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# Impacts in a Mini Grid by Micro Hydro Plants Interconnected with Grid: A Case Study of Taplejung Mini Grid, Taplejung, Nepal

By:

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Impacts in a Mini Grid by Micro Hydro plants interconnected with Grid: A Case Study of Taplejung Mini Grid, Taplejung, Nepal**" submitted by Ramani Bajagain, in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

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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. Small hydro power plants give more benefits to remote people special hills and mountainous region. Till 2018, more than 3000 MHPs totaling to 35 MW of power produced in our country. The price is NPR17-25 per Unit for Utility grid to supply in the remote location and 9-15 per unit via a 50-100 kW MHP that is tied to the large system. So, In Nepal, it is suitable for tied the running isolated mini grid and MHPs to the grid.

In case study, a mini grid by MHPs connected grid of Taplejung, Province 1, Nepal consisting of MHP and rural electrification load is modeled. Load flow analysis for various cases of generation and connection are performed using ETAP software. There are six number of MHPs with installed capacity of 826 kW, around 2.2 MVA load in the system.  The losses of the line in Grid is 206 kW, When mini grid and MHP plant is tied to Grid, then the losses of the system is reduced 6.2 kW. Similarly, % voltage drop of the line in Local Distribution Grid is 22% .As mini grid and MHP plant is connected to Grid, then the % voltage drop of the system is decreased to 0%. Likewise, the terminal voltage of the Grid is 333V. As mini grid and MHP plant is connected to Grid, then the terminal voltage of the system is increased to 399 V. The Overall system losses without DG installation is 6.2 kW, when DG of 250 kW is installed and losses in bus no 3 is found Lowest 1.4 kW and available voltage is highest 400 V.

Hence above result shows that the loss of the overall system as well as % voltage drop of the system is reduced by significant level and the terminal voltage at various load point get improved which helps to find the quality of electric supply. The accurate location of DG is vital for minimizing losses and improving voltage profile, which indicates positive results on the overall economy. The large investment incurred in the distributed micro hydro generation can be realized in economic benefits.

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## ABBREVIATIONS

| | |
|---|---|
| AEPC | Alternative Energy promotion Center |
| AVR | Automatic Voltage Regulator |
| CT | Current Transformer |
| DC | Direct Current |
| DERs | Distributed Energy Resources |
| DFS | Detail Feasibility Study |
| DG | Diesel Generator |
| EHS | Energy Home System |
| ELC | Electronic Load Controller |
| ESCOS | Energy Service companies |
| ETAP | Electrical Transient Analyzer Program |
| GPS | Global Positioning System |
| HHs | House Holds |
| HT | High Tension |
| KVA | kilo Volt Ampere |
| KW | kilo Watt |
| LCT | Load Tap Changing Transformer |
| LDC | Line Drop Compensator |
| LPS | Liter per Second |
| LT | Low Tension |
| MG | Mini Grid |
| MHMGs | Micro-Hydro mini grids |
| MHP | Micro hydro plant |
| MW | Mega Watt |

| | |
|---|---|
| NEA | Nepal Electricity Authority |
| PSAT | Power System Analysis Tool |
| RERL | Renewable Energy for Rural Development |
| SHP | Small Hydro power |
| SHSs | Solar Home Systems |
| SLD | Singe Line Diagram |
| UG | Utility Grid |
| UNDP | United Nations Development Program |
| W | Watt |

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Electricity is important parameter 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 (Pabla, 2015).

Micro hydro power plants are very much successful for electrification in remote of Nepal as compared to other countries in the world (Paudel & Gyawali, 2016). Micro hydropower plants (MHPs) were started in Nepal in the 1960s and since then they have been provide electricity to the remote area's people. (World Bank Group). Till 2018, more than 3000 MHPs aggregating to 35 MW of generation capacity have been developed in Nepal (Hydro Empowerment Network, 2018). It is cheaper to deliver electricity in rural hilly areas via 50-100 kW MHP interconnected to grid than via Nepal electricity Authority's Grid (World Bank Group). Mini-grids also help minimize distribution-end losses for Distribution Companies (DISCOMs) and enable localized generation and consumption of power (Das, Sharan, Rao, & Bhardwaj, 2017).

Micro hydro has been serving the rural communities for more than four decades in Nepal. Most of them were located in hilly areas where road is not accessible. Micro hydro uses locally made turbines, induction/synchronous generator, manual intake gates, simple load and frequency controller, these factors all contributed to the low efficiency of the plants. Alternative Energy Promotion Center, Nepal is responsible for promoting community micro hydropower based rural electrification as off grid rural electrification. In an average, 100 Watt electricity has been prescribed for lighting the house holds from the community run power plant. Initially 100 W power for each house holds was enough for the rural demand with decentralized energy supply system. Within few decades, lighting the house with the micro hydro-electricity has led to increase the load demand as people used more electrical utilities, more light than before. The energy demand of people increased with increase in economic activities, road access in the region in the later days (Gyawali, 2014).

Micro- hydropower located in the separated areas in the remote area is serving mostly the lighting needs of the vicinity. Though the connection of multiple end uses seem to be possible and increase the utilization capacity. Now time has come to think of increasing the reliability of the systems as well as to increase the possibility of transferring spare power from one area to the other where it can have more productive use and hence can increase the overall utilization factor of the generated energy. Formulation of mini-grid is an attractive and less price solution to deliver the reliable electricity to the customer.

With the advent of growing technology and development of Transportation accesses, technology has become common reach to the general public. The electricity has multi facets to create more demand day by day. So, the electricity demand shall be increased due to addition of end uses, growing public facilities and with growing population. People would like to have the electricity supplies for continuous. As soon as the national grid line approaches to nearby villages, people having connection with MHP would become tempted to have round the clock supply in abundant quantity. So, in one hand people demand to have round the clock supply of electricity whereas on other hand distributed plants do really need to be integrated to increase the load/plant factor to generate more revenue. Following limitations always remains with isolated micro hydropower system (District Development Committee, Taplejung, 2016).

### 1.1.1 Limitations of an isolated micro hydropower System

- Limited capacity of generation to meet the demand (to supply additional loads).
- No supply during breakdown or planned maintenance of the plant.
- Limitation of power to the motor due to switching surges (Inrush Current).
- Lower load factor due to limited consumer.
- Same consumption pattern.
- Difficult to improve quality of power.
- Impossible to provide regular water for milling or irrigation.

So, number of limitations and challenges of distributed system can be overcome by constructing mini grid (integration of multi MHPs).

### 1.1.2 Advantages of Mini Grid Power System

- Meeting Energy demand by supplying power from lightly loaded community groups to heavily loaded one or vice versa.
- Sales of additional Energy to consumers within same or different community.
- Taking advantage of consumption pattern.
- Preventive maintenance is possible without interruption of supply for enhanced life of plant.
- Sharing of Power Generation in cyclic order during time of low demand to reduce wear and tear of the machine.
- Sales can be increased either by supplying power to additional motors or by increasing running hour of existing motors (Problem of inrush current can drastically be reduced).
- Larger sized Machines can also receive power from Mini Grid network (Gyawali, 2014) .

Connection arrangement shall not be cost effective and technically unfeasible for a single micro hydro plant to connect with Local distribution grid. So, mini grid is a basic requirement and cost effective solution for future grid connection to improve Load factor to the maximum possible extent.

## 1.2 Problem Statement

Nepal has scattered population due to land topography especially remote areas. The national grid hasn't reach in every village of the country. The NEA is developing grid system and expected to reach to every household in near future. In the meantime, as an immediate arrangement mini-grid with distributed resources are used as source of energy. A large number of distributed resources has been installed with the local participation with monetary or/and technical assistance of government and non-government entities promoting distributed resources. Unlike previous practices of using single alternative source of energy to cater the load, a practice of combing multiple sources of energy is common. The mini-grid with multiple distributed resources are used to supply local load (Bhattarain, 2018).

The policy of government is to connect grid to all parts of the country. The remote areas are connect by weak distributed line to the national grid. In that case, the existing mini-grid can be connected to the grid with some change.

There exists a policy regarding the connection of micro hydropower with the national grid in Nepal. But there are no policies for connection of the existing MHP to form distribution network. Hence policies need to be formulated specifying the level and range of supports that the government can provide. Effective institutions and regulatory framework should be established to promote the mini grid development in Nepal. Clear roles and responsibilities between different governmental bodies should be made.

There is a large contribution of the nation in isolated micro hydro distribution, mini grid system as well as rural electrification through national grid. The line lengths and lack of proper distributiveness of generation and load involves large losses in the rural electrification while the investment in micro hydro like alternative sources is being abandoned. This problem is creating a duplication of resource in a resource scarce economy of Nepal. Therefore, the loss of national grid occurring due to rural electrification shall have to be minimized along with continual operation of isolated generation sources for the adequate usage of investment. (Bhandari & Adhikari, 2018)

The connection of rural households to Local distribution grid improves the quality of supply but impacts the supply with a large loss and the electrification system needs to be planned so as to cope with the requirements involving large investment.

### 1.3 Rationale of the Study

In rural electrification, connection of the DERs such as wind turbine, Micro-hydro, solar PV are feasible to operate as a mini-grid network. The power balance is require to obtain the standard level of electricity parameter in power system. If there is any unbalance between the production and consumption make unbalance in the power system that generates negative effect on the frequency and voltage thus impact the performance of critical loads connected in the system. In on grid mode, balance of frequency and voltage standard in system can be maintained by the main supply. (Bhattarain, 2018).

The electricity supply in the rural hills of Nepal is not reliable and loss in grid is heavy due to rural electrification through grid. The running MHPs is affected due to the expansion of National grid by NEA. Up to 2015, 90 MHPs with a power of 2.7 MW were closed due to national grid expansion. So, tied the small hydro to the grid support above demerits & the extra power can be export to the grid and increased income source of company. The transmission & distribution loss of the system can be reduced by installing DG near to load Centre which also help to reduce voltage drop and improve voltage profile of system. Financial and economic condition of MHPs also good due improvement of Load factor.  (AEPC/RERL, 2015).

The effect of grid connection of alternative sources of generation and mini grid systems necessarily has to be studied in order to optimize the resource allocation in electrification projects. Alongside it is essential to supply quality electricity in the rural hills too which could be assistance for the economic growth.

## 1.4 Research Questions

This research guides the following questions:

How to improve quality of Supply along with minimizing loss in Grid due to rural electrification?

What is the result of connecting isolated mini grid with Grid?

## 1.5 Objectives of Research

### 1.5.1 Main Objective

The main objective of this research is to assess the impacts in a mini-grid by micro-hydro plants interconnected with Grid.

### 1.5.2 Specific Objectives

- To assess the role of mini- grid by micro-hydro inter connected with  Grid in minimizing losses
- To assess the role of mini- grid by micro-hydro inter connected with  Grid to improve the quality of power supply
- To find the Optimal placement of distribution generator in Network

## 1.6 Limitation of the Study

This research is based on the various load flow conditions of the grid connected Taplejung mini grid situated in Taplejung, Nepal. So the outcome may vary depending on the nature of mini grid. The study is focused on the loss parameter and terminal voltage parameter to determine the economy and quality of supply respectively. The optimization of distributed generation is performed for a small system.

# CHAPTER TWO

# LITERATURE REVIEW

Electricity is essential for accelerating the economic development of any country and is also taken as an important input to improve quality of life (Dhakal & Ghimire, 2018). Non-renewable energy resources are continuously decreasing, hence the demand for the renewable energy resources are increasing. Nowadays electricity generation from renewable sources is becoming famous. In many remote areas these power plants are generating power in isolated mode. In case of maintenance of plant, power supply to those areas is disturbed. Hence to improve the power quality of such areas, Mini -Grid is necessary.

## 2.1 Access to Electricity

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% (AEPC, 2018/19).

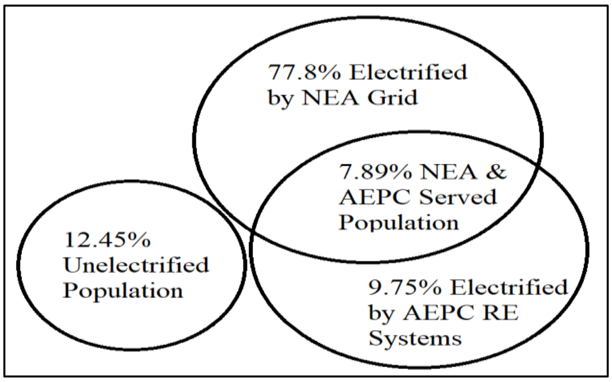


Figure 1: Diagrammatic Representation of Population served by sources of electricity (AEPC, 2018/19)

## 2.2 Mini Grids

Mini-Grids are electric network containing loads & supply resources which clearly demark area of supply, which is off grid or on grid operate in proper way. Mini-Grid is a separate, small electrical network, providing supply to a small society (Chaudhary & Dhital, 2016).

In an isolated mini grid, the Generator controls the frequency of mini grid while in a grid connected mini grid, the frequency of the grid controls the generator making the operation efficient (Paudel & Gyawali, 2016). Likewise, the voltage in an island mini grid can be controlled by the generator, while in tied Network, the voltage control at the tied point is received. (Paudel & Gyawali, 2016).The frequency controlled in micro -hydro plants application can be obtained by Electronic load controller (ELC).

Mini-Grid provide economic and environmental advantage to the rural people. Mini grids helps to promote modern energy services in remote areas, focus to productive use and social services as well as cogeneration. Mini-girds have high investment but low energy price (AEPC/RERL, 2015).

### 2.3 Rural Electrification through mini grid

The areas where at least 5 to 10 year time need to expansion of national grid are minimum criteria for making mini grid. The renewable system will generally have a larger capital at starting and small running price (AEPC/RERL, 2015).

It is essential to recognize that renewable energy mini grid are very site specific. Where these systems have been most successful, specialized institutions with experienced experts are able to efficiently identify and develop projects. Where these institutions and capabilities are missing, and must be developed, early projects will likely have high preparation costs (relative to the project cost) and may require extra effort to develop (AEPC/RERL, 2015).

Private sector may be involved for extension of mini grid in remote area . However, these potential suppliers need policy and institutional support from government to provide channels by which they can access rural electrification subsidies and market concessions that will enable them to offer affordable electricity service to poor populations. (AEPC/RERL, 2015).

### 2.4 Grid interconnected to Micro Hydro plant in Nepal

Remote areas electrification in Nepal is successful as compared to other country which helps to develop rural and mountainous areas. Green energy available in Nepal, which around 36 MW provide service to above 350,000 families in hilly location far from the national network (Mallik, 2019).

The first MHP was interconnected with grid in Nepal on 11 January 2018 after the rule change in July 2014. This help to share an isolate system to grid tied system has several benefits for both the grid and the MHP, the grid gets surplus power near the load centers by minimizing line losses and provide power quality whereas MHP gets extra revenue. (Koirala B. , 2019).

### 2.5 Mechanism of Grid Interconnected Micro Hydro Plant

The frequency and voltage control of large hydro has slight difference as compared to MHP. In isolated MHP, the ELC load controller maintained frequency by controlling water flow through unregulated turbine produced power between connected load and ballast load. In large hydro, governor maintain this works.

The figure 2 shows MHP governor working in isolated mode. As the relation between water flows in the turbine is proportional to the power output, the power output from the turbine remains constant for the constant water flow turbine until or unless it is operated manually. The power generated is directly averted to the ballast load by ELC when the load on the consumer end is null. But, in case of high load on consumer end, the constant power generated cannot be balanced by the low ballast load. In big hydro, the water strike in the blade of turbine is used as a reference to control the power flow. (Mallik, 2019).

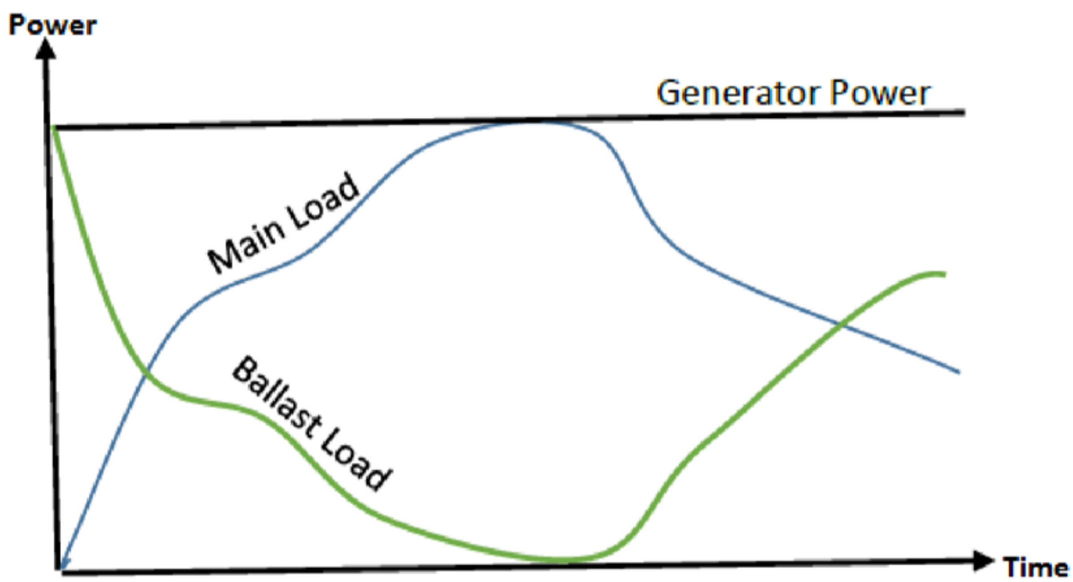


Figure 2: Governing Mechanism of MHP using ELC ( (Paudel & Gyawali, 2016))

### 2.6 The ELC Technology for Isolated MHP System

An ELC maintains the constant momentum of synchronous generator during variable consumer load. As the load of consumer changes, then frequency also changes. The coordination of all error signal and power utilized by the ballast load is controlled by

PI controller with the help of change frequency which helps to operate the generator at its best performance with constant momentum. The overall governing mechanism of ELC is shown schematically on Figure 3. (Koirala B. , 2019).

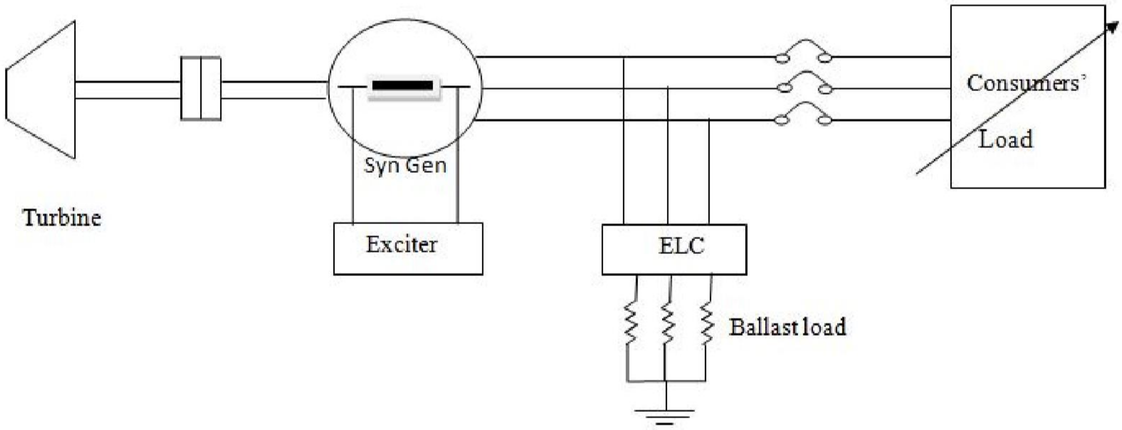


Figure 3: Schematic diagram of ELC used for Isolated MHP (Mallik, 2019)

The diagram represents that, the extra power generated in the specific phase will be loss in the ballast of corresponding phase. All the generated active power can be consumed by ELC when there will be no load which is induced in the ballast load. Fig. 3 shows the control diagram of the Electronic Load Control mechanism adopted in Nepal.

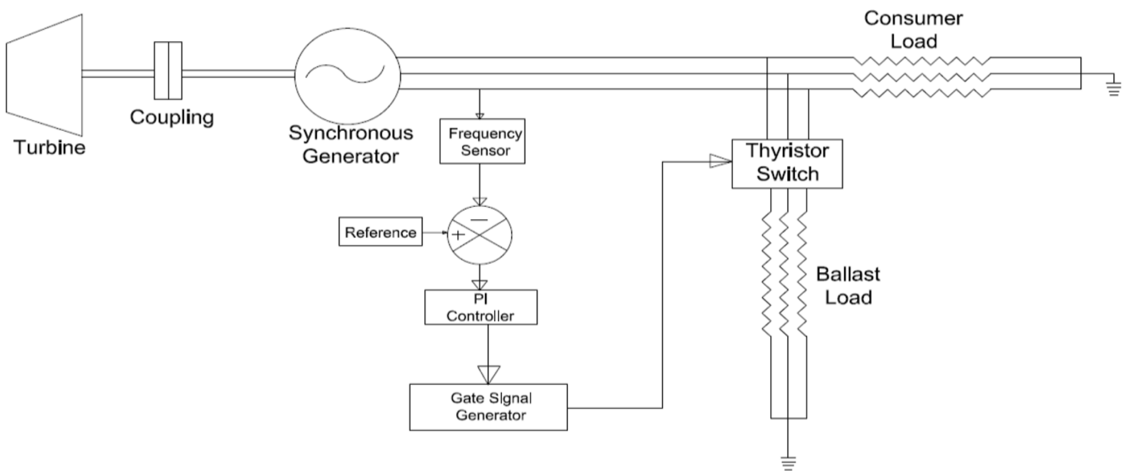


Figure 4: Control Strategy of ELC practiced in Nepal (Gautam, 2019)

## 2.7 ELC for Grid Interconnection

The switching device thyristor (based on phase angle) have the demerit of creating hunting in the system during the situation of firing at 90˚ due to inoculation of harmonic current. It disturbs during the operation of grid tied MHP, when any fault is encountered in the system and the MHP have to be detached from the grid. When grid is connected with MHP, the ELC is not working during tied. ELC starts working if any fault is occurred in the system, and all the power is sent to ballast load. In this case, the voltage level increase beyond permissible limit. It is utmost technical problem faced during interconnection. Figure 5 represents the line diagram of grid interconnected of MHP (Gautam, 2019).

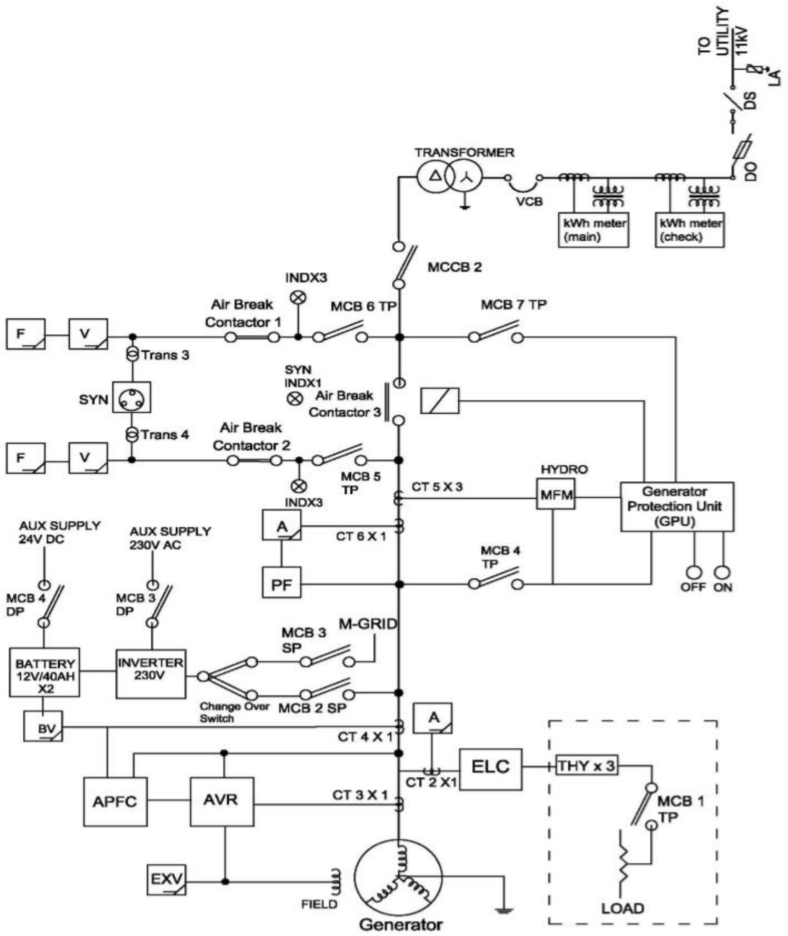


Figure 5: Single Line Diagram of Grid Interconnection of MHP (Koirala B. , 2019)

Similarly, the interconnection between MHP's requires sag characterized ELC which must be able to ensure the sharing of active power generated on ballast depending upon its power capacity. Taplejung Mini Grid will be tied in the network which generates the total capacity 326kW and 500kW, when it is interconnected with 5

MHPs with capacity 36kW to 95kW. When the frequency in the system is changed constantly, the ΔP1 for MHP 1 ballast varies from the ΔP2 of MHP2 ballast as represented in Fig 6. The reciprocal relation between the MHP capacity and slope is the reason behind this variation i.e. higher the slope (MHP2), lower the MHP capacity and vice versa. As per the study, the drop varies from 2 percent to 12 percent (Kundor, Mc graw-hill,1994). A detailed study is required to identify and mitigate the confusion on revenge sharing among IPP when the loads on consumer end is not shared in the proportioning ratio with the ballast power during the interconnection between the MHP's in mini grid. (Mallik, 2019) .

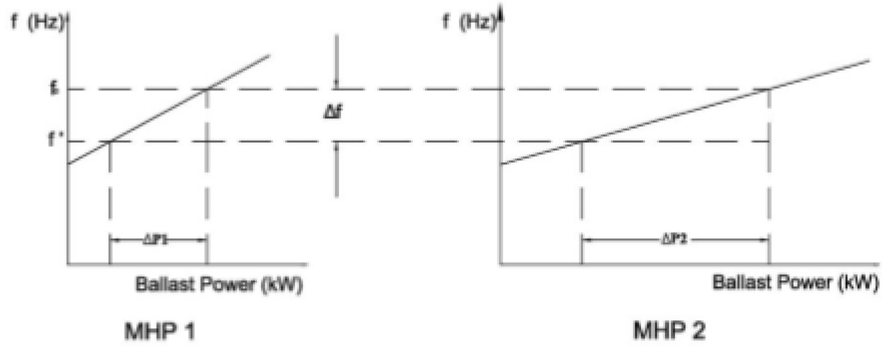


Figure 6: Parallel operation mechanism of MHP representing p-f droop (Mallik, 2019)

## 2.8 Automatic Voltage Regulator (AVR)

AVR is used to control the excitation of synchronous generator which is then controls the terminal voltage as well as reactive power injection to the mini-grid. AVR builds up the terminal voltage to a desired level and maintains the air gap flux to maintain desired terminal voltage of generator (Paudel & Gyawali, 2016).

The exciter in the synchronous generator is able to produce the reactive power as well as deliver a constant excitation which will help to generate the terminal voltage at full load. In order to have the brushless excitation system (Figure 7), the generator (synchronous) used in Nepal for MHP has built in electronic AVR in the compounding transformer.

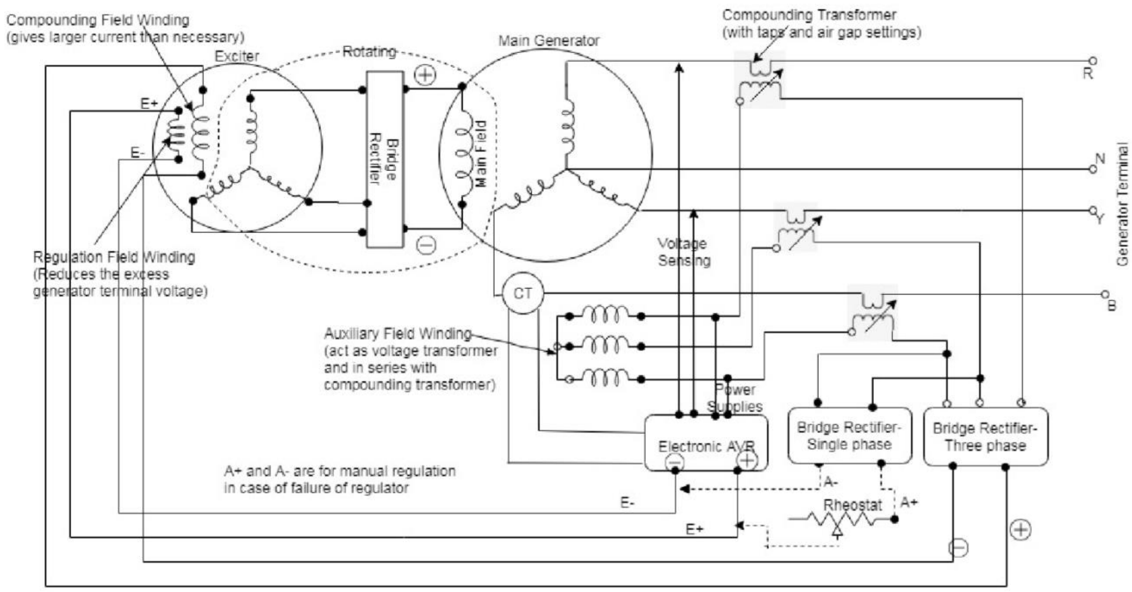


Figure 7: Architecture of Excitation System in MHP (Mallik, 2019)

## 2.9 Distributed Generation

Distributed Generation plays increasingly important part in the Electric industry. The function of the distributed generator is to regulate the power system in a controlled manner and have a proper influence on operation (kazemi, 2009/IEEE). These devices can be located in power systems for multi functionalities like improvement of grid, minimizing the power loss and enhancing the load factor and voltage profile, and minimizing the maintenance frequency in terms of upgrade and improving the system as a whole. These generations are beneficial in reducing the losses like active Power losses, VAR losses. The use of distribution generation on the distribution system brings a significant impact in the voltage condition and flow of power in the consumers end as they are connected on the radial distribution network. In order to maintain the voltage condition within the allowable limit, Load-tab Changing Transformer (LCT) and Line Drop Compensator (LDC) are used at the substation bus. Distributed Generation (DG) have various beneficial characteristics when placed at ideal location (which can be at or near load Centre) such as providing undisturbed electric power to the consumers. The basic characteristics of distribution generator like the rating of distribution generation, the technology used in it, the geometrical properties like sizing, the optimal location for it and the method, mode of operating as well as the DG penetration must be taken into consideration beforehand (Okhueleigbe, 2017). DG is generally known by their radial network system and large system reactance to the system resistance ratio generally known and R/X ratio. The use of DG helps for initial power flow in the radial distribution system by backward/forward sweep method. The losses in the buses and economic aspect in the network can be minimized by performing load flow analysis using the N-R method to identify the best location and sizing of distribution generator.

The various issues in the power system like, deregulation, increased consumption of power, and shortage in the transmission capacities can be mitigated using the distributed generations. Some important advantages for the promoting DG are as follows:

- Transmission and distribution costs reduce due to closer to beneficiary.
- High efficiency
- Easy to place as they are small in size.
- Stable pricing and easy availability of fuel.
- Less time need for construction and low risk

Electricity consumption in all over the world is continuously improving. It is well known that the consumption of electricity is increasing rapidly all over the world. The main reason is due to easily available distribution generation. (Khan, 2019) . DG gives lower running costs and is easily construction with less cost and time. As well as renewable energy support a vital role in building reliable power infrastructure. DG provide bi-directional power flow to consumer. If the level of penetration is very high in the generation then the issue of voltage rise will be observed. To solve this problem, proper sizing and appropriate placement of DG is necessary. So DG planning is important (Shukla, 2010).

### 2.9.1 Impact of DGs on the Electrical Parameters

#### 2.9.1.1 Impact of the Voltage

In a power system, the level of voltage has an effect on consumers' equipment. Depending on whether we have a lower or higher level of voltage, consumers' equipment can malfunction or be damaged. Therefore, it is required to retain the grid voltage at an acceptable level.

In old system, the voltage and reactive power can flow from transmission to distribution system, whereas with the presence of a DG in the distribution system, this assumption is not used. So voltage in the distribution may be large in some cases. (Bhattarain, 2018)

#### 2.9.1.2 Impact on the Power

The presence of DGs changes the current flow in the distribution system depending on the size and number of DG connected to the distribution system.

#### 2.9.1.3 Impact on Short Circuit Current

The fastening of distribution generation in the distribution network changes the overall impedance of the network and therefore the current and the power. It is possible that the current is modified and provokes the malfunction of protective equipment.

#### 2.9.1.4 Impact on Voltage Quality

Connecting DG to the distribution network can also affect the quality of the voltage wave. This is determined by a set of indices such as Flicker, voltage dips, harmonics and unbalanced three phase system.

## 2.10 Renewable Energy Technologies in Nepal

In Nepal, renewable energy such as Micro hydro mini grids (MHMGs), and solar Home Systems (SHSs) are tools help to electrify in many rural places and gives supply to 15% of population (Shakya, Bruce, & MacGrill, 2015) .The demand of energy has been consistently increasing annually and the peak demand growth rate of around 10% per year requires addition of generation as well (Ray & Jha, 2017) . However, RET do not provide reliable supply to rural areas, so the socio-economic benefits are not yet effective (Koirala, Schies, Ortiz, Limbu, & Shakya, 2013).

The importance of renewable energy has been increased all over the world (Thapa, Maharjan , Kaphle, Joshi, Rauniyaar, & Aryal, 2018) .Till 2018, more than 3000 MHPs around to 35 MW of produced in Nepal. It cost about NPR17-25 per Unit 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 unit via a 50-100 KW MHP that is tied to the Network. Proper utilization of MHP helps to earning works for rural people. The loss of underutilization is up to 72% which is huge loss. If connect mini grid, it helps to divert extra energy, loss reduces. Similarly, during less production, mini grid or MHPs can also get power from the Local distribution Network (Hydro Empowerment Network, 2018).

Load shedding of Nepal is being managed by significant import of electricity from India, thus increasing the trade deficit of Nepal (Shrestha & Raut, Assessment of Urban roof top Grid Connected Solar Potential in Nepal, 2018).

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 (Paudel & Gyawali, 2016) .If isolated mini grids will be tied to the distribution network , they could feed surplus electricity to the Local distribution grid and receive deficit energy from the Local distribution network (Bhandari & Adhikari, 2018).

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 (Pandey & Agrawal, 2018).The existing mini grid power will contribute to stabilize the weak national grid that will serve to the rural villages (Bhandari & Adhikari, 2018).

Community power is local power generation for users in rural areas for poor people who have no access to power grid electricity. Distributed renewables are not a replacement for centralized generation, bulk transmission or distribution facilities. They are another way to meet consumers' demand for power. With about 12.45% of Nepali's population without access to electricity, these smaller renewable applications offer electricity now where it is needed until we can expand the grid to reach them. These distributed resources may be small scale, but they are growing. Small hydro, Biomass, Geo-thermal can also be constructed fairly rapidly. Renewables tend to be modular.

### 2.11 Load Flow Analysis / Power Flow Analysis

Power flow analysis is very important tool in which helps in installing, operating, managing and maintaining the power system which incorporate planning, designing, expansion, addition of power system. Also it helps in meeting the demand of increased load and identifying location for new sites (Kothari, 2017).

- In Electrical engineering, load-flow study is a numerical solution of the flow of electric power in a connected system. A power-flow study uses one line diagram and per unit system which is a very simplified technique and focuses on various aspects of AC power parameters (Husain, 2011).

- The load flow solution yields the nodal voltages and the phase angles, the power injection, power flows and the line losses in a network.
- The best place, as well as the optimal capacity of a generating station, substation and new lines can regulate by load flow study.

The different conventional techniques for solving the power flow problem are:

- DC Load flow Method
- Newton Raphson (NR) Method
- DC Load flow Method
- Decoupled Load flow Method
- Fast Decoupled Load Flow (FDLF)
- Gauss-Seidel (GS) Method

### 2.11.1 Newton-Raphson Method

It has better convergence characteristics and faster method as they are mainly dependent on the initial values of bus voltage. The selection of initial values for bus voltage must be taken with utmost care. The Newton –Raphson method is used for update state variables and it gives to faster convergence characteristics. This method have very important functioning in identifying the location of capacitor placement, network configuration for optimal performance and restoration of service which is very essential for functioning of distribution system. (Pabla, 2015).

### 2.11.2 Backward / forward sweep Method

Distribution grid is numerically ill conditioned, due to small range of system reactance to system resistance i.e. X/R ratios and the radial topology, so it is recommended to use the Newton-Raphson method and decoupled method for transmission and sub-transmission grid. Due to the radial topology, Distribution power flow equations are slightly different in nature from transmission / sub-transmission power -flow equations. Efficient power-flow algorithms for solving radial distribution power problems are based on the backward / forward sweep which updates and calculates the state variable from the source node of the radial network to the end of the feeders and laterals and vice versa (Pabla, 2015).

## 2.12 ETAP

Electrical Transient Analyzer Program (ETAP) is used for the design, imitation, operation, and automation of generation, distribution, and industrial power systems and is the most comprehensive analysis platform. It is an electrical network modeling and simulation software tool used by Electrical engineers to find electrical power system dynamics, transients and protection (Khan, 2019). The ETAP gives unique quadratic convergence characteristic. Generally, it is a very fast convergence speed compared to other.

## CHAPTER THREE

## RESEARCH METHODOLOGY

### 3.1 Methodology

This study is targeted on analyzing the effect of grid interconnection of isolated mini grid with Grid. To obtain objective of a research, the mini network is modelled and simulation is performed for various operating conditions.

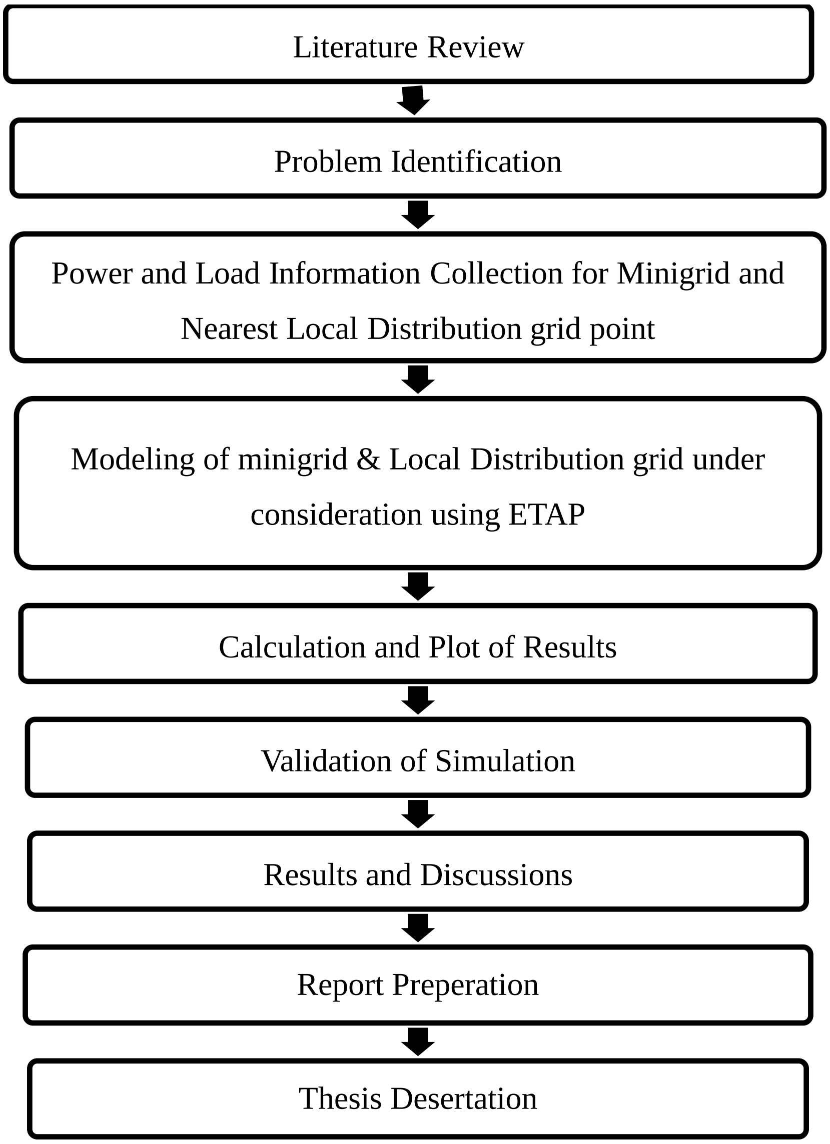


Figure 8: Flowchart for Complete Research Work

The analysis and finalization of research work in the aforementioned flowchart may be detailed with the following flowchart:

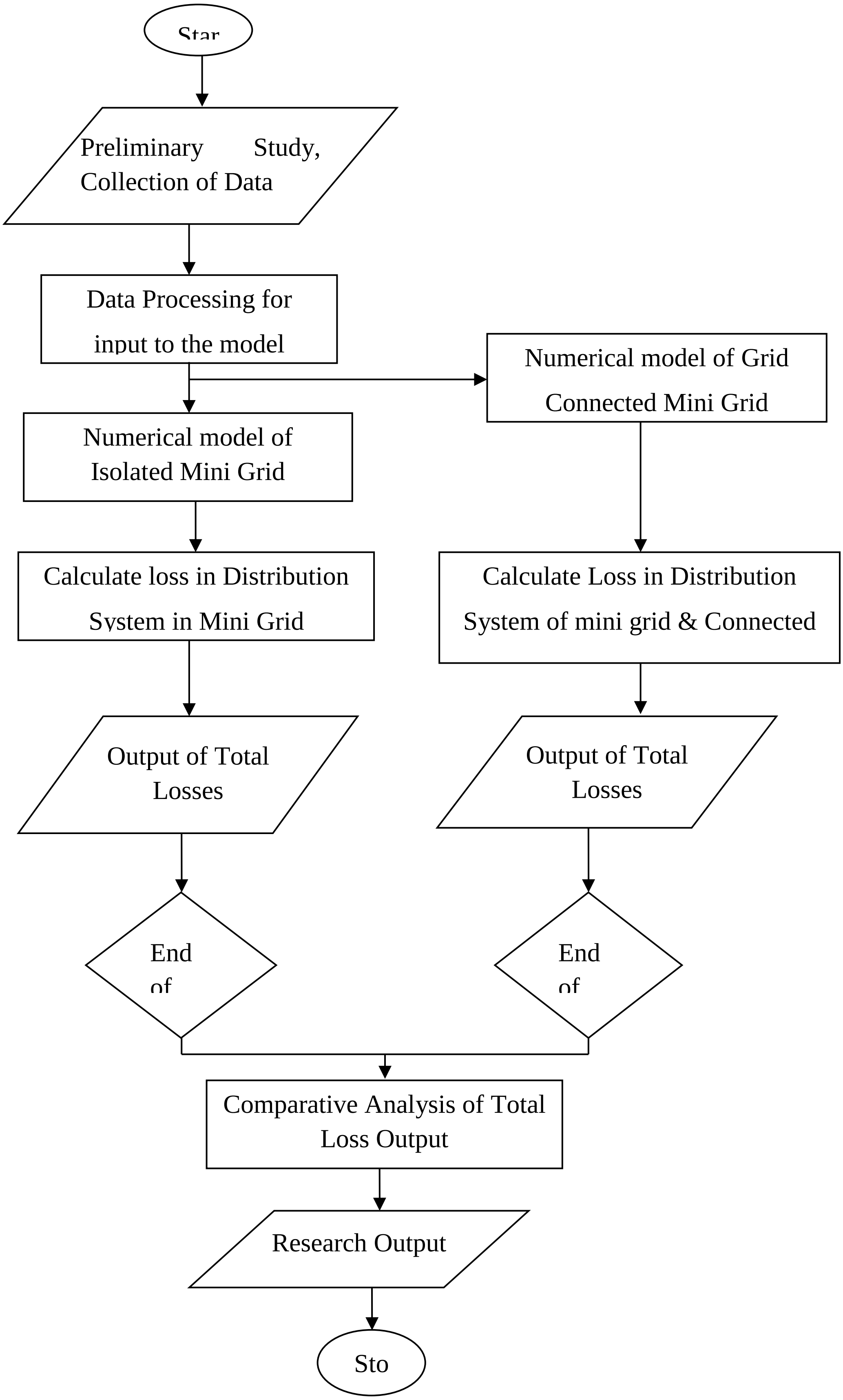


Figure 9: Flowchart for Analysis of Research work

The system under study is modelled and simulated in ETAP and the results are presented and discussed in this research.

### 3.2 Preliminary Study

The mini grid system was thoroughly studied and various information of mini grid regarding to technical aspects are collected and studied. The literatures in connection with the mini grid were studied and the study area was selected. Preliminary study is performed based on the information available at various agencies like NEA, AEPC, etc. The Taplejung Mini Grid, Taplejung, Province 1, Nepal selected as the operational mini grid near to grid , interconnected operational data available and considerable size of generation are the study area as the result of preliminary study. (AEPC, 2018/19)

### 3.3 Study Area

The research location for this research is taken as Taplejung District. It located around 850 km North East of Kathmandu. Taplejung district lies in the Mechi zone of Province no. 1 of Nepal. Taplejung district is one of the districts which are recently connected by National Network.

Six MHPs in the study area running in off grid mode. The house mark in the diagram represents the off grid MHP. These plants are proposed for tied making 11kV mini-grid and connected to grid. The layout of MHP in isolation mode is presented in figure 30 in annex 1.

The location of the above micro hydropower plant with their GPS co-ordinate location, village development committee, installed capacity and the name of the plants are shown in the table 1:

Table 1: The micro hydropower plant with their size, location, and GPS co-ordinate (District Development Committee, Taplejung, 2016)

| **S.N** | **Descriptions of Scheme** | **Power (kW)** | **Northing** | **Easting** |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | Metham Khola | 65 | 27°27'27.06"N | 87°42'16.60"E |
| 2 | Tewa-Mekwa khola | 60 | 27°29'26.23"N | 87°44'46.23"E |
| 3 | Tawa Khola | 36 | 27°27'6.43"N | 87°43'32.01"E |
| 4 | Yafre-Mauwa Khola | 95 | 27°25'38.66"N | 87°42'14.34"E |
| 5 | Phawa Khola | 70 | 27°23'3.29"N | 87°46'50.40"E |
| 6 | Middle Phawa | 500 | 27°21'25.68"N | 87°46'53.99"E |

The total connected power of the above 6 plants is 826 kW.

The micro hydropower plant which were connected to form mini grid power system are as follows: (District Development Committee, Taplejung, 2016)

### 3.3.1 Phawa Khola Micro Hydropower Plant

The Phawa Khola MHP is located at Phawa Khola of Sikaicha VDC of Taplejung Districit with 42 m gross head, 305 LPS design discharge and an installed capacity of 70 kW benefitting 545 Households.

### 3.3.2 Yafre-Mauwa Khola Micro Hydropower Plant

Yafre - Mauwa Khola MHP is located at Hangdewa and Phurumbu VDC of Taplejung district with 147 m gross head, 113 LPS design discharge and installed capacity of 95 kW benefitting 800 Households.

### 3.3.3 Tawa Khola Micro Hydropower Plant

Tawa Khola MHP is located at Linkhim VDC of Taplejung district with 119 m gross head, 63 LPS design discharge and installed capacity of 36 kW serving 289 Households.

### 3.3.4 Methem Khola Micro Hydropower Plant

Methem Khola MHP is located at Khejenim VDC of Taplejung District with 178 m gross head, 65 LPS design discharge and 65 kW installed capacity serving 400 households.

### 3.3.5 Tewa-Mekwa Khola Micro Hydropower Plant

Tewa-Mekwa Khola MHP is located at Ekhabu, Lingkhim & Tapethok VDC of Taplejung district with 70 m gross head, 160 LPS design discharge and installed capacity of 60 kW serving 407 households.

### 3.3.6 Middle Phawa Khola Mini Hydropower Plant

Middle Phawa Khola MHP is located at Hangpang VDC of Taplejung district with 50 m gross head, 950 LPS design discharge and installed capacity 500 kW serving 1700 households.

### 3.3.7 Sobuwa Khola Micro Hydropower Plant-Chimal

Sobuwa Khola MHP is located at Hangpang VDC , Taplejung district with 68 m gross head, 211 LPS design discharge and installed capacity of 90 kW serving 750 households. This MHP is recently connected to Local Distribution Grid.

### 3.3.8 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 Substation located at Amarpur (Singhapur )(Now: Hilihang Rural Municipality) of Pachathar districit about 40 km with Dog Conductor. 6/8 MVA Power Transformer is installed in Phungling Bazar. The load of Taplejung is about 2 MVA (NEA, A year in review -fiscal year , 2018/19).

## 3.4 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).

## 3.5 Field Visit

The field visit is conducted for in depth study of the sample. Electrification data are acquired from the field. The data collection is focused in the Technical aspects of operational mini grid system.

The major data are collected from field visit are as follows:

### 3.5.1 Generation Data

The daily generation data of each generating stations in the MHP is received by from study area.

### 3.5.2 Demand side data

The daily load for all the load centers is received from the study area.

### 3.5.3 Grid data

The data regarding the Grid supply to the nearest connecting point of the mini grid with is acquired. Also, the load center characteristics of load centers supplied by the Grid near to the connecting point is collected (NEA, A year book fiscal year , 2018/19).

### 3.5.4 Others

Other relevant data necessary for the study shall be acquired from the mini grid during field visit (Gyawali, 2014).

## 3.6 Data Processing and Analysis

The technical aspects for connecting the mini grid system with Grid is analyzed. The model of the mini grid is prepared in ETAP software. The data collected during the field visit is processed for preparing the input for the model.

The data are analyzed with the intent of determining comparative losses and reliability in various cases. The comparative study of the data received from grid connected mini grid model and isolated mini grid model is performed to determine the impact of mini grids in LDG.

## 3.7 Interpretation of Results

The output of data analysis are compared and interpreted to reach a conclusion on the impact of grid connected mini grid.

The results of data analysis are interpreted and presented in reportable form in order to reach a concluding remarks on the research. The research outcome are presented in the form of research article too.

# CHAPTER FOUR

# MODELLING AND CALCULATION

## 4.1 Modelling

The model developed including Taplejung Grid, NEA distribution and transmission system with step-up transformer for grid impact study is shown in figure 18. The simulation study is done with following assumptions (NEA, A year in review -fiscal year , 2018/19).

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.

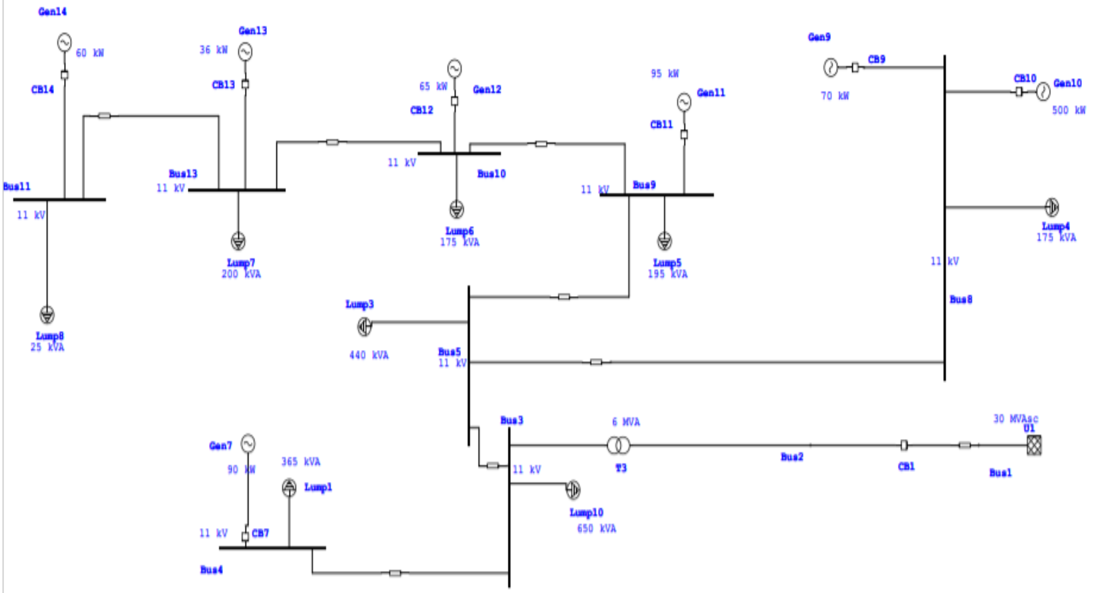


Figure 10: Single Line Diagram of Grid, Mini-grid & Chimal Plant (90kW)

The grid integration study is done with seven cases. The simulation diagram for various cases are elaborated ahead.

### 4.1.1 Simulation including Grid Only

The simulation is done including the grid only in this case to determine the current scenario of distribution systems. This can also be considered as the base case (Case I).

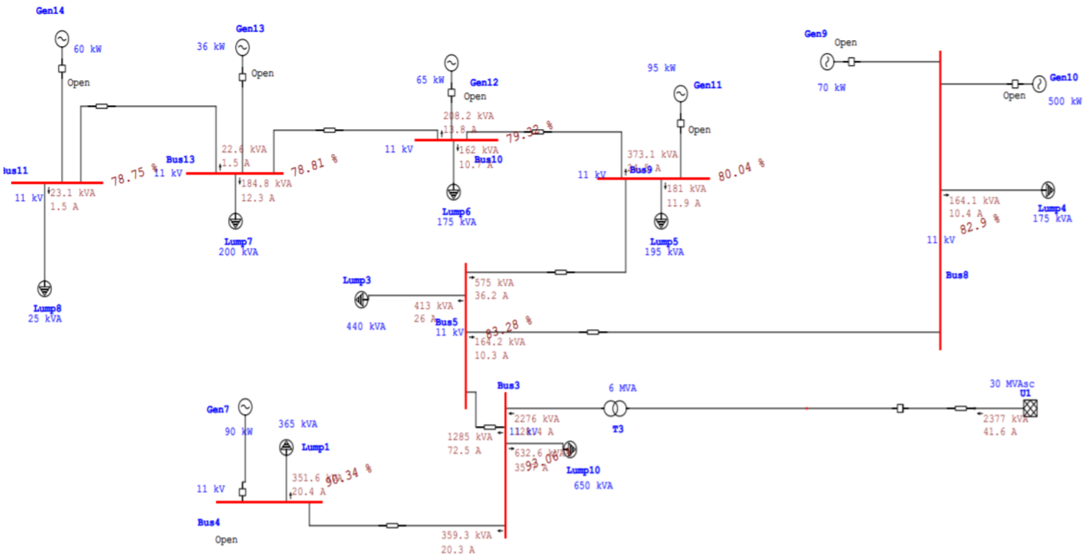


Figure 11: Simulation Diagram for Grid Only.

Tabular output including various parameters in Case I is presented in the table:

Table 2: Load Data for Simulation for Grid supply only

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** |
|---|---|---|---|---|---|---|---|
| 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 |

%Average Voltage: 83.3 3 Phase Voltage: 333.0 V

Table 3: Source Data for Simulation for Grid supply only

| ID | Bus No. | Source | Voltage kV | Power | MVAR | Amp | % PF |
|---|---|---|---|---|---|---|---|
| U1 | Bus1 | 30 MVA | 33 | 2.002 | 1.283 | 41.59 | 84.2 |

Table 4: Branch Data for Simulation for Grid supply only

| 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 |

Table 5: Bus Data for Simulation for Grid supply only

| Bus ID | Standard 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 |

Table 6: General Data for Simulation for Grid supply only

| Description | Value |
|---|---|
| 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 |

### 4.1.2 Simulation including grid and Chimal MHP

The simulation is performed including the grid connected with Chimal Micro hydro plant in this case. The results and their comparison to the earlier case (Case I) are analyzed. This case shall be referred to as Case II.

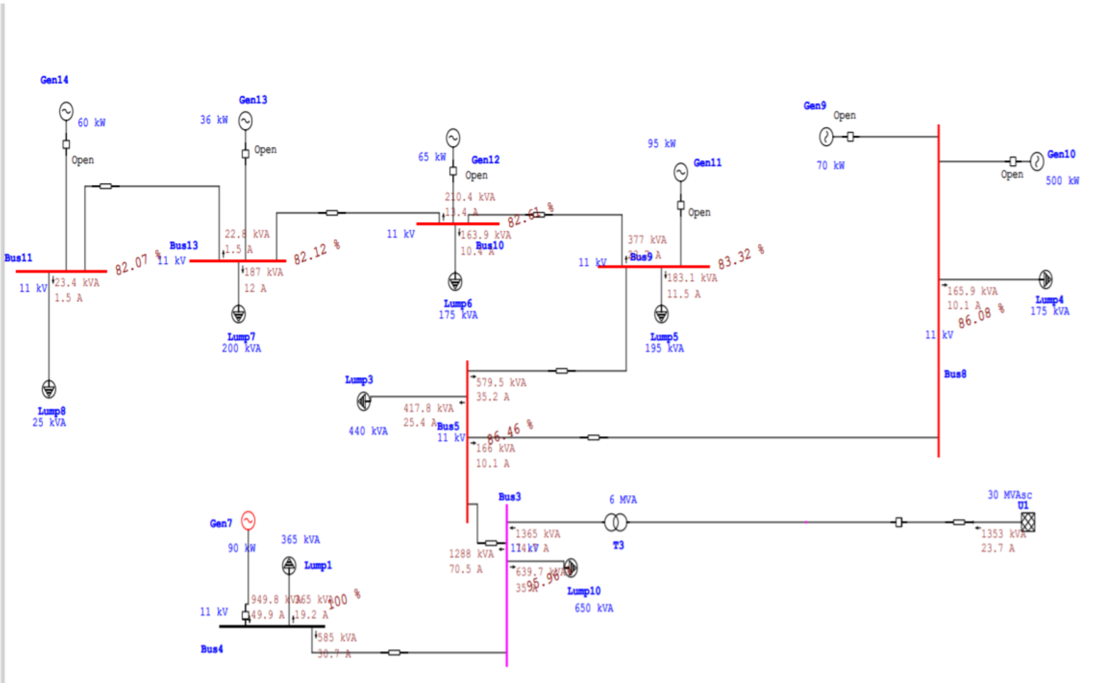


Figure 12: Simulation Diagram for Grid and Chimal MHP

Tabular output including various parameters in Case II is presented in the table:

Table 7: Load Data for Simulation for Grid and Chimal MHP

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** |
|---|---|---|---|---|---|---|---|
| 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 |

% Average Terminal Voltage: 87.3 3 phase voltage: 349.28 V

Table 8: Source Data for Simulation for Grid and Chimal MHP

| **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 |

Table 9: Branch Data for Simulation for Grid and Chimal MHP

| **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 |

Table 10: Bus Data for Simulation for Grid and Chimal MHP

| **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 |

Table 11: General Data for Simulation for Grid and Chimal MHP

| **Description** | **Value** |
|---|---|
| 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 |

### 4.1.3 Simulation including Grid and 500 KW MHP

The simulation is performed including the grid connected with 500 kW Micro hydro plant in this case. The results and their comparison to the earlier cases (Case I & Case II) are analyzed. This case shall be referred to as Case III.

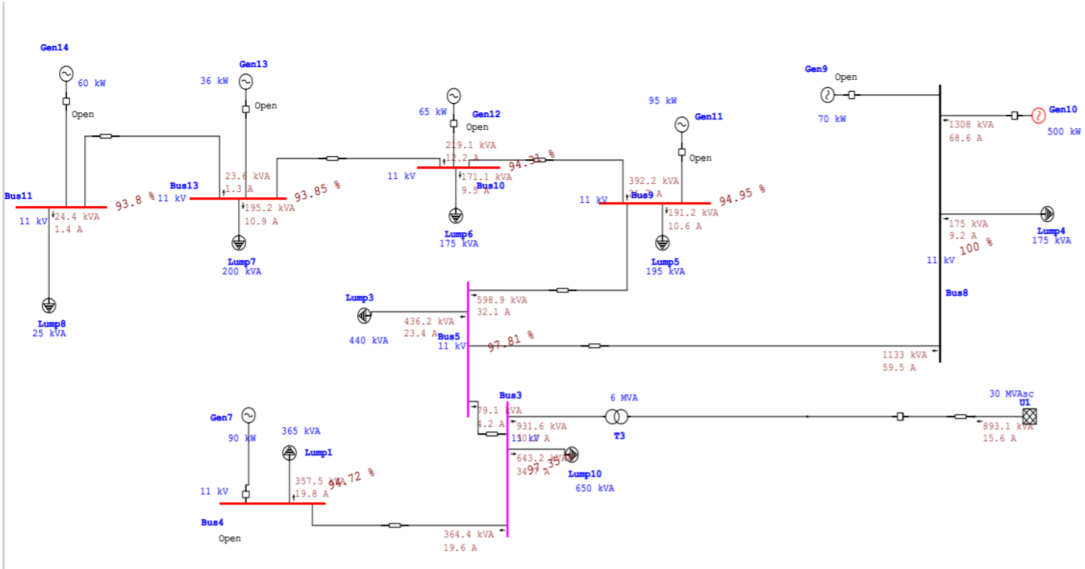


Figure 13: Simulation Diagram including Grid and 500 KW MHP

Tabular output including various parameters in Case III is presented in the table:

Table 12: Load Data for Simulation for Grid and 500KW MHP

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| Lump 1 | 365 kVA | 11 | 304.6 | 188.8 | 19.72 | 85 | 103 | 95.37 |
| Lump 3 | 440 kVA | 11 | 374 | 231.8 | 23.09 | 85 | 100 | 100 |
| Lump 4 | 175 kVA | 11 | 148.5 | 92.06 | 9.204 | 85 | 100.2 | 99.66 |
| Lump 5 | 195 kVA | 11 | 163.9 | 101.6 | 10.41 | 85 | 101.8 | 97.18 |
| Lump 6 | 175 kVA | 11 | 146.7 | 90.94 | 9.385 | 85 | 102.2 | 96.55 |
| Lump 7 | 200 kVA | 11 | 167.4 | 103.7 | 10.76 | 85 | 102.5 | 96.1 |
| Lump 8 | 25 kVA | 11 | 20.92 | 12.97 | 1.345 | 85 | 102.5 | 96.05 |
| Lump | 650 kVA | 11 | 548.1 | 339.7 | 34.54 | 85 | 101.2 | 97.99 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10 | | | | | | | | |

%Average Terminal Voltage: 98.3 3 Phase Voltage: 393 V

Table 13: Source Data for Simulation for Grid and 500kW MHP

| ID | Terminal Bus | Source | Voltage(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 |

Table 14: Branch Data for Simulation for Grid and 500kW MHP

| 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 |

Table 15: Bus Data for Simulation for Grid and 500kw MHP

| Bus ID | Standard 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 |

Table 16: Bus Data for Simulation for Grid and 500kw MHP

| **Description** | **Value** |
|---|---|
| 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 | 0.05030 |
| Loss- MVAR | -0.101 |

### 4.1.4 Simulation of Grid excluding 500 kW MHP Plant

The simulation is performed including the Grid and all other plants but excluding the 500 kW Micro hydro plant in this case. The results and their comparison to the earlier case (Case I, II & III) are analyzed. This case shall be referred to as Case IV.

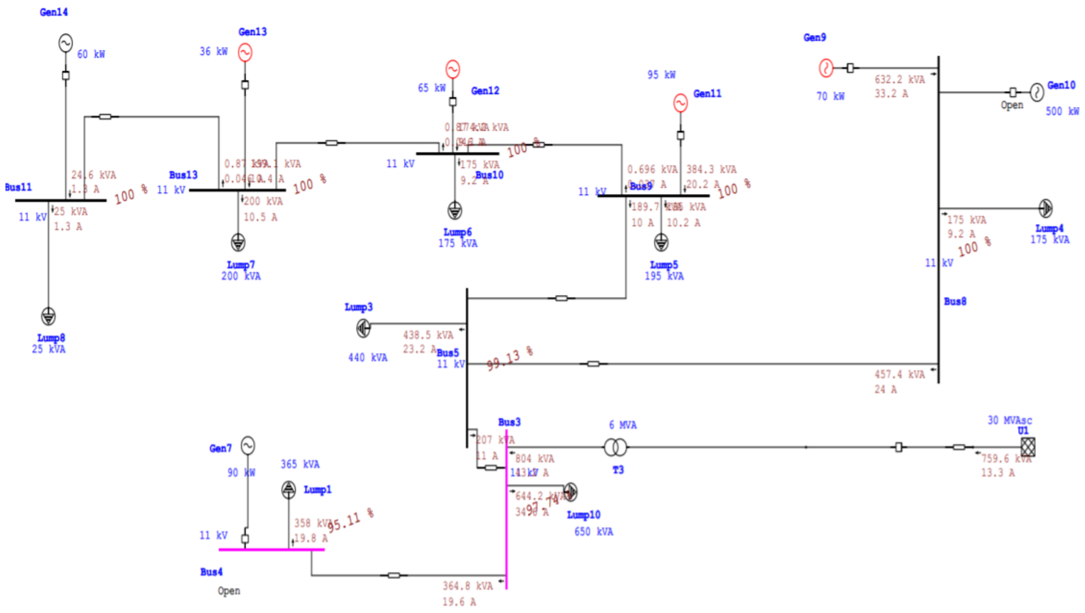


Figure 14: Simulation Diagram for Grid excluding 500 kW MHP

Tabular output including various parameters in Case IV is presented in the table:

Table 17: Load Data for Simulation of Grid excluding 500kW MHP

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| Lump1 | 365 kVA | 11 | 304.3 | 188.6 | 19.76 | 85 | 103.1 | 95.11 |
| Lump3 | 440 kVA | 11 | 372.7 | 231 | 23.22 | 85 | 100.5 | 99.13 |
| 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 | 547.6 | 339.3 | 34.59 | 85 | 101.4 | 97.74 |

%Average Terminal Voltage: 97.5 3 Phase Voltage: 390 V

Table 18: Source Data for Simulation of Grid excluding 500kW MHP

| **ID** | **Bus Number** | **Source** | **Voltage( 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 |

Table 19: Branch Data for Simulation of Grid excluding 500kW MHP

| **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 |

Table 20: Bus Data for Simulation of Grid excluding 500kW MHP

| **Bus ID** | **Standard 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 |
| Bus13 | 11 | 100 | 0.17 |

Table 21: Bus Data for Simulation of Grid excluding 500kW MHP

| **Description** | **Value** |
|---|---|
| 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 |

### 4.1.5 Simulation with mini grid and Chimal MHP

The simulation is performed including the Mini grid and Chimal Micro hydro plant in this case. The results and their comparison to the earlier case (Case I, II, III & IV) are analyzed. This case shall be referred to as Case V.

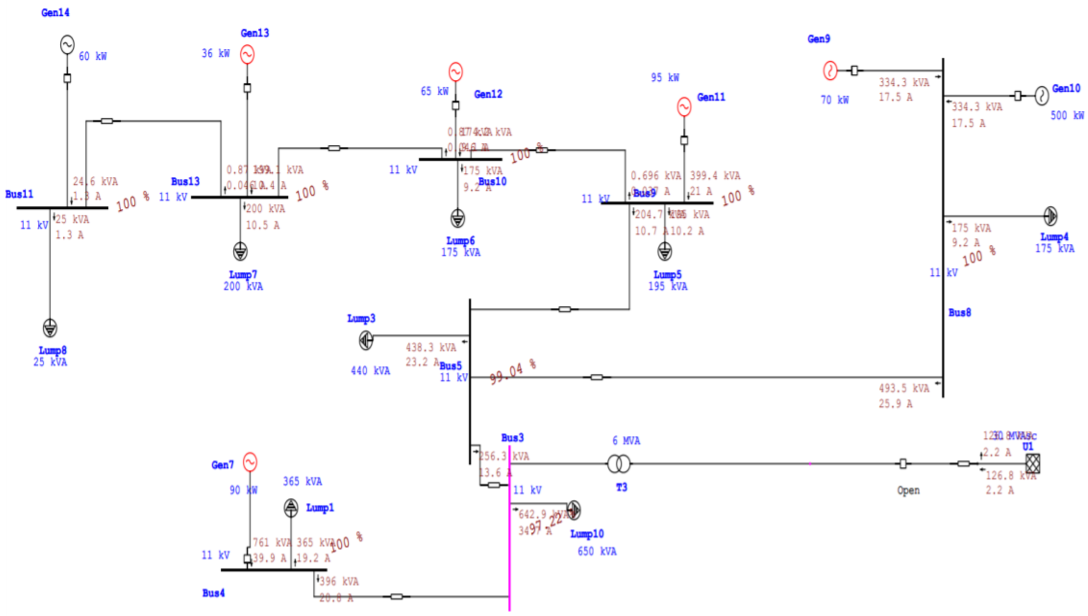


Figure 15: Simulation Diagram for Mini-grid with Chimal MHP

Tabular output including various parameters in Case V is presented in the table:

Table 22: Load Data for Simulation for mini grid and Chimal MHP Plant

| **Load** | **Voltage (kV)** | **Power (Kw)** | **Kvar** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| 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 |

%Average Terminal Voltage: 99.5 3 Phase Voltage: 398 V

Table 23: Source Data for Simulation for mini grid and Chimal MHP Plant

| ID | Bus number | Source | Voltage (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 |

Table 24: Branch Data for Simulation for mini grid and Chimal MHP Plant

| 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 |

Table 25: Bus Data for Simulation for mini grid and Chimal MHP Plant

| Bus ID | Standard 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 |

Table 26: General Data for Simulation for mini grid and Chimal MHP Plant

| **Description** | **Value** |
|---|---|
| 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 | 0.0144 |
| Loss- MVAR | -0.137 |

### 4.1.6 Simulation with grid integration of Chimal MHP, mini grid and Grid

The simulation is performed including the Mini grid, Grid and Chimal Micro hydro plant in this case. The results and their comparison to the earlier case (Case I, II, III, IV & V) are analyzed. This case shall be referred to as Case VI.

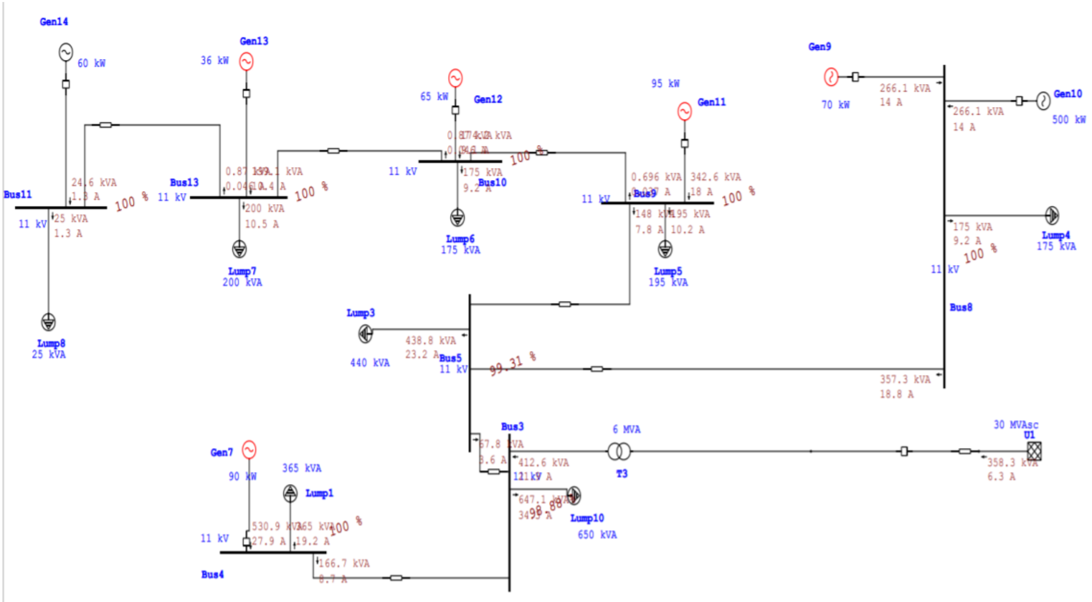


Figure 16: Simulation Diagram for simulation including Grid, Mini grid and Chimal MHP

Tabular output including various parameters in Case VI is presented in the table:

Table 27: Load Data Simulation for mini grid, Chimal MHP and Grid

| Load | Voltage (kV) | Power (Kw) | kVA R | Amp | % PF | % Loading | V (%) terminal | Load |
|---|---|---|---|---|---|---|---|---|
| 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 |

%Average Terminal Voltage: 99.9 3 Phase Voltage: 399.0 V

Table 28: Source Data Simulation for mini grid, Chimal MHP and Grid

| ID | Bus Number | Sourc | Voltage (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 |

Table 29: Branch Data Simulation for mini grid, Chimal MHP and Grid

| 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 |

Table 30: Bus Data Simulation for mini grid, Chimal MHP and Grid

| Bus ID | Standard ( 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 |

Table 31: General Data Simulation for mini grid, Chimal MHP and Grid

| **Description** | **Value** |
|---|---|
| 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 | 0.0062 |
| Loss- MVAR | -0.143 |

### 4.1.7 Simulation including mini grid only

The simulation is performed including the Mini grid and Chimal Micro hydro plant in this case. The results and their comparison to the earlier case (Case I, II, III, IV, V & VI) are analyzed. This case shall be referred to as Case VII.

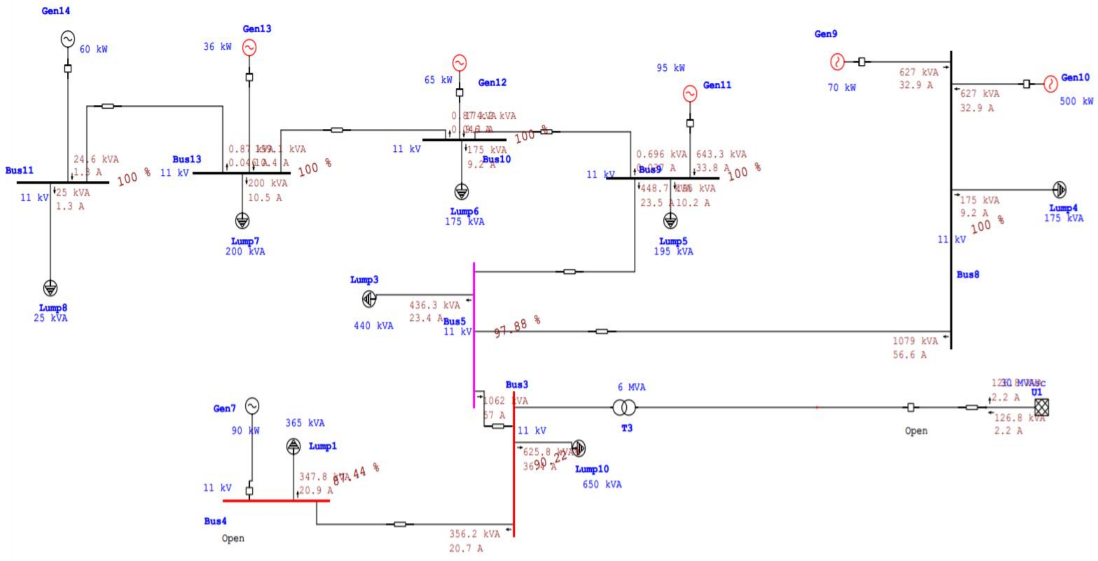


Figure 17: Simulation Diagram for Mini Grid Only.

Tabular output including various parameters in Case VII is presented in the table:

Table 32: Load Data Simulation for mini grid only

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVA R** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| 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 |
| nLump 6 | 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 | 92.47 |

%Average Terminal Voltage: 96.7    3 Phase Voltage: 387 V

Table 33: Source Data for Simulation for mini grid only

| ID | Bus Number | Source | Voltage (kV) | MW | MVAR | Amp | % PF |
|---|---|---|---|---|---|---|---|
| Gen9 | Bus8 | 0.07 MW | 11 | 0.149 | 0.0913 | 9.161 | 85.22 |
| Gen10 | Bus5 | 0.5 MW | 11 | 1.266 | 0.814 | 79.02 | 84.12 |
| 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 |

Table 34: Branch Data for Simulation for mini grid only

| 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 |

Table 35: Bus Data for Simulation for mini grid only

| Bus ID | Standard( 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 |

Table 36: General Data for Simulation for mini grid only

| **Description** | **Value** |
|---|---|
| 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 | 0.0803 |
| Loss- MVAR | -0.0696 |

## 4.2 Optimization of DG

### 4.2.1 Simulation Phase I: Power System excluding DG connection:

The Grid with the capacity of 30MVA is tied to bus no.2 of power Network shown in Fig. 18. The standard supply voltage of the distribution network is 33KV which is supplied 11 KV buses of given 8 buses through 33/11 KV, 6MVA Transformer.

The transformer T3 is tied to bus no.-2 which steps down for entire power system. The voltage and capacity of T3 is 33/11kV and 6 MVA respectively. No load is connected directly to bus- no.2 while other buses are loaded.

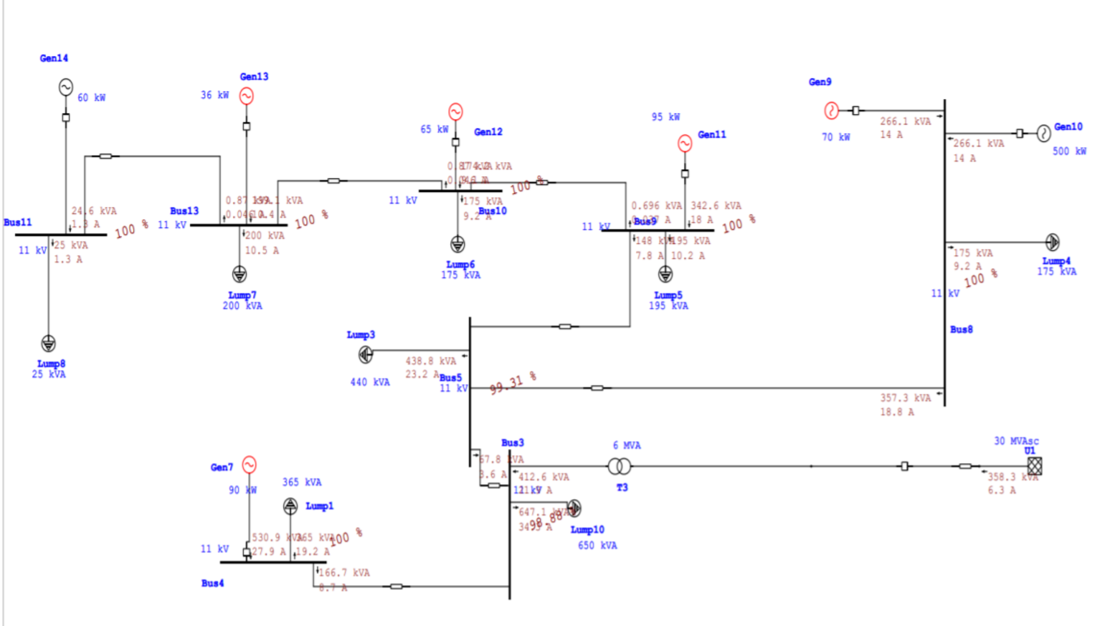


Figure 18: Load flow analysis of power system excluding DG.

Table 37: Load Data of Load flow analysis of power system excluding DG.

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| 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 |

%Average Terminal Voltage: 99 3 Phase Voltage: 399 V

Table 38: Source Data of Load flow analysis of power system excluding DG

| ID | Bus Number | Source | Voltage (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 |

Table 39: Branch Data of Load flow analysis of power system excluding DG

| 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 |

Table 40: Bus Data of Load flow analysis of power system excluding DG

| Bus ID | Standard 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 |

Table 41: General Data of Load flow analysis of power system excluding DG

| **Description** | **Value** |
|---|---|
| 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 | 0.0062 |
| Loss-MVAR | -0.143 |

Optimization in phase First, the load flow analysis is done on entire network excluding connecting the DG so that the effect of losses and voltage profile studied. The analysis shows load terminal voltage and total losses of entire network as shown in Table 37-41 and figure 26.

The whole network losses after load flow study excluding DG is 6.2 kW and three phase load terminal voltage is 399 V. This is the power losses and voltage drop for any power system that must be reduce by siting of distribution generation. We have selected DG 20% to 30% of installed capacity rating of 826kW. The DG must be placed in right place so that DG may be tied to the bus bar provides smallest losses as well reduces prices respectively and improved Voltage profile which gives in maximizing the potential benefits.

### 4.2.2 Simulation Phase II: Power System including DG

Distributed generator having capacity 250kW is now tied to the network and find out the impact of DG on the entire system. Bus-no.2 is connected to the main distribution network so its standard voltage rating is 33kV, while the remaining buses are rated with 11kV.

#### *4.2.2.1 Power system including DG to Bus-3*

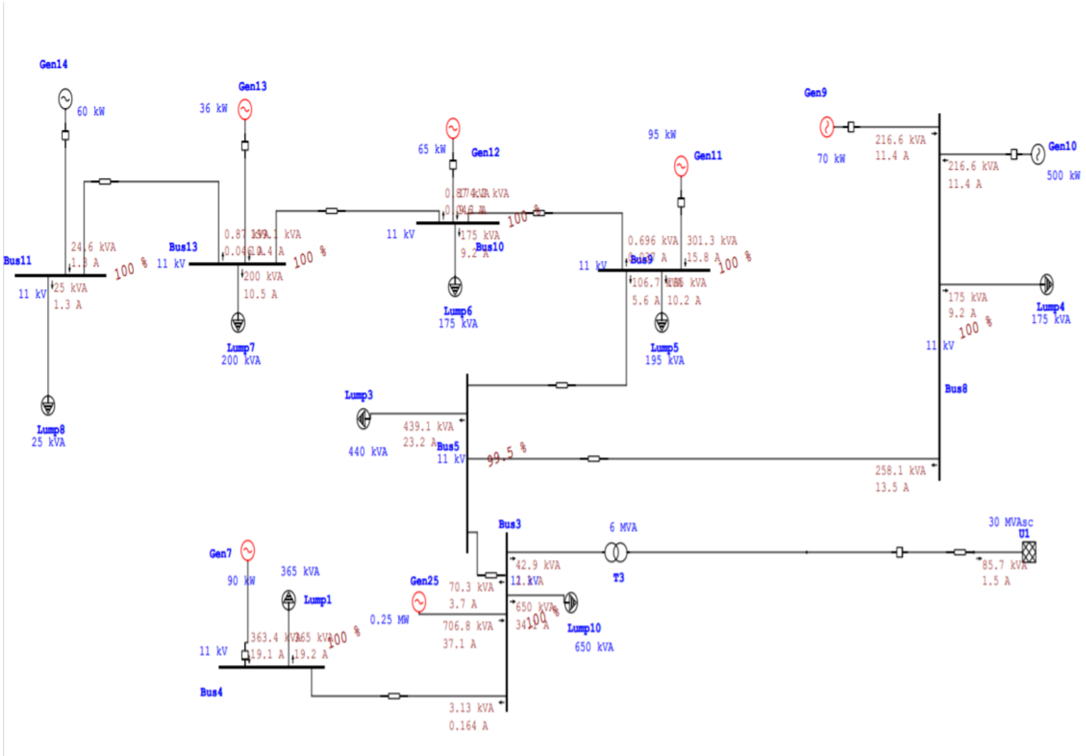

Figure 19: Load flow analysis of power system including DG to Bus 3

Table 42: Load Data of Load flow analysis of power system including DG to Bus 3

| Load | Voltage (kV) | Power (Kw) | kVAR | Amp | % PF | % Loading | V (%) terminal |
|---|---|---|---|---|---|---|---|
| Lump1 | 365 kVA | 11 | 310.3 | 192.3 | 19.16 | 85 | 100 |
| Lump3 | 440 kVA | 11 | 373.3 | 231.3 | 23.16 | 85 | 100.3 |
| Lump4 | 175 kVA | 11 | 148.8 | 92.19 | 9.185 | 85 | 100 |
| Lump5 | 195 kVA | 11 | 165.8 | 102.7 | 10.23 | 85 | 100 |
| Lump6 | 175 kVA | 11 | 148.8 | 92.19 | 9.185 | 85 | 100 |
| Lump7 | 200 kVA | 11 | 170 | 105.4 | 10.5 | 85 | 100 |
| Lump8 | 25 kVA | 11 | 21.25 | 13.17 | 1.312 | 85 | 100 |
| Lump10 | 650 kVA | 11 | 552.5 | 342.4 | 34.12 | 85 | 100 |

%Average Terminal Voltage: 99.93 3 Phase Voltage: 399.75V

Table 43: Source Data of Load flow analysis of power system including DG to Bus 3

| ID | Bus Number | Source | Voltage (kV) | MW | MVAR | Amp | % PF |
|---|---|---|---|---|---|---|---|
| Gen7 | Bus4 | 0.09 MW | 11 | 0.31 | 0.189 | 19.07 | 85.38 |
| Gen9 | Bus8 | 0.07 MW | 11 | 0.185 | 0.113 | 11.37 | 85.39 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gen10 | Bus8 | 0.5 MW | 11 | 0.185 | 0.113 | 11.37 | 85.39 |
| Gen11 | Bus9 | 0.095 MW | 11 | 0.258 | 0.156 | 15.81 | 85.59 |
| 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 |
| Gen25 | Bus3 | 0.25 MW | 11 | 0.624 | 0.332 | 37.1 | 88.3 |
| U1 | Bus1 | 30 MVA | 33 | -0.0101 | -0.0851 | 1.499 | 11.83 |

Table 44: Branch Data of Load flow analysis of power system including DG to Bus 3

| ID | Type | kW Flow | kVAR Flow | Amp Flow |
|---|---|---|---|---|
| Line1 | Line | 10.14 | 85.09 | 1.499 |
| Line2 | Line | 0 | -3.13 | 0.164 |
| Line10 | Line | 61.19 | 40.03 | 3.857 |
| Line13 | Line | 220.3 | 133.8 | 13.6 |
| Line19 | Line | 91.78 | 57.47 | 5.712 |
| Line21 | Line | 0 | -0.696 | 0.037 |
| Line22 | Line | 0 | -0.87 | 0.046 |
| Line24 | Line | 0 | -0.87 | 0.046 |
| T3 | Transf. 2W | 10.15 | -41.68 | 0.75 |

Table 45: Bus Data of Load flow analysis of power system including DG to Bus 3

| Bus ID | Standard kV | Voltage | MW Loading |
|---|---|---|---|
| Bus1 | 33 | 100 | 0.0101 |
| Bus3 | 11 | 100 | 0.624 |
| Bus4 | 11 | 100 | 0.31 |
| Bus5 | 11 | 99.5 | 0.373 |
| Bus8 | 11 | 100 | 0.37 |
| Bus9 | 11 | 100 | 0.258 |
| Bus10 | 11 | 100 | 0.149 |
| Bus11 | 11 | 100 | 0.0213 |
| Bus13 | 11 | 100 | 0.17 |

Table 46: General Data of Load flow analysis of power system including DG to Bus 3

| Description | Value |
|---|---|
| Buses | 10 |
| Branches | 9 |
| Generators | 8 |
| Power Grids | 1 |
| Loads | 8 |
| Load-MW | 1.892 |
| Load- MVAR | 1.024 |
| Generation-MW | 1.892 |
| Generation- MVAR | 1.024 |
| Loss-MW | 0.0014 |
| Loss- MVAR | -0.148 |

The Percentage voltage drop, load terminal voltage, kVA and current flowing at each bus is shown in Table 42 - 46 and Figure 19. From table, it is clear that the total network losses after the load flow analysis including DG to Bus 3 was 1.4 kW and three phase load terminal voltage is 400 V.

### *4.2.2.2 Power system including DG to Bus-4:-*

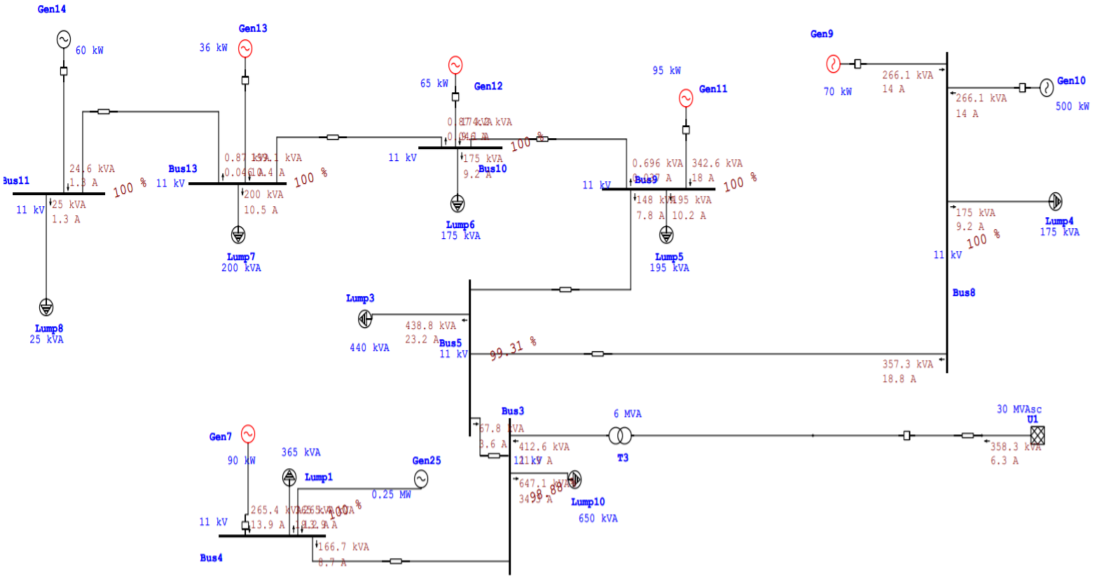


Figure 20: Load flow analysis of power system including DG to Bus 4

Table 47: Load Data of Load flow analysis of power system including DG to Bus 4

| Load | Voltage (kV) | Power (Kw) | kVAR | Amp | % PF | % Loading | V (%) terminal | Load |
|---|---|---|---|---|---|---|---|---|
| Lump1 | 365 kVA | 11 | 310.3 | 192.3 | 19.16 | 85 | 100 | 100 |
| Lump3 | 440 kVA | 11 | 373 | 231.2 | 23.19 | 85 | 100.4 | 99.31 |
| 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 | 340.9 | 34.35 | 85 | 100.7 | 98.88 |

%Average Terminal Voltage: 98.9 3 Phase Voltage: 395 V

Table 48: Source Data of Load flow analysis of power system including DG to Bus 4

| ID | Bus Number | Source | Voltage (kV) | MW | MVAR | Amp | % PF |
|---|---|---|---|---|---|---|---|
| Gen7 | Bus4 | 0.09 MW | 11 | 0.231 | 0.131 | 13.93 | 86.93 |
| Gen9 | Bus8 | 0.07 MW | 11 | 0.23 | 0.135 | 13.97 | 86.28 |
| Gen10 | Bus8 | 0.5 MW | 11 | 0.23 | 0.135 | 13.97 | 86.28 |
| Gen11 | Bus9 | 0.095 MW | 11 | 0.295 | 0.174 | 17.98 | 86.14 |
| 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 |
| Gen25 | Bus4 | 0.25 MW | 11 | 0.231 | 0.131 | 13.93 | 86.93 |
| U1 | Bus1 | 30 MVA | 33 | 0.338 | 0.119 | 6.269 | 94.37 |

Table 49: Branch Data of Load flow analysis of power system including DG to Bus 4

| ID | Type | kW Flow | KVAR Flow | Amp Flow |
|---|---|---|---|---|
| Line1 | Line | 335.9 | 242 | 7.301 |
| Line2 | Line | 150 | 74.61 | 8.891 |
| Line10 | Line | 64.39 | 26.31 | 3.692 |
| Line13 | Line | 308.9 | 176.4 | 18.8 |
| Line19 | Line | 128.7 | 75.2 | 7.878 |
| Line21 | Line | 0 | -0.696 | 0.037 |
| Line22 | Line | 0 | -0.87 | 0.046 |
| Line24 | Line | 0 | -0.87 | 0.046 |
| T3 | Transf. 2W | 335.9 | 242 | 7.301 |

Table 50: Bus Data of Load flow analysis of power system including DG to Bus 4

| Bus ID | Standard kV | Voltage | MW Loading |
|---|---|---|---|
| Bus1 | 33 | 100 | 0.338 |
| Bus3 | 11 | 98.88 | 0.55 |
| Bus4 | 11 | 100 | 0.461 |
| Bus5 | 11 | 99.31 | 0.438 |
| Bus8 | 11 | 100 | 0.459 |
| Bus9 | 11 | 100 | 0.295 |
| Bus10 | 11 | 100 | 0.149 |
| Bus11 | 11 | 100 | 0.0213 |
| Bus13 | 11 | 100 | 0.17 |

Table 51: Branch Data of Load flow analysis of power system including DG to Bus 4

| **Description** | **Value** |
| --- | --- |
| Buses | 10 |
| Branches | 9 |
| Generators | 8 |
| Power Grids | 1 |
| Loads | 8 |
| Load-MW | 1.894 |
| Load-MVAR | 1.03 |
| Generation-MW | 1.894 |
| Generation-MVAR | 1.03 |
| Loss-MW | 0.0062 |
| Loss-MVAR | -0.139 |

The Percentage voltage drop, load terminal voltage, kVA and current flowing at each bus are shown in Table 47-51 and Figure 20. From table, it is clear that the total network losses after execution of load flow analysis including DG to Bus 4 was 6.2 kW and three phase load terminal voltage is 395 V.

#### *4.2.2.3 Power system including DG to Bus-5*

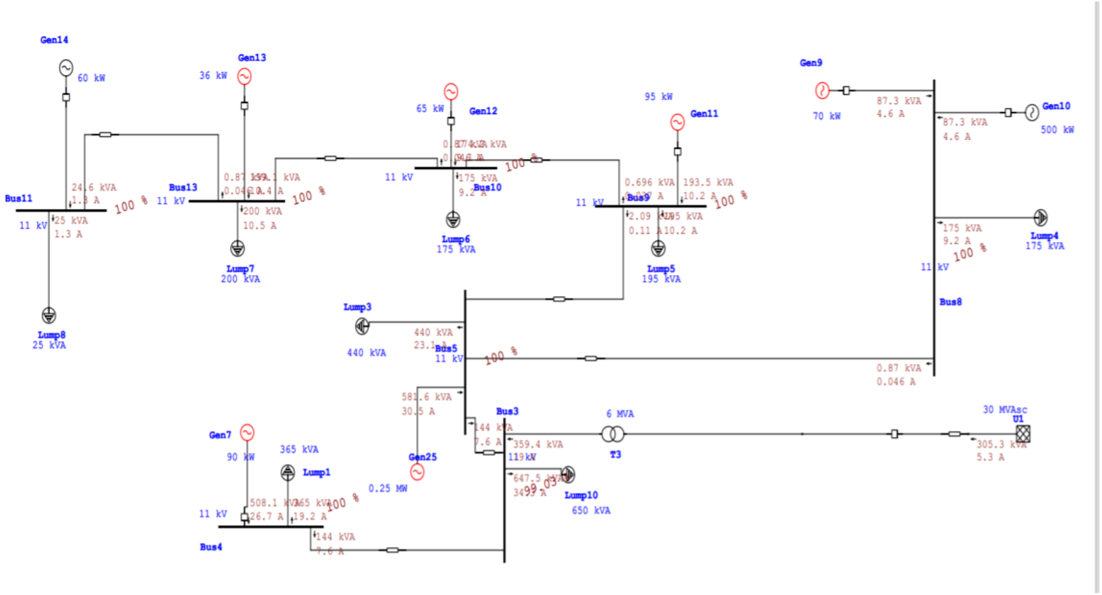


Figure 21: Load flow analysis of power system including DG to Bus 5

Table 52: Load Data of Load flow analysis of power system including DG to Bus 5

| **Load** | **Voltage (kV)** | **Power (Kw)** | **kVAR** | **Amp** | **% PF** | **% Loading** | **V (%) terminal** | **Load** |
|---|---|---|---|---|---|---|---|---|
| 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 |

%Average Terminal Voltage: 99 3 Phase Voltage: 398 V

Table 53: Source Data of Load flow analysis of power system including DG to Bus 5

| ID | Bus Number | Source | Voltage (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 | 0.0744 | 0.0457 | 4.581 | 85.22 |
| Gen10 | Bus8 | 0.5 MW | 11 | 0.0744 | 0.0457 | 4.581 | 85.22 |
| 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 |
| Gen25 | Bus5 | 0.25 MW | 11 | 0.505 | 0.288 | 30.53 | 86.84 |
| U1 | Bus1 | 30 MVA | 33 | 0.292 | 0.0894 | 5.342 | 95.61 |

Table 54: Branch Data of Load flow analysis of power system including DG to Bus 5

| 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 |

Table 55: Bus Data of Load flow analysis of power system including DG to Bus 5

| Bus ID | Standard 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 |

Table 56: General Data of Load flow analysis of power system including DG to Bus 5

| Description | Value |
|---|---|
| Buses | 10 |
| Branches | 9 |
| Generators | 8 |
| 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 |

The Percentage voltage drop, load terminal voltage, kVA and current flowing at each bus are shown in Table 52-56 and Figure 21. From table, it is clear that the total network losses after the load flow analysis including DG to Bus 5 was 3.7 kW and three phase load terminal voltage is 398 V.

# CHAPTER FIVE

# RESULTS AND DISCUSION

## 5.1 Grid Impact Study

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

### 5.1.1 Load Flow Result

For power 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. The entire load on the network is equal to total load connected to distribution grid only in case-1 and in other cases the total demand is same to the total load connected to distribution network as well as total load connected at Consumer. Amarpur substation 33 kV bus is considered as slack bus for power flow analysis. The details of power supply and demand under seven different cases are shown in Table.

With power flow analysis, the entire losses on different Cases is analyses under various cases and shown in Figure. The total power loss of the system is the largest in case-1, which is around 206 kW, and the loss decreases as the power exported from mini grid increases. The loss in the network is the smallest in case-6 and it is around 6.2 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 Figure. 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.

## 5.2 Result and Discussion

Power Losses at various cases is presented in the diagrams indicating reduction in losses for the interconnection of mini grid with Grid. The interconnection of mini grids with 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.

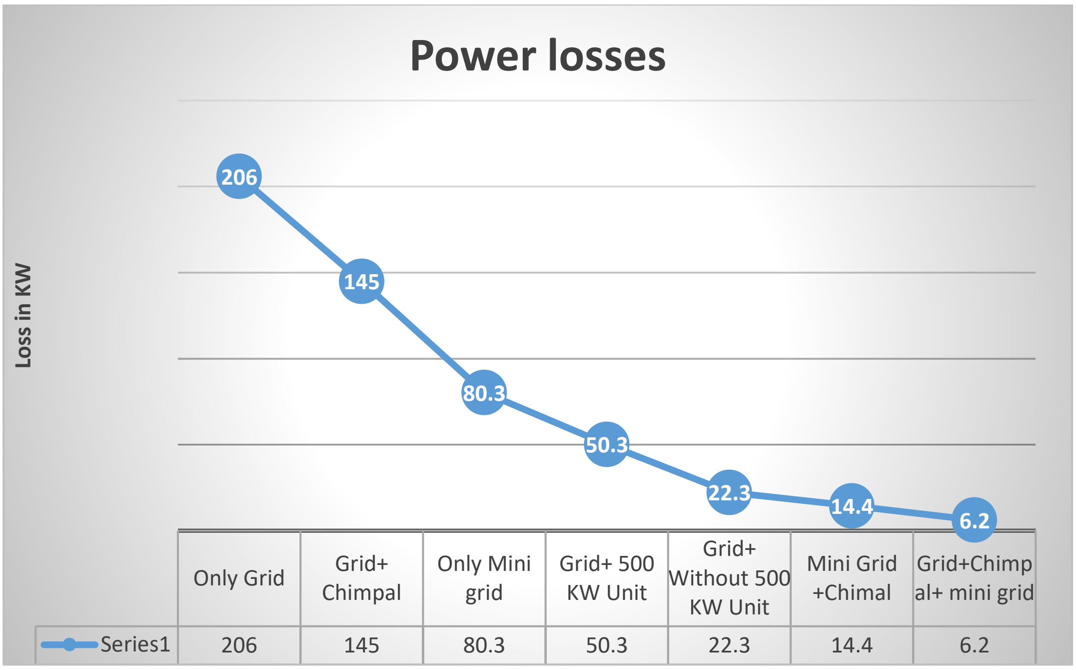


Figure 22: Power losses in system at various cases

The quality of electricity supply through combined system of interconnected mini grid & Grid is found to be better examining the terminal voltage at equipment. The terminal voltage is found to be under acceptable limits when the mini grid is connected with the Grid which can be well illustrated by the figure23.

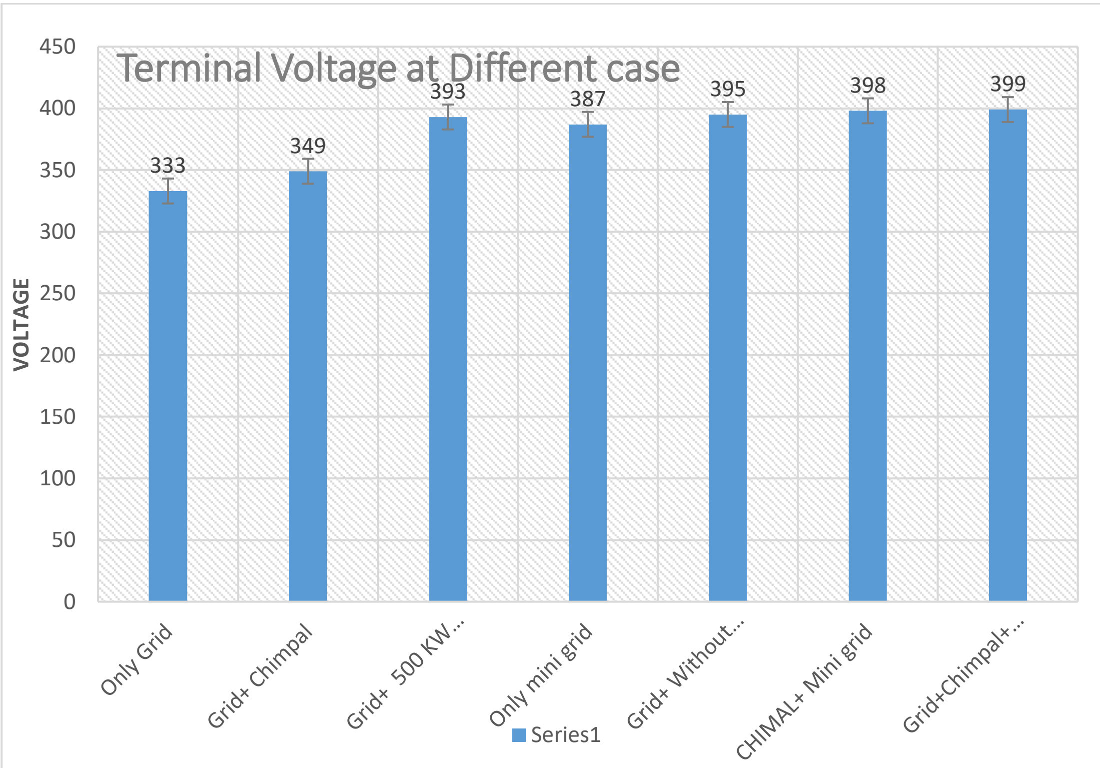


Figure 23: Terminal Voltage at various conditions

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 show that when the interconnected system is operated, loads receive terminal voltage at an acceptable level of supply. The cases Grid (NEA) supply only, Grid (NEA) & Chimal show terminal voltage below standard limit at some loads while the cases interconnected Mini Grid-Grid-Chimal, Grid-Mini Grid and Mini Grid-Chimal show the supply at standard level of terminal voltage.

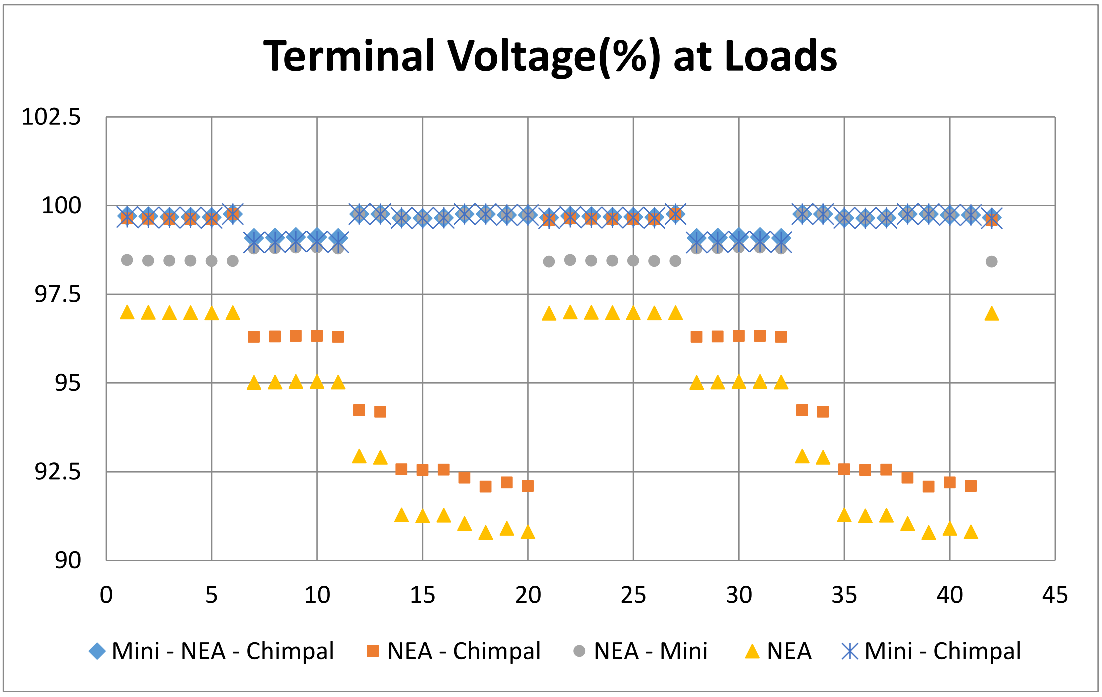


Figure 24: Terminal Voltage at various loads in different conditions of Operation

The voltage drop in the various case is observed and shown in figure 25 .From figure it is clear that the voltage drop decrease as the power is exported from mini grid and MHP Plant.

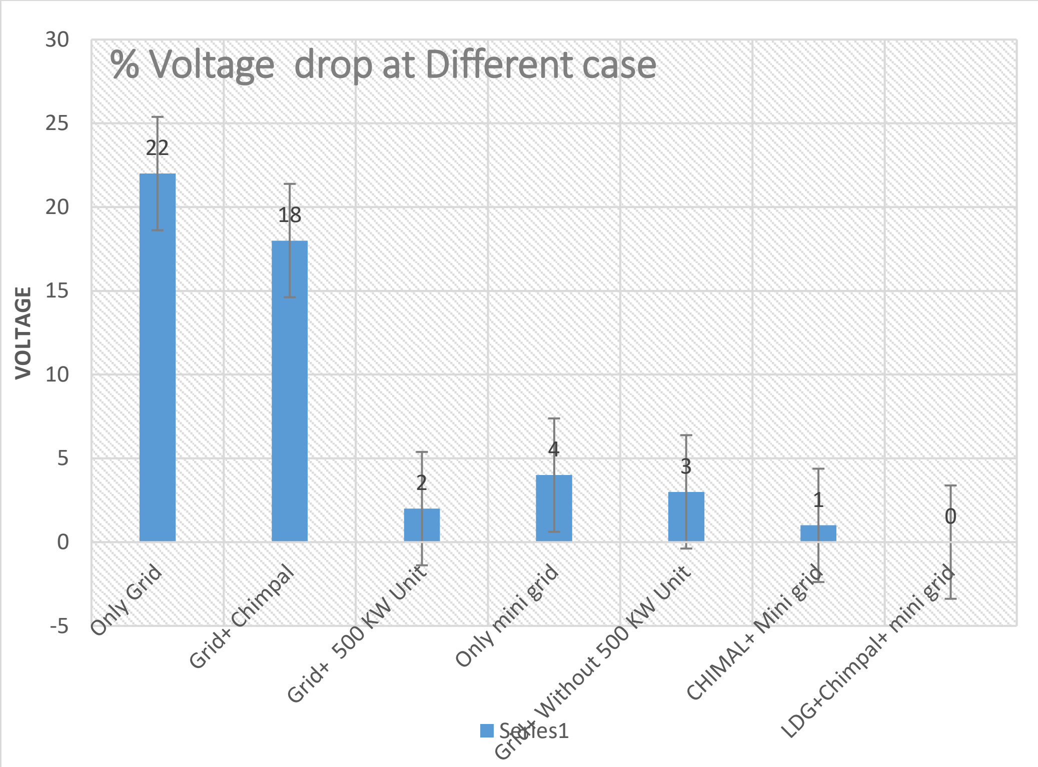


Figure 25: Percentage Voltage drop at various conditions of Operation

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

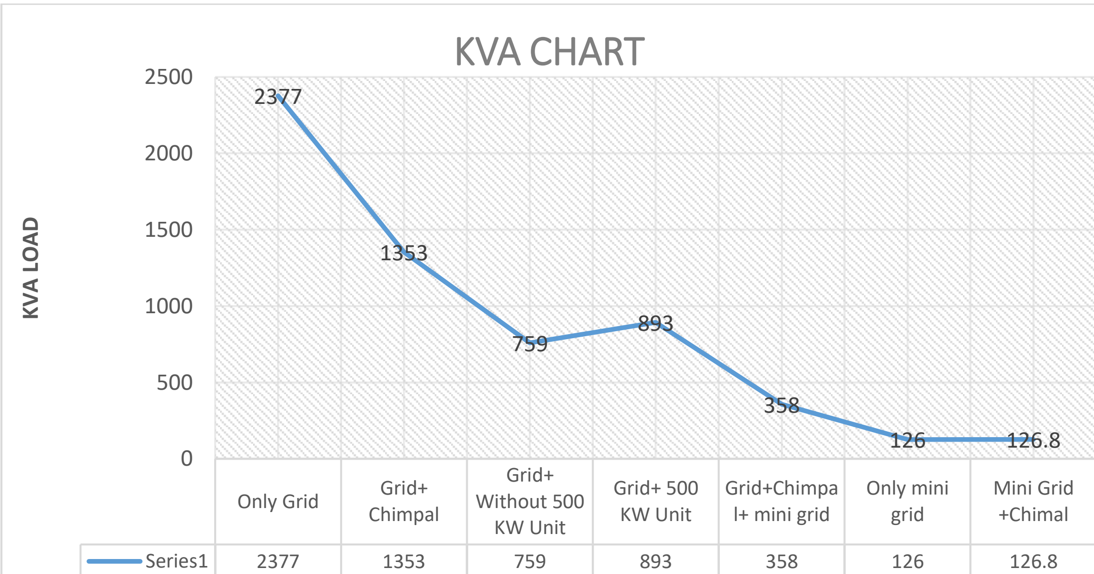


Figure 26: KVA Chart at various cases

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

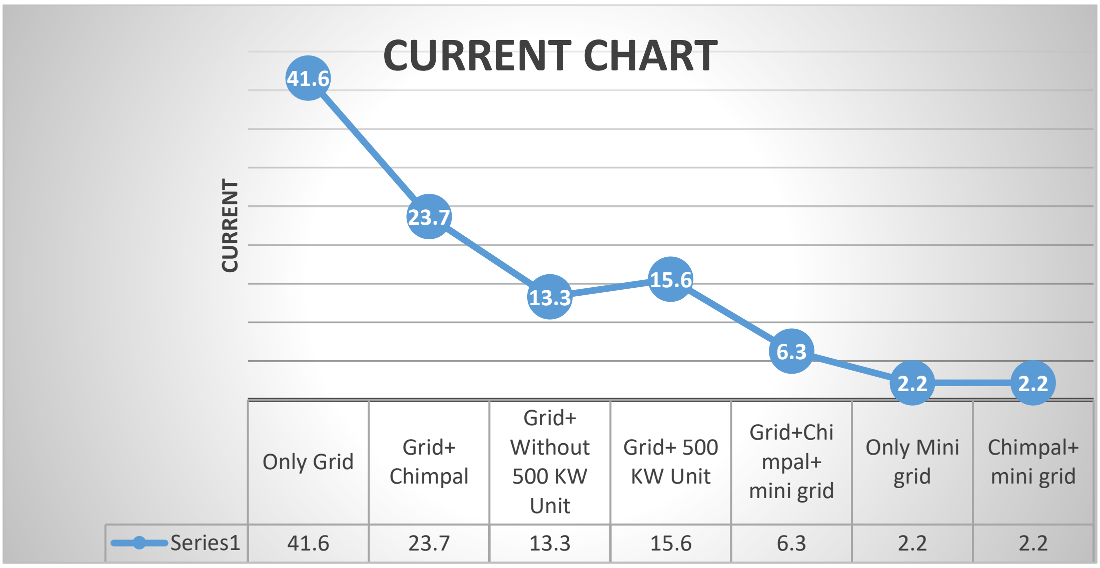


Figure 27: Current Chart at various Cases

## 5.3 Optimization of DG

The comparative analysis of various simulation cases for optimization of distributed generation is performed. Comparing network Losses at various Buses after connecting of DG, the summary is shown in the table:

Table 57: Comparative Data of power flow analysis of power system including DG to Various Buses.

| **Bus ID** | **Nominal kV in KV** | **Load terminal Voltage in V** | **Losses in kW** |
|---|---|---|---|
| Bus3 | 11 | 400 | 1.4 |
| Bus4 | 11 | 395 | 6.2 |
| Bus5 | 11 | 398 | 3.7 |
| Bus 8 | 11 | 397 | 6.2 |
| Bus 9 | 11 | 396 | 6.2 |
| Bus 10 | 11 | 395 | 6.2 |
| Bus 11 | 11 | 393 | 6.2 |
| Bus 13 | 11 | 395 | 6.2 |

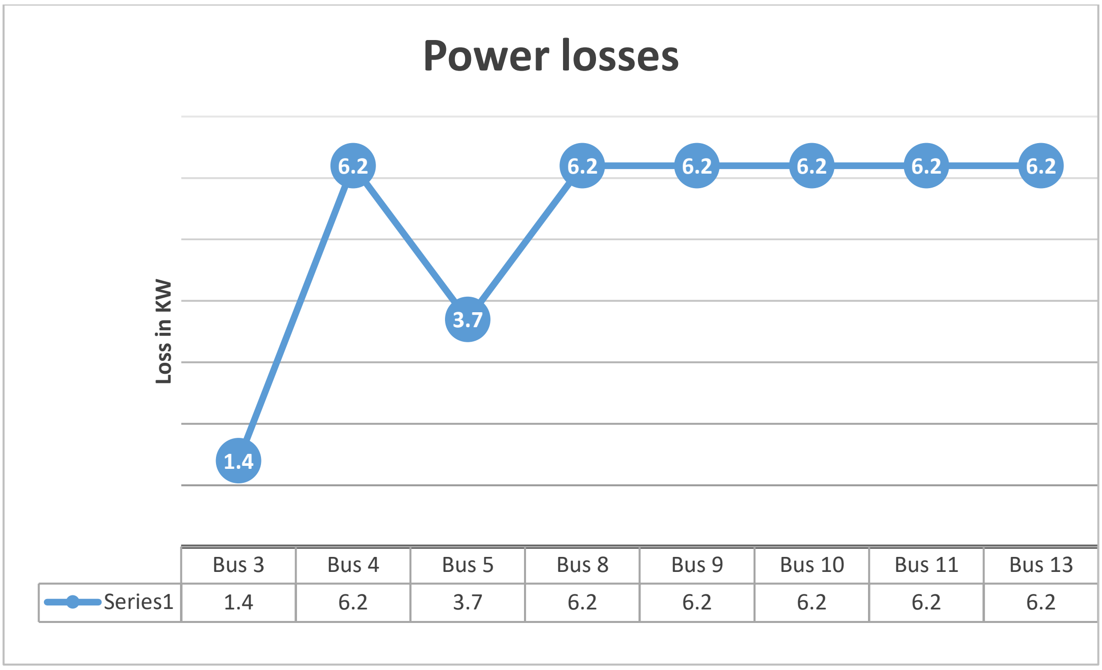


Figure 28: Network Losses at various Busses after connecting of DG

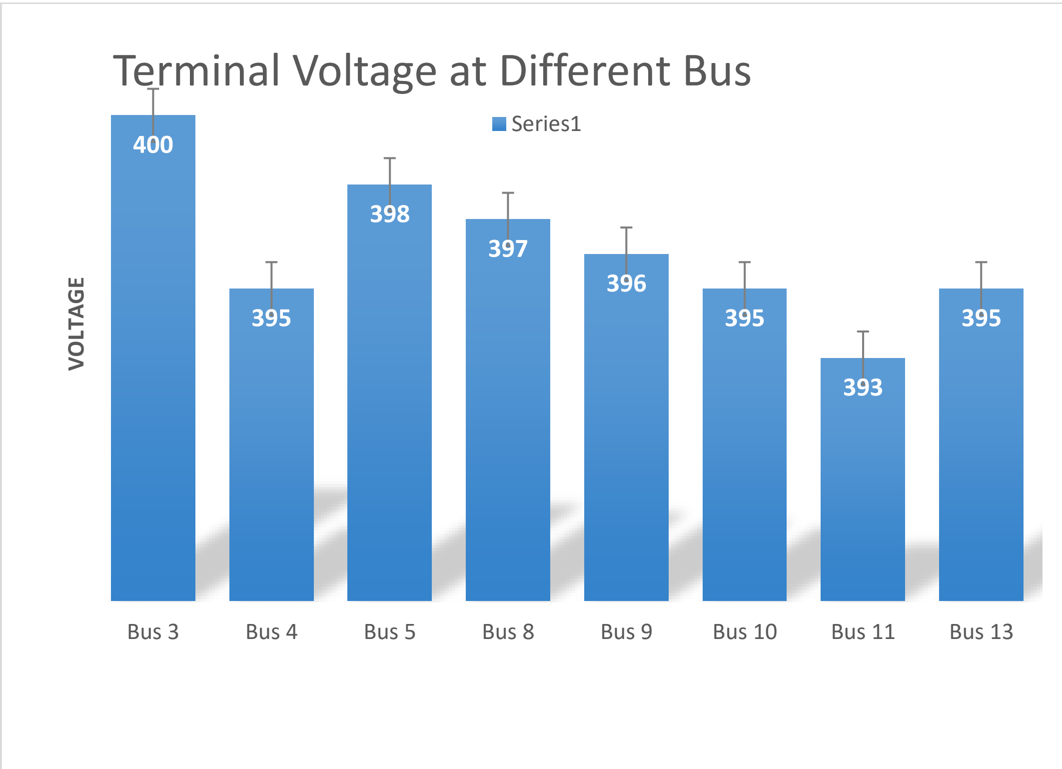


Figure 29: Voltage at various Busses after connecting of DG

Above results of simulation show the losses of the entire network. DG is connected at various buses step by step and Bus no.3 is the only bus where losses of the entire network is least recorded which is 1.4 KW and voltage profile of bus 3 is highest among the buses which are 400 V, therefore, the Bus-3 is the optimal location of distributed generation for Entire network. Consequently, the Bus-3 is the optimal placement of the system because at this location the voltage profile is generally improved while losses are reduced.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

The overall losses of Grid is 206 kW, as mini grid and MHP plant is connected to Grid, then the losses of the system is reduced 6.2 kW. Similarly, the percentage voltage drop of the Grid is 22%. As mini-grid and MHP plant is connected to Grid, then the percentage voltage drop of the system is decreased to 0%. Likewise, the terminal voltage of the Grid is 333V. As mini grid and MHP plant is connected to Grid, then the terminal voltage of the system is increased to 399 V. The Overall system losses without DG installation is 6.2 KW, as DG of 250 kW is installed in eight buses step by step , then losses in bus no 3 is lowest found (1.4 kW) and available voltage is highest (400 V).

Hence above result shows that the loss of the overall system as well as percentage voltage drop of the system is reduced by significant level and the terminal voltage at various load point get improved which helps to find the quality of electric supply. The accurate location of DG is vital for reducing losses and improving voltage profile, which indicates positive results on the overall economy. The large investment incurred in the distributed micro hydro generation can be realized in economic benefits.

The overarching view from the results shows positive outlook for grid interconnected mini grid and MHP plant in Nepal

## 6.2 Recommendation

The work done in this thesis can be further extended in different regions. The following recommendations have been made for future work:

- The impacts in a mini-grid by micro-hydro plants interconnected with grid system for cases of stability and faults analysis shall be studied
- The impacts in a mini-grid by micro-hydro plants interconnected with grid for cases of Economic and financial analysis shall be studied

- Rural electrification program should also include the interconnection of isolated generators in the vicinity with Grid for minimization of loss and improvement in quality of electric supply.

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

**Rajmani Bajagain, Nawraj Bhattarai, Tek Raj Subedi**

**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).

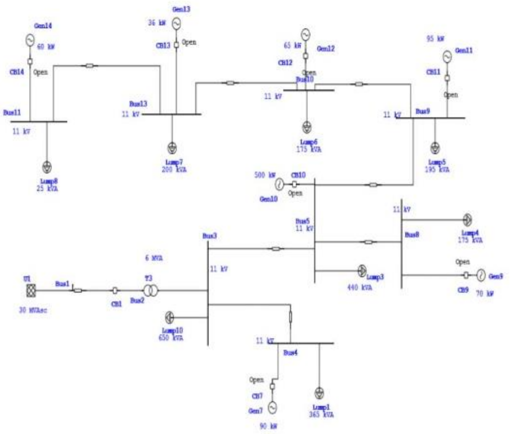


Fig.3 Single Line Diagram of System

- 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.

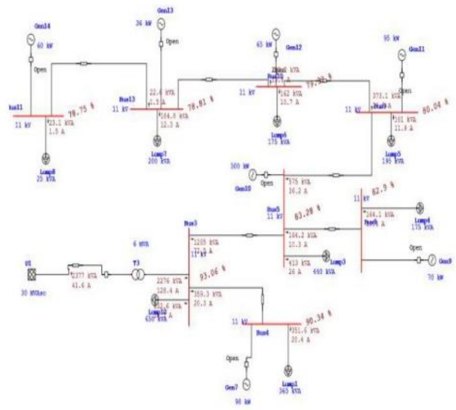


Fig.4 Load flow analysis of LDG System

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***)***.

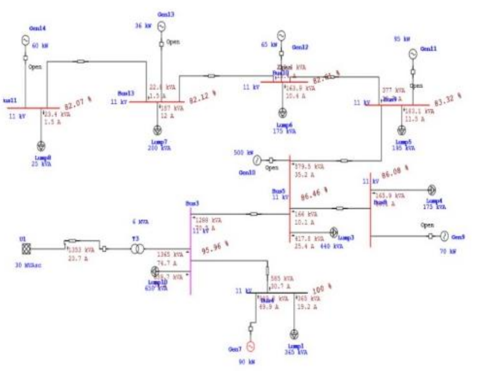


Figure 5: Load flow analysis for Local Distribution Grid (LDG) and Chimal MHP .

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 | 108.6 | 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

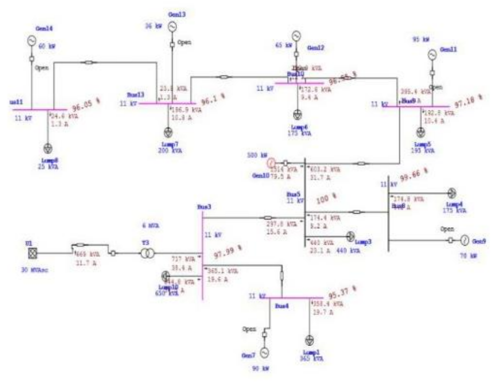


Figure 6: Load flow analysis for Local Distribution Grid (LDG) and 500 KW MHP Plant.

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 |

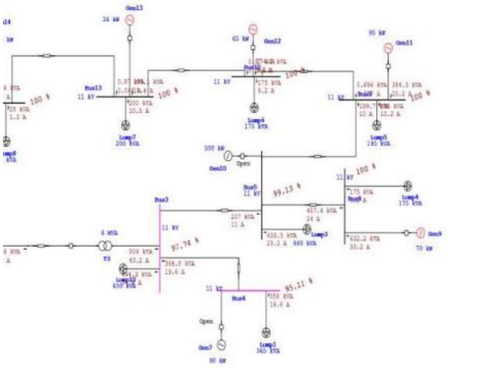
**GENERAL DATA**

| | |
|---|---|
| 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 |

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



re 7: Load flow analysis for Local Distribution Grid
G) 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 | Vter |
| 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 | 1 |
| Lump5 | 195 kVA | 11 | 165.8 | 102.7 | 10.23 | 85 | 100 | 1 |
| Lump6 | 175 kVA | 11 | 148.8 | 92.19 | 9.185 | 85 | 100 | 1 |
| Lump7 | 200 kVA | 11 | 170 | 105.4 | 10.5 | 85 | 100 | 1 |
| Lump8 | 25 kVA | 11 | 21.25 | 13.17 | 1.312 | 85 | 100 | 1 |
| 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).

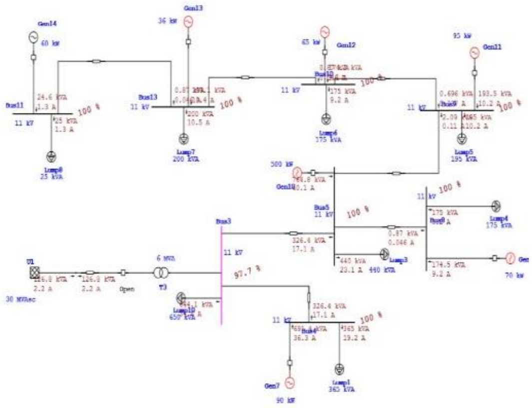


Figure 8: Load flow analysis for Mini-grid and Chimal MHP (90 KW).

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. |
| | | | | | | | | 99.7 |
| | | | | | | 3 Phase Load Terminal Voltage | | 398. |

| 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 .

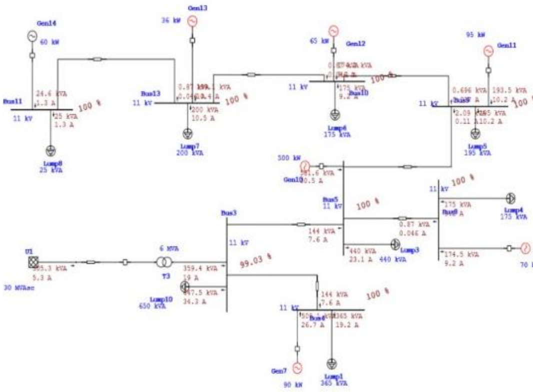


Figure 9: Load flow analysis for Local Distribution Grid (LDG),Mini grid and Chimal MHP Plant.

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 .

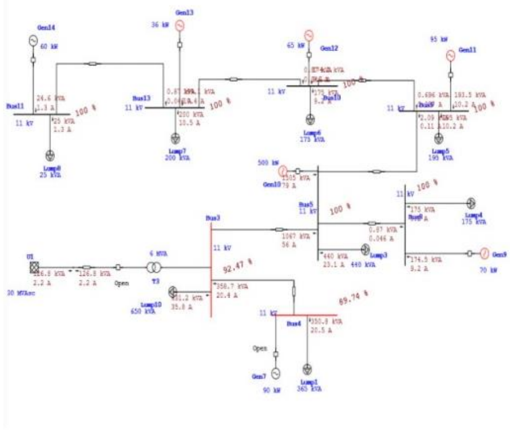


Figure 10: Simulation Diagram for Mini Grid Only.

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 | 1.268 |
| 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.

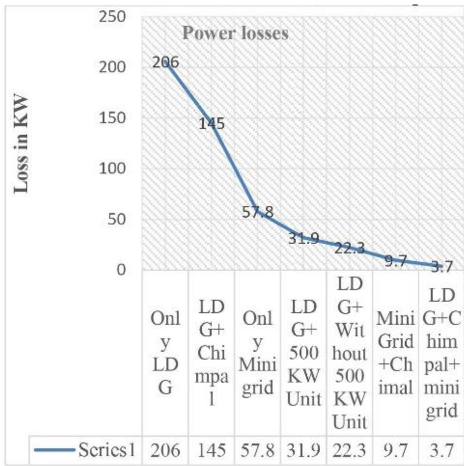



Figure 11: Power losses in system at various cases

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.

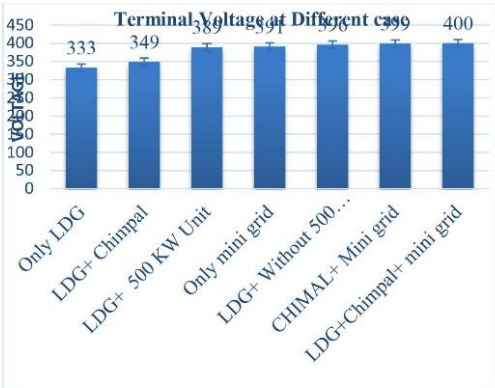



Figure 12: Terminal Voltage at various conditions

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.

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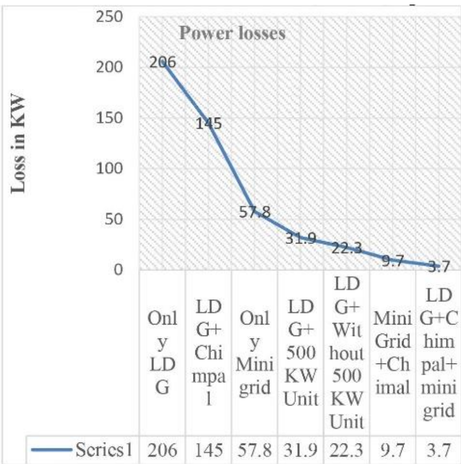


Figure 11: Power losses in system at various cases

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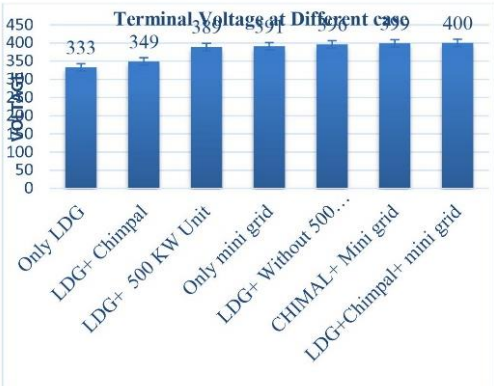


Figure 12: Terminal Voltage at various conditions

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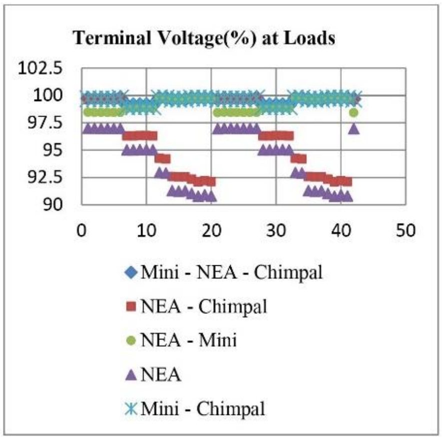


Figure 13: Terminal Voltage at various loads in different conditions of Operation

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.

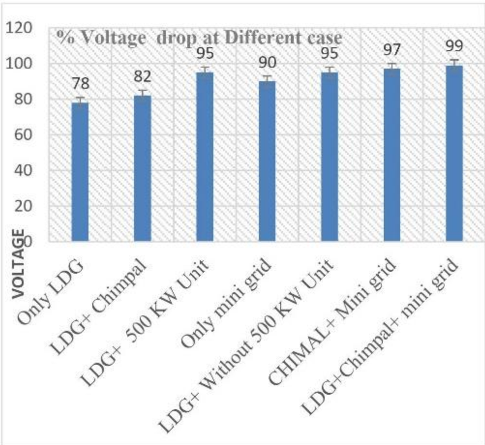


Figure 14: Percentage Voltage drop at different conditions of Operation

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.

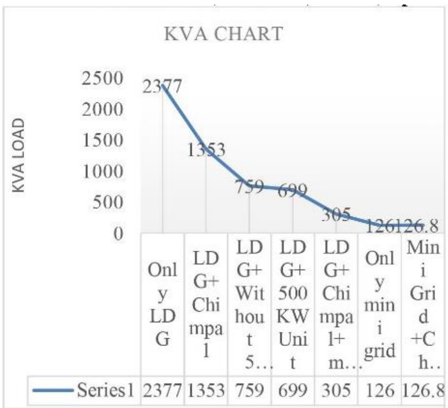


*Figure15: KVA Chart at various cases*

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*

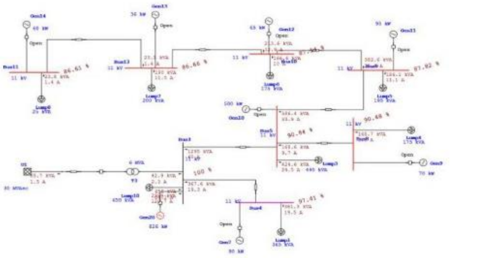

Figure 17: Load flow analysis of power system when DG to Bus 3

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 | 101.8 | 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:*

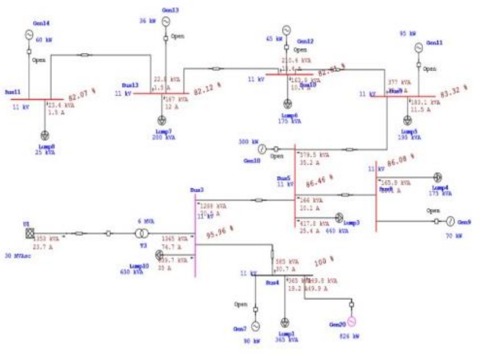

Figure 18: Load flow analysis of power system when DG to Bus 4

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*

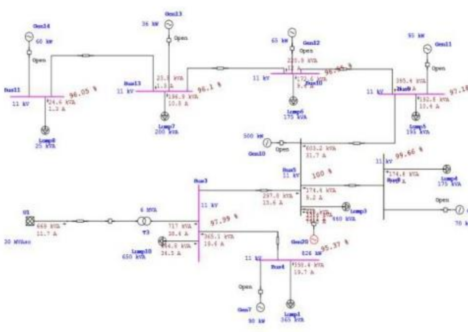

Figure 19: Load flow analysis of power system when DG to Bus 5

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*

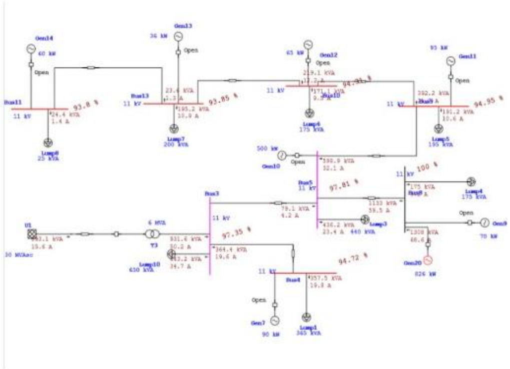

Figure 20: Load flow analysis of power system when DG to Bus 8

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 ar current flowing at each bus is shown in Table 11 and Figu 20. From table , it is clear that he overall system losses aft execution of load flow analysis when DG to Bus 8 was 50 KW and three phase load terminal voltage is 383 V.

*e) Power system when DG to Bus-9*

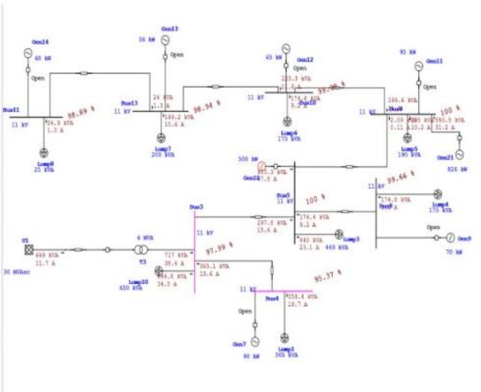

Figure 21: Load flow analysis of power system when DG to Bus 9

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*

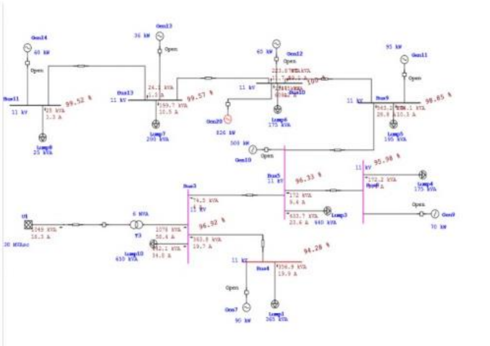

Figure 22: Load flow analysis of power system when DG to Bus 10

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*

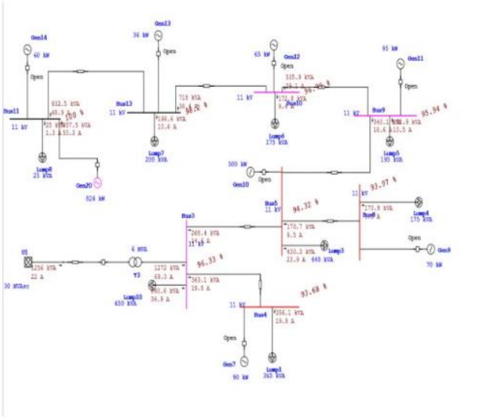

Figure 23: Load flow analysis of power system when DG to Bus 11

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 | Vterminal |
|---|---|---|---|---|---|---|---|---|
| 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*

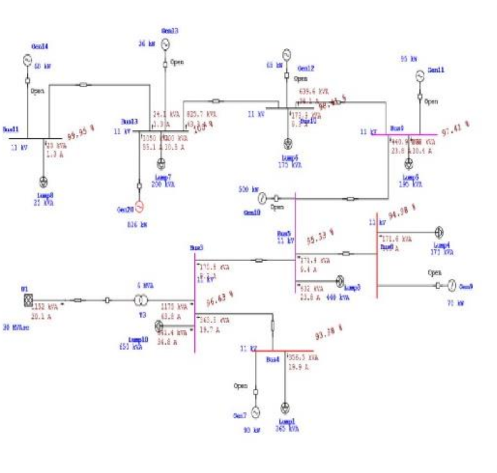

Figure 24: Load flow analysis of power system when DG to Bus 13

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 | Vterminal |
|---|---|---|---|---|---|---|---|---|
| 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 |

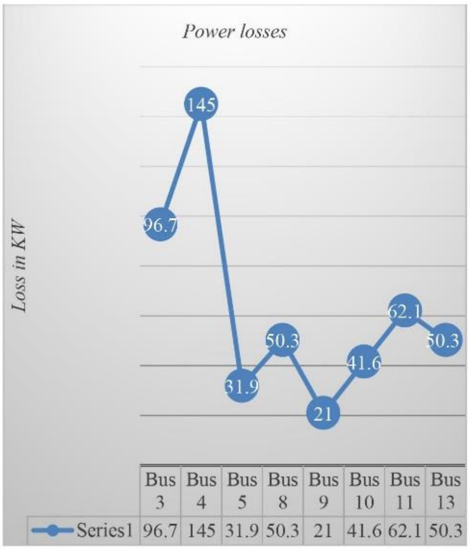


Figure 25: Power Losses at Different Busses after Installation of DG

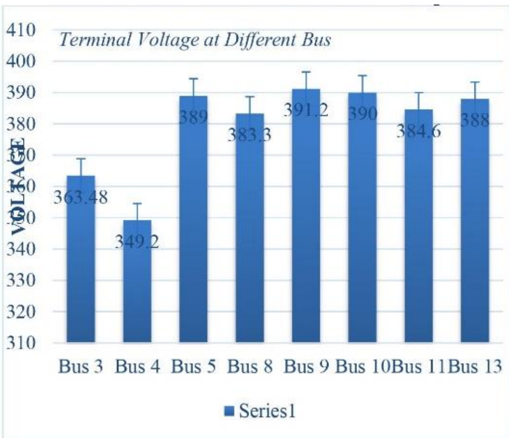


Figure 26: Voltage at Different Busses after Installation of DG

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.


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## ANNEX : PHOTOGRAPHS AND SINGLE LINE DIAGRAM


Figure 30: Layout of MHP in isolation mode (District Development Committee, Taplejung, 2016)

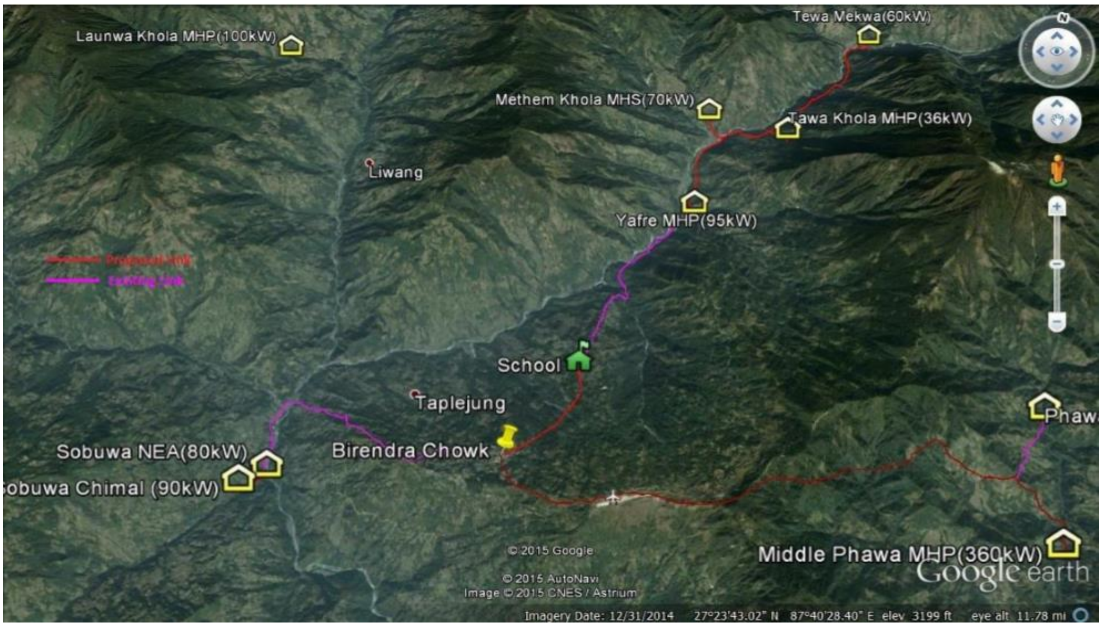


Figure 31: Interconnection View of Taplejung Mini Grid (District Development Committee, Taplejung, 2016)

Figure 32: Power House (Left) and EM Equipments (Right) of Phawa Khola MHP (District Development Committee, Taplejung, 2016)

Figure 33: Powerhouse of Yafre - Mauwa Khola MHP (District Development Committee, Taplejung, 2016)

Figure 34: Power House of Tawa Khola MHP (District Development Committee, Taplejung, 2016)

Figure 35: Powerhouse of Methem Khola MHP (District Development Committee, Taplejung, 2016)

Figure 36: Powerhouse of Tewa-Mekwa Khola MHP (District Development Committee, Taplejung, 2016)

Figure 37: Electromechanical Equipments of Chimal MHP (District Development Committee, Taplejung, 2016)

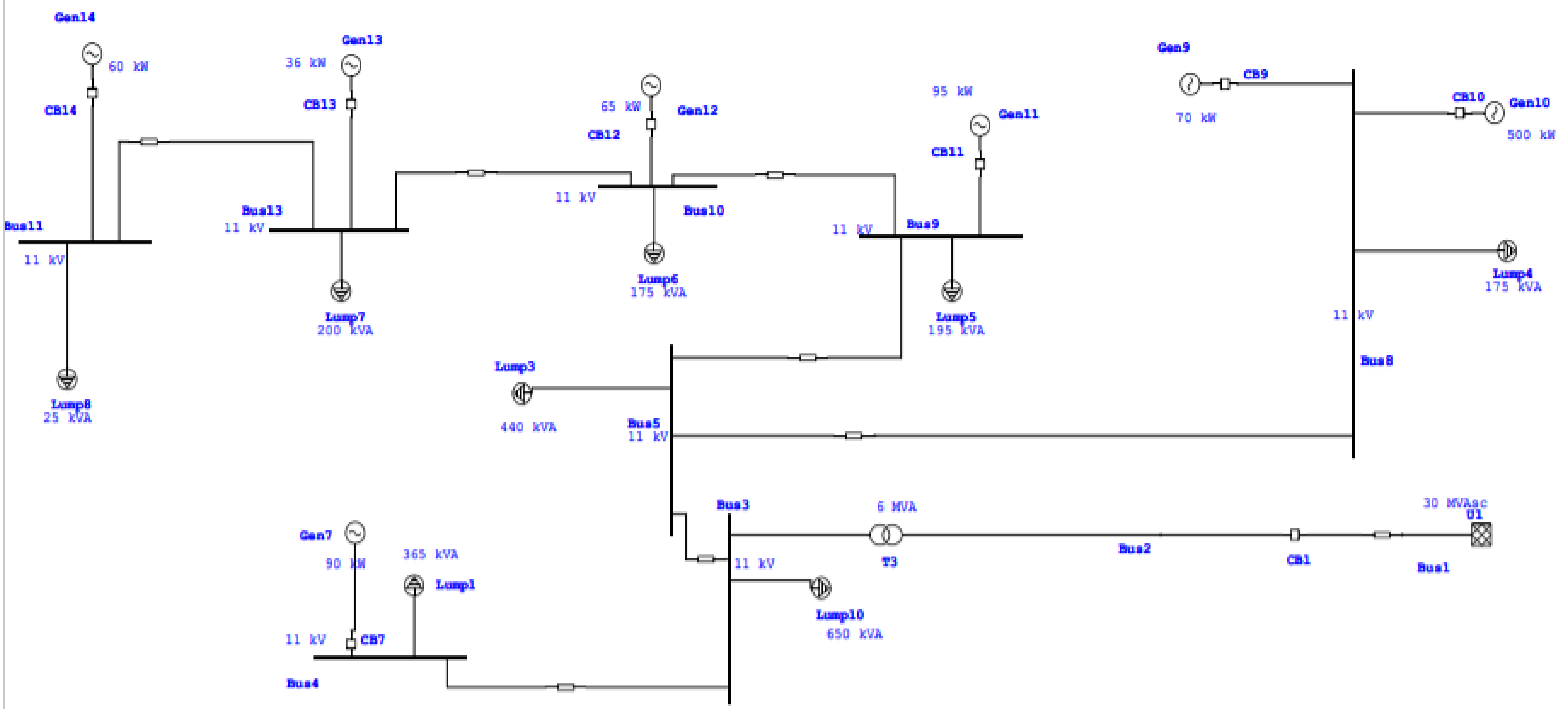


Figure 38: Single Line Diagram of Grid, Mini-grid & Chimal Plant

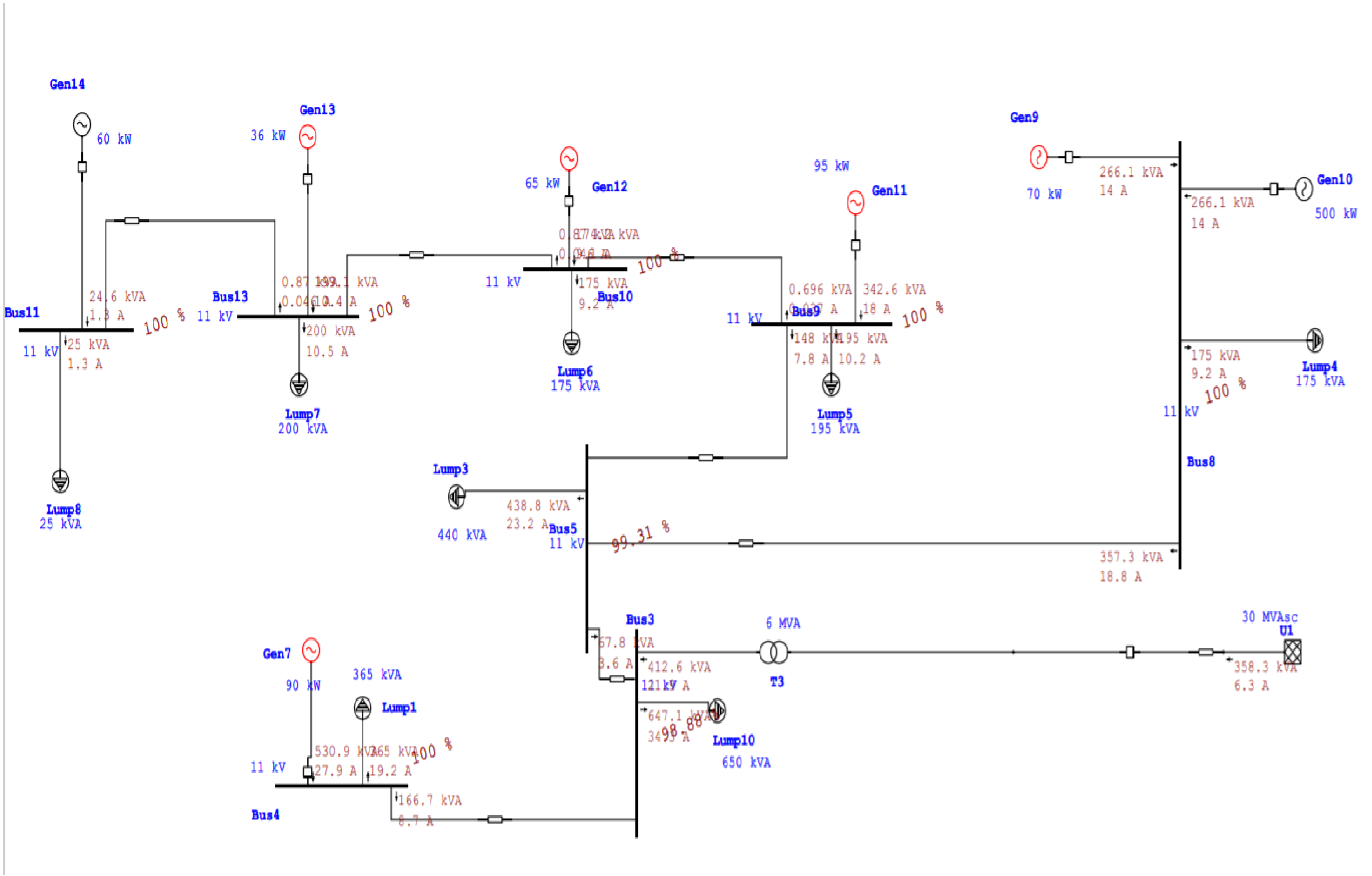


Figure 39: Simulation of Grid, Mini-grid & Chimal Plant