International Journal of Scientific & Engineering Research Volume 10, Issue 4, April-2019
ISSN 2229-5518

Analysis to Integrate Microhydro Power Plant as Distributed Generation with 11kV Utility Feeder in Dow Bandow, Upper Dir, Pakistan Using ETAP

[1]Sajid, [1]M. Iftikhar Khan, [2*]Anis Ur Rehman
[1]Electrical Engineering Department, UET Peshawar, Pakistan
[2]Electrical Engineering Department, Balochistan UET Khuzdar, Pakistan, 89100
[*]Email: engrroghani85@gmail.com

Abstract— In this paper technical impacts of the integration of microhydro as Distributed Generation (DG) with distribution network has been studied. An eleven kilovolt distribution system of Dir-Upeer valley located in northern region of Khyber Pakhtunkhwa province of Pakistan, has been taken as a case study. Upper Dir has a huge potential for small and microhydro power (MHP) production especially in summer season, where there is an abundant water falls in hills. Before the integration of DG, the existing distribution system provided by Peshawar Electric Supply Company is facing voltage fluctuations, low voltage profiles, high line losses and maximum interruptions with forced outages due to shortage of electricity all over the country. With the integration of such microhydro DG(s) under different scenarios, technical impacts have been evaluated and it is observed that these DGs not only enhance dependency on national grid but also improve voltage at end users and reduce line losses. The simulation work has been carried out in user friendly Software package of Electrical Transient Analyzer Program (ETAP). The proposed DGs are modelled under each scenario and it is investigated that with changing locations of DGs the power loss and voltage drop varied. The most appropriate scenario of DG operation in this work is to integrate the DGs which injects active and reactive both power as per line demand.

Index Terms— Power distribution system, Distributed Generation (DG), microhydro power (MHP), Voltage profile, Power loss, ETAP, Active and reactive power.

1 Introduction

THe shares of renewable energies has been increased in the traditional power generating system from the last three decades [1]. United states of America, most of the European countries, China and India have adopted wind and solar power production in a huge amount, whereas in most of the Asian and African countries bulk power is still generated from the conventional energy sources like, oil, gas and coal [2-3]. Pakistan is blessed by nature with abundant of natural resources and huge potential for wind, solar and hydroelectricity, but unfortunately about 63% of electricity is generated from the thermal power plants utilizes oil, gas and coal [4].

In modern world the dependency on centralized power plants has been decreased, whereas in Pakistan the distributed generation is insignificant [5]. The capacity of installed generators in the country is exceeded 30,000 MW, however the integrated DGs capacity according to a report is only few megawatts [6]. In situation like this it is mandatory for the government to increase the shares of renewable energy based power production and promote DG. No doubt the projects of DGs have high initial costs, however the operational and maintenance costs are negligible by the way [7, 8]. Pakistan possesses more than 50,000 MW of economical viable wind power potential, and more than 1000 Gigawatt of solar potential [6]. The term DG is linked with the low or medium voltage level distribution system, as impractical to anticipate in transmission network. The basic model of DG integrated in radial feeder with load each bus is shown in the Figure 1.

Despite of these renewable sources, northern areas of country are blessed with hydro potential. Small and microhydro power plants are installed at remote areas of these regions as it is very challenging and uneconomical to supply power through traditional lengthy distribution lines. It is worth mentioning that still most of the hilly areas of the country are supplied power through such costly and lengthy feeders, which results in huge power loss, high voltage drops, and high rate of interruptions and maximum failures of supply under abnormal weather conditions. For this purpose small and hydro power plants are installed which are operated in off-grid mode to electrify the remote areas and consumers at high altitudes. One basic advantage of microhydro power is that wind and solar are unreliable, whereas, the hydro power plants works 24 hours of the day in such areas without any interruption.

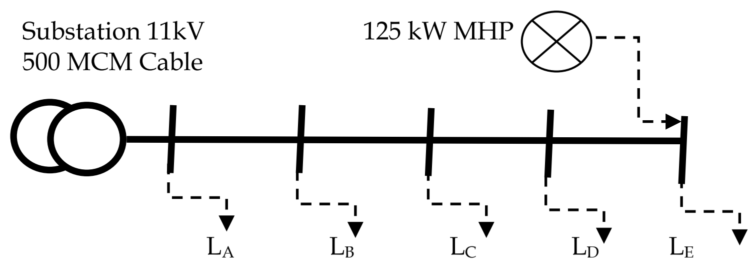

Fig. 1 Simple DG schematic integrated with distribution network

In this case study an integration of MHP as DG with distribution system of Upper-Dir, comes under the jurisdiction of Peshawar Electric Supply Company (PESCo.) has been analyzed. The existing system is supplied power from 66kV substation, and is modelled in ETAP. The power loss and voltage profile of this system are obtained from the model simulations. The power loss significantly reduced with integration of proposed sizes of MHPs, while the voltage level at end user is increased. The MHPs are integrated while considering different operating scenarios, like providing active power only, injecting both active and reactive power also. It is important to mention here that actual power factor of the load is taken and locations of DGa are varied for the appropriate outcomes of the research work. The simulations carried out in ETAP, effectively presents the effectiveness of microhydro power plants with traditional national grid or distribution system.

2 Overview of Existing Distribution Network

The eleven kilovolt distribution network under study, is supplied power from a 66kV substation, single sketched in ETAP is presented in Figure 2. According to PESCo. Most of the consumers are of domestic and commercial type, while this region has negligible industrial and agricultural loads.

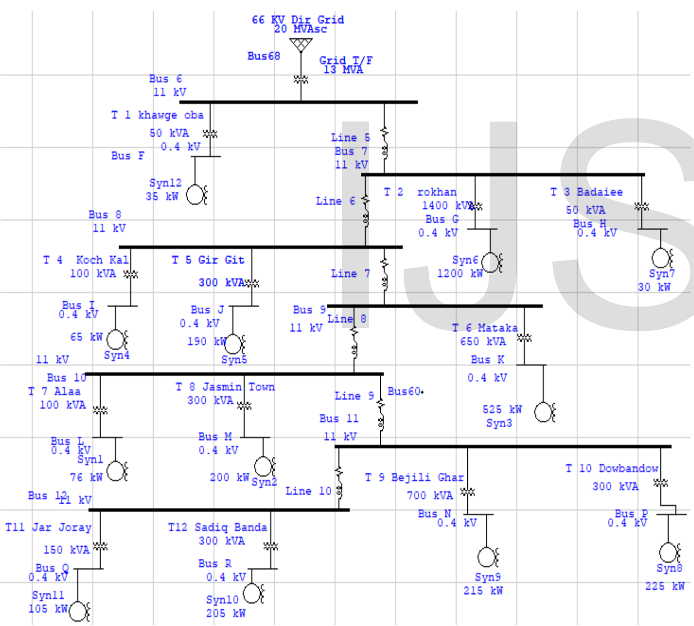

Fig. 2 single line model of 66kV substation and distribution network of proposed area

The proposed distribution system is of radial type and is about 2.5 km long, suitable for the DG incorporation at optimal sites. The load dispersion and capacities of the total twelve distribution transformers having cumulative capacities of 4.4 Mega volt-amperes (MVA), is illustrated in table 1 and table 2, respectively. The peak load considered in this work is 2.84 MVA and 2.42 MW. The practical power factor of each type of load observed at substation is 0.85 lagging. The network modelled in ETAP, is tested for the analysis of power loss and voltage profile at each bus. The line parameters and the transformer positive and zero sequence impedances are taken as per manufacturer's standards. It is depicted here, that without the integration of DGs, line losses and voltage levels are beyond the permissible limits of IEEE standards. The voltage drop along the feeder is so high, that about 95% of the feeder is facing under voltage. The power loss is 1.2 MW out of total demand of 2.4 megawatt, which becomes 50% of the total demand.

Table 1. Load profile and classes of load

Bus	Loads (KVA)	Loads (KW)	Loads (KVAR)	Load types
01	0	0	0	None
02	9680.00	9599.00	14.00	Residential
03	883.00	550.00	691.00	Residential
04	315.00	4.00	5.00	Residential
05	240.00	8.00	6.00	Residential
06	194.00	12.00	13.00	Residential
07	110	6.00	7.00	Residential
08	59	6.00	10	Residential
Total	11481.00	10185.00	746.00	

Table 2. Transformers' loading in kVA

Dist. Transformers	Voltage (kV)	Rating (kVA)	Load (kVA)
T1	66	13000	11481
T2	11	100	12.75
T3	11	50	10.00
T4	11	100	15.00
T5	11	50.00	10.00
T6	11	100.00	13.00
T7	11	150.00	20.00
T8	11	100.00	16
T9	11	50.00	10
T10	11	100.00	15
T11	11	100.00	15
T12	11	50.00	12

3 Literature Review

Related work of DG integration in distribution system for the said objectives of decreasing power loss and enhancing voltage level at each bus is carried out in several researches. A work in paper [5] demonstrated small scale solar DG plants, incorporated at different locations in highly loaded distribution system, by replacing agricultural loads. The integration of these DGs not only reduced peak demand on grid but also improved the power quality. The overall power loss along the hundred kilometer feeder was reduced from 2462 kW to only 655 kW. The drawback of this proposed work is that with disinserting of large number of DGs, the stability of the feeder will be challenged and also at nearby location, the system will gone in to an unbalanced condition. Integration of DG in network will support the system by shaving peaks, improving power quality. Small scale DG integration in distribution system for power loss minimization and improving system voltages, was performed by H. Goto et. al. published in year 2014 [9]. Wei et. al., [10] worked on integrating DG in grid for the voltage and reliability improvement. Most of the researchers have selected wind or solar power as a DG source, however microhydro power is rarely used. The reason is that waterfalls and flows are scarcely available in most of the countries. This work is taking an opportunity of injecting hydro power in system, to share a cheaper energy source, reducing overall cost of energy fuels.

4 Proposed Methodology

In this work most important constraint is to select the appropriate size of microhydro DG source(s), so that not only technical advantages will be achieved, but also the high penetration demerits will be avoided. Several scenarios have been considerably taken for the analysis of technical impacts of DGs. These are presented in detail as under;

Scenario-1: Analysis of the system modelled in ETAP without injecting DG's power in system

Scenario-2: Analysis of the system modelled in ETAP with DG's active power only

Scenario-3: Analysis of the system modelled in ETAP with DG's supplying both active and reactive both power

Scenario-4: Analysis of the system modelled in ETAP with multiple DGs' at optimal sites

Scenario-5 Analysis of the system modelled in ETAP with disconnecting loads from utility grid and supplying from only DGs

The main constraints in the design of such models are the power loss and voltage profile. Power loss allowed is only 6%, whereas the voltage variation according to the IEEE standard is ±5%. For 11kV distribution system the node voltage should'nt exceede the lower limit of 10,450 volts while the upper limit of 11,550 volts [Anis].

Scenario-1 is actually a base test case of the existing system. In scenario-2, 130kW DG is to be incorporated in the system. In this case DG is located at bus 6 as shown in Fig. 3. While the same DG with unity power factor is tested also at bus 8, providing only active power. Similarly in one other case in scenario-3, DG with power factor 0.85 lagging, i;e providing 85% active and 15% reactive power to the test feeder, at location of bus 10.

In scenario-4, six different size of DGs having rating 50 kW, 70 kW, 85 kW, 100 kW, 125 kW and 130 kW are injected in the system at six neighboring buses 6, 7, 8, 9, 10 and 11 respectively. In last scenario-5, the proposed MHP distributed generation unit of 130kW will supply power in an off-grid mode.

5 Modelling of Proposed Schemes in ETAP

The proposed schemes of MHP with different capacities and power factor are modelled here to investigate the technical impacts of proposed DGs at different locations, in different circumstances. The system in scenario-1 and 2 are modelled separately in Fig. 3 and Fig. 4 respectively. The ETAP provides the load flow analysis of the models and hence power loss and voltage drop can easily be evaluated.

5.1 Modelling of Existing system without DG

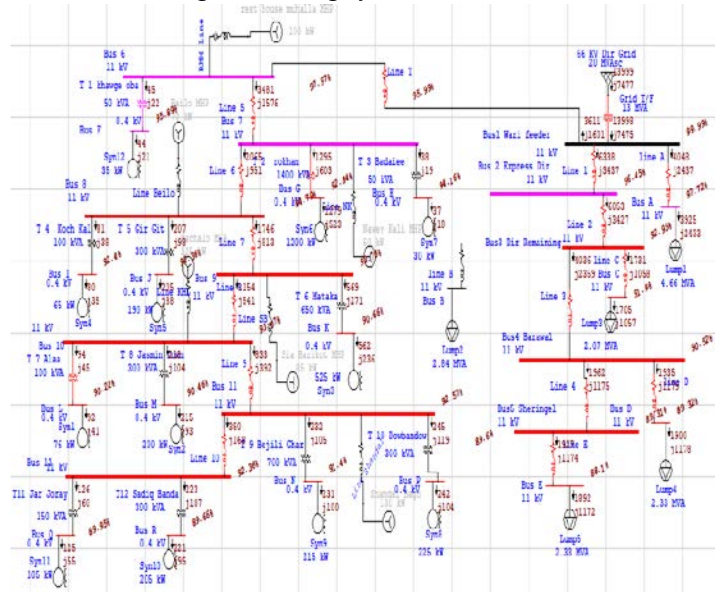

Fig. 3 Modelling of 11kV test feeder for power flow analysis without DG

5.2 Modelling of 11kV Test Feeder with Single DG at Unity Power Factor

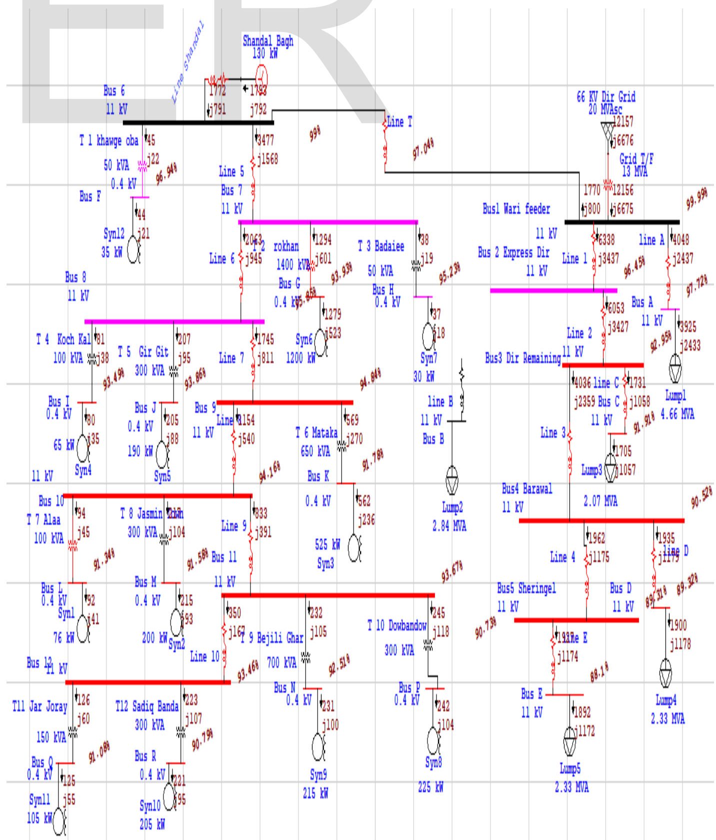

Fig. 4 modelling of test system with single DG of 130 kW at Bus-6

5.3 Modelling of System with DG at 0.85 P.F

In this case a DG of size 125kW and 130 kW are separately installed with 0.85 lagging power factor, at bus number 10 and 11 respectively. The designed model is presented in Fig. 5.

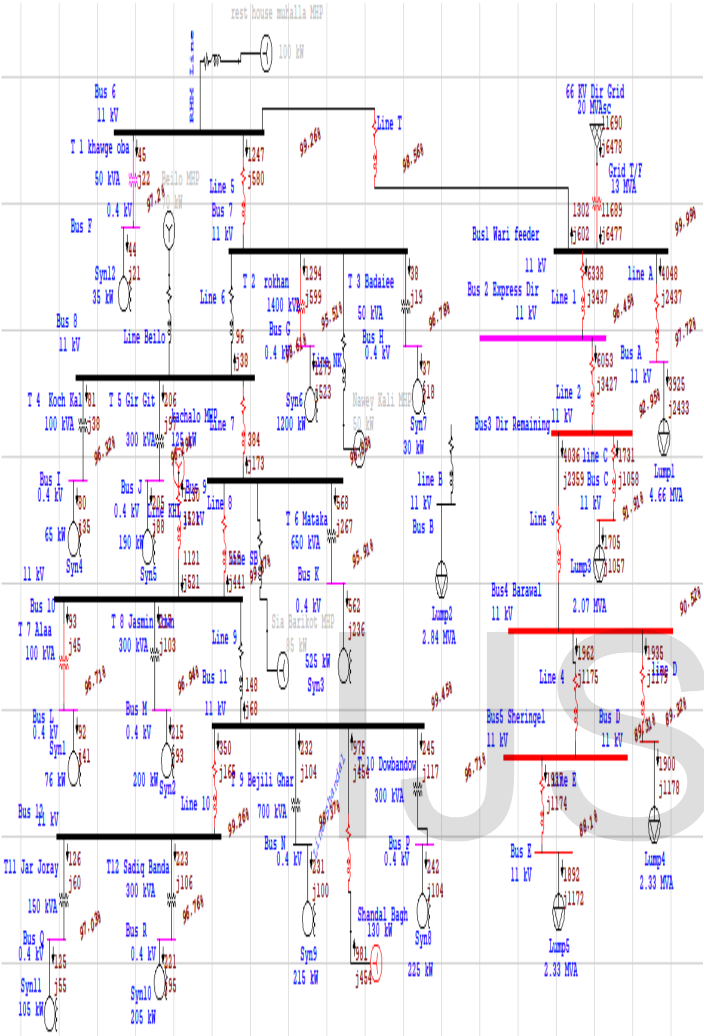

Fig. 5 modelling of DGs of 125 kW and 130 kW at bus-10 and bus-11 with 0.85 power factor

The other scenarios are aslo modelled in the same mannerin ETAP software, for the performance analysis of feeder. The voltage profile and power loss in all such scenarios are evaluated and is resulted.

6 Results

6.1 Voltage Profile in Scenario-1 & Scenario-2

When microhydro power plant as DG was not integrated in the test system, the total real power loss occurred in system are 1243.7 KW whilst the total VAR losses in this circuit will be 230.2 KVAR for this scenario. Furthermore, it too indicates comprehensive description of power flow studies to branch and outgoing flows from that branch. Bus voltages are shown voltage drop too in percent from one bus to other. It is evaluated that not only power loss is more than 6% of allowed limit in distribution system, but also voltage drop of 2500 volts is exceeding standard permissible IEEE limit. The results obtained in this base case are shown in Fig. 6, representing the voltage pattern of radial feeder. The voltage profile of base case scenario-1 is also depicted from Fig. 7 with comparison of incorporating DGs of size 125 KW and 130 kW at bus-6 and bus-7.

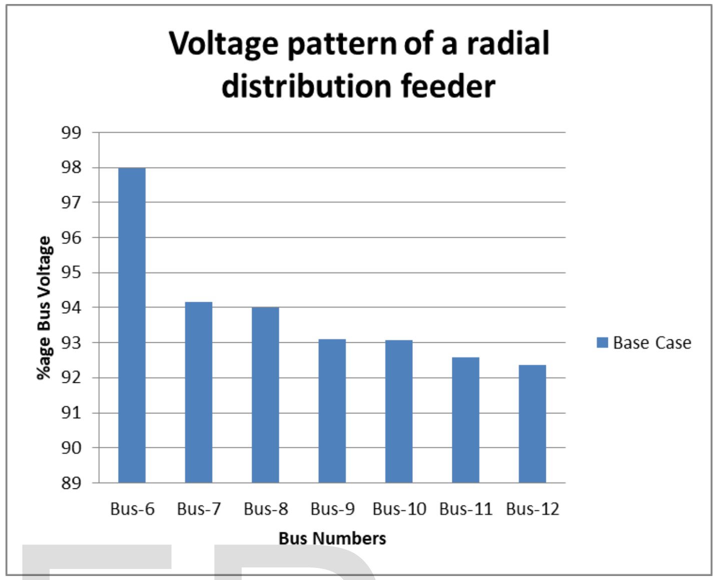

Fig. 6 Voltage profile in radial distribution system without DG

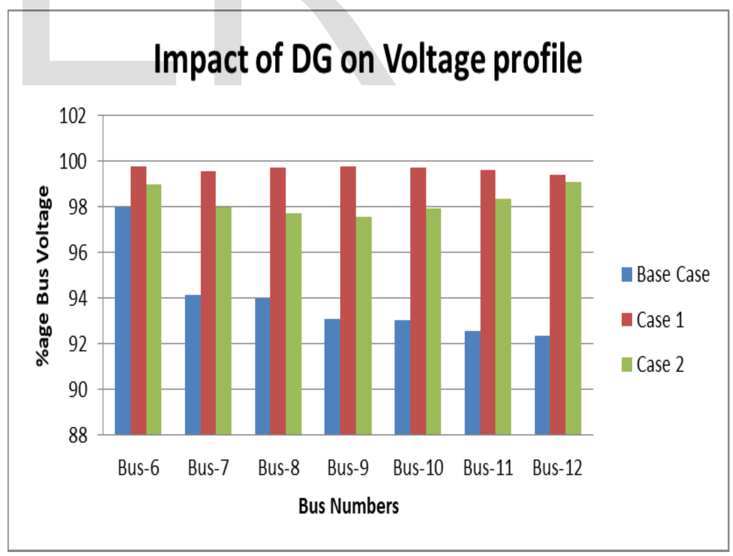

Fig. 7 Comparison of voltage levels in scenario-1 & scenario-2 (DG size 125kW & 130kW)

It is observed that as the DG is integrated in the system with appropriate size, voltage at the end side user, has been improved. It is depicted that voltage level is increased from 92.08% to 99.76% with 125kW DG. The higher penetration of DG may create problems [7], which is one of the significant drawback of DG integration in system.

6.2 Power loss in Scenario-1 & Scenario-2

The analysis of power loss in the scenario-1 & scenario-2, as discussed in methodology section is presented in Table 3. The more graphical analysis is shown in Fig. 8 and Fig. 9, respectively.

Table 3. Power loss without DG and with DG at unity Power Factor

Power losses	Scenario 01	Scenario 02	
		DG 125 KW	DG 130kW
KW	1243.7	1195.1	1089.7
KVAR	230.2	220.6	207.8

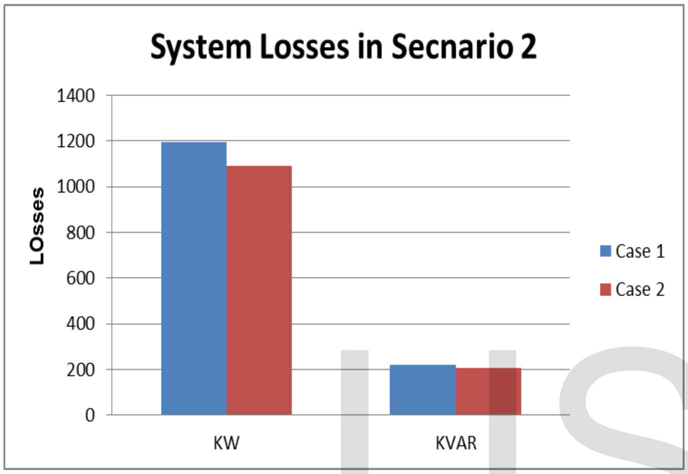

Fig. 8 Power loss in scenario-2 with DGs at bus-6 & bus-7

Before the implementation of these DGs of rating 125 and 130 KW, the real power loss in existing system was 1243 kW, while the reactive power loss was 243 kVAr. The power loss in both cases in scenario-2 has ben decreased to only 1184 kW with DGs.

6.3 Power Loss in Scenario-3 & scenario-4

When the DG positions and capacities were changed, the technical impacts of DGs on system were also automatically changed. It is depicted from the table 4.

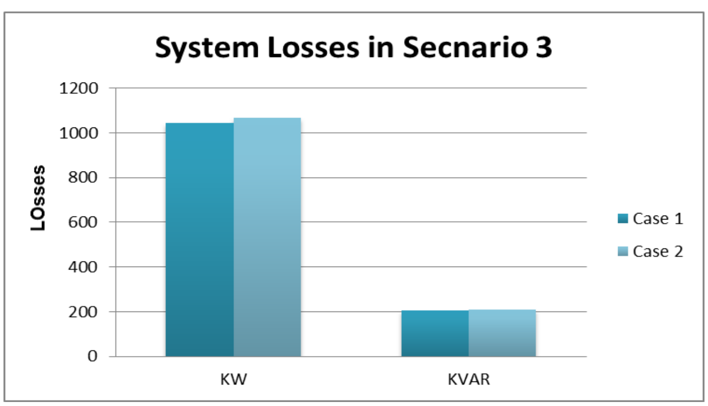

Fig. 9 Power loss with 125 kW and 130KW injecting both active and reactive power

The graphical analysis of the system under scenarios 3, 4 and 5 are analyzed in Fig. 8, 9 and 10 respectively. It is illustrated from the figures discussed that in case of DGs when injecting both active and reactive power, with different ratings at separate locations as already discussed, the power loss is also varied accordingly. The lowest power loss occurred when the DG os capacity 125 KW is injected at bus-6 and also at bus-7. The power loss is reduced to only about 1 MW.

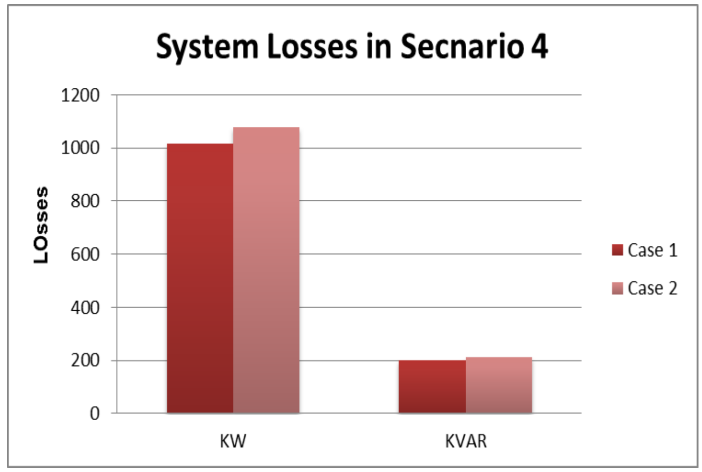

Fig. 10 Power loss in scenario-4 when DGs is operated in an off-grid position

It is also observed that when the feeder having rated load os 2.34 megawatt is totally disconnected from the main utility supply and is feed from only the microhydro power plant as DG, the net power loss is also reduced and hence the voltage fluctuation and imabalancing issues are aslo achieved.

Table 4. Power loss comparison in scenario-3 & scenario-4

Power losses	Scenario 03		Scenario 04	
	Case 01	Case 02	Case 01	Case 02
KW	1045.4	1067.2	1015.1	1079.2
KVAR	205.9	208.6	201.9	210.1

6.4 Voltage Profile in scenario-3 & Scenario-4

Since it is investigated that with DG the end user customer voltage improved, but with the high integration of DG at inappropriate position create disturbannces. However at proper location and changing capacities of DGs, the net results obtained are satisfactory. At bus 7, 8, 9, 10 and 11, with DG size of 50 kW, 70 kW, 85 kW, 100 kW, 125 kW and 130 kW respectively, the voltage profile is very near to the desired level. The per unit voltage value at each bus is about 100%. The results obtained are graphically presented in Fig. 11 and 12, for case 3 and case 4. The comparison of case 1 and case 2 with base case is here presented too, showing the improvement in voltage level and also the effectiveness of the proposed method. The case 1 is presenting 125 kW of MHP DG, whereas the case 2 is for the 130 kW DG at bus number 6 and 7 respectively.

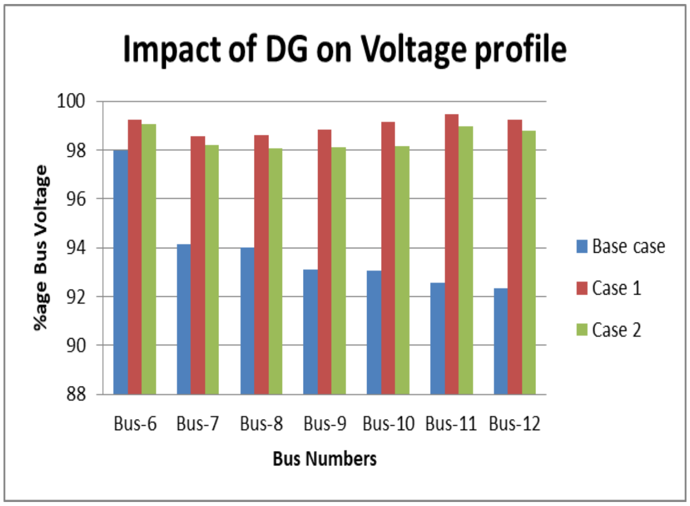

Fig. 11 DG integration in scenario-3 with injecting power at 0.85 power factor

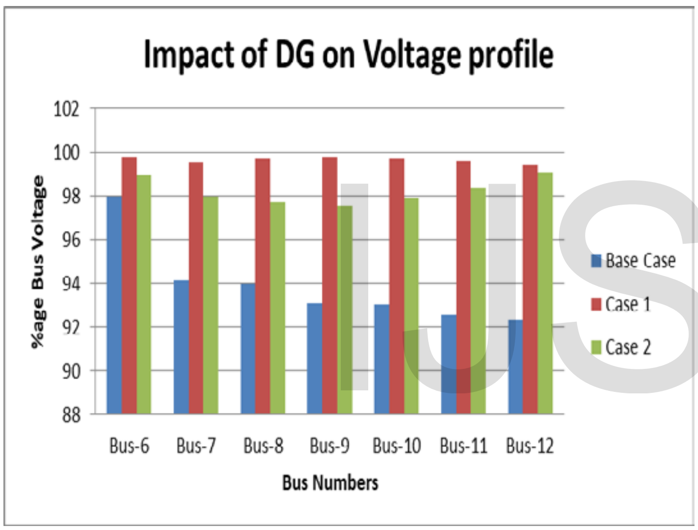

Fig. 12 Voltage level at improvement with several DGs at location without utility grid supply

It is depicted from the above Fig. 11 and Fig. 12 that the voltage is improved with DG as located at bus number 6 to bus number 12, having proposed ratings as discussed in scenario-3 and 4. The voltage is near to the 100% of desired value in both cases, whether the grid supply is available or not. The overall results obtained are obtained from the load flow analysis and simulations in ETAP software.

7 Conclusions

Distributed Generation (DG) is nowadays an appropriate option for the performance enhancement of highly loaded distribution networks. In this work instead of renewable energy sources like wind or solar photovoltaic system, microhydro power plants were integrated in the system at optimal sites with proper capacities under different circumstances. A performance analysis carried out in such scenarios were analyzed through ETAP software, and is concluded that without DG, the power loss and voltage drop both were beyond the IEEE standard permissible limit. With 125 kW Dg-1 at bus-6 and DG-2 of 130kW at bus-7, with injecting only real power in test feeder, the voltage profile at end user was enhanced to a desired value of about 0.985 p.u value. Whereas the power loss reduced from 1244 kW to only 1000 KW, with injecting a samller DG as discussed. Similarly with injecting both real and reactive power from several DGs at optimal sites from bus-6 to bus-11, the overall power loss has been declined to a smallest value of 980 kW, while voltage level is boosted up to 0.995 p.u value. It is concluded finally that in an off-grid mode of MHP operation the performance in terms of power quality of test feeder in Upper-Dir region of KPK, is enhanced while dependency on national grid was reduced at 130 kW size of DG.

Acknowledgment

The authors wish to thank PESCO sub-divisional officer (SDO), for his valuable suggestions and providing relevant grid data used primiraly for modelling, analysis and load flow study in ETAP software.

References

[1] Anis Ur Rehman, "design and operation of microgrid with renewable energy sources and energy storage system: A case study". 2017 IEEE 3rd Intl. Conference on Engineering Technologies and Social Sciences (ICETSS)., AIT, Bangkok, Thailand Aug-2017.

[2] C, V., G. Conio, V. Galdi, G. Massa, and A. Piccolo. Active management of renewable energy sources for maximizing power production. International Journal of Electrical Power & Energy Systems, vol. 57, pp. 64-72, 2014.

[3] Rahmanov, N. R., S. T. Ahmadova, and J. Bilbao. 2013. Distributed generation system with renewable energy sources: grid modelling and simulation. p. 984-991. In *EUROCON*, IEEE, 1 July. 2013. Zagreb.

[4] Anis Ur Rehman, "comparison based distributed generation implementation algorithm for the performance enhacement of extremely loaded distribution system". 2015 IEEE 2nd Power Generation System and Renewable Energy Technologies (PGSRET), Islamabad, Pakistan, June-2015. Pp: 1-9.

[5] Nouman Khan, "Performance Enhancement of an Overloaded Distribution Network with the Penetration of Solar PV Distributed Generation". IEEP proceedings, NED Karachi, Pakistan, 2019.

[6] Anis Ur Rehman, "Prospects of rural electrification of Balochistan province with renewable energy sources". IEEE 3rd Intl. conference on Power Generation and renewable Energy Technologies (PGSRET), Malaysia, 2017.

[7] J.P Aviles, "Optimal design of low voltage distribution networks using a PSO-PRIM algorithm". Ecuador technical chapters Meeting (ETCM) 2018 IEEE third, pp. 1-6, 2018.

[8] P, R., and T. Jamasb. Distributed generation, storage, demand response and energy efficiency as alternatives to grid capacity enhancement. *Energy Policy*, vol. 67, pp. 222-231, 2014.

[9] H. Goto, Y. Hasegawa, and M. Tanaka, "Efficient Scheduling Focusing on the Duality of MPL Representation," *Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS '07)*, pp. 57-64, Apr. 2007, doi:10.1109/SCIS.2007.367670. (Conference proceedings)

[10] W, M. Y. Impact of distributed generation on power system. Applied Mechanics and Materials vol. 543, pp. 681-684, 2014.