Impact of Grid interconnected micro-hydro based mini-grid system on Local Distribution Grid: A Case study of Taplejung mini-grid, Nepal

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Abstract- Electricity is essential for accelerating the economic development of any country and is also taken as an important input to improve quality of life. Micro hydro power plants are very much successful for rural electrification in Nepal as compared to other countries in the world. Till 2018, more than 3000 MHPs aggregating to 35 MW of generation capacity have been developed in Nepal. It cost about NPR17-25 per kWh for Nepal Electricity Authority (NEA)'s grid to deliver electricity in the rural hilly areas (depending on the distance) whereas it cost about 9-15 per KWH via a 50-100 KW MHP that is connected to the grid. So, In Nepal, it is more economically feasible for interconnected the existing isolated mini grid Or MHPs to the Local Distribution grid. Mini-Grids are electricity distribution systems containing loads & distributed energy resources within clearly defined electrical boundaries acting as a single controllable entity with respect to the utility grid that can be operated in a controlled and coordinated way to operate in both grid connected or island mode. This paper presents the impacts of installing mini-grid on a distribution grid. The work is focused on analyzing the impact of mini-grid installation on distribution grid operation including voltage analysis and power losses of the system. Different DG penetration levels, locations and the impacts of installing one large-scale DG on the main distribution line and distributing it several locations on voltage profile and losses are explored.

The research involves several case studies that explore the impacts of installing distributed generation (DG) on a distribution network operation including the voltage profile and losses of the system. Water Turbine Generators are introduced as Distributed Generators (DGs) at various nodes and the impacts that DG produces on power losses and voltage profile is studied. Simulated results obtained using load flow are presented and discussed.

Keywords – Voltage Profile, Losses, Local Distribution Network, Economic Development

I. INTRODUCTION

Electricity plays a key role in the modern society because of its versatility with respect to the input-energy form. Electric power in the form of synchronized alternating current is generated by generating plants, and delivered to users as per requirements. The electricity travels at about the speed of light and is consumed within a fraction of a second after it is generated [18]. Nowadays electricity generation from Small, Mini and Micro hydropower plants is becoming popular. In many remote hilly areas these power plants are generating power in isolated mode i.e., not grid connected, and supplying power in local areas due to unavailability of Distribution Grid[8]. In case of shut down of plant, power supply to those areas is affected. Hence to increase the reliability of the power supply to such areas, Mini Grid can be very effective solution [5].

The analysis by AEPC shows that the percentage of population having access of electricity till date is 87.55% indicating 12.45% population deprived of access to electricity. Rural electrification serves 9.75% (Solar 6.25% and Micro hydro 3.5%) of the population while NEA grid serves 77.8% [1].

Nepal is known for its successful rural electrification efforts through community owned and managed standalone MHP that have helped transform a large part of its remote and hilly districts [12]. Nepal's green energy, which totals more than 36 MW today, has not only brought electricity to more than 350,000 families in remote areas away from the grid, it has created an environment conducive for new economic activities, relieved people of drudgeries, improved their health and helped better children's education[9].

The adoption of renewable energy has been increasing in a very encouraging way all over the world [7]. The lack of productive activities in the rural areas have also resulted in underutilization of the mini grid or MHPs. During under-utilization, the loss of energy can be as high as 72%. Connecting to the Local distribution grid help to divert this extra energy via the Local distribution grid & reduce losses. Likewise, during under production, mini grid or MHPs can also receive power from the Local distribution grid.

Load shedding of Nepal is being managed by significant import of electricity from India, thus increasing the trade deficit of Nepal [11].

Electrification in rural areas by grid extension seems particularly unfeasible in the country because of high transmission/distribution cost, low consumption per household and less number of consumers/sparse load [6].If isolated mini grids will be connected to the Local distribution grid, they could feed surplus electricity to the Local distribution grid and receive deficit energy from the Local distribution grid [16].

The government policy for off grid/no connection regarding national electrification plan needs to be revised and rethought for future development and growth of this sector [9].The existing mini grid power will contribute to stabilize the weak national grid that will serve to the rural villages [16].

One of the greatest and the most obvious problem that Nepal and the other developing countries are facing today is the increasing demand of electricity and its poor supply [15]. The rising gap between demand and supply of electricity is the major factor of concern to developing countries like Nepal. At the same time, customers often suffer from poor power quality such as variations in voltage or electrical flow that results from a variety of factors, including poor switching operations in the network, voltage dips, interruptions, transients, and network disturbances from loads [14]. The DG can be placed at several locations depending upon the network to address these issues. Overall, DG proponents highlight the inefficiency of the existing large-scale electrical transmission and distribution network [10]. Properly coordinated DG can improve the voltage profile of the system and enhance the power system stability. Placing the DG at optimal location can reduce the losses on the feeder. With the growing use of DG, [12] it is critical to study its impacts on the distribution system operation.

The power system is prone to failures and disturbances due to weather related issues, accidents, human errors [14] [15]. Having the DG as a backup source ensures the reliability of power supply which is critical to business and industry. The overall reliability of the system can be improved. One of the main advantages of DG is their close proximity to the customer loads they are serving [12]. DG can play an important role in improving the reliability of the current grid, reducing the losses, providing voltage support and improving power quality [15]. The major obstacle for the distributed generation has been the high cost. However, the costs have decreased significantly over the past 20 years [3]. The distributed generation also reduces greenhouse gas emission addressing pollutant concerns by providing clean and efficient energy [17]. Distributed generation is the key to meeting growing demands of electricity and provides benefits to customers, utility and market.

Interconnecting a DG to the distribution feeder can have significant effects on the system such as power flow, voltage regulation, reliability etc. A DG installation changes traditional characteristics of the distribution system. Most of the distribution systems are designed such that the power flows in one direction [15]. The installation of a DG introduces another source in the system. When the DG power is more than the downstream load, it sends power upstream reversing the direction of power flow and at some point between the DG and substation; the real power flow is zero due to back flow of power from DG [14].

The DG installation can impact the overall voltage profile and losses of the system. Inclusion of DG can improve feeder voltage of distribution networks in areas where voltage dip or blackouts are of concern for utilities[10].

II. *METHODOLOGY*

It specifically employs the case study approach to explore the power generation and surplus power exported from mini-grid to the nearest distribution grid. The analytical software ETAP (Electrical Transient Analyzer Program) is used to study grid impact. Amarpur Substation is selected to analyses the grid impact upon integration of mini grid.

A. *Case Study Area*

The study area for this paper is chosen as Taplejung District of Nepal. Taplejung lies approximately 850 km North East of Kathmandu. Taplejung district lies in the Mechi zone of Provience no 1 of Nepal. The economy of the district is dependent on the agricultural production in which water, one of the known natural resources of the district, plays a great role. Taplejung district is one of the district which is recently powered by central grid electricity. There are 6 Micro Hydro Project in the proposed area currently operating in islanding mode. The house mark in the figure represents the isolated MHP. These micro hydropower projects are proposed for interconnection forming 11kV transmission line in connected to Local Distribution grid. The layout of MHP in isolation mode is presented in the figure below:

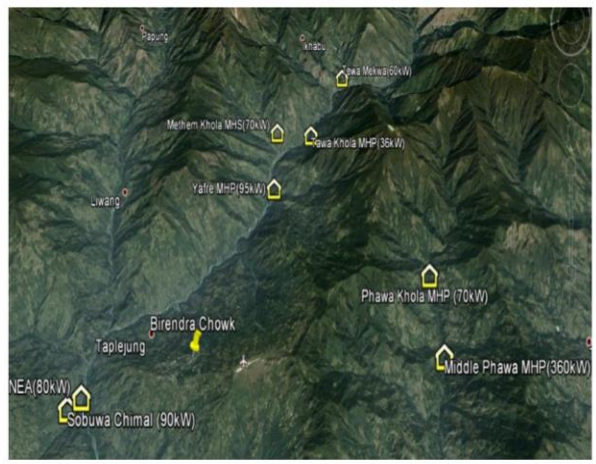

Fig.1:- Layout of MHP in isolation mode (district development commiunity, 2016)

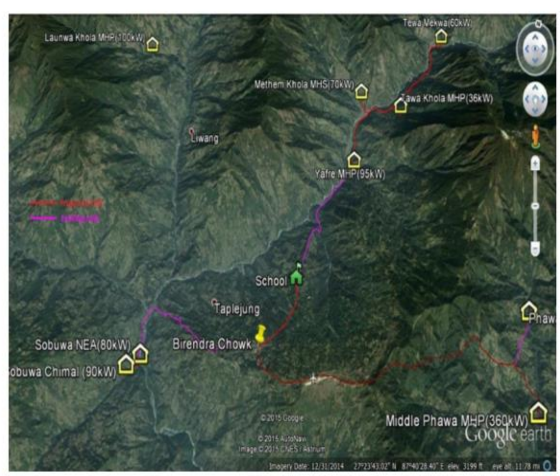

Figure2:- Interconnection View of Taplejung Mini Grid (district development commiunity, 2016)

B. Local Distribution Grid in Taplejung District

Taplejung district is one of the districts recently powered by central grid electricity. 33 KV Line is connected from Amarpur132/33 KV, 30 MVA Power Transformer S/S of Pachathar districit about 40 km with Dog Conductor. 6/8 MVA Power Transformer is installed in Phuling Bazar. The load of Taplejung is 2 MVA (NEA, 2018/19).

C. Data Collection

Basic data regarding the mini grids are collected which includes length of grid, single line diagram, capacity of generator, type of conductor, transformer (Gyawali, 2014).

D. Modelling

The model developed containing Taplejung substation distribution network, NEA distribution and transmission systems with step-up transformer for grid impact study is shown in Figure 3. The simulation study is done with following assumptions (NEA, 2018/19).

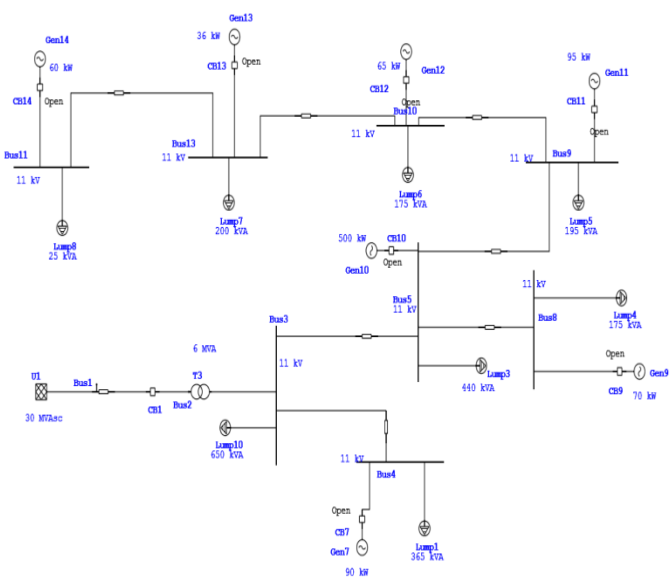

Fig.3 Single Line Diagram of System

- The power generation from each generators is 90%.
- The conductor used for 11kV and 33kV are RABBIT and DOG conductor respectively.
- Amarpur substation 33kV bus is considered as slack bus.

E. The grid integration study is done with seven cases.

a) In Case-1, Load flow analysis for Local Distribution Grid Only.

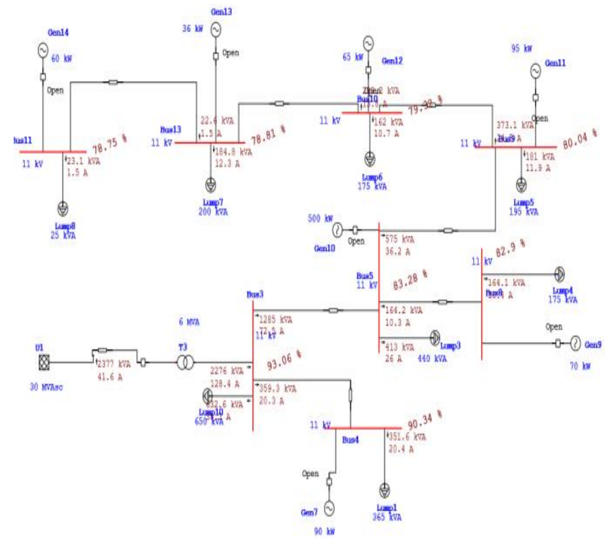

Fig.4 Load flow analysis of LDG System

Table 1: Simulation Data for Local Distribution Grid (LDG) supply only

LOAD DATA

Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
365 kVA	11	298.8	185.2	20.43	85	106.6	90.34
440 kVA	11	351.1	217.6	26.03	85	112.7	83.28
175 kVA	11	139.4	86.42	10.39	85	113.1	82.9
195 kVA	11	153.8	95.34	11.87	85	116	80.04
175 kVA	11	137.7	85.35	10.72	85	116.7	79.32
200 kVA	11	157.1	97.37	12.31	85	117.3	78.81
25 kVA	11	19.64	12.17	1.54	85	117.3	78.75
650 kVA	11	537.7	333.2	35.68	85	104.6	93.06
							666.5
							83.3125
					3 Phase Load Terminal Voltage		333.2

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
U1	Bus1	30 MVA	33	2.002	1.283	41.59	84.2

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	1913.4	1316.2	42.79
Line2	Line	298.8	185.2	20.43
Line10	Line	976.5	611.4	72.61
Line13	Line	139.4	86.42	10.39
Line19	Line	471.3	291.3	36.33
Line21	Line	315.3	193.9	24.49
Line22	Line	176.7	108.5	13.81
Line24	Line	19.63	12.17	1.54
T3	Transf. 2W	1913.4	1316.2	42.79

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	2.002
Bus3	11	93.06	1.905
Bus4	11	90.34	0.299
Bus5	11	83.28	0.977
Bus8	11	82.9	0.139
Bus9	11	80.04	0.471
Bus10	11	79.32	0.315
Bus11	11	78.75	0.0196
Bus13	11	78.81	0.177

GENERAL DATA

Buses	10
Branches	9
Generators	0
Power Grids	1
Loads	8
Load-MW	2.002
Load-Mvar	1.283
Generation-MW	2.002
Generation-Mvar	1.283
Loss-MW	0.206
Loss-Mvar	0.17

b) In Case-2, simulation is done with Local Distribution grid and Chimal plant (90 KW***).***

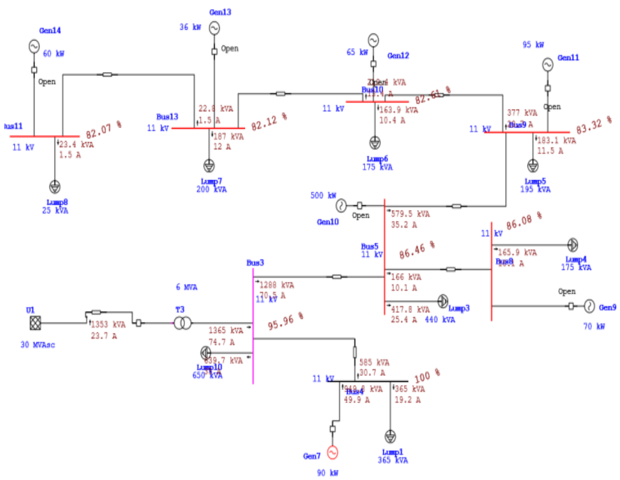

Figure 5: Load flow analysis for Local Distribution Grid (LDG) and Chimal MHP .

Table 2: Simulation Data for Local Distribution grid and Chimpal MHP

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	1.151
Bus3	11	95.96	1.611
Bus4	11	100	0.818
Bus5	11	86.46	0.987
Bus8	11	86.08	0.141
Bus9	11	83.32	0.477
Bus10	11	82.61	0.319
Bus11	11	82.07	0.0199
Bus13	11	82.12	0.179

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.969
Load-Mvar	1.195
Generation-MW	1.969
Generation-Mvar	1.195
Loss-MW	0.145
Loss-Mvar	0.0649

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	1121.3	806.7	24.89
Line2	Line	492.4	275.5	30.86
Line10	Line	986.6	616.3	70.62
Line13	Line	141	87.41	10.12
Line19	Line	476.5	294.2	35.28
Line21	Line	318.9	195.9	23.78
Line22	Line	178.8	109.6	13.41
Line24	Line	19.86	12.31	1.494
T3	Transf. 2W	1121.3	806.7	24.89

LOAD DATA

Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
365 kVA	11	310.3	192.3	19.16	85	100	100
440 kVA	11	355.1	220.1	25.36	85	109.8	86.46
175 kVA	11	141	87.41	10.12	85	110.1	86.08
195 kVA	11	155.6	96.44	11.53	85	112.7	83.32
175 kVA	11	139.3	86.33	10.41	85	113.4	82.61
200 kVA	11	158.9	98.49	11.95	85	113.8	82.12
25 kVA	11	19.86	12.31	1.495	85	113.9	82.07
650 kVA	11	543.8	337	34.99	85	102.6	95.96
							698.62
							87.3275
						3 Phase Load Terminal Voltage	349.28

SOURCE DATA

Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Bus4	0.09 MW	11	0.818	0.483	49.85	86.12
Bus1	30 MVA	33	1.151	0.712	23.68	85.02

c) In Case-3, simulation is done with Local Distribution grid and 500 KW MHP

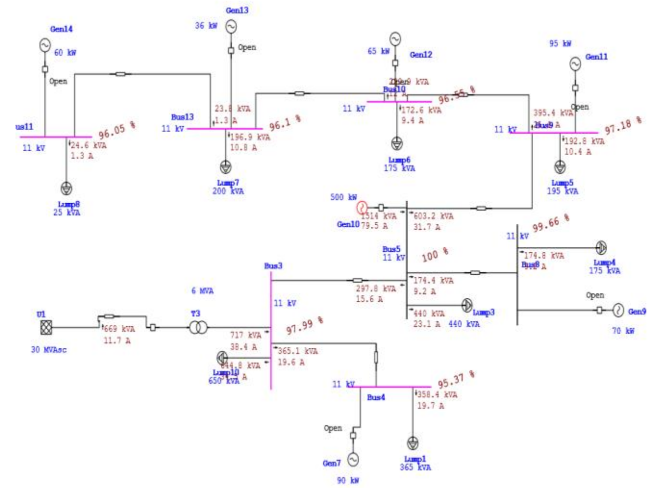

Figure 6: Load flow analysis for Local Distribution Grid (LDG) and 500 KW MHP Plant.

Table 3: Simulation Data for Local Distribution Grid (LDG) and 500 KW MHP Plant.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vter
Lump1	365 kVA	11	304.6	188.8	19.72	85	103	95.3
Lump3	440 kVA	11	374	231.8	23.09	85	100	100
Lump4	175 kVA	11	148.5	92.06	9.204	85	100.2	99.6
Lump5	195 kVA	11	163.9	101.6	10.41	85	101.8	97.1
Lump6	175 kVA	11	146.7	90.94	9.385	85	102.2	96.5
Lump7	200 kVA	11	167.4	103.7	10.76	85	102.5	96.1
Lump8	25 kVA	11	20.92	12.97	1.345	85	102.5	96.0
Lump10	650 kVA	11	548.1	339.7	34.54	85	101.2	97.9
								778.
								97.3
						3 Phase Load Terminal Voltage		389.

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen10	Bus5	0.5 MW	11	1.302	0.773	79.48	85.99
U1	Bus1	30 MVA	33	0.604	0.288	11.7	90.29

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	596.6	405.1	12.8
Line2	Line	304.6	188.8	19.72
Line10	Line	263.1	132.4	15.78
Line13	Line	148.5	92.06	9.204
Line19	Line	501.3	307.8	31.77
Line21	Line	335.7	205.3	21.39
Line22	Line	188.3	115.1	12.06
Line24	Line	20.92	12.97	1.345
T3	Transf. 2W	596.6	405.1	12.8

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.906
Load-Mvar	1.06
Generation-MW	1.906
Generation-Mvar	1.06
Loss-MW	0.0319
Loss-Mvar	-0.101

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.604
Bus3	11	97.99	0.859
Bus4	11	95.37	0.305
Bus5	11	100	1.302
Bus8	11	99.66	0.149
Bus9	11	97.18	0.501
Bus10	11	96.55	0.336
Bus11	11	96.05	0.0209
Bus13	11	96.1	0.188

d) In Case-4, simulation is done with Local Distribution grid and Without 500 KW MHP Plant .

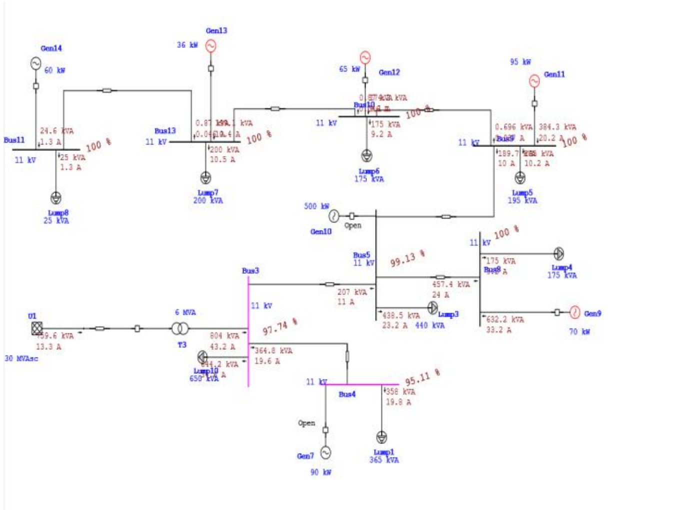

Figure 7: Load flow analysis for Local Distribution Grid (LDG) and Without 500 KW MHP Plant .

Table 4: Simulation for mini grid and Chimpal MHP

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vte
Lump1	365 kVA	11	304.3	188.6	19.76	85	103.1	95
Lump3	440 kVA	11	372.7	231	23.22	85	100.5	99
Lump4	175 kVA	11	148.8	92.19	9.185	85	100	10
Lump5	195 kVA	11	165.8	102.7	10.23	85	100	10
Lump6	175 kVA	11	148.8	92.19	9.185	85	100	10
Lump7	200 kVA	11	170	105.4	10.5	85	100	10
Lump8	25 kVA	11	21.25	13.17	1.312	85	100	10
Lump10	650 kVA	11	547.6	339.3	34.59	85	101.4	97
								791
								98
						3 Phase Load Terminal Voltage		395

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp
Gen9	Bus8	0.07 MW	11	0.548	0.316	33.18
Gen11	Bus9	0.095 MW	11	0.332	0.194	20.17
Gen12	Bus10	0.065 MW	11	0.149	0.0906	9.142
Gen13	Bus13	0.036 MW	11	0.17	0.104	10.45
Gen14	Bus11	0.06 MW	11	0.0213	0.0123	1.289
U1	Bus1	30 MVA	33	0.682	0.335	13.29

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	672.3	450.3	14.39
Line2	Line	304.3	188.6	19.76
Line10	Line	186.8	88.41	11.1
Line13	Line	396.3	221.9	24.05
Line19	Line	165.1	94.14	10.06
Line21	Line	0	-0.696	0.037
Line22	Line	0	-0.87	0.046
Line24	Line	0	-0.87	0.046
T3	Transf. 2W	672.3	450.3	14.39

GENERAL DATA

Buses	10
Branches	9
Generators	5
Power Grids	1
Loads	8
Load-MW	1.901
Load-Mvar	1.051
Generation-MW	1.901
Generation-Mvar	1.051
Loss-MW	0.0223
Loss-Mvar	-0.114

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.682
Bus3	11	97.74	0.858
Bus4	11	95.11	0.304
Bus5	11	99.13	0.561
Bus8	11	100	0.548
Bus9	11	100	0.332
Bus10	11	100	0.149
Bus11	11	100	0.0213

e) In Case-5 , simulation is done with mini grid and Chimal plant (90 KW).

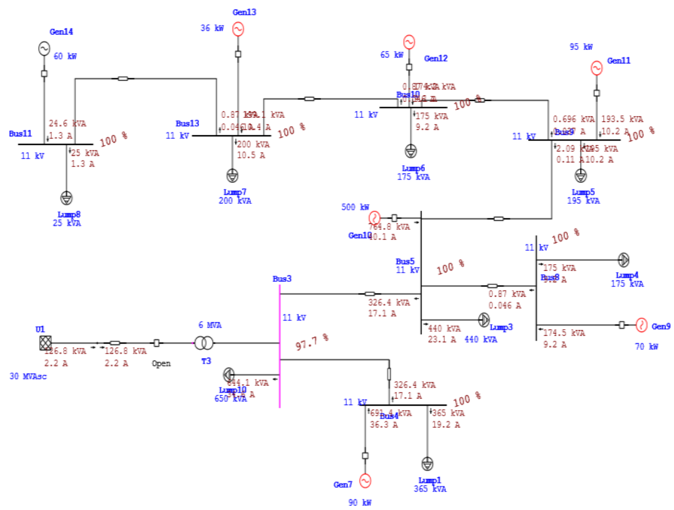

Figure 8: Load flow analysis for Mini-grid and Chimal MHP (90 KW).

Table 5: Simulation Data for mini grid and Chimpal MHP Plant

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterr
Lump1	365 kVA	11	310.3	192.3	19.16	85	100	100
Lump3	440 kVA	11	374	231.8	23.09	85	100	100
Lump4	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump5	195 kVA	11	165.8	102.7	10.23	85	100	100
Lump6	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump7	200 kVA	11	170	105.4	10.5	85	100	100
Lump8	25 kVA	11	21.25	13.17	1.312	85	100	100
Lump10	650 kVA	11	547.5	339.3	34.6	85	101.4	97.7
								797.7
								99.71
						3 Phase Load Terminal Voltage		398.8

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen7	Bus4	0.09 MW	11	0.589	0.362	36.29	85.16
Gen9	Bus8	0.07 MW	11	0.149	0.0913	9.161	85.22
Gen10	Bus5	0.5 MW	11	0.653	0.399	40.14	85.32
Gen11	Bus9	0.095 MW	11	0.166	0.0999	10.16	85.64
Gen12	Bus10	0.065 MW	11	0.149	0.0906	9.142	85.4
Gen13	Bus13	0.036 MW	11	0.17	0.104	10.45	85.39
Gen14	Bus11	0.06 MW	11	0.0213	0.0123	1.289	86.55
U1	Bus1	30 MVA	33	0.0001	-0.127	2.218	-0.05

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	0.061	-126.8	2.218
Line2	Line	273.7	169.7	17.3
Line10	Line	273.7	169.7	17.3
Line13	Line	0	-0.87	0.046
Line19	Line	0	-2.09	0.11
Line21	Line	0	-0.696	0.037
Line22	Line	0	-0.87	0.046
Line24	Line	0	-0.87	0.046
T3	Transf. 2W	0	0	0

GENERAL DATA

Buses	11
Branches	9
Generators	7
Power Grids	1
Loads	8
Load-MW	1.896
Load-Mvar	1.032
Generation-MW	1.896
Generation-Mvar	1.032
Loss-MW	0.0097
Loss-Mvar	-0.137

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.0001
Bus3	11	97.7	0.547
Bus4	11	100	0.589
Bus5	11	100	0.653
Bus8	11	100	0.149
Bus9	11	100	0.166
Bus10	11	100	0.149
Bus11	11	100	0.0213
Bus13	11	100	0.17

f) InCase-6, simulation is done with grid integration of Chimal plant (90 KW), mini grid and Local Distribution grid .

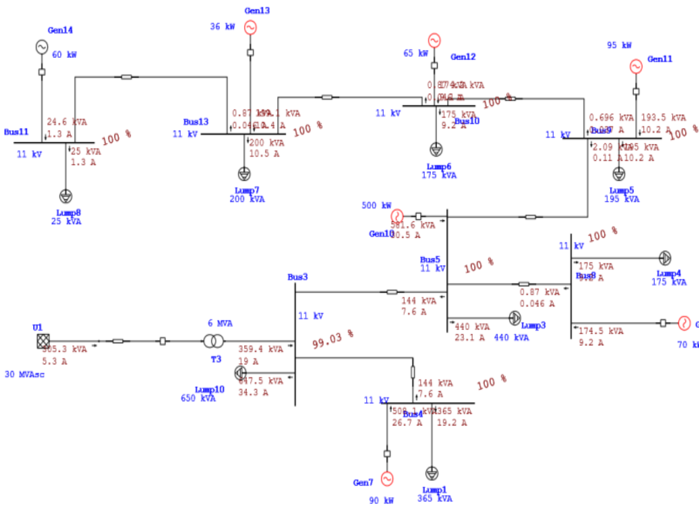

Figure 9: Load flow analysis for Local Distribution Grid (LDG),Mini grid and Chimal MHP Plant.

Table 6: Simulation Data for mini grid , Chimal MHP and Local Distribution grid .

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
Lump1	365 kVA	11	310.3	192.3	19.16	85	100	100
Lump3	440 kVA	11	374	231.8	23.09	85	100	100
Lump4	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump5	195 kVA	11	165.8	102.7	10.23	85	100	100
Lump6	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump7	200 kVA	11	170	105.4	10.5	85	100	100
Lump8	25 kVA	11	21.25	13.17	1.312	85	100	100
Lump10	650 kVA	11	550.4	341.1	34.32	85	100.6	99.03
								799
								99.9
								399

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen7	Bus4	0.09 MW	11	0.441	0.252	26.67	86.85
Gen9	Bus8	0.07 MW	11	0.149	0.0913	9.161	85.22
Gen10	Bus5	0.5 MW	11	0.505	0.288	30.53	86.84
Gen11	Bus9	0.095 MW	11	0.166	0.0999	10.16	85.64
Gen12	Bus10	0.065 MW	11	0.149	0.0906	9.142	85.4
Gen13	Bus13	0.036 MW	11	0.17	0.104	10.45	85.39
Gen14	Bus11	0.06 MW	11	0.0213	0.0123	1.289	86.55
U1	Bus1	30 MVA	33	0.292	0.0894	5.342	95.61

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	290.3	213.7	6.349
Line2	Line	130.1	64.48	7.697
Line10	Line	130.1	64.48	7.697
Line13	Line	0	-0.87	0.046
Line19	Line	0	-2.09	0.11
Line21	Line	0	-0.696	0.037
Line22	Line	0	-0.87	0.046
Line24	Line	0	-0.87	0.046
T3	Transf. 2W	290.3	213.7	6.349

GENERAL DATA

Buses	10
Branches	9
Generators	7
Power Grids	1
Loads	8
Load-MW	1.893
Load-Mvar	1.027
Generation-MW	1.893
Generation-Mvar	1.027
Loss-MW	0.0037
Loss-Mvar	-0.143

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.292
Bus3	11	99.03	0.55
Bus4	11	100	0.441
Bus5	11	100	0.505
Bus8	11	100	0.149
Bus9	11	100	0.166
Bus10	11	100	0.149
Bus11	11	100	0.0213
Bus13	11	100	0.17

g) InCase-7, simulation is done only for mini grid .

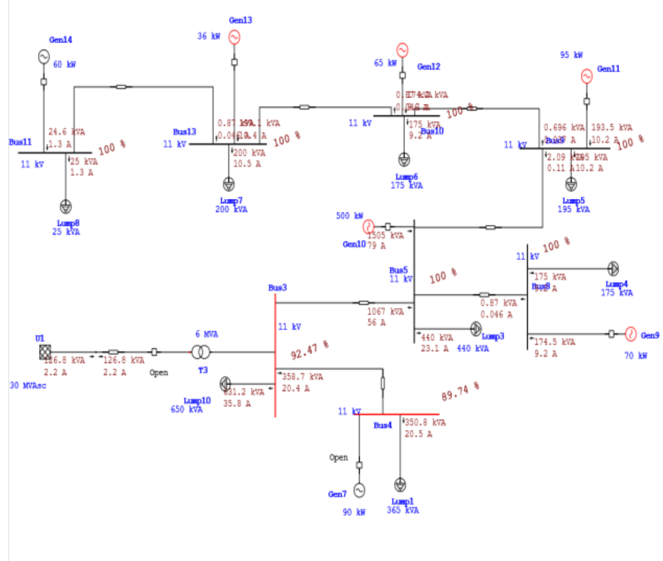

Figure 10: Simulation Diagram for Mini Grid Only.

Table 7: Simulation for mini grid Only.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterm
Lump1	365 kVA	11	298.2	184.8	20.52	85	107.1	89.74
Lump3	440 kVA	11	374	231.8	23.09	85	100	100
Lump4	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump5	195 kVA	11	165.8	102.7	10.23	85	100	100
Lump6	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump7	200 kVA	11	170	105.4	10.5	85	100	100
Lump8	25 kVA	11	21.25	13.17	1.312	85	100	100
Lump10	650 kVA	11	536.5	332.5	35.82	85	105	92.4
								782.2
								97.77
						3 Phase Load Terminal Voltage		391.0

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen9	Bus8	0.07 MW	11	0.149	0.0913	9.161	85.22
Gen12	Bus10	0.065 MW	11	0.149	0.0906	9.142	85.4
Gen13	Bus13	0.036 MW	11	0.17	0.104	10.45	85.39
Gen14	Bus11	0.06 MW	11	0.0213	0.0123	1.289	86.55
U1	Bus1	30 MVA	33	0.0001	-0.127	2.218	-0.05

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	0.061	-126.8	2.218
Line2	Line	298.2	184.8	20.52
Line10	Line	841.4	521.3	56.18
Line13	Line	0	-0.87	0.046
Line19	Line	0	-2.09	0.11
Line21	Line	0	-0.696	0.037
Line22	Line	0	-0.87	0.046
Line24	Line	0	-0.87	0.046
T3	Transf. 2W	0	0	0

GENERAL DATA

Buses	11
Branches	9
Generators	6
Power Grids	1
Loads	8
Load-MW	1.921
Load-Mvar	1.085
Generation-MW	1.921
Generation-Mvar	1.085
Loss-MW	0.0578
Loss-Mvar	-0.0696

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.0001
Bus3	11	92.47	0.841
Bus4	11	89.74	0.298
Bus5	11	100	1.266
Bus8	11	100	0.149
Bus9	11	100	0.166
Bus10	11	100	0.149
Bus11	11	100	0.0213
Bus13	11	100	0.17

III. GRID IMPACT STUDY

A technical evaluation is performed using ETAP to illustrate the viability of integration of MHP plant and mini grid with Local distribution grid.

A. Load Flow Analysis

For load flow analysis ,the Taplejung substation distribution network and the existing electrical network at Mini grid together with digitized on ETAP software as per the information collected and then simulated for the corresponding load. Amarpur substation 33 kV bus is considered as slack bus for load flow analysis.

With load flow analysis, the total losses on different Cases is analyzed under different cases and depicted in Figure 11. The total power loss of the system is maximum in case-1, which is around 206 KW, and the loss decreases as the power exported from mini grid increases. The losses on the system is minimum for case-6 and it is around 3.7 KW. This is because the line loss is proportional to square of the current flowing through the line. Likewise the voltage drop in the line and terminal voltage at the different load point is observed and shown in Figure12. It is seen that the voltage drop in the lines decreases and terminal voltage at different load points get improved as the surplus power is exported from mini grid and MHP plant.

IV. RESULTS AND DISCUSSION

- Power Losses at different cases is presented in the diagrams below indicating reduction for the interconnection of mini grid with Local Distribution grid.
- The interconnection of mini grids with Local Distribution grid is seen to be significant in minimizing the distribution system losses in Taplejung Mini grid, hence, it shall greatly impart the benefits to the economy.

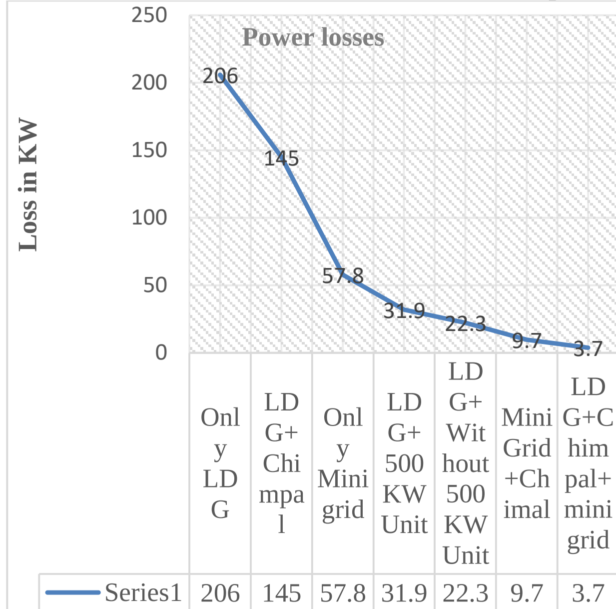

Figure 11: Power losses in system at various cases

The quality of electricity supply through combined system of interconnected mini grid & LDG is found to be better examining the terminal voltage at equipment. The terminal voltage is found to be acceptable limits when the mini grid, MHP is connected with the LDG which can be well illustrated by the figure below.

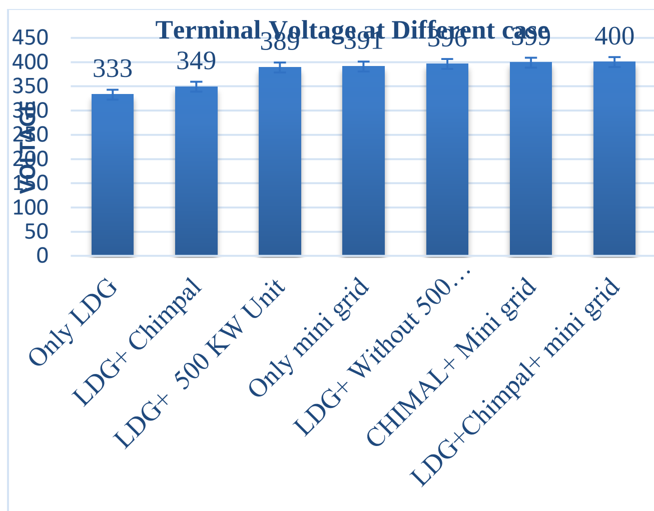

Figure 12: Terminal Voltage at various conditions

The terminal voltage at various loads modelled is plot graphically each point indicating percentage of terminal voltage received to that should have been received. The results of simulation shows that when the interconnected system is operated, loads receive terminal voltage at an acceptable level of supply. The cases LDG(NEA) supply only, LDG & Chimpal show terminal voltage below standard limit at some loads while the cases interconnected Mini Grid-LDG-Chimpal, LDG-Mini Grid and Mini Grid-Chimpal show the supply at standard level of terminal voltage.

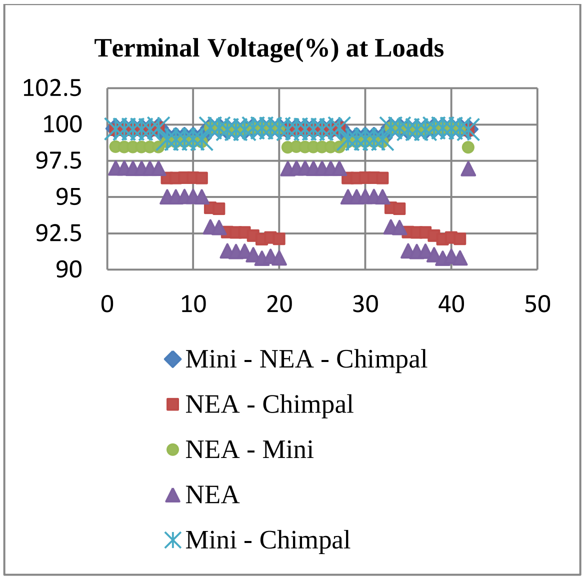

Figure 13: Terminal Voltage at various loads in different conditions of Operation

The voltage drop in the different case is observed and shown in figure 14 .From figure it is seen that the voltage drop decrease as the power is exported from mini grid and MHP Plant.

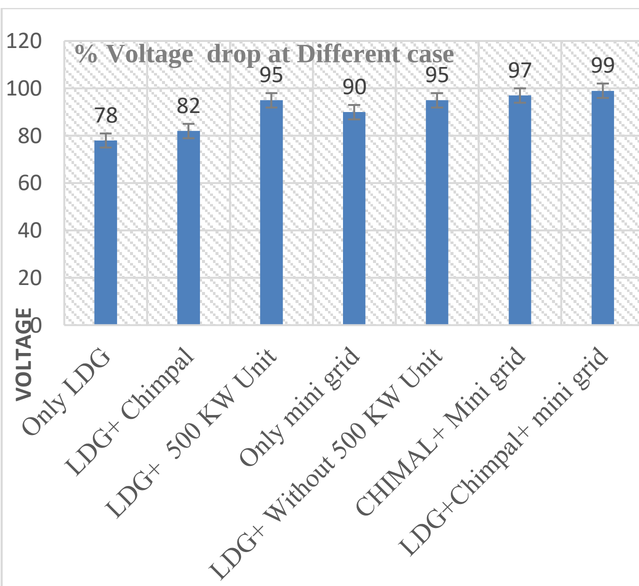

Figure 14: Percentage Voltage drop at different conditions of Operation

The KVA chart illustrates that the load supplied by LDG is greatly reduced when the mini grid & isolated generator both are interconnected with the LDG indicating the economy of electric supply.

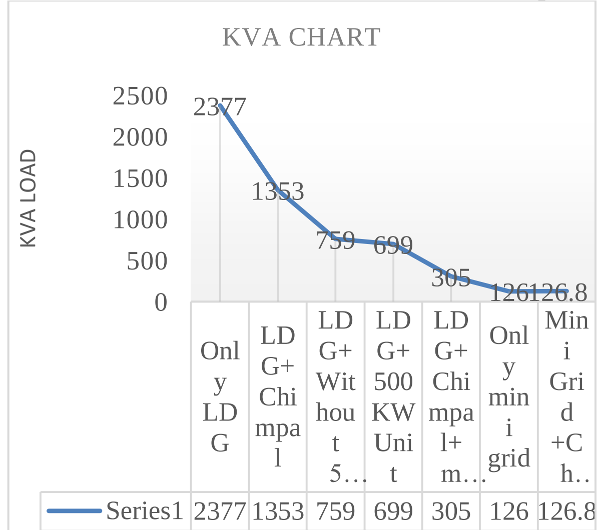

Figure15: KVA Chart at various cases

The current chart illustrates the reduction in current flowing during the interconnected system operation, which eventually minimizes loss serving benefits to the system.

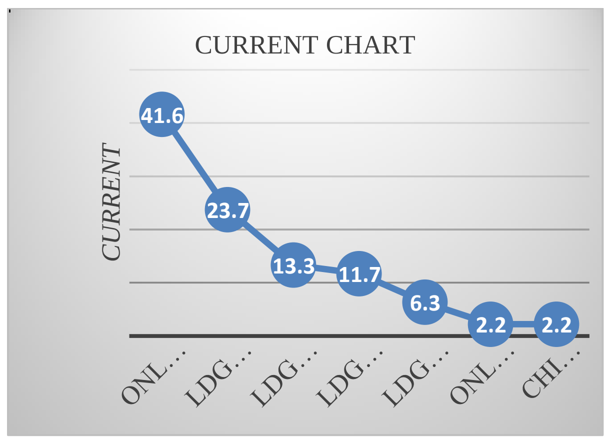

Figure 16: Current Chart at various Cases

V. OPTIMIZATION OF DG

To improve the voltage magnitudes and reduce power losses, Distributed Generators were placed optimally in the Network [10][12].

A. Simulation Phase I: Power System without DG

In Phase-I of optimization, the load flow analysis was executed on power system without being installing the DG so that the impact of power losses was studied. The simulation shows total losses of entire power system as shown in fig 4 and Table 1.

The overall system losses after execution of load flow analysis without DG were 206 KW. This is the huge power losses for any power system that must be minimized by insertion of distribution generation. We have selected DG with the rating of 826KW. The DG must be placed in optimal location so that

DG may be connected to the bus which gives lowest overall power system losses and improve in voltage profile.

B. Simulation Phase II: Power System with DG

Distributed generation having capacity 826KW is now connected to the power system and find out the effect of DG on the entire system. Bus-2 is connected to the main grid station so its voltage rating is 33KV; while the remaining buses are rated with 11KV.

a) Power system when DG to Bus-3

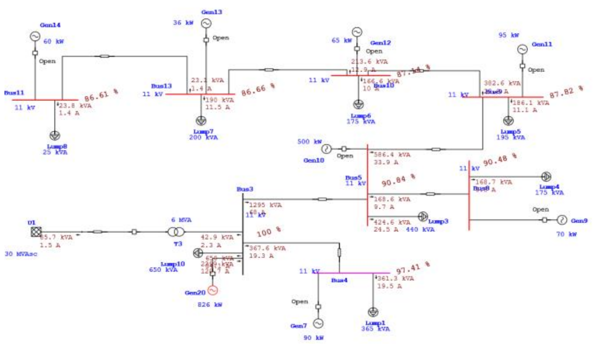

Figure 17: Load flow analysis of power system when DG to Bus 3

Table 8: Data of Load flow analysis of power system when DG to Bus 3.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterm
Lump1	365 kVA	11	307.1	190.3	19.47	85	101.6	97.41
Lump3	440 kVA	11	360.9	223.7	24.53	85	106.2	90.84
Lump4	175 kVA	11	143.4	88.84	9.783	85	106.5	90.48
Lump5	195 kVA	11	158.2	98.02	11.12	85	108.7	87.82
Lump6	175 kVA	11	141.6	87.75	10.03	85	109.2	87.14
Lump7	200 kVA	11	161.5	100.1	11.51	85	109.6	86.66
Lump8	25 kVA	11	20.19	12.51	1.439	85	109.7	86.61
Lump10	650 kVA	11	552.5	342.4	34.12	85	100	100
								726.96
								90.87
						3 Phase Load Terminal Voltage		363.48

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus3	0.826 MW	11	1.952	1.214	120.7	84.92
U1	Bus1	30 MVA	33	-0.0101	-0.0851	1.499	11.83

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	10.14	85.09	1.499
Line2	Line	307.1	190.3	19.47
Line10	Line	1001.3	623.7	68.16
Line13	Line	143.4	88.84	9.783
Line19	Line	484.1	298.3	33.99
Line21	Line	324.1	198.8	22.9
Line22	Line	181.7	111.3	12.91
Line24	Line	20.19	12.51	1.439
T3	Transf. 2W	10.15	-41.68	0.75

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.942
Load-Mvar	1.129
Generation-MW	1.942
Generation-Mvar	1.129
Loss-MW	0.0967
Loss-Mvar	-0.0149

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.0101
Bus3	11	100	1.952
Bus4	11	97.41	0.307
Bus5	11	90.84	1.001
Bus8	11	90.48	0.143
Bus9	11	87.82	0.484
Bus10	11	87.14	0.324
Bus11	11	86.61	0.0202
Bus13	11	86.66	0.182

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 8 and Figure 17.

From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 3 was 96.7 KW and three phase load terminal voltage is 363 V.

b) Power system when DG to Bus-4:

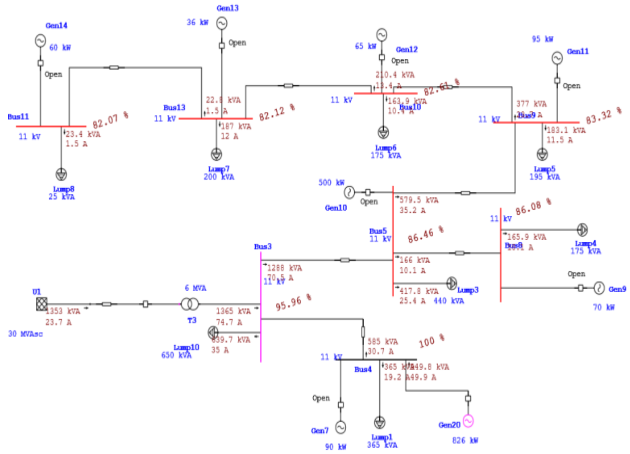

Figure 18: Load flow analysis of power system when DG to Bus 4

Table 9: Data of Load flow analysis of power system when DG to Bus 4.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterm
Lump1	365 kVA	11	310.3	192.3	19.16	85	100	100
Lump3	440 kVA	11	355.1	220.1	25.36	85	109.8	86.46
Lump4	175 kVA	11	141	87.41	10.12	85	110.1	86.08
Lump5	195 kVA	11	155.6	96.44	11.53	85	112.7	83.32
Lump6	175 kVA	11	139.3	86.33	10.41	85	113.4	82.61
Lump7	200 kVA	11	158.9	98.49	11.95	85	113.8	82.12
Lump8	25 kVA	11	19.86	12.31	1.495	85	113.9	82.07
Lump10	650 kVA	11	543.8	337	34.99	85	102.6	95.96
								698.62
								87.327
						3 Phase Load Terminal Voltage		349.2

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus4	0.826 MW	11	0.818	0.483	49.85	86.12
U1	Bus1	30 MVA	33	1.151	0.712	23.68	85.02

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	1121.3	806.7	24.89
Line2	Line	492.4	275.5	30.86
Line10	Line	986.6	616.3	70.62
Line13	Line	141	87.41	10.12
Line19	Line	476.5	294.2	35.28
Line21	Line	318.9	195.9	23.78
Line22	Line	178.8	109.6	13.41
Line24	Line	19.86	12.31	1.494
T3	Transf. 2W	1121.3	806.7	24.89

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	1.151
Bus3	11	95.96	1.611
Bus4	11	100	0.818
Bus5	11	86.46	0.987
Bus8	11	86.08	0.141
Bus9	11	83.32	0.477
Bus10	11	82.61	0.319
Bus11	11	82.07	0.0199
Bus13	11	82.12	0.179

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.969
Load-Mvar	1.195
Generation-MW	1.969
Generation-Mvar	1.195
Loss-MW	0.145
Loss-Mvar	0.0649

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 9 and Figure 18. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 4 was 145 KW and three phase load terminal voltage is 349 V.

c) Power system when DG to Bus-5

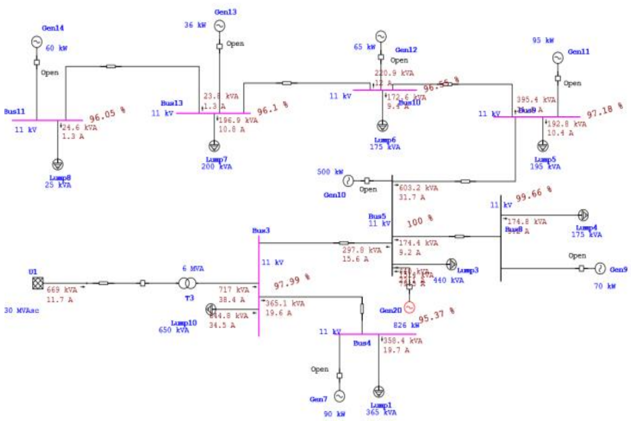

Figure 19: Load flow analysis of power system when DG to Bus 5

Table 10: Data of Load flow analysis of power system when DG to Bus 5.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
Lump1	365 kVA	11	304.6	188.8	19.72	85	103	95.37
Lump3	440 kVA	11	374	231.8	23.09	85	100	100
Lump4	175 kVA	11	148.5	92.06	9.204	85	100.2	99.66
Lump5	195 kVA	11	163.9	101.6	10.41	85	101.8	97.18
Lump6	175 kVA	11	146.7	90.94	9.385	85	102.2	96.55
Lump7	200 kVA	11	167.4	103.7	10.76	85	102.5	96.1
Lump8	25 kVA	11	20.92	12.97	1.345	85	102.5	96.05
Lump10	650 kVA	11	548.1	339.7	34.54	85	101.2	97.99
								778.9
								97.36
						3 Phase Load Terminal Voltage		389.4

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus5	0.826 MW	11	1.302	0.773	79.48	85.99
U1	Bus1	30 MVA	33	0.604	0.288	11.7	90.29

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	596.6	405.1	12.8
Line2	Line	304.6	188.8	19.72
Line10	Line	263.1	132.4	15.78
Line13	Line	148.5	92.06	9.204
Line19	Line	501.3	307.8	31.77
Line21	Line	335.7	205.3	21.39
Line22	Line	188.3	115.1	12.06
Line24	Line	20.92	12.97	1.345
T3	Transf. 2W	596.6	405.1	12.8

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.604
Bus3	11	97.99	0.859
Bus4	11	95.37	0.305
Bus5	11	100	1.302
Bus8	11	99.66	0.149
Bus9	11	97.18	0.501
Bus10	11	96.55	0.336
Bus11	11	96.05	0.0209
Bus13	11	96.1	0.188

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.906
Load-Mvar	1.06
Generation-MW	1.906
Generation-Mvar	1.06
Loss-MW	0.0319
Loss-Mvar	-0.101

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 10 and Figure 19. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 5 was 31.9 KW and three phase load terminal voltage is 389 V.

d) Power system when DG to Bus-8

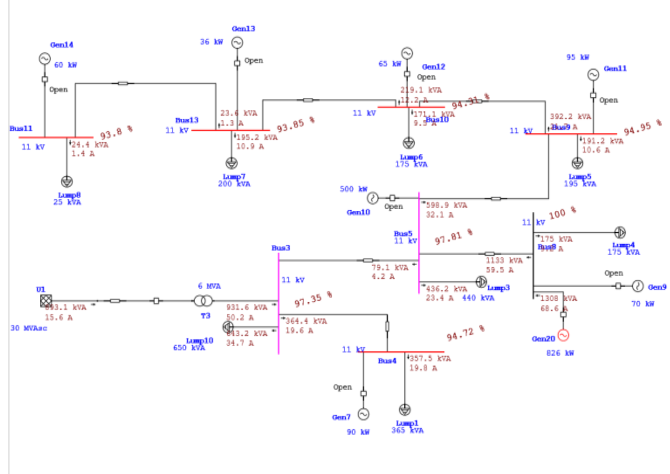

Figure 20: Load flow analysis of power system when DG to Bus 8

Table 11: Data of Load flow analysis of power system when DG to Bus 8.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
Lump1	365 kVA	11	303.9	188.3	19.81	85	103.4	94.72
Lump3	440 kVA	11	370.8	229.8	23.41	85	101.4	97.81
Lump4	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump5	195 kVA	11	162.5	100.7	10.57	85	103.2	94.95
Lump6	175 kVA	11	145.5	90.15	9.524	85	103.7	94.31
Lump7	200 kVA	11	165.9	102.8	10.92	85	104	93.85
Lump8	25 kVA	11	20.74	12.85	1.365	85	104	93.8
Lump10	650 kVA	11	546.7	338.8	34.68	85	101.6	97.35
								766.79
								95.849
						3 Phase Load Terminal Voltage		383.36

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus8	0.826 MW	11	1.122	0.673	68.65	85.75
U1	Bus1	30 MVA	33	0.794	0.41	15.63	88.85

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	780.6	521.4	16.74
Line2	Line	303.9	188.3	19.81
Line10	Line	77.62	19.42	4.314
Line13	Line	956.9	560.5	59.51
Line19	Line	497	305.5	32.25
Line21	Line	332.8	203.7	21.72
Line22	Line	186.7	114.2	12.24
Line24	Line	20.74	12.85	1.365
T3	Transf. 2W	780.6	521.4	16.74

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.794
Bus3	11	97.35	0.857
Bus4	11	94.72	0.304
Bus5	11	97.81	0.957
Bus8	11	100	1.122
Bus9	11	94.95	0.497
Bus10	11	94.31	0.333
Bus11	11	93.8	0.0207
Bus13	11	93.85	0.187

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.915
Load-Mvar	1.083
Generation-MW	1.915
Generation-Mvar	1.083
Loss-MW	0.0503
Loss-Mvar	-0.073

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 11 and Figure 20. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 8 was 50.3 KW and three phase load terminal voltage is 383 V.

International Journal of Engineering and Applied Sciences (IJEAS)
ISSN: 2394-3661, Volume-7, Issue-4, April 2020

e) Power system when DG to Bus-9

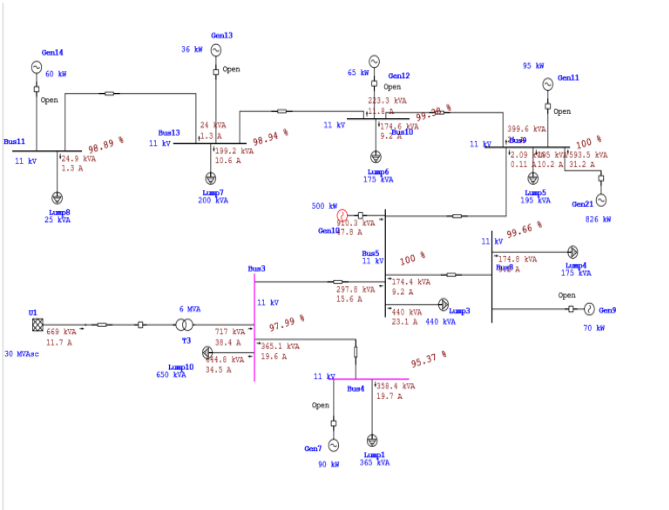

Figure 21: Load flow analysis of power system when DG to Bus 9

Table 12: Data of Load flow analysis of power system when DG to Bus 9.

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
Lump1	365 kVA	11	303.6	188.2	19.84	85	103.5	94.51
Lump3	440 kVA	11	369.7	229.1	23.51	85	101.8	97.11
Lump4	175 kVA	11	146.9	91.01	9.371	85	102	96.77
Lump5	195 kVA	11	165.8	102.7	10.23	85	100	100
Lump6	175 kVA	11	148.4	91.96	9.22	85	100.4	99.38
Lump7	200 kVA	11	169.3	104.9	10.56	85	100.6	98.94
Lump8	25 kVA	11	21.16	13.11	1.321	85	100.7	98.89
Lump10	650 kVA	11	546.3	338.6	34.72	85	101.8	97.15
								782.75
								97.8
							3 Phase Load Terminal Voltage	391.2

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus9	0.826 MW	11	1.05	0.623	64.08	86.02
U1	Bus1	30 MVA	33	0.858	0.446	16.92	88.71

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	843	555.6	18.04
Line2	Line	303.6	188.2	19.84
Line10	Line	14.75	-19.3	1.313
Line13	Line	146.9	91.01	9.371
Line19	Line	531.8	299.8	32.99
Line21	Line	339.5	207.4	21.01
Line22	Line	190.4	116.3	11.84
Line24	Line	21.16	13.11	1.321
T3	Transf. 2W	843	555.6	18.04

BUS DATA

Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	0.858
Bus3	11	97.15	0.856
Bus4	11	94.51	0.304
Bus5	11	97.11	0.532
Bus8	11	96.77	0.147
Bus9	11	100	1.05
Bus10	11	99.38	0.339
Bus11	11	98.89	0.0212
Bus13	11	98.94	0.19

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.908
Load-Mvar	1.069
Generation-MW	1.908
Generation-Mvar	1.069
Loss-MW	0.021
Loss-Mvar	-0.0905

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 12 and Figure 21. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 9 was 21 KW and three phase load terminal voltage is 391.2 V.

f) Power system with DG to Bus-10

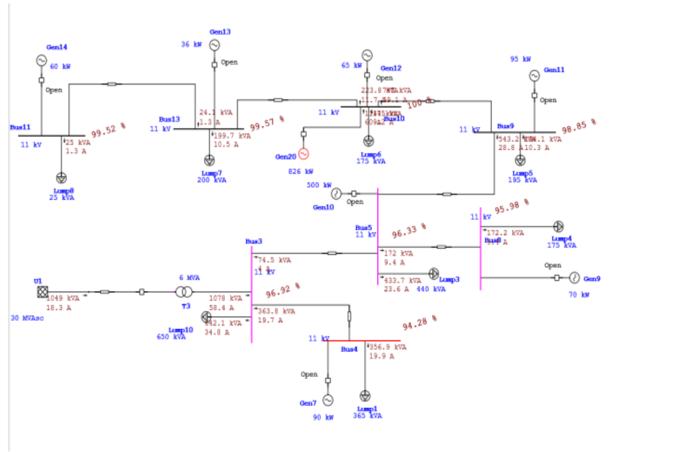

Figure 22: Load flow analysis of power system when DG to Bus 10

Table 13: Data of Load flow analysis of power system when DG to Bus 10

LOAD DATA

ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterma
Lump1	365 kVA	11	303.4	188	19.87	85	103.7	94.28
Lump3	440 kVA	11	368.6	228.4	23.63	85	102.3	96.33
Lump4	175 kVA	11	146.4	90.73	9.419	85	102.5	95.98
Lump5	195 kVA	11	165	102.3	10.31	85	100.7	98.85
Lump6	175 kVA	11	148.8	92.19	9.185	85	100	100
Lump7	200 kVA	11	169.7	105.2	10.52	85	100.3	99.57
Lump8	25 kVA	11	21.21	13.14	1.316	85	100.3	99.52
Lump10	650 kVA	11	545.8	338.3	34.77	85	101.9	96.92
								781.45
								97.68
						3 Phase Load Terminal Voltage		390

SOURCE DATA

ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF
Gen20	Bus10	0.826 MW	11	0.983	0.584	60.03	85.97
U1	Bus1	30 MVA	33	0.927	0.491	18.35	88.39

BRANCH DATA

ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	909.4	597	19.47
Line2	Line	303.4	188	19.87
Line10	Line	51.88	58.6	4.265
Line13	Line	146.4	90.73	9.419
Line19	Line	463.5	259.5	28.95
Line21	Line	637.5	370.1	39.14
Line22	Line	190.9	116.6	11.79
Line24	Line	21.21	13.14	1.316
T3	Transf. 2W	909.4	597	19.47

BUS DATA

Bus1	33	100	0.927
Bus3	11	96.92	0.908
Bus4	11	94.28	0.303
Bus5	11	96.33	0.515
Bus8	11	95.98	0.146
Bus9	11	98.85	0.638
Bus10	11	100	0.983
Bus11	11	99.52	0.0212
Bus13	11	99.57	0.191

GENERAL DATA

Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.91
Load-Mvar	1.075
Generation-MW	1.91
Generation-Mvar	1.075
Loss-MW	0.0416
Loss-Mvar	-0.0835

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 13 and Figure 22. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 10 was 41.6 KW and three phase load terminal voltage is 390 V.

g) Power system when DG to Bus-11

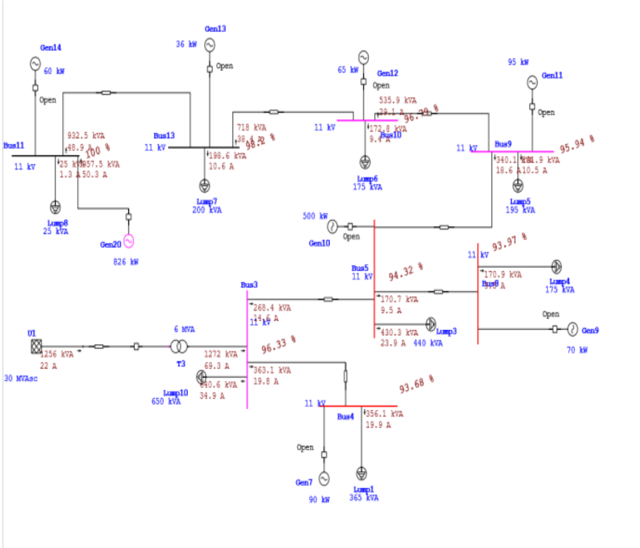

Figure 23: Load flow analysis of power system when DG to Bus 11

Table 14: Data of Load flow analysis of power system when DG to Bus 11.

LOAD DATA								
ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vtermal
Lump1	365 kVA	11	302.7	187.6	19.95	85	104.1	93.68
Lump3	440 kVA	11	365.7	226.7	23.94	85	103.7	94.32
Lump4	175 kVA	11	145.3	90.03	9.546	85	103.9	93.97
Lump5	195 kVA	11	163.1	101.1	10.5	85	102.6	95.94
Lump6	175 kVA	11	146.9	91.02	9.37	85	102	96.79
Lump7	200 kVA	11	168.8	104.6	10.61	85	101.1	98.2
Lump8	25 kVA	11	21.25	13.17	1.312	85	100	100
Lump10	650 kVA	11	544.5	337.5	34.91	85	102.3	96.33
								769.23
								96.1538
						3 Phase Load Terminal Voltage		384.6
SOURCE DATA								
ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF	
Gen20	Bus11	0.826 MW	11	0.82	0.495	50.26	85.62	
U1	Bus1	30 MVA	33	1.101	0.605	21.97	87.64	

BRANCH DATA				
ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	1075.4	703.4	23.1
Line2	Line	302.7	187.6	19.95
Line10	Line	215.8	155.6	14.81
Line13	Line	145.3	90.03	9.546
Line19	Line	295.6	160.2	18.71
Line21	Line	462.4	262.6	29.09
Line22	Line	612.4	356.5	38.42
Line24	Line	787.8	468.5	48.99
T3	Transf. 2W	1075.4	703.4	23.1

BUS DATA			
Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	1.101
Bus3	11	96.33	1.073
Bus4	11	93.68	0.303
Bus5	11	94.32	0.511
Bus8	11	93.97	0.145
Bus9	11	95.94	0.462
Bus10	11	96.79	0.612
Bus11	11	100	0.82
Bus13	11	98.2	0.788

GENERAL DATA	
Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.92
Load-Mvar	1.1
Generation-MW	1.92
Generation-Mvar	1.1
Loss-MW	0.0621
Loss-Mvar	-0.0521

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 14 and Figure 23. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 11 was 62 KW and three phase load terminal voltage is 384.6 V.

h) Power system when DG to Bus-13

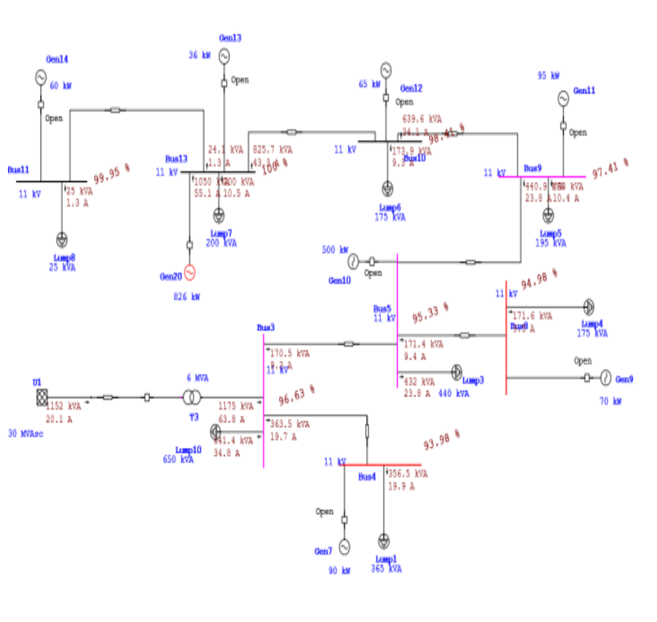

Figure 24: Load flow analysis of power system when DG to Bus 13

Table 15: Data of Load flow analysis of power system when DG to Bus 13.

LOAD DATA								
ID	Rating/Limit	Rated kV	kW	kvar	Amp	% PF	% Loading	Vterm
Lump1	365 kVA	11	303	187.8	19.91	85	103.9	93.98
Lump3	440 kVA	11	367.2	227.6	23.78	85	103	95.33
Lump4	175 kVA	11	145.8	90.38	9.481	85	103.2	94.98
Lump5	195 kVA	11	164.1	101.7	10.4	85	101.6	97.41
Lump6	175 kVA	11	147.8	91.6	9.275	85	101	98.41
Lump7	200 kVA	11	170	105.4	10.5	85	100	100
Lump8	25 kVA	11	21.25	13.17	1.313	85	100	99.95
Lump10	650 kVA	11	545.2	337.9	34.84	85	102.1	96.63
								776.69
								97.086
						3 Phase Load Terminal Voltage		388
SOURCE DATA								
ID	Terminal Bus	Rating/Limit	Rated kV	MW	Mvar	Amp	% PF	
Gen20	Bus13	0.826 MW	11	0.901	0.539	55.1	85.84	
U1	Bus1	30 MVA	33	1.013	0.547	20.15	88.01	

BRANCH DATA				
ID	Type	kW Flow	kvar Flow	Amp Flow
Line1	Line	992.2	649.5	21.27
Line2	Line	303	187.8	19.91
Line10	Line	134.1	107.2	9.454
Line13	Line	145.8	90.38	9.481
Line19	Line	379.3	209.7	23.86
Line21	Line	549.5	315.9	34.15
Line22	Line	701.5	411.9	43.39
Line24	Line	21.25	13.17	1.313
T3	Transf. 2W	992.2	649.5	21.27

BUS DATA			
Bus ID	Nominal kV	Voltage	MW Loading
Bus1	33	100	1.013
Bus3	11	96.63	0.99
Bus4	11	93.98	0.303
Bus5	11	95.33	0.513
Bus8	11	94.98	0.146
Bus9	11	97.41	0.549
Bus10	11	98.41	0.701
Bus11	11	99.95	0.0212
Bus13	11	100	0.901

GENERAL DATA	
Buses	10
Branches	9
Generators	1
Power Grids	1
Loads	8
Load-MW	1.915
Load-Mvar	1.085
Generation-MW	1.915
Generation-Mvar	1.085
Loss-MW	0.0503
Loss-Mvar	-0.0701

The Percentage voltage drop, load terminal voltage, KVA and current flowing at each bus is shown in Table 15 and Figure 24. From table , it is clear that he overall system losses after execution of load flow analysis when DG to Bus 13 was 50.3 KW and three phase load terminal voltage is 388 V.

VI. COMPARISON

Comparing Power Losses and Voltages at Different Busses after Installation of DG, the summary is presented in the table 16 below.

Table 16: Comparison Of Losses and voltage Data of Load flow analysis of power system when DG installation to Different Bus.

Bus ID	Nominal kV in KV	Load terminal Voltage in V	Losses in KW
Bus2	33		0
Bus3	11	363	96.7
Bus4	11	349	145
Bus5	11	389	31.9
Bus 8	11	383	50.3
Bus 9	11	391	21
Bus 10	11	390	41.6
Bus 11	11	384	62.1
Bus 13	11	388	50.3

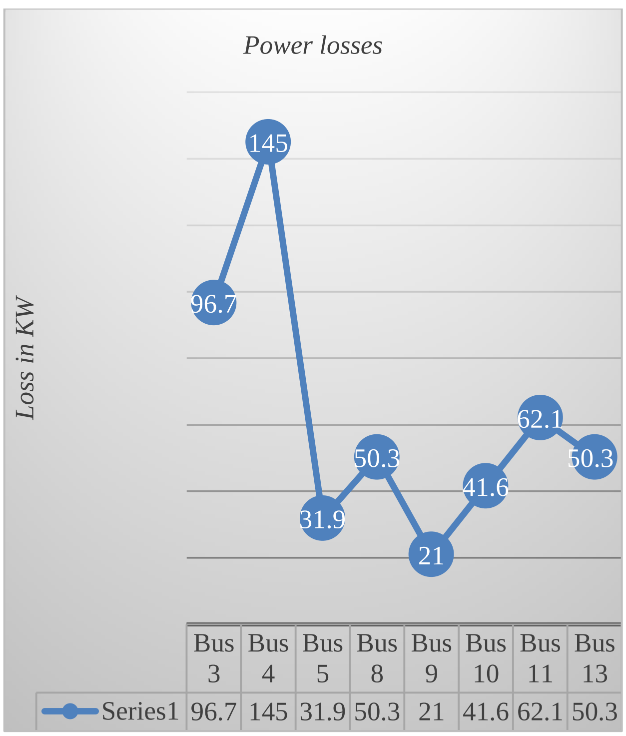

Figure 25: Power Losses at Different Busses after Installation of DG

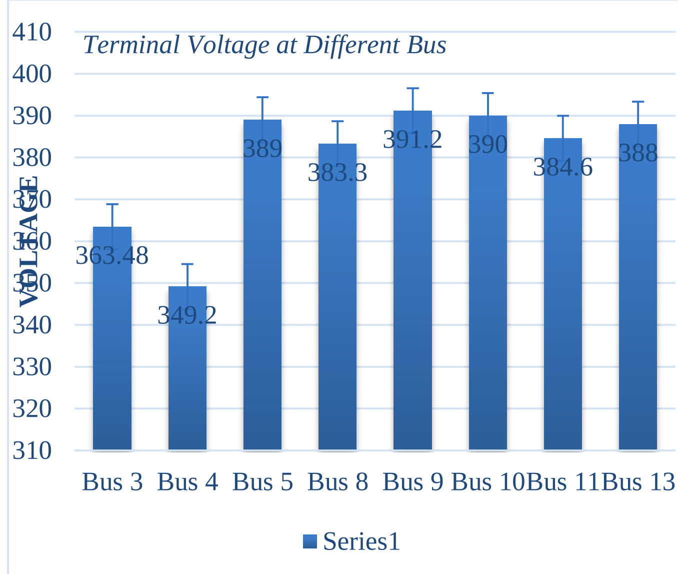

Figure 26: Voltage at Different Busses after Installation of DG

Above results of simulation show the losses of the power system. DG is connected at different buses step by step and Bus-9 is the only bus where losses of the power system are least recorded which is21 KW and voltage of bus 9 is highest among the buses which is 391.2 V, therefore, the Bus-9 bus is the optimal placement of distributed generation for power system. Consequently, the Bus-9 is the optimal placement of the system because at this location the voltage profile is generally improved while losses are drastically minimized.

CONCLUSION

Demonstration of the grid impact study shows the losses on lines as well as percentage voltage drop on the network decreases with the increase in power export from Mini grid and MHP Plant. Terminal voltage at different load point also get improved with increase in power export from Mini grid and MHP Plant. The overarching view from the results is that the outlook for Local Distribution grid interconnected mini grid and MHP plant in future is positive in Nepal.

In this research, detailed analysis on some of the impacts of distributed generation (DG) on a distribution network operation is conducted.
The obtained results have shown that the DG influences the distribution network and that their precise location are vital in reducing power losses and improving the voltage Profile. It is noted that DG placement cannot always results to effective loss reduction i.e., it depends on the location of DG unit. DG implementation as a source of active power has a great positive impact on improving the voltage profile through the entire distribution network.

ACKNOWLEDGEMENT

The authors extend their hearty gratitude to the faculties and colleagues at Tribhuvan University, Institute of Engineering, Pulchowk Campus and engineers of Nepal Electricity Authority for their constant help, support and recommendations.

REFERENCES

[1] Aepc, 2018/19. Progress at a Glance :A year in Review. s.l., s.n.

[2] District development commiunity, t., 2016. Taplejung mini grid development project, s.l.: s.n.

[3] Gyawali, n., 2014. Analysis and design of Taplejung mini grid, s.l.: Multi Electrical Solutions.

[4] NEA, 2018/19. A year in review -fiscal year , s.l.: s.n.

[5] Ray, S. & Jha, A. K., 2017. Grid Integration Studies of Captive and Cogeneration Plant in Sugar Industry: Case Study of Indushankar Sugar Industry Pvt. Ltd.. Kathmandu, s.n.

[6] Paudel, B. & Gyawali, N., 2016. Improvement of Power Control Strategy for Islanded Microgrid Power System. Kathmandu, s.n.

[7] Thapa, K. et al., 2018. Modelling of wind-solar Hybrid Power System for Off-Grid in Nepal and a case study. Kathmandu, RETRUD-18.

[8] Tiwari, B. R., Bhattarai, N. & Jha, A. K., 2017. Performance analysis of a 100 kWp grid connected Solar Photovoltaic Power Plant in Kharipati, Bhaktapur, Nepal. s.l., s.n.

[9] World Bank Group, n.d. Nepal: Scaling Up Electricity Access through Mini and Micro Hydropower Applications, s.l.: s.n.

[10] Shukla, T., 2010. Allocation of optimal distributed generation using ga for minimum system inradial distribution networks. s.l., s.n.

[11] Shrestha, J. N. & Raut, D. B., 2018. Assessment of Urban roof top Grid Connected Solar Potential in Nepal. Kathmandu, Retrud_18.

[12] Okhueleigbe, O. P. a. E. I., 2017. Optimal Placement of Distributed Generation (DG) in a Distribution Network. s.l., International Journal of Latest Research in Engineering and Technology (IJLRET) .

[13] mallik, j. k., 2019. Micro Hydro Power in Nepal: A Journey from stand alone system to distributed generation. s.l., s.n.

[14] Kothari, D. P., 2017. Modern power system. Fourth Edition ed. s.l.:Mc graw-hill.

[15] Kundor, P., Mc graw-hill,1994. Powersystem stability and control. s.l., s.n.

[16] Bhandari, K. R. & Adhikari, N. P., 2018. Grid integration of Solar and Solar/Wind hybrid Mini-Grid Projects: A case of Solar/Wind Hybrid Mini-Grid Project Implemented by AEPC. Kathmandu, Retrud-18.

[17] Aepc/Rerl, December,2015. Detail study of transmission survey/mapping/design and cost estimation of seven mhp for mini grid formation in Taplejung district. , Smart consult pvt.ltd.volume -1.

[18] Pabla,A.S., Mc graw-hill,Electric power planning, second Edition

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