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Impact of Increasing Load on the Distribution Network with the addition of Electric Cooking Stoves in Nepali Context

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The undersigned certify that they have read, and recommended to the Institute of Engineering, for acceptance, a thesis report entitled "**Impact of Increasing Load on the Distribution Network with the addition of Electric Cooking Stoves in Nepali Context**" submitted by Prashant Kumar Shah in partial fulfillment of the requirements for the degree of Master of Science in Power System Engineering.

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ABSTRACT

According to Nepal's budget for fiscal year 2079/80, the government has planned to distribute electric cooking stoves (ECS) to each household. With the use of ECS on a large scale, the load on the distribution feeder will increase significantly, resulting in a reduced voltage level at buses, increased loading on the distribution transformer, and, in fact, increased current carried by the feeder conductor. The study focuses mainly on the loading of the distribution transformer (DT), the voltage level at the buses, and the ampacity of the feeder conductor. The study is carried out considering two feeders: the Jorpati feeder in Kathmandu district and the Malangwa feeder in Sarlahi district of Nepal. The impedance, current and power (ZIP) coefficients and load of the study area are estimated by the polynomial load modeling technique on a seasonal basis. The results show that after connecting ECS of different power ratings, the major impact is seen on the Jorpati feeder during the winter season. After incorporating 2000W ECS to each household in Jorpati feeder, there is overloading on 18 DTs and the existing dog conductor will not be able to handle the increasing load current demand. Thus, the optimal cable selection suggests that the existing feeder conductor must be upgraded to a wolf conductor. In order to upgrade the size of 18 DTs and the conductor to a wolf conductor, the utility should invest approximately one crore, seventy-five lakhs and after upgrading the system, use of ECS can be promoted in the Jorpati area. After incorporating 3000W and 4000W ECS, there is overloading on most of the DTs, low voltage levels at buses and the existing dog conductor will not be able to handle the increasing demand for load current. Thus, feeder reconfiguration would be required. Similarly, in the Malangwa feeder, the results show that after connecting ECS of different power ratings, the major impact is seen in the summer season. There is overloading on almost all DTs except the private DTs, low voltage levels at buses and the existing feeder conductor will not be able to handle the increasing load current requirement. Also, the power requirement will not be met by the existing 8MVA power transformer. Hence, Malangwa feeder needs restructuring.

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LIST OF ABBREVIATIONS

LPG:	Liquefied Petroleum Gas
ECS:	Electric Cooking Stoves
DT:	Distribution Transformer
IC:	Induction Cooker
IRC:	Infra-red Cooker
NEA:	Nepal Electricity Authority
ETAP:	Electrical Transient Analyzer Program
CVR:	Conservation Voltage Reduction
DCS:	Distribution & Consumer Services Directorate

CHAPTER ONE
INTRODUCTION

1.1 Background

Electricity is a basic human need and is used for various purposes in our day-to-day lives, such as lighting, cooking, running domestic appliances, and many more. Electricity is widely used for cooking purposes in developed countries. But if we observe the scenario of Nepal, cooking is highly dominated by liquefied petroleum gas (LPG) in the urban areas and in some parts of the rural areas too. In rural areas, cooking is mainly dominated by firewood. The use of electric cooking stoves (ECS) for cooking purposes is rare in Nepal. The increasing price of LPG and its shortage have seriously affected the kitchen expenses of the Nepalese society, and moreover, LPG needs to be imported into Nepal. That is why the government of Nepal is promoting the use of ECS for cooking purposes.

According to Nepal's budget for the fiscal year 2079/80, the government has declared to distribute ECS to each household in Nepal to promote the use of ECS for cooking purposes. In Nepal, a majority (52.4%) of the population still depends on solid biomass for cooking. About one-third (33.1%) of the population uses liquefied petroleum gas (LPG) as cooking fuel, as shown in Figure 1 below. The use of firewood is more prevalent in rural areas (65.8%) compared to urban areas (35.4%). More than half (54.1%) of urban households use LPG for cooking, while only 16.5% of rural households use LPG. In 2015/16, the proportion of the urban population using electricity for cooking was 37.9%, which stood at 33% in the previous year (2016). The practice of electric cooking has been gradually increasing in recent years, particularly after the mega earthquake and energy crisis in 2015[1].

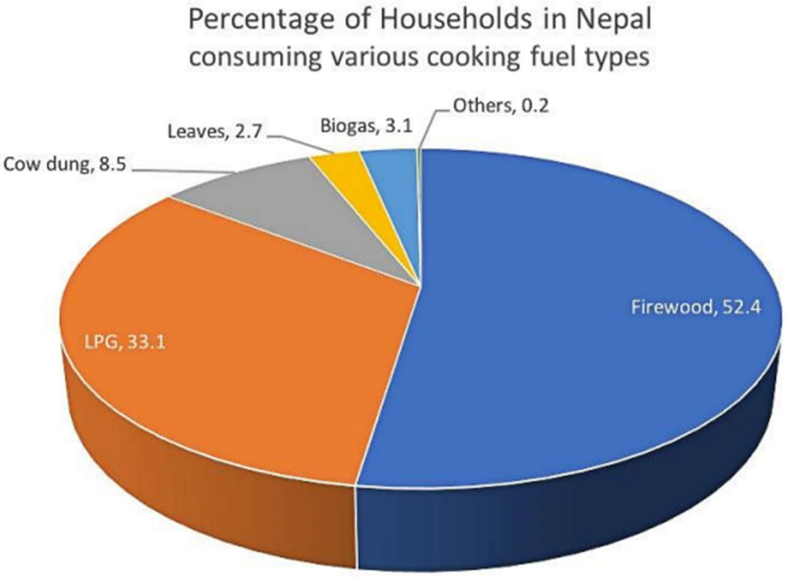


Figure 1: Percentage share of households using various cooking fuel

The statistics shows that ECS is very rarely used for cooking purposes in Nepal. It is used by few households in the urban areas. Now, the government of Nepal is promoting the use of ECS for cooking purposes to replace LPG. The addition of load on the feeder will have various impacts on the distribution line. But before the penetration of ECS in such a large scale, the existing distribution system of Nepal can meet the growing load or not need to be analyzed. Without any proper plan and coordination with Nepal Electricity Authority (NEA), promoting the use of ECS at each household is worthless.

With the addition of ECS at each household, the load profile of the distribution network is going to change for sure. As we know, the peak demand is observed mainly in the morning and evening time. If ECS is widely used for cooking purposes, this increasing load is going to reflect on the peak load of the feeder, and for sure, this will even increase the peak load of the feeder. With the increasing peak load, the ampacity of the feeder line needs to be verified, and if necessary, this also needs to be upgraded. While validating the ampacity of the feeder line, we also need to consider the annual load growth of the area, and considering the combined effect, the feeder sizing needs to be proposed. Also, the power loss and voltage profile need to be monitored. There is a possibility that the growing load may not be met by the distribution transformer that is currently installed. Resizing the distribution transformer may be needed. If the feeder line and distribution transformer need upgrading, utility must invest further to meet the growing load.

1.2 Problem Statement:

We observe in our society that due to overloading on the distribution transformer (DT), the transformer gets exploded and the service gets interrupted for few days. This is due to growing load in our society and huge demand on DT at the peak load situation. Similarly, the addition of ECS at each household is further going to increase the load demand on the DT. Before promoting the use of ECS at each household, research is required to verify whether the present size of DT can meet the growing load or not. Without any research, promoting the use of ECS at each household may lead to overloading on the DT and DT may explode also which is a loss utility. To meet this growing load along with the annual load growth a detailed study must be done to verify whether the growing load will be met by the existing distribution transformer or not and upgradation is required or not.

Similarly increasing load also increases the current demand. Thus, the current flowing through the existing feeder conductor also increases. So, research is required to verify whether the existing feeder conductor can carry the growing load current with safety or not. If the ampacity of existing feeder conductor is not enough to meet the growing load current demand, then the feeder sizing needs to be upgraded.

Also, low voltage is a serious problem in the distribution network. Most of the appliances do not work in peak time due to low voltage problems. Such as motors, micro-ovens, electric heaters, etc. With the growing load, bus voltage is further going to drop. So, before the penetration of ECS at each household a close study is required to know the voltage level at different buses. If the voltage level drops down drastically with the increasing load, a solution to the problem must be found out.

Also, the increasing load also increases the system loss. Power loss is a loss to utility and the country which has deficit of power supply should focus on the minimization of power loss. So, research is required to know whether power loss is within the acceptable limit or not.

1.3 Scope of study

This study is primarily concerned with whether the existing system will be able to meet the growing load demand with the addition of ECS at each household in the study area. If ECS is used for cooking purposes at each household in the study area, then the current flowing through the existing feeder conductor will increase and the loading on the transformer will also increase. So, the study aims to verify whether the existing feeder conductor and transformer meet the growing load demand or not, and if not, to propose new feeder and transformer sizes. Also, the voltage level will drop and power loss will increase and it is intended to verify whether the voltage drop and power loss are within acceptable limits or not.

As we know LPG is a nonrenewable source of energy and the excessive use of these nonrenewable sources is not recommended. The world is shifting towards a renewable and smart source of energy. Electricity can be the best alternative to the problem. Thus, electricity is widely used for cooking purposes in the developed countries. Whereas in Nepal, LPG and fossil fuels are widely used for cooking purposes. So, the government of Nepal is promoting the use of ECS for cooking. But before penetration of ECS in large scale, a detail study must be done to verify whether the growing load will be met by the existing DT and feeder conductor or not. Similarly, the voltage level on different buses and system loss also needs to be considered before promoting the use of ECS at each household.

The study is carried out considering two feeders: the Jorpati feeder in Kathmandu district and the Malangwa feeder in Sarlahi district of Nepal. With the addition of ECS at each household of the study area, the load on the feeder will increase significantly. After incorporating ECS in the existing system, the study verifies whether the existing distribution transformers (DTs) will meet growing load demand or not. If there will be overloading on the DTs then new size of DTs will be proposed. Similarly, with the addition of ECS at each household the load current carried by the existing feeder conductor will increase. The study verifies whether the existing feeder conductor will safely carry the growing load current demand or not. If not the new feeder conductor size will be proposed along with the capital investment required for upgradation. Also, the voltage levels on different buses are within the acceptable limit will be verified. The power loss increased due to growing load demand will be analyzed but power loss reduction technique will not be proposed.

The results obtained from the research may be useful to power utility to know whether the growing load will be met by the existing DTs and feeder conductor or not. Also, the voltage level at different buses is going to vary with the addition of ECS at each household. The research will give them an idea that a similar kind of study can be done on other feeder lines to verify whether growing load demand will be met or not and upgradation is required or not. If upgradation is required then, capital investment required by power utility to upgrade the to meet the growing demand due to the same and how they are going to arrange the huge fund.

1.4 Objectives

1.4.1 Main Objective:

- To evaluate whether the existing system will be able to meet the growing load demand with the addition of Electric cooking stoves (ECS) at each household of the Jorpati and Malangwa feeders.
- To estimate the capital investment required by utility to upgrade the system.

1.4.2 Specific Objectives

After incorporating ECS at each household of the study area, the following will be the objective of the research.

- To verify whether the existing feeder conductor and distribution transformers meet the growing load demand.
- To propose new feeder size and transformer size if upgradation is required.
- To verify whether the voltage level is within the acceptable limit.
- To estimate the amount utility need to invest to meet the growing load demand.

1.5 Limitations:

If population of the study area increases or decreases excessively then this will have further impact on the distribution feeders which is not considered. If the socio-economic condition of the people in the study area changes then consumption profile will also change. This effect is not considered in this thesis research. In such a case the proposed feeder size and transformer size may not be correct as per the situation. Such situations are beyond one’s control and such effect is not considered in the research. The willingness of the consumers to shift towards the use of ECS over LPG is not considered as a part of research.

After incorporating ECS at each household of the study area, the voltage level drops, and power loss of the system increases. In this research we are only focused on whether the system will meet the growth after LPG is replaced by ECS. But the research does not focus on methods of improving voltage profile after addition of ECS at each household. The study does not cover the methods of decreasing the power loss of the system. Also, the study does not cover the harmonic distortion caused by addition of ECS at such a large scale.

The study is carried out on Jorpati feeder of Kathmandu valley and Malangwa feeder of sarlahi district. So, the results suggested gets limited to these particular sample feeders only. But the government is promoting the use of ECS nationwide and the study need to be carried out on each feeder separately. The government has only studied about the cost incurred in distribution of ECS at each household, but they have not studied whether the growing load demand can be met by the existing power system of Nepal. If upgradation of feeder size and distribution transformer is required in many areas then power utility will have to invest huge amount which has not been studied properly. If power utility has limited budget then they cannot afford to upgrade the feeders and transformer of many areas.

In urban areas like Kathmandu Valley, many families live in rented flats. In a single house, at least two to three families live. In some buildings, even five to six families live, and it is difficult to get the exact number of families living in the Jorpati area. Also, there are people with an old mentality who try to rely on traditional and existing cooking systems, and thus, the number of families willing to use ECS at their home cannot be estimated exactly. So, the use of ECS at each household is considered as the number of consumers connected to that feeder.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

In the Nepalese market, the electric cooking stoves (ECS) that are readily available are induction cookers (IC) and infrared cookers (IRC). IC works on the principle of mutual induction. Only utensils made of ferromagnetic materials like stainless steel or cast iron can be used for cooking with IC. IRC operates on the principle of infrared heat radiation. Any kind of utensil can be used for cooking using IRC. When LPG is used for cooking, only 40% of the heat energy is transferred to the utensils, whereas ECS transfer 90% of the heat energy to the utensils [1]. Hence, ECS are more energy efficient than LPG.

Even though the use of ECS is both beneficial to consumers and the nation as a whole, the use of ECS on a large scale may cause problems on the distribution feeder, such as low voltage at the buses, increased power loss, overloading on the distribution transformers (DTs), and many more. Some of these problems can be solved by techniques like installing distributed generation in the distribution system, bundling conductors, upgrading the feeder, and many more [2], [3]. The distribution load flow analysis can be carried out using different methods like the Newton-Raphson method, the accelerated Gauss-Seidel method, the fast decoupled method, etc., but they are not very efficient as the R/X ratio of the distribution feeder is high. For distribution load flow, the two major techniques are ladder theory and backward-forward sweep methods. Due to its fast conversion rate and efficient computation, the backward-forward sweep algorithm is generally preferred [2], [3].

Load modeling is carried out to estimate the total load of the study area. An accurate load model is required for distribution networks to get proper results. There are numerous load modeling techniques, such as polynomial load modeling, exponential load modeling, frequency-dependent load modeling, ANN-based modeling, an exponential recovery load model, composite load models, and so on [4]. Among all the available techniques, the polynomial load model and the exponential load model are widely used for modeling the loads of distribution networks [4]–[8]. The electrical loads are usually categorized as constant impedance (Z), constant current (I), and constant power (P) loads [4]–[8]. We can find all these kinds of electric loads in the service area, and load modeling should be done for mixed loads.

Load modeling can be component-based load modeling and measurement-based load modeling. For component-based load modeling an extensive survey must be carried out. The survey should find out the different types of electrical loads used by the consumers living in the study area. Similarly, another load modeling technique is measurement-based load modeling technique where the actual data collected from the utility to model the load of the study area. Here, the data from power quality monitors, dielectric frequency response devices, phasor measurement units, etc. can be used for modeling the load of the study area. If we studying the penetration of a particular electrical load to the system then component-based load modeling is preferred but a proper survey is required to know the various electrical loads used by the consumers in the study area.

Static load models are simple to understand and give clear physical meaning. It is easy to apply to those systems where the voltage variation is small [20]. Frequency dependent models are usually not used because most of the time the frequency variation is within the acceptable limit. Static load models can be easily combined with dynamic model to form composite load model [4]. Dynamic load modeling represents multiple dynamic loads in a single model. The dynamic load model is generally applied for those dynamic loads which are subjected to the voltage disturbance which changes under different conditions [13].

2.2 Electric Cooking Stoves

In the Nepalese market, the electric cooking stoves (ECS) that are readily available are induction cookers (IC) and infrared cookers (IRC). The working principles of these ECS are different but both of them are used for cooking purposes. The working principle of these ECS are explained below.

2.2.1 Working of Induction Cooker

Induction cooker works on the principle of mutual induction. When ac is applied to a coil surrounding the metal, a magnetic field is generated by the current flowing in the coil and induced loss (hysteresis loss) is generated causing a heat. At the same time, in the magnetic field which alternates with the ac, eddy current is generated in the core (i.e Metal) which causes heating in the core metal developing loss in the core called as eddy current loss. In an induction cooker both hysteresis loss and eddy current loss occurs in the core metal causing heating and this heat gets transferred to the utensils placed on the IC. In this way, IC helps in cooking purposes by the use electricity.

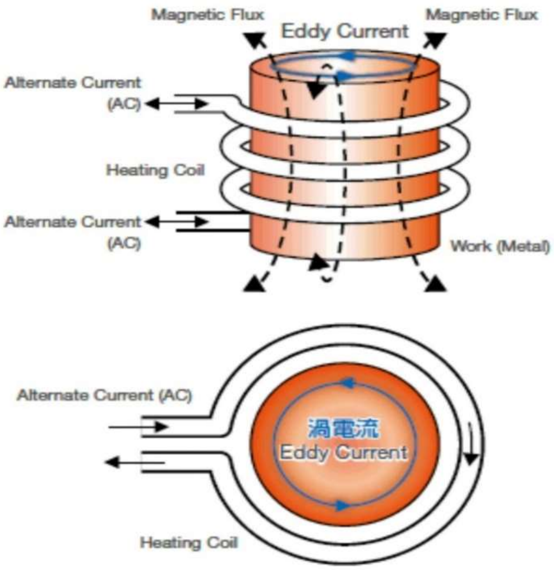


Figure 2: Working Principle of Induction Cooker

2.2.2 Working Principle of Infra-red Cooker:

Infra-red cooker (IRC) works on the principle of infrared heat radiation i.e., conduction. IRC contains halogen lamps and radiant coils which transfer heat to the cooking utensils through direct infra-red radiation. Any kind of utensil can be used for cooking using IRC. IRC heats up slowly and transfer heat to the utensils by conduction process. The heat is transferred to the entire utensils but using IC heat is transferred only at the bottom which is the stainless steel.

Figure 3: Infra-red Cooker

2.2.3 Difference between Induction cooker and Infra-red cooker

Induction cookers and Infra-red cookers are electric cookers used for cooking purposes but there are some differences between them in their working and performance. Some of the basic differences are tabulated below.

Induction cooker (IC)	Infra-red cooker (IRC)
Works on the principle of mutual induction.	Works on the principle of infrared heat radiation i.e., conduction.
In an induction cooker both hysteresis loss and eddy current loss occurs in the core metal causing heating and this heat gets transferred to the utensils placed on the IC.	IRC contains halogen lamps and radiant coils which transfer heat to the cooking utensils through direct infra-red radiation.
Heat up fast but the heat remains concentrated at the bottom of the utensil.	Heat up slowly but heat is evenly distributed to the cooking utensils.
Only utensils made of ferromagnetic materials like stainless steel or cast iron can be used for cooking with IC.	Any kind of utensil can be used for cooking using IRC.
More energy efficient compared to IRC	Less energy efficient compared to IC

2.3 Types of Electrical Load

There are different types of electrical appliances used by consumers. Various electrical loads can be classified as follows:

i) Constant Power Load:

Those loads which consumes constant power irrespective of the change in voltage. Such loads are called as Constant power loads. If the voltage drops down then then the current drawn by these loads increases keeping power consumed by the load constant and viceversa.

Example: Motor loads

ii) Constant Current Load

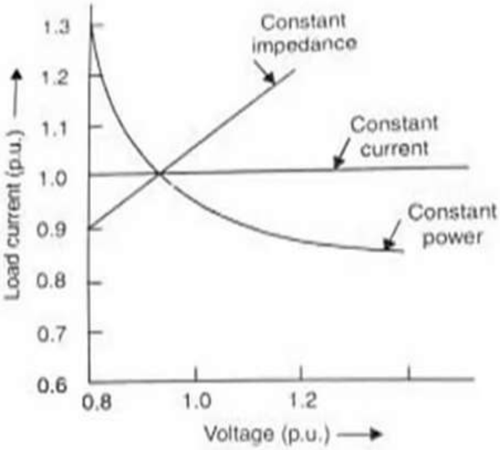
Those loads which draws constant current irrespective of voltage change. Such loads are called as Constant Current loads. As the voltage level increases impedance increases to maintain constant current and vice versa. As voltage increases power drawn by the load increases and vice versa.

Example: Power Electronic Devices, VFD and UPS

iii) Constant Impedance Load

At any instant, load maintains constant impedance irrespective of voltage change. Such loads are called as Constant impedance loads. If the voltage drops down the current drawn by the load also reduces keeping impedance constant and vice versa. Load power depends on voltage level since the load is constant impedance load. It is used in Conservation Voltage Reduction (CVR). Suppose Voltage reduces to 0.9 pu then current reduces to 0.9 pu and power consumption reduces to 0.81pu ($P=I^2Z$).

Example: Electric Arc Furnace and heaters.



Power (P) = $P_i \left(\frac{V}{Vi}\right)^k$

Where,

P = Power at Voltage V ,

Pi = Nominal Power at Nominal Voltage Vi

k = 0 for constant power load,

k = 1 for constant Current load,

k = 2 for constant Impedance load.

Figure 4: Load current vs voltage graph for different types of electric loads

2.4 Different load Modeling Techniques:

The mathematical equation representing the relationship between power and voltage of a load bus is called load modeling. Load modeling techniques are categorized as following [5]:

A) Static load modeling Technique

B) Dynamic load modeling Technique

A) Static Load Modeling Technique:

This model gives the relation for the active and reactive power at any instant of time as a function of voltage level at bus & frequency.

a) ZIP Model:

The ZIP model combines constant impedance(Z), current(I) and power(P) components which gives the relationship between the voltage magnitude and power in a polynomial equation.

b) Exponential load model:

The model is represented by an exponential equation which gives the relation between power and voltage at a load bus. This model represents mixed loads of the study area. This model has less parameter compared to other models.

c) Frequency dependent load model:

The frequency dependent load modeling technique is developed by multiplying the ZIP load model or exponential load model by a frequency dependent factor of the bus. The factor is given by the equation:

$\text{factor}(\boldsymbol{\alpha}) = [1+a_f(f-f_0)]$

where,

f :- Frequency of bus voltage

f_0 :- nominal frequency

a_f :- coefficient of frequency

The ZIP model relates constant impedance term which is frequency independent. Thus, adding the frequency term to ZIP model has no physical meaning.

d) Electric Power Research Institute (EPRI) LOADSYN model:

This model has wide application in dynamic studies. Such as: EPRI LOADSYN computational program and Extended Transient Midterm Stability Program (ETMSP). This model is a combination of polynomial load model (ZIP load Model), exponential load model and frequency-dependent load model.

B) Dynamic Load Modeling Technique:

A mathematical representation of active and reactive powers as a function of voltage and time defines dynamic load modeling technique. Some of the widely used dynamic load models are listed below.

a) Induction Motor (IM) Model:

In this model, the active and reactive power consumption is a function of the past and present voltage magnitude and frequency of the load bus. The equivalent circuit of an induction motor represents this type of model.

b) Exponential Recovery Load (ERL) Model:

The active and reactive power responses to step disturbances of the bus voltage are represented in this model. Those loads which show slow recovery over a time period (which ranges from several seconds to tens of minutes) are represented by this model. On-load tap changers (OLTCs) are modeled by ERL modeling technique which restores nominal voltage after a disturbance.

c) Composite Load Models:

These types of models are combination of static and dynamic load models. The widely used composite models are ZIP+IM, Exponential+IM and so on. Sometimes the load models are developed by combining 80 percent static loads and 20 percent dynamic loads forming mixed load.

d) Artificial Neural Networks (ANN) Based Modelling:

The load modeling is done using ANN training. This type of model is a composite load model (combination of static and dynamic loads) and load modeling is carried out using ANN algorithm.

e) Low Voltage (LV) Load Models:

Distribution system loads are low voltage loads. Distribution system loads are represented as lumped models. The need for more detailed modeling of LV loads is due to the integration of renewable DGs and the implementation of demand side management. In recent days most of the existing research focuses on characterizing the consumption profiles of residential LV loads. LV loads are commonly represented by ZIP and exponential load modeling technique.

2.5 Static Load Modeling:

Conventional load flow programs consider electrical loads as constant power loads, but the power consumed by the electrical load differs as the voltage level at the bus differs [20]. So, a proper load modeling is carried out considering constant power load, constant current load and constant impedance load at a time.

Static load models are simple to understand and give clear physical meaning. It is easy to apply to those systems where the voltage variation is small [20]. Frequency dependent models are usually not used because most of the time the frequency variation is within the acceptable limit. Static load models can be easily combined with dynamic model to form composite load model [4]. The most widely used static load modeling for distribution systems are polynomial load modeling technique (ZIP load modeling) and exponential load modeling technique.

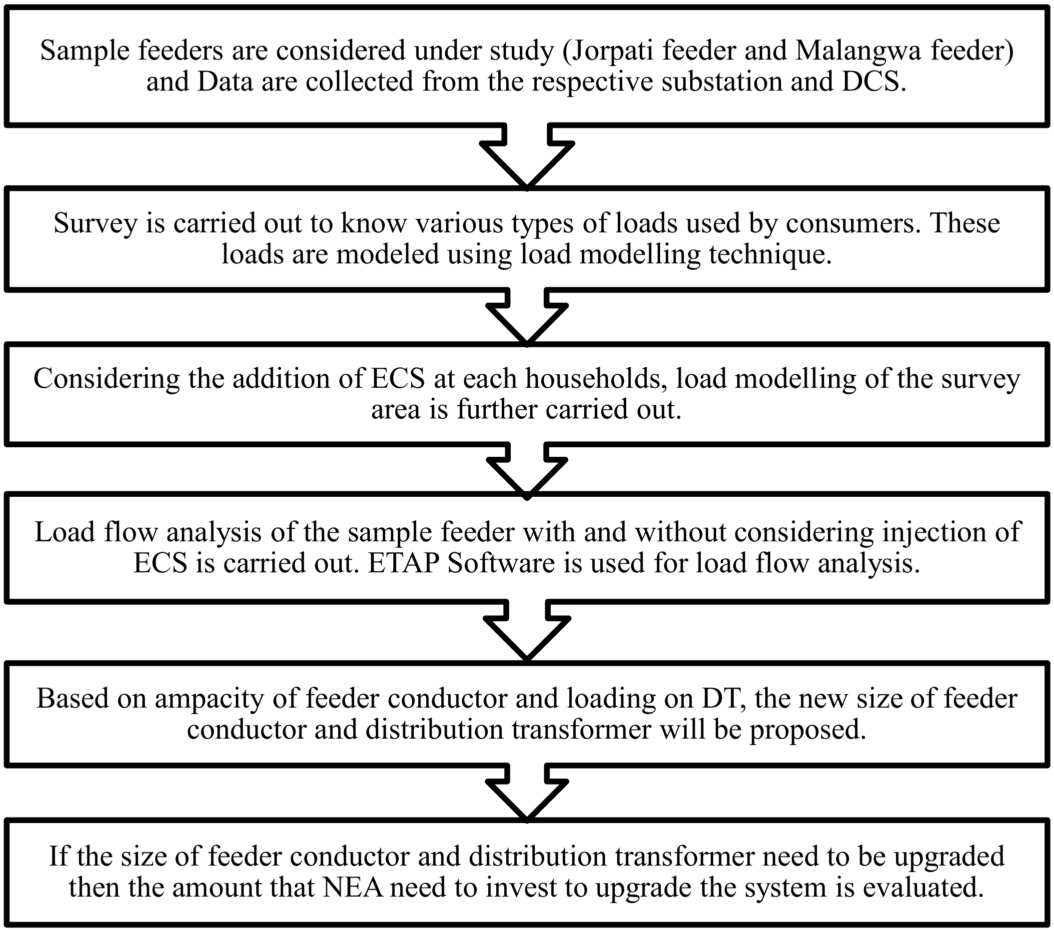
For modeling the LV loads, static load models are widely used because of low voltage variation in the system and also most of the time the frequency variation remains within the acceptable limit. Most popularly used static load modeling technique for modeling LV loads is exponential load modeling technique. In literature, we observe that exponential load models are widely used for modeling LV load. But it is not reasonable to represent the mixed load of the study area by a single term. As we all know, the composite loads of the study area are the combination of a number of electrical loads which behave differently with the changing voltage level at the buses. Thus, to overcome this problem polynomial load model is used where aggregate load is expressed as the sum of individual components with particular weight.

CHAPTER THREE

METHODOLOGY

3.1 General Methodology Approach:

The flow chart given below describes the steps to carry out the research.



Sample feeders are considered under study (Jorpati feeder and Malangwa feeder) and Data are collected from the respective substation and DCS.

Survey is carried out to know various types of loads used by consumers. These loads are modeled using load modelling technique.

Considering the addition of ECS at each households, load modelling of the survey area is further carried out.

Load flow analysis of the sample feeder with and without considering injection of ECS is carried out. ETAP Software is used for load flow analysis.

Based on ampacity of feeder conductor and loading on DT, the new size of feeder conductor and distribution transformer will be proposed.

If the size of feeder conductor and distribution transformer need to be upgraded then the amount that NEA need to invest to upgrade the system is evaluated.

Figure 5: Steps to carry out the research

The study is carried out considering two feeders: the Jorpati feeder of Kathmandu district and the Malangwa feeder of Sarlahi district of Nepal. A survey is carried out to find out the types of electrical appliances used by consumers living in the Jorpati and Malangwa areas, and based on the various electrical appliances used by the consumers, different prototype homes are formulated. The total number of households connected to the respective feeder line can be obtained from the concerned DCS of NEA. The loading on the feeder can be determined using the data obtained from the substation in the study area. Now the load of the study area is estimated, considering different prototype homes. The loads of the consumers are modeled, and then load flow analysis is carried out. Load flow analysis is carried out to determine the feeder current, bus voltages, power loss, and loading on DTs. Similarly, the load flow analysis is further carried out considering the inclusion of ECS at each household. Induction cookers (IC) and infrared cookers (IRC) are considered ECS. IC works on the principle of mutual induction. IRC operates on the principle of infrared heat radiation, i.e., conduction. The results of the load flow analysis will be useful for planning. The maximum current flowing through the feeder conductor can be obtained from the results of a load flow analysis, and this will help determine whether the existing feeder conductor will meet the growing load current demand or not. If not, a new size of feeder conductor will be proposed. Also, after connecting ECS to each household, the voltage level will drop and power loss will increase and it is intended to verify whether the voltage drop and power loss are within acceptable limits or not. The National Electrical code recommends the maximum allowable voltage drop can be 5%. Similarly, the loading on the DTs can also be obtained from the results of the load flow report, and those DTs which are overloaded will be recommended for upgradation. Considering the new feeder conductor size and number of DTs that need to be upgraded, a cost estimate is carried out. The amount that utility needs to invest to meet the growing load demand will be recommended.

3.2 Sample Feeder selection:

It is intended to evaluate whether the existing distribution system in Nepal will be able to meet the growing load demand due to the addition of ECS at each household. But studying all the feeder lines in Nepal in a short period of time is impossible. With the intent to apply the study approach to all the feeder lines in Nepal, one urban feeder and one rural feeder were selected as sample feeders. Here, the Jorpati feeder of Kathmandu valley is selected for the research as a sample urban feeder, and the Malangwa feeder of Sarlahi district is selected as a sample rural feeder. The study is carried out in one sample urban feeder with the intent that the behavior would be almost similar in other urban feeders in Nepal. Similarly, the impact would differ in the rural area and cannot be compared with the results of the urban feeder. Thus, the study is also carried out in a sample rural feeder with the intent that the behavior would be almost similar in other rural feeders in Nepal.

3.3 Load Estimation:

Load estimation is the most important part of the research. The total load on the sample feeder needs to be estimated before conducting a load flow analysis. An accurate load model is required for distribution networks to get proper results. There are numerous load modeling techniques, such as polynomial load modeling, exponential load modeling, frequency-dependent load modeling, ANN-based modeling, an exponential recovery load model, composite load models, and so on [4]. Among all the available techniques, the polynomial load model and the exponential load model are widely used for modeling the loads of distribution networks [4]–[8]. In this research, we make use of the polynomial load modeling approach (ZIP load modeling).

As we all know, Nepal is a diversified country with different seasons. The season changes every three months, and the use of electrical loads also varies with the changing seasonal factors. In the summer season, we observe that fans are widely used, whereas in the winter season, fans are not used but halogen heaters, water heaters, etc. are widely used. Similarly, in the spring and autumn seasons, the climate is moderate, and we do not observe the use of electrical loads like fans, halogen heaters, water boilers, etc. Thus, the use of electrical loads varies with the changing climatic conditions of Nepal. Hence, the load on the feeder line also changes with the changing climatic conditions in Nepal. Here, the load estimation is carried out separately for different seasons.

Load estimation is carried out considering various prototype homes. The category of the prototype home is selected based on the monthly billing of the particular home and considering the various electrical appliances used by the particular household. A one-on-one interview is carried out to learn about the various types of electrical appliances used by consumers. The survey was carried out in the Jorpati area to learn about various electrical appliances used by different households. Similarly, offices, malls, commercial buildings, shops, etc. make use of different appliances, and the types of appliances used by them are also surveyed. Considering different prototype homes, shops, malls, commercial buildings, etc., the load is estimated for different seasons. Similarly, surveys are also carried out in the Malangwa area to know the different electrical appliances used by households, offices, shops, etc. The load on the feeder is estimated to be seasonal.

Based on the survey, the electrical appliances used by various consumers are determined. The survey also finds out how frequently and how long the appliances are used. The survey also finds out the types of electrical appliances used in different seasons. Based on the seasonal loads and the type of electrical appliances used by the consumers, prototype homes are classified, and the load on the feeder is estimated as different seasonal loads. Further, load estimation is carried out for different seasonal loads, incorporating ECS at each household.

3.4 Load flow analysis:

Load flow analysis is a pre-requisite for many planning and operational problems.

- Network Reconfiguration: Loss reduction, load balancing, service restoration
- Volt-var control: Voltage profile improvement, volt-var optimization
- DG and Capacitor placement: Loss reduction, renewable integration, reactive power management
- Regulator placement and control settings of regulator

All these tasks should be completed without violating our system constraints.

Standard algorithms like the Newton-Raphson method, the accelerated Gauss-Seidel method, the fast decoupled method, etc. can be used for load flow analysis. These load flow analysis methods assume a high X/R ratio, whereas in a distribution system, the X/R ratio is very poor, i.e., the R/X ratio is very high. If these methods are used for distribution systems, the rate of convergence is slow, and the memory requirement is also high. Thus, a special algorithm is used for the load flow analysis of radial distribution systems, named the backward-forward sweep algorithm. The rate of convergence of this algorithm is also high; it has a low memory requirement and good accuracy.

After the estimation of load based on the seasonal factors of the study area, load flow analysis is carried out with and without incorporating ECS at each household. The load flow is carried for summer, winter, spring, and autumn loads. Based on the results of load flow analysis, branch current, bus voltages, power loss, and transformer loading can be known with and without considering the addition of ECS at each household. Knowing the value of the current flowing through the existing feeder conductor, we can determine whether the current feeder size will be enough to handle the growing load current or not. Similarly, the voltage level at each bus can also be known, which will give us an idea of how the voltage level is going to change with the inclusion of ECS. Similarly, the loading on different transformers can also be determined, and we can decide whether the upgradation of DT is required or not.

3.5 System to be considered, tools and software to be used:

There are numerous tools and software available on the market to carry out load flow analysis. Such as MATLAB, ETAP, DIgSILENT, etc. Particularly for this research purpose, ETAP software is used for the load flow study. ETAP software is a user-friendly tool to carry out load flow studies and is widely used. MATLAB is used for load estimation and determining the ZIP coefficients of the mixed load of the study area. Similarly, MS Excel will be used for plotting various graphs and for estimating budgets.

3.5.1 ETAP Program:

ETAP stands for Electrical Transient Analyzer Program. It is software that provides a platform for electrical design engineers to model a power system from source to load. After modeling the system, one can simulate various kinds of faults.

The ETAP program can be used for the following purposes:

- Fault Calculations
- Protection and coordination
- Design of cable as per load flow
- short circuit calculation
- study of transient stability, and so on.

ETAP has wide applications, and in this project also, ETAP can be used to model the load of the consumers and conduct load flow studies for optimal cable size selection, voltage level at different buses, power loss of the system, and to determine the loading on the distribution transformer.

3.5.2 MATLAB Program:

MATLAB stands for Matrix Laboratory. MATLAB is a programming language widely used by design engineers, students, researchers, and so on. MATLAB operates on matrices and arrays. It can be used for low- to high-level programs. MATLAB can be used for various purposes such as algorithm development, data analysis, visualization, numerical computations, simulation, signal and image processing, communications, control design, test and measurement, financial modeling and analysis, etc.

Particularly in this research work, the MATLAB program is used for developing a code to determine the ZIP coefficient of the mixed load of the study area. The ZIP coefficient is determined for different season conditions for both Jorpati and Malangwa feeders. Also, three cases are considered here, using 2000W, 3000W, and 4000W electric cookers, and for each case, based on a seasonal basis, ZIP coefficients are determined. MATLAB code provides an easy way to determine the ZIP coefficients of different cases in no time with a few minor changes in the code.

3.6 Cost Estimation:

The results of the load flow will give us an idea of whether the existing feeder conductor will be able to meet the growing load current demand. If the existing feeder current cannot handle the increasing load current, then the feeder size needs to be upgraded. Similarly, there are chances that there may be overloading on the DTs, and if the existing DTs cannot meet the growing load, then their size needs to be upgraded. Thus, when upgradation is required, power utility must invest further to meet the growing load current demand. Hence, a cost estimation is done to know the approximate cost and time utility needs to upgrade the feeder size and transformer. Cost estimation is carried out considering the current market pricing of the DTs, feeder conductors, labor charges, and so on.

Table 1: Format of cost estimation for upgrading feeder and transformer size

S. N	Description	Unit	Quantity	Rate	Amount
1	11KV High Tension line (ACSR Conductor)	km			
2	Pole Mounting Sub-stations	No.			
3	Distribution transformers (size)	No.			
4	Labour Charges for pole erection, transportation and installation charges	LS			
	Sub-total				
	15% Contractors Overhead				
	Total				
	13% VAT				
	Grand total with VAT				

CHAPTER FOUR

LOAD MODELLING

Load modeling is the process of estimating the power consumption of different consumer classes. An accurate load model is required for the proper design and adjustment of transmission and distribution networks. There are numerous load modeling techniques that can be used for estimating the load of the study area. Among all the available techniques, the polynomial load model and the exponential load model are widely used for modeling the loads of distribution networks [4].

4.1 Polynomial Load Model:

This load modeling is also called as ZIP load model. The electrical loads are usually categorized as constant impedance (Z), constant current (I), and constant power (P) loads [4]. We all know that consumers make use of different electrical appliances, and the electrical loads are a mixture of constant power load, constant current load and constant impedance load. These appliances behave differently with variations in voltage. The consumption of power varies with the change in voltage represented by the equation as follows [5], [6], [8].

$P(V_a) = (P_p + I_p|\frac{Va}{V0}| + Z_p|\frac{Va}{V0}|^2)\ P_0$

Where,

P_0 = Nominal/rated power of the load

V_0= Nominal/rated voltage of the load

V_a= actual bus voltage at which load is operating

$P_p + I_p + Z_p = 1$

P_p, I_p and Z_p represents the three different kinds of loads

$Q(V_a) = (P_q + I_q|\frac{Va}{V0}| + Z_q|\frac{Va}{V0}|^2)\ Q_0$

Where,

Q_0 = Nominal/rated reactive power of the load

V_0= Nominal/rated voltage of the load

V_a= actual bus voltage at which load is operating

$P_q + I_q + Z_q = 1$

P_q, I_q and Z_q represents the three different kinds of loads

P_p, I_p, Z_p and P_q, I_q, Z_q will be different as the real and reactive power behave differently with respect to the voltage change.

Case 1: $P_p = P_q=1$, $I_p=I_q = Z_p = Z_q = 0$

$P(V_a) = P_0$

$Q(V_a) = Q_0$

These types of loads are called constant power loads.

Case 2: $I_p=I_q=1$, $P_p= P_q= Z_p=Z_q=0$

$P(V_a) = P_0 |\frac{Va}{V0}|$

$Q(V_a) = Q_0 |\frac{Va}{V0}|$

These types of loads are called constant current loads.

Case 3: $Z_p= Z_q=1$, $P_p= P_q= I_p=I_q=0$

$P(V_a) = P_0 |\frac{Va}{V0}|^2$

$Q(V_a) = Q_0 |\frac{Va}{V0}|^2$

These types of loads are called constant impedance loads.

4.2 Exponential Load Model:

$P(V_a) = P_0 |\frac{Va}{V0}|^{K_1}$

$Q(V_a) = Q_0 |\frac{Va}{V0}|^{K_2}$

$K_1 \neq K_2$, the behavior P and Q to the voltage change will differ.

$K_1 = 0.6$ to 1.8 (for general kinds of loads)

$K_2 = 1.6$ to 6 (for general kinds of loads)

The values of K_1 and K_2 will be based on variation of power to variation of voltage. A curve can be plotted to know the variation of power with respect to the variation of voltage. Using Curve fitting technique K_1 and K_2 can be determined.

a) For constant power load: $K_1=K_2=0$

$P(V_a) = P_0$

$Q(V_a) = Q_0$

b) For constant current load: $K_1=K_2=1$

$P(V_a) = P_0 |\frac{Va}{V0}|$

$Q(V_a) = Q_0 |\frac{Va}{V0}|$

c) For constant impedance load: $K_1=K_2=2$

$P(V_a) = P_0 |\frac{Va}{V0}|^2$

$Q(V_a) = Q_0 \, |\frac{Va}{V0}|^2$

In literature, we observe that exponential load models are widely used for modeling LV load. But it is not reasonable to represent the mixed load of the study area by a single term. As we all know, the composite loads of the study area are the combination of a number of electrical loads which behave differently with the changing voltage level at the buses. Thus, to overcome this problem polynomial load model is used where aggregate load is expressed as the sum of individual components with particular weight.

4.3 Load Modeling of Jorpati and Malangwa Feeder:

There are different load modeling approaches, and in this research, we make use of the polynomial load modeling approach (ZIP load modeling). There are generally two approaches to load modeling reported in the literature: component-based modeling and measurement-based load modeling. Here, we are focused on how the load profile changes with the inclusion of a particular electrical component, i.e., electric cooking stoves (ECS); hence, we make use of component-based load modeling and verify the result using the load modeled with the help of actual data collected from the concerned DCS of NEA. The loads are modeled as summer loads, winter loads, spring loads, and autumn loads.

As we all know, all the electrical appliances available in each household are not used every day. Some of the electrical appliances are used only once a day for a few minutes, some are used once a week or twice a week, and some are used on a seasonal basis as well. For example, a mixer is used once or twice a day, whereas a washing machine may be used once or twice a week. Similarly, fans and coolers are used only in the summer season. Whereas halogen heaters, water boilers, water heaters, etc. are mainly used in the winter season. Similarly, in the spring and autumn seasons, the temperature is moderate, and households rarely make use of fans, coolers, halogen heaters, and so on. Thus, the loads are modeled as summer load, winter load, spring load, and autumn load, and the loads are provided with a certain percentile of use based on how frequently the appliances are used in day-to-day life.

4.3.1 Development of Algorithm to Determine ZIP Coefficient for Mixed Load:

We all know that consumers use different electrical appliances. The loads are a mixture of constant power, constant current, and constant impedance. These appliances behave differently with variations in voltage. The active power consumption varies with the change in voltage represented by the equation as follows:

$P(V_a) = (P_p + I_p|\frac{Va}{V0}| + Z_p|\frac{Va}{V0}|^2)\, P_0$ …………………. (1)

Where,

P_0 = Nominal/rated power of the load

V_0= Nominal/rated voltage of the load

V_a= actual bus voltage at which load is operating

$P_p + I_p + Z_p = 1$

P_p, I_p and Z_p represents the three different kinds of loads

The reactive power consumption varies with the change in voltage represented by the equation as follows:

$Q(V_a) = (P_q + I_q|\frac{Va}{V0}| + Z_q|\frac{Va}{V0}|^2)\ Q_0$ …………………. (2)

Where,

Q_0 = Nominal/rated reactive power of the load

V_0= Nominal/rated voltage of the load

V_a= actual bus voltage at which load is operating

$P_q + I_q + Z_q = 1$

P_q, I_q and Z_q represents the three different kinds of loads

P_p, I_p, Z_p and P_q, I_q, Z_q will be different as the real and reactive power behave differently with respect to the voltage change and P_p, I_p, Z_p and P_q, I_q, Z_q are called as ZIP Cofficients.

Let us consider, V_a be the actual bus voltage and V_0 be the rated voltage. Suppose three electrical appliances are connected to the same bus with actual bus voltage of V_a. The three electrical appliances are named as component 1, component 2 and component 3. P_{01} and Q_{01} is the rated active and reactive power of component 1. P_{02} and Q_{02} is the rated active and reactive power of component 2. P_{03} and Q_{03} is the rated active and reactive power of component 3. P_p^1 , I_p^1 , Z_p^1 , P_q^1 , I_q^1 and Z_q^1 are ZIP coefficients of component 1. P_p^2 , I_p^2 , Z_p^2 , P_q^2 , I_q^2 and Z_q^2 are ZIP coefficients of component 2. P_p^3 , I_p^3 , Z_p^3 , P_q^3 , I_q^3 and Z_q^3 are ZIP coefficients of component 3. The active power consumed by the three components at bus voltage of V_a is given by,

$P_1 = [\ P_p^1 + I_p^1\ (|\frac{Va}{V0}|) + Z_p^1\ (|\frac{Va}{V0}|^2)]\ P_{01}$ …………………. (3)

$P_2 = [\ P_p^2 + I_p^2\ (|\frac{Va}{V0}|) + Z_p^2\ (|\frac{Va}{V0}|^2)]\ P_{02}$ …………………. (4)

$P_3 = [\ P_p^3 + I_p^3\ (|\frac{Va}{V0}|) + Z_p^3\ (|\frac{Va}{V0}|^2)]\ P_{03}$ …………………. (5)

Adding equation (3), (4) and (5)

$P_1+P_2+P_3 = \quad [\ P_p^1 + I_p^1\ (|\frac{Va}{V0}|) + Z_p^1\ (|\frac{Va}{V0}|^2)]\ P_{01} + [\ P_p^2 + I_p^2\ (|\frac{Va}{V0}|) + Z_p^2\ (|\frac{Va}{V0}|^2)]\ P_{02} +$

$[\ P_p^3 + I_p^3\ (|\frac{Va}{V0}|) + Z_p^3\ (|\frac{Va}{V0}|^2)]\ P_{03}$

$= \ P_p^1\ P_{01}+\ I_p^1\ (|\frac{Va}{V0}|)\ P_{01}+ +\ Z_p^1\ (|\frac{Va}{V0}|^2)P_{01}+\ P_p^2\ P_{02}+\ I_p^2\ (|\frac{Va}{V0}|)\ P_{02}+ +\ Z_p^2\ (|\frac{Va}{V0}|^2)P_{02}+\ P_p^3\ P_{03}+\ I_p^3\ (|\frac{Va}{V0}|)\ P_{03}+ +\ Z_p^3\ (|\frac{Va}{V0}|^2)P_{03}$

$= \{(P_p^1\ P_{01} + P_p^2\ P_{02}+\ P_p^3\ P_{03}) + (I_p^1\ P_{01} + I_p^2\ P_{02}+\ I_p^3\ P_{03})\ (|\frac{Va}{V0}|) +$

$(Z_p^1\, P_{01} + Z_p^2\, P_{02} + Z_p^3\, P_{03})\, (|\frac{Va}{V0}|^2)\}$

$= \{[P_p^1\, P_{01} + P_p^2\, P_{02} + P_p^3\, P_{03}] + [I_p^1\, P_{01} + I_p^2\, P_{02} + I_p^3\, P_{03}]\, (|\frac{Va}{V0}|) +$

$[Z_p^1\, P_{01} + Z_p^2\, P_{02} + Z_p^3\, P_{03}]\, (|\frac{Va}{V0}|^2)\} * (P_{01}+P_{02}+P_{03})/(P_{01}+P_{02}+P_{03})$

$= \{[P_p^1\, P_{01} + P_p^2\, P_{02} + P_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03}) + ([I_p^1\, P_{01} + I_p^2\, P_{02} + I_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03})\, (|\frac{Va}{V0}|) + [Z_p^1\, P_{01} + Z_p^2\, P_{02} + Z_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03})\, (|\frac{Va}{V0}|^2)\} * (P_{01}+P_{02}+P_{03})$

Therefore,

$P_1+P_2+P_3 = [\, P_p^{new} + I_p^{new}\, (|\frac{Va}{V0}|) + Z_p^{new}\, (|\frac{Va}{V0}|^2)\,] * (P_{01}+P_{02}+P_{03})$

$P_{new}^{consumed} = [\, P_p^{new} + I_p^{new}\, (|\frac{Va}{V0}|) + Z_p^{new}\, (|\frac{Va}{V0}|^2)\,] * P_0^{actual}$

Where,

$P_p^{new} = [P_p^1\, P_{01} + P_p^2\, P_{02} + P_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03})$

$I_p^{new} = [I_p^1\, P_{01} + I_p^2\, P_{02} + I_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03})$

$Z_p^{new} = [Z_p^1\, P_{01} + Z_p^2\, P_{02} + Z_p^3\, P_{03}] / (P_{01}+P_{02}+P_{03})$

Similarly, the reactive power consumed by the three components at bus voltage of V_a is given by,

$Q_1 = [\, P_q^1 + I_q^1\, (|\frac{Va}{V0}|) + Z_q^1\, (|\frac{Va}{V0}|^2)]\, Q_{01}$ …………………. (6)

$Q_2 = [\, P_q^2 + I_q^2\, (|\frac{Va}{V0}|) + Z_q^2\, (|\frac{Va}{V0}|^2)]\, Q_{02}$ …………………. (7)

$Q_3 = [\, P_q^3 + I_q^3\, (|\frac{Va}{V0}|) + Z_q^3\, (|\frac{Va}{V0}|^2)]\, Q_{03}$ …………………. (8)

Adding equation (6), (7) and (8)

$Q_1+Q_2+Q_3 = [\, P_q^1 + I_q^1\, (|\frac{Va}{V0}|) + Z_q^1\, (|\frac{Va}{V0}|^2)]\, Q_{01} + [\, P_q^2 + I_q^2\, (|\frac{Va}{V0}|) + Z_q^2\, (|\frac{Va}{V0}|^2)]\, Q_{02} +$

$[\, P_q^3 + I_q^3\, (|\frac{Va}{V0}|) + Z_q^3\, (|\frac{Va}{V0}|^2)]\, Q_{03}$

$= P_q^1\, Q_{01} + I_q^1\, (|\frac{Va}{V0}|)\, Q_{01} + + Z_q^1\, (|\frac{Va}{V0}|^2) Q_{01} + P_q^2\, Q_{02} + I_q^2\, (|\frac{Va}{V0}|)\, Q_{02} + Z_q^2\, (|\frac{Va}{V0}|^2) Q_{02} + P_q^3\, Q_{03} + I_q^3\, (|\frac{Va}{V0}|)\, Q_{03} + + Z_q^3\, (|\frac{Va}{V0}|^2) Q_{03}$

$= \{(P_q^1\, Q_{01} + P_q^2\, Q_{02} + P_q^3\, Q_{03}) + (I_q^1\, Q_{01} + I_q^2\, Q_{02} + I_q^3\, Q_{03})\, (|\frac{Va}{V0}|) +$

$(Z_q^1\, Q_{01} + Z_q^2\, Q_{02} + Z_q^3\, Q_{03})\, (|\frac{Va}{V0}|^2)\}$

$= \{[P_q^1\, Q_{01} + P_q^2\, Q_{02} + P_q^3\, Q_{03}] + [I_q^1\, Q_{01} + I_q^2\, Q_{02} + I_q^3\, Q_{03}]\, (|\frac{Va}{V0}|) +$

$[Z_q^1\, Q_{01} + Z_q^2\, Q_{02} + Z_q^3\, Q_{03}]\, (|\frac{Va}{V0}|^2)\} * (Q_{01}+Q_{02}+Q_{03})/(Q_{01}+Q_{02}+Q_{03})$

$= \{[P_q^1\ Q_{01} + P_q^2\ Q_{02} + P_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03}) + ([I_q^1\ Q_{01} + I_q^2\ Q_{02} + I_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03}) (|\frac{Va}{V0}|) + [Z_q^1\ Q_{01} + Z_q^2\ Q_{02} + Z_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03}) (|\frac{Va}{V0}|^2)\} * (Q_{01}+Q_{02}+Q_{03})$

Therefore,

$Q_1+Q_2+Q_3 = [\ P_q^{new} + I_q^{new} (|\frac{Va}{V0}|) + Z_q^{new} (|\frac{Va}{V0}|^2)\ ] * (Q_{01}+Q_{02}+Q_{03})$

$Q_{new}^{consumed} = [\ P_q^{new} + I_q^{new} (|\frac{Va}{V0}|) + Z_q^{new} (|\frac{Va}{V0}|^2)\ ] * Q_0^{actual}$

Where,

$P_q^{new} = [P_q^1\ Q_{01} + P_q^2\ Q_{02} + P_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03})$

$I_q^{new} = [I_q^1\ Q_{01} + I_q^2\ Q_{02} + I_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03})$

$Z_q^{new} = [Z_q^1\ Q_{01} + Z_q^2\ Q_{02} + Z_q^3\ Q_{03}] / (Q_{01}+Q_{02}+Q_{03})$

$(P_{01}+P_{02}+P_{03})$ represents the active power Consumption of the study area of those three components and $(Q_{01}+Q_{02}+Q_{03})$ represents the reactive power Consumption of the study area of those three components.

If n number of electrical appliances are considered in the study area, then

Let us consider that V_a is the actual bus voltage and V_0 is the rated voltage. Consider n electrical appliances are connected to the same bus with an actual bus voltage of V_a. Components 1, 2, 3,….., and n are assigned to the n electrical appliances. P_{01} and Q_{01} are the rated active and reactive power of component 1. P_{02} and Q_{02} are the rated active and reactive power of component 2. P_{03} and Q_{03} are the rated active and reactive power of component 3. Similarly, P_{0n} and Q_{0n} are the rated active and reactive powers of component n. P^1_p, I^1_p , Z^1_p , P^1_q, I^1_q and Z^1_q are ZIP coefficients of component 1. P^2_p , I^2_p , Z^2_p , P^2_q, I^2_q and Z^2_q are ZIP coefficients of component 2. P^3_p , I^3_p , Z^3_p , P^3_q, I^3_q and Z^3_q are ZIP coefficients of component 3. P^n_p , I^n_p , Z^n_p , P^n_q, I^n_q and Z^n_q are ZIP coefficients of component n. The active power consumed by the n components at a bus voltage of V_a is given by,

$P_1 = [P^1_p + I^1_p (|V_a/V_0|) + Z^1_p (|V_a/V_0|^2)]\ P_{01}$ …………………. (9)

$P_2 = [P^2_p + I^2_p (|V_a/V_0|) + Z^2_p (|V_a/V_0|^2)]\ P_{02}$ …………………. (10)

$P_3 = [P^3_p + I^3_p (|V_a/V_0|) + Z^3_p (|V_a/V_0|^2)]\ P_{03}$ …………………. (11)

Similarly,

$P_n = [P^n_p + I^n_p (|V_a/V_0|) + Z^n_p (|V_a/V_0|^2)]\ P_{0n}$ …………………. (12)

Adding equations 9, 10, 11 and 12

$P_1+P_2+P_3 + \ldots\ldots\ldots\ldots + P_n = [P^1_p + I^1_p (|V_a/V_0|) + Z^1_p (|V_a/V_0|^2)]P_{01} + [P^2_p + I^2_p (|V_a/V_0|) + Z^2_p (|V_a/V_0|^2)]P_{02} + [P^3_p + I^3_p (|V_a/V_0|) + Z^3_p (|V_a/V_0|^2)]P_{03} + \ldots\ldots\ldots\ldots\ldots\ldots + [P^n_p + I^n_p (|V_a/V_0|) + Z^n_p (|V_a/V_0|^2)]P_{0n}$

or, $P_1+P_2+P_3 + \ldots\ldots +P_n = P^1{}_p\, P_{01} + I^1{}_p\, (|V_a/V_0|)\, P_{01} + Z^1{}_p\, (|V_a/V_0|^{\,2}\, P_{01} + P^2{}_p\, P_{02} + I^2{}_p\, (|V_a/V_0|)\, P_{02} + Z^2{}_p\, (|V_a/V_0|^{\,2}\, P_{02} + P^3{}_p\, P_{03} + I^3{}_p\, (|V_a/V_0|)\, P_{03} + Z^3{}_p\, (|V_a/V_0|^{\,2}\, P_{03} + \ldots\ldots + P^n{}_p\, P_{0n} + I^n{}_p\, (|V_a/V_0|)\, P_{0n} + Z^n{}_p\, (|V_a/V_0|^{\,2}\, P_{0n}$

or, $P_1+P_2+P_3 + \ldots\ldots +P_n = [P^1{}_p\, P_{01} + P^2{}_p\, P_{02}+ P^3{}_p\, P_{03}+\ldots + P^n{}_p\, P_{0n}] + [I^1{}_p\, P_{01} + I^2{}_p\, P_{02}+ I^3{}_p\, P_{03}+\ldots + I^n{}_p\, P_{0n}]\, (V_a/V_0) + [Z^1{}_p\, P_{01} + Z^2{}_p\, P_{02}+ Z^3{}_p\, P_{03}+\ldots + Z^n{}_p\, P_{0n}]\, (V_a/V_0)^2$

Multiplying numerator and denominator by $(P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

or, $P_1+P_2+P_3 + \ldots\ldots +P_n = [(P^1{}_p\, P_{01} + P^2{}_p\, P_{02}+ P^3{}_p\, P_{03}+\ldots + P^n{}_p\, P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n}) + (I^1{}_p\, P_{01} + I^2{}_p\, P_{02}+ I^3{}_p\, P_{03}+\ldots + I^n{}_p\, P_{0n}) * (V_a/V_0) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n}) + (Z^1{}_p\, P_{01} + Z^2{}_p\, P_{02}+ Z^3{}_p\, P_{03}+\ldots + Z^n{}_p\, P_{0n}) * (V_a/V_0)^2 / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})] * (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

Therefore,

$P_1+P_2+P_3 + \ldots\ldots +P_n = [\, P^m{}_p + I^m{}_p\, (V_a/V_0) + Z^m{}_p\, (V_a/V_0)^{\,2}\,] * (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

Where,

$P^m{}_p = (P^1{}_p\, P_{01} + P^2{}_p\, P_{02}+ P^3{}_p\, P_{03}+\ldots + P^n{}_p\, P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

$I^m{}_p = (I^1{}_p\, P_{01} + I^2{}_p\, P_{02}+ I^3{}_p\, P_{03}+\ldots + I^n{}_p\, P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

$Z^m{}_p = (Z^1{}_p\, P_{01} + Z^2{}_p\, P_{02}+ Z^3{}_p\, P_{03}+\ldots + Z^n{}_p\, P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

The reactive power consumed by all electrical components at bus voltage of Va will be given by,

$$Q_1 = [\, P_q{}^1 + I_q{}^1\, (|\frac{Va}{V0}|) + Z_q{}^1\, (|\frac{Va}{V0}|^2)]\, Q_{01} \ldots\ldots\ldots\ldots \text{(13)}$$

$$Q_2 = [\, P_q{}^2 + I_q{}^2\, (|\frac{Va}{V0}|) + Z_q{}^2\, (|\frac{Va}{V0}|^2)]\, Q_{02} \ldots\ldots\ldots\ldots \text{(14)}$$

$$Q_3 = [\, P_q{}^3 + I_q{}^3\, (|\frac{Va}{V0}|) + Z_q{}^3\, (|\frac{Va}{V0}|^2)]\, Q_{03} \ldots\ldots\ldots\ldots \text{(15)}$$

Similarly,

$$Q_n = [P^n{}_q + I^n{}_q\, (|V_a/V_0|) + Z^n{}_q\, (|V_a/V_0|^{\,2})]\, Q_{0n} \ldots\ldots\ldots\ldots \text{(16)}$$

Adding equation 13, 14, 15 and 16

$Q_1+Q_2+Q_3 + \ldots\ldots +Q_n = [P^1{}_q + I^1{}_q\, (|V_a/V_0|) + Z^1{}_q\, (|V_a/V_0|^{\,2}\,)]Q_{01} + [P^2{}_q + I^2{}_q\, (|V_a/V_0|) + Z^2{}_q\, (|V_a/V_0|^{\,2}\,)]Q_{02} + [P^3{}_q + I^3{}_q\, (|V_a/V_0|) + Z^3{}_q\, (|V_a/V_0|^{\,2}\,)]Q_{03}+ \ldots\ldots + [P^n{}_q + I^n{}_q\, (|V_a/V_0|) + Z^n{}_q\, (|V_a/V_0|^{\,2}\,)]Q_{0n}$

or, $Q_1+Q_2+Q_3 + \ldots\ldots +Q_n = P^1{}_q\, Q_{01} + I^1{}_q\, (|V_a/V_0|)\, Q_{01} + Z^1{}_q\, (|V_a/V_0|^{\,2}\, Q_{01} + P^2{}_q\, Q_{02} + I^2{}_q\, (|V_a/V_0|)\, Q_{02} + Z^2{}_q\, (|V_a/V_0|^{\,2}\, Q_{02} + P^3{}_q\, Q_{03} + I^3{}_q\, (|V_a/V_0|)\, Q_{03} + Z^3{}_q\, (|V_a/V_0|^{\,2}\, Q_{03} + \ldots\ldots + P^n{}_q\, Q_{0n} + I^n{}_q\, (|V_a/V_0|)\, Q_{0n} + Z^n{}_q\, (|V_a/V_0|^{\,2}\, Q_{0n}$

or, $Q_1+Q_2+Q_3 + \ldots +Q_n = [P^1_q Q_{01} + P^2_q Q_{02}+ P^3_q Q_{03}+\ldots + P^n_q Q_{0n}] + [I^1_q Q_{01} + I^2_q Q_{02}+ I^3_q Q_{03}+\ldots + I^n_q Q_{0n}] (V_a/V_0) + [Z^1_q Q_{01} + Z^2_q Q_{02}+ Z^3_q Q_{03}+\ldots + Z^n_q Q_{0n}] (V_a/V_0)^2$

Multiplying numerator and denominator by $(Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$Q_1+Q_2+Q_3 + \ldots +Q_n = [(P^1_q Q_{01} + P^2_q Q_{02}+ P^3_q Q_{03}+\ldots + P^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n}) + (I^1_q Q_{01} + I^2_q Q_{02}+ I^3_q Q_{03}+\ldots + I^n_q Q_{0n}) * (V_a/V_0) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n}) + (Z^1_q Q_{01} + Z^2_q Q_{02}+ Z^3_q Q_{03}+\ldots + Z^n_q Q_{0n}) * (V_a/V_0)^2 / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})] * (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

Therefore,

$Q_1+Q_2+Q_3 + \ldots +Q_n = [\, P^m_q + I^m_q (V_a/V_0) + Z^m_q (V_a/V_0)^2 \,] * (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

Where,

$P^m_q = (P^1_q Q_{01} + P^2_q Q_{02}+ P^3_q Q_{03}+\ldots + P^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$I^m_q = (I^1_q Q_{01} + I^2_q Q_{02}+ I^3_q Q_{03}+\ldots + I^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$Z^m_q = (Z^1_q Q_{01} + Z^2_q Q_{02}+ Z^3_q Q_{03}+\ldots + Z^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$(P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$ represents the active power consumption of the study area of those n loads and $(Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$ represents the reactive power Consumption of the study area of those three components P^m_p, I^m_p , Z^m_p , P^m_q , I^m_q , Z^m_q represents the ZIP Coefficients for mixed load.

As the loads available in the study area are mixed loads. Thus, the values of P_p , I_p , Z_p and P_q, I_q , Z_q will be different but their sum will remain 1. The values of P_p , I_p , Z_p and P_q, I_q , Z_q vary as the appliances available in the study area change. Thus, the ZIP coefficients of the mixed load will be different for different areas and will differ as per the change in the seasonal loads as well. Thus, ZIP coefficients for summer, winter, spring and autumn loads are separately determined. The load modeling is carried out considering different prototype homes, offices, commercial buildings, and so on.

4.3.2 Load Estimation and ZIP Coefficient determination

ZIP Coefficients are determined considering various prototype homes, offices, commercial building, welding shops and so on. The various electrical appliances used by the prototype homes are surveyed by one-to-one interview method and for mixed load ZIP Coefficients are determined. Also, the load on the feeder is estimated. The usage of various electrical loads differs as per the seasonal condition also. So, the load on the feeder is estimated separately for spring load, summer load, autumn load and winter load considering

Demand factor = 0.7 and Diversity factor = 2

After the load estimation on the feeder line, the load is further estimated incorporating electric cooking stoves at each household with coincidence factor of 0.7.

Table 2: List of Electrical loads used in different Seasonal Condition

Spring and Autumn Load	Summer Load	Winter load
Lighting load	Lighting load	Lighting load
LCD TV Model	LCD TV Model	LCD TV Model
Air conditioner	Air conditioner	Air conditioner
Refrigerator	Refrigerator	Refrigerator
Microwave	Microwave	Microwave
desktop	desktop	desktop
Washing Machine	Washing Machine	Washing Machine
Vacuum Cleaner	Vacuum Cleaner	Vacuum Cleaner
Mixer	Mixer	Mixer
Iron	Iron	Iron
Motor load	Motor load	Motor load
Air compressor 1ph	Air compressor 1ph	Air compressor 1ph
Welding Machine	Welding Machine	Welding Machine
Charger	Charger	Charger
Copier	Copier	Copier
Elevator	Elevator	Elevator
	Fan	Halogen Heater
		Water heater/Boiler

Above table is the list of electrical appliances used by the consumers in the study area. The usage of appliances is different based on seasonal conditions and thus, these appliances used by the consumers are classified based on seasonal basis. Considering these appliances in each season the load and ZIP coefficients are estimated incorporating 2000W, 3000W and 4000W ECS respectively.

Table 3: List of electrical appliances considered and their ZIP coefficients (source: [5], [6], [8])

Name of appliances	Zp	Zq	Ip	Iq	Pp	Pq
LED Light	0.73	0.52	-1.7	-1.41	1.97	1.89
Fan	0.26	0.5	0.9	0.62	-0.16	-0.12
LCD TV Model	-0.4	3.92	0.45	-4.86	0.95	1.94
Halogen Heater	0.51	0.43	0.55	0.52	-0.06	0.05
Air conditioner	1.55	1.56	-2.12	-2.14	1.57	1.58
Refrigerator	1.04	5.69	-1.57	-8.56	1.53	3.87
Microwave	1	0	0.6	2.02	-0.6	-1.02
desktop	-0.32	1.56	1.14	-2.13	0.18	1.57
Washing Machine	0.78	-2.29	0.34	5.51	-0.12	-2.22
Vacuum Cleaner	0.82	5.95	0.22	-7.33	-0.04	2.38
Water Heater/Boiler	0.95	0.29	0.07	1.02	-0.02	-0.31
Mixer	0.94	0.61	0.09	0.56	-0.03	-0.17
Charger	0.25	0.14	-0.48	0.32	1.23	0.54
Iron	0.99	3.92	0.01	-4.86	0	1.94
Copier	0.52	0.39	0.45	-0.25	0.03	0.86
Motor load	-0.07	0.01	0.08	0.01	0.99	0.98
Air compressor 1ph	0.73	0.45	0.38	0.51	-0.11	0.04
Welding Machine	-3.16	-1	6.85	1.98	-2.69	0.02
Elevator	2.36	-2.93	-4.15	6.5	2.79	-2.57
Induction Cooker	0	1.91	1	0	0	-0.91
Infra-red Cooker	0.51	0.43	0.55	0.52	-0.06	0.05

Electrical loads are categorized as constant current, constant impedance, and constant power loads. But none of the appliances available on the market are purely of the constant power, constant current, or constant impedance type. The electrical loads available on the market are mixed types. i.e., the appliances behave with a mixture of constant power, constant current, and a constant impedance load. The power consumed by the electrical appliances depends on the voltage level at the buses given by equations (1) and (2), and Z_p, I_p, P_p, Z_q, I_q, and P_q represent ZIP coefficients whose values are different for different appliances. The ZIP coefficient value represents the percentage of constant power, constant current, and constant impedance load. The ZIP coefficients of different appliances have been determined by researchers in the lab by varying the voltage level. For different voltage levels, the power consumed by the appliances is determined experimentally in the lab. Based on the curve plotted, the values of ZIP coefficients are determined, which satisfy equations (1) and (2). The ZIP coefficients of the electrical appliances available in the study area are sourced from the research papers.

Table 4 : Prototype Home 1 – Spring Load – Jorpati Feeder – Determination ZpIpPp Incorporating ECS

No of Household (a) = 345

Name of appliances	Zp	ZpPo	Ip	IpPo	Pp	PpPo	NO. of items available(b)	Percitile of use (c)	Average loading (d)	active power Consumption (Po=abcd)
Lighting load	0.73	47221.875	-1.7	-109968.75	1.97	127434.375	25	0.5	15	64687.5
LCD TV Model	-0.4	-15676.8	0.45	17636.4	0.95	37232.4	2	0.4	142	39192
Air conditioner	1.55	192510	-2.12	-263304	1.57	194994	1	0.2	1800	124200
Refrigerator	1.04	40365	-1.57	-60935.625	1.53	59383.125	1	0.5	225	38812.5
Microwave	1	52785	0.6	31671	-0.6	-31671	1	0.1	1530	52785
desktop	-0.32	-4471.2	1.14	15928.65	0.18	2515.05	1	0.1	405	13972.5
Washing Machine	0.78	101719.8	0.34	44339.4	-0.12	-15649.2	1	0.3	1260	130410
Vacuum Cleaner	0.82	30553.2	0.22	8197.2	-0.04	-1490.4	1	0.1	1080	37260
Mixer	0.94	21890.25	0.09	2095.875	-0.03	-698.625	1	0.1	675	23287.5
Iron	0.99	30739.5	0.01	310.5	0	0	1	0.1	900	31050
Infrared Heater	0.51	166272.75	0.55	179313.75	-0.06	-19561.5	1	0.7	1350	326025
Induction Heater	0	0	1	147487.5	0	0	1	0.7	1425	147487.5

Sums		663909.375		12771.9		352488.225				1029169.5
Average ZIP Coefficients value	0.6450924		0.01241		0.3425					1

Table 5: Prototype Home 1 - Spring Load - Jorpati Feeder - Determination ZqIqPq Incorporating ECS

No of Households (a) = 345

Name of appliances	Zq	ZqQo	Iq	IqQo	Pq	PqQo	No. of items available (b)	percitile of use (c)	average loading (reactive) (d)	reactive power consumption (Qo=abcd)
Lighting load	0.52	10539.75	-1.41	-28578.938	1.89	38307.9375	25	0.5	4.7	20268.75
LCD TV Model	3.92	48686.4	-4.86	-60361.2	1.94	24094.8	2	0.4	45	12420
Air conditioner	1.56	93862.08	-2.14	-128759.52	1.58	95065.44	1	0.2	872	60168
Refrigerator	5.69	103060.125	-8.56	-155043	3.87	70095.375	1	0.5	105	18112.5
Microwave	0	0	2.02	51222.15	-1.02	-25864.65	1	0.1	735	25357.5
desktop	1.56	10548.72	-2.13	-14403.06	1.57	10616.34	1	0.1	196	6762
Washing Machine	-2.29	-144579.15	5.51	347873.85	-2.22	-140159.7	1	0.3	610	63135
Vacuum Cleaner	5.95	106743	-7.33	-131500.2	2.38	42697.2	1	0.1	520	17940
Mixer	0.61	6839.625	0.56	6279	-0.17	-1906.125	1	0.1	325	11212.5
Iron	3.92	58423.68	-4.86	-72433.44	1.94	28913.76	1	0.1	432	14904
Infrared Heater	0.43	67810.785	0.52	82003.74	0.05	7884.975	1	0.7	653	157699.5
Induction Heater	1.91	92516.58	0	0	-0.91	-44078.58	1	0.7	468	48438

Sums		454451.595		-103700.62		105666.773				456417.75
Average ZIP Coefficients value	0.9956922		-0.22721		0.23151					1

At first, the model is developed in MS Excel for determining the ZIP coefficient of the mixed load of the study area. The ZIP coefficient is determined for different prototype homes, offices, malls and commercial building and so on. Later considering all these prototype homes, offices, malls and commercial buildings and so on the ZIP coefficient of the study area is determined. Using this model in MS Excel, MATLAB code is developed to directly determine the ZIP coefficients value.

Table 5 shows steps to determine ZIP coefficients (Z_p, I_p & P_p) of prototype home 1 of Jorpati area for spring season. In similar fashion Z_p, I_p & P_p of other prototype homes, offices, maals and commercial building can be determined for different seasonal conditions. The only changes we would observe for different prototype homes, offices, malls and commercial builds are number of consumers and the appliances used by them. Table 6 shows steps to determine ZIP coefficients (Z_q, I_q & P_q) of prototype home 1 of jorpati area for spring season. In similar fashion Z_q, I_q & P_q of other prototype homes, offices, maals and commercial building can be determined for different seasonal condition. The same procedure can be carried out for ZIP coefficient determination of Malangwa feeder. The load on the feeder is also estimated using MS Excel same table considering number and types of appliances used, percentile of use of those appliances, the number of consumers for different prototype homes, offices, malls and commercial buildings and so on. There are altogether 6910 consumers connected to Jorpati feeder and 13980 consumers connected to Malangwa feeder.

4.3.2.1 ZIP Coefficient and load estimation of Jorpati Feeder

i) Without incorporating ECS

The ZIP coefficient of the mixed load of Jorpati area without incorporating the use of ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Jorpati feeder.

Table 6 : Load estimation and ZIP coefficient determination of Jorpati Feeder without incorporating ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load without ECS	0.339	0.09	0.571	0.47	0.117	0.413	8631058	6580836
Summer Load without ECS	0.41	0.083	0.507	0.527	0.07	0.403	11609986	8021570
Winter Load Without ECS	0.573	0.119	0.308	0.353	0.457	0.19	17705002	10635639

ii) Incorporating 2000W ECS

The ZIP coefficient of the mixed load of Jorpati area incorporating the use of 2000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Jorpati feeder.

Table 7: Load estimation and ZIP coefficient determination of Jorpati Feeder incorporating 2000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring Load with ECS	0.242	0.35	0.408	0.681	0.1	0.219	12096658	7719012
Summer Load with ECS	0.316	0.294	0.39	0.7	0.061	0.239	15075586	9159746
Winter Load With ECS	0.479	0.263	0.258	0.503	0.413	0.084	21170602	11773815

iii) Incorporating 3000W ECS

The ZIP coefficient of the mixed load of Jorpati area incorporating the use of 3000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Jorpati feeder.

Table 8: Load estimation and ZIP coefficient determination of Jorpati Feeder incorporating 3000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load with ECS	0.345	0.385	0.27	0.579	0.217	0.204	16975858	10213636
Summer Load with ECS	0.385	0.337	0.278	0.605	0.172	0.223	19954786	11654370
Winter Load With ECS	0.502	0.302	0.196	0.461	0.442	0.097	26049802	14268439

iv) Incorporating 4000W ECS

The ZIP coefficient of the mixed load of Jorpati area incorporating the use of 4000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Jorpati feeder.

Table 9: Load Estimation and ZIP coefficient determination of Jorpati Feeder incorporating 4000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load with ECS	0.346	0.428	0.226	0.6	0.236	0.164	19757458	11425988
Summer Load with ECS	0.381	0.38	0.239	0.622	0.193	0.185	22736386	12866722
Winter Load With ECS	0.487	0.34	0.173	0.486	0.438	0.076	28831402	15480791

v) Estimated load on Jorpati feeder

Here, the load is estimated considering various prototype homes and number of consumers connected to the feeder line. The load estimated is the total connected load on the feeder line based on climatic condition. The actual load on the feeder line is calculated considering,

Demand Factor = 0.7

Diversity Factor = 2

Similarly, while incorporating ECS as load to each household, the coincidence factor is considered as 0.7.

Table 10: Load on the Jorpati feeder in different climatic condition without incorporating ECS

Climatic condition	Estimated load on Jorpati feeder (KVA)
Spring Load without ECS	3798.79
Autumn Load without ECS	3798.79
Summer Load without ECS	4939.06
Winter Load Without ECS	6196.16

The load estimated on the jorpati feeder is cross verified with the load estimated using the actual data collected from the concerned DCS and substation of NEA. After the cross verification the estimated load by this process was found to be almost similar. Thus, with a similar calculation procedure the load on the feeder is estimated incorporating ECS for different seasonal conditions.

Table 11: Load on the Jorpati feeder in different climatic condition incorporating ECS

Climatic condition	Estimated load on Jorpati feeder (KVA)		
	2000W ECS	3000 W ECS	4000W ECS
Spring Load with ECS	5022.37	6934.04	7988.21
Autumn Load with ECS	5022.37	6934.04	7988.21
Summer Load with ECS	6174.04	8088.08	9143.61
Winter Load With ECS	7267.29	10395.53	11453.63

4.3.2.2 ZIP Coefficient and load estimation of Malangwa Feeder

i) Without incorporating ECS

The ZIP coefficient of the mixed load of Malangwa area without incorporating the use of ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Malangwa feeder.

Table 12: Load estimation and ZIP coefficient determination of Malangwa Feeder without incorporating ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load without ECS	0.042	0.622	0.336	0.361	0.219	0.42	14735358	13310925
Summer Load without ECS	0.143	0.571	0.286	0.421	0.234	0.345	20736347	17072581
Winter Load Without ECS	0.316	0.43	0.254	0.303	0.395	0.302	20223828	16033111

ii) Incorporating 2000W ECS

The ZIP coefficient of the mixed load of Malangwa area incorporating the use of 2000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Malangwa feeder.

Table 13: Load estimation and ZIP coefficient determination of Malangwa Feeder incorporating 2000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load with ECS	0.029	0.741	0.23	0.583	0.187	0.23	21508668	15535423
Summer Load with ECS	0.108	0.677	0.215	0.593	0.207	0.2	27509657	19297078
Winter Load With ECS	0.264	0.524	0.212	0.5	0.347	0.153	24208128	18257609

iii) Incorporating 3000W ECS

The ZIP coefficient of the mixed load of Malangwa area incorporating the use of 3000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Malangwa feeder.

Table 14: Load estimation and ZIP coefficient determination of Malangwa Feeder incorporating 3000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load with ECS	0.204	0.658	0.138	0.522	0.231	0.247	31044776	16896376
Summer Load with ECS	0.234	0.624	0.142	0.542	0.242	0.216	37045765	20658031
Winter Load With ECS	0.327	0.514	0.159	0.45	0.396	0.154	298117603	23133203

iv) Incorporating 4000W ECS

The ZIP coefficient of the mixed load of Malangwa area incorporating the use of 4000W ECS based on seasonal basis is tabulated below. The table also contains the estimated total connected load on the Malangwa feeder.

Table 15: Load estimation and ZIP coefficient determination of Malangwa Feeder incorporating 4000W ECS

Load	Zp	Ip	Pp	Zq	Iq	Pq	P(W)	Q(VAR)
Spring & Autumn Load with ECS	0.226	0.663	0.111	0.566	0.224	0.210	36481248	17452500
Summer Load with ECS	0.249	0.632	0.119	0.577	0.236	0.187	42482237	21214156
Winter Load With ECS	0.33	0.530	0.14	0.479	0.396	0.125	33015528	25502674

v) Estimated load on Malangwa feeder

Here, the load is estimated considering various prototype homes and number of consumers connected to the feeder line. The load estimated is the total connected load on the feeder line based on climatic condition. The actual load on the feeder line is calculated considering,

Demand Factor = 0.7

Diversity Factor = 2

Similarly, while incorporating ECS as load to each household, the coincidence factor is considered to be 0.7.

Table 16: Estimated load on the Malangwa feeder without incorporating ECS in different climatic condition

Climatic condition	Estimated load on Malangwa feeder(KVA)
Spring Load without ECS	5957.1835
Autumn Load without ECS	5957.1835
Summer Load without ECS	8058.0531
Winter Load Without ECS	7742.464

The load estimated on the Malangwa feeder is cross verified with the load estimated using the actual data collected from the concerned DCS and substation of NEA. After the cross verification the estimated load by this process was found to be almost similar. Thus, with a similar calculation procedure the load on the feeder is estimated incorporating ECS for different seasonal conditions.

Table 17: Estimated load on the Malangwa feeder incorporating ECS in different Climatic Condition

Climatic condition	Estimated load on Malangwa feeder (KVA)		
	2000W ECS	3000 W ECS	4000W ECS
Spring Load with ECS	7959.7421	10603.48	12132.28
Autumn Load with ECS	7959.7421	10603.48	12132.28
Summer Load with ECS	10080.886	12724.89	14245.36
Winter Load With ECS	9096.353	11321.709	12515.47

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Load Flow Results of Jorpati Feeder:

i) Incorporating 2000W ECS

After load modeling for summer, winter, spring and autumn loads with and without incorporating ECS of 2000W (two ECS of 1000W each) at each household of the Jorpati feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

Table 18: Summary of Load flow report of Jorpati Feeder incorporating 2000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	203.1	108	100	147.187	2.058559
Spring & Autumn Load with ECS	253.2	167.8	155.4	228.7051	3.198672
Summer Load with ECS	308.9	249.7	231.3	340.3671	4.760379
Winter load with ECS	353.8	325.7	303	444.8477	6.221646

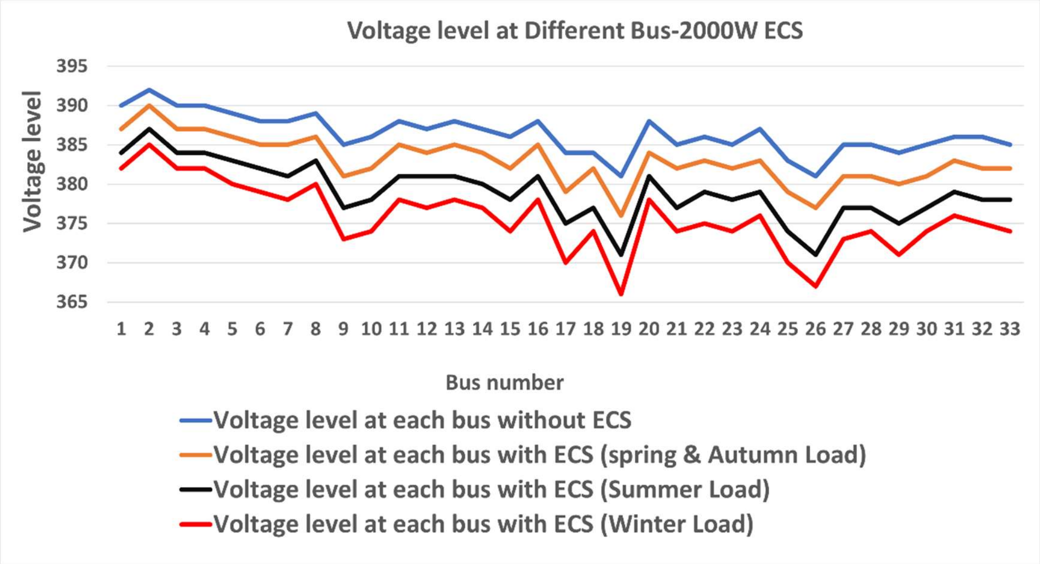


Figure 6: Voltage level at different bus incorporating 2000W ECS – Jorpati Feeder

Without incorporating ECS, two transformers are operating at around 90% loading and the voltage level is within the acceptable limit, i.e., ± 10% for distribution system.

After incorporating 2000W ECS at each household, we observe that in the spring and autumn season, there are two transformers that are overloaded. This is because these two transformers were normally operating at 90% loading. The voltage level at this condition is also within an acceptable limit. Similarly, in the summer season, seven transformers are overloaded and voltage level with acceptable limit of ±10%. Also, the feeder conductor is marginally overloaded, operating at 93.3%. Similarly, in the winter season, we observe that 12 transformers are overloaded and need to be upgraded, and one transformer is operating at 99.8% loading. The voltage level drops by 8% on a few buses at which DTs were initially 90% loaded. Further analysis shows that other five transformers are operating at around 94% loading. Also, there is overloading on the feeder conductor. The existing dog conductor can carry only 331A current at an ambient temperature of 30^0C whereas the current flowing through the feeder conductor is 353.8A. Thus, all these 18 transformers need to be upgraded, along with the feeder conductor. Optimal cable selection suggest that the feeder conductor must be upgraded to a wolf conductor to safely carry the growing load current demand because it can safely carry 429A at an ambient temperature of 30^0C.

ii) Incorporating 3000W ECS

After load modeling for summer, winter, spring and autumn loads with and without incorporating ECS of 3000W (two ECS of 1500W each) at each household of the Jorpati feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

Table 19: Summary of Load flow report of Jorpati Feeder incorporating 3000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	203.1	108	100	147.187	2.058559
Spring & Autumn Load with ECS	350.7	321.7	297.9	438.4465	6.132118
Summer Load with ECS	419.7	460.5	426.5	627.6643	8.778522
Winter load with ECS	529.9	733.5	679.5	999.8712	13.98421

After incorporating 3000W ECS at each household, we observe that in the spring and autumn seasons, there are ten DTs that are overloaded, and three DTs are operating above 95% loading. The current flowing through the feeder conductor is 350.7A, which is above the ampacity of the existing dog conductor. In the summer season, 20 DTs are overloaded, and 4 DTs are operating above 95% loading. The current flowing through the feeder conductor is 419.7A which is way above the ampacity of the feeder conductor. Even wolf conductor cannot meet this huge load current demand. Similar is the same in winter season also. Out of 33 DTs in the Jorpati feeder, 32 DTs are overloaded and one DT is operating at 95% loading. Also, the voltage level drops by 12.5% on few buses, and marginally low voltage is observed in almost all buses placed towards the end of the feeder. Even the power loss in the system is about 14%, which is a huge loss. Power loss will be a loss to the utility. This huge loss in the system is also not acceptable in a country like Nepal, which has a power deficit.

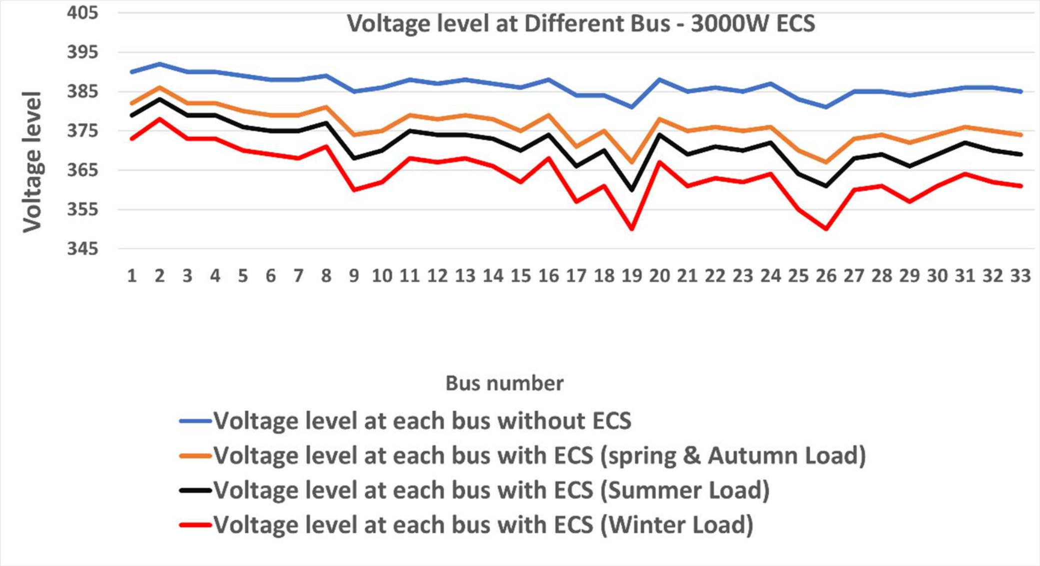


Figure 7: Voltage level at different bus incorporating 3000W ECS – Jorpati Feeder

iii) Incorporating 4000W ECS

After load modeling for summer, winter, spring and autumn loads with and without incorporating ECS of 4000W (two ECS of 2000W each) at each household of the Jorpati feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

Table 20: Summary of Load flow report of Jorpati Feeder incorporating 4000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	203.1	108	100	147.187	2.058559
Spring & Autumn Load with ECS	409.1	437.5	405.2	596.3164	8.34009
Summer Load with ECS	473.6	571.5	529.4	779.0229	10.89542
Winter load with ECS	586.2	897.5	831.4	1223.41	17.11063

After incorporating 4000W ECS at each household, we observe that in the spring and autumn seasons, there are 19 DTs that are overloaded, and 4 DTs are operating above 95% loading. In the summer season, 28 DTs are overloaded, and 4 DTs are operating above 95% loading. In the winter season, all the DTs are overloaded. The current flowing through the feeder conductor is way above the ampacity of the existing dog conductor. Even wolf conductor cannot meet this huge load current demand. Also, the voltage level drops by 13.5% on few buses, and low voltage is observed at almost all buses placed towards the end of the feeder. Even the power loss in the system is about 17.11% which is a huge loss. This huge loss in the system is not acceptable in a country like Nepal, which has a load shedding problem. Thus, use of 4000W ECS can be promoted after feeder reconfiguration and proper load management on the distribution transformers.

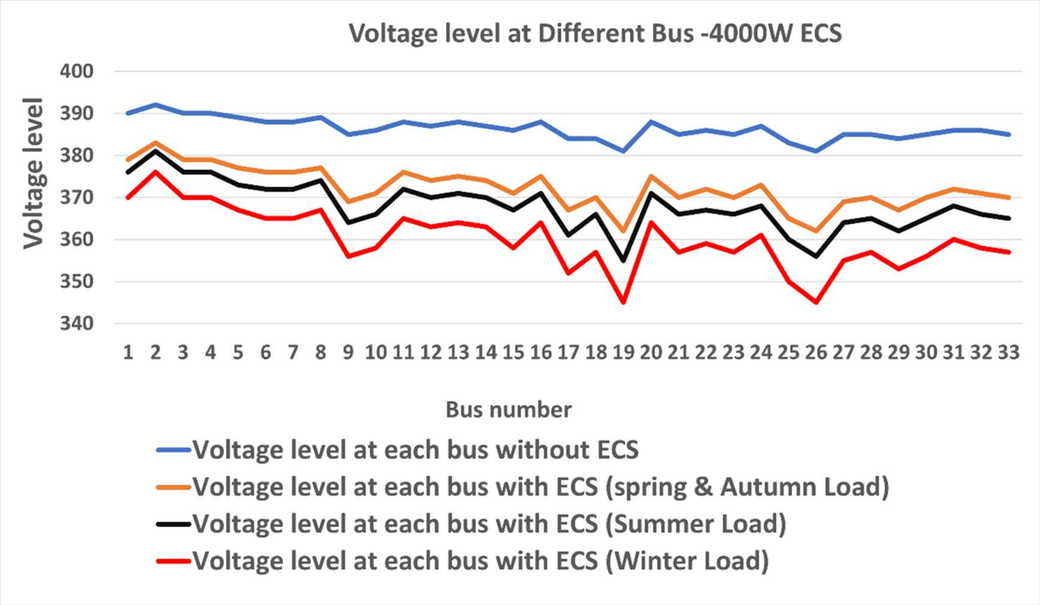


Figure 8: Voltage level at different bus incorporating 4000W ECS – Jorpati Feeder

5.2 Load Flow Results of Malangwa Feeder:

i) Incorporating 2000W ECS

After load modeling for summer, winter, spring and autumn loads with and without incorporating ECS of 2000W (two ECS of 1000W each) at each household of the Malangwa feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

Table 21: Summary of load flow report of Malangwa feeder incorporating 2000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	219.4	105.5	84.6	135.23095	1.639163
Spring and Autumn Load with ECS	327.7	250.3	195.6	317.66248	3.850454
Summer Load with ECS	425.6	432	336.8	547.77572	6.639706
Winter load with ECS	380.9	342.7	267.3	434.61774	5.268094

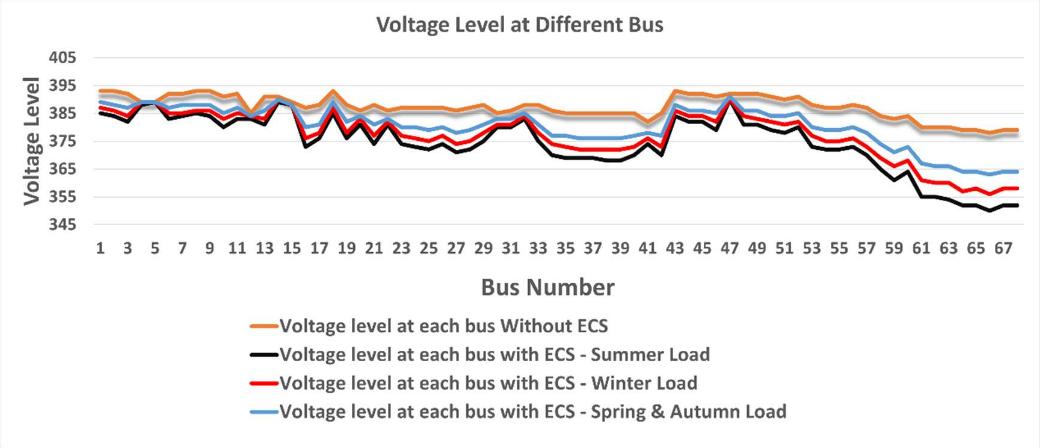


Figure 9: Voltage level at different bus incorporating 2000W ECS – Malangwa Feeder

After incorporating ECS at each household, we observe that in the spring season the feeder conductor is operating at 99% loading. i.e., the existing feeder conductor may be overloaded with a slight change in load. In the summer, with the inclusion of ECS at each household, 50 transformers get overloaded. All the transformers except the private one are overloaded and under voltage is observed. The voltage level drops to 350V. Also, the current flowing through the feeder conductor increases to 425.6 A, which is way above the ampacity of the existing dog conductor. Similarly, in the winter season, we observe that 14 transformers are overloaded and 15 transformers are operating above 96% loading. Under voltage is observed at the buses placed towards the end of the feeder line. Also, there is overloading on the feeder conductor. The dog conductor can carry only 331A current at an ambient temperature of 30^0C whereas the current flowing through the feeder conductor is 380.9A. The power requirement will not be met by the existing 8 MVA power transformer. Thus, the complete system needs to be restructured if the use of ECS is promoted over LPG in the Malangwa area.

ii) Incorporating 3000W & 4000W ECS

After load modeling for summer, winter, spring and autumn loads with and without incorporating ECS of 3000W (two ECS of 1500W each) at each household of the Malangwa feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

Table 22: Summary of load flow report of Malangwa feeder incorporating 3000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	219.4	105.5	84.6	135.23095	1.639163
Spring & Autumn Load with ECS	482.8	527.5	195.6	562.5972	6.81936
Summer Load with ECS	573.4	734.2	586.3	939.57295	11.38876
Winter load with ECS	511.7	601.7	477.5	768.14656	9.310867

Table 23: Summary of load flow report of Malangwa feeder incorporating 4000W ECS

Load Condition	Current flowing through feeder Conductor (A)	Power Loss			% Power Loss
		KW	KVAR	KVA	
Normal	219.4	105.5	84.6	135.23095	1.639163
Spring & Autumn load with ECS	548.7	683	541.6	871.67629	10.56577
Summer Load with ECS	605.3	832.4	678.3	1073.7694	13.01539
Winter load with ECS	559.9	728.6	578	930.02256	11.273

After incorporating ECS of 3000W and 4000W (two ECS of 1500W & 2000W each) at each household of Malangwa area, it has been found that there will be overloading on all the DTs except the private one in any season. Also, the voltage level drops down by 15.25% and under voltage is observed at most of the buses. Also, the current flowing through the feeder conductor is way above the ampacity of the existing dog conductor. Even wolf conductor cannot meet this huge load current demand. The power loss in the system is about 13%, which is a huge loss. The loss will be a loss to utility. This huge loss in the system is not acceptable in a country like Nepal, which has a power deficit and load shedding problem. The power requirement will not be met by the existing 8 MVA power transformer. Thus, the complete system need to be restructured if an ECS of 3000W & 4000W is used by each household in the Malangwa area.

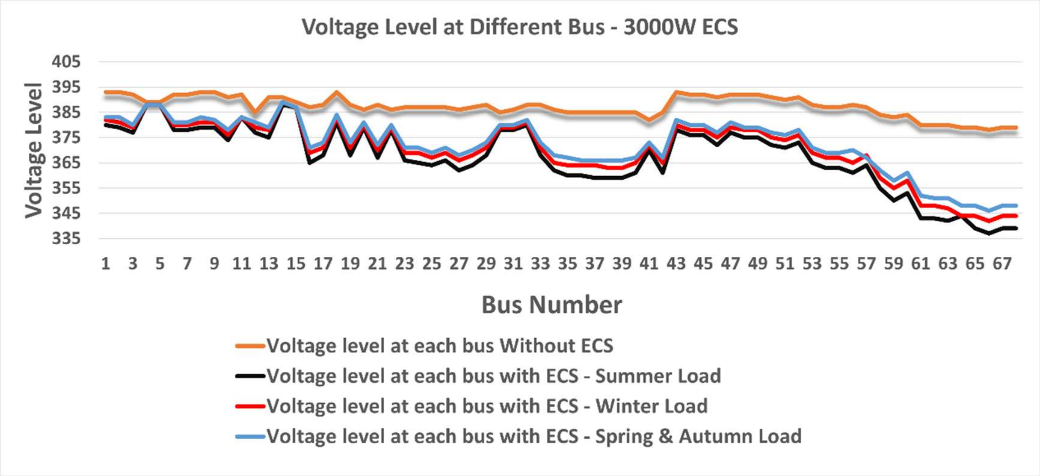


Figure 10: Voltage level at different bus incorporating 3000W ECS – Malangwa Feeder

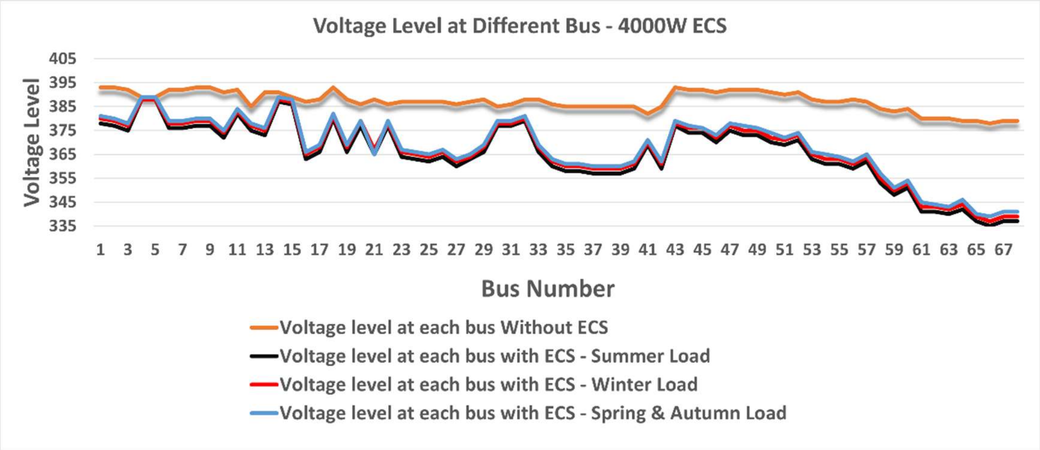


Figure 11: Voltage level at different bus incorporating 4000W ECS – Malangwa Feeder

5.3 Discussion on the result:

The use of 2000W ECS may be promoted in the Jorpati area with some upgradations. Before promoting the use of 2000W ECS at each household of Jorpati area, 18 DTs need to be upgraded and the existing dog conductor must be replaced by wolf conductor. The results clarify us with the use of ECS of 3000W and 4000W at each household of Jorpati area most of the DTs get overloaded or operating above 90% loading and the voltage level also drops drop by almost 13.5% and huge system power loss will be observed.

Similarly, if we observe the scenario of Malangwa feeder, after the addition of ECS at each household, there is overloading on almost all the DTs except the private one. Even the existing 8 MVA power transformer cannot meet the growing load demand for the same. A low voltage problem will be observed on most of the buses which are placed towards the end of the feeder line. Also, huge power loss will be observed. Thus, it is not economical and viable to promote the use of ECS in Malangwa area with the existing system. Before promoting ECS the system must be restructured.

5.4 Present Status of few sample feeder:

In this research, we have only considered two sample feeders to evaluate if electric cooking stoves are used by each household of study area, then the existing system will meet the load demand or not. A similar kind of study can be carried out on other feeders to evaluate whether use of electric cooking stoves can be promoted or not. Some of the sample feeder loading status is tabulated below to evaluate whether the existing feeder conductor will meet the load demand or not if electric cooking stoves are used by each household of these areas.

Table 24: Present status of few sample feeder

Name of feeder	Peak current (A)	Peak load of feeder (MVA)	Existing feeder conductor
Thakre	124	2.36	Dog
Bindwasani Feeder(Industrial feeder, Birgunj	300	5.72	Dog
Gajuri	122	2.32	Dog
Pidakiran chowk	10	0.2	Rabbit
Munglin bazar	89	1.72	Rabbit
Tharpu	90	1.75	Rabbit

CHAPTER SIX

FINANCIAL ANALYSIS

The load flow results shows that the system need to be upgraded in different aspect before addition of the ECS at each household in both Jorpati and Malangwa feeder.

6.1 Financial Analysis of Jorpati Feeder:

i) Upgradation cost estimate incorporating 2000W ECS

In Jorpati feeder, after incorporating 2000W ECS (two ECS of 1000W each) at each household, it is clarified that the existing feeder conductor cannot meet the growing load demand and also 12 transformers are overloaded, and one transformer is operating at 99.8% loading. Further analysis shows that 5 transformers are such that they are operating around 94% loading. Thus, these 18 transformers along with the feeder conductor need to be upgraded. The existing Dog conductor need to be upgraded to Wolf conductor to meet the growing load current demand. The list of transformers that need to be upgraded are as follows:

Table 25: List of overloaded transformers and their upgradation plan

Transformer	Current Size (KVA)	Operating KVA	Current Loading %	Proposed Size	Usage Plan
Baba Boarding	200	218	108.80%	300	200+100 (old)
Bash Jhyang	200	200	100%	300	300 old
Boudha pool2	200	260	132%	400	new
Chauchau Kharkhana	250	250	100.20%	400	new
Chhabahil Dhungedhara	200	250	126.20%	350	250+100 (old)
GMB Pump	300	370	122.50%	500	new
Investment Bank	200	230	115.10%	300	old
Jorpati Park	200	260	131.90%	400	new
Lama Pump	100	160	158.60%	250	old
Sarswoti	200	280	141.50%	400	new
Shankharapur	100	100	103.40%	200	old
Unknown 1	100	110	106.10%	200	old
Om Shanti	300	299.4	99.80%	400	200+200 (old)
Boudha gate 1	300	280	94%	400	new
Boudha gate 2	200	190	94.80%	300	old
venus Model	200	190	94%	300	200+100 (old)
Narantar pool	100	94	94%	200	old
Shantigoreto	250	232	93%	300	200+100 (old)

From the above table, although upgradation is required for 18 DTs, these DTs can be internally used and only one 500KVA transformer and 5 number of 400KVA transformer need to be purchased. The cost-effective plan shows that instead of buying a large number of DTs, the existing DTs can be reused within the system but five pole mounted substation need to be constructed for pole mounting four 100 KVA transformer and one 200KVA transformer.

ii) Incorporating 3000W and 4000W ECS

The use of 2000W ECS (two ECS of 1000W each) may be promoted in the Jorpati area with some upgrades. But the results clarify us that use of ECS of 3000W and 4000W (two ECS of 1500W and 2000W each) at each household of Jorpati cannot be promoted because most of the DTs get overloaded or operating above 90% loading and the voltage level also drops drop by almost 13.5% and huge system power loss will be observed which will be a huge loss to the country. Also, the existing dog conductor cannot meet the growing load demand. Even wolf and panther conductor cannot meet the growing load current demand. Panther conductor is not recommended to be used in the distribution system because of cost benefit analysis. If 3000W and 4000W ECS are used by each household, then the existing feeder cannot meet the load demand and a new feeder line may be required to meet the load demand and have voltage level and power loss within the acceptable limit. Since a new feeder line and system restructuring will be required a huge amount must be invested to meet the load demand. Before making any changes, proper planning is required along with that a lot of time and money must be invested. Hence, promoting the use of ECS on such a large scale is not recommendable in the present context.

6.1.1 Cost Estimation for upgrading Feeder conductor and DTs incorporating 2000W ECS

Pole Mounted Substations (5 Numbers) with 4* 100KVA and 1* 200KVA 3-ϕ Transformers

S. N.	Description	Unit	Quantity	Rate	Amount
1	PCC-Pole of 11 Meters length	No.	10	6000	60000
2	Supply of galvanized steel components such as pole clamp of size 6.5x0.8 cm, back clamps of size 6.5x0.8 cm, cross-arm of size 10*5*0.6 cm, pole clamp of size 6.5*0.8 cm, DT belting set of size 5 * 5* 0.6 cm, DT mounting channel of size 10*5*0.6 mm, DT clamping set of size 5*5*0.6 cm, DO mounting channel of size 10*5*0.6 cm, as per the technical standard.				
2.1	Supply of one number M.S. channel of dimension 10*5*0.6 cm-220 cm- 2 no.* 17.38 Kg * 5 no. = 173.8 Kg.	kg	173.8	920	159896
2.2	Supply of one number M.S. angle iron of dimension 5*5*0.6 cm -240 cm for earthing purposes- 1 no. * 5 no.*10.8 Kg = 54 Kg.	kg	54	920	49680
2.3	Supply of M.S. channel of dimension 7.5*4*0.6cm-220 cm (1 Number) - 2 no. * 5 no.*14.965 Kg = 119.72 Kg.	kg	149.65	920	137678
2.4	Supply of one set of platforms for DT - 1 no. * 5 no.*58.85 Kg = 29425Kg.	kg	294.25	920	270710
2.5	Supply of half clamp - 14 no. * 5 no.*1.47 Kg. = 102.9Kg.	kg	102.9	920	94668
2.6	Supply of full clamp - 4 no. * 5 no.*2.325 Kg. = 46.5 Kg.	kg	46.5	920	42780

3	Supply of GI nuts, bolts with washers as per the technical standard	kg	50	150	7500
4	Supply of anchor plate having dimension of 20x20x0.6cm, galvanized stay set with stay clamp of size 5x0.8 cm, two numbers of turn-buckles, two numbers of stay insulator, nut bolts, solid GS stay rod of 1.6 cm diameter and GI stranded wire of 7/3.15 mm diameter as per technical standard	No.	20	2300	46000
5	Disc Insulator – 11KV with appropriate hardware fittings	No.	15	700	10500
6	11 KV, Pin Insulators with hardware fittings	No.	30	800	24000
7	Supply of 160A HRC fuse, 4 nos. of 90 A Single Pole MCCB & 200 A TPN isolator for 3-ϕ DT of 100 KVA	No.	4	3200	12800
8	Supply of 300A HRC fuse, 4 numbers of 180A Single Pole MCCB & 400 A TPN isolator for 3-ϕ DT of 200 KVA	No.	1	4800	4800
9	Supply of 11 KV LA for distribution transformer (distribution class) as per the technical standard, approved drawings and scope as mentioned in TOR.	No.	15	16000	240000
10	11 kV, 3-ϕ, 200 A, 3 Pin type, Vertical Mounting type, Gang Operated, AB Switch along with Support Insulators, Base Channel, down Pipe, arcing Horns etc. in all complete way as per the technical standard, approved drawings and scope as mentioned in TOR.	set	4	89600	358400
11	11 kV, 3-ϕ, 400A, AB switch along with support insulators, base channel, arcing horns, gang operated, vertical mounting type, down pipe, three pin type insulator, etc. as per the technical standard and scope as mentioned in TOR.	set	1	92000	92000

12	Pipe earthing using 4cm diameter GI pipe having length of 3 m, IS code 1161, earth grid using 5*0.6cm GI flat and riser as mentioned in TOR of distribution transformer substations, as per standard & approved drawing.	set	5	6500	32500
13	Supply of barbed wire	kg	10	200	2000
14	Supply of danger Plate (with Clamp)	No.	10	300	3000
	Total				1888912

Table 26: Cost Estimation of Pole- Mounting Substation

Table 27:Total Cost Estimation for Upgradation

S. N.	Description	Unit	Quantity	Rate	Amount
1	11KV High Tension line 150mm^2-ACSR Conductor (wolf Conductor)	km	21	112,000	2352000
2	Pole Mounted substations (5 Numbers) with 4* 100KVA and 1* 200KVA Three Phase Transformers	No.	1	1888912	1888912
3	400 KVA transformers	No.	5	1399000	6995000
4	500 KVA transformers	No.	1	1747000	1747000
5	Labor Charges for transformer shifting transportation and some minor upgradation cost	LS	18	20000	360000
6	Labor Charges for pole erection, transportation, and installation charges	LS	5	20000	100000
	Sub-total				13442912
	15% Contractors Overhead				2016436.8
	Total				15459348.8
	13% VAT				2009715.344
	Grand total with VAT				17469064.14

Thus, the cost estimate shows that utility must invest almost 1 crore 75 lakhs to upgrade the feeder and distribution transformer. The project goes to the tendering process and the minimum time required to complete the task would be 6 months. Without upgrading the system, it is not recommended to promote the use of ECS extensively.

6.2 Financial Analysis of Malangwa Feeder:

After the addition of ECS at each household of Malangwa feeder, the major impact is observed during summer season. In the summer season, the load on the feeder is initially high and with the penetration of ECS in large scale there is overloading on all the transformers except the private transformer. The power requirement will not be met by the existing 8 MVA power transformer also. The existing feeder conductor cannot meet growing load current demand. So, the feeder conductor sizing should also be upgraded. Even wolf and panther conductor will not be able to meet the growing load current demand. Also, Panther conductor is not recommended in distribution analyzing the cost benefit. Since a lot of upgradations is required to meet the growing load demand a huge investment would be required. Better than upgrading the entire system the load can be shifted to some new substation. Since the complete system need to be restructured, in the present context promoting the use of ECS at each household in Malangwa area is not recommended.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion:

With the inclusion of ECS at each household of the Jorpati and Malangwa feeders, the load growth will be on a large scale in no time. The results of this research work shows that the existing system cannot meet the growing load demand. In the Jorpati feeder, if there is inclusion of 2000W ECS (two ECS of 1000W each) at each household, out of 33 DTs, 18DTs size need to be upgraded and the feeder conductor should be upgraded to a wolf conductor to meet the growing load current demand. The capital cost required by utility will be around one crore seventy-five lakhs for upgrading the system. The voltage profile improves further after the upgrade. Hence, the use of 2000W ECS can be promoted in the Jorpati area after upgrading the system. Similarly, after incorporating 3000W (two ECS of 1500W each) and 4000W (two ECS of 2000W each), overloading is observed on almost all the DTs of the Jorpati feeder and moreover, in the winter season, all the DTs get overloaded. Also, the load current demand increases excessively which cannot be met by the wolf and panther conductors. The voltage level gets worse and huge power loss is observed. Hence, neither the voltage level nor this huge power loss is acceptable. The consumers may use any power rated ECS as per their comfort and requirement. Thus, before promoting the use of ECS extensively, Jorpati feeder needs reconfiguration and load management must be carried out so that the DTs will not be overloaded. Thus, the use ECS in large scale can be promoted only after feeder reconfiguration.

Similarly, in the Malangwa feeder, after incorporating ECS (two ECS of 1000W or 1500W or 2000W each) it has been clearly observed that there would be overloading on almost all DTs and the feeder conductor. There is under voltage problem observed at the buses, which are placed towards the end of the feeder line and huge power loss is observed. Also, power requirements will not be met by the existing 8 MVA power transformer. Thus, to meet the growing load demand due to the addition of ECS at each household, a number of upgrades would be required. Thus, system restructuring should be done before promoting the use of ECS over LPG gas in Malangwa area.

7.2 Recommendations:

As the government is promoting the use of ECS for cooking purposes over LPG, people will shift towards the use of ECS for cooking purposes in the upcoming years. The result of this research clearly indicates that it is recommended to promote the use of ECS only after upgrading the existing system of Jorpati and Malangwa area. The system must be upgraded and restructuring must be done to meet the growing load demand due to the addition of ECS at each household. So, the results clearly suggest power utility must invest in upgrading and restructuring the system to meet the growing load demand due to addition of ECS at each household. Before, system upgradation and restructuring proper planning is required and along with that a lot of time and money must be invested.

LPG is a nonrenewable source of energy. The increasing price of LPG and its shortage has seriously affected the kitchen expenses of Nepalese Society and moreover LPG needs to be imported in Nepal. Whereas the use of ECS is pollution free and environment friendly. For the country like Nepal which has higher potential of electricity generation, the government must invest in promoting use of ECS for cooking purposes instead of investing in importing LPG.

Most of the consumers of Malangwa area and few consumers of Jorpati area have 5A load approval from NEA. Since, ECS draw current more than 5A, before using ECS, it is recommended to request consumers to have at least 15A load approval from NEA. In the case of Jorpati area, many families live in rented house/flats and in a single house two to three family tend to live. If each family makes use of ECS for cooking purposes, then even 15A load approval will not be enough. Thus, it is recommended to request consumers to have at load approval of 30A or even higher to promote cooking using ECS.

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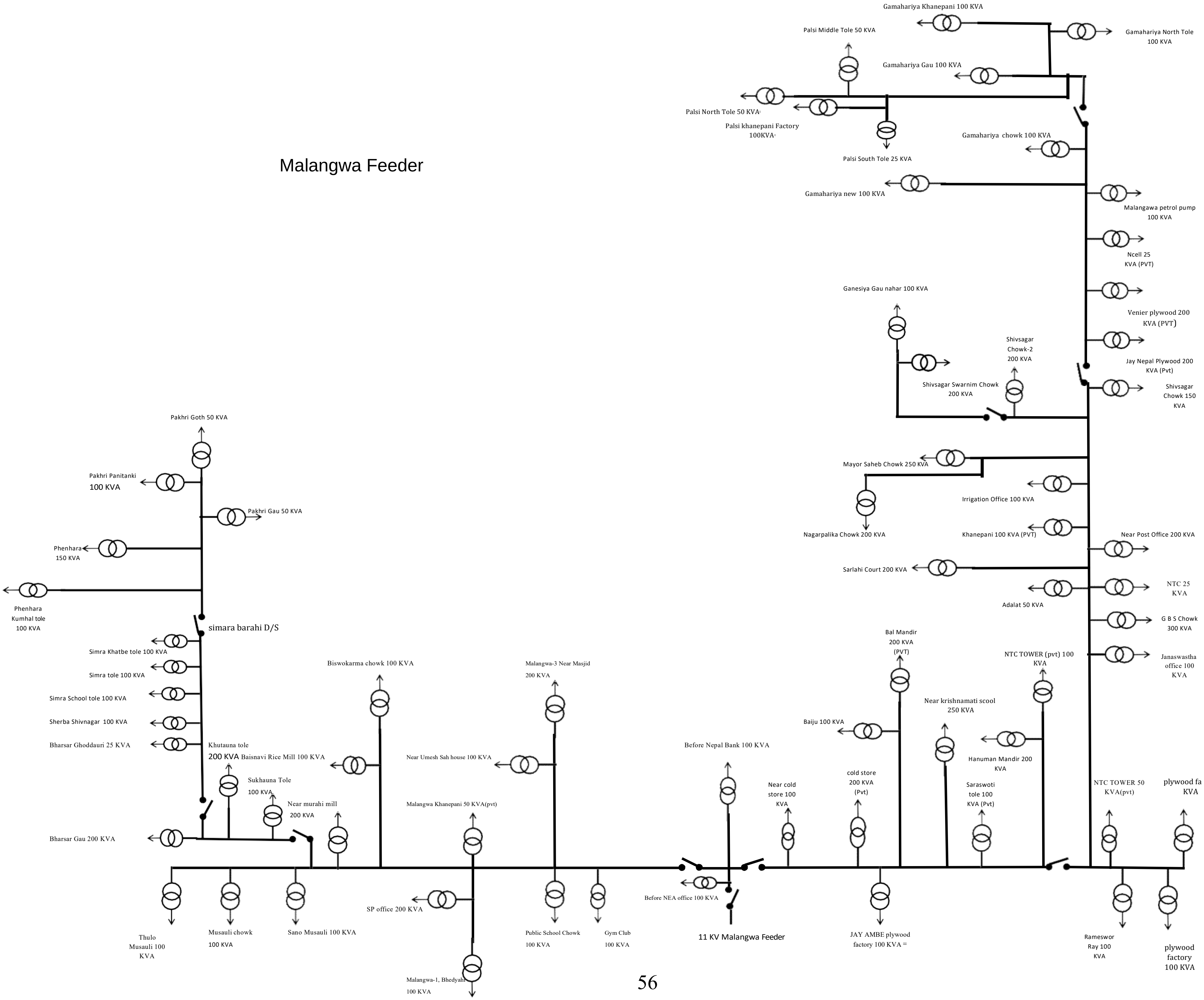
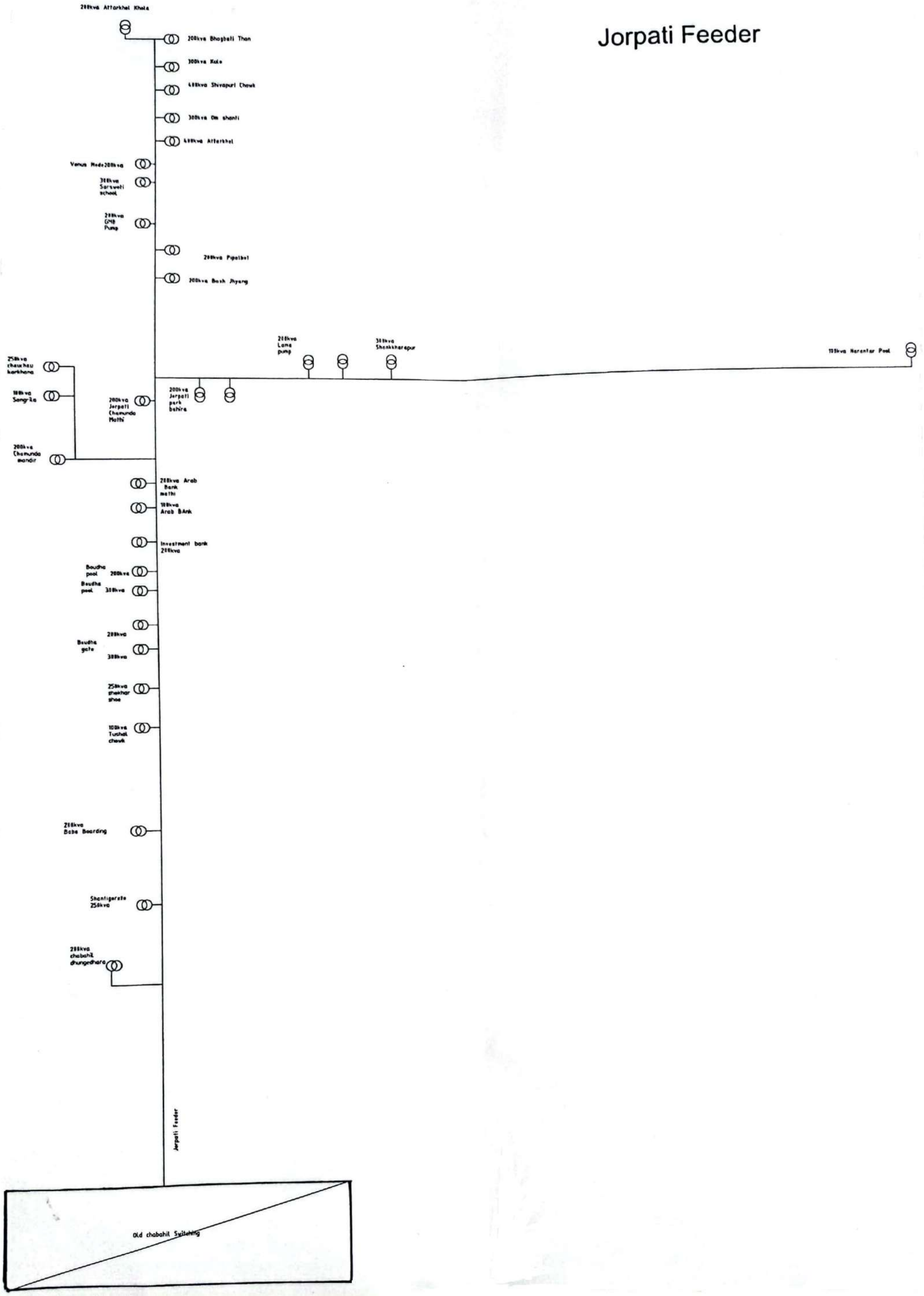
ANNEX-1

Malangwa Feeder



Jorpati Feeder



नेपाल विद्युत प्राधिकरण

Timestamp	जोरपाटी फिडर पिक लोड (Ampere)	जोरपाटी फिडर Shutdown संख्या	जोरपाटी फिडर Shutdown Duration(minute)	जोरपाटी फिडर Tripping संख्या
12/11/2022 17:50:25	230	0	0	0
12/12/2022 16:30:06	250	0	0	0
12/13/2022 16:34:35	305	0	0	0
12/21/2022 23:13:30	275	0	0	1
12/22/2022 7:03:50	290	0	0	0
12/23/2022 5:51:16	270	0	0	1
12/24/2022 8:55:28	275	0	0	0
12/25/2022 8:51:13	260	0	0	0
12/26/2022 10:12:17	280	1	45 Min	0
12/27/2022 10:36:29	300	0	0	1
12/28/2022 8:17:14	300	1	1hrs20Min	0
12/29/2022 10:46:03	300	0	0	0
12/30/2022 13:10:25	300	1	1hrs7min	0
12/31/2022 8:41:24	300	0	0	1
1/1/2023 19:36:50	300	0	0	0
1/2/2023 6:53:27	300	2	35Min	0
1/3/2023 7:07:47	300	0	0	1
1/4/2023 7:06:54	300	0	0	0
1/5/2023 4:57:12	300	0	0	1
1/6/2023 5:24:15	300	0	0	0
1/7/2023 6:05:24	300	0	0	0
1/8/2023 14:18:45	300	0	0	0
1/9/2023 15:15:45	280	1	1Hrs45min	1
1/10/2023 12:43:05	300	1	1Hrs20min	0
1/11/2023 13:16:49	285	2	2Hrs20min	0
1/12/2023 17:32:42	290	2	45Min	0
1/13/2023 16:16:49	235	0	0	0
1/14/2023 17:31:02	225	0	0	0
1/16/2023 19:07:12	220	0	0	0
1/17/2023 6:52:05	240	0	0	0
1/18/2023 19:04:57	230	0	0	0
1/19/2023 6:47:04	255	0	0	0
1/20/2023 19:15:00	265	0	0	0
1/21/2023 19:46:47	240	1	15 min	0
1/22/2023 19:46:00	230	0	0	1
1/23/2023 13:40:30	230	1	19 min	1
1/24/2023 14:46:58	225	0	0	0
1/25/2023 18:02:02	240	0	0	0
1/27/2023 17:47:41	210	0	0	0
1/28/2023 14:03:54	205	0	0	0
1/28/2023 14:06:46	220	0	0	0
1/29/2023 14:08:51	200	0	0	0

1/30/2023 13:42:27	205	0	0	0
2/1/2023 18:55:46	220	0	0	0
2/1/2023 18:58:27	205	0	0	0
2/3/2023 19:13:05	205	0	0	0
2/3/2023 19:18:58	200	0	0	0
2/4/2023 19:16:48	205	0	23 Min	0
2/5/2023 19:15:04	200	0	0	0
2/6/2023 19:05:11	205	0	0	0
2/7/2023 12:12:32	205	0	0	0
2/8/2023 13:09:41	200	0	0	0
2/9/2023 10:13:50	205	0	0	0
2/10/2023 7:18:30	205	0	0	0
2/11/2023 8:08:46	200	0	0	0
2/12/2023 8:20:20	195	0	0	0
2/17/2023 19:12:49	200	0	0	0
2/17/2023 19:17:37	200	0	0	0
2/17/2023 19:19:41	200	0	0	0
2/17/2023 19:21:28	200	0	0	0
2/17/2023 19:24:45	195	0	0	0
2/18/2023 20:49:03	195	0	0	0
2/20/2023 6:15:32	180	0	0	0
2/21/2023 6:36:48	185	0	0	0
2/21/2023 6:38:53	200	0	0	0
2/22/2023 12:44:47	230	0	0	0
2/23/2023 15:56:22	185	1	21 Min	0
2/24/2023 12:49:56	185	0	0	0
2/25/2023 13:36:10	185	0	0	0
2/26/2023 12:36:40	185	1	45 Min	0
2/27/2023 13:15:52	230	1	1:12min	0
2/28/2023 10:30:18	190	0	0	0
3/4/2023 19:08:51	190	2	29 Min	0
3/4/2023 19:12:10	185	0	0	0
3/4/2023 19:14:23	185	0	0	0
3/4/2023 19:17:10	185	0	0	0
3/5/2023 20:08:51	175	0	0	0
3/6/2023 20:03:31	190	0	0	0
3/7/2023 20:02:47	160	0	0	0
3/8/2023 6:32:19	180	0	0	0
3/9/2023 7:51:55	175	0	0	0
3/10/2023 8:33:10	190	2	26 Min	0
3/11/2023 7:57:48	165	1	45 Min	0
3/12/2023 8:19:15	190	2	20 Min	0
3/13/2023 8:22:35	140	0	0	0
3/14/2023 7:24:23	165	1	1Hrs	0
3/19/2023 19:19:37	145	0	0	2
3/19/2023 19:22:54	150	0	0	0
3/19/2023 19:27:16	140	0	0	0
3/19/2023 19:34:09	145	0	0	0
3/19/2023 19:40:55	140	0	0	0
3/20/2023 19:13:28	150	0	0	0
3/21/2023 19:20:45	145	0	0	0
3/22/2023 19:44:11	155	0	0	0
3/25/2023 13:06:07	155	0	0	0
3/25/2023 13:08:56	145	0	0	0
3/26/2023 12:25:19	185	0	0	0

						R	Y	B	N
49	Jorpati	Chabahil One Cafe agadi	200	2079.08.01	18:00	158	136	210	47
49	Jorpati	Chabahil santi goreto	200	2079.08.01	18:08	145	165	190	133
49	Jorpati	Chuchepati Baba boarding	200	2079.08.01	18:12	180	155	125	105
49	Jorpati	Chuchepati salik	200	2079.08.01	18:17	65	34	57	43
49	Jorpati	Tusal chok	200	2079.08.01	18:22	44	57	66	36
49	Jorpati	Tusal Badijya bank opposite	250	2079.08.01	18:27	340	191	66	180
49	Jorpati	Bauddha Dhara tole tr 1	200	2079.08.01	18:35	218	200	220	117
49	Jorpati	Bauddha Dhara tole tr 2	300	2079.08.01	18:37	200	165	180	96
49	Jorpati	Bauddha Gate tr 1	300	2079.08.01	18:42	235	105	92	156
49	Jorpati	Bauddha Gate tr 2	200	2079.08.01	18:48	160	45	28	139
49	Jorpati	chaauchau karkhana	250						
49	Jorpati	Investment bank	200	2079.08.02	17:31	195	140	184	140
49	Jorpati	Purano aarab bank tr 1	150	2079.08.02	17:39	54	66	48	30
49	Jorpati	Purano aarab bank tr 2	100	2079.08.02	17:43	129	141	105	102
49	Jorpati	Chamunda gate	200	2079.08.02	17:49	124	51	99	56
49	Jorpati	Jorpati chok	300	2079.08.02	17:52	119	140	225	100
49	Jorpati	Jorpati Bas Jhang	200	2079.08.02	18:03	168	99	111	90
49	Jorpati	Jorpati aamda	200	2079.08.02	18:08	159	135	140	80
49	Jorpati	Saraswati school	250	2079.08.02	18:12	174	176	242	132
49	Jorpati	JMB pump	300	2079.08.02	18:17	260	92	310	
49	Jorpati	venus oralo	200	2079.08.02	18:23	114	153	139	93
49	Jorpati	Jorpati fohor falne thau tr 1	200	2079.08.03	17:30	116	45	96	94
71	Jorpati	Jorpati fohor falne thau tr 2 new	200	2079.08.03	17:31	131	61	116	87
72	Jorpati	Everest bank aagadi	200	2079.08.03	17:33	57	37	76	60
73	Jorpati	Shankarapur hospital opposite	300	2079.08.03	17:35	73	56	26	64
74	Jorpati	Chamunda school jane new tr	200	2079.08.03	17:40	125	88	104	57
75	Jorpati	Rai school	300	2079.08.03	17:45	143	156	168	77
76	Jorpati	Kriya Putri bhawan ganeshmandir	200	2079.08.03	17:50	106	98	93	59
77	Jorpati	Dholak dhara	100	2079.08.03	17:53	43	8	71	62
78	Jorpati	Naya nagarpalika opposite	100	2079.08.03	17:55	51	28	21	48
79	Jorpati	Narayantar marga coloni gate	200	2079.08.03	18:00	50	60	92	51
80	Jorpati	Narayantar pool	200	2079.08.03	18:05	114	55	77	70

ANNEX – 2

ALUMINIUM CONDUCTORS STEEL REINFORCED

ACSR

BS 215 Part 2

TABLE 6A

BRITISH SIZES

Code Name	Nominal Area	No./Nominal diameter of wires		Approximate Overall Diameter	Sectional Area			Approximate Weight	Nominal Breaking Load	Nominal DC Resistance at 20° C	Current Rating (*)
		Aluminium	Steel		Aluminium	Steel	Total				
	mm²	No./mm	No./mm	mm	mm²	mm²	mm²	kg/km	KN	ohm/km	A
Gopher	25	6/2.36	1/2.36	7.08	26.24	4.38	30.62	106	9.61	1.0930	115
Weasel	30	6/2.59	1/2.59	7.77	31.61	5.27	36.88	128	11.45	0.9077	129
Ferret	40	6/3.00	1/3.00	9.00	42.41	7.07	49.48	172	15.20	0.6766	155
Rabbit	50	6/3.35	1/3.35	10.05	52.88	8.82	61.70	214	18.35	0.5426	178 ✓
Horse	70	12/2.79	7/2.79	13.95	73.37	42.83	116.20	538	61.20	0.3936	225 ✓
Dog	100	6/4.72	7/1.57	14.15	105.00	13.50	118.50	394	32.70	0.2733	271
Dingo	150	18/3.35	1/3.35	16.75	158.70	8.80	167.50	506	35.70	0.1815	346
Wolf	150	30/2.59	7/2.59	18.13	158.10	36.80	194.90	726	69.20	0.1828	351
Lynex	175	30/2.79	7/2.79	19.53	183.40	42.80	226.20	842	79.80	0.1576	384
Caracal	175	18/3.61	1/3.61	18.05	184.30	10.20	194.50	587	41.10	0.1563	379
Panther	200	30/3.00	7/3.00	21.00	212.10	49.40	261.50	974	92.25	0.1363	420
Jaguar	200	18/3.86	1/3.86	19.30	210.60	11.70	222.30	671	46.55	0.1367	411
Zebra	400	54/3.18	7/3.18	28.62	428.90	55.60	484.50	1621	131.90	0.0674	636

Other Popular Sizes
BS EN 50182

TABLE 6B

Code Name	No./Nominal diameter of wires		Approximate Overall Diameter	Sectional Area			Approximate Weight	Nominal Breaking Load	Nominal DC Resistance at 20° C	Current Rating (*)
	Aluminium	Steel		Aluminium	Steel	Total				
	No./mm	No./mm	mm	mm²	mm²	mm²	kg/km	KN	ohm/km	A
Mole	6/1.50	1/1.50	4.50	10.6	1.77	12.4	42.8	4.14	2.7027	66
Squirrel	6/2.11	1/2.11	6.33	21.0	3.50	24.5	84.7	7.87	1.3659	101
Fox	6/2.79	1/2.79	8.37	36.7	6.11	42.8	148.1	13.21	0.7812	142
Mink	6/3.66	1/3.66	10.98	63.1	10.50	73.6	254.9	21.67	0.4540	199
Skunk	12/2.59	7/2.59	12.95	63.2	36.90	100.1	463.0	52.79	0.4568	206
Beaver	6/3.99	1/3.99	11.97	75.0	12.50	87.5	302.9	25.76	0.3820	221
Racoon	6/4.09	1/4.09	12.27	78.8	13.10	91.9	318.3	27.06	0.3635	228
Otter	6/4.22	1/4.22	12.66	83.9	14.00	97.9	338.8	28.81	0.3415	237
Cat	6/4.50	1/4.50	13.50	95.4	15.90	111.3	385.3	32.76	0.3003	256
Hare	6/4.72	1/4.72	14.16	105.0	17.50	122.5	423.8	36.04	0.2730	271
Coyote	26/2.54	7/1.91	15.89	131.7	20.10	151.8	520.7	45.86	0.2192	311
Cougar	18/3.05	1/3.05	15.25	131.5	7.31	138.8	418.8	29.74	0.2188	308
Tiger	30/2.36	7/2.36	16.52	131.2	30.60	161.8	602.2	57.87	0.2202	313
Lion	30/3.18	7/3.18	22.26	238.3	55.60	293.9	1093.4	100.47	0.1213	450
Bear	30/3.35	7/3.35	23.45	264.4	61.70	326.1	1213.4	111.50	0.1093	480
Goat	30/3.71	7/3.71	25.97	324.3	75.70	400.0	1488.2	135.13	0.0891	543
Sheep	30/3.99	7/3.99	27.93	375.1	87.50	462.6	1721.3	156.30	0.0771	592
Antelope	54/2.97	7/2.97	26.73	374.1	48.50	422.6	1413.8	118.88	0.0773	586
Bison	54/3.00	7/3.00	27.00	381.7	49.50	431.2	1442.5	121.30	0.0758	593
Deer	30/4.27	7/4.27	29.89	429.6	100.20	529.8	1971.4	179.00	0.0673	643
Elk	30/4.50	7/4.50	31.50	477.1	111.30	588.4	2189.5	198.80	0.0606	684
Camel	54/3.35	7/3.35	30.15	476.0	61.70	537.7	1798.8	146.40	0.0608	677
Moose	54/3.53	7/3.53	31.77	528.5	68.50	597.0	1997.3	159.92	0.0547	720

(*) Note: The values of current rating mentioned in above Table are based on wind velocity of 0.6 metre/second, solar heat radiation of 1200 watt/metre², ambient temperature of 50° C & conductor temperature of 80° c.

Considering,

Ambient Temperature (T_A): 30^0C

Allowable conductor Temperature (T_C): 75^0C

Change Factor = $\left(\frac{Tc,New \quad ,new}{Tc,old-TA,old} \right)^{0.5}$

= $\left(\frac{75-30}{80-50} \right)^{0.5}$

= 1.225

For Rabbit Conductor:

Ampacity = 178 * 1.225 = 218.05 A

For Dog Conductor:

Ampacity = 271 * 1.225 = 331.975 A

For Weasel Conductor:

Ampacity = 129 * 1.225 = 158.025 A

For Wolf Conductor:

Ampacity = 351* 1.225 = 429 A

For Panther Conductor:

Ampacity = 420* 1.225 = 514.5 A

For Zebra Conductor:

Ampacity = 636* 1.225 = 779 A

Similarly, the resistance of the conductor also changes with temperature change

$R_1 = R_0 (1+ \alpha \Delta t_1)$…………………(1)

$R_2 = R_0 (1+ \alpha \Delta t_2)$…………………(2)

Dividing Equation (1) by (2) to get new value of R_2

$T_1 = 20^0$C (as per the given temperature) and $T_2 = 75^0$C (Cable Temperature)

On solving We get,

$R_2 = 1.203 * R_1$

Thus, for Rabbit,

$R_2 = 1.203 * R_1 = 1.203 * 0.5426 = 0.6531\ \Omega$

Similarly,

For Wolf Conductor

$R_2 = 1.203 * R_1 = 1.203 * 0.1828 = 0.2199\ \Omega$

For Dog Conductor

$R_2 = 1.203* R_1 = 1.203 * 0.2733 = 0.3287\ \Omega$

For Weasel Conductor

$R_2 = 1.203* R_1 = 1.203 * 0.9077 = 1.0919\ \Omega$

Cost of Distribution Transformer and other Materials

S. No.	Transformer Rating	No load Loss (Watt)	Load Loss (Watt)	Per unit Price (NRs.) without VAT
1	11/0.4KV, 25 KVA	75	400	280,000.00
2	11/0.4KV, 50 KVA	120	750	400,000.00
3	11/0.4KV, 75 KVA	170	1000	481,800.00
4	11/0.4KV, 100 KVA	220	1210	590,600.00
5	11/0.4KV, 125 KVA	255	1430	700,000.00
6	11/0.4KV, 150 KVA	295	1675	800,000.00
7	11/0.4KV, 200 KVA	365	2100	1,023,000.00
8	11/0.4KV, 250 KVA	455	2550	1,097,400.00
9	11/0.4KV, 300 KVA	550	3000	1,170,900.00
10	11/0.4KV, 350 KVA	650	3550	1,350,000.00
11	11/0.4KV, 400 KVA	745	4025	1,399,000.00
12	11/0.4KV, 500 KVA	960	5150	1,747,000.00
13	33/0.4KV, 25 KVA	75	460	368,300.00
14	33/0.4KV, 50 KVA	140	800	513,600.00
15	33/0.4KV, 100 KVA	290	1800	716,000.00

Cost of Conductors and other Materials

S.No.	Material	Cost (NRS.)
1	ACSR Wolf conductor	112,000/Km
2	Suspension Fitting for ACSR DOG conductor	480/Kg
3	Aluminium Round ACSR squirrel conductor	21,600/Kg
4	ACSR DOG Conductor	160/m
5	ACSR Weasel Conductor	32,000/km
6	ACSR Panther Conductor	212/m
7	ACSR Rabbit Conductor	70/m

ANNEX-3

MATLAB Code for ZIP Coefficient Determination

```
com1 = [0.73, -1.7, 1.97; 0.52, -1.41,1.89]; %lighting load (LED Light)
com2 = [-0.4, 0.45, 0.95; 3.92,-4.86,1.94]; %Tv model(LCD TV)
com3 = [1.55, -2.12, 1.57; 1.56,-2.14,1.58]; % Air Conditioner
com4 = [1.04,-1.57,1.53;5.69,-8.56,3.87]; % Refrigerator
com5 = [1,0.6,-0.6; 0, 2.02, -1.02]; % Microwave
com6 = [-0.32, 1.14, 0.18; 1.56,-2.13, 1.57]; % Desktop
com7 = [0.78,0.34,-0.12; -2.29, 5.51, -2.22]; % Washing Machine
com8 = [0.82,0.22,-0.04; 5.95, -7.33,2.38]; % Vacuum Cleaner
com9 = [0.94, 0.09, -0.03; 0.61,0.56, -0.17]; % Mixer
com10 = [0.99, 0.01,0; 3.92,-4.86, 1.94]; % Iron
com11 = [-0.07, 0.08, 0.99; 0.01, 0.01, 0.98]; % Motor Load
com12 = [0.73, 0.38, -0.11; 0.45,0.51,0.04]; % Air Compressor 1 ph
com13 = [-3.16,6.85,-2.69; -1,2.98,-0.98]; % Welding Machine
com14 = [0.25, -0.48, 1.23; 0.14, 0.32, 0.54]; % Charger
com15 = [0.52, 0.45, 0.03; 0.39,-0.25, 0.86]; % Copier
com16 = [2.36,-4.15, 2.79; -2.93, 6.5, -2.57]; % Elevator
com17 = [0.51, 0.55,-0.06; 0.43, 0.52, 0.05]; % Halogen Heater
com18 = [0.95,0.07,-0.02; 0.29, 1.02,-0.31]; % Water heater/Boiler
com19 = [0.26,0.9,-0.16; 0.5,0.62,-0.12]; % Fan
com20 = [0,1,0; 1.91,0,-0.91]; % Induction Cooker
com21 = [0.51,0.55,-0.06; 0.43, 0.52, 0.05]; % Infrared Cooker
proto1 = [com1(1,:);com2(1,:);com3(1,:);com4(1,:);com5(1,:);com6(1,:);
com7(1,:);com8(1,:);com9(1,:);com10(1,:)]; % Matrix formation of prototype1
proto1q = [com1(2,:);com2(2,:);com3(2,:);com4(2,:);com5(2,:);com6(2,:);
com7(2,:);com8(2,:);com9(2,:);com10(2,:)];
proto2 = [com1(1,:);com2(1,:);com4(1,:);com5(1,:);
   com7(1,:);com8(1,:);com9(1,:);com10(1,:)];
% Matrix formation of prototype2
proto2q = [com1(2,:);com2(2,:);com4(2,:);com5(2,:);
   com7(2,:);com8(2,:);com9(2,:);com10(2,:)];
proto3 = [com1(1,:);com2(1,:);com4(1,:);com5(1,:);
   com9(1,:);com10(1,:)];
% Matrix formation of prototype3
proto3q = [com1(2,:);com2(2,:);com4(2,:);com5(2,:);
   com9(2,:);com10(2,:)];
proto4 = [com1(1,:);com2(1,:);com4(1,:);com10(1,:)];
% Matrix formation of prototype4
proto4q = [com1(2,:);com2(2,:);com4(2,:);com10(2,:)];
proto5 = [com1(1,:);com11(1,:);com12(1,:);com13(1,:)];
% Matrix formation of garages and welding shops
proto5q = [com1(2,:);com11(2,:);com12(2,:);com13(2,:)];
proto6 = [com1(1,:);com3(1,:);com5(1,:);com6(1,:);
   com8(1,:);com14(1,:);com15(1,:)];
% Matrix formation of offices
proto6q = [com1(2,:);com3(2,:);com5(2,:);com6(2,:);
   com8(2,:);com14(2,:);com15(2,:)];
proto7 =  [com1(1,:);com19(1,:);com3(1,:);com16(1,:);com6(1,:);
   com8(1,:);com2(1,:);com14(1,:);com15(1,:);com11(1,:)];
```

```
% Matrix formation of malls and commercial building
proto7q =  [com1(2,:);com19(2,:);com3(2,:);com16(2,:);com6(2,:);
   com8(2,:);com2(2,:);com14(2,:);com15(2,:);com11(2,:)];
pow1 = [64687.5;39192;124200;38812.5;52785;13972.5;130410;37260;23287.5;
   31050];
% Active power calculated based on number of components and their use factor
pow2 = [114015;78497.6;77737.5;105723;87066;74628;46642.5;124380];
pow3 = [129600;98150.4;155520;264384;116640;155520];
pow4 = [298440;188348.8;223830;298440];
pow5 = [20700;514740;182160;621000];
pow6 = [37350;298800;63495;1400625;44820;57768;186750];
pow7 = [63000;31500;201600;756000;425250;75600;59640;8120;75600;313320];
reac1 = [20268.75;12420;60168;18112.5;25357.5;6762;63135;17940;
   11212.5;14904];
% reactive power calculated based on number of components and their use factor
reac2 = [35724.7;24876;36277.5;50788.5;42151;35932;22457.5;59702.4];
reac3 = [40608;31104;90720;127008;56160;74649.6];
reac4 = [93511.2;59688;174090;143251.2];
reac5 = [3243;1158165;409860;1397250];
reac6 = [11703;144752;30502.5;610050;21580;27888;90470];
reac7 = [9870;15225;97664;567000;205800;36400;18900;3920;36624;234990];
% Zp, Ip, Pp calculation
add1 = sum(pow1);
M1 = transpose(proto1)*pow1;
Rp1 = M1/add1; % display Zp, Ip, Pp values
check1 = sum(Rp1);
add2 = sum(pow2);
M2 = transpose(proto2)*pow2;
Rp2 = M2/add2; % display Zp, Ip, Pp values
check2 = sum(Rp2);
add3 = sum(pow3);
M3 = transpose(proto3)*pow3;
Rp3 = M3/add3; % display Zp, Ip, Pp values
check3 = sum(Rp3);
add4 = sum(pow4);
M4 = transpose(proto4)*pow4;
Rp4 = M4/add4; % display Zp, Ip, Pp values
check4 = sum(Rp4);
add5 = sum(pow5);
M5 = transpose(proto5)*pow5;
Rp5 = M5/add5; % display Zp, Ip, Pp values
check5 = sum(Rp5);
add6 = sum(pow6);
M6 = transpose(proto6)*pow6;
Rp6 = M6/add6; % display Zp, Ip, Pp values
check6 = sum(Rp6);
add7 = sum(pow7);
M7 = transpose(proto7)*pow7;
Rp7 = M7/add7; % display Zp, Ip, Pp values
check7 = sum(Rp7);
```

```
M = M1+M2+M3+M4+M5+M6+M7;
add = add1+add2+add3+add4+add5+add6+add7;
Rp = M/add;
checkp = sum(Rp);
% Zq, Iq and Pq calculation
add1q = sum(reac1);
M1q = transpose(proto1q)*reac1;
Rq1 = M1q/add1q; % display Zq, Iq, Pq values
check1q = sum(Rq1);
add2q = sum(reac2);
M2q = transpose(proto2q)*reac2;
Rq2 = M2q/add2q; % display Zq, Iq, Pq values
check2q = sum(Rq2);
add3q = sum(reac3);
M3q = transpose(proto3q)*reac3;
Rq3 = M3q/add3q; % display Zq, Iq, Pq values
check3q = sum(Rq3);
add4q = sum(reac4);
M4q = transpose(proto4q)*reac4;
Rq4 = M4q/add4q; % display Zq, Iq, Pq values
check4q = sum(Rq4);
add5q = sum(reac5);
M5q = transpose(proto5q)*reac5;
Rq5 = M5q/add5q; % display Zq, Iq, Pq values
check5q = sum(Rq5);
add6q = sum(reac6);
M6q = transpose(proto6q)*reac6;
Rq6 = M6q/add6q; % display Zq, Iq, Pq values
check6q = sum(Rq6);
add7q = sum(reac7);
M7q = transpose(proto7q)*reac7;
Rq7 = M7q/add7q; % display Zq, Iq, Pq values
check7q = sum(Rq7);
Mq = M1q+M2q+M3q+M4q+M5q+M6q+M7q;
addq = add1q+add2q+add3q+add4q+add5q+add6q+add7q;
Rq = Mq/addq;
checkq = sum(Rq);
```

ANNEX – 4

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	110.0	105.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
lama pump	Transformer	Overload	0.100	MVA	0.115	115.2	3-Phase
Sarswoti	Transformer	Overload	0.200	MVA	0.21	102.9	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Boudha pool2	Transformer	Overload	0.200	MVA	0.190	95.2	3-Phase
Bus100	Bus	Under Voltage	0.400	kV	0.38	94.9	3-Phase
Bus63	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus65	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus77	Bus	Under Voltage	0.400	kV	0.38	94.9	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
jorpati park	Transformer	Overload	0.200	MVA	0.19	95.5	3-Phase

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	110.0	105.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Boudha pool2	Transformer	Overload	0.200	MVA	0.231	115.7	3-Phase
Chhabahil Dhungedhara	Transformer	Overload	0.200	MVA	0.22	109.8	3-Phase
GMB Pump	Transformer	Overload	0.300	MVA	0.32	107.8	3-Phase
Investment Bank	Transformer	Overload	0.200	MVA	0.20	100.9	3-Phase
jorpati park	Transformer	Overload	0.200	MVA	0.23	116.0	3-Phase
lama pump	Transformer	Overload	0.100	MVA	0.14	139.8	3-Phase
Sarswoti	Transformer	Overload	0.200	MVA	0.25	124.8	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus100	Bus	Under Voltage	0.400	kV	0.375	93.7	3-Phase
Bus31	Bus	Under Voltage	0.400	kV	0.38	94.2	3-Phase
Bus35	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus48	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus56	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus58	Bus	Under Voltage	0.400	kV	0.379	94.8	3-Phase
Bus63	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus65	Bus	Under Voltage	0.400	kV	0.37	92.8	3-Phase
Bus67	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus75	Bus	Under Voltage	0.400	kV	0.38	94.3	3-Phase
Bus77	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus79	Bus	Under Voltage	0.400	kV	0.38	94.3	3-Phase
Bus82	Bus	Under Voltage	0.400	kV	0.38	94.8	3-Phase
Bus84	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus86	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase
Bus94	Bus	Under Voltage	0.400	kV	0.38	94.7	3-Phase
Bus96	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.37	92.7	3-Phase
Bus99	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase

Project:		ETAP	Page:	1
Location:	Chhabahil	16.0.0C	Date:	21-01-2023
Contract:			SN:	4359168
Engineer:		Study Case: Incorporating 2000W ECS	Revision:	Base
Filename:	Jorpati feeder		Config.:	Winter Load

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	110.0	105.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Baba Boarding	Transformer	Overload	0.200	MVA	0.218	108.8	3-Phase
bash Jhyang	Transformer	Overload	0.200	MVA	0.20	100.0	3-Phase
Boudha pool2	Transformer	Overload	0.200	MVA	0.26	132.0	3-Phase
Cable1	Cable	Overload	331.000	Amp	353.76	106.9	3-Phase
Cable2	Cable	Overload	331.000	Amp	340.46	102.9	3-Phase
ChauChau Karkhana	Transformer	Overload	0.250	MVA	0.25	100.2	3-Phase
Chhabahil Dhungedhara	Transformer	Overload	0.200	MVA	0.25	126.2	3-Phase
GMB Pump	Transformer	Overload	0.300	MVA	0.37	122.5	3-Phase
Investment Bank	Transformer	Overload	0.200	MVA	0.23	115.1	3-Phase
jorpati park	Transformer	Overload	0.200	MVA	0.26	131.9	3-Phase
lama pump	Transformer	Overload	0.100	MVA	0.16	158.6	3-Phase
Sarswoti	Transformer	Overload	0.200	MVA	0.28	141.5	3-Phase
Shankkharapur	Transformer	Overload	0.100	MVA	0.10	103.4	3-Phase
unknown1	Transformer	Overload	0.100	MVA	0.11	106.1	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus100	Bus	Under Voltage	0.400	kV	0.371	92.8	3-Phase
Bus22	Bus	Under Voltage	0.400	kV	0.38	94.8	3-Phase
Bus25	Bus	Under Voltage	0.400	kV	0.38	94.7	3-Phase
Bus31	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus35	Bus	Under Voltage	0.400	kV	0.37	93.7	3-Phase
Bus37	Bus	Under Voltage	0.400	kV	0.38	94.7	3-Phase
Bus40	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus44	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus48	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus50	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase
Bus52	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus56	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus58	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus63	Bus	Under Voltage	0.400	kV	0.37	92.5	3-Phase
Bus65	Bus	Under Voltage	0.400	kV	0.37	91.7	3-Phase
Bus67	Bus	Under Voltage	0.400	kV	0.37	93.3	3-Phase
Bus75	Bus	Under Voltage	0.400	kV	0.37	93.5	3-Phase
Bus77	Bus	Under Voltage	0.400	kV	0.37	92.9	3-Phase
Bus79	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus82	Bus	Under Voltage	0.400	kV	0.38	94.0	3-Phase
Bus84	Bus	Under Voltage	0.400	kV	0.37	93.7	3-Phase
Bus86	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus94	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus96	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus97	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.37	91.7	3-Phase
Bus99	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Cable5	Cable	Overload	331.000	Amp	328.19	99.2	3-Phase
Cable7	Cable	Overload	331.000	Amp	316.67	95.7	3-Phase
Om Shanti	Transformer	Overload	0.300	MVA	0.30	99.8	3-Phase

Project:		**ETAP**	Page:	1
Location:	Chhabahil	16.0.0C	Date:	21-01-2023
Contract:			SN:	4359168
Engineer:		Study Case: Incorporating 2000W ECS	Revision:	Base
Filename:	Jorpati feeder		Config.:	Winter Load

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	110.0	105.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Baba Boarding	Transformer	Overload	0.200	MVA	0.218	108.8	3-Phase
bash Jhyang	Transformer	Overload	0.200	MVA	0.20	100.0	3-Phase
Boudha pool2	Transformer	Overload	0.200	MVA	0.26	132.0	3-Phase
Cable1	Cable	Overload	331.000	Amp	353.76	106.9	3-Phase
Cable2	Cable	Overload	331.000	Amp	340.46	102.9	3-Phase
ChauChau Karkhana	Transformer	Overload	0.250	MVA	0.25	100.2	3-Phase
Chhabahil Dhungedhara	Transformer	Overload	0.200	MVA	0.25	126.2	3-Phase
GMB Pump	Transformer	Overload	0.300	MVA	0.37	122.5	3-Phase
Investment Bank	Transformer	Overload	0.200	MVA	0.23	115.1	3-Phase
jorpati park	Transformer	Overload	0.200	MVA	0.26	131.9	3-Phase
lama pump	Transformer	Overload	0.100	MVA	0.16	158.6	3-Phase
Sarswoti	Transformer	Overload	0.200	MVA	0.28	141.5	3-Phase
Shankkharapur	Transformer	Overload	0.100	MVA	0.10	103.4	3-Phase
unknown1	Transformer	Overload	0.100	MVA	0.11	106.1	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus100	Bus	Under Voltage	0.400	kV	0.371	92.8	3-Phase
Bus22	Bus	Under Voltage	0.400	kV	0.38	94.8	3-Phase
Bus25	Bus	Under Voltage	0.400	kV	0.38	94.7	3-Phase
Bus31	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus35	Bus	Under Voltage	0.400	kV	0.37	93.7	3-Phase
Bus37	Bus	Under Voltage	0.400	kV	0.38	94.7	3-Phase
Bus40	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus44	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus48	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus50	Bus	Under Voltage	0.400	kV	0.38	94.4	3-Phase
Bus52	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus56	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus58	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus63	Bus	Under Voltage	0.400	kV	0.37	92.5	3-Phase
Bus65	Bus	Under Voltage	0.400	kV	0.37	91.7	3-Phase
Bus67	Bus	Under Voltage	0.400	kV	0.37	93.3	3-Phase
Bus75	Bus	Under Voltage	0.400	kV	0.37	93.5	3-Phase
Bus77	Bus	Under Voltage	0.400	kV	0.37	92.9	3-Phase
Bus79	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus82	Bus	Under Voltage	0.400	kV	0.38	94.0	3-Phase
Bus84	Bus	Under Voltage	0.400	kV	0.37	93.7	3-Phase
Bus86	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus94	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus96	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus97	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.37	91.7	3-Phase
Bus99	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Cable5	Cable	Overload	331.000	Amp	328.19	99.2	3-Phase
Cable7	Cable	Overload	331.000	Amp	316.67	95.7	3-Phase
Om Shanti	Transformer	Overload	0.300	MVA	0.30	99.8	3-Phase

Project:		**ETAP**	Page:	1
Location:	Malangwa	16.0.0C	Date:	24-01-2023
Contract:			SN:	4359168
Engineer:		Study Case: Incorporating 2000W ECS	Revision:	Base
Filename:	Malangwa Feeder		Config.:	Summer Load

Alert Summary Report

% Alert Settings

	Critical	Marginal
Loading		
Bus	100.0	90.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	105.0	102.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Adalat-2	Transformer	Overload	0.200	MVA	0.223	111.3	3-Phase
Baiju	Transformer	Overload	0.100	MVA	0.11	107.3	3-Phase
Baisnabi Rice mill	Transformer	Overload	0.100	MVA	0.12	118.6	3-Phase
BalMandir	Transformer	Overload	0.200	MVA	0.22	111.0	3-Phase
Bharsar Gau	Transformer	Overload	0.200	MVA	0.23	113.9	3-Phase
bhedyahi	Transformer	Overload	0.100	MVA	0.11	106.0	3-Phase
Biswakarma Chowk	Transformer	Overload	0.100	MVA	0.11	111.3	3-Phase
Bus167	Bus	Under Voltage	0.400	kV	0.36	88.8	3-Phase
Bus169	Bus	Under Voltage	0.400	kV	0.35	88.7	3-Phase
Bus171	Bus	Under Voltage	0.400	kV	0.35	88.6	3-Phase
Bus176	Bus	Under Voltage	0.400	kV	0.35	88.0	3-Phase
Bus177	Bus	Under Voltage	0.400	kV	0.35	87.9	3-Phase
Bus181	Bus	Under Voltage	0.400	kV	0.35	88.0	3-Phase
Bus185	Bus	Under Voltage	0.400	kV	0.35	87.6	3-Phase
Bus187	Bus	Under Voltage	0.400	kV	0.35	88.0	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Cable96	Cable	Overload	218.000	Amp	239.141	109.7	3-Phase
Dog cond	Cable	Overload	331.000	Amp	425.56	128.6	3-Phase
Gamahariya Chowk	Transformer	Overload	0.100	MVA	0.10	104.7	3-Phase
Gamahariya gau	Transformer	Overload	0.100	MVA	0.11	105.8	3-Phase
Gamahariya khanepani	Transformer	Overload	0.100	MVA	0.11	109.2	3-Phase
Gamahariya new	Transformer	Overload	0.100	MVA	0.10	103.9	3-Phase
Ganesiya gau	Transformer	Overload	0.100	MVA	0.11	105.2	3-Phase
GBS	Transformer	Overload	0.100	MVA	0.10	104.2	3-Phase
Ghordaura	Transformer	Overload	0.025	MVA	0.03	119.3	3-Phase
Gym Club	Transformer	Overload	0.100	MVA	0.10	104.9	3-Phase
janswata	Transformer	Overload	0.100	MVA	0.12	124.5	3-Phase
Khutauna	Transformer	Overload	0.100	MVA	0.11	105.0	3-Phase
Khutauna tole	Transformer	Overload	0.200	MVA	0.23	114.9	3-Phase
Krrishnamati	Transformer	Overload	0.250	MVA	0.26	102.1	3-Phase
Malangwa petrol Pump	Transformer	Overload	0.100	MVA	0.10	103.3	3-Phase
masjid	Transformer	Overload	0.200	MVA	0.23	115.3	3-Phase
Mayor Saheb	Transformer	Overload	0.250	MVA	0.27	107.5	3-Phase
musaili Chowk	Transformer	Overload	0.100	MVA	0.11	109.8	3-Phase
Nagarpalika	Transformer	Overload	0.200	MVA	0.23	116.1	3-Phase
Near Cold store	Transformer	Overload	0.100	MVA	0.11	112.0	3-Phase
Near Murhi mill	Transformer	Overload	0.200	MVA	0.24	120.9	3-Phase
Near NEA	Transformer	Overload	0.100	MVA	0.11	109.4	3-Phase
Near Nepal Bank	Transformer	Overload	0.100	MVA	0.11	113.5	3-Phase
NTC Tower(PVT.)	Transformer	Overload	0.100	MVA	0.11	109.4	3-Phase
pakri gao	Transformer	Overload	0.050	MVA	0.05	105.0	3-Phase
palsi south	Transformer	Overload	0.025	MVA	0.03	109.2	3-Phase
phaonhora kumhal	Transformer	Overload	0.100	MVA	0.11	106.8	3-Phase
phonhora	Transformer	Overload	0.150	MVA	0.16	109.4	3-Phase
Post office	Transformer	Overload	0.100	MVA	0.11	105.6	3-Phase
Public School Chowk	Transformer	Overload	0.100	MVA	0.11	112.5	3-Phase
Rameswor ray	Transformer	Overload	0.100	MVA	0.11	112.4	3-Phase
Sano Musaili	Transformer	Overload	0.100	MVA	0.10	103.0	3-Phase
Sarswoti Tole	Transformer	Overload	0.100	MVA	0.10	102.3	3-Phase
Shiva Sagar Chowk-2	Transformer	Overload	0.150	MVA	0.16	105.4	3-Phase
shivnagar	Transformer	Overload	0.100	MVA	0.11	106.9	3-Phase
Shivsagar Chowk	Transformer	Overload	0.200	MVA	0.23	116.4	3-Phase

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
simra khatbe tole	Transformer	Overload	0.100	MVA	0.102	102.5	3-Phase
Simra school	Transformer	Overload	0.100	MVA	0.10	101.2	3-Phase
Simra Tole	Transformer	Overload	0.100	MVA	0.10	100.5	3-Phase
SP Office1	Transformer	Overload	0.200	MVA	0.24	119.1	3-Phase
Subba Saheb	Transformer	Overload	0.100	MVA	0.11	113.5	3-Phase
Swarnim firm	Transformer	Overload	0.200	MVA	0.23	117.1	3-Phase
thulo Musaili	Transformer	Overload	0.100	MVA	0.11	105.6	3-Phase
umesh ghar nira	Transformer	Overload	0.100	MVA	0.12	124.9	3-Phase
utarwariya tole	Transformer	Overload	0.100	MVA	0.11	105.1	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus100	Bus	Under Voltage	0.400	kV	0.369	92.4	3-Phase
Bus104	Bus	Under Voltage	0.400	kV	0.37	92.2	3-Phase
Bus106	Bus	Under Voltage	0.400	kV	0.37	92.1	3-Phase
Bus108	Bus	Under Voltage	0.400	kV	0.37	92.3	3-Phase
Bus111	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus113	Bus	Under Voltage	0.400	kV	0.37	92.5	3-Phase
Bus115	Bus	Under Voltage	0.400	kV	0.37	92.5	3-Phase
Bus117	Bus	Under Voltage	0.400	kV	0.37	92.1	3-Phase
Bus127	Bus	Under Voltage	0.400	kV	0.38	94.8	3-Phase
Bus140	Bus	Under Voltage	0.400	kV	0.38	94.8	3-Phase
Bus143	Bus	Under Voltage	0.400	kV	0.38	94.9	3-Phase
Bus144	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus149	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus150	Bus	Under Voltage	0.400	kV	0.37	92.9	3-Phase
Bus151	Bus	Under Voltage	0.400	kV	0.37	92.9	3-Phase
Bus154	Bus	Under Voltage	0.400	kV	0.37	93.2	3-Phase
Bus155	Bus	Under Voltage	0.400	kV	0.37	92.5	3-Phase
Bus157	Bus	Under Voltage	0.400	kV	0.37	91.3	3-Phase
Bus159	Bus	Under Voltage	11.000	kV	10.39	94.5	3-Phase
Bus160	Bus	Under Voltage	11.000	kV	10.39	94.5	3-Phase
Bus161	Bus	Under Voltage	0.400	kV	0.36	90.3	3-Phase
Bus164	Bus	Under Voltage	11.000	kV	10.39	94.4	3-Phase
Bus165	Bus	Under Voltage	0.400	kV	0.36	90.9	3-Phase
Bus166	Bus	Under Voltage	11.000	kV	10.15	92.2	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus168	Bus	Under Voltage	11.000	kV	10.145	92.2	3-Phase
Bus170	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus172	Bus	Under Voltage	11.000	kV	10.15	92.3	3-Phase
Bus173	Bus	Under Voltage	11.000	kV	10.15	92.3	3-Phase
Bus174	Bus	Under Voltage	11.000	kV	10.09	91.7	3-Phase
Bus175	Bus	Under Voltage	11.000	kV	10.09	91.7	3-Phase
Bus178	Bus	Under Voltage	11.000	kV	10.09	91.7	3-Phase
Bus179	Bus	Under Voltage	11.000	kV	10.07	91.5	3-Phase
Bus180	Bus	Under Voltage	11.000	kV	10.06	91.5	3-Phase
Bus184	Bus	Under Voltage	11.000	kV	10.06	91.5	3-Phase
Bus186	Bus	Under Voltage	11.000	kV	10.06	91.5	3-Phase
Bus52	Bus	Under Voltage	0.400	kV	0.37	93.3	3-Phase
Bus56	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus60	Bus	Under Voltage	0.400	kV	0.38	94.0	3-Phase
Bus66	Bus	Under Voltage	0.400	kV	0.37	93.6	3-Phase
Bus70	Bus	Under Voltage	0.400	kV	0.37	93.5	3-Phase
Bus73	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus75	Bus	Under Voltage	0.400	kV	0.37	93.1	3-Phase
Bus79	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus82	Bus	Under Voltage	0.400	kV	0.37	92.7	3-Phase
Bus84	Bus	Under Voltage	0.400	kV	0.37	93.1	3-Phase
Bus86	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus95	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.37	92.6	3-Phase
Pakri got	Transformer	Overload	0.050	MVA	0.05	98.0	3-Phase
pakri panitanki	Transformer	Overload	0.100	MVA	0.10	99.3	3-Phase
palsi middle	Transformer	Overload	0.050	MVA	0.05	99.5	3-Phase
palsi north tole	Transformer	Overload	0.050	MVA	0.05	99.5	3-Phase

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	90.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	105.0	102.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Baisnabi Rice mill	Transformer	Overload	0.100	MVA	0.105	105.1	3-Phase
Bharsar Gau	Transformer	Overload	0.200	MVA	0.20	101.2	3-Phase
Bus171	Bus	Under Voltage	0.400	kV	0.36	90.0	3-Phase
Bus176	Bus	Under Voltage	0.400	kV	0.36	89.4	3-Phase
Bus177	Bus	Under Voltage	0.400	kV	0.36	89.4	3-Phase
Bus181	Bus	Under Voltage	0.400	kV	0.36	89.4	3-Phase
Bus185	Bus	Under Voltage	0.400	kV	0.36	89.1	3-Phase
Bus187	Bus	Under Voltage	0.400	kV	0.36	89.4	3-Phase
Dog cond	Cable	Overload	331.000	Amp	380.89	115.1	3-Phase
Ghordaura	Transformer	Overload	0.025	MVA	0.03	106.0	3-Phase
janswata	Transformer	Overload	0.100	MVA	0.11	110.3	3-Phase
Khutauna tole	Transformer	Overload	0.200	MVA	0.20	102.0	3-Phase
masjid	Transformer	Overload	0.200	MVA	0.20	102.1	3-Phase
Nagarpalika	Transformer	Overload	0.200	MVA	0.21	103.0	3-Phase
Near Murhi mill	Transformer	Overload	0.200	MVA	0.21	107.2	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Near Nepal Bank	Transformer	Overload	0.100	MVA	0.100	100.5	3-Phase
Shivsagar Chowk	Transformer	Overload	0.200	MVA	0.21	103.2	3-Phase
SP Office1	Transformer	Overload	0.200	MVA	0.21	105.5	3-Phase
Subba Saheb	Transformer	Overload	0.100	MVA	0.10	100.7	3-Phase
Swarnim firm	Transformer	Overload	0.200	MVA	0.21	103.9	3-Phase
umesh ghar nira	Transformer	Overload	0.100	MVA	0.11	110.6	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Adalat-2	Transformer	Overload	0.200	MVA	0.197	98.7	3-Phase
BalMandir	Transformer	Overload	0.200	MVA	0.20	98.3	3-Phase
Biswakarma Chowk	Transformer	Overload	0.100	MVA	0.10	98.7	3-Phase
Bus100	Bus	Under Voltage	0.400	kV	0.37	93.2	3-Phase
Bus104	Bus	Under Voltage	0.400	kV	0.37	93.0	3-Phase
Bus106	Bus	Under Voltage	0.400	kV	0.37	93.0	3-Phase
Bus108	Bus	Under Voltage	0.400	kV	0.37	93.1	3-Phase
Bus111	Bus	Under Voltage	0.400	kV	0.38	94.0	3-Phase
Bus113	Bus	Under Voltage	0.400	kV	0.37	93.3	3-Phase
Bus115	Bus	Under Voltage	0.400	kV	0.37	93.3	3-Phase
Bus117	Bus	Under Voltage	0.400	kV	0.37	93.0	3-Phase
Bus149	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus150	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus151	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus154	Bus	Under Voltage	0.400	kV	0.38	94.0	3-Phase
Bus155	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Bus157	Bus	Under Voltage	0.400	kV	0.37	92.3	3-Phase
Bus161	Bus	Under Voltage	0.400	kV	0.37	91.4	3-Phase
Bus165	Bus	Under Voltage	0.400	kV	0.37	92.0	3-Phase
Bus166	Bus	Under Voltage	11.000	kV	10.25	93.2	3-Phase
Bus167	Bus	Under Voltage	0.400	kV	0.36	90.1	3-Phase
Bus168	Bus	Under Voltage	11.000	kV	10.25	93.1	3-Phase
Bus169	Bus	Under Voltage	0.400	kV	0.36	90.0	3-Phase
Bus170	Bus	Under Voltage	11.000	kV	10.24	93.1	3-Phase
Bus172	Bus	Under Voltage	11.000	kV	10.25	93.2	3-Phase
Bus173	Bus	Under Voltage	11.000	kV	10.25	93.2	3-Phase
Bus174	Bus	Under Voltage	11.000	kV	10.19	92.7	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus175	Bus	Under Voltage	11.000	kV	10.194	92.7	3-Phase
Bus178	Bus	Under Voltage	11.000	kV	10.20	92.7	3-Phase
Bus179	Bus	Under Voltage	11.000	kV	10.18	92.5	3-Phase
Bus180	Bus	Under Voltage	11.000	kV	10.17	92.5	3-Phase
Bus184	Bus	Under Voltage	11.000	kV	10.17	92.5	3-Phase
Bus186	Bus	Under Voltage	11.000	kV	10.17	92.5	3-Phase
Bus52	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus56	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus60	Bus	Under Voltage	0.400	kV	0.38	94.6	3-Phase
Bus66	Bus	Under Voltage	0.400	kV	0.38	94.3	3-Phase
Bus70	Bus	Under Voltage	0.400	kV	0.38	94.2	3-Phase
Bus73	Bus	Under Voltage	0.400	kV	0.38	94.1	3-Phase
Bus75	Bus	Under Voltage	0.400	kV	0.38	93.8	3-Phase
Bus79	Bus	Under Voltage	0.400	kV	0.38	94.2	3-Phase
Bus82	Bus	Under Voltage	0.400	kV	0.37	93.5	3-Phase
Bus84	Bus	Under Voltage	0.400	kV	0.38	93.9	3-Phase
Bus86	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus95	Bus	Under Voltage	0.400	kV	0.38	94.5	3-Phase
Bus98	Bus	Under Voltage	0.400	kV	0.37	93.4	3-Phase
Cable96	Cable	Overload	218.000	Amp	216.04	99.1	3-Phase
Gamahariya khanepani	Transformer	Overload	0.100	MVA	0.10	96.9	3-Phase
Mayor Saheb	Transformer	Overload	0.250	MVA	0.24	95.4	3-Phase
musaili Chowk	Transformer	Overload	0.100	MVA	0.10	97.5	3-Phase
Near Cold store	Transformer	Overload	0.100	MVA	0.10	99.2	3-Phase
Near NEA	Transformer	Overload	0.100	MVA	0.10	96.9	3-Phase
NTC Tower(PVT.)	Transformer	Overload	0.100	MVA	0.10	96.9	3-Phase
palsi south	Transformer	Overload	0.025	MVA	0.02	96.9	3-Phase
phaonhora kumhal	Transformer	Overload	0.100	MVA	0.10	95.2	3-Phase
phonhora	Transformer	Overload	0.150	MVA	0.15	97.5	3-Phase
Public School Chowk	Transformer	Overload	0.100	MVA	0.10	99.6	3-Phase
Rameswor ray	Transformer	Overload	0.100	MVA	0.10	99.6	3-Phase
shivnagar	Transformer	Overload	0.100	MVA	0.10	95.1	3-Phase

Impact of Increasing Load on the Distribution Network with the addition of Electric Cooking Stoves in Nepali Context

ORIGINALITY REPORT

10%

SIMILARITY INDEX

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Impact of Increasing Load on the Distribution Network with the addition of Electric Cooking Stoves at each Household: Case Study of Nepal

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***Abstract*— According to Nepal's budget for fiscal year 2079/80, the government has planned to distribute electric cooking stoves (ECS) to each household. With the use of ECS on a large scale, the load on the distribution feeder will increase significantly, resulting in a reduced voltage level at buses, increased loading on the distribution transformer, and, in fact, increased current carried by the feeder conductor. The study focuses mainly on the loading of the distribution transformer (DT), the voltage level at the buses, and the ampacity of the feeder conductor. The study is carried out considering two feeders: the Jorpati feeder in Kathmandu district and the Malangwa feeder in Sarlahi district of Nepal. The load and ZIP Coefficients of the study area are estimated by polynomial load modeling technique on a seasonal basis. The results show after connecting ECS, the major impact is seen on the Jorpati feeder during the winter season. There is overloading on 18 DTs, the existing dog conductor will not be able to handle the increasing demand for load current and voltage level at buses drops slightly. Thus, system upgradation is required to meet the growing load due to the addition of ECS at each household. Similarly, in the Malangwa feeder, the results show that after connecting ECS, the major impact is seen in the summer season. There is overloading on almost all DTs, low voltage levels at buses, and the existing feeder conductor will not be able to handle the increasing current requirement. Since the complete system needs to be restructured, in the present context, promoting the use of ECS at each household in the Malangwa area is not recommended.**

***Keywords*— Electric cooking stoves, ZIP Coefficients, Ampacity of feeder conductor, distribution transformer sizing**

I. INTRODUCTION

Electricity is a basic human need and is used for various purposes in our day-to-day lives, such as lighting, cooking, running domestic appliances, and many more. Electricity is widely used for cooking purposes in developed countries. But if we observe the scenario of Nepal, cooking is highly dominated by liquefied petroleum gas (LPG) in the urban areas and in some parts of the rural areas too. In rural areas, cooking is mainly dominated by firewood [1]. In Nepal, 52.4% of total households are dependent on firewood, and 33.1% of total households are dependent on LPG [1]. The use of electric cooking stoves (ECS) for cooking purposes is rare in Nepal. The increasing price of LPG and its shortage have seriously affected the kitchen expenses of the Nepalese society, and moreover, LPG needs to be imported into Nepal. That is why the government is promoting the use of ECS for cooking purposes.

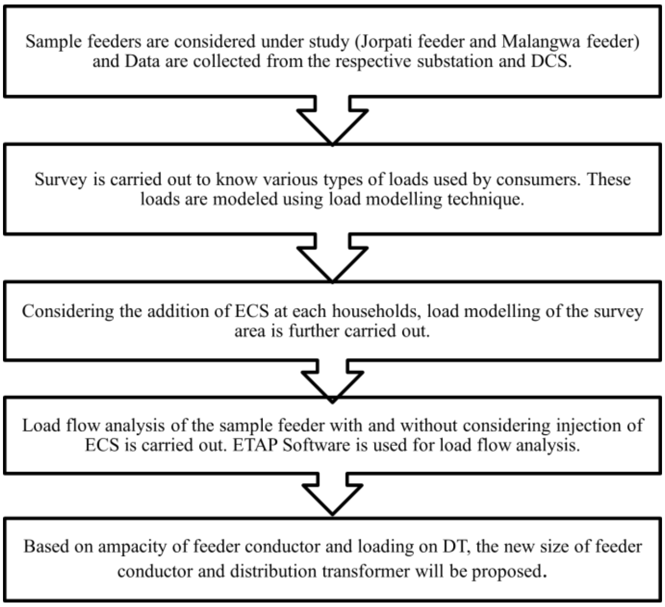
In the Nepalese market, the ECS that are readily available are induction cookers (IC) and infrared cookers (IRC). IC works on the principle of mutual induction. Only utensils made of ferromagnetic materials like stainless steel or cast iron can be used for cooking with IC. IRC operates on the principle of infrared heat radiation. Any kind of utensil can be used for cooking using IRC. When LPG is used for cooking, only 40% of the heat energy is transferred to the utensils, whereas ECS transfer 90% of the heat energy to the utensils [1]. Hence, ECS are more energy efficient than LPG.

Even though the use of ECS is both beneficial to consumers and the nation as a whole, the use of ECS on a large scale may cause problems on the distribution feeder, such as low voltage at the buses, increased power loss, overloading on the distribution transformers (DTs), and many more. Some of these problems can be solved by techniques like installing distributed generation in the distribution system, bundling conductors, upgrading the feeder, and many more [2], [3]. The distribution load flow analysis can be carried out using different methods like the Newton-Raphson method, the accelerated Gauss-Seidel method, the fast decoupled method, etc., but they are not very efficient as the R/X ratio of the distribution feeder is high. For distribution load flow, the two major techniques are ladder theory and backward-forward sweep methods. Due to its fast conversion rate and efficient computation, the backward-forward sweep algorithm is generally preferred [2], [3].

Load modeling is carried out to estimate the total load of the study area. An accurate load model is required for distribution networks to get proper results. There are numerous load modeling techniques, such as polynomial load modeling, exponential load modeling, frequency-dependent load modeling, ANN-based modeling, an exponential recovery load model, composite load models, and so on [4]. Among all the available techniques, the polynomial load model and the exponential load model are widely used for modeling the loads of distribution networks [4]–[8]. The electrical loads are usually categorized as constant impedance (Z), constant current (I), and constant power (P) loads [4]–[8]. We can find all these kinds of electric loads in the service area, and load modeling should be done for mixed loads.

This study is primarily concerned with whether the existing system will be able to meet the growing load demand with the addition of ECS at each household in the study area. If ECS is used for cooking purposes at each household in the study area, then the current flowing through the existing feeder conductor will increase and the loading on the transformer will also increase. So, the study aims to verify whether the existing feeder conductor and transformer meet the growing load demand or not, and if not, to propose new feeder and transformer sizes. Also, the voltage level will drop and power loss will increase and it is intended to verify whether the voltage drop and power loss are within acceptable limits or not.

II. METHODOLOGY



Sample feeders are considered under study (Jorpati feeder and Malangwa feeder) and Data are collected from the respective substation and DCS.

Survey is carried out to know various types of loads used by consumers. These loads are modeled using load modelling technique.

Considering the addition of ECS at each households, load modelling of the survey area is further carried out.

Load flow analysis of the sample feeder with and without considering injection of ECS is carried out. ETAP Software is used for load flow analysis.

Based on ampacity of feeder conductor and loading on DT, the new size of feeder conductor and distribution transformer will be proposed.

Fig. 1. Methodology for the study

The study is carried out considering two feeders: the Jorpati feeder of Kathmandu district and the Malangwa feeder of Sarlahi district of Nepal. A survey is carried out to find out the types of electrical appliances used by consumers living in the Jorpati and Malangwa areas, and based on the various electrical appliances used by the consumers, different prototype homes are formulated. The total number of households connected to the respective feeder line can be obtained from the concerned DCS of NEA. The loading on the feeder can be determined using the data obtained from the substation in the study area. Now the load of the study area is estimated, considering different prototype homes. The loads of the consumers are modeled, and then load flow analysis is carried out. Load flow analysis is carried out to determine the feeder current, bus voltages, power loss, and loading on DTs. Similarly, the load flow analysis is further carried out considering the inclusion of ECS at each household. Induction cookers (IC) and infrared cookers (IRC) are considered ECS. IC works on the principle of mutual induction. IRC operates on the principle of infrared heat radiation, i.e., conduction. The results of the load flow analysis will be useful for planning. The maximum current flowing through the feeder conductor can be obtained from the results of a load flow analysis, and this will help determine whether the existing feeder conductor will meet the growing load current demand or not. If not, a new size of feeder conductor will be proposed. Also, after connecting ECS to each household, the voltage level will drop and power loss will increase and it is intended to verify whether the voltage drop and power loss are within acceptable limits or not. The National Electrical code recommends the maximum allowable voltage drop can be 5%. Similarly, the loading on the DTs can also be obtained from the results of the load flow report, and those DTs which are overloaded will be recommended for upgradation.

III. LOAD MODELING

There are numerous load modeling techniques that can be used for estimating the load of the study area. Among all the available techniques, the polynomial load model and the exponential load model are widely used for modeling the loads of distribution networks [4]. Particularly in this research, polynomial load modeling is used.

A. *Polynomial Load Model*

This load modeling is also called as ZIP load model. The electrical loads are usually categorized as constant impedance (Z), constant current (I), and constant power (P) loads [4]. We all know that consumers make use of different electrical appliances, and the electrical loads are a mixture of constant power load, constant current load and constant impedance load. These appliances behave differently with variations in voltage. The consumption of power varies with the change in voltage represented by the equation as follows [5], [6], [8].

$$P(V_a) = (P_p + I_p|V_a/V_0| + Z_p|V_a/V_0|^{2})P_0 \qquad (1)$$

Where,

P_0 = Nominal/rated power of the load

V_0 = Nominal/rated voltage of the load

V_a = actual bus voltage at which load is operating

$P_p + I_p + Z_p = 1$

P_p, I_p and Z_p represents the three different kinds of loads

$$Q(V_a) = (P_q + I_q|V_a/V_0| + Z_q|V_a/V_0|^{2})Q_0 \qquad (2)$$

Where,

Q_0 = Nominal/rated reactive power of the load

V_0 = Nominal/rated voltage of the load

V_a = actual bus voltage at which load is operating

$P_q + I_q + Z_q = 1$

P_q, I_q and Z_q represents the three different kinds of loads P_p , I_p , Z_p and P_q, I_q , Z_q will be different as the real and reactive power behave differently with respect to the voltage change. P_p , I_p , Z_p, P_q, I_q , Z_q are called as ZIP Coefficients.

B. *Development of Algorithm to Determine ZIP Coefficient for Mixed Load*

Let us consider that V_a is the actual bus voltage and V_0 is the rated voltage. Consider n electrical appliances are connected to the same bus with an actual bus voltage of V_a. Components 1, 2, 3,…….., and n are assigned to the n electrical appliances. P_{01} and Q_{01} are the rated active and reactive power of component 1. P_{02} and Q_{02} are the rated active and reactive power of component 2. P_{03} and Q_{03} are the rated active and reactive power of component 3. Similarly, P_{0n} and Q_{0n} are the rated active and reactive powers of component n. P^1_p , I^1_p , Z^1_p , P^1_q, I^1_q and Z^1_q are ZIP coefficients of component 1. P^2_p , I^2_p , Z^2_p , P^2_q, I^2_q and Z^2_q are ZIP coefficients of component 2. P^3_p , I^3_p , Z^3_p , P^3_q, I^3_q and Z^3_q are ZIP coefficients of component 3. P^n_p , I^n_p , Z^n_p , P^n_q, I^n_q and Z^n_q are ZIP coefficients of component n. The power consumed by the n components at a bus voltage of V_a is given by,

$$P_1 = [P^1_p + I^1_p (|V_a/V_0|) + Z^1_p (|V_a/V_0|^2)]P_{01} \tag{3}$$

$$P_2 = [P^2_p + I^2_p (|V_a/V_0|) + Z^2_p (|V_a/V_0|^2)]P_{02} \tag{4}$$

$$P_3 = [P^3_p + I^3_p (|V_a/V_0|) + Z^3_p (|V_a/V_0|^2)]P_{03} \tag{5}$$

Similarly,

$$P_n = [P^n_p + I^n_p (|V_a/V_0|) + Z^n_p (|V_a/V_0|^2)]P_{0n} \tag{6}$$

Adding above equations

$$P_1+P_2+P_3 + \ldots\ldots\ldots +P_n = [P^1_p + I^1_p (|V_a/V_0|) + Z^1_p (|V_a/V_0|^2)]P_{01} + [P^2_p + I^2_p (|V_a/V_0|) + Z^2_p (|V_a/V_0|^2)]P_{02} + [P^3_p + I^3_p (|V_a/V_0|) + Z^3_p (|V_a/V_0|^2)]P_{03} + \ldots\ldots\ldots + [P^n_p + I^n_p (|V_a/V_0|) + Z^n_p (|V_a/V_0|^2)]P_{0n}$$

or, $P_1+P_2+P_3 + \ldots\ldots +P_n = [P^1_p P_{01} + P^2_p P_{02} + P^3_p P_{03} + \ldots + P^n_p P_{0n}] + [I^1_p P_{01} + I^2_p P_{02} + I^3_p P_{03} + \ldots + I^n_p P_{0n}] (V_a/V_0) + [Z^1_p P_{01} + Z^2_p P_{02} + Z^3_p P_{03} + \ldots + Z^n_p P_{0n}] (V_a/V_0)^2$

Multiplying numerator and denominator by $(P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

or, $P_1+P_2+P_3 + \ldots\ldots +P_n = [(P^1_p P_{01} + P^2_p P_{02} + P^3_p P_{03} + \ldots + P^n_p P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n}) + (I^1_p P_{01} + I^2_p P_{02} + I^3_p P_{03} + \ldots + I^n_p P_{0n}) * (V_a/V_0) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n}) + (Z^1_p P_{01} + Z^2_p P_{02} + Z^3_p P_{03} + \ldots + Z^n_p P_{0n}) * (V_a/V_0)^2 / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})] * (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

Therefore,

$$P_1+P_2+P_3 + \ldots\ldots +P_n = [\, P^m_p + I^m_p (V_a/V_0) + Z^m_p (V_a/V_0)^2 \,] * (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$$

Where,

$P^m_p = (P^1_p P_{01} + P^2_p P_{02} + P^3_p P_{03} + \ldots + P^n_p P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

$I^m_p = (I^1_p P_{01} + I^2_p P_{02} + I^3_p P_{03} + \ldots + I^n_p P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

$Z^m_p = (Z^1_p P_{01} + Z^2_p P_{02} + Z^3_p P_{03} + \ldots + Z^n_p P_{0n}) / (P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$

Similarly, the reactive power consumed by all electrical components at bus voltage of Va will be given by,

$Q_1+Q_2+Q_3 + \ldots\ldots +Q_n = [(P^1_q Q_{01} + P^2_q Q_{02} + P^3_q Q_{03} + \ldots + P^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n}) + (I^1_q Q_{01} + I^2_q Q_{02} + I^3_q Q_{03} + \ldots + I^n_q Q_{0n}) * (V_a/V_0) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n}) + (Z^1_q Q_{01} + Z^2_q Q_{02} + Z^3_q Q_{03} + \ldots + Z^n_q Q_{0n}) * (V_a/V_0)^2 / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})] * (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

Where,

$P^m_q = (P^1_q Q_{01} + P^2_q Q_{02} + P^3_q Q_{03} + \ldots + P^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$I^m_q = (I^1_q Q_{01} + I^2_q Q_{02} + I^3_q Q_{03} + \ldots + I^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$Z^m_q = (Z^1_q Q_{01} + Z^2_q Q_{02} + Z^3_q Q_{03} + \ldots + Z^n_q Q_{0n}) / (Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$

$(P_{01}+P_{02}+P_{03}+\ldots +P_{0n})$ represents the active power consumption of the study area of those n loads and $(Q_{01}+Q_{02}+Q_{03}+\ldots +Q_{0n})$ represents the reactive power Consumption of the study area of those three components P^m_p, I^m_p , Z^m_p , P^m_q , I^m_q , Z^m_q represents the ZIP Coefficients for mixed load.

As the loads available in the study area are mixed loads. Thus, the values of P_p , I_p , Z_p and P_q, I_q , Z_q will be different but their sum will remain 1. The values of P_p , I_p , Z_p and P_q, I_q , Z_q vary as the appliances available in the study area change. Thus, the ZIP coefficients of the mixed load will be different for different areas and will differ as per the change in the seasonal loads as well. Thus, ZIP coefficients for summer, winter, spring, and autumn loads are separately determined. The load modeling is carried out considering different prototype homes, offices, commercial buildings, and so on.

C. *Load Estimation and ZIP Coefficient Determination*

TABLE I
LIST OF ELECTRICAL APPLIANCES CONSIDERED AND THEIR ZIP COEFFICIENTS (SOURCE: [5], [6], [8])

Name of appliances	Zp	Zq	Ip	Iq	Pp	Pq
LED Light	0.73	0.52	-1.7	-1.41	1.97	1.89
Fan	0.26	0.5	0.9	0.62	-0.16	-0.12
LCD TV	-0.4	3.92	0.45	-4.86	0.95	1.94
Halogen Heater	0.51	0.43	0.55	0.52	-0.06	0.05
Air conditioner	1.55	1.56	-2.12	-2.14	1.57	1.58
Refrigerator	1.04	5.69	-1.57	-8.56	1.53	3.87
Microwave	1	0	0.6	2.02	-0.6	-1.02
desktop	-0.32	1.56	1.14	-2.13	0.18	1.57
Washing Machine	0.78	-2.29	0.34	5.51	-0.12	-2.22
Vacuum Cleaner	0.82	5.95	0.22	-7.33	-0.04	2.38
Water Heater	0.95	0.29	0.07	1.02	-0.02	-0.31
Mixer	0.94	0.61	0.09	0.56	-0.03	-0.17
Charger	0.25	0.14	-0.48	0.32	1.23	0.54
Iron	0.99	3.92	0.01	-4.86	0	1.94
Copier	0.52	0.39	0.45	-0.25	0.03	0.86
Motor load	-0.07	0.01	0.08	0.01	0.99	0.98
Air compressor 1p	0.73	0.45	0.38	0.51	-0.11	0.04
Welding Machine	-3.16	-1	6.85	1.98	-2.69	0.02
Elevator	2.36	-2.93	-4.15	6.5	2.79	-2.57
Induction Cooker	0	1.91	1	0	0	-0.91
Infra-red Cooker	0.51	0.43	0.55	0.52	-0.06	0.05

The various types of electrical appliances used by the consumers of Jorpati and Malangwa areas are surveyed by the one-on-one interview method. The appliances used by the different consumers differ, and based on the types of appliances used by the consumers, various prototype homes are formulated in order to determine the ZIP coefficients of the mixed load and to estimate the load of the study area. The values of ZIP coefficients depend on the types of electrical appliances used by the consumers living in the study area and the usage of appliances differs as per the seasonal condition. Thus, the ZIP coefficient needs to be determined separately for each seasonal condition. As the active and reactive power consumption differs with the change in voltage level and the ZIP coefficient values of the study area, the load of the study area is estimated to find out the actual loading on the feeder conductor in each season condition. The values of the ZIP coefficients of the individual electrical appliances are referred to [5], [6], [8]. The ZIP coefficients of the mixed load and the load of the area are estimated considering the various prototype homes. As we know, the appliances used by consumers also differ based on the seasonal conditions, which is why the load of the study area and ZIP coefficient are evaluated separately for different seasonal conditions. Similarly, with the addition of ECS of 2000 W at each household and a co-incidence factor of 0.7, new ZIP coefficients for the mixed load and the load of the study area are evaluated based on the seasonal conditions.

TABLE II
ZIP COEFFICIENTS FOR MIXED LOAD FOR VARIOUS SEASONAL CONDITION (JORPATI FEEDER)

Load	Zp	Ip	Pp	Zq	Iq	Pq
Spring Load	0.339	0.09	0.571	0.47	0.117	0.413
Autumn Load	0.339	0.09	0.571	0.47	0.117	0.413
Summer Load	0.41	0.083	0.507	0.527	0.07	0.403
Winter Load	0.573	0.119	0.308	0.353	0.457	0.19
Spring Load with ECS	0.242	0.35	0.408	0.681	0.1	0.219
Autumn Load with ECS	0.242	0.35	0.408	0.681	0.1	0.219
Summer Load with ECS	0.316	0.294	0.39	0.7	0.061	0.239
Winter Load With ECS	0.479	0.263	0.258	0.503	0.413	0.084

TABLE III
ZIP COEFFICIENTS FOR MIXED LOAD FOR VARIOUS SEASONAL CONDITION (MALANGWA FEEDER)

Load	Zp	Ip	Pp	Zq	Iq	Pq
Spring Load	0.042	0.622	0.336	0.361	0.219	0.42
Autumn Load	0.042	0.622	0.336	0.361	0.219	0.42
Summer Load	0.143	0.571	0.286	0.421	0.234	0.345
Winter Load	0.316	0.43	0.254	0.303	0.395	0.302
Spring Load with ECS	0.029	0.741	0.23	0.583	0.187	0.23
autumn Load with ECS	0.029	0.741	0.23	0.583	0.187	0.23
Summer Load with ECS	0.108	0.677	0.215	0.593	0.207	0.2
Winter Load with ECS	0.264	0.524	0.212	0.5	0.347	0.153

TABLE IV
ESTIMATED LOAD OF JORPATI AND MALANGWA FEEDER

Seasonal Condition	Estimated load Jorpati Feeder KVA	Estimated load Malangwa feeder KVA
Spring Load without ECS	3798.791146	5957.1835
Autumn Load without ECS	3798.791146	5957.1835
Summer Load without ECS	4939.06131	8058.0531
Winter Load Without ECS	7228.867775	7742.464
Spring Load with ECS	5022.375377	7959.7421
Autumn Load with ECS	5022.375377	7959.7421
Summer Load with ECS	6174.046032	10080.886
Winter load with ECS	7267.292466	9096.353

IV. RESULTS AND DISCUSSION

A. Load Flow Results of Jorpati Feeder

After load modeling for summer, winter, spring and autumn loads with and without inclusion of ECS at each household of the Jorpati feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different busses, and the system power loss. The results of the load flow are tabulated below.

TABLE V
SUMMARY OF LOAD FLOW REPORT OF JORPATI FEEDER

Load Condition	Current flowing through feeder conductor(A)	power loss (in %)
Normal	203.1	2.058559
Spring Load with ECS	253.2	3.198672
Autumn Load with ECS	253.2	3.198672
Summer Load with ECS	308.9	4.760379
Winter load with ECS	353.8	6.221646

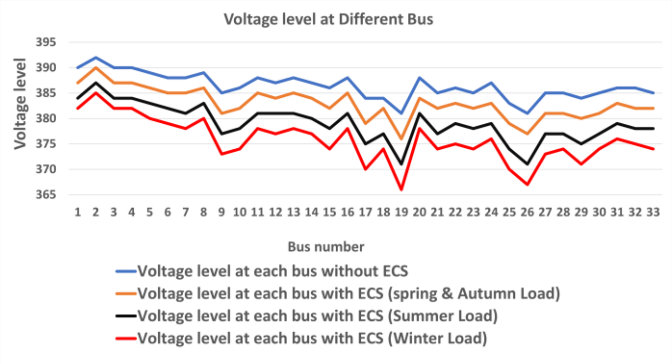


Fig. 2. Voltage level at different bus – Jorpati Feeder

Without incorporating ECS, two transformers are operating at around 90% loading and the voltage level is within the acceptable limit, i.e., below 5%. After incorporating ECS at each household, we observe that in the spring season, there are two transformers that are overloaded. This is because these two transformers were normally operating at 90% loading. The voltage level at this condition is also within an acceptable limit. Similarly, in the summer season, seven transformers are overloaded and marginally low voltage is observed on a few buses. Also, the feeder conductor is marginally overloaded, operating at 93.3%. Similarly, in the winter season, we observe that 12 transformers are overloaded and need to be upgraded, and one transformer is operating at 99.8% loading. The voltage level drops by 8% on a few buses at which DTs were initially 90% loaded, but most of the buses have marginally low voltage. Further analysis shows that five transformers are operating at around 94% loading. Also, there is overloading on the feeder conductor. The existing dog conductor can carry only 331A current at an ambient temperature of 30^{0}C whereas the current flowing through the feeder conductor is 353.8A. Thus, all these 18 transformers need to be upgraded, along with the feeder conductor. It is recommended to upgrade the feeder conductor to a wolf conductor to safely carry the growing load current demand because it can safely carry 429A at an ambient temperature of 30^{0}C.

B. Load Flow Results of Malangwa Feeder

After load modeling for summer, winter, spring and autumn loads with and without inclusion of ECS at each household of the Malangwa feeder, a load flow is conducted to know the current flowing through the feeder conductor, loading on the transformer, the voltage at different buses and the system power loss. The results of the load flow are tabulated below.

TABLE VI
SUMMARY OF LOAD FLOW REPORT OF MALANGWA FEEDER

Load Condition	Current flowing through feeder conductor(A)	power loss (in %)
Normal	219.4	1.639163
Spring Load with ECS	327.7	3.850454
Autumn Load with ECS	327.7	3.850454
Summer Load with ECS	425.6	6.639706
Winter load with ECS	380.9	5.268094

Without incorporating ECS to the feeder line, i.e., under normal conditions, marginally low voltage is observed on a few buses placed at the end of the feeder line. After incorporating ECS at each household, we observe that in the spring season the feeder conductor is operating at 99% loading. i.e., the existing feeder conductor may be overloaded with a slight change in load. Also, the voltage level is marginally low at different bus of the feeder line. In the summer, with the inclusion of ECS at each household, 50 transformers get overloaded. All the transformers except the private one are overloaded and under voltage is observed. The voltage level drops to 350V. Also, the current flowing through the feeder conductor increases to 425.6 A, which is way above the ampacity of the existing dog conductor. Similarly, in the winter season, we observe that 14 transformers are overloaded and 15 transformers are operating above 96% loading. Under voltage is observed at the buses placed towards the end of the feeder line. Also, there is overloading on the feeder conductor. The dog conductor can carry only 331A current at an ambient temperature of 30^0C whereas the current flowing through the feeder conductor is 380.9A. The power requirement will not be met by the existing 8 MVA power transformer. Thus, the complete system needs to be restructured if the use of ECS is promoted over LPG in the Malangwa area.

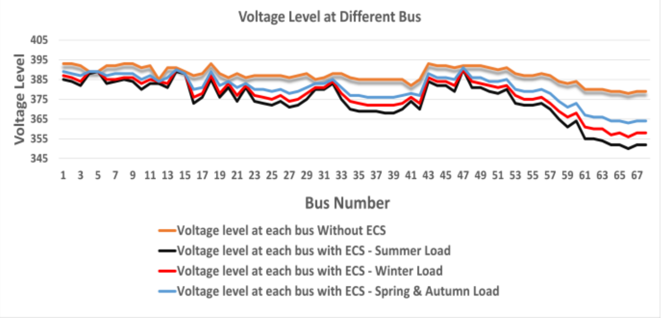


Fig. 3. Voltage level at different bus – Malangwa Feeder

V. CONCLUSION

With the inclusion of ECS at each household of the Jorpati and Malangwa feeders, the load growth will be on a large scale in no time. The results of this research work show that the existing system cannot meet the growing load demand. In the Jorpati feeder, if there is inclusion of ECS at each household, out of 33 DTs, 18DTs size need to be upgraded and the feeder conductor should be upgraded to a wolf conductor to meet the growing load current demand. The voltage level reaches an acceptable limit after the upgrade.Hence, the use of ECS may be promoted in the Jorpati area after upgrading the system. Similarly, in the Malangwa feeder, it has been clearly observed that there would be overloading on almost all DTs and the feeder conductor. There is under voltage problem observed at the buses, which are placed towards the end of the feeder line and system power loss is also increased. Also, power requirements will not be met by the existing 8 MVA power transformer. Thus, to meet the growing load demand due to the addition of ECS at each household, a number of upgrades would be required, which is economically not feasible. Thus, in the present scenario, it is not recommended to promote the use of ECS over LPG gas in the Malangwa area.

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