been carried out in the field of finding optimal location, size, and capacity of DG. Genetic Algorithm (GA) based optimization technique (which can give near optimal results) is suitable for multi-objective problems like, DG allocation with optimal power flow (GA-OPF) has been used by Silvestri [11, 20]. Iterative approaches based on Newton Raphson are also reported in the literature for optimal DG placement [12]. These approaches are based on the analysis of power flow equations for both the voltage and loss sensitivities in order to identify the best location of DG units in the distribution system.

A hybrid GA-OPF approach was proposed by Harrison [13] for finding optimal location for connecting a predefined numbers of DGs in a distribution network. Jabr and Pal [14] presented an ordinal optimization (OO) method for specifying the locations and capacities of DG such that, a trade-off between loss minimization and DG capacity maximization is achieved. Acharya in [15] suggested a heuristic method to select appropriate location and optimal value of DG capacity for minimum real power losses of the system by calculating DG size at different buses. Though the method is effective in selecting location, it requires more computational effort. The heuristic method used to calculate DG size is based on approximate loss formula and it may lead to an inappropriate solution. Other methods used in DG location and integration are Ant Colony Optimization [16] which illustrates the cost effective DG allocation and investment, Tabu Search [17],

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ISSN 2229-5518

Analytical Expression [15] and Particle Swarm [18]. The analytical expression approach is used to calculate the optimal size or capacity of DG and it also provide the methodology for finding the DG optimal location. However this approach is limited to simple networks and is based on only one feeder and one DG integration on particular distribution side.

The method of Tabu search is applied for finding the optimal allocation of DGs from a viewpoint of loss minimization. In short, the literature discusses about an implementation method of Tabu search to find how much distribution loss can be minimized if DGs are optimally allocated at the demand side of distribution network.

In this paper the analytical expressions and methods are used for 132kV grids with more than 15 feeders for entire Peshawar region. The proposed method have an advantage over previous one in Literature review that as it is long computational method but can be applied to many feeders with complex data and several parameters like MW demand, current, voltage, "%" overloading, line losses and energy loss etc. The results are accurate and DG location can easily be investigated with modification of electrical values or parameters in a grid. The paper also addresses the load shedding duration which was not applied in [13-15].

2 Problem Formulations

Distributed generators are small scale generators located close to domestic consumers on distribution side. Distributed generators are of 1kW to 100MW or the power rating may range from few kW to several hundreds of MW [19].

The purpose of DG integration to the power system network may be as backup power to enhance reliability or as a means of deferring investment in transmission and distribution networks, avoiding network charges, reducing line losses, reduced environmental impacts, peak shaving, and increased overall energy efficiency by saving kWh energy. The voltage and load flow in the transmission lines will be in limit so that DG installation remains cost effective to enhance voltage. The formulation for determining the optimal location, size, and type of location for DG in a system is as follows:

2.1 DG Optimal Location Selection

Most optimal location for DG installation have been evaluated on the basis of load, MW demand, line losses, transmission line overloading, "MWh" energy losses for specific grids. If the mentioned parameters are on large scale, the power system requires an alternate energy source to meet the extra power demand of cosumers at distribution side.

DG integration enhances system performance in such affected areas. Analytical approaches for DG optimal location with the given power factor can achieve all the discussed benefits for the system. Calculation has been carried out for % overloading of line, line losses, MWh loss, and total MW demand on grids.

Technical data of all the 132kV grid stations in Peshawar is provided for the statistical analysis and comparison of energy consumption and losses, transmission line loading, and MW demand on power houses or grid stations. All information regarding transmission lines that connects a particular grid will be discussed in great detail in coming sections.

For ease of analysis the whole Peshawar is divided into five major areas namely, central Peshawar, western, eastern, northern, and southern areas. The central Peshawar includes commercial and densely populated areas. The major commercial buildings, Mall shops, restaurants, and educational institutes exist in this region. Power demand in this area is therefore normally greater than other areas mentioned above. Northern and southern areas have same weather and load conditions while the east and west of Peshawar is industrial and residential respectively.

3 Solution Methodologies and Implementations

The most suitable location for distributed generation on the basis of some parameters like "%" overloading of transmission lines, line losses, and load shedding duration, MWh energy consumption, and energy losses is investigated. The statistical analysis for the grids is carried out manually without any software and an accurate result for DG location has been suggested. The transmission line that carries more than 85% of its current carrying capacity in amperes would be considered as over loaded and means it needs to be relieved.

Likewise, grid stations having load shedding duration on its distribution lines i.e. 11kV feeders more than four hours a day will be provided with DG having capacity depends upon power demand in that location. Resistance of the transmission line is calculated to find out the total line losses for comparison with each other. The line with more line losses and "MWh" losses will require DG integration to that particular grid on distribution side with proper capacity. For the purpose Table 1 is provided that compares various grids of Peshawar on the basis of parameters described earlier.

3.1 The "%" Overloading of Transmission Lines

First of all the "%" overloading of 132kV transmission lines is listed and it is obtained using Eq. (1).

$$\text{"\%"}\ \boldsymbol{Overloading\ of\ a\ feeder}$$

$$= \frac{\text{Max}\ load\ of\ line\ in\ Amps}{Capacity\ of\ line\ in\ Amps} \times 100 \qquad Eq.(1)$$

It is investigated that 132kV line connecting new Shahi Bagh to 132kV old Shahi Bagh grid is 102.46% overloaded and is showing that it has high power demand from load side, thus it may be relieved by installing DG source. The 132kV line between new Shahi Bagh and Dalazak-Nowshera industrial zone is carrying current of 500A, that is more than its rated capacity, and hence it is 102.46% overloaded. Peshawar Cantt is fed with 132kV line from WARSAK power house and it is 92.21% overloaded. The Warsak power house is feeding Jamrud grid station with more than 55MW and hence this line is carrying sufficient power to be overloaded. Here '%' overloading is 86.07%. Moreover, it is noticed that Peshawar

ISSN 2229-5518

Industrial 11kV feeders are heavily loaded and the three power transformers for this area are also upgraded to enhance load pickup by grid. Here the "%" overloading is 70.68%.

These feeders are overloaded since 2010 and continuously the efficiency of these feeders is becoming lower and lower due to increase in "MWh"energy losses. The feeders having low overloading percentages are also listed in Table 1, which shows that Peshawar Fort feeders are 16.13% and 12.67% overloaded. Peshawar University to Peshawar Industrial feeder is 24.59% overloaded.

3.2 MWh Losses in Grid Stations

The listed 132kV grid stations are also compared on the basis of energy losses in "MWh" (energy units). These Megawatt hour energy losses are calculated from the expression showing sent out and received "MWh" at grid station.

$$MWh_{loss} = MWh_{sent} - MWh_{received} \qquad Eq.(2)$$

3.3 Line Losses of 132kV Grid Stations

Some losses occur due to line resistance and may be considered in analysis. These are calculated in "MW" and are added to the power demand in "MW" on grid station. The line losses can be calculated from first finding the line resistance. The mathematical expression to find out the resistance of the line is as below.

$$R_{ac} = 1.6R \times L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

where "R" is the DC resistance, "L" is the length of given transmission line in km. DC resistance for Zaigalo conductor is 0.1509Ω/km, for Lynx 0.158Ω/km while for Rail it is 0.06Ω/km. Total line losses in "MW" are calculated as under.

$$P_{loss} = I^2 \times R_{ac} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Where "I" is the maximum current in "A" in transmission line and R_{ac} is the total line resistance in "Ω". For the total line loss in Peshawar region we have expression as,

$$Total\ power\ loss = \sum_{n=1}^{18} P_{loss} \ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

3.4 MW Demand on Grid Stations in Peshawar

Three phase power supplied or demanded is calculated from the following expression.

$$P = \sqrt{3} \times V \times I \times cos\emptyset \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

where, "P" is the power demand in MW, "V" is the line voltage in kV, "I" is the maximum load current in "A" and Cos∅ is the load power factor on line.

TABLE 1
LINE LOSSES OF 132KV GRIDS IN MW
Line Losses Estimation of Various Grids

S. No	Name of 132kV Grid Station	Type of Conductor Used	Length of Line in (km)	Resistance of Line in (Ohms)	Max. load in (Amp)	Total Line-Losses (MW)
1.	132kV Line Warsak to 132kV Shahi Bagh New	Zaigalo	26.54	6.41	375	0.9
2.	132kV Line Warsak to 132kV Shahi Bagh (Old)	Lynx	31.95	8.077	300	0.73
3.	132kV Warsak to Pesh. Cant.	Lynx, Zaigalo	26.66	6.74	450	1.364
4.	132kV Warsak to Jamrud Grid Station	Zaigalo, Lynx	27.69	7	420	1.234
5.	132kV Pesh. University to Pesh. Cant.	Lynx, Zaigalo	19.69	4.02, 0.91	180	0.16
6.	132kV Pesh. University to Pesh.Industrial	Zaigalo, Lynx	20.07	5.07	120	0.073
7.	132kV Line Jamrud to Hayatabad Grid	Lynx	2.54	0.642	220	0.03
8.	132 kV line Shahibagh to Pesh. Fort-I	Rail	8.124	0.78	140	0.015
9.	132kV Pesh Univ. to S/Muhdi	Zaigalo, Rail	20.21	1.432, 1.337	330	0.3
10.	132kV S/yard S/Muhdi to City.	Rail	17.91	1.72	285	0.24

The calculated grid data in Table 2 provides information about the transmission lines incoming and outgoing from grid to interconnect with other grids to increase reliability and meet power demand. The Warsak power house with installed capacity of 243MW have four 132kV transmission lines, one is L-1 connecting Warsak power house with new 132kv Shahi-bagh with Zaigalo conductor. Power in MW exported on this transmission line is 44.56MW, while the MWh energy exported is 168000MWh. Line L-2 is connecting Warsak power house with 132kV old Shahi-bagh grid station of Lynx and Zaigalo type conductors (as double circuit line). The current capacity of the conductors is 488A, while the maximum load recorded was 300A. Total MW demand on this line is 40.09 and MWh exported from Warsak power house is 119559.48.

The line L-3 from Warsak to Peshawar Cantt with Lynx and Zaigalo conductor has current carrying capacity of 488A but the load on it was 450A. MW exported on this transmission line is 16.7 and energy in MWh sent out is 80940.1 approximately. Line L-4 links Warsak to Jamrud (having 75% industrial load) consists of Lynx conductor with current capacity of 488A and maximum load on the line was recorded 420A in month of April. MW supplied through the lines is 54.19 and MWh exported is 497000. Jamrud is exporting about 16.19 MW to 132kV Landi Kotal and 7.57 MW to 132kV Hayat Abad Peshawar. Similarly Jamrud is exporting about 30MW to Peshawar university grid Station.

ISSN 2229-5518

TABLE 2
132kV Grids Data for MW Demand and KWH Imported/ Exported

Technical 132kV Grid Stations Data for the April, 2014

S. No	Name of Grid Station	Location or Region	132kV Transmission Lines or circuits	MW Demand	MAX Load (Amps)	kWh exported /imported
1.	Warsak Power House	North	132kV Warsak To Pesh. Cantt	16.7	450	2.61E+08
2.	Warsak Power House	North	132kv Warsak to Jamrud	61.76	420	4.97E+08
3.	132kV Switchyard in 500kV S/M Grid Station	South	132kV IS/M to 132kV Pesh. Industrial	72.43	280	95615280
4.	132kV Jamrud G/S	West	132kV Jamrud to 132kV Hayatabad	7.57	220	44323008
5.	132kV Pesh. University	Central	132kV Pesh. Uni to 132kV Pesh. Cant	36.19	180	Nil
6.	132kV Pesh Industrial Grid	Central	132kV line Pesh.Industrial to 132kV-S/Muhammadi	Nil	352	95615280

4 Results and Discussions

From the statistical analysis of 132kV grid stations in Peshawar, the optimal DG location and type for installation has been identified. The DG type is selected on the basis of weather conditions in Peshawar, like Warsak power house is located in area where wind type DG source would be more efficient. Similarly, Hayatabad grid where Photovoltaic DG will be best option as the solar potential is highly available in this location. A computer program has been written in MATLAB® to analyze the best possible location & losses of DG at various grids and corresponding delivered power after DG installation is plotted as shown in Fig. 1 and 2 respectively.

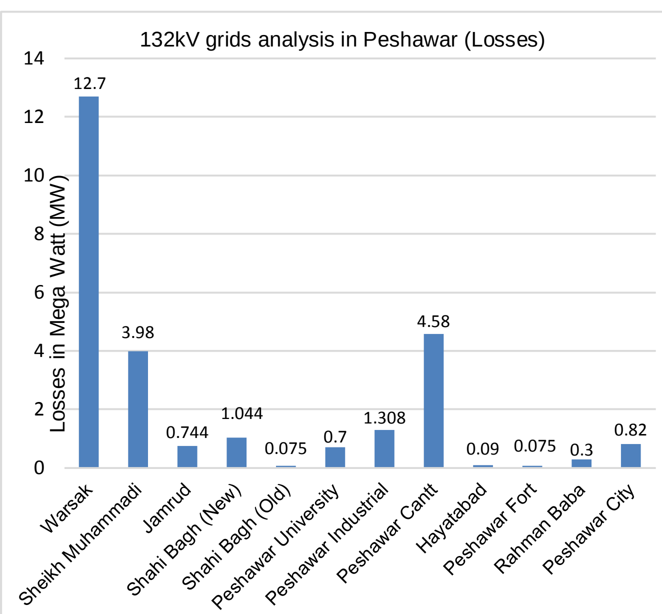

Fig. 1. Determination of location and losses at various 132kV grid stations for DG installation

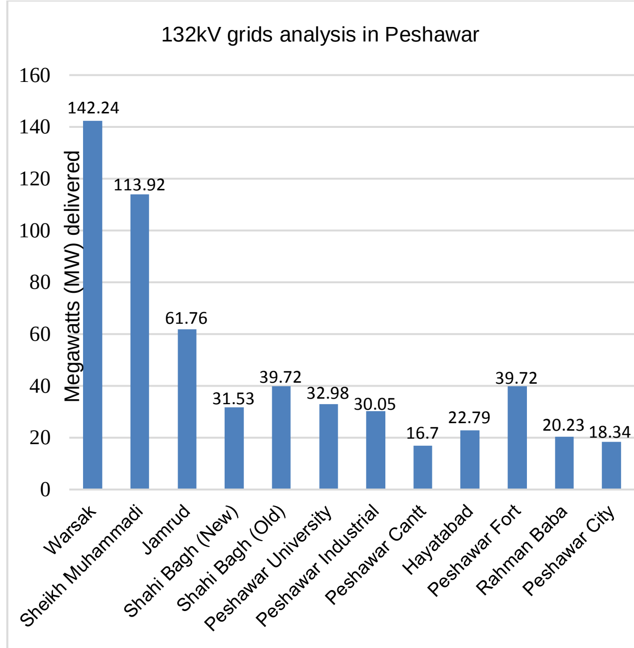

Fig. 2. Delivered power in various locations

The grid stations in Peshawar are compared for "%" DG requirements on the basis of "MW" demand, "%" transmission lines overloading, MWh losses, line losses, and duration of load shedding. To ensure brevity only line losses and overloading of transmission lines are plotted as shown in Fig. 3(a-b). It is noticed that % DG requirements in a particular grid increases linearly with the mentioned parameters.

The grid comparison on the basis of DG requirements based

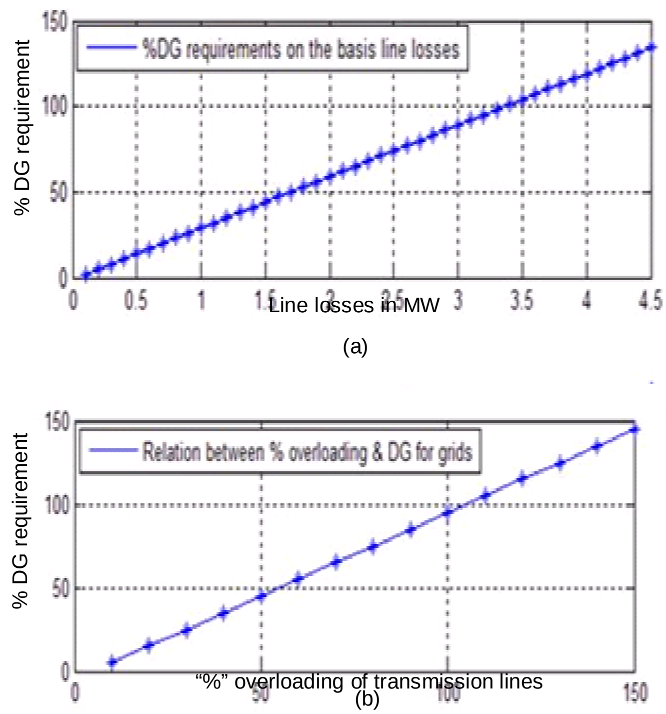

Fig. 3. Determination of % DG requirements on the basis of (a) line losses (b) overloading of transmission lines

on the mentioned five parameter analysis is ploted as shown in Fig. 4. To ensure brevity only the size of DG for line losses in four grid station is listed in Table 3. This table is based upon the rule of thumb mentioned in section 3.4.

The plot for "MW" demand shows that four 132kV grids namely, WARSAK power house, Sheikh muhammadi grid station, Shahi bagh and Peshawar industrial have above or near 100% DG requirements. This means that these grids have high load and it is necessary to install another energy source. The grids which have about 80% or more over loaded transmission lines would be considered suitable for DG integration with grid. In such cases the "%" DG requirements are for WARSAK power house, Sheikh muhammadi grid, Shahi bagh (new), Dalazak, and Peshawar Cantt.

Looking at "MWh" energy losses it is revealed that they are negligible in most of the listed grids. However, the Jamrud grid station having industrial load have high "MWh" energy losses due to low power factor. It is recommended that DG should be installed to recover the losses and hence a major portion of revenues.

Power failure due to excessive load is a major problem that needs to be addressed. Power system reliability, protection, and the availability of supply round the clock to consumers would be possible if this issue is properly investigated. Finally, only four grids having lot of consumers (high "MW" demand) have been analyzed and the DG requirements are suggested accordingly as shown in Table 3.

3.4 Rule of Thumb for the DG Installation

1) If the MW delivered by grid station is 50 MW then the "%" DG requirements will be100%.
2) If the "MWh" losses are equal to 500MWh then "%" DG requirements will be 100%.
3) If line losses are equal to 10% of the total MW supplied then "%" DG requirements will be 100%.
4) If transmission lines are 80% or more overloaded then "%" DG requirements for a particular grid station will be 100%.

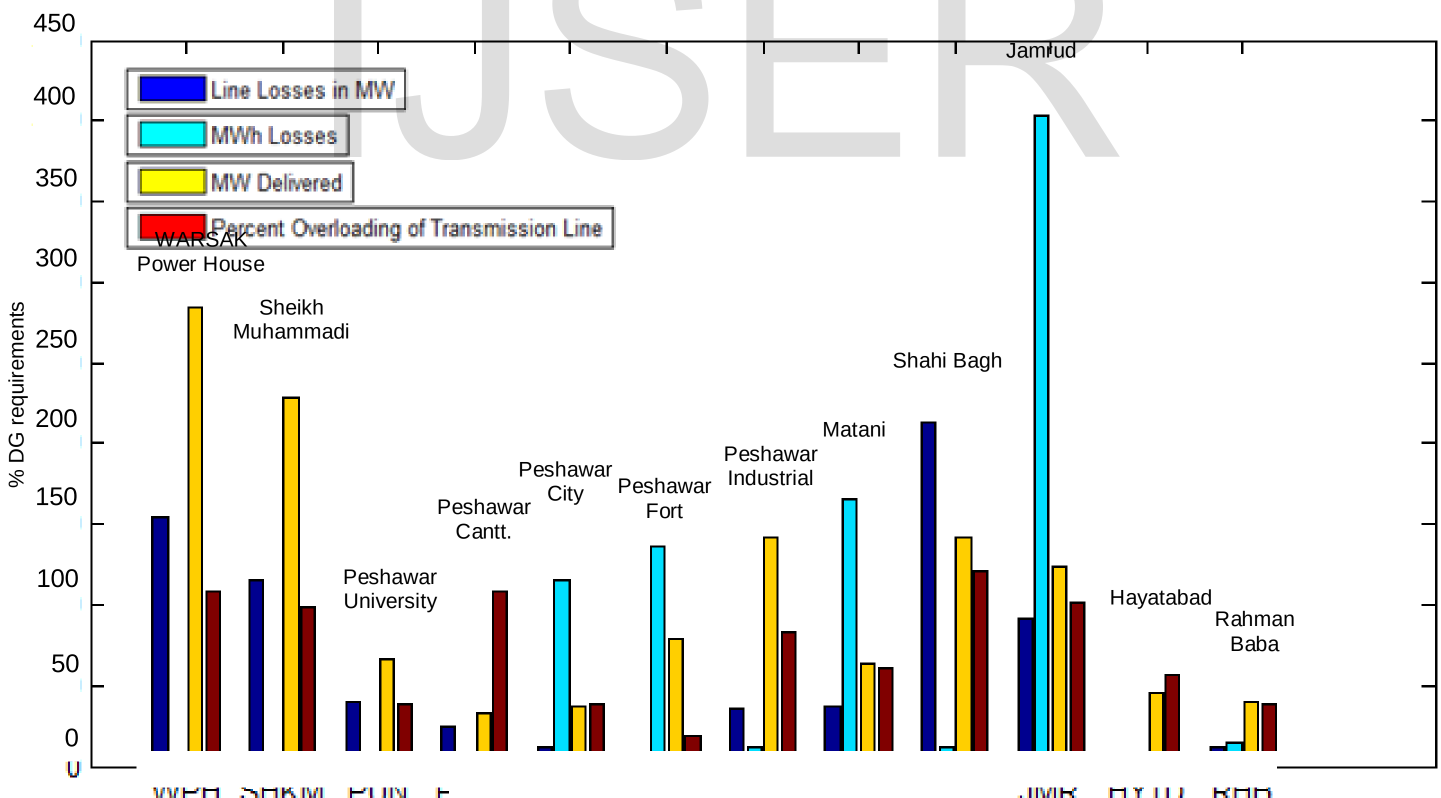

Fig. 4. DG requirements in "%" for 132kV grid stations inside Peshawar region

TABLE 3
TYPE OF DG INSTALLATION IN VARIOUS GRID STATIONS
Size of DG for line losses in four grid stations

S. No.	132kV Grid Stations in Peshawar	Type of required DG	Size of DG for line losses in "MW"	"%" DG requirements
1.	WARSAK Power House	Wind	3.1	100%
2.	JAMRUD	Wind/PV	1.81	100%
3.	SHAHI BAGH (old)	Wind/PV	4.27	100%
4.	HAYATABAD	Wind/PV	2.57	100%

5 CONCLUSION

This paper has addressed the comparative analysis of all 132kV grid stations in Peshawar region for the distributed generation (DG) based on various parameters. It is concluded from analytical comparisons of the calculated data that, grids having high "MW" demand, high line and "MWh" losses, and grids with increased load shedding hours are the best locations for integration of DG to bus system. Using such scheme will greatly improve system efficiency and availability of energy from the grids in summer season. It is convenient to find the type of DG selection based upon weather conditions.

This work has provided an opportunity to minimize the losses in Peshawar grid stations and to find the optimal size and location of DG installation in general for fifteen grids and in particular for only four major grids.

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