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Reliability Assessment of Power Distribution System of Industrial Estate: A Case Study in Balaju Industrial Estate

By

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CERTIFICATE OF APPROVAL

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ABSTRACT

The main task of distribution system is to provide acceptable reliability, economic and quality service of electricity according to the demanded load value. To fulfill this task more accurately, the reliability assessment of the distribution system can be performed and measured using a wide variety of reliability indices. This study evaluates the reliability indices of industrial distribution network, Balaju Industrial District, and deals with the reliability of four different network configurations (Case 0-1-2-3) to increase reliability and achieve more realistic results. Using ETAP, distribution networks are designed, comparisons are made. Reliability changes achieved by network configuration have demonstrated the importance of optimal configuration planning to improve the uninterrupted and sustainable energy quality of the system. In addition, cost of electricity outage, i.e. unserved energy cost, is estimated in this paper based on industrial consumer survey for the financial analysis from the reliability point of view. Outage cost is estimated by production loss method, backup generation method and willingness to pay method. The overall and the best feasible value of cost of unserved energy of BID power distribution system is calculated by taking the weighted average of estimated values from production loss method and backup generation method, and it is found to be Rs. 28.26 per kWh. This figure was utilized in the reliability worth analysis for the ECOST computation. The base is taken case 0 which is the existing distribution system. Cases 1, 2 and 3 are separating of two 11kV feeders by separate VCBs, adding redundant power supply and interconnections between three 11kV feeders, i.e. creating ring main, respectively. Results have concluded that all three modifications improve the reliability of the system with financial gain. As these modifications have their own importances for the reliability enhancement from the industries point of view, this paper recommends the utility office, BIDMO, for the implementation of the modifications.

Keywords: Distribution Power System Reliability, Reliability Indices, Industrial Consumer Surveys, Cost of Unserved Energy, System Modifications

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LIST OF ABBREVIATIONS

AENS Average Energy Not Supplied

ALII Average Load Interruption Index

ASAI Avergae Service Availability Index

ASUI Avergae Service Unavailability Index

BID Balaju Industrial District

BIDMO Balaju Industrial District Management Office

BIE Balaju Industrial Estate

CAIDI Customer Average Interruption Duration Index

CAIFI Customer Average Interruption Frequeny Index

CCDF Composite Customer Damage Function

CDF Customer Damage Function

CUE Cost of Unserved Energy

CVM Contingent Valuation Method

DCS Distribution Center Service

DG Distributed Generation

ECOST Expected Interruption Cost

EENS Expected Energy Not Served

EIR Energy Index of Reliablity

EIU Energy Index of Unreliability

ERC Electricity Regulation Commission

FMEA Failure Mode an Effect Analysis

GDP Gross Domestic Product

HT High Tension

IDML Industrial District Management Limited

IEEE Institute of Electrical and Electronics Engineering

IPP	Independence Power Producer
LT	Low Tension
MAIFI	Momentary Average Interruption Event Frequency Index
MTBF	Mean Time Between Failure
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
NEA	Nepal Electricity Authority
NEM	National Electricity Market
NPC	National Planning Commission
P/F	Active power/ Frequency
RES	Renewable Energy Sources
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCDF	Sector Customer Damage Function
SDP	State Domestic Product
SEZ	Special Economic Zone
SREQOM	Society for Reliability Engineering, Quality and Operations Management
S/S	Substation
UG	Underground
VOLL	Value of Lost Load
WtA	Willingness to Accept
WtP	Willingness to Pay
U	Unavailability
λ	Frequency of Failure Rate
γ	Frequency of Repair Rate

CHAPTER ONE: INTRODUCTION

1.1 Background

An uninterrupted, secure and reliable supply of power is essential to the nation's economic development. A secure and consistent supply of power is a crucial component of many industrial operations in the manufacturing sector, as well as industrial automation and computerization in the contemporary service sector. Power outages occur in the system as a result of improper knowledge and planning regarding supply and demand patterns. Government of Nepal has declared “National Electricity Crises Reduction and Electricity Decade (2016-2026)” for continuous electricity supply and Government of Nepal also encourage the small renewable sources of energy integration in the grid for reliable and affordable electricity for the country.

Electricity customers experience a variety of power outages, such as those caused by programmed, instantaneous tripping of protection devices, long-term interruptions due to faults, and others. Industrial customers lose out on processing raw materials, which causes annual production damages to increase significantly. The primary cause of industrial customers not having a 24-hour energy supply is a lack of or an inadequate backup power system for industries, as well as unplanned power outages and unstable utility power supplies. Over the past five years, Nepal has completely avoided load shedding; but, consumers continue to experience unscheduled short- and long-term power outages as a result of system failures, transmission and distribution line instantaneous faults, lengthy maintenance intervals, etc. According to the NEA study, the Nepal Electricity Authority possesses adequate supply capacity to fulfill the demand for electricity from its own hydropower generation, as well as that of its subsidiary firms, IPPs, and imports from India via a cross-border transmission link. However, infrastructure for distribution and transmission is constantly being upgraded. Thus, even though the demand for power is growing daily, customers continue to use outdated transmission and distribution networks to get their power. This is an additional cause of the unplanned power outage in the Nepal electricity system. Industrial customer have higher cost of unserved energy than other customer catageory and average outage cost of industrial customer is found as Rs.38.42 per kWh [1]. Among all of the customer catagory industrial customers have high loss of process raw materials, loss of income, worker payment during outage, penalties for failing to satisfy consumer and market demand in the specified deadline and cost of backup power system. Therefore, cost of expected energy not served will impact the utility itself and national economy as a whole.

Small and cottage industries lack the technical know-how to calculate the cost of a power loss and lack the resources to set up a standby secondary backup power system throughout the business or company planning and strategy stage of initial establishment and formation. Ultimately, they have to bear electricity outage cost. Ten industrial estates are in operation under the government company, Industrial District Management Limited. This thesis focuses on the outage cost estimation in the case of Balaju Industrial District (BID) for both the general and pilot survey. BID has three number of underground dedicated feeders, each nearly one kilometer long from Balaju substation of NEA with 7 MVA, 4.5 MVA and 3.5 MVA approved loads serving 157 customers under Balaju Industrial District Management Office (BIDMO). Almost 84% are industrial consumers and remaining are commercial and non-commercials types. Balaju Industrial Estate is the largest customer under Balaju Distribution Centre.

As a whole, industrial customers have very high electricity demand and consumption capacity compared to other type of customers like residential, commercial customer etc. Production activities of industrial customer are heavely depend upon elecrtricity, industrial customer have to bear heavy loss if unplanned electricity interruption occur. The extent of loss is depend upon type of industries like polymer and plastic based industries have higher losses than food and beverage and dairy industries but more or less all type of industries have to face loss due to unserved energy.

The estimation of unserved energy cost will provide the most important and necessary data for planning and establishing reliable electricity distribution system from the perspective of utility and customer. It is found that, in the greatest economy in the world, the cost of an electrical outage is projected to be between US $26 and US $400 billion (Lacommare and Eto et al., 2004). From this report, the remaining 2% is solely borne by residential customers, with the remaining 98% of outage costs coming from commercial and industrial customers. (Oseni et al., 2013) proposes methodologies for estimation of cost of EENS by marginal cost approach, incompelete backup approach and subjective evaluation technique. Besides these other CUE evalution techniques are direct assessment method, indirect assessment method and willingness to pay survey method (Bose et al., 2006) [2].

1.2 Problem Statement

The idea of a deregulated energy market has encouraged consumers to consider the direct costs of power services more carefully. Impact of power interruption on utility and customer plays a vital role on justifying modification of distribution system is benificial or not. To calculate the service reliability, consumer interruption cost and reduced energy revenues of utility related with electricity failure are required to derive. Many research papers showed that over 80% of the power interruptions are due to failures of distribution systems. One of the main factors in the cost-benefit analysis of a reliable electricity supply system is the economic cost of a power outage. Getting a reliable assessment of the cost of unserved energy is crucial for deciding how much money to invest in development planning and system upgrades. Lack of sufficient accurate data and financial impact of electricity supply outages is one of the reasons for not giving it as much thought by utilities to get better power supply reliability. The core of the national economy is comprised of industrial customers. Therefore, industrial customers should pay close attention to the expense of power outages. Once the loss incurred by industrial customers due to unsupplied electricity has been calculated, planners and policy makers will seriously consider strategies to reduce outages and the negative effects they have on consumers.

Annual electricity demand growth in Nepal is in the range of 7-10%. Government of Nepal and NEA have sincere effort to meet increasing demand and supply balance by adding new generation plants and have planning to deregulate and restructure NEA for better operation and control of service reliability with market competition and expansion and upgradation of transmission and distribution systems. However, many projects face obstacles to complete in time and get delayed for a variety of causes, including political instability which altogether will cause unplanned power outages that affect electricity customers. In context of Nepal, share of agriculture sector, industry sector and service sector in GDP stands 23.95%, 14.29% and 61.76% respectively in fiscal year 2021/22 according to Nepal Rastra Bank (Based on Annual Data of 2020/2021). Contribution of manufacturing industries in GDP increases if sustainability and growth of the industries by relibility and availibility of electricity. Reliability of power system equipment is critical to the success of many industries. Due to the significant financial risk associated with power outages and interruptions, these equipments maintaining high operational capability have become essential. Since the frequency and duration of power outages shorten the life of distribution network equipment and lower the quality of power services, they also cause a considerable financial loss. Reliable and interruption free electricity facilities benefit both the utility and customer significaltly.

Industrial consumer contributes 38.44% of the revenue collection in Nepal having only 1.31% of industrial consumer among all of the consumer category (based on the F/Y 2022/2023 annual report of NEA). Industrial consumers lose money as a result of unforeseen interruptions in the electrical supply, which represents losses across the board for the Nepal economy. Estimating the price or cost of unsupplied electricity help for investment planning to upgrade the industrial distribution system to achieve the more reliable supply. Moreover, this thesis is focused to find consumer willingness to pay additional reliability cost of electricity for uninterruptible supply.

Sustained and momentary interruptions (unexpected outages) of electricity in Balaju Industrial Estate cause high financial lossses to industrial customers. As a result, it's necessary to calculate the cost of EENS and analyze the reliability of the BID specific distribution feeders. This thesis is suggested to modify distribution feeders to reduce EENS and improve reliability of network with finacial analysis.

1.3 Objectives

The following are the main objectives or primary goals of this thesis:

- To assess the reliability of existing electricity distribution system in BID.
- To evaluate the cost of energy not served and suggest viable solutions to improve the reliability.
- To perform the reliability worth analysis.

1.4 Scope and Limitation of the Work

1.4.1 Scope of the Thesis

In this thesis work, real and operating industrial distribution feeders are taken for the study and the reliability assessment with economic analysis is done. Analysis of unreliability cost of electricity and its effects on economics of utility and consumers will help to investigate the investment planning to get the reliable and uninterruptable supply of electricity. This thesis will also help to find the consumer perception and their willingness to pay higher tariff in industrial sector to ensure high reliability of electricity service.

Different methods of CUE evaluation provide upper bound and lower bound value of electricity tariff. So, it will be very helpful and potential tool to policy planner while determining the tariff during policy making and implementation phase, like it will be helpful for Electricity Regulation Commission (ERC) and concern authorities of Nepal. Reliability worth analysis with distribution feeders modification options will help to reduce EENS and ECOST of distribution feeder and finds the customer financial gain from reliability improvement.

1.4.2 Limitation of the Thesis

- This thesis only covers the study of typical industrial feeders, output data of this research will be insufficient information for analysis whole scenario of Nepal electricity outage cost in industrial sector.
- Estimation of expected energy not served is based on consumers survey and their response on extent of production losses, backup generation cost etc. This estimated value of outage cost of electricity may vary from theoretical value of CUE.
- Analysis of reliability indices of industrial distribution system has used substation and utilities offices manual log sheets and records; the results may have minor difference from real time data analysis.
- Distribution system modification with redunant line extension from common grid substation can not mitigate the power outage problem due to failure of grid substation.

1.5 Report Organazation

This report is divided into four chapters for the thesis. Thesis report is based on worth analysis of industrial distribution feeders along with reliability assessment and estimation of cost of unserved energy (EENS). An outline of the study, its characteristics, and its goals are outlined in chapter one, including introduction of the research, problem statement, objectives, scope and limitation of thesis. In chapter two, few literatures were reviewed and it illustrated a compressive technique and method used for estimation of outage cost and reliability indices evaluation for the distribution system of Industrial Estate. Research work related different paper are studied from IEEE Xplore, Springer, Elsevier, research gate, Wikipedia, Google, etc.

Chapter three contains methodologies which elaborate how the thesis will be carried out. Details methodologies process to complete the research is explore in this chapter. List of output results and their discussion till this progress are presented in chapter five. At last, list of references and appendices are presented.

CHAPTER TWO: LITERATURE REVIEW

2.1 Literature Review

Within the national electricity market (NEM), the term "unserved energy" refers solely to supply disruptions that customers have endured due to inadequate generation and connectivity. The amount of customer demand that cannot be met in a region of the NEM because of a lack of generation, demand-side involvement, or interconnector capacity is measured as unserved energy. Stated differently, the quantity of wholesale unserved energy that matters when it comes to reporting on the reliability criteria.

Reliability of power delivery varies from customer to customer and from utility to utility. Almost all customers expect good power delivery. In today's world, electricity being the major source of energy, power outages disrupt more business than any other factor. Circuit arrangement, storms, protection practices and circuit voltage are the some of the factors which impacts reliability statistics of power outage. Overall reliability standards pertain to overall performance and are usually quantified through the use of an indicator. In general, the utilities use customer-based indices to benchmark and evaluate their service reliability. For this, the most commonly and wildely used indices are System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), Average Service Availability Index (ASAI), Average Service Unavailability Index (ASUI), Average Energy Not Served (AENS), Expected Energy Not Supplied (EENS), Energy Index of Reliability (EIR), Energy Index of Unreliability (EIU), etc. Under the minimum standard scheme, the utilities are required to serve customers beyond a minimum interruption duration threshold. Numerous earlier research works have been examined and reviewed to estimate or calculate the costs of unreliable electricity supplies and reliability indices evaluation of distribution system using a variety of techniques.

(Mehmet Rida Tur, 2020) proposed the reliability of electrical distribution system of Istanbul city taking into account the method of energy storage configuration [3]. Literature studied the general reliability assessment of the existing system and the reliability of network for different storage configurations.

Three distinct analytical approaches were put forth by (Bose et al. 2006) to calculate the CUE for the both industrial domain and agricultural sector. This research surveyed the

500 manufacturing plants using two-phase random sampling in order to evaluate cost of EENS. From the result of this research, financial loss as a consequence of industrial field power disruptions fluctuates between 0.04% and 0.17% of SDP overall varying with industry size. Among three analytical methods, it is discovered that the cost of unserved energy is Rs. 22.10 per kWh (from the direct assessment method, i.e. production loss method), Rs. 2.63 per kWh (from the indirect assessment method, i.e. backup generation method) and Rs. 4.89 per kWh (from WtP method) in Indian currency.

According to (Karki et al. 2010), the consumer survey method is proposed based on preparatory action approach for estimating or calculating the cost of unserved energy (CUE). Outage cost beared by customer were found to be much higher than prevailing electricity prices. In this time, Nepal had been suffering from severe power shortages and consumers had to endure load shedding for up to 16 hours per day during the dry season. Literature concluded the evaluated cost of EENS indicates the urgent need of distribution feeders reinforcement with revision of electricity of prices.

Alekhya et al. 2011 had analyzed and compared the reliability of rural, urban and industrial distribution feeder on basis of cost benefit analysis under manual control, under partial automated control and under fully automated control.

(K. Zou et al 2020) had done research on the reliability assessment of distribution system with hybrid DG systems was undertaken. In this paper, optimal restoration strategies and system uncertainties are considered [4].

(Hashemi et al. 2016) proposed the contribution method to measure the cost imposed by power outages. Literature found that one of the main reasons why manufacturing costs are so expensive in underdeveloped, i.e. developing nations is the unreliability of electrical sources.

(Bental and Ravid 1982; Beenstock 1991; Matsukawa and Fujii 1994; Beenstock and Goldin 1997; Oseni and Pollitt 2015) had estimated the cost of EENS by considering the cost of back-up generation method. These research used the observation that businesses insure against power outages by purchasing backup generators to calculate the opportunity cost of unsupplied power. It was expected that the marginal cost of a kWh produced by a backup generator would be the marginal cost of unsupplied power. However, backup generation could not be a perfect replacement for utility-supplied electricity for industrial uses. In other situations, the cost of producing energy by self-generation could be so high that the plant cannot function profitably through back-up generation for longer than brief blackouts.

(Munasinghe and Gellerson 1979; Munasinghe, 1981; Pasha et al., 1989; Tishler 1993; De Nooij et al. 2007), used the loss of production method based on the production-function approach. Lost production was used to estimate the effects of outages (measured as gross value added for firms) or lost opportunity cost of time.

(Chen and Vella, 1994; Ju et al., 2016) used the input-output method. Due to the interconnection of all economic sectors, the input-output approach assessed how power outages affected the loss of value contributed across the board.

(Baarsma and Hop 2009; Morrison and Nalder 2009; Hensher et al. 2014; Ozbafli and Jenkins, 2015) had used the WtP method. Consumer surveys are used in stated preference approaches, such as choice experiments and contingent assessments, to gather the set of preferences needed to estimate households' willingness to pay (WtP) with more reliability.

The idea of value added has typically been used in the literature on electricity economics (Munasinghe, 1981; Pasha et al., 1989; Lehtonen and Lemstrom, 1995; De Nooij et al. 2007) to estimate the cost of power outages among various sectors of an economy. An organization's value addition is calculated as its revenue from product sales less the amount it spends on intermediary goods and services from other businesses. The entire salary bill plus the cost of the capital services used in the amount of production that was lost as a result of the power outages are used to calculate the loss.

(Billinton & Wang, 1999) had used the Monte Carlo Simulation for reliability evaluation. It has been demonstrated in this research that connecting reliability evaluation to the annual dispersion associated with these indices can significantly improve it. A time sequential simulation technique for assessing intricate radial distribution systems was demonstrated in this research. Analytical and simulation methods were used to show the examination of a real-world test distribution system. Because an analytical technique uses a series of mathematical equations to assess the average dependability indices, it is a reasonably straightforward process that takes a little amount of computer time to complete. Simulation techniques are more complex and require longer computing times since they analyze the reliability indices through a series of trials. However, a simulation approach can offer details on the system indices and load point that the analytical techniques cannot.

(Chowdhury et al., 2003) had used DISREL program in determining Distributed Generation equivalence to find reliability. The program's goal is to assist industrial/commercial and electric utility clients in predicting the reliability of a electrical power distribution network. For the purpose of solving reliability issues, the customer-responsive utility would choose project options that offer the greatest advantages both internally and outside. Based on component outage data and customer interruption costs, DISREL calculated a series of reliability indexes, such as SAIFI, SAIDI, ASAI, load/energy curtailed, and the cost of outages. The research found that the distribution generation addition is the most expensive option, with the appropriate generator size chosen using reliability techniques and the distribution capital credit acquired from the utility company; however, the distributed generation option may eventually prove to be a financially advantageous solution to the energy supply issue, helping both the energy.

(Neto et al., 2006) had calculated the reliability indices of radial feeder connecting the distributed generation on the feeder. They assumed that the DG is 100% reliable when they are operated in isolation and interconnected mode. These findings drive the creation of strategies for Distributed Generation allocation in distribution networks with the objectives of voltage profile correction, loss minimization, and reduced interruption costs. In this literature, the total life cycle cost for the entire system with or without Distributed Generation is analyzed and the reliability indices with or without Distributed Generation are compared.

2.2 Cost of EENS

2.2.1 What is unserved energy?

"Unserved energy" generally refers to blackouts or supply disruptions. It can be defined as an approximation of the amount of electricity that users would have utilized in the absence of a supply disruption (power outage). These supply disruptions could come from a number of supply chain nodes (seen in the figure below), including:

- Insufficient and inadequate generation and interconnection;
- reliability-related supply interruptions;

- Supply interruptions linked to power system security, resulting from voltage stability or other power system security constraints;
- Insufficient and inadequate transmission and distribution network capacity
- Customer actions include adhering to agreements reached under the mandatory limits clause of the NER.

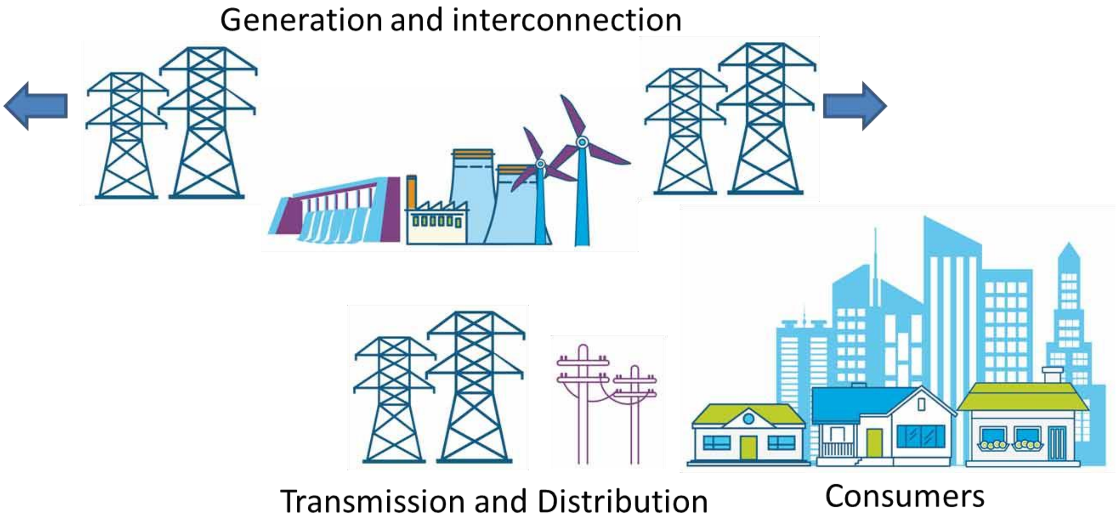


Figure 2.1 Split of Supply Chain for Measuring Unserved Energy

2.2.2 Reliability Standard

As previously stated, the maximum projected unserved energy in an area of 0.002 percent for a particular financial year as a share of total energy requested in that region serves as the dependability criterion (for generating and inter-regional transmission elements). As was covered in greater detail above, "unserved energy" generally refers to the quantity of customer demand that cannot be met within a region of the NEM because of a lack of generation (including demand response) or interconnector capacity.

When predicted unsold energy in a region in a given fiscal year surpasses 0.002% of the region's yearly demand, it is considered a breach of the reliability requirement. To put it plainly, the reliability criterion stipulates that a region must have enough generation and transmission connectivity so that at least 99.998% of the projected total energy demand in a given fiscal year is anticipated to be provided.

2.2.3 What is the reliability standard?

The reliability standard's goal is to balance the trade-offs that reliability entails on behalf of consumers, while permitting efficient investment sufficient to deliver power to the agreed-upon standard. The reliability standard balances the following costs:

- Costs of reliability - Maintaining reliability involves costs.
- Costs of unserved energy - The alternative to providing energy, no matter the cost, is not to supply the energy under certain conditions.

Stated differently, the standard of dependability embodies a compromise between the expenses incurred for power and the loss of energy during emergencies: a higher quality of reliability entails higher expenditures. Based on what customers value, the reliability standard is determined at a level that strikes an economic trade-off between affordability and reliability—that is, offering dependable energy supply while maintaining affordable pricing for customers. That's the reason it's not zero. Since a 100% dependable system would also be extremely expensive, consumers would not be ready to pay for it. The fact that it is always possible for some extremely unlikely combination of factors to occur makes it impossible to guarantee a dependability criterion of 0% anticipated USE.

2.2.4 Customer Data

The size of the estimate will be greatly influenced by the number of customers taken into account when calculating the cost of power outages or incidents involving poor power quality. Significant ambiguity may arise from variations in the definition of the client. It is crucial to remember that customers are not the same as people, and that one household, residence, business, or commercial or industrial facility is frequently referred to as one electrical client.

2.3 Reliability

While reliability is a new discipline, it is an old notion. A trustworthy individual would never—or very rarely—fail to fulfill their promises, just as a trustworthy watch would consistently tell the time. A device's reliability has been rated as high if it has successfully completed its task on multiple occasions and low if it has a tendency to malfunction over repeated attempts. The likelihood that a system or equipment will operate as intended for the duration of the intended use, under met operational circumstances, is known as reliability.

A distribution, transmission, and generating system make up a power system. Since distribution outages are more confined and less expensive than generation or transmission level outages, reliability research and evaluation procedures at the distribution level have historically been significantly less developed than at the generation level. Nevertheless, distribution system failure accounts for the highest individual contribution to supply unavailability, according to examination of utility customer outage data.

Distribution networks are usually operated as radial networks and have a radial or meshing configuration. Energy is transported unidirectionally from the supply point to the consumer load locations via bus bars, cables, and distribution lines that are connected in series. Failure rates and repair times are included in the component reliability indices. A number of other factors need to be taken into account when assessing distribution networks' dependability. First off, even if a particular reinforcement technique could be reasonably cheap, these systems together require large sums of money to operate. Secondly, it is necessary to guarantee a rational equilibrium in the dependability of the many components that comprise a power system, namely generation, transmission, and distribution. Thirdly, the distribution engineer has several options at their disposal to attain satisfactory customer reliability. These include different reinforcing schemes, the distribution of spare parts, enhancements to the maintenance policy, and alternative operating policies. Comparing their impact per unit of money spent is impossible without using quantitative reliability assessment. Power system reliability is a very wide notion that encompasses all aspects of the system's capacity to meet customer demands. There is a reason able subdivision of the concern designated as “system reliability”, which is shown in Fig 2.2.

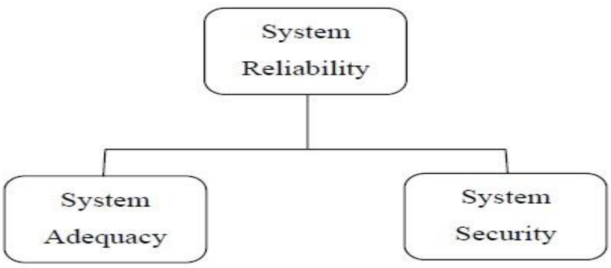


Figure 2.2 System Reliability Division

Fig. 2.2 represents two basic aspects of a power system i.e. system adequacy and security. The term "adequacy" refers to the system's ability to support the consumer load demand by having enough facilities. These comprise the infrastructure needed to produce enough energy as well as the related transmission and distribution infrastructure needed to deliver the energy to the real consumer load points. The ability of the system to react to disruptions that occur within it is related to security. Therefore, security is related to how the system reacts to any disruptions that it experiences. Adequacy assessment encompasses the majority of probabilistic methodologies now used for power system reliability assessments.

Adequacy naturally correlates with forecasting (load and capacity). Nonetheless, assessments of power system reliability are typically carried out independently within the functional domains of distribution, transmission, and production. The entire system generation capacity is assessed to see if it is sufficient to meet the demand for the overall system load during the generation system reliability evaluation process. Individual load point reliability indices are not intended to be provided by generation adequacy analysis. Conversely, the distribution system is typically examined independently.

2.3.1 Distribution System Adequacy

The average failure rate, average outage duration, and average yearly unavailability or average annual outage time are the three main reliability indices that have been assessed. Since they represent the average or expected values of a probability distribution that underlies it, rather than deterministic values, they only reflect the long run average value.

Despite their essential importance, the three main indices don't always provide a comprehensive picture of the behavior and responsiveness of the system. For example, the same indices would be assessed whether the average load point was 10 kW or 100 MW, or whether one customer or 100 consumers were connected to the load point. It is possible and often is to analyze additional reliability indices to demonstrate the seriousness or relevance of a electrical power system outage. The following defines the additional indices.

2.3.2 Distribution System Reliability Indices

In this section, a reliability evaluation technique is applied to the distribution system. A sample distribution test system is as shown in Fig. 2.3.

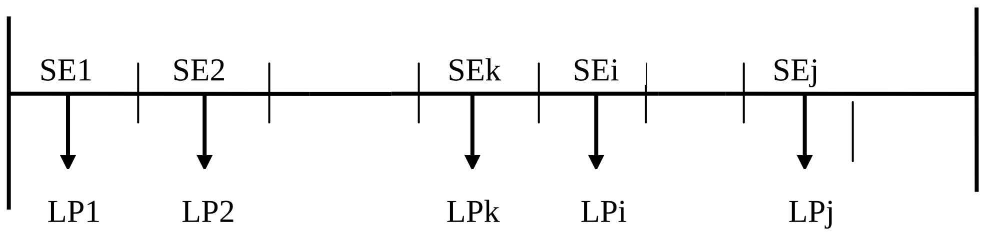


Figure 2.3 Sample Distribution System

Reliability indices are classified into two types, firstly, load based reliability secondly customer and based reliability indices. Load point reliability indices can be calculated using minimal cut set technique.

2.3.3 Customer Oriented Indices

1. System Average Interruption Frequency Index (SAIFI)

It is determined by dividing the accumulated number of customer interruptions in a year by the number of customers served.

$$SAIFI = \frac{total\ number\ of\ customers\ interruption}{total\ number\ of\ customers\ served}$$

2. System Average Interruption Duration Index (SAIDI)

It is the ratio of sum of the duration of each sustained interruption (in minutes or hours) attributable solely to distribution divided by the number of customers served.

$$SAIDI = \frac{sum\ of\ all\ customers\ interruption\ duration}{total\ number\ of\ customers\ served}$$

The unit of SAIDI is hour per customer per year. SAIDI is more commonly known as "average customer minutes off supply" and is generally reported over a one-year period.

3. Customer Average Interruption Duration Index (CAIDI)

It is the average interruption duration for customers interrupted during a year

$$CAIDI = \frac{sum\ of\ all\ customers\ interruption\ duration}{total\ number\ of\ customers}$$

. The unit of CAIDI is hour per year.

4. Average Service Availability Index (ASAI)

This is the ratio of the total number of customer hours that service was available during a year to the total customer hours demanded. Customer hours demanded is the twelve-month average number of customers served times 8760 hours. This is also known as the service reliability index.

$$ASAI = \frac{customer\ hour\ of\ available\ services}{customer\ hour\ demanded}$$

5. Average service unavailability index (ASUI)

It is defined as the annual customer hours that service is unavailable.

$$ASUI = \frac{customer\ hour\ of\ unavailable\ services}{customer\ hour\ demanded}$$

2.3.4 Load and Energy Oriented Indices (Loss of Energy Indices)

2.3.4.1 Expected Energy not Served Index (EENS):

The term ‘expected energy not served (EENS)’ defines the total energy not supplied by the system. The basic expected energy curtailed concept can be used to determine the expected energy produced by each unit in the system and therefore provides a relatively simple approach to production cost modelling.

EENS = Load × Outage Duration

2.3.4.2 Energy Index of Reliability (EIR)

The daily peak load variation curve or the individual daily peak loads are used in the conventional or standard LOLE (Loss of Load Expectation) approach to determine the expected or predicted number of days in the period that the daily peak load exceeds the installed capacity that is available. Either the load duration curve or the individual hourly numbers can be used to compute a LOLE index. The energy used within the allotted time is represented by the area under the load duration curve, which can be used to estimate the projected energy that is not delivered (an expected energy not supplied) because of insufficient capacity. This method's outcomes can alternatively be described in terms of the probable ratio between the load energy curtailed due to deficiencies in the generating capacity availale and the total load energy required to serve the requirements of the systemThis ratio is independent of the time period taken into consideration, which is often a month or a year, for a certain load duration curve. In most cases, the ratio is far smaller than one and can be defined as the 'energy index of unrelaibility'. It is more usual, however, to substract this quantity from unity and consequently, ascertain the likely ratio between the load energy that will be provided and the overall load energy that the system needs. This is known as the 'energy index of relaibility (EIR)'.

Energy Index of Unrelaibility (EIU) = $\frac{EENS}{Total\ Energy\ Required}$

Energy Index of Reliability (EIR) = 1 - EIU

$$= 1 - \frac{EENS}{Total\ Energy\ Required}$$

$$= 1 - \frac{EENS}{Total\ Energy\ Served + EENS}$$

$$= \frac{Total\ Energy\ Sereved}{Total\ Energy\ Served + EENS}$$

The required data are of the time time period considered, usually monthly or yearly.

2.4 Electrical Transients Analysis Program (ETAP)

Electrical Transients Analysis Program (ETAP) is analytical software which is used for the simulation. ETAP is the most comprehensive analysis platform for the design, simulation, operation, control, optimization, and automation of generation, transmission, distribution, and industrial power systems.

Inside the ETAP simulator, we have different simulators like Load Flow Analysis, Transient Stability Analysis, Optimal Power Flow, Optimal Capacitor Placement, and Reliability Analysis & Short Circuit Analysis.

Among the above, the Load Flow Analysis was used for primary purpose constructed Test System which were run to find the bus Voltage Profile, Line Losses, Reactive and Active Power Flow through the lines. Short circuit analysis is used to calculate the current at weak bus after the application of fault.

CHAPTER THREE: METHODOLOGY

3.1 Research Execution Process

There are multiple ways of considering cost of unserved energy (CUE) which can impact productivity, therefore choosing the appropriate manipulative technique for cost of EENS is quite difficult. CUE will differ on each individual case depending upon following factors;

- Customer suffer from power outage because of power instability, voltage and frequency fluctuation.
- Pre information to consumer about extent of interruption of supply.
- Schedule maintenance interruption and seasonal fluctuations and supply fails.

The importance of this study cover following areas or topics;

- It's the initial widespread application of the contingent valuation methodology (CVM) to evaluate the willingness to pay (WtP) for reliable electrical power supply in industrial estate or somewhere else in Nepal.
- Application of the following three distinct methodologies to estimate CUE will prove a helpful evaluation of CVM reliability in the electrical power.
- Finally, and the most significant, the result and conclusion of this research will provide potentially useful data for ongoing and upcoming new industrial estates, special economic zones (SEZ), industrial corridors and it also will be helpful informational tool for unbundling power sector reform in Nepal and its tariff structure reconsideration.

The method for estimating cost of EENS and sample survey layout for gathering data, information are selected as below. Also using survey data and nework data, the reliability indices of industrial distribution system is calculated in next phase. This thesis is carried out in following execution process.

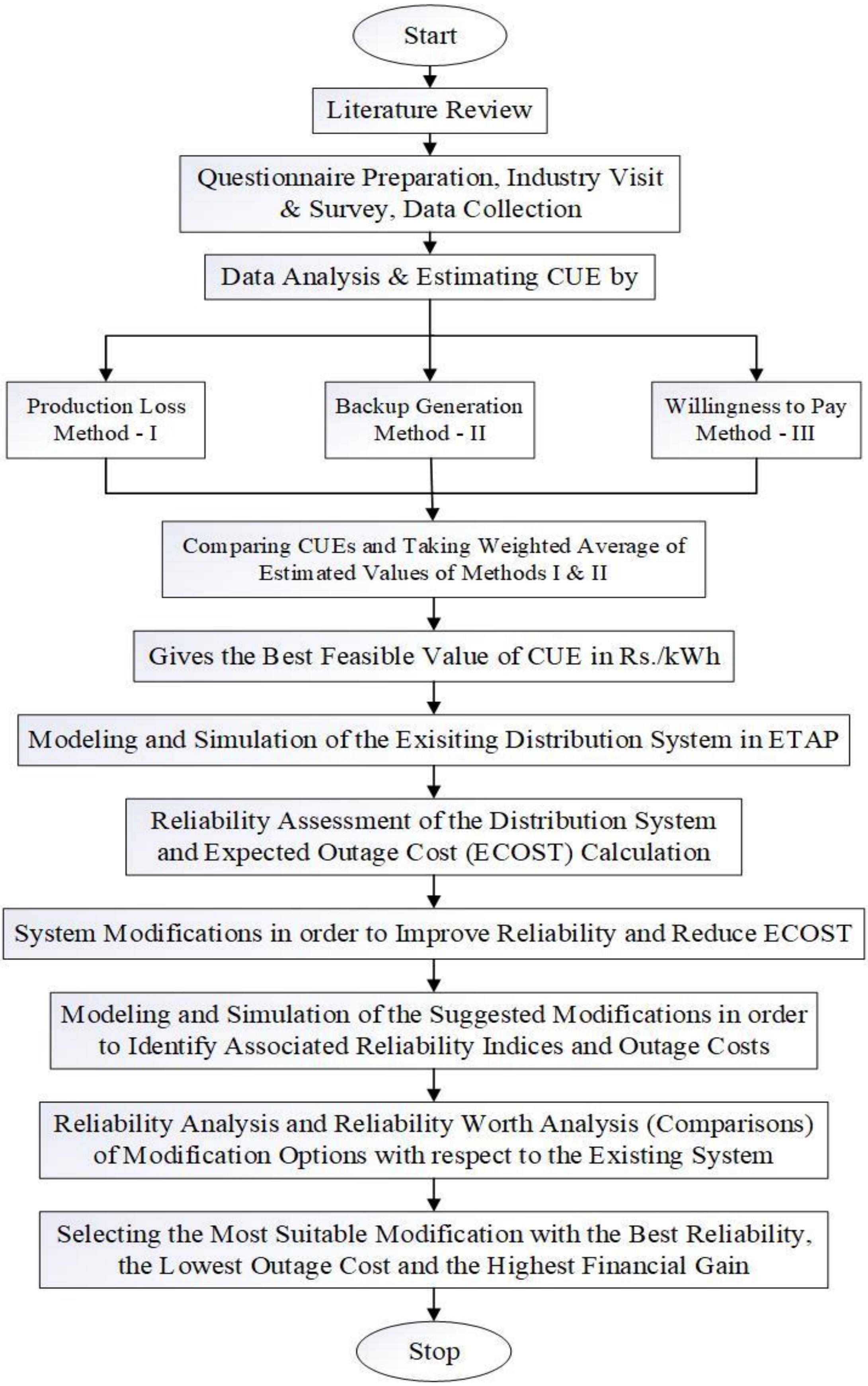


Figure 3.1 Block Diagram of Research Execution Process

3.2 Methods for Estimation of Cost of EENS

Following three methods have been used for the estimation of cost of unserved energy in the Balaju Industrial Estate;

- Production Loss Method (Direct Assessment Method)
  This method is dealed with the amount lost in production for every unit of blackout.
- Backup Generation Method (Indirect Assessment Method)
  This has provided the price of substitute or backup power supply.
- Willingness to Pay Method
  This method of estimation of CUE using the contingency valuation method to provide reliable, trustworthy and uninterruptable power supply.

3.2.1 Production Loss Method (Method I)

Production loss method, aslo known as direct assessment method, is described as the production loss brought on by the grid's unavailability of electrical supply. Customer survey is done by use of prepared checklist and questionnaire to calculate the price of a supply disruption or a drop in product quality caused by an industrial consumer. This consumer survey has produced a helpful initial line of indication of potential price of blackouts.

The mathematical expression of production loss per each unit of power outages by the i^{th} industrial customer is given by,

$$L_i = \frac{(value\ of\ production\ loss/hours\ of\ outage)_i}{(electricity\ consumed\ from\ grid/hours\ of\ electrcity\ available\ from\ grid)_i} \ldots \text{ Equation 3.1}$$

However, simple average of L_i cannot capture the correct each unit outage for same consumer category as a result of the wide range in plant sizes and power consumption capacities. So, it is necessary to calculate by applying weighted parameter to L_i and computing the weighted average. According to this perspective, the i^{th} consumer's use of grid electricity is taken into as weighted corresponding to L_i. Then weighted average of L_i provides the typical average production loss cost per electrical unit unavailability from the grid, this is represented by L.

Mathematically,

$$L = \frac{\sum_i L_i U_i}{\sum_i U_i} \text{………. Equation 3.2}$$

$$L_i = \frac{P_i/O_i}{U_i/A_i} \text{… ….Equation 3.3}$$

Here, L is expressed in Rs/kWh.

In the above equation 3.3, annual production loss value expressed in Rs. is represented by P, An annual hours of grid-available power (electricity) is denoted by A, O is annual outage hours of power unavailable through the grid, U is the yearly use of grid power, expressed in kWh (i.e., annual electricity consumed from grid) and i is the quantity or number of legitimate customers (industries in this case).

Ideally, this method of estimating value of CUE, it is significant to remember that a consumer's net value loss as a result of a power outage is unknown because of this strategy fails to account for scrap and to explain the adopt of the production loss minimization approach that is commonly used in industries. Therefore, the cost of an industrial client power outage is determined by the reported gross output loss that results from a disruption in the power electricity supply.

3.2.2 Backup Generation Method (Method II)

This method is the indirect assessment method and is the widely used method to estimate the costing of unserved energy that the customer ensures a reliable power supply by making investment in auto generation or backup generation, distributed generation, diesel generators etc. It provides helpful details regarding transparent and clear about the cost of one electrical unit.

Mathematically, financial cost of backup power generated system for the i^{th} customer making use of j^{th} backup unit is denoted by C_{ij} is given by,

$$C_{ij} = \frac{(annual\ capital\ cost + annual\ maintainace\ cost + annual\ fuel\ cost)_{ij}}{(total\ unit\ of\ electricity\ generated\ in\ a\ year)_{ij}} \text{……Equation 3.4}$$

Additionally, the weighted average of the financial cost of the electrical power produced from the i^{th} consumer-owned backup generator is provided as follows:

$$C_i = \frac{\sum_j C_{ij}}{\sum_j U_{ij}} \text{… … ….Equation 3.5}$$

Finally, typical average financila cost of backup power generation system over the industrial estate those have backup facilities by the all the consumers is weighted by electricity generated captive unit or backup generator. Such value of weighted average cost of CUE in industrial estate using indirect method is denoted by C and mathematically expressed as;

$$C = \frac{\sum_i C_i U_i}{\sum_{ij} U_{ij}} \text{… … … … … ….Equation 3.6}$$

$$C_{ij} = \frac{K_{ij} R_j + M_{ij} + F_{ij}}{U_{ij}} \text{… … …Equation 3.7}$$

$$R_j = \frac{r}{1-(1+r)^{-nj}} \text{… … … ..Equation 3.8}$$

Where, C is the yearly cost in rupees per kWh of backup power generation, K is the backup power generation's capital cost, expressed in current values in rupees, U is the amount of electricity generated in kWh by backup generation, the capital recovery factor is represented by R, the yearly maintnence cost (may also include operation cost) in Rs. is represented by M, the annual fuel cost in Rs. by consumption of backup supply is represented by F, the annual interest rate (generally 10% will be taken) is r, n denotes the entire lifespan of backup supply system in year, i is the number of industry which is valid and j represents the quantity of backup supply unit.

3.2.3 Willingness to Pay (WtP) Survey Method (Method III)

An industrialist’s or consumer’s factor estimate of the CUE is WtP, which is the specific quantity needed to solve their power output issue. In spite of the foregoing techniques, WtP is determined using contingent valuation method (CVM), CVM approach allow to estimate the CUE even in the absence of information about alternative price of supply. The WtP estimations' marginal value of enhanced supply is only applicable to individuals who are prepared to pay for it. WtP is similar to the cost of alternate power supply system in which data record a cost of unserved energy (CUE) estimate only for those individuals who have backup supply system, such as generators. WtP method of estimating ECOST involved following process.

- Value of lost production of all consumer has recorded (whether or not any production losses)
- Average value of WtP finding by combining WtP for improved supply (for WtP>0) with the current payment (for those WtP=0). The current price has been determined to be the lowest that may be tolerated (acceptable).
- Open ended payment vehicles, the straight forward question “what is your maximum WtP?” has not seem appropriate for this research. It is difficult to find the straight forward answer.
- The price ranges for the biding game (for each customer) has formed via inquiry by open ended question taking in depth interview by the use of prepared questionnaire in pre-testing stage of the field survey.
- Most of the paper review found that bidding starting from higher WtP rate will be more feasible than lower starting price being first. Same approach has applied during survey.
- It is widely used practice and accepted approach that means bid value which are taken as mid-point between highest price accepted and lowest price rejected if an industrialist / respondent says ‘Yes’ to Rs.10/kWh but no to Rs.11/kWh the bid has taken as 10.5 kWh. Diagrammatically, WtP survey process is as shown in follow chart below.

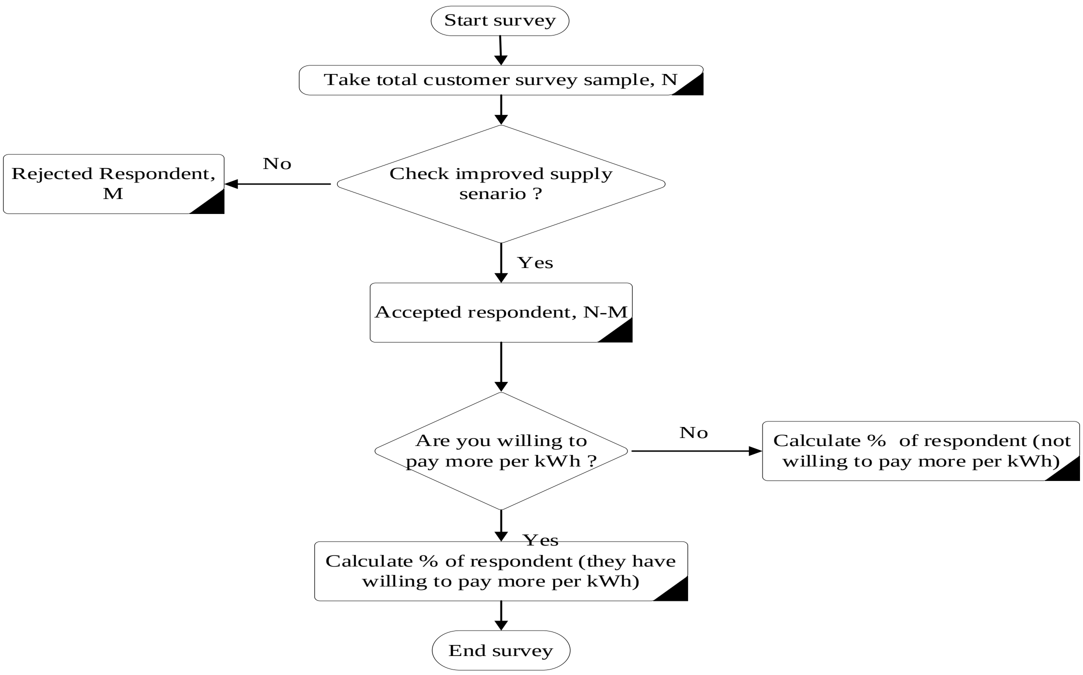


Figure 3.2 Flow Chart of WtP Survey

Finally, comparing value given by above three methods and taking weighted average of method I and II has given the appropriate cost of EENS which must be kept in mind that;

- ✓ Method I: - this method is likely to overestimate (exceed in magnitude) the CUE because by the rearrangement of the production period could potentially result in cost savings.
- ✓ Method II: - likely to underestimate CUE, because businesses in the industrial sector have already spent or will spend at least this amount (even if they might be prepared to pay a lot more).
- ✓ Method III: - has underestimate the CUE, industrialist already have extent of investment to interruption to supply measures.

3.3 Estimation of Economic Losses due to Power Outage

The annual expected energy unserved for industrial feeder can be found from its average load and annual outage duration.

$$EENS = averge\ load\ of\ feeder * annual\ outage\ duration \ldots\ldots\ldots \text{Equation 3.9}$$

$$unserved\ energy\ (\%) = \frac{kWh\ shed(\text{EENS})}{\text{anual}\ energy\ demanded} * 100\ \% \ldots\ldots\ldots\ldots\ldots \text{Equation 3.10}$$

The annual outage duration interruption, interruption type, outage cause and average load of the feeder has taken from respective utilities offices. Distribution system cost of expected energy not served (EENS) is estimated by taking the weighted average of results (i.e., values) from production loss method (method I) and backup generation method (method II) given as;

$$CUE_{feeder} = \frac{L \times U_l + C \times U_C}{\sum_i U_i} \ldots\ldots\ldots\ldots\ldots \text{Equation 3.11}$$

Where, L is the CUE estimated from production loss method;

U_l is the annual energy consumption of customers who experience lost production as a result of power outages;

C is the CUE estimated back up generation method;
the annual energy consumption of customers with standby generators is denoted by U_C;
and U_i is the very customer's yearly energy consumption.

In general, category wise contribution of EENS is given by,

$$ECOST_i = EENS_i * CUE_{ij} \dots\dots\dots\dots\text{..Equation 3.12}$$

Where, $ECOST$ is the financial loss resulting from HT (11kV) and LT (400-230V) sections, stated in Rs.

$EENS_i$ is the annual EENS for i customer sector, i, e HT and LT sector in kWh,

i is the sector of estimation HT and LT

j is the method applied for the estimation or calculation of CUE, where CUE varies according to the three methods (production losss method, captive generation method and willingness to pay method).

3.4 Feeder Modelling and Reliability Assessment

A real industrial distribution system of Balaju Industrial Estate has been used as a model for research and reliability assesment with cost-benefit analysis has been assessed after modification.

3.4.1 Case Study

For reliability assessment and worth analysis, BID industrial distribution feeder of NEA, Balaju Distribution Centre has taken for case study. The process of evaluating the distribution system reliability indices involves the following steps:

- Distribution system model development.
- Reliability evaluation concept development.
- Calculation reliability parameter using ETAP simulation method.
- Calculation of cost of EENS from different calculation method.
- Calculation of economic loss due to due to power outage.
- Cost benefit analysis of reliability improvement system modification options.

3.4.2 Reliability Indices Evaluation

Reliability evaluation techniques in distribution feeder are briefly discuss in this section. The sample model of distribution system is as shown in figure below.

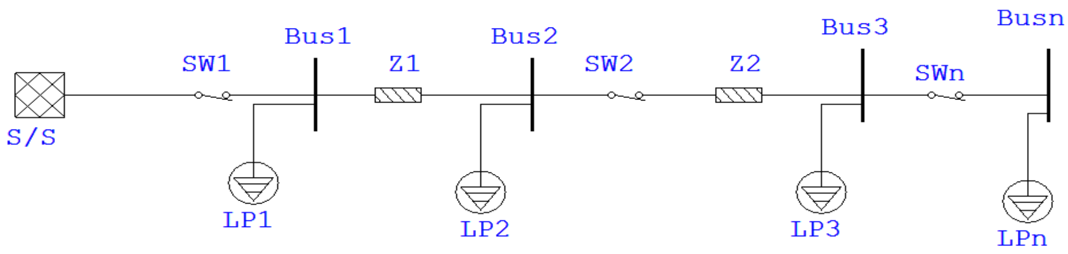


Figure 3.3 Sample Model of Distribution System

Distribution system consists of series set of electrical components including transformers, protection devices, circuits breakers, cables, conductors, insulators, disconnectors, sectionalizers, loads, etc. From grid to load point a customer connected through these series set of components. In radial distribution system, failure of any of these series component fails the supply of the consumer. So, cut set method of reliability evaluation is a powerful and efficient reliability evaluation method. By finding the unavailability of each cut sets (i, e series components), reliability of distribution feeder is calculated easily. Every load point is regarded as a cut set. So, by knowing the failure rate and repair rate of series section (Load points) unreliability of the feeder can be calculated as follows;

$$U_j = \lambda_j * \gamma_j \ldots \ldots \ldots . . \text{Equation 3.13}$$

$$\lambda_{LP_i} = \sum_{i=1}^{m} \lambda_j \ldots \ldots \text{Equation 3.14}$$

$$\mathrm{U}_{LP_i} = \sum_{i=1}^{m} \mathrm{U}_j \ldots \ldots \text{Equation 3.15}$$

$$\gamma_{LP_i} = \frac{U_{LP_i}}{\lambda_{LP_i}} \ldots \ldots \ldots \ldots \ldots \text{Equation 3.16}$$

$$U_S = \sum_{i=1}^{n} \lambda_{LP_i} * \gamma_{LP_i} \ldots \text{Equation 3.17}$$

$$\lambda_S = \sum_{i=1}^{n} \lambda_{LP_i} \ldots \ldots \ldots \ldots . \text{Equation 3.18}$$

$$\gamma_S = \frac{U_S}{\lambda_S} \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . \text{Equation 3.19}$$

Where, the number (or quantity) of contingencies in the portion that result in a supply failure up to the load point LP_i is m.

λ_j, γ_j, U_j are the failure rate, repair rate and yearly unavailability respsectively of contingency j.

λ_{LP_i}, γ_{LP_i}, U_{LP_i} are the respective reliability rates up to load point i.

λ_S, γ_S, U_S are failure rate, repair rate and yearly unavailability of distribution system respectively.

The performance of distribution system of Balaju Industrial District has assessed using the following indices.

1. System Average Interruption Frequency Index (SAIFI)

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i}\ f/customer.yr \text{ ……….Equation 3.20}$$

2. System Average Interruption Duration Index (SAIDI)

$$SAIDI = \frac{\sum U_i N_i}{\sum N_i}\ \text{hr}/customer.yr \text{ ……….Equation 3.21}$$

3. Customer Average Interruption Duration Index (CAIDI)

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i}\ \text{hr}/customer.interrupt \text{ ……...Equation 3.22}$$

4. Average Service Availability Index (ASAI)

$$ASAI = \frac{\sum N_i * 8760 - \sum U_i N_i}{N_i * 8760}\ p.u \text{ ………………….. ...Equation 3.23}$$

5. Average Service Unavailability Index (ASUI)

$$ASUI = \frac{\sum U_i N_i}{N_i * 8760}\ p.u \text{ ………………..Equation 3.24}$$

Also, $ASUI = 1 - ASAI$

6. Expected Energy Not Served (EENS)

   Expected energy not served in the distribution system is total energy that the power source system does not supply. EENS is the summation of the products of average load of distrubution system and unreliabitly of the system. The unit of EENS is MWh/year.

   $EENS = \sum average\ load * outage\ duration$

   $EENS = \sum_S L_S U_s \frac{kWh}{year} MWhr/customer.\text{yr}$………Equation 3.25

3.5 Tools and Software

ETAP is used for modelling and evaluation of reliability indices of distribution system and EXCEL have been used for data analysis and processing for estimation, i.e. calcultion, of unserved energy cost and cost estimation of system modification options.

3.6 ETAP as the Modeling Tool

For the design, simulation, operation and automation of generation, distribution and industrial power systems, ETAP is the most complete analysis platform available. It creates and tests electrical power systems in a full simulation environment with access to tools for designing and adjusting all kinds of objects and structures with real-time load flow analysis, reliability analysis, short-circuit analysis, motor acceleration analysis, harmonic analysis and transient stability analysis. ETAP is developed with various features which aim to provide users with intelligent power visual monitoring, system optimizations, energy management, automation and forecasting. ETAP is a fully functional analysis tool which can be used for analyzing any of the AC/DC electrical power system.

ETAP is trustworthy, consistent and dependable tool for reliability assessment. Advanced distribution reliability assessment provides engineers with an efficient and effective tool for estimating the performance of power system. Using flexible input parameters, results can be quickly obtained for both radial and looped systems. Powerful calculation techniques allow engineers to choose the depth of system design and the associated results.

It helps to make confident decisions with reliable results. In ETAP, we can model reliability characteristics of each component, implement user-defined parameters and settings, calculate load point reliability indices, bus reliability indices, system reliability indices and reliability energy Indices, etc. It is also useful for plotting and reporting. Reporting includes graphical display of reliability results, load point and bus reliability indices, system reliability indices, EENS and ECOST sensitivity analysis, access databases of output results, export output reports to our favorite word processor, export one-line diagrams with results to third party CAD systems.

Due to all reliability assessment related features, ETAP software is chosen as the modeling tool in this thesis. Furthermore, similar other analysis like load flow analysis, short circuit analysis, transient stability analysis, etc. of distribution system of Balaju Industrial Estate can be done in the created design or model of Balaju Industrial Estate as actual in the real field.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Cost of Unserved Energy (EENS) Estimation

First of all, customers are classified according to North American Industrial Classification System (NAICS) and moved to field for customer survey to collect customer data by use of prepared questionnaire. After data collection, data have been analyzed and CUE calculation is done. Three different analytical methods of CUE have estimated the distinct values of CUE in the productive (manufacturing) industries of Balaju Industrial Estate. These calculations are based on first-hand (primary) information gathered from the 114 productive industries those give positive response for data preparation. Production loss method, back up generation method and willingness to pay method have estimated cost of unserved energy (EENS) as Rs. 27.68 per kWh, Rs. 50.93 per kWh and Rs. 11.03 per kWh respectively. Estimated value is like flat tariff in case of WtP method. Again, taking the weighted average of estimated values obtained from the production loss method and the backup (captive power) generation method has calculated the overall cost of expected energy not served (EENS) of BID distribution system as Rs. 28.26 per kWh. This figure was used to calculate the ECOST during the distribution system's reliability worth study.

The key driving factors of each method that appeared from results are;

1) Production loss method have been found as relatively weak because it is really challenging to acquire the exact estimate of net production losses because of electrical power outages (there is the chances of all the lost value added to this reason).
2) Among the total surveyed industries, 46 (40.35%) industries have installed backup power generation for critical load. The rest have no backup power facility and they have no any plan to install captive power generation plants. All of the backup power generation plants are diesel generators. Taking the accounting of capital cost of DG at the time of investment, annual interest rate of their loan, recorded annual rate of repair and maintenance cost, annul energy generation from captive power generator and life of 15 years of diesel generators, the cost of CUE is estimated.
3) For willingness to pay (WtP) method, values are estimated for the customers who agree to cover the cost of the enhanced electricity supply scenario. Almost 82 %

of customers have shown the interest to pay higher tariff than prevailing electricity prices.

4.2 Feeder Outage Duration

Feeder outage record, details have been taken from the Kathmandu Grid Division and 132/66, 66/11 kV Balaju substation feeding the three 11 kV BID feeders and BID internal breaker tripping record have taken from log sheet of BIDMO. Last one-year trip data are used (from 2079 Magh to 2080 Magh) for analysis. The average outage duration of the whole distribution system is 100 hr/yr. All the tripping details of each feeder are shown in tables 4.1, 4.2 and 4.3 and that of the whole BID distribution system is shown in table 4.4.

Tripping Details:-

Table 4.1 Tripping Details of 11kV 7000kVA Feeder

Study Period: 2079 Magh - 2080 Magh										
11kV 7000kVA Feeder (BID -1)	No. of Auto Trip Fault Types					No. of Manual Trips for Maintenance	No. of Undeclared Load Shedding in Dry Season	Electricity Outage Duration, minutes		
	Three Phase OC Protection			Earth Fault Protection						
	Low Stage: 3I >	High Stage: 3I >>	Instantaneous Stage: 3I >>>	Low Stage: Io >	High Stage: Io >>			Auto	Manual	Load Shedding
NEA S/S VCB	5	8		32	10	30	5	892	948	900
BID S/S VCB	15	10		85	25	120		1596	2263	
Total:-	**20**	**18**		**117**	**35**	**150**	**5**	**2488**	**3211**	**900**
Total Outage Duration (hrs./yr.):								**109.98**		
Approximate Outage Duration:								**110 hrs./yr.**		

Table 4.2 Tripping Details of 11kV 3500kVA Feeder

Study Period: 2079 Magh - 2080 Magh										
11kV 3500kVA Feeder (BID -2)	No. of Auto Trip Fault Types					No. of Manual Trips for Maintenance	No. of Undeclared Load Shedding in Dry Season	Electricity Outage Duration, minutes		
	Three Phase OC Protection			Earth Fault Protection						
	Low Stage: 3I >	High Stage: 3I >>	Instantaneous Stage: 3I >>>	Low Stage: Io >	High Stage: Io >>			Auto	Manual	Load Shedding
NEA S/S VCB	2	4		21	5	9	5	668	502	900
BID S/S VCB	12	14		75	18	64		1232	2103	
Total:-	**14**	**18**		**96**	**23**	**73**	**5**	**1900**	**2605**	**900**
Total Outage Duration (hrs./yr.):								**90.08**		
Approximate Outage Duration:								**90 hrs./yr.**		

Table 4.3 Tripping Details of 11kV 4500kVA Feeder

Study Period: 2079 Magh - 2080 Magh										
11kV 4500kVA Feeder (BID -2)	No. of Auto Trip Fault Types					No. of Manual Trips for Maintenance	No. of Undeclared Load Shedding in Dry Season	Electricity Outage Duration, minutes		
	Three Phase OC Protection			Earth Fault Protection						
	Low Stage: 3I >	High Stage: 3I >>	Instantaneous Stage: 3I >>>	Low Stage: Io >	High Stage: Io >>			Auto	Manual	Load Shedding
NEA S/S VCB	2	4		21	5	9	5	668	502	900
BID S/S VCB	8	18		70	10	60		1487	2450	
Total:-	**10**	**22**		**91**	**15**	**69**	**5**	**2155**	**2952**	**900**
Total Outage Duration (hrs./yr.):								**100.12**		
Approximate Outage Duration:								**100 hrs./yr.**		

Table 4.4 Tripping Details of Whole 11kV Distribution System

Study Period: 2079 Magh - 2080 Magh										
3 BID Feeders	No. of Auto Trip Fault Types					No. of Manual Trips for Maintenance	No. of Undeclared Load Shedding in Dry Season	Electricity Outage Duration, minutes		
	Three Phase OC Protection			Earth Fault Protection						
	Low Stage: 3I >	High Stage: 3I >>	Instantaneous Stage: 3I >>>	Low Stage: Io >	High Stage: Io >>			Auto	Manual	Load Shedding
NEA S/S VCB	9	16		74	20	48	15	2228	1952	2700
BID S/S VCB	35	42		230	53	244		4315	6816	
Total:-	**44**	**58**		**304**	**73**	**292**	**15**	**6543**	**8768**	**2700**
Total Outage Duration (hrs./yr.):								**300.18**		
Average Outage Duration of the whole distribution System (hrs./yr.):								**100**		

During the study period, NEA has cut-off power supply of BID five times during peak time of dry season. Electrical line was cut-off 3 hours per day (per time). This was like undeclared load shedding in the industrial estate.

4.3 Customer Survery Results and Analysis

There are 141 consumers categorized as transformer installed HT TOD meter connected industries, transformer installed LT TOD meter connected industries, transformer installed LT meter – without TOD meter, small industries, rural and cottage industries, commercial consumers and non-commercial consumers.

114 industries have given the positive response for data collection. Survey carried out in the Balaju Industrial Estate using prepared questionnaire, interruption data and log sheet kept in respective utilities and are analyzed during primary data collection. Industrial customers belonging to 11 categories based on NAICS were surveyed. Customer classification according to NAICS and their production type with details is as presented in the table below.

Table 4.5 NACIS Classification

NAICS Code	Categorization of Manufacturing Industries
311	Food Manufacturing
312	Beverages and Tobacco Product Manufacturing
313	Textile Mills
314	Textile Product Mills
315	Clothing or Apparel Manufacturing
316	Leather and Allied Product Manufacturing
321	Wood Product Manufacturing
322	Paper Manufacturing
323	Printing and Related Support Activities
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastic and Rubber Products Manufacturing
332	Fabricated Metal Product Manufacturing
335	Electrical Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Products Manufacturing (Oxygen Gas, Concrete Products, Hatchery, etc.) – Not Covered Above

Case study of BID feeder is 11 kV, so surveyed customers are in 11 kV and 400 V industrial category and their prevailing electricity tariff is presented in the table 4.6 below.

Table 4.6 Prevailing Industrial Customer Tariff

Industrial Customer Category	**Demand Charge (Rs./kVA/Month)**	**Energy Charge (Rs./kWh)**	**Remaks**	
1. Lower voltage level 230/400 V				
Rural and cottage industries	60	7.8	<10 kW	
Small industries	**110**	**9.6**	>10kW	
2. High voltage level (without ToD meter)				
Medium volltge -11 kV	**255**	**8.6**		
3. High voltage level (with ToD meter)				
Baishakh to Poush	Demand charge (Rs./kVA/Month)	Energy charge (Rs./kWh)		
		Peak time (5 PM to 11 PM)	Normal time (5 AM to 5 PM)	Off peak time (11 PM to 5 AM)
Medium volltge -11 kV	**250**	**10.5**	**8.55**	**5.4**
Poush to Chaitra				
Medium volltge -11 kV	**250**	**10.5**	**8.55**	**8.55**

4.4 Outage Duration and Frequency of Customer

During survey, every customer was asked for supply outage experiences and their replies and provided records or log sheets of past one year has collected with those have records for estimation of expected outage duration and frequency. The majority of consumers reported experiencing numerous unexpected outages, but they were unable to provide an accurate record of the outage's duration or frequency and resulted loss of the plant. Thus, information about feeder outages was obtained from utility grid SCADA record for Balaju Distribution Centre (outage incurred due to system fails, grid to BID boundary is NEA ownership side of distribution system) faults side outage as well as BIDMO for BID internal outage (records from BID internal breakers that is owned and operated by BID itself) after NEA 11kV metering unit distribution system fault. With all of this data, the anticipated outage duration for the previous year is estimated to be about 100 hours. Trip records and details are attached as shown in the above tables 4.1, 4.2, 4.3 and 4.4.

4.5 Estimation of Outage Cost and Overall Cost of EENS

11 types of manufacturing industries are operating in Balaju Industrial Estate. Balaju DCS collects nearly NRs. 340 million annual revenues from BID, which is the largest customer.

BID is an independent autonomous government organization under Industrial District Management Limited which owns and operates its utility services like, electricity distribution, water supplies, road and drain facilities, etc. within its periphery. BIDMO receives 10% NEA rebate in the event that an electricity bill is paid on time, i.e. within the 7 days from meter reading day.

Outage cost for given outage duration has been estimated by production loss method that includes loss of raw materials and finished products, loss of overtime and idle worker cost, increase in machine maintenance cost and market opportunity and penalty cost.

Outage cost is also estimated by backup generation method for those customers have standby supply.

Finally, WtP survey is conducted for consumer perception to pay greater tariff for better and reliable electricity supply.

So, estimation of cost of unserved energy (EENS) uses each respective industry category weighted average and finally weighted average of estimated values from production loss method and backup power generation method ultimately estimates as a whole distribution system cost of EENS as Rs. 28.26 per kWh. which is used for reliability and economical worth analysis of case study. Results obtained from three different methods are shown in the figure 4.1 and the table 4.7.

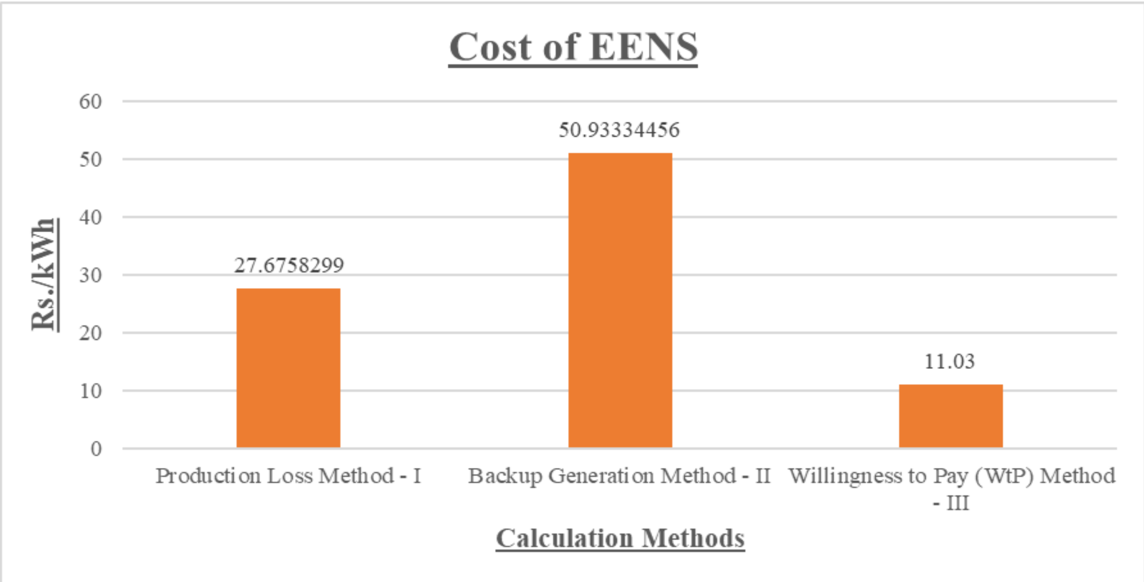


Figure 4.1 Graph of Costs of EENS

Table 4.7 Cost of EENS

S.N.	Type	Cost of EENS(Rs./kWh)	Enery Consumption (kWh)	Remarks
1	Production Loss Method - I	27.68	35612220	
2	Backup Generation Method - II	50.93	918964	
3	Willingness to Pay (WtP) Method - III	11.03		
	Weighted Average Outage Cost (Rs./kWh) of I & II	28.26		

4.6 Comparision and Discussion on Costs of EENS

4.6.1 Earlier Survey and Present Survey in Nepal

Karki et al. 2010 (Estimation of cost of unserved energy: a customer survey Approach) has estimated the average outage cost for the industrial customer Rs 38.42 per kWh s obtained using weighted average method. The outage cost was computed based on the information obtained from the survey regarding loss of raw materials, loss of profit, wages paid to idle workers, penalty for not meeting the delivery deadline, cost of standby supply, etc. Three years of outage data were obtained for two selected feeders in urban, semi-urban and semi-rural areas of Kathmandu valley.

But in case of Balaju Industrial Estate by productive industries survey method, the outage cost obtained using weighted average method is estimated as Rs. 28.26 per kWh shown in the above table 4.7.

The earlier estimated valu of outage cost is higher by 26.45%. Following points are to be noted worth considering.

1. At that time, Nepal had been suffering from severe power shortages and consumers had to face up to 16-hour load shedding in a day during dry season. The study has also focused on the poor infrastructure of distribution system of Kathmandu valley and indicated the urgent need of enhancing supply reliability.
2. The earlier survey was done in different areas of Kathmandu valley. But thesis survey is based on the typical industrial estate, Balaju industrial estate, owned by the Nepal Government which has improved and better electrical distribution system for industries i.e. relaible supply than outside the industrial estate.

4.6.2 Production Loss Method vs Backup Generation Method

In this thesis, the outage cost by production loss method is under estimated and that by backup generation method is over estimated.

As already mentioned above, production loss method is relatively weak because it is really challenging to acquire the precise estimate of the overall production losses because of power supply disruptions. Most of the industries have no records of exact data of raw materials and finished products loss, maintenance cost, opportunity loss. Also, average wage to staff is low. These cause the low estimation of the outage cost.

Only 35 % of the industries having generators have log sheet of generator operation during grid outage. According to these log sheets, almost all generators are operated fully during outage period. The lack of full information about the time of operation of generators and assuming generators are operated whole outage period may have resulted over estimate of outage cost.

4.7 Reliability Assessment of Distribution System

Following the estimation of the cost of unserved energy by the process of three analytical methods, we have calculated the overall financial loss as a result of an inconsistent and unreliable electricity supply. To calculate the ECOST of the distribution system, reliability analysis is done on ETAP by simulating the real system. Every line component's failure rate and repair rate are derived from IEEE standard 493-1990.

4.7.1 Power Distribution Network

Three BID feeders are dedicated each around 1 km long 11 kV underground radial distribution feeders. These feeders are fed from the 132 kV – 66 kV – 11kV Balaju S/S, Kathmandu. From these, power is fed to industrial customers of Balaju Industrial Estate. This radial distribution system is owned and operated by NEA, Balaju DCS from 132 kV Balaju S/S to HT (11kV) metering units at BID premises. BIDMO owns and runs the distribution system after the feeders are entered into the BID region. The government agency known as BIDMO was created to oversee, manage, and develop various industries. These feeders supply power to different customers inside the industrial estate. Large industries having approved load > 100 kVA have their own step-down transformers (11/0.4 kV), whereas small and cottage industries have power supply from the BIDMO owned transformers. Distribution feeder data details are presented in tables 4.8, 4.9, 4.10 and 4.11. Recorded maximum loads are presented in the figures 4.2, 4.3 and 4.4.

Table 4.8 11kV 7000kVA Feeder Details

11 kV BID **Feeder 1: 7000kVA** of Balaju DCS (Dedicated feeder)		Remarks
Nos of consumers	102	
Nos of HT consumer	24	
Number of LT consumer	78	
Line Length, km	5	
Nos of Distribution transformer	24	
Average Maximum Demand, MVA (Per Month)	4.5	FY 2079/80
Annual Electricity consumption, GWh	18.7	
Annual Electricity bill, NRs. (Without 10% Rebate)	168,762,802.83	

Table 4.9 11kV 3500kVA Feeder Details

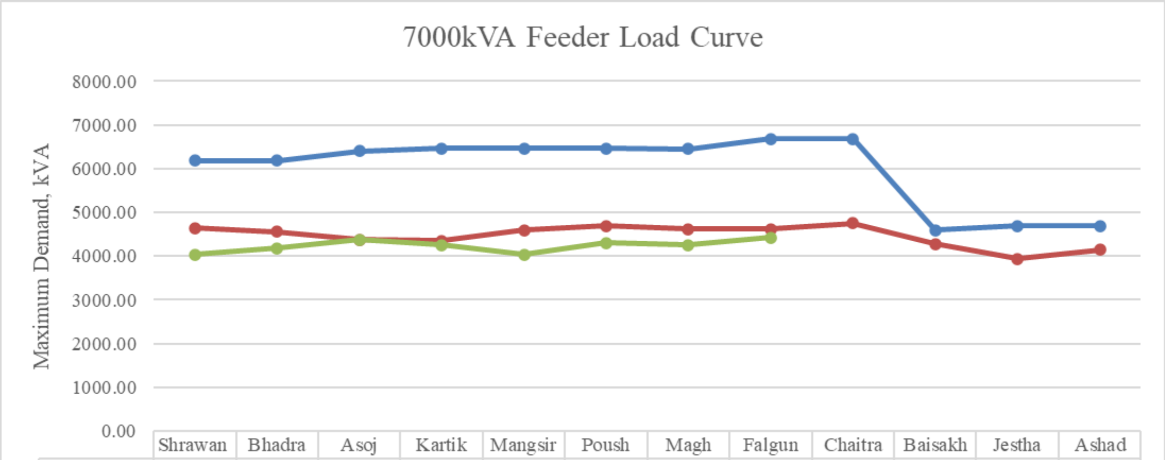
11 kV BID **Feeder 2: 3500kVA** of Balaju DCS (Dedicated feeder)		Remarks
Nos of consumers	27	
Nos of HT consumer	22	
Number of LT consumer	5	
Line Length, km	4	
Nos of Distribution transformer	22	
Average Maximum Demand, MVA (Per Month)	2.6	FY 2079/80
Annual Electricity consumption, GWh	9.5	
Annual Electricity bill, NRs. (Without 10% Rebate)	89,553,056.35	

Table 4.10 11kV 4500kVA Feeder Details

11 kV BID **Feeder 3: 4500kVA** of Balaju DCS (Dedicated feeder)		Remarks
Nos of consumers	28	
Nos of HT consumer	28	
Number of LT consumer	0	
Line Length, km	2.5	
Nos of Distribution transformer	28	
Average Maximum Demand, MVA (Per Month)	2.9	FY 2079/80
Annual Electricity consumption, GWh	8.5	
Annual Electricity bill, NRs. (Without 10% Rebate)	80,342,862.50	

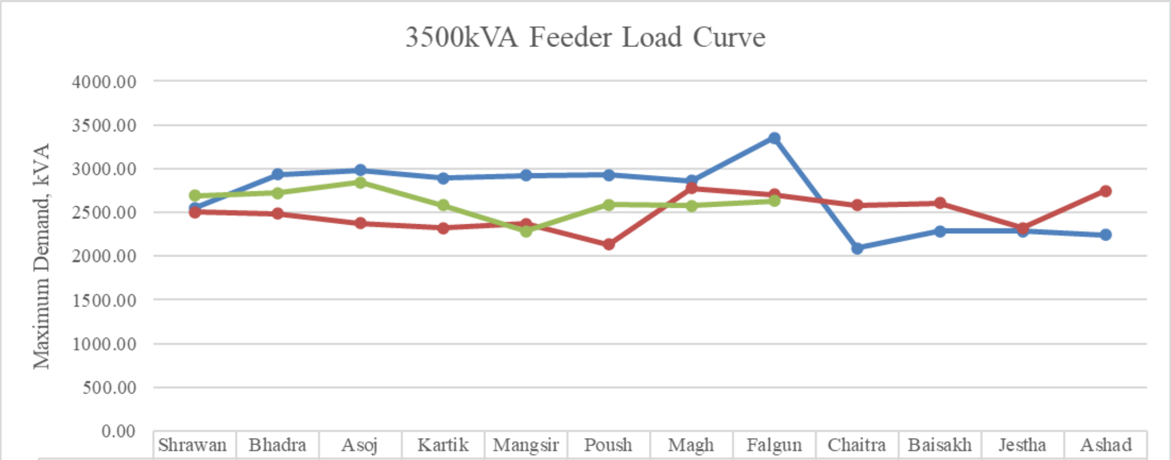
Table 4.11 Entire Distribution System Details

11 kV BID **Feeder Total: 1500kVA**		Remarks
Nos of consumers	157	
Nos of HT consumer	74	
Number of LT consumer	83	
Line Length, km	11.5	
Nos of Distribution transformer	74	
Average Maximum Demand, MVA (Per Month)	10	FY 2079/80
Annual Electricity consumption, GWh	36.7	
Annual Electricity bill, NRs. (Without 10% Rebate)	338,658,721.68	



	Shrawan	Bhadra	Asoj	Kartik	Mangsir	Poush	Magh	Falgun	Chaitra	Baisakh	Jestha	Ashad
078/79	6181.20	6181.20	6403.63	6458.51	6458.51	6458.51	6452.12	6688.00	6688.00	4592.00	4696.00	4696.00
079/80	4640	4560	4380	4352	4600	4688	4616	4616	4752	4280	3944	4140.52
081/81	4032.94	4179.65	4375.28	4251.96	4036.40	4298.67	4257.20	4426.79				

Figure 4.2 Maximum Load Pattern of 7000 kVA Feeder



	Shrawan	Bhadra	Asoj	Kartik	Mangsir	Poush	Magh	Falgun	Chaitra	Baisakh	Jestha	Ashad
078/79	2553.60	2937.00	2985.60	2890.80	2919.60	2929.20	2859.60	3352.00	2088.00	2288.00	2288.00	2240.00
079/80	2504	2488	2376	2320	2368	2136	2776	2704	2584	2608	2320	2747.73
081/81	2694.27	2720.03	2842.29	2581.20	2287.11	2588.59	2576.71	2629.31				

Figure 4.3 Maximum Load Pattern of 3500 kVA Feeder

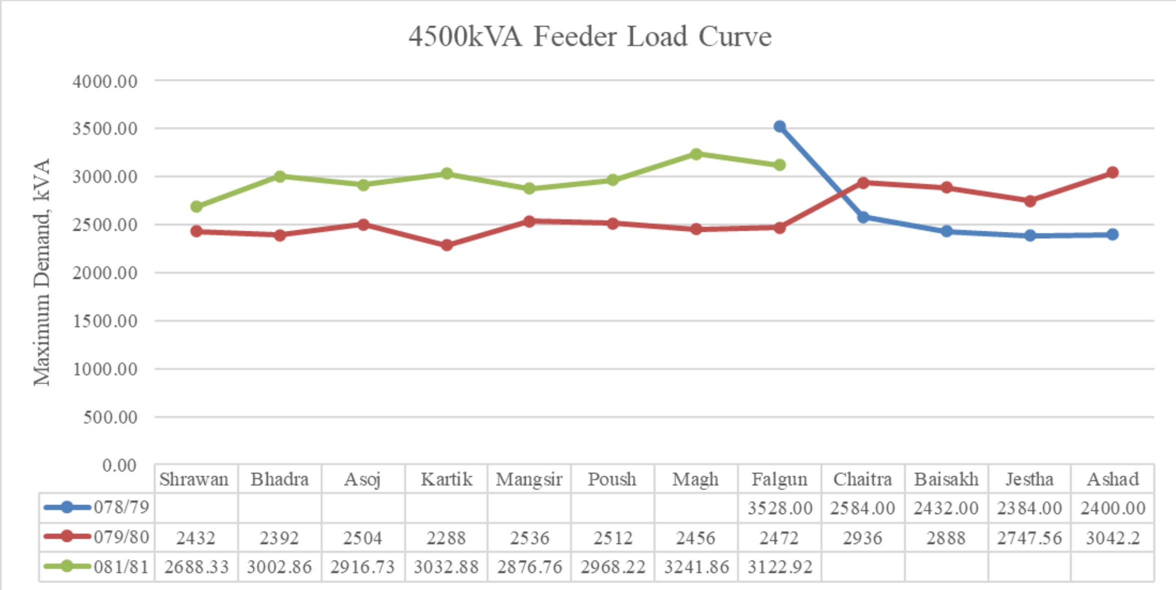


Figure 4.4 Maximum Load Pattern of 4500 kVA Feeder

4.7.2 Reliability Assessment

Distribution system basically consists of circuit breakers, feeders, power cables, sectionalize switches, insulators, protections devices, transformers, load points, etc. Industrial loads are very sensitive to electricity supply outages. Hence, this thesis calculates the existing system reliability indices, outage cost (from customer damage function, estimated as above), finance risks associated with existing setup, etc. To reduce the outage cost system modification is needed to improve system reliability. For better reliability and lower outage cost following distribution feeder modification options are simulated in ETAP and these cases are analyzed and results are obtained as shown the table 4.12 below. Cost estimation and reliability worth analysis of modification options are discussed in next section. Plotting of modification case-by-case reliability indices in bar chart shown in figure 4.5 to figure 4.16.

Outage cost (Rs./kWh) = 28.26088673

Utility Office = NEA

Annual Billing (Energy - kWh Charges Only), Rs. = 314229554.3

Annual Energy Served, kWh = 36596869

Table 4.12 Summary of ETAP Results for all Study Cases

Cases	SAIFI (f /cus.yr)	SAIDI (hr/cus.yr)	CAIDI (hr/cust.int)	ASAI (p.u.)	ASUI (p.u.)	AENS (MWhr/cus.yr)	EENS (MWhr/yr)	EIR (p.u.)	ECOST (Rs./yr)	NEA Revenue loss (Rs./yr)	BIDMO income loss (Rs./yr)	NEA Revenue loss (%)	BIDMO income loss (%)	Percentage Reduction in ECOST
Case 0: Grid Only	1.1224	114.9161	102.387	0.9869	0.01312	29.2704	2429.443	0.9377	68,658,213.44	21,075,418.03	2,107,541.80	6.7070	0.6707	
Case 1: Separate VCB (BID 3)	1.1136	95.4164	85.685	0.9891	0.01089	24.3008	2016.963	0.9478	57,001,162.88	17,497,154.03	1,749,715.40	5.5683	0.5568	16.98%
Case 2: Grid + Redundant Supply	0.6971	16.9443	24.307	0.9981	0.00193	4.2910	356.151	0.9904	10,065,143.07	3,089,609.93	308,960.99	0.9832	0.0983	85.34%
Case 3: Ring Main (Interconnections between Feeders)	1.4305	96.7756	67.651	0.9890	0.01105	25.6832	1053.011	0.9720	29,759,024.60	9,134,870.43	913,487.04	2.9071	0.2907	56.66%

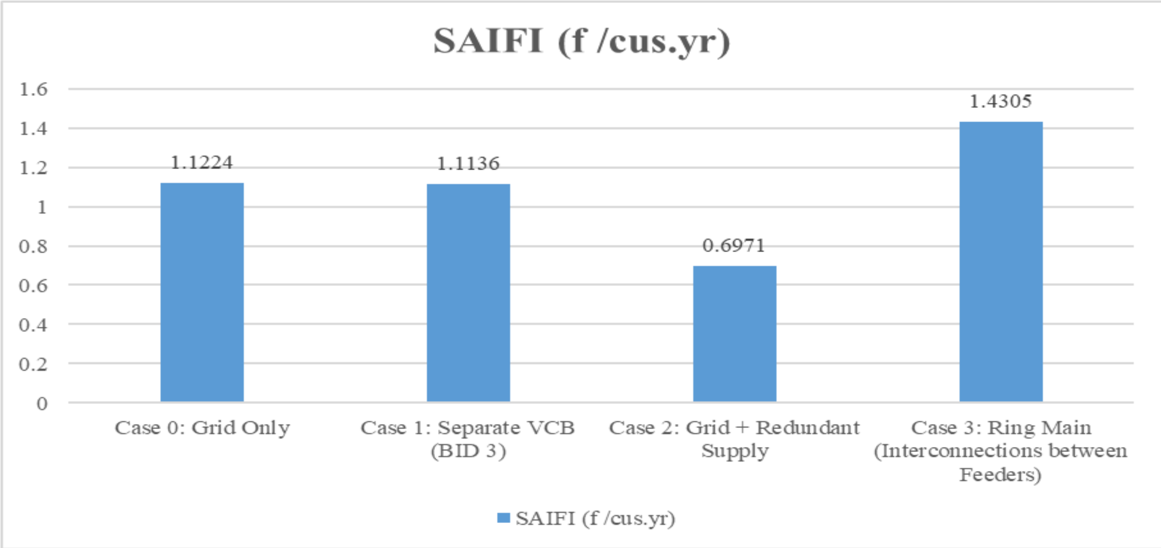


Figure 4.5 Plot of SAIFI

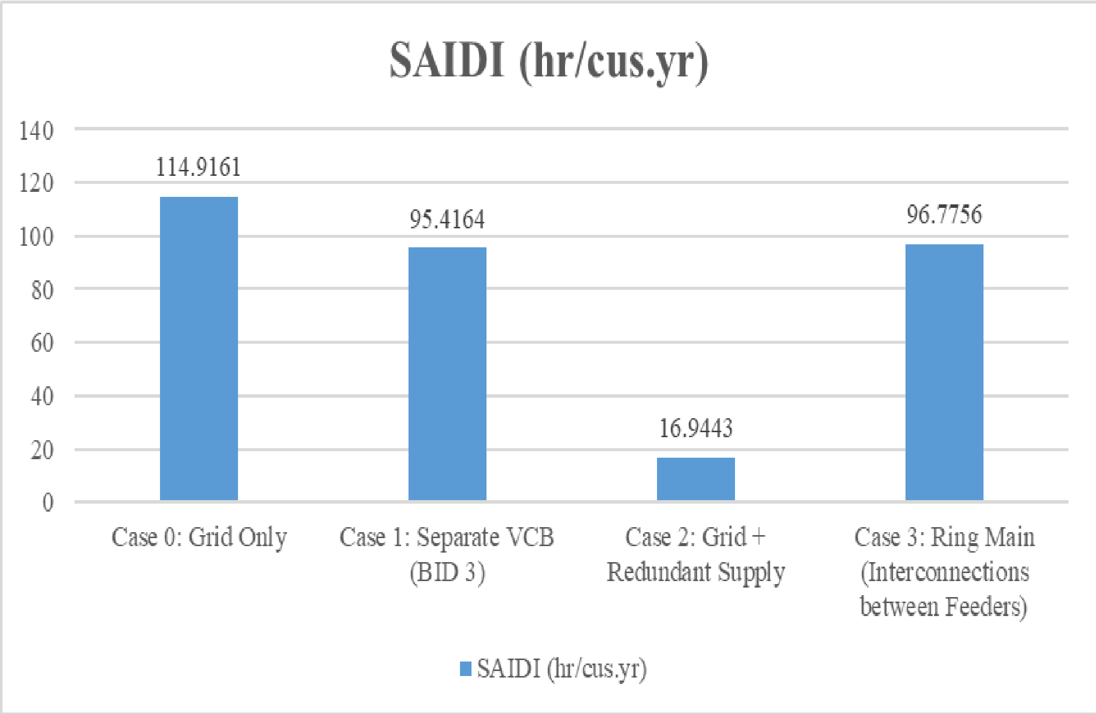


Figure 4.6 Chart of SAIDI

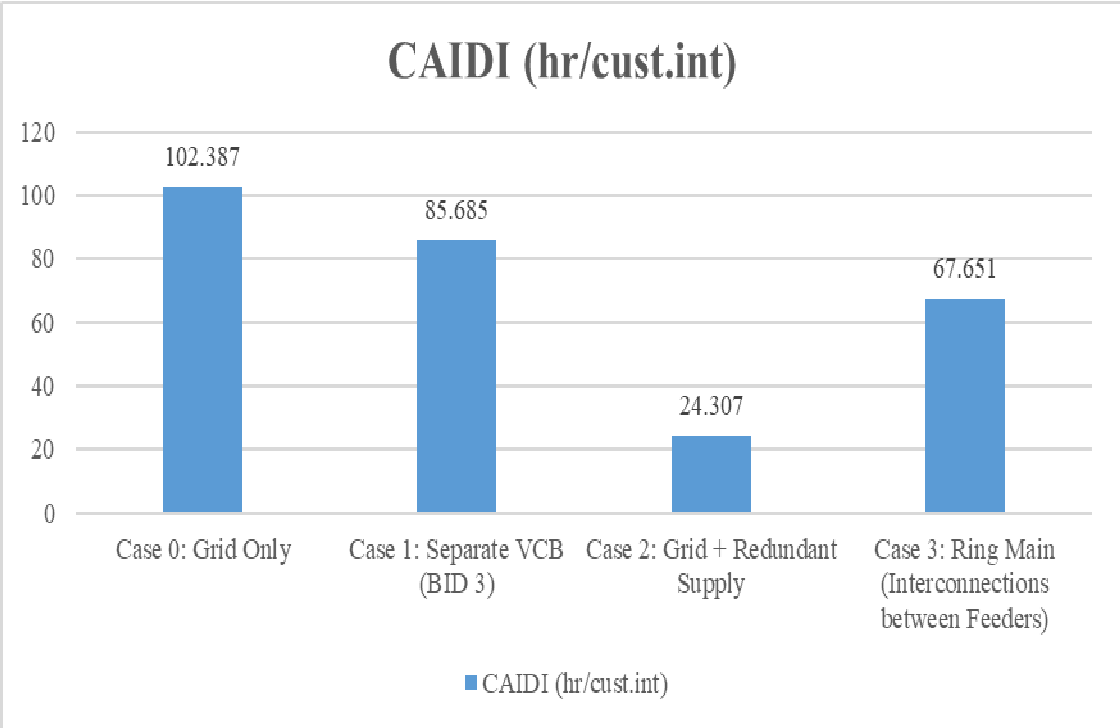


Figure 4.7 Chart of CAIDI

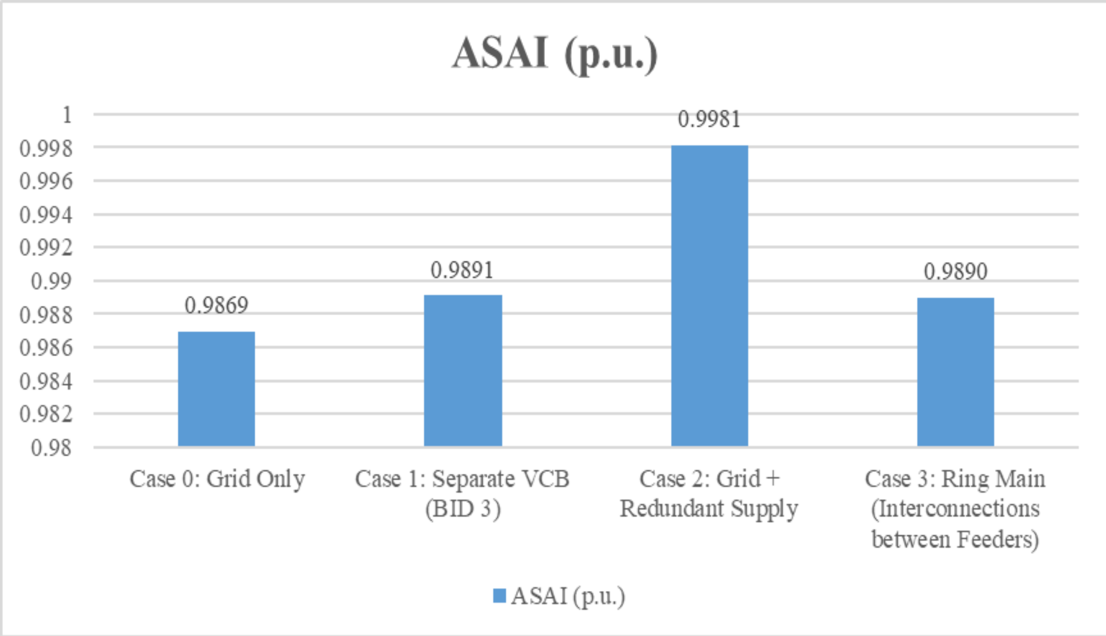


Figure 4.8 Chart of ASAI

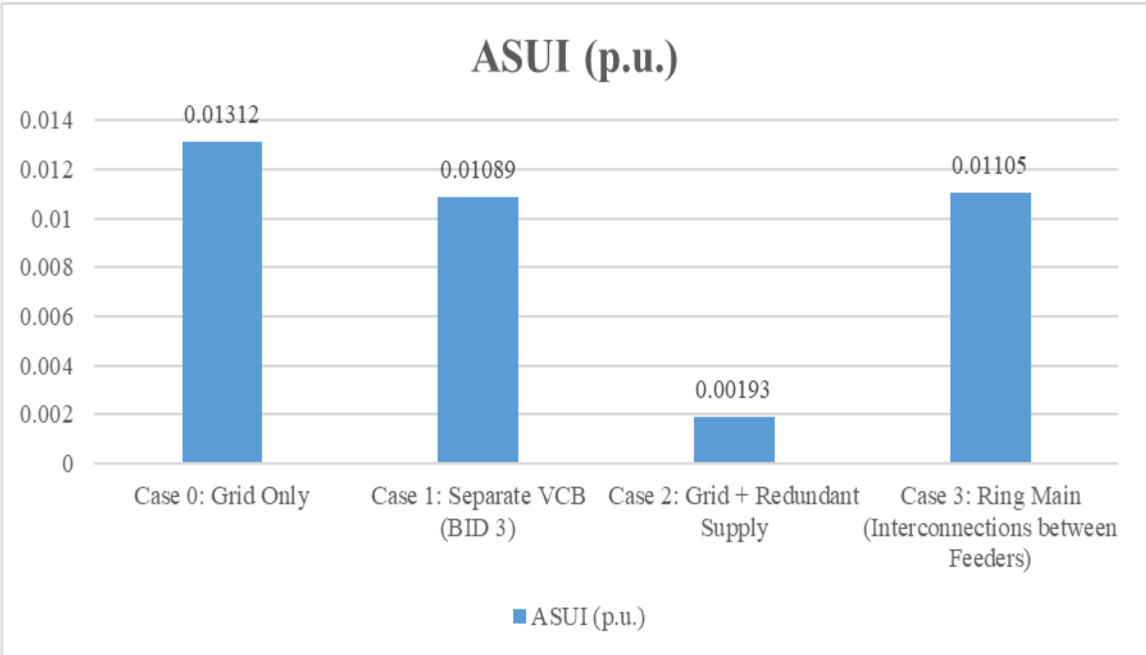


Figure 4.9 Chart of ASUI

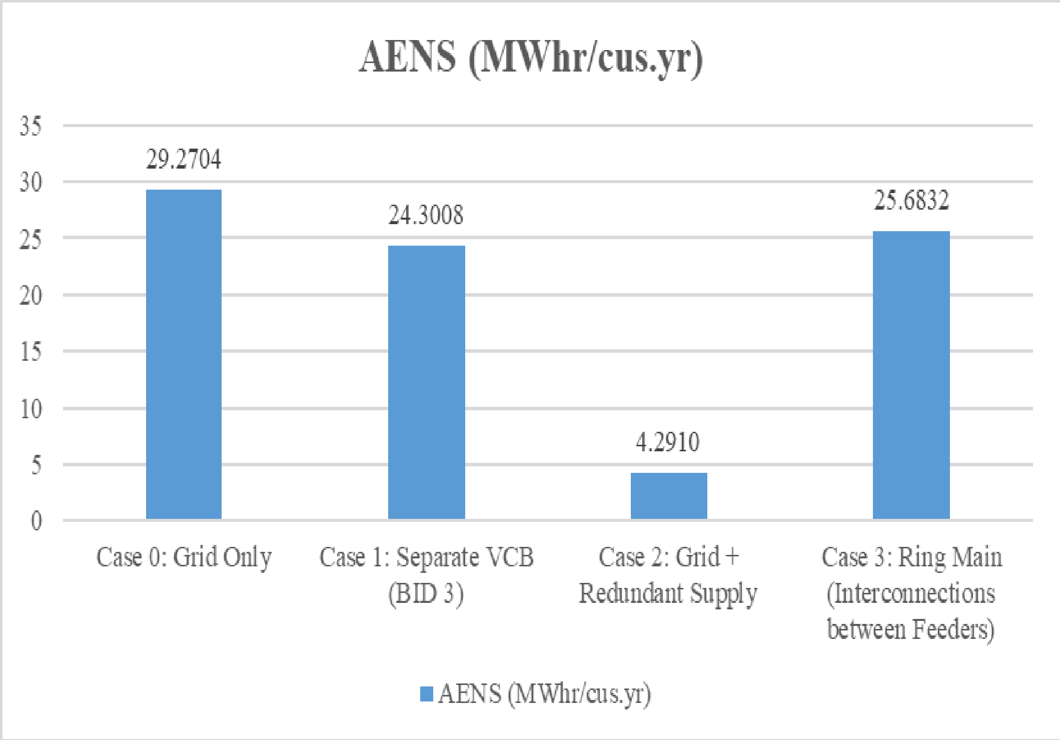


Figure 4.10 Chart of AENS

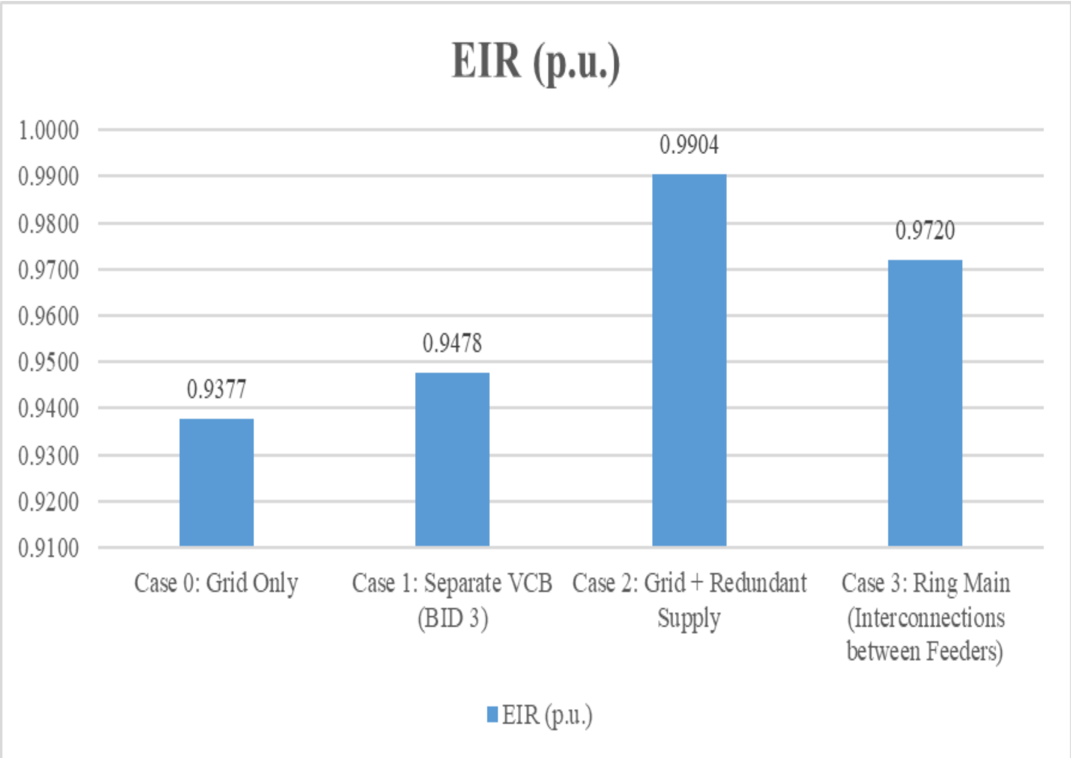


Figure 4.11 Chart of EIR

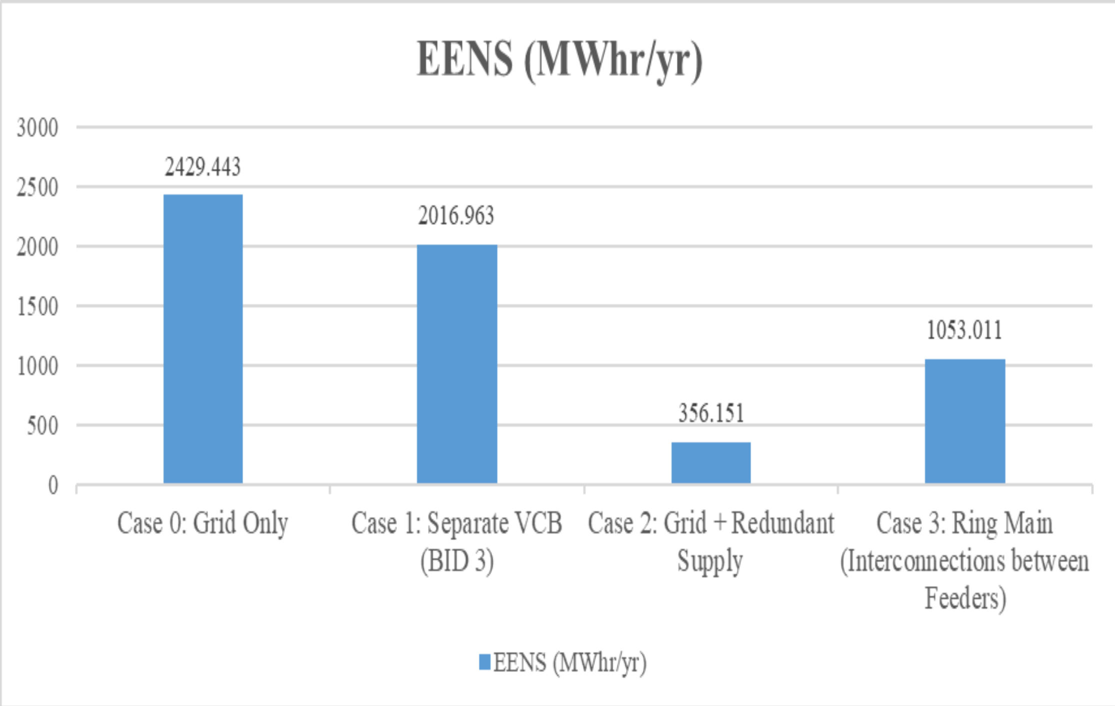


Figure 4.12 Graph of EENS

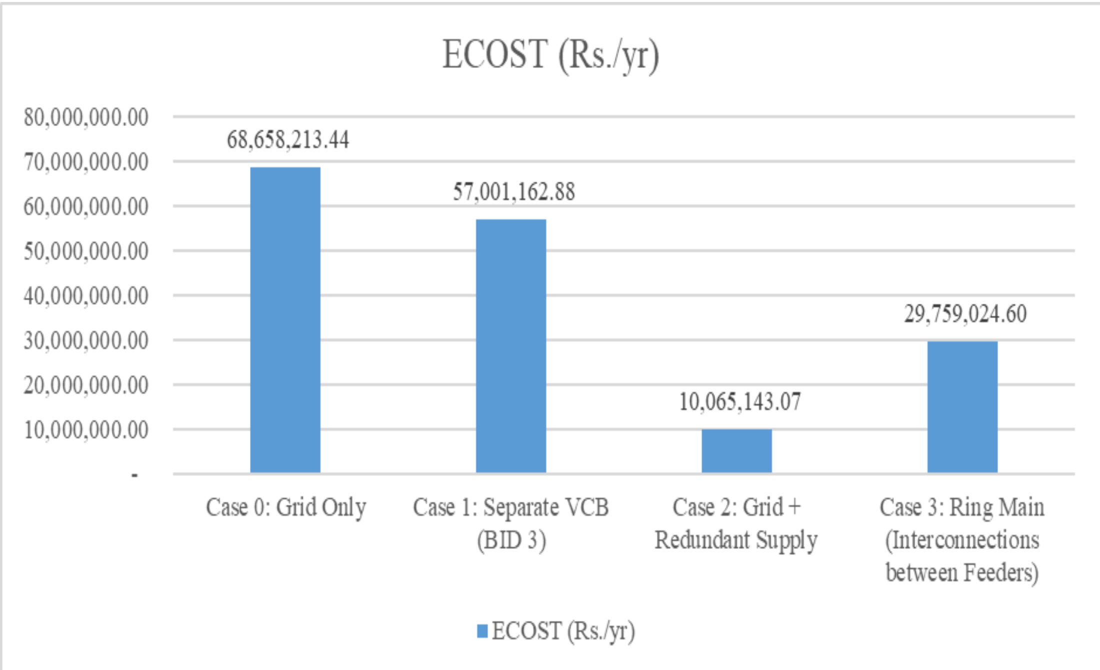


Figure 4.13 Graph of ECOST

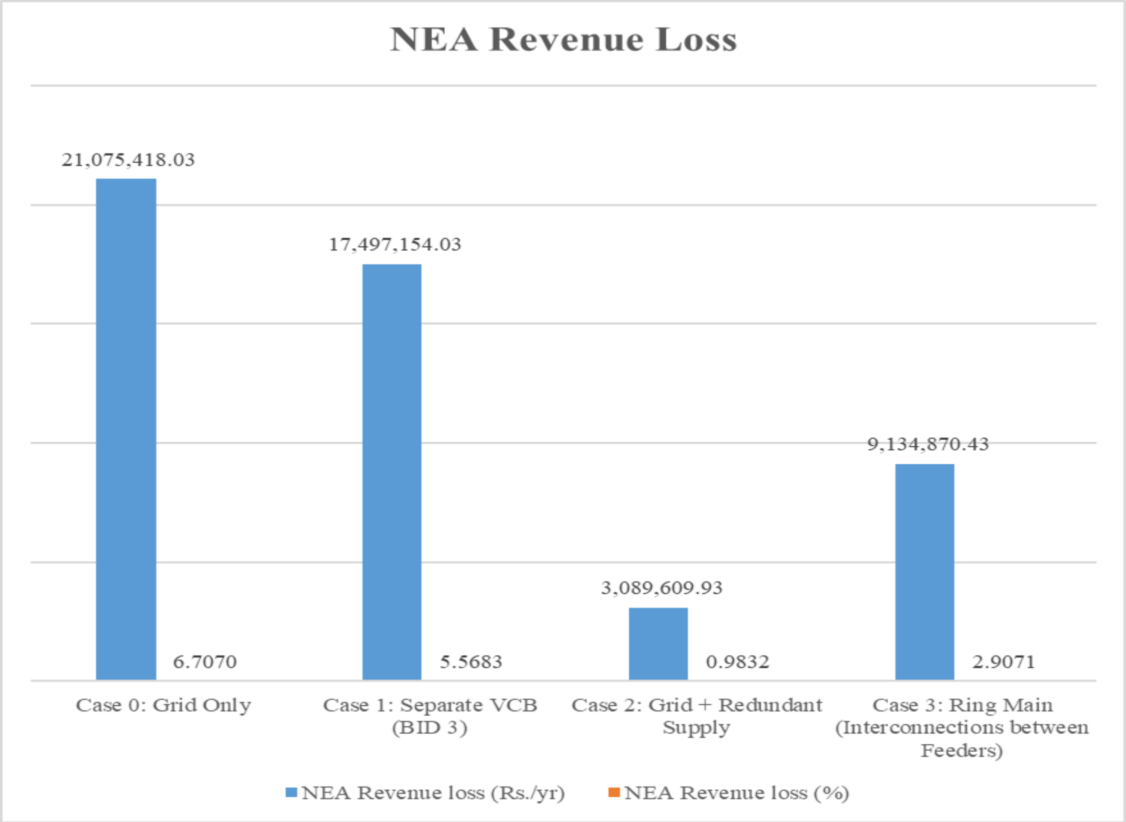


Figure 4.14 Graph of NEA Revenue Loss

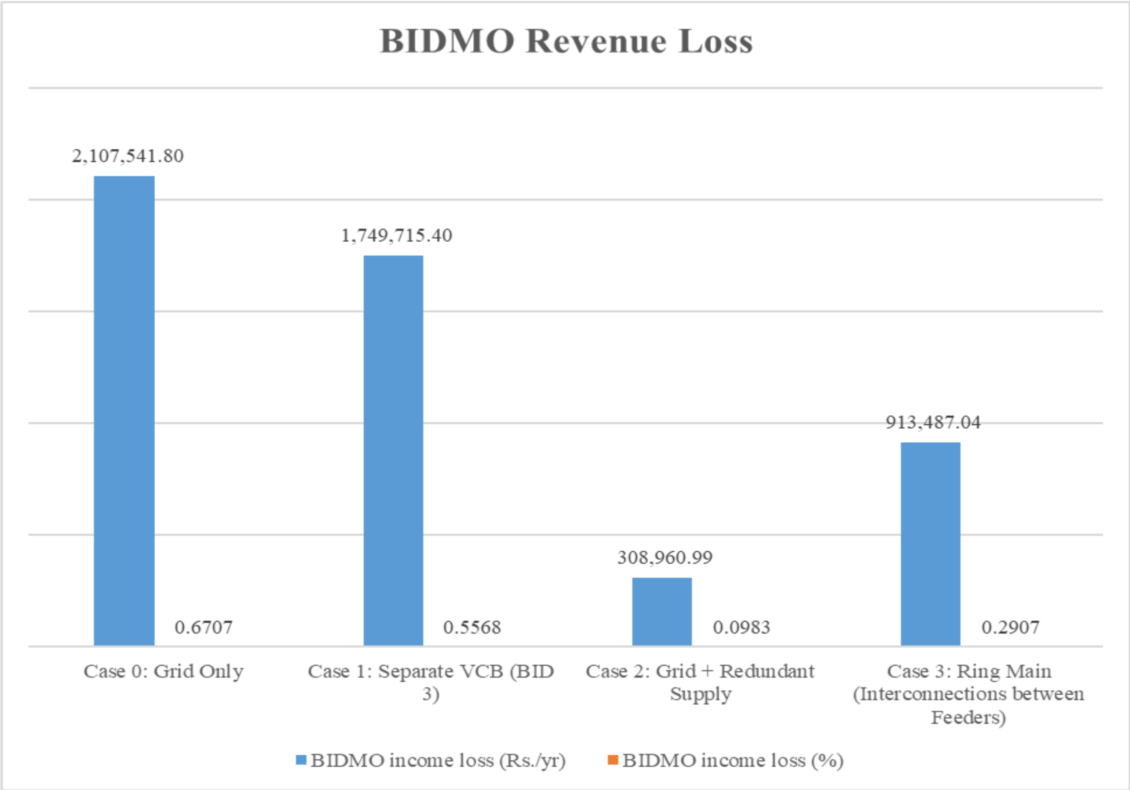


Figure 4.15 Graph of BIDMO Revenue Loss

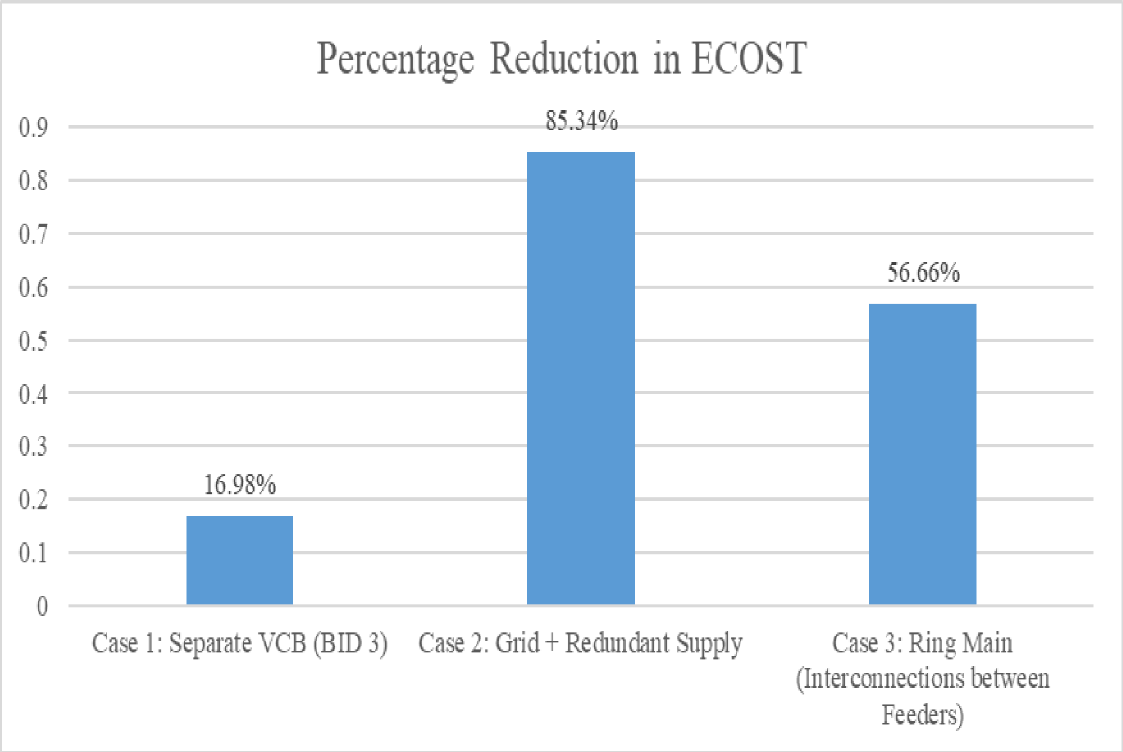
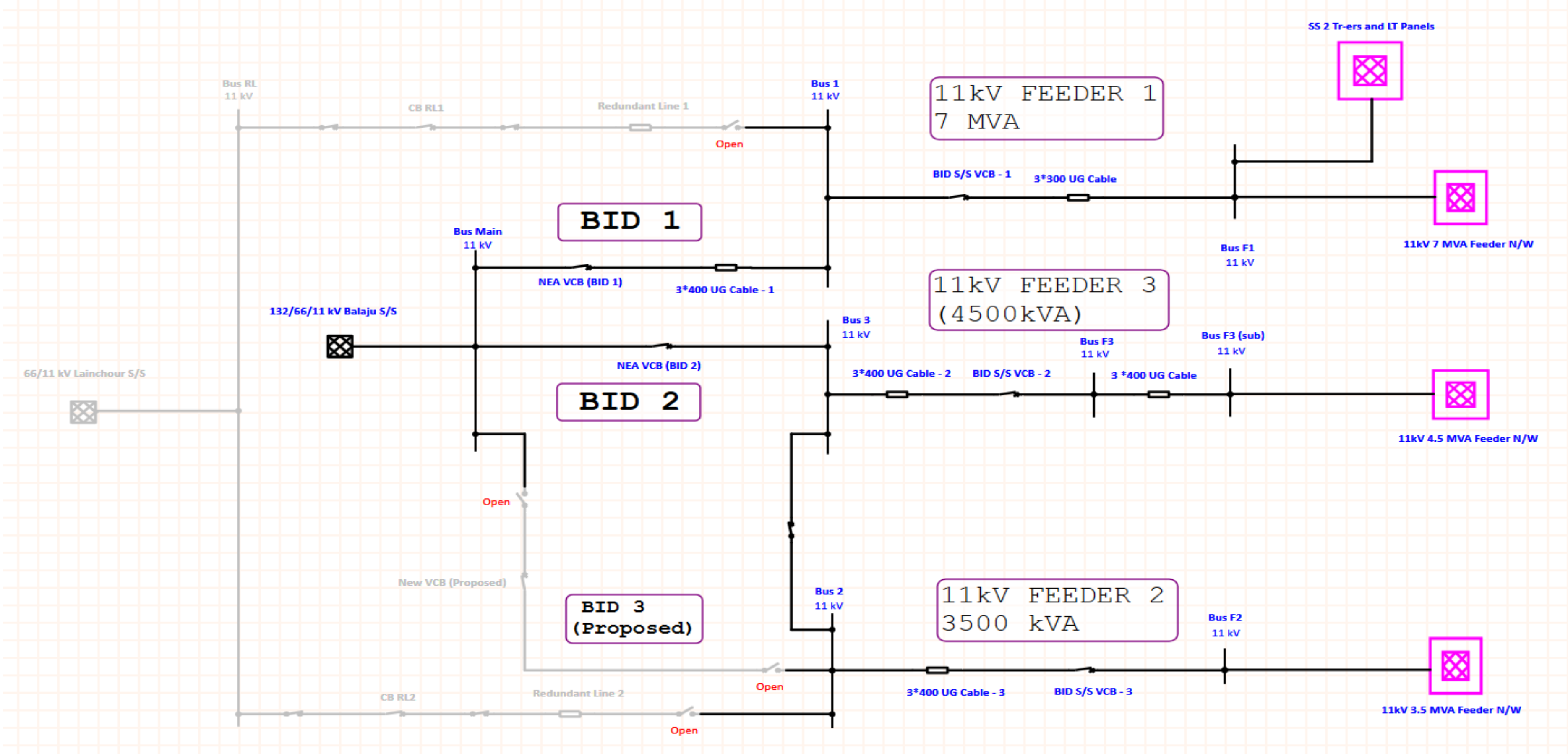


Figure 4.16 Graph of ECOST Reduction

4.8 Study Cases and ETAP Modeling and Simulation

Figure 4.17 Existing Electrical Distribution System of Balaju Industrial District



In the above model of the existing System, there are four composite networks, viz. S/S 2 transformers and LT panels, 11kV 7 MVA feeder network, 11kV 4.5 MVA feeder network and 11kV 3.5MVA feeder network. The compositions of the networks are shown as below.

Figure 4.18 S/S 2 Transformers and LT Panels

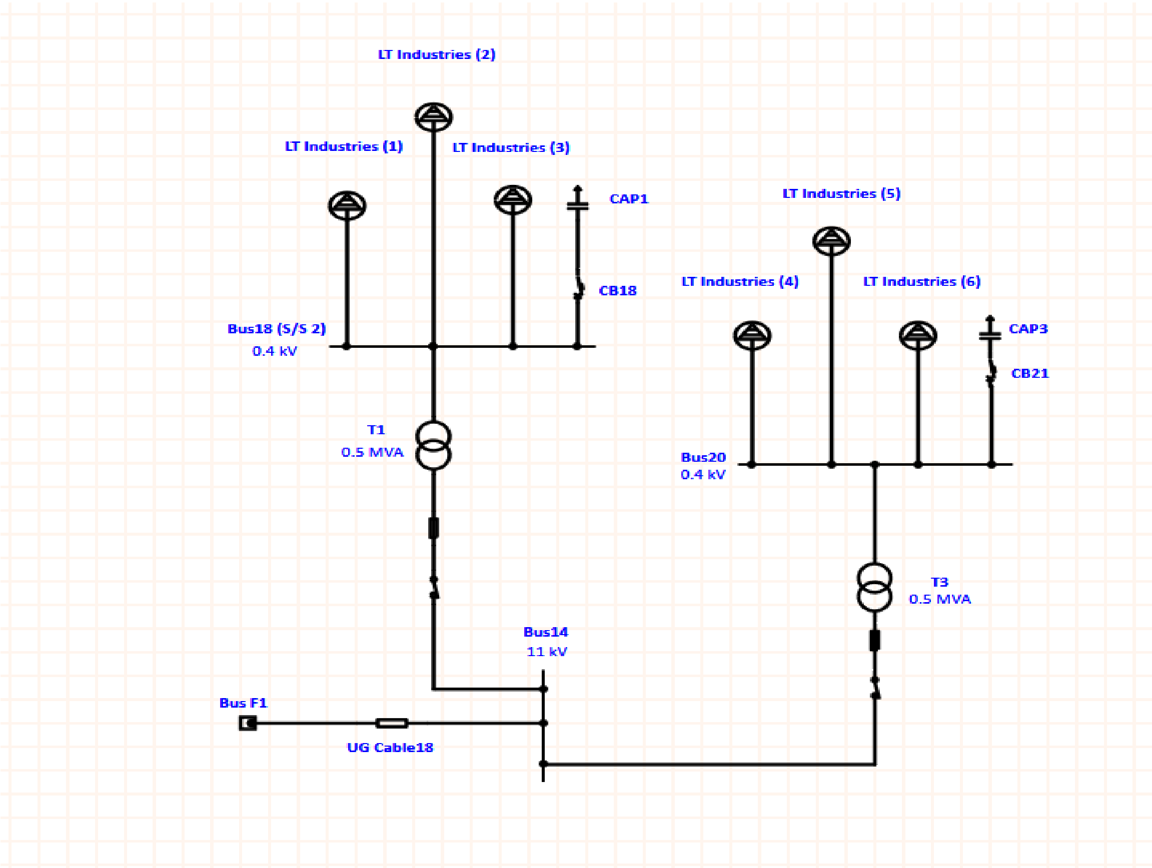


Figure 4.19 11kV 7 MVA Feeder Network

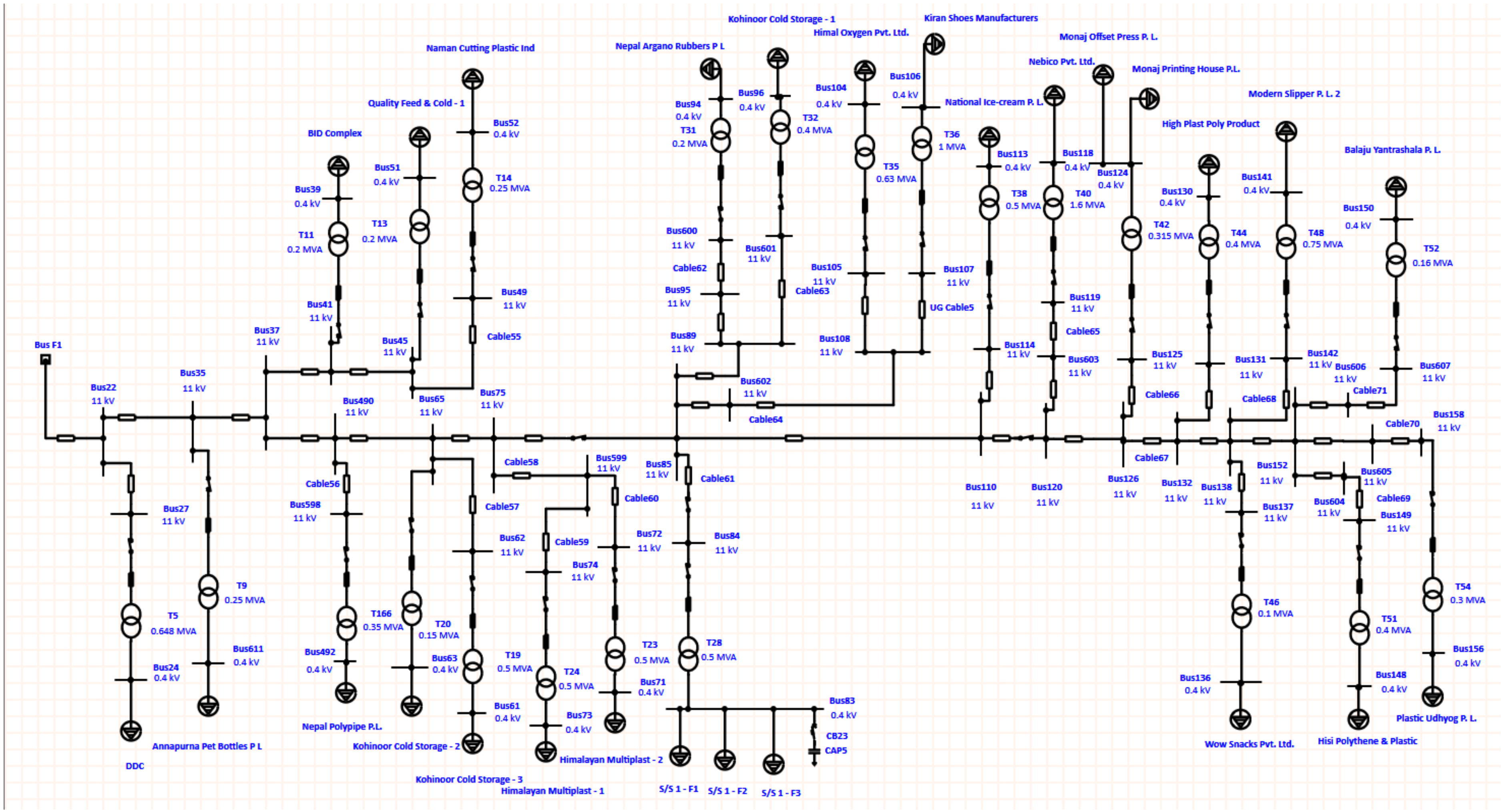


Figure 4.20 11kV 3.5 MVA Feeder Network

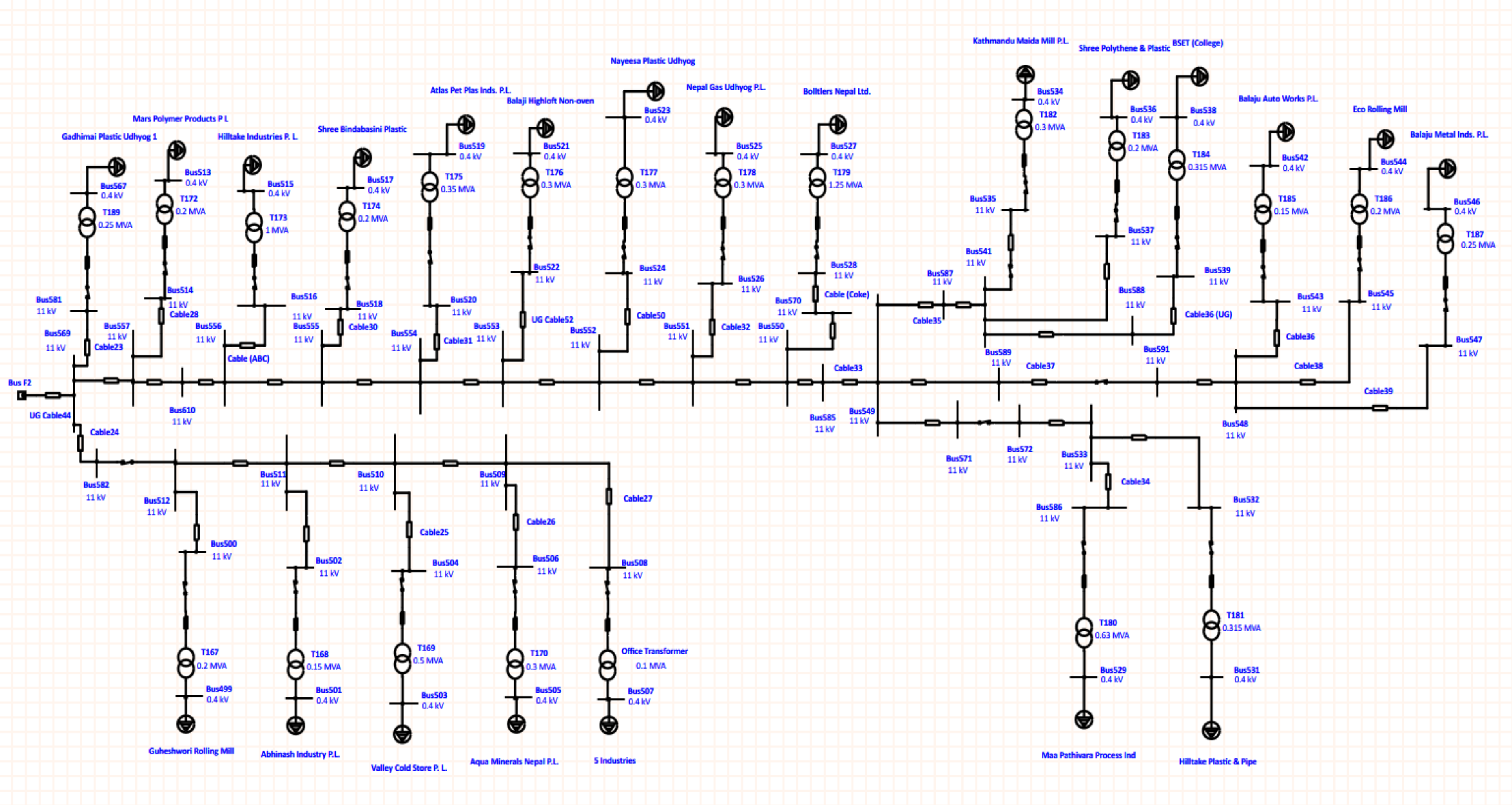
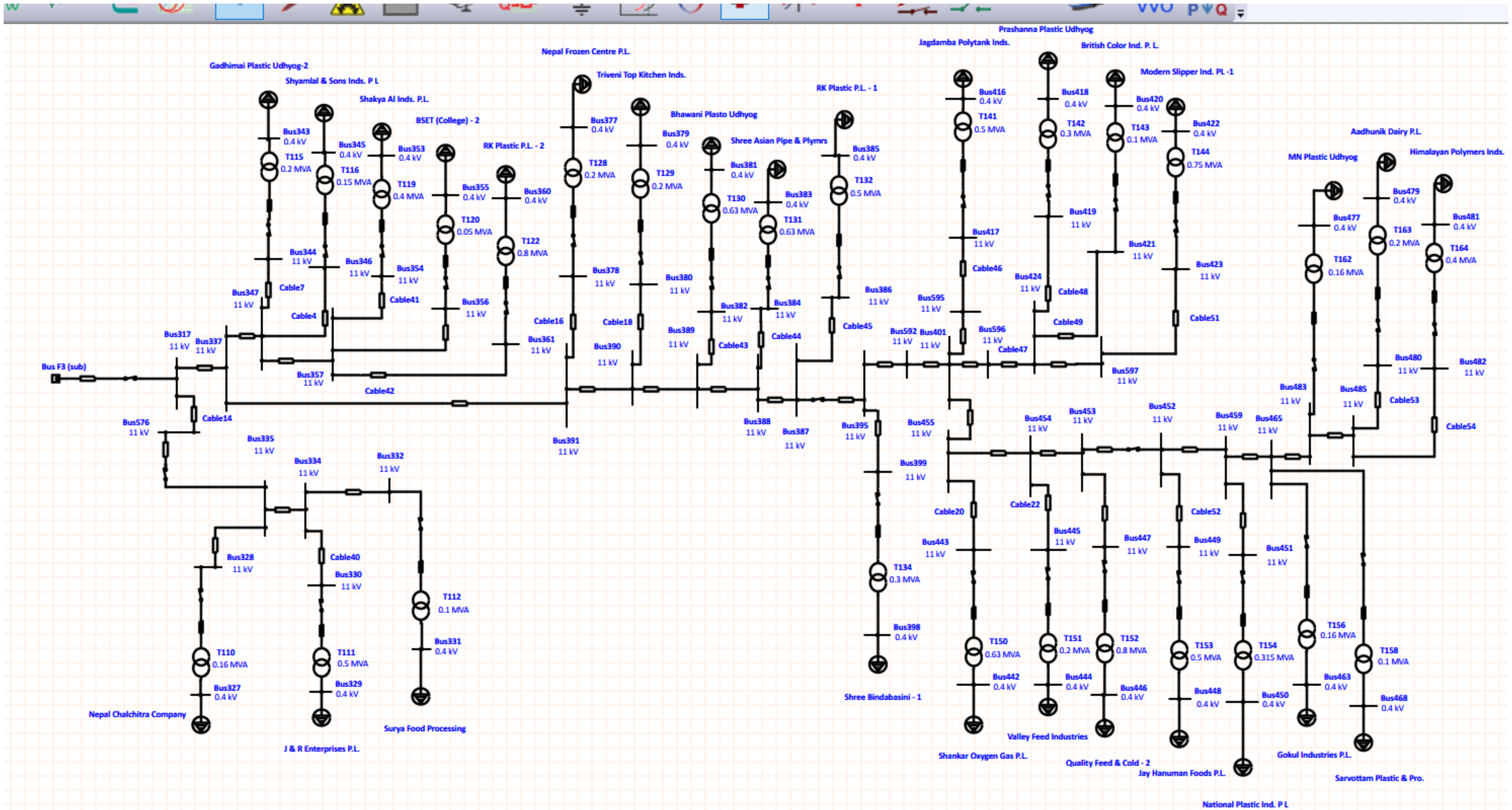


Figure 4.21 11kV 4.5 MVA Feeder Network



4.8.1 Considering the Existing Distribution System: Case 0

Modelling and simulation of existing system in ETAP is shown in figure 4.22 and this system has tested for reliability indices. Expected energy not served (EENS) and thus expected outage cost (ECOST) are obtained as 2429.443 MWh/yr. and Rs. 6,86,58,213.44 per year respectively. The availability of the system is 0.9869 pu. The expected revenue loss of NEA is Rs. 2,10,75,418.03 per year which is 6.707 % annual revenue loss and 10 % of NEA revenue loss, i.e., Rs. 21,07,541.80 is the annual income loss of BIDMO.

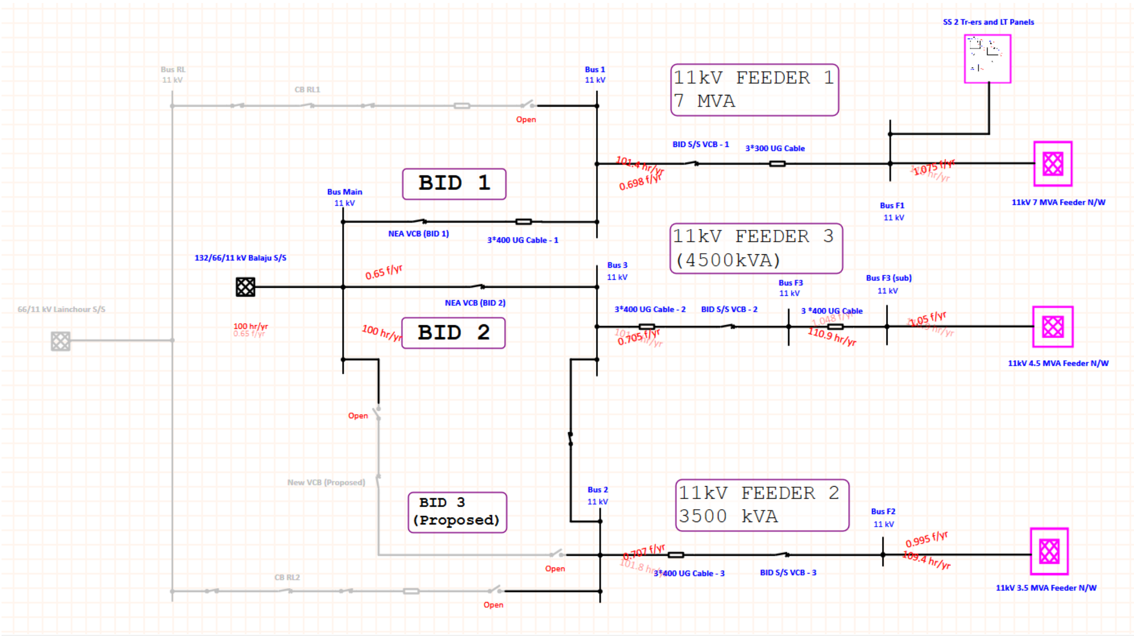


Figure 4.22 Modelling and Simulation of the Existing System: Case 0

4.8.2 Separating 4.5 MVA Feeder and 3.5 MVA Feeder in NEA S/S: Case 1

There are three 11kV feeders from Balaju S/S supplying power to the Balaju Industrial District each having separate 11kV metering units. But there are only two vacuum circuit breakers, one for the 7 MVA feeder and other for 3.5 MVA and 4.5 MVA feeders. Due to having only one VCB for 3.5 MVA and 4.5 MVA feeders, the following problems have been faced by the respective industries.

1. If there is fault in any one feeder in between NEA S/S and BID S/S, both feeders (one healthy and other faulted) have to be kept in shutdown during the maintenance period of the faulted line.
2. If there occurs problem in the NEA VCB, both feeders suffer tripping.
3. If we have to take NEA shutdown for the maintenance (VCB maintenance, metering unit maintenance, etc.) of any one feeder, another feeder also suffers shutdown.

4. In case of high stage faults in any one feeder, BID VCB including NEA VCB trip causing the healthy feeder electricity outage too.

In this case, industries related to the healthy feeder have to face unwanted electricity interruption resulting financial losses, sometimes equipment damages also. Hence, idea of separate VCB for separate feeders has been proposed in this case for study from the reliability point of view.

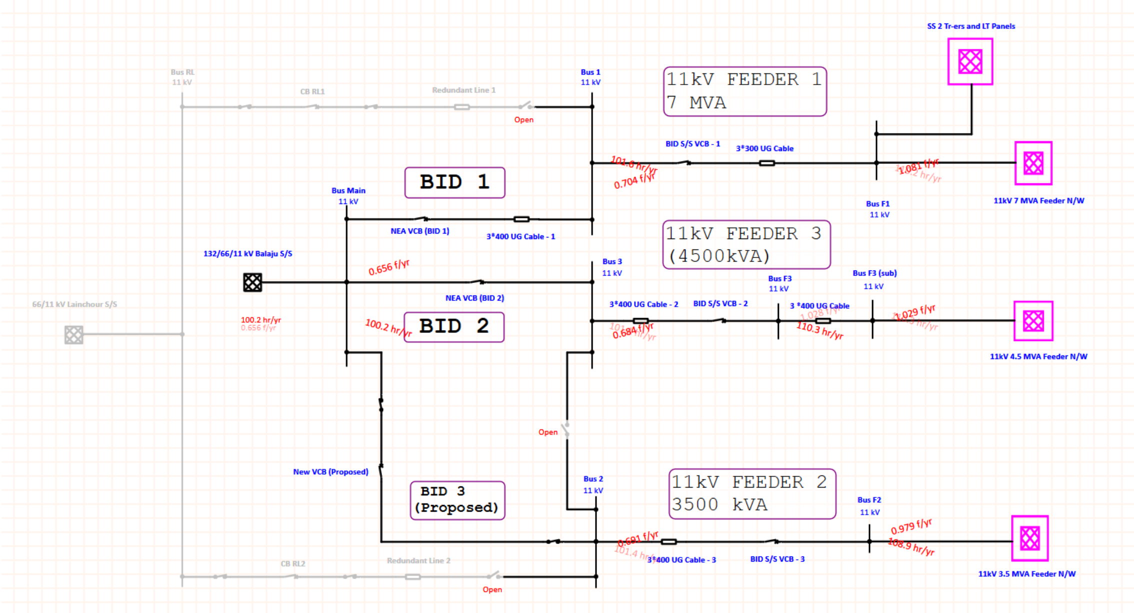


Figure 4.23 Modelling and Simulation of the Case 1

EENS and thus ECOST are acquired as 2016.963 MWh/yr. and Rs. 5,70,01,162.88 per year respectively. The availability of the system is 0.9891 pu. The expected revenue loss of NEA is Rs. 1,74,97,154.03 per year and Rs. 17,49,715.40 is the annual income loss of BIDMO. The percentage reduction in ECOST is 16.98.

In this case, the improvement in the system reliability is observed but slight.

4.8.3 Adding Redundant Power Supply: Case 2

From 66kV Lainchour S/S:

In this instance, it is advised to supplement the current distribution system from the Lainchour substation with a comparable redundant supply in order to increase reliability and lower outage costs. In the unlikely event that the primary radial distribution system is unable to continue supplying power, the recommended redundant supply can serve the entire distribution system load. This modified system is also simulated on ETAP reliability indices are calculated. Reliability is improved to 0.9981 pu, EENS has reduced to 356.151 MWh/yr. In this modification, reliability indices are much more favorable than the existing system. The percentage reduction in ECOST is 85.34.

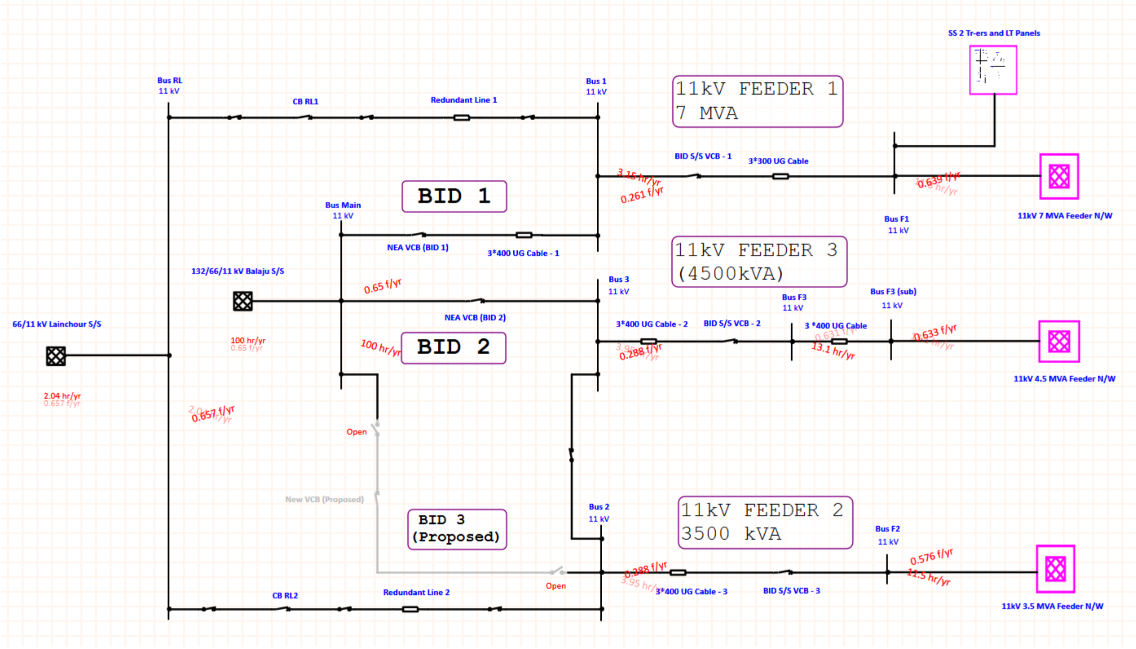


Figure 4.24 Adding Redundant Supply

4.8.4 Creating Ring Main Between Feeders: Case 3

In general, all the feeders are not shutdown simultaneously and if happens, only for very short period. Also, faults do not occur simultaneously in all feeders. It's generally one time in one feeder. Depending upon faults type, feeder shutdown period may be very long and the critical industries, such as, medical oxygen plants, cold storages, dairy plants, food and drinking water plants, etc. suffer.

For the continuous supply of power to these critical industries, ring main between feeders is created installing isolators as one or two feeders are always in operation. In this case, power is supplied only to the critical industries considering the loading capacity of operating feeder or feeders.

In this case, the availability of the system is 0.9890 pu. EENS and ECOST are 1053.01 MWhr/yr and Rs. 2,97,59,024.60 year respectively. System reliability has improved compared to the existing system.

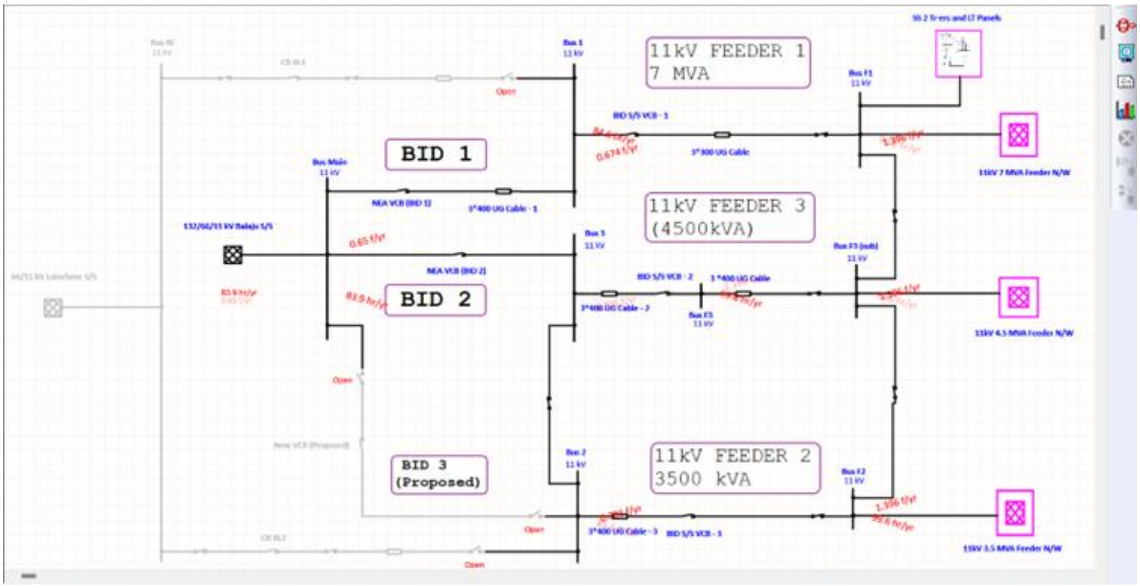


Figure 4.25 Creating Ring Main Between Feeders

4.9 Reliability Worth Analysis

Poor reliability indices were discovered during the distribution network's reliability assessment which led to high EENS, low ASAI and EIR and more ECOST. Two modification options of the original distribution system are suggested to improve reliability indices and reduce outage cost as discussed in the above section. Simulated reliability assessment results of modification options from ETAP are presented in the above table 4.8 and figure 4.5 to figure 4.16. Simulation diagrams are also presented in the above figure 4.22 to figure 4.25 respectively from case 0 to case 3.

4.9.1 Physical Possibility of System Modifications and Worth Analysis

From the result, reliability indicators for cases 1, 2, and 3 are observed to have significantly improved compared to case 0 but financial risk and burden associated with the modifications are unknown. All the suggested system reconfiguration schemes, i.e. case 1, case 2 and case 3, are practically and physically possible with investments according to the estimations. The only issue will be the cost of adopting them.

For the reliability worth analysis, it is required to assess the cost of the recommended changes and compare them to the basic case. Customer cost of reliability is the sum of modification cost and outage cost. Cost estimate and reliability worth analysis of modifications cases are discussed in following sub sections. The Nepal Electricity Authority's and the government of Nepal's current regulations, as well as the equipment's market pricing, form the basis of rate analysis and estimates. A synopsis of the cost estimate and a reliability analysis worth looking at are given in the table 4.13 and the figures 4.26, 4.27 respectively below.

Table 4.13 Overview of Modification Cost and Financial Gain

S.N.	Equipment Descriptions	Estimated total cost of units including supply, installation, testing & commisioning (NRs.)			
		Case0	Case 1	Case 2	Case 3
1	11 kV Distribution Feeder			7,312,230.00	
2	400 Sq.mm XLPE Cable			551,440.00	
3	HV Circuit Breaker		1,480,300.00	2,917,660.00	
4	Disconnect / Isolator Switches			56,500.00	141,250.00
5	Materials and their installations for Isolators (only in case of Case 3)				1,488,492.50
	Total Modification cost (NRs.):		**1,480,300.00**	**10,837,830.00**	**1,629,742.50**
	Outages Cost (NRs) (ECOST):	**68,658,213.44**	**57,001,162.88**	**10,065,143.07**	**29,759,024.60**
	Customer Cost of Realibility (NRs.):		**58,481,462.88**	**20,902,973.07**	**31,388,767.10**
	Financial Gain compared to the base case (NRs.):		**10,176,750.56**	**47,755,240.37**	**37,269,446.34**

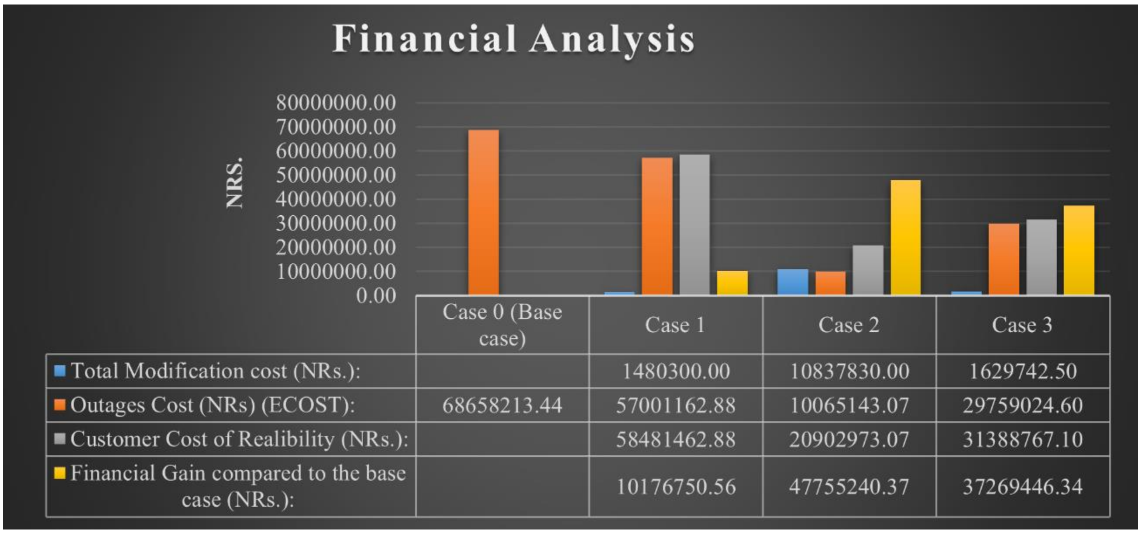


Figure 4.26 Reliability Worth Analysis

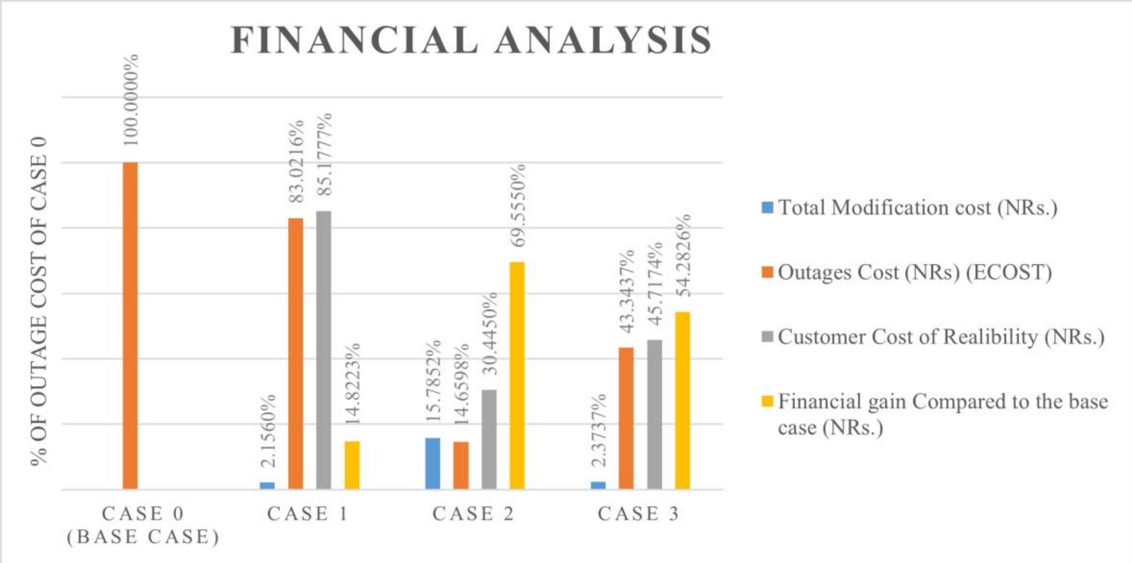


Figure 4.27 Percent Reliability Worth Analysis

4.9.2 Cost Estimate and Relaibility Worth Analysis of Case 1

After separating 3500 kVA and 4500 kVA feeders by adding another separate VCB in NEA S/S, reliability of system is slightly improved and outage cost is reduced as presented in the above sections. This modification requires one number of VCB with its accessories. Estimated cost of every component is shown in table 4.13 and their detail rate analyses are attached in appendix. The total modification cost is NRs. 14,80,300.00. The cost study shows that the outage cost drops to 83% of the initial instance case 0 i.e., NRs. 5,70,01,162.88 (reduced by 17%). Additionally, the cost to the client of reliability (cost of modification plus cost of downtime) is NRs. 5,84,81,462.88 which, in the absence of any changes, is less than the original distribution system's outage cost. Lastly, the financial benefit of putting the recommended change option into practice is NRs. 1,01,76,750.56 as indicated in the table 4.13 which is favorable compared to case 0.

4.9.3 Cost Estimate and Reliability Worth Analysis of Case 2

After adding redundant lines with the existing distribution system, reliability of system is significantly improved and outage cost is reduced as presented in the above sections. The added redundant lines have similar loading capacity as that of the existing feeders which are able to supply power in the industrial estate in case of main distribution system fails. Suggested modification shown in figure 4.24 above requires double circuit 11kV overhead lines, 2 number of HV breakers, XLPE cable, isolator switches, etc. Estimated cost of every component is shown in table 4.13 and their detail rate analyses are attached in appendix. The total modification cost is NRs. 1,08,37,830.00. The cost study shows that the outage cost drops to 15% of the basic case 0 i.e., NRs. 1,00,65,143.07 (reduced by 85%). Additionally, the cost to the client of reliability (cost of modification plus cost of outage) is NRs.2,09,02,973.07 which is less than the outage cost of existing distribution system without any modification. Lastly, the financial benefit of putting the recommended adjustment choice into practice is NRs. 4,77,55,240.37 as indicated in the table 4.13 which is far better than alternative customization options. Because it increases system reliability and results in a much-reduced outage cost, this improvement is likewise advised.

4.9.4 Cost Estimate and Relaibility Worth Analysis of Case 3

For creating the ring main between three 11kV feeders, installations of isolators with other required materials, such as, poles, conductors, insulator, etc., are necessary and the investment is NRs. 16,29,742.50.

In this case, economic gain is NRs. 3,72,69,446.34 which is around 54% of the outage cost of case 0.

4.10 Importance and Comparision of the above Cases

All the three modification cases have their own importances. Case 1 for separating 3500 kVA feeder and 4500 kVA feeder is in the favor of consumers related to the healthy feeder by remedying unwanted tripping and reducing outage duration. Case 2 of adding redundant double circuit lines is in the favor of whole industrial estate because it plays a role of emergency backup supply from the 66kV Lainchour S/S in case of failure of Balaju S/S. Case 3 of creating ring main between feeders is in the favor of critical industries, which require continuous supply of power, during the shortage of full power required by whole industrial estate.

Case 1 and case 3 can be implemented very easily within short period with low cost compared to case 2.

In each case, we observe improvement in reliability and also financial gain by comparing investments and savings.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

The results obtained from the reliability assessment of distribution power system of Balaju Industrial Estate seem to be very useful as it shows the different ways to improve the reliability which ultimately results in financial gain to industrial consumers and respective utility offices. Results give information about planning, upgrading, designing, maintenance programming of distribution system to enhance reliability. Real data collected help to identify the weak parts of the industrial distribution system, then viable solutions are recommended to increase reliability and achieve the best performance of the system.

ASAIs of all configurations, existing distribution system (case 0), separating two feeders by installing separate VCB (case 1), adding redundant supply (case 2) and creating ring main (case 3), are 0.9869 pu, 0.9891 pu, 0.9981 pu and 0.9890 pu respectively. Similarly, EENSs of each case are 2429.443 MWhr/yr, 2016.963 MWhr/yr, 356.151 MWhr/yr and 1053.011 MWhr/yr respectively. It can be noticed that system EENS decreases with increase in its reliability. EIRs are found to be 0.9337 pu, 0.9478 pu, 0.9904 pu and 0.9720 pu respectively. Adding redundant supply is the most reliable configuration. Other two modifications also have better reliability than the existing system.

In this paper, cost of unserved energy is also estimated by the three analytical methods, production loss method, backup generation method and willingness to pay method, for the reliability worth analysis and the overall cost of BID is found Rs. 28.26 per kWh, higher than the prevailing electricity rate.

One-year electrical power outage duration of each 11kV feeder is also calculated from system outage records. Approximate outage durations of 11kV 7000kVA, 3500kVA and 4500kVA feeders are found to be 110 hrs./yr, 90 hrs./yr and 100 hrs./yr respectively. From this, the average outage duration of the whole BID distribution system is obtained as 100 hours per year.

Using this CUE and the EENS of four different configurations, investment and its return analysis is done and the outage costs (ECOSTs) are Rs. 6,86,58,213.44, Rs. 5,70,01,162.88, Rs. 1,00,65,143.07 and Rs. 2,97,59,024.60 respectively. From the analysis, the financial gains in each modified case are found Rs. 1,01,76,750.56, Rs. 4,77,55,240.37 and 3,72,69,446.34 respectively. From this, it is also concluded that redundant supply with existing distribution system configuration has the lowest ECOST and the highest financial gain and is the most suitable configuration. Other two cases have also significant financial gain but high ECOST too.

NEA revenue losses are also calculated for each case and found to be Rs. 2,10,75,418.03, Rs. 1,74,97,154.03, Rs. 30,89,609.93 and Rs. 91,34,870.43 respectively. Ten percent of this NEA revenue loss is the income loss of BIDMO. After modifications of the existing distribution system as cases 1-2-3, there are reduction in ECOSTs by 16.98%, 85.34% and 56.66% respectively. Therefore, all the reconfigurations made to increase the system reliability also reduce the NEA revenue losses and increase the BIDMO incomes compared to the existing distribution system.

All the suggested options (i.e. study cases) for reliability enhancement have their own importances. Case 1 for separating 11kV 3500 kVA feeder and 11kV 4500 kVA feeder in NEA substation is in the favor of consumers related to the healthy feeder by remedying unwanted tripping and reducing outage duration, case 2 of adding redundant double circuit lines is in the favor of whole industrial estate and case 3 of creating ring main between three 11kV feeders is in the favor of critical industries inside BID. The reliability assessment of power distribution system of BID with financial analysis results in improved system reliability with financial gains in each case, therefore, these modifications are recommended for implementation to the concerned utility offices, BIDMO and NEA.

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APPENDIX A: Questionnaire

Estimation of Cost of Expected Energy Not served

Name of Industry:

NACIS Category:

Name and Post of Respondent:

Approved Load:

Transformer Size (If installed):

Method I: Production Loss (Raw Materials and Finished Product Loss)

<u>Section A</u>

1. How much the annual production capacity or volume of the factory? (In tones, cartoons, packets, etc.)

2. How much annual production losses from total production capacity due to electricity outage?

   Production loss volume (tones/cartoons/packets, etc.) =

   Rate of lost product (Rs. / Unit) =

   Total cost of production loss (Rs.) =

   Annual Loss Percentage = $\frac{Total\ Production\ Loss}{Total\ Production\ Capacity} * 100$

3. Please provide the following annual data:

Cost of Production Loss	Electricity Outage from Grid (hrs./annual)	Total Energy Consumed from the Grid (kWh)	Electricity Available from the Grid	Remarks

4. Have any log sheets, records? Please attach it (if yes).

Section B

Estimation of salary to idle worker during electricity outage from grid.

Description	Quantity	Remarks
Total no. of personnel/workers		
No. of table staff		
No. of labor/worker		
Average salary/wages per hour		
Average wages of table staff		
Average wages of labor/worker		
Average wages of idle worker (compulsory)		
Total number of ideal workers (compulsory)		
Cost of ideal worker per hour		
Annual electricity outage duration (hr.)		
Annual cost of ideal worker due to electricity outage (Rs.)		

Please attached if any log sheets, records are available.

Section C

Estimation of increase in maintenance cost due to unexpected electricity outage.

1. How much the cost of time spent to remove the damaged products from the plant?

2. Cost of re-starting and pickup time of plant/unit?

3. Cost of DG overwhelming?

Section D

Estimation of business productivity loss, penalty cost/ loss in opportunity cost due to unexpected electricity outage.

1. Target of market demand & date line:

2. Cost of not meting the market demand in time?

Method II: Backup Generation

Do you have back up generation?

If yes,

Size of backup generation (kVA):

Average load of factory (KVA):

Percentage of load backup by DG (KVA):

Capital cost of backup generation (Rs.):

Life of DG (year):

Interest rate (%):

Annual maintenance cost (Rs.):

Annual fuel cost (Rs.):

Annual energy generation by backup power (kWh):

If no,

Any planning to install DG?

Method III: Willingness to Pay

1. Are you willing to pay higher electricity tariff than current electricity prices?

2. What is your maximum and minimum WtP?

   Maximum ……….…..... Rs. / kWh

   Minimum ……………. Rs. / kWh

   Hints: Minimum acceptable figure for different types of customers are as follows;
   For TOD installed customer (11 kV)
   T1 = Rs.10.5 per kWh
   T2 = Rs.8.55 per kWh
   T3 = Rs.5.40 per kWh for wet season
   T3 = Rs.8.55 per kWh for dry season
   For non-TOD installed customer (11 kV)
   Flat rate: - Rs. 8.60 per kWh
   For non-TOD installed customer (400 V)
   Flat rate: - Rs. 9.60 per kwh

APPENDIX B: Surveyed Customer List

S.N.	Customer Name	Approved Load (kVA)	Installed Transformer Capacity (kVA)	NAICS Code	Description	Type of Product
A	**11kV, 7000kVA FEEDER**					
1	Kohinoor Cold Storage Pvt.Ltd. - 3	281.25	500	339	Miscellaneous Manufacturing	Agriculture related products storage
2	Kohinoor Cold Storage Pvt.Ltd. - 1	327	400	339	Miscellaneous Manufacturing	Agriculture related products storage
3	National Ice Cream Industries Pvt.Ltd.	300	500	311	Food Manufacturing	Ice Cream
4	Nebico Pvt.Ltd.	1600	1600	311	Food Manufacturing	Biscuits & Cookies
5	Modern Slipper Industries Pvt.Ltd. - 2	750	750	339	Miscellaneous Manufacturing	Slippers
6	Himal Oxygen Pvt.Ltd.	435	630	339	Miscellaneous Manufacturing	Medical Oxygen Gas
7	Hisi Polythene & Plastic Industries Pvt.Ltd.	250	400	326	Plastic and Rubber Product Manufcturing	HDPE Pipes
8	Kiran Shoes Manufacturers Pvt.Ltd.	1000	1000	339	Miscellaneous Manufacturing	Shoes
9	High Plast Poly Product Pvt.Ltd.	320	400	326	Plastic and Rubber Product Manufcturing	Polythene Bags
10	Himalayan Multiplast Industries Pvt.Ltd. (HT MU)	400	500	326	Plastic and Rubber Product Manufcturing	Water Jars
11	Quality Feed & Cold Storage Pvt.Ltd.	140	200	339	Miscellaneous Manufacturing	Chicken Feeds
12	Kathmandu Dairy Development Corporation	648.75	648	311	Food manufacturing	Dairy Products
13	Kohinoor Cold Storage Pvt.Ltd. - 2	250	150	339	Miscellaneous Manufacturing	Agriculture related products storage
14	Nepal Agrano Rubbers Pvt.Ltd.	216.25	200	326	Plastic and Rubber Product Manufcturing	Rice Mill Rubber Rollls
15	Plastic Udhyog Industries Pvt.Ltd.	210	300	326	Plastic and Rubber Product Manufcturing	Bottles and Jerkins
16	Himalayan Multiplast Industries Pvt.Ltd. (LT MU)	400	500	326	Plastic and Rubber Product Manufcturing	Water Jars
17	Nepal Poly Pipe Pvt. Ltd.	200	350	326	Plastic and Rubber Product Manufcturing	HDPE Pipes
18	Annapurna Pet Bottles Pvt.Ltd.	215.50	250	326	Plastic and Rubber Product Manufcturing	Pet Bolltles
19	Wow Snacks Pvt.Ltd.	85	100	311	Food Manufacturing	Different Snacks
20	Monaj Offset Press Pvt.Ltd. + Monaj Printing House Pvt. Ltd.	160 + 50	315	323	Printing and Related Support Activities	Books
21	Naman Cuttting Plastic Pipe Udhyog Pvt. Ltd.	170.75	250	326	Plastic and Rubber Product Manufcturing	Plastic Materials

22	Balaju Yantrashala Pvt.Ltd.	140	160	332	Fabricated Metal Product Manufacturing	Suspension bridges, Turbines, etc.
23	Valley Poultry Pvt.Ltd.	50		339	Miscellaneous Manufacturing	Chickens
24	Himali Bakery Company Pvt.Ltd.	52		311	Food Manufacturing	Bakery Products
25	Shree Phuyal Poultry Feed and Hatchery Udhyog Pvt.Ltd.	50		339	Miscellaneous Manufacturing	Chicken Eggs
26	Bajra Footwear Industries Pvt.Ltd.	100		339	Miscellaneous Manufacturing	Shoes
27	Hyonjan Electronic Fabricator Pvt.Ltd.	35		332	Fabricated Metal Product Manufacturing	Electrical Panel Boards
28	KGN Engineering Workshop	60		339	Miscellaneous Manufacturing	Machine dies, Plastic products
29	Niruj Plastic Udhyog Pvt.Ltd	150		326	Plastic and Rubber Product Manufcturing	Plastic Shopping Bags
30	Buddha Metal Industries	87		332	Fabricated Metal Product Manufacturing	Al Utensils
31	Balaju Engineering and Structures Works Pvt.Ltd.	37.50		332	Fabricated Metal Product Manufacturing	Iron Materials
32	Nepal Poultry Pvt.Ltd	70		339	Miscellaneous Manufacturing	Chickens / Hatchery
33	Wooden Accessories and Supports Industries	75		321	Wood Product Manufacturing	Wooden Shoes & Slippers Keys
34	Abhishek Packaging Manufacturing	98		339	Miscellaneous Manufacturing	Paper cartoons and Plastic pipes
35	New Asian Pipe Udhyog	100		326	Plastic and Rubber Product Manufcturing	Plastic Pipes
36	Valley Furniture Pvt.Ltd.	100		337	Furniture and Related Product Manufacturing	Wooden Furnitures
37	S.P. Footwear Industries	56		339	Miscellaneous Manufacturing	Shoes - slippers soles
38	Karmacharya Plastic Udhyog	56		326	Plastic and Rubber Product Manufcturing	Plastic Sheets & Bags
39	Mohit Spices & Food Product Pvt. Ltd.	100		311	Food Manufacturing	Spices
40	Jenas Engineering Works	37.50		332	Fabricated Metal Product Manufacturing	Grill, Truss, Shutter
41	Kathmandu Domestic Appliances	56		332	Fabricated Metal Product Manufacturing	Al Utensils
42	Godawari Printing	70		323	Printing and Related Support Activities	Printing Services
43	Tricone Metal Works	68.75		332	Fabricated Metal Product Manufacturing	Rollings, Grills, Shutters
44	Tricone Beverage Industries	99		312	Beverages and Tobacco Product Manufacturng	Drinking Water
45	Utsav Detergent and Cosmetic Udhyog	86.60		325	Chemical Manufacturing	Cosmetic Products, Plastic Materials
46	Surya Sunshine Home Appliances Industries Pvt.Ltd.	35		332	Fabricated Metal Product Manufacturing	Al Utensils

47	Angel Feed Industries Pvt.Ltd.	50		339	Miscellaneous Manufacturing	Birds & Fish Feeds
48	Aadhunik Feed Pvt.Ltd.	94.60		339	Miscellaneous Manufacturing	Bird Feeds
49	G.Pac Lubricants Pvt.Ltd.	25		324	Petroleum and Coal Products Manufacturing	Lubricants Oil
50	Nepal Valley Engineering and Auto Works Pvt.Ltd.	70		333	Machinery Manufacturing	Machining and Automobiles Maintenance
51	Fun Food Industry Pvt.Ltd.	26.50		311	Food Manufacturing	Cookies
52	Modern Packaging Industries	50		339	Miscellaneous Manufacturing	Paper Packing Boxes
53	Bishnu Textile Processing Industries	80		313	Textile Mills	Textile Coloring
54	Ashok LT Engineering Services Pvt.Ltd.	70		333	Machinery Manufacturing	Vehicle Parts
55	Sudarshan Nirman Samagri Udhyog	24.15		339	Miscellaneous Manufacturing	Hume Pipes
56	Safe Medical Supply Nepal Pvt.Ltd.	20		339	Miscellaneous Manufacturing	Medical Surgical, Disposal
57	Tulip Products	20		314	Textile Product Mills	Pillow, Cushion, Quilt, etc.
58	Baluna Industries Pvt.Ltd.	87		326	Plastic and Rubber Product Manufcturing	Jars, Bottles
59	Chirag Foam Industries Pvt.Ltd.	78.20		339	Miscellaneous Manufacturing	Foam Mattress
60	Shah Cold Store	52		311	Food Manufacturing	Meat Items
61	Samuhik Krishak Dairy Limited	75		311	Food Manufacturing	Dairy Products
62	Quality Kitchen Equipment Pvt.Ltd.	18.75		332	Fabricated Metal Product Manufacturing	Kitchen Equipments
63	Ganesh Kamal Metal Industry Pvt.Ltd.	50		332	Fabricated Metal Product Manufacturing	Al Utensils
64	Sitala Feed Industries Pvt.Ltd.	50		339	Miscellaneous Manufacturing	Birds Feeds
65	Delite Food Packaging Industries Pvt.Ltd.	25		339	Miscellaneous Manufacturing	Oats, Packaging
66	Kathmandu Dairy Development Corporation (LT Line)	50		311	Food Manufacturing	Dairy Products
B	**11kV, 3500kVA FEEDER**					
67	Bottlers Nepal Limited	1250	1250	312	Beverages and Tobacco Product Manufacturng	Cold Drinks
68	Maa Pathivara Poly Process Industry Pvt.Ltd.	600	630	326	Plastic and Rubber Product Manufcturing	HDPE Pipes
69	Kathmandu Maida Mills Pvt.Ltd.	291.55	300	311	Food Manufacturing	Maida
70	Balaji Hiloft Non-oven Industry Pvt.Ltd.	250	300	314	Textile Product Mills	Non-oven Fabric-sheet, Carpet-sheet, etc.
71	Hilltake Industries Pvt.Ltd. (Main Unit)	805.50	1000	326	Plastic and Rubber Product Manufcturing	Water Tanks
72	Valley Cold Store Pvt.Ltd.	400	500	311	Food Manufacturing	Meat Products
73	Guheshwori Rolling Mills Pvt.Ltd.	170.85	200	332	Fabricated Metal Product Manufacturing	Cu Utensils

74	Mars Polymer Products Pvt.Ltd.	175	200	326	Plastic and Rubber Product Manufcturing	Polythene Sheets
75	Shree Gadhimai Plastic Udhyog - 1	200	250	326	Plastic and Rubber Product Manufcturing	Plastic materials, Sheets & Pipes
76	Shree Bindabasini Plastic Udhyog (2)	200	200	326	Plastic and Rubber Product Manufcturing	Plastic Sheets & Bags
77	Nepal Gas Udhyog Pvt.Ltd.	237.50	300	339	Miscellaneous Manufacturing	LPG Gas
78	Abhinash Industry Pvt.Ltd.	104	150	339	Miscellaneous Manufacturing	Hatchery
79	Aqua Minerals Nepal Pvt.Ltd.	200	300	312	Beverages and Tobacco Product Manufacturng	Drinking Water
80	Hilltake Plastic and Pipe Industries Pvt.Ltd.	250	315	326	Plastic and Rubber Product Manufcturing	HDPE Pipes
81	Balaju Metal Industries Pvt.Ltd.	140	250	332	Fabricated Metal Product Manufacturing	Al Utensils
82	Shree Polythene and Plastic Udhyog Pvt.Ltd.	200	200	326	Plastic and Rubber Product Manufcturing	Polythene Pipes, Shipping Bags
83	Nayeesa Plastic Udhyog	276.43	300	326	Plastic and Rubber Product Manufcturing	Plastic Bottles, Lids, etc.
84	Atlas Pet Plus Industries Pvt.Ltd.	200	350	326	Plastic and Rubber Product Manufcturing	Plastic Bottles, Boxes
85	Eco Rolling Mill	100	200	332	Fabricated Metal Product Manufacturing	Al Utensils
86	Aadhunik Meat Products	50		311	Food manufacturing	Meat Products
87	Nepal Knitting Industries Pvt.Ltd.	27.50		314	Textile Product Mills	Shocks
88	Continental Components and Services Pvt.Ltd.	32.50		339	Miscellaneous Manufacturing	Vehicle Maintenance
89	Balaju Auto Works Pvt.Ltd.	105	150	339	Miscellaneous Manufacturing	Auto Workshop
C	**11kV, 4500kVA FEEDER**					
90	J & R Enterprises Pvt.Ltd.	350	500	337	Furniture and Related Product Manufacturing	Furnitures
91	Modern Slipper Industries Pvt.Ltd. - 1	500	750	339	Miscellaneous Manufacturing	Slippers
92	Jai Hanuman Foods Pvt.Ltd.	400	500	311	Food Manufacturing	Fine Flour, Flour, Semolina
93	Shankar Oxygen Gas Pvt.Ltd.	625	630	339	Miscellaneous Manufacturing	Medical Oxygen Gas
94	Quality Feed & Cold Storage Pvt.Ltd. - 2	752	800	339	Miscellaneous Manufacturing	Chicken Feeds
95	Jagadamba Polytank Industries	350	500	326	Plastic and Rubber Product Manufcturing	Water Tanks
96	Shakya Aluminium Industries Pvt.Ltd.	312.50	400	332	Fabricated Metal Product Manufacturing	Kitchen Equipments
97	Bhawani Plasto Udhyog	400	630	326	Plastic and Rubber Product Manufcturing	Plastic Containers, Caps, Bags
98	R.K. Plastic Pvt.Ltd. - 1	475	500	326	Plastic and Rubber Product Manufcturing	Disposabe Plastic Products
99	Shree Asian Pipe and Polymers Udhyog	600	630	326	Plastic and Rubber Product Manufcturing	Pipes
100	R.K. Plastic Pvt.Ltd. - 2	800	800	326	Plastic and Rubber Product Manufcturing	Disposabe Plastic Products

101	Surya Food Processing Industries	105	100	311	Food Manufacturing	Rice Processing
102	Shyamlal and Sons Industries Pvt.Ltd.	125	150	326	Plastic and Rubber Product Manufcturing	Helmets, Visors, Dummies
103	Nepal Frozen Centre Pvt.Ltd.	162.50	200	311	Food Manufacturing	Cold Storage Food Products
104	Triveni Top Kitchen Industries	125	200	332	Fabricated Metal Product Manufacturing	Kitchen Equipments
105	Shree Gadhimai Plastic Udhyog - 2	200	200	326	Plastic and Rubber Product Manufcturing	Plastic materials, Sheets & Pipes
106	Aadhunik Dairy Pvt.Ltd.	172.50	200	311	Food Manufacturing	Dairy Products
107	Himalayan Polymers Industries	375	400	326	Plastic and Rubber Product Manufcturing	Plastic Materials
108	M.N. Plastic Udhyog	122	160	326	Plastic and Rubber Product Manufcturing	Plastic Bags, Sheets
109	Sarvottam Plastic and Products Pvt.Ltd.	100	100	326	Plastic and Rubber Product Manufcturing	Plastic Materials Recycling
110	National Plastic Industry Pvt.Ltd.	250	300	326	Plastic and Rubber Product Manufcturing	Plastic Materials
111	Shree Bindabasini Plastic Udhyog (1)	250	300	326	Plastic and Rubber Product Manufcturing	Plastic Sheets & Bags
112	Prashanna Plastic Udhyog	200	300	326	Plastic and Rubber Product Manufcturing	Plastic Bags
113	Valley Foods Pvt.Ltd.	150	200	311	Food Manufacturing	Meat Products
114	British Color Industry Pvt.Ltd.	85	100	325	Chemical Manufacturing	Ink Manufacturing

Other Installed Transformers:

1. In 11/0.4 kV Substation 1: 2 Numbers of 500 kVA Transformers
2. In 11/0.4 kV Substation 2: 2 Numbers of 500 kVA Transformers and 1 Number of 100 kVA Transformer
3. BID Complex: 160 kVA Transformer in 11kV 7000 kVA Feeder
4. Balaju School of Engineering and Technology: 315 kVA Transformer in 11kV 3500 kVA Feeder, Approved Load 225 kVA
5. Balaju School of Engineering and Technology: 50 kVA Transformer in 11kV 4500 kVA Feeder, Approved Load 40.47 kVA

APPENDIX C: Estimation of Cost of EENS

S.N.	Customer Name	Method I: Annual Production Loss (Raw Materials and Finished Products Losses)															Remarks
		Raw Materials and Finished Products Loss	Value of Production Loss per Hour of Electricity Outage (Pi/Oi)	Hours of Outages	Electricity Consumed from the Grid (Ui)	Full Backup Indstries Grid Consumption	Hour of Electricity Available from the Grid	CUE (Li)	Li*Ui	No.of Idle Workers	Avg Wages (Rs.)	Cost of Idle Worker per Hour	Outage Duraion (hrs.)	Annual Idle Worker Cost	Increase in Maintenance Cost	Loss in Opportunity Cost, Penalty	
A	**11kV, 7000kVA FEEDER**																
1	Kohinoor Cold Storage Pvt.Ltd. - 3		2644.23077	110	891159		4882	14.4858	12909134.62	22	25000	120.1923	110	290865.38			
2	Kohinoor Cold Storage Pvt.Ltd. - 1		1802.88462	110	260617		4882	33.7725	8801682.692	15	25000	120.1923	110	198317.31			
3	National Ice Cream Industries Pvt.Ltd.	200000	6625.87413	110	550617		2386	28.712	15809335.66	50	20000	96.15385	110	528846.15			
4	Nebico Pvt.Ltd.	50000	24493.007	110	2058729		2386	28.3866	58440314.69	250	20000	96.15385	110	2644230.8			
5	Modern Slipper Industries Pvt.Ltd. - 2	500000	37779.7203	110	2430691		2386	37.0851	90142412.59	300	18000	86.53846	110	2855769.2	800000		
6	Himal Oxygen Pvt.Ltd.	800000	10878.4965	110	947234		2386	27.402	25956092.66	30	25000	120.1923	110	396634.62			
7	Hisi Polythene & Plastic Industries Pvt.Ltd.	500000	7445.36713	110	266207		2386	66.7325	17764645.98	15	15000	72.11538	110	118990.38	200000		
8	Kiran Shoes Manufacturers Pvt.Ltd.	600000	20817.3077	110	2043000		2386	24.3123	49670096.15	150	15000	72.11538	110	1189903.8	500000		
9	High Plast Poly Product Pvt.Ltd.	150000	3260.48951	110	520644		2386	14.9421	7779527.972	20	15000	72.11538	110	158653.85	50000		
10	Himalayan Multiplast Industries Pvt.Ltd. (HT MU)	150000	4530.15734	110	718823		2386	15.037	10808955.42	25	15000	72.11538	110	198317.31	50000	100000	

11	Quality Feed & Cold Storage Pvt.Ltd.		1442.30769	110	410994		2386	8.37323	3441346.154	15	20000	96.15385	110	158653.85			
12	Kathmandu Dairy Development Corporation		4230.76923	110	1239000		2386	8.14739	10094615.38	40	22000	105.7692	110	465384.62			
13	Kohinoor Cold Storage Pvt.Ltd. - 2		1802.88462	110	277162		2386	15.5205	4301682.692	15	25000	120.1923	110	198317.31			
14	Nepal Agrano Rubbers Pvt.Ltd.	100000	2084.79021	110	75316		2386	66.0459	4974309.441	10	15000	72.11538	110	79326.923	50000		
15	Plastic Udhyog Industries Pvt.Ltd.	200000	4890.73427	110	168253		2386	69.3556	11669291.96	25	18000	86.53846	110	237980.77	100000		
16	Himalayan Multiplast Industries Pvt.Ltd. (LT MU)	100000	2805.94406	110	340091		2386	19.6859	6694982.517	20	15000	72.11538	110	158653.85	50000		
17	Nepal Poly Pipe Pvt. Ltd.	100000	2639.86014	110	210652		2386	29.901	6298706.294	20	18000	86.53846	110	190384.62			
18	Annapurna Pet Bottles Pvt.Ltd.	50000	1536.27622	110	128960		2386	28.424	3665555.07	15	15000	72.11538	110	118990.38			
19	Wow Snacks Pvt.Ltd.		1442.30769	110	35700		2386	96.3963	3441346.154	20	15000	72.11538	110	158653.85			
20	Monaj Offset Press Pvt.Ltd.	50000	2012.23776	110	106280		2386	45.175	4801199.301	18	18000	86.53846	110	171346.15			
21	Naman Cuttting Plastic Pipe Udhyog Pvt. Ltd.	200000	2993.88112	110	199692		2386	35.7721	7143400.35	10	15000	72.11538	110	79326.923	50000		
22	Balaju Yantrashala Pvt.Ltd.		2163.46154	110	23360		2386	220.977	5162019.231	25	18000	86.53846	110	237980.77			
23	Valley Poultry Pvt.Ltd.	400000	5627.18531	110	23360		2386	574.763	13426464.16	15	15000	72.11538	110	118990.38	100000		
24	Himali Bakery Company Pvt.Ltd.		1442.30769	110	88210		2386	39.0131	3441346.154	20	15000	72.11538	110	158653.85			
25	Shree Phuyal Poultry Feed and Hatchery Udhyog Pvt.Ltd.	200000	2510.48951	110	4580		2386	1307.87	5990027.972	8	18000	86.53846	110	76153.846			

26	Bajra Footwear Industries Pvt.Ltd.	200000	4075.61189	110	42876		2386	226.803	9724409.965	25	15000	72.11538	110	198317.31	50000		
27	Hyonjan Electronic Fabricator Pvt.Ltd.		1298.07692	110	11380		2386	272.163	3097211.538	15	18000	86.53846	110	142788.46			
28	KGN Engineering Workshop	300000	4790.20979	110	114760		2386	99.5943	11429440.56	16	15000	72.11538	110	126923.08	100000		
29	Niruj Plastic Udhyog Pvt.Ltd	200000	3426.57343	110	181260		2386	45.1054	8175804.196	16	15000	72.11538	110	126923.08	50000		
30	Buddha Metal Industries		1298.07692	110	111140		2386	27.8677	3097211.538	18	15000	72.11538	110	142788.46			
31	Balaju Engineering and Structures Works Pvt.Ltd.		1153.84615	110	7771		2386	354.276	2753076.923	15	16000	76.92308	110	126923.08			
32	Nepal Poultry Pvt.Ltd	300000	5439.24825	110	282960		2386	45.8653	12978046.33	25	15000	72.11538	110	198317.31	100000		
33	Wooden Accessories and Supports Industries		576.923077	110	28880		2386	47.6641	1376538.462	8	15000	72.11538	110	63461.538			
34	Abhishek Packaging Manufacturing	100000	2084.79021	110	203310		2386	24.4666	4974309.441	10	15000	72.11538	110	79326.923	50000		
35	New Asian Pipe Udhyog	100000	1990.82168	110	92580		2386	51.3081	4750100.524	15	15000	72.11538	110	118990.38			
36	Valley Furniture Pvt.Ltd.		865.384615	110	22040		2386	93.6846	2064807.692	10	18000	86.53846	110	95192.308			
37	S.P. Footwear Industries	50000	1536.27622	110	37850		2386	96.8443	3665555.07	15	15000	72.11538	110	118990.38			
38	Karmacharya Plastic Udhyog	100000	1630.24476	110	29336		2386	132.594	3889763.986	10	15000	72.11538	110	79326.923			
39	Mohit Spices & Food Product Pvt. Ltd.		1442.30769	110	6780		2386	507.573	3441346.154	20	15000	72.11538	110	158653.85			
40	Jenas Engineering Works		1298.07692	110	8629		2386	358.931	3097211.538	15	18000	86.53846	110	142788.46			

41	Kathmandu Domestic Appliances		721.153846	110	18980		2386	90.6572	1720673.077	10	15000	72.11538	110	79326.923			
42	Godawari Printing	200000	3765.73427	110	45310		2386	198.302	8985041.958	12	18000	86.53846	110	114230.77	100000		
43	Tricone Metal Works	100000	2351.3986	110	162502		2386	34.5253	5610437.063	20	15000	72.11538	110	158653.85			
44	Tricone Beverage Industries		1298.07692	110	39646		2386	78.1217	3097211.538	18	15000	72.11538	110	142788.46			
45	Utsav Detergent and Cosmetic Udhyog	100000	1678.32168	110	80124		2386	49.9785	4004475.524	10	16000	76.92308	110	84615.385			
46	Surya Sunshine Home Appliances Industries Pvt.Ltd.		692.307692	110	11292		2386	146.285	1651846.154	8	18000	86.53846	110	76153.846			
47	Angel Feed Industries Pvt.Ltd.		615.384615	110	6108		2386	240.391	1468307.692	8	16000	76.92308	110	67692.308			
48	Aadhunik Feed Pvt.Ltd.		721.153846	110	30840		2386	55.7935	1720673.077	10	15000	72.11538	110	79326.923			
49	G.Pac Lubricants Pvt.Ltd.	50000	1031.46853	110	8530		2386	288.521	2461083.916	8	15000	72.11538	110	63461.538			
50	Nepal Valley Engineering and Auto Works Pvt.Ltd.		721.153846	110	16891		2386	101.869	1720673.077	10	15000	72.11538	110	79326.923			
51	Fun Food Industry Pvt.Ltd.		1081.73077	110	7960		2386	324.247	2581009.615	15	15000	72.11538	110	118990.38			
52	Modern Packaging Industries	100000	2639.86014	110	91442		2386	68.882	6298706.294	20	18000	86.53846	110	190384.62			
53	Bishnu Textile Processing Industries	100000	3166.52098	110	208720		2386	36.1983	7555319.056	25	15000	72.11538	110	198317.31	50000		
54	Ashok LT Engineering Services Pvt.Ltd.		1730.76923	110	45204		2386	91.3551	4129615.385	20	18000	86.53846	110	190384.62			
55	Sudarshan Nirman Samagri Udhyog		865.384615	110	12110		2386	170.504	2064807.692	10	18000	86.53846	110	95192.308			

56	Safe Medical Supply Nepal Pvt.Ltd.		1081.73077	110	3498		2386	737.853	2581009.615	15	15000	72.11538	110	118990.38			
57	Tulip Products	50000	1536.27622	110	12880		2386	284.593	3665555.07	15	15000	72.11538	110	118990.38			
58	Baluna Industries Pvt.Ltd.	100000	1678.32168	110	49400		2386	81.0623	4004475.524	10	16000	76.92308	110	84615.385			
59	Chirag Foam Industries Pvt.Ltd.	150000	2229.02098	110	47400		2386	112.203	5318444.056	12	15000	72.11538	110	95192.308			
60	Shah Cold Store		1081.73077	110	83900		2386	30.7629	2581009.615	15	15000	72.11538	110	118990.38			
61	Samuhik Krishak Dairy Limited		1557.69231	110	32298		2386	115.074	3716653.846	18	18000	86.53846	110	171346.15			
62	Quality Kitchen Equipment Pvt.Ltd.		865.384615	110	3365		2386	613.613	2064807.692	12	15000	72.11538	110	95192.308			
63	Ganesh Kamal Metal Industry Pvt.Ltd.		576.923077	110	8600		2386	160.063	1376538.462	8	15000	72.11538	110	63461.538			
64	Sitala Feed Industries Pvt.Ltd.		769.230769	110	79540		2386	23.075	1835384.615	10	16000	76.92308	110	84615.385			
65	Delite Food Packaging Industries Pvt.Ltd.		865.384615	110	8576		2386	240.766	2064807.692	12	15000	72.11538	110	95192.308			
66	Kathmandu Dairy Development Corporation (LT Line)		1153.84615	110	25440		2386	108.218	2753076.923	12	20000	96.15385	110	126923.08			
B	**11kV, 3500kVA FEEDER**																
67	Bottlers Nepal Limited		14423.0769	90	2937389		2406	11.8139	34701923.08	100	30000	144.2308	90	1298076.9			
68	Maa Pathivara Poly Process Industry Pvt.Ltd.	500000	9262.82051	90	710897		2406	31.3496	22286346.15	30	18000	86.53846	90	233653.85	100000		
69	Kathmandu Maida Mills Pvt.Ltd.	100000	3034.18803	90	645313		2406	11.3127	7300256.41	25	16000	76.92308	90	173076.92			

70	Balaji Hiloft Non-oven Industry Pvt.Ltd.	50000	3830.12821	90	337111		2406	27.3361	9215288.462	25	18000	86.53846	90	194711.54	100000		
71	Hilltake Industries Pvt.Ltd. (Main Unit)	50000	3920.94017	90	714226		2406	13.2084	9433782.051	35	20000	96.15385	90	302884.62			
72	Valley Cold Store Pvt.Ltd.	100000	4957.26496	90	1113000		2406	10.7162	11927179.49	40	20000	96.15385	90	346153.85			
73	Guheshwori Rolling Mills Pvt.Ltd.		1923.07692	90	289247		2406	15.9964	4626923.077	20	20000	96.15385	90	173076.92			
74	Mars Polymer Products Pvt.Ltd.	50000	2841.88034	90	122160		2406	55.9722	6837564.103	20	18000	86.53846	90	155769.23	50000		
75	Shree Gadhimai Plastic Udhyog - 1	250000	3931.62393	90	341460		2406	27.7031	9459487.179	15	16000	76.92308	90	103846.15			
76	Shree Bindabasini Plastic Udhyog (2)	400000	7719.01709	90	520440		2406	35.6851	18571955.13	25	18000	86.53846	90	194711.54	100000		
77	Nepal Gas Udhyog Pvt.Ltd.		3846.15385	90	209636		2406	44.1424	9253846.154	40	20000	96.15385	90	346153.85			
78	Abhinash Industry Pvt.Ltd.		1153.84615	90	14190		2406	195.642	2776153.846	15	16000	76.92308	90	103846.15			
79	Aqua Minerals Nepal Pvt.Ltd.		2884.61538	90	284320		2406	24.4105	6940384.615	30	20000	96.15385	90	259615.38			
80	Hilltake Plastic and Pipe Industries Pvt.Ltd.	250000	5662.39316	90	106954		2406	127.379	13623717.95	30	20000	96.15385	90	259615.38			
81	Balaju Metal Industries Pvt.Ltd.		1730.76923	90	35888		2406	116.034	4164230.769	20	18000	86.53846	90	155769.23			
82	Shree Polythene and Plastic Udhyog Pvt.Ltd.	200000	4818.37607	90	280916		2406	41.2686	11593012.82	30	18000	86.53846	90	233653.85			
83	Nayeesa Plastic Udhyog	400000	6802.88462	90	449200		2406	36.4375	16367740.38	25	15000	72.11538	90	162259.62	50000		
84	Atlas Pet Plus Industries Pvt.Ltd.	200000	3303.95299	90	363851		2406	21.8477	7949310.897	15	15000	72.11538	90	97355.769			

85	Eco Rolling Mill		721.153846	90	20023		2406	86.6552	1735096.154	10	15000	72.11538	90	64903.846			
86	Aadhunik Meat Products		1298.07692	90	75820		2406	41.1919	3123173.077	15	18000	86.53846	90	116826.92			
87	Nepal Knitting Industries Pvt.Ltd.		1081.73077	90	11560		2406	225.142	2602644.231	15	15000	72.11538	90	97355.769			
88	Continental Components and Services Pvt.Ltd.		1730.76923	90	40856		2406	101.925	4164230.769	20	18000	86.53846	90	155769.23			
89	Balaju Auto Works Pvt.Ltd.		2163.46154	90	103800		2406	50.1473	5205288.462	25	18000	86.53846	90	194711.54			
C	**11kV, 4500kVA FEEDER**																
90	J & R Enterprises Pvt.Ltd.		1802.88462	100	24578		2396	175.755	4319711.538	25	15000	72.11538	100	180288.46			
91	Modern Slipper Industries Pvt.Ltd. - 1	500000	13192.3077	100	1544000		2396	20.472	31608769.23	80	20000	96.15385	100	769230.77	50000		
92	Jai Hanuman Foods Pvt.Ltd.		2596.15385	100	804619		2396	7.73084	6220384.615	30	18000	86.53846	100	259615.38			
93	Shankar Oxygen Gas Pvt.Ltd.	800000	11846.1538	100	1208000		2396	23.4962	28383384.62	40	20000	96.15385	100	384615.38			
94	Quality Feed & Cold Storage Pvt.Ltd. - 2		1923.07692	100	533110		2396	8.64304	4607692.308	25	16000	76.92308	100	192307.69			
95	Jagadamba Polytank Industries	150000	2581.73077	100	240740		2396	25.6951	6185826.923	15	15000	72.11538	100	108173.08			
96	Shakya Aluminium Industries Pvt.Ltd.	100000	3163.46154	100	115495		2396	65.6275	7579653.846	25	18000	86.53846	100	216346.15			
97	Bhawani Plasto Udhyog	200000	3634.61538	100	560599		2396	15.5343	8708538.462	20	17000	81.73077	100	163461.54			
98	R.K. Plastic Pvt.Ltd. - 1	300000	7076.92308	100	1147000		2396	14.7832	16956307.69	40	16000	76.92308	100	307692.31	100000		
99	Shree Asian Pipe and Polymers Udhyog	50000	1942.30769	100	537173		2396	8.66345	4653769.231	20	15000	72.11538	100	144230.77			
100	R.K. Plastic Pvt.Ltd. - 2	50000	2302.88462	100	401843		2396	13.731	5517711.538	25	15000	72.11538	100	180288.46			

101	Surya Food Processing Industries		1442.30769	100	52219		2396	66.1784	3455769.231	20	15000	72.11538	100	144230.77			
102	Shyamlal and Sons Industries Pvt.Ltd.	40000	1481.73077	100	18240		2396	194.64	3550226.923	15	15000	72.11538	100	108173.08			
103	Nepal Frozen Centre Pvt.Ltd.	50000	2038.46154	100	120180		2396	40.6403	4884153.846	20	16000	76.92308	100	153846.15			
104	Triveni Top Kitchen Industries		1298.07692	100	116200		2396	26.7659	3110192.308	18	15000	72.11538	100	129807.69			
105	Shree Gadhimai Plastic Udhyog - 2	50000	1884.61538	100	139980		2396	32.2585	4515538.462	18	16000	76.92308	100	138461.54			
106	Aadhunik Dairy Pvt.Ltd.		1903.84615	100	231600		2396	19.6961	4561615.385	22	18000	86.53846	100	190384.62			
107	Himalayan Polymers Industries	250000	6096.15385	100	490356		2396	29.7873	14606384.62	30	18000	86.53846	100	259615.38	100000		
108	M.N. Plastic Udhyog	100000	2442.30769	100	260640		2396	22.4515	5851769.231	20	15000	72.11538	100	144230.77			
109	Sarvottam Plastic and Products Pvt.Ltd.	50000	1942.30769	100	127248		2396	36.5724	4653769.231	20	15000	72.11538	100	144230.77			
110	National Plastic Industry Pvt.Ltd.	50000	2423.07692	100	144468		2396	40.1867	5805692.308	25	16000	76.92308	100	192307.69			
111	Shree Bindabasini Plastic Udhyog (1)	150000	3721.15385	100	398080		2396	22.3972	8915884.615	28	16500	79.32692	100	222115.38			
112	Prashanna Plastic Udhyog	100000	3163.46154	100	278360		2396	27.2297	7579653.846	30	15000	72.11538	100	216346.15			
113	Valley Foods Pvt.Ltd.		576.923077	100	8526		2396	162.129	1382307.692	8	15000	72.11538	100	57692.308			
114	British Color Industry Pvt.Ltd.	80000	2482.69231	100	39270		2396	151.478	5948530.769	20	17500	84.13462	100	168269.23			
	SUM:				**35612220**				**985597743.1235**								
	LOSS PER HOUR OF ELECTRICITY OUTAGE:							**27.6758299**									

S.N.	Customer Name	Method II: Backup Genaration Cost														Method III: Willingness to Pay			Remarks
		Size of DG (kVA)	Backup Load %	Capital Cost (NRs.)	Life (yrs.)	Interest Rate	Capital Recovery (R)	annual Interest Cost (Rs.)	Annual Maiantnace Cost (Rs.)	Fuel Cosumption per Hour (Litre)	Annual Fuel Cost (Rs.)	Annual Cost of Standby (Rs.)	Annual Energy Generation, kWh (Ui)	Ui*Ci	CUE (Ci)	Accept	Reject	Willing Rate	
A	**11kV, 7000kVA FEEDER**																		
1	Kohinoor Cold Storage Pvt.Ltd. - 3	250	89	3000000	15	10	0.1315	394421.331	100000	50	852500	1346921.33	22000	1346921.33	61.2237	yes		12.00	
2	Kohinoor Cold Storage Pvt.Ltd. - 1	40	12	500000	15	10	0.1315	65736.8884	30000	10	170500	266236.888	3520	266236.888	75.63548	yes		11.00	
3	National Ice Cream Industries Pvt.Ltd.	100	33	1000000	15	10	0.1315	131473.777	40000	15	255750	427223.777	8800	427223.777	48.54816	yes		11.00	
4	Nebico Pvt.Ltd.	500	31	4000000	15	10	0.1315	525895.108	100000	80	1364000	1989895.11	44000	1989895.11	45.22489	yes		11.00	
5	Modern Slipper Industries Pvt.Ltd. - 2	1250	100	10000000	15	10	0.1315	1314737.77	150000	150	2557500	4022237.77	110000	4022237.77	36.5658	yes		12.00	
6	Himal Oxygen Pvt.Ltd.							0			0	0	0			yes		11.00	
7	Hisi Polythene & Plastic Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
8	Kiran Shoes Manufacturers Pvt.Ltd.	696	70	7000000	15	10	0.1315	920316.438	100000	100	1705000	2725316.44	61248	2725316.44	44.49642	yes		12.00	
9	High Plast Poly Product Pvt.Ltd.															yes		11.50	
10	Himalayan Multiplast Industries Pvt.Ltd. (HT MU)	250	63	3000000	15	10	0.1315	394421.331	100000	50	852500	1346921.33	22000	1346921.33	61.2237	yes		11.50	
11	Quality Feed & Cold Storage Pvt.Ltd.	130	93	1250000	15	10	0.1315	164342.221	50000	18	306900	521242.221	11440	521242.221	45.56313		yes		
12	Kathmandu Dairy Development Corporation	1000	100	8000000	15	10	0.1315	1051790.22	200000	150	2557500	3809290.22	88000	3809290.22	43.28739		yes		

13	Kohinoor Cold Storage Pvt.Ltd. - 2							0			0	0				yes		12.00	
14	Nepal Agrano Rubbers Pvt.Ltd.							0			0	0				yes		11.50	
15	Plastic Udhyog Industries Pvt.Ltd.							0			0	0				yes		11.50	
16	Himalayan Multiplast Industries Pvt.Ltd. (LT MU)							0			0	0				yes		11.00	
17	Nepal Poly Pipe Pvt. Ltd.	125	63	1200000	15	10	0.1315	157768.532	50000	18	306900	514668.532	11000	514668.532	46.78805		yes		
18	Annapurna Pet Bottles Pvt.Ltd.							0			0	0	0			yes		12.00	
19	Wow Snacks Pvt.Ltd.							0			0	0	0				yes		
20	Monaj Offset Press Pvt.Ltd.	30	19	300000	15	10	0.1315	39442.1331	25000	8	136400	200842.133	2640	200842.133	76.07657		yes		
21	Naman Cuttting Plastic Pipe Udhyog Pvt. Ltd.												0			yes		11.50	
22	Balaju Yantrashala Pvt.Ltd.												0			yes		11.00	
23	Valley Poultry Pvt.Ltd.	250	100	2700000	15	10	0.1315	354979.198	50000	55	937750	1342729.2	22000	1342729.2	61.03315	yes		12.00	
24	Himali Bakery Company Pvt.Ltd.	103	100	1000000	15	10	0.1315	131473.777	50000	15	255750	437223.777	9020	437223.777	48.4727		yes		
25	Shree Phuyal Poultry Feed and Hatchery Udhyog Pvt.Ltd.	500	100	4000000	15	10	0.1315	525895.108	100000	80	1364000	1989895.11	44000	1989895.11	45.22489	yes		11.00	
26	Bajra Footwear Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
27	Hyonjan Electronic Fabricator Pvt.Ltd.							0			0	0	0			yes		10.00	
28	KGN Engineering Workshop	15	25	150000	15	10	0.1315	19721.0665	25000	5	85250	129971.067	1320	129971.067	98.46293	yes		10.00	
29	Niruj Plastic Udhyog Pvt.Ltd							0			0	0	0			yes		11.50	
30	Buddha Metal Industries							0			0	0	0			yes		10.50	

31	Balaju Engineering and Structures Works Pvt.Ltd.							0			0	0	0				yes		
32	Nepal Poultry Pvt.Ltd	70	100	800000	15	10	0.1315	105179.022	50000	20	341000	496179.022	6160	496179.022	80.54854	yes		12.00	
33	Wooden Accessories and Supports Industries							0			0	0	0				yes		
34	Abhishek Packaging Manufacturing							0			0	0	0			yes		11.00	
35	New Asian Pipe Udhyog							0			0	0	0			yes		10.50	
36	Valley Furniture Pvt.Ltd.							0			0	0	0			yes		10.50	
37	S.P. Footwear Industries										0		0			yes		11.00	
38	Karmacharya Plastic Udhyog							0			0	0	0			yes		11.00	
39	Mohit Spices & Food Product Pvt. Ltd.							0			0	0	0			yes		10.50	
40	Jenas Engineering Works	8	21	100000	15	10	0.1315	13147.3777	20000	5	85250	118397.378	704	118397.378	168.1781		yes		
41	Kathmandu Domestic Appliances							0			0	0	0			yes		11.00	
42	Godawari Printing							0			0	0	0			yes		11.50	
43	Tricone Metal Works							0			0	0	0			yes		11.00	
44	Tricone Beverage Industries	65	66	750000	15	10	0.1315	98605.3327	50000	16	272800	421405.333	5720	421405.333	73.67226	yes		11.00	
45	Utsav Detergent and Cosmetic Udhyog							0			0	0	0			yes		11.50	

46	Surya Sunshine Home Appliances Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
47	Angel Feed Industries Pvt.Ltd.							0			0	0	0			yes		10.00	
48	Aadhunik Feed Pvt.Ltd.	62.5	66	700000	15	10	0.1315	92031.6438	50000	15	255750	397781.644	5500	397781.644	72.32394	yes		11.00	
49	G.Pac Lubricants Pvt.Ltd.	30	100	300000	15	10	0.1315	39442.1331	25000	8	136400	200842.133	2640	200842.133	76.07657	yes		11.00	
50	Nepal Valley Engineering and Auto Works Pvt.Ltd.							0			0	0	0				yes		
51	Fun Food Industry Pvt.Ltd.	22	83	250000	15	10	0.1315	32868.4442	20000	6	102300	155168.444	1936	155168.444	80.14899		yes		
52	Modern Packaging Industries	20	40	200000	15	10	0.1315	26294.7554	20000	5	85250	131544.755	1760	131544.755	74.74134	yes		11.00	
53	Bishnu Textile Processing Industries							0			0	0	0			yes		11.00	
54	Ashok LT Engineering Services Pvt.Ltd.	20	29	200000	15	10	0.1315	26294.7554	20000	5	85250	131544.755	1760	131544.755	74.74134	yes		11.00	
55	Sudarshan Nirman Samagri Udhyog							0			0	0	0				yes		
56	Safe Medical Supply Nepal Pvt.Ltd.							0			0	0	0				yes		
57	Tulip Products							0			0	0	0			yes		10.00	
58	Baluna Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
59	Chirag Foam Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
60	Shah Cold Store							0			0	0	0			yes		10.50	

61	Samuhik Krishak Dairy Limited	125	100	1200000	15	10	0.1315	157768.532	500000	18	306900	964668.532	11000	964668.532	87.69714	yes		11.00	
62	Quality Kitchen Equipment Pvt.Ltd.							0			0	0	0			yes		10.00	
63	Ganesh Kamal Metal Industry Pvt.Ltd.							0			0	0	0				yes		
64	Sitala Feed Industries Pvt.Ltd.							0			0	0	0				yes		
65	Delite Food Packaging Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
66	Kathmandu Dairy Development Corporation (LT Line)							0			0	0	0				yes		
B	**11kV, 3500kVA FEEDER**																		
67	Bottlers Nepal Limited	2520	100	20000000	15	10	0.1315	2629475.54	500000	400	5580000	8709475.54	181440	8709475.54	48.00196	yes		11.50	
68	Maa Pathivara Poly Process Industry Pvt.Ltd.							0			0	0	0			yes		11.00	
69	Kathmandu Maida Mills Pvt.Ltd.							0			0	0	0			yes		11.00	
70	Balaji Hiloft Non-oven Industry Pvt.Ltd.	325	100	3500000	15	10	0.1315	460158.219	100000	65	906750	1466908.22	23400	1466908.22	62.68839	yes		11.00	
71	Hilltake Industries Pvt.Ltd. (Main Unit)	875	100	7500000	15	10	0.1315	986053.327	200000	125	1743750	2929803.33	63000	2929803.33	46.50481	yes		11.50	
72	Valley Cold Store Pvt.Ltd.	250	63	2800000	15	10	0.1315	368126.575	50000	52	725400	1143526.58	18000	1143526.58	63.52925	yes		12.00	
73	Guheshwori Rolling Mills Pvt.Ltd.							0			0	0	0			yes		11.00	
74	Mars Polymer Products Pvt.Ltd.	82	47	800000	15	10	0.1315	105179.022	30000	18	251100	386279.022	5904	386279.022	65.42666	yes		11.50	
75	Shree Gadhimai Plastic Udhyog - 1							0			0	0	0			yes		11.00	

76	Shree Bindabasini Plastic Udhyog (2)	120	60	1200000	15	10	0.1315	157768.532	40000	22	306900	504668.532	8604	504668.532	58.65511	yes		11.50	
77	Nepal Gas Udhyog Pvt.Ltd.	144	61	1400000	15	10	0.1315	184063.288	50000	25	348750	582813.288	10368	582813.288	56.2127	yes		12.00	
78	Abhinash Industry Pvt.Ltd.							0			0	0	0			yes		10.50	
79	Aqua Minerals Nepal Pvt.Ltd.	25	12.5	250000	15	10	0.1315	32868.4442	20000	7	97650	150518.444	1800	150518.444	83.62136	yes		11.50	
80	Hilltake Plastic and Pipe Industries Pvt.Ltd.							0			0	0	0			yes		11.00	
81	Balaju Metal Industries Pvt.Ltd.	125	89	1200000	15	10	0.1315	157768.532	50000	25	348750	556518.532	9000	556518.532	61.83539	yes		11.00	
82	Shree Polythene and Plastic Udhyog Pvt.Ltd.	82.5	41.25	800000	15	10	0.1315	105179.022	40000	20	279000	424179.022	5940	424179.022	71.41061	yes		11.50	
83	Nayeesa Plastic Udhyog							0			0	0	0			yes		11.00	
84	Atlas Pet Plus Industries Pvt.Ltd.							0			0	0	0			yes		11.50	
85	Eco Rolling Mill	30	30	250000	15	10	0.1315	32868.4442	20000	10	139500	192368.444	2160	192368.444	89.05946		yes		
86	Aadhunik Meat Products	12.5	25	120000	15	10	0.1315	15776.8532	15000	6	83700	114476.853	900	114476.853	127.1965	yes		10.50	
87	Nepal Knitting Industries Pvt.Ltd.							0			0	0	0			yes		10.00	
88	Continental Components and Services Pvt.Ltd.	50	100	500000	15	10	0.1315	65736.8884	20000	15	209250	294986.888	3600	294986.888	81.9408	yes		10.50	
89	Balaju Auto Works Pvt.Ltd.	125	100	1250000	15	10	0.1315	164342.221	50000	25	348750	563092.221	9000	563092.221	62.5658	yes		11.00	

C	**11kV, 4500kVA FEEDER**																		
90	J & R Enterprises Pvt.Ltd.	82.5	24	800000	15	10	0.1315	105179.022	35000	18	279000	419179.022	6600	419179.022	63.51197		yes		
91	Modern Slipper Industries Pvt.Ltd. - 1	380	76	3900000	15	10	0.1315	512747.73	100000	60	930000	1542747.73	30400	1542747.73	50.74828	yes		11.50	
92	Jai Hanuman Foods Pvt.Ltd.							0			0	0	0			yes		11.00	
93	Shankar Oxygen Gas Pvt.Ltd.	15	2	100000	15	10	0.1315	13147.3777	15000	8	124000	152147.378	1200	152147.378	126.7895	yes		11.50	
94	Quality Feed & Cold Storage Pvt.Ltd. - 2							0			0	0	0			yes		11.50	
95	Jagadamba Polytank Industries							0			0	0	0			yes		11.00	
96	Shakya Aluminium Industries Pvt.Ltd.							0			0	0	0			yes		10.90	
97	Bhawani Plasto Udhyog							0			0	0	0			yes		11.50	
98	R.K. Plastic Pvt.Ltd. - 1							0			0	0	0			yes		11.00	
99	Shree Asian Pipe and Polymers Udhyog							0			0	0	0			yes		10.80	
100	R.K. Plastic Pvt.Ltd. - 2							0			0	0	0			yes		11.00	
101	Surya Food Processing Industries							0			0	0	0			yes		10.50	
102	Shyamlal and Sons Industries Pvt.Ltd.	24	19	200000	15	10	0.1315	26294.7554	25000	7	108500	159794.755	1920	159794.755	83.22644		yes	11.00	
103	Nepal Frozen Centre Pvt.Ltd.	62	38	600000	15	10	0.1315	78884.2661	40000	14	217000	335884.266	4960	335884.266	67.7186	yes		10.50	
104	Triveni Top Kitchen Industries	82.5	66	800000	15	10	0.1315	105179.022	45000	16	248000	398179.022	6600	398179.022	60.33015		yes		
105	Shree Gadhimai Plastic Udhyog - 2							0			0	0	0			yes		10.00	

106	Aadhunik Dairy Pvt.Ltd.	125	72	1200000	15	10	0.1315	157768.532	50000	24	372000	579768.532	10000	579768.532	57.97685	yes		10.50	
107	Himalayan Polymers Industries							0			0	0	0			yes		11.00	
108	M.N. Plastic Udhyog							0			0	0	0			yes		10.60	
109	Sarvottam Plastic and Products Pvt.Ltd.							0			0	0	0				yes		
110	National Plastic Industry Pvt.Ltd.							0			0	0	0			yes		10.50	
111	Shree Bindabasini Plastic Udhyog (1)	200	80	2000000	15	10	0.1315	262947.554	150000	45	697500	1110447.55	16000	1110447.55	69.40297	yes		11.00	
112	Prashanna Plastic Udhyog															yes		10.00	
113	Valley Foods Pvt.Ltd.																yes		
114	British Color Industry Pvt.Ltd.															yes		10.00	
SUM:													**918964**	**46805910.1**	**3184.309**			**1025.80**	
LOSS PER HOUR OF ELECTRICITY OUTAGE:													**50.93334456**					**11.03**	

APPENDIX D: Detail Cost Estimate of Installing Separate VCB

S.N.	Particulars	Unit	Quantity	Rate (Rs.)	Rate with 13% VAT	Amount (NRs.)	Remarks
1	**HV Circuit Breaker**						
1.1	Supply, installation, testing & commisioning of indoor type cubical single panel, metal clad, dead front, fully drawout switchgear with motor operated spring closing mechanism (with over-current and earth fault protection relay facilities) as well as 3 phase 4 wire CT/PT (accuracy class:- 5P20 for relay & 0.5 for metering) operated Tri-vector energy meter for 12 kV, 3 phase, 50 Hz supply system, 630 A, 25kA (for 3 sec.) interrupting capacity VCB having following. Make:- Crompton / Siemens / ABB / Areva / Schneider / Alshom or Equivalent The switchgear panel having trip ckt supervision relay, auxiliary (O/C, E/F, S/C) relays with shunt trip coil as per requirement, CTs (two core, capacity:- 200-300-400-500/1 A), suitable PTs for the above system (arranged in seperate compartment top most point of the VCB cabinet-fixed type), measuring & indication instruments, digital multifuntction energy meter, master trip relay, antipumping relay, IDMT relay, 9kV LA panel mounting and all other necessary assosories as per IEC standard. Indicating Lamps to indicate OPEN, CLOSE, TRIP, SPRING CHARGED, TRIP CIRCUIT with protection as per requirements (IEC Standard).	Set	1	1,200,000.00	1,356,000.00	1,356,000.00	
1.2	Two set of 100Ah, 12V tubular battery (autocut system) with suitable two set 24V battery charger.	Set	1	60,000.00	67,800.00	67,800.00	
1.3	Chemical earthing using copper electrode, 50 kg back-fill compound chemical, 1 swg or equivalent down coductor and other necessary works acording to specification. (earthing resistance should be less than 5 Ohm by adding necessary parallel electrode)	Set	2	25,000.00	28,250.00	56,500.00	
	Grand Total:					**1,480,300.00**	

APPENDIX E: Detail Cost Estimate of Redundant Power Supply

S.N.	Particulars	Unit	Quanty	Rate (Rs.)	Rate with 13% VAT	Amount (NRs.)	Remarks
1	**11 kV Distribution Feeders (Double Circuit)**						
1.1	Supply and Stringing of 0.1 Sq.Inch ACSR Conductor	km	30	100,000.00	113,000.00	3,390,000.00	
1.2	Supply and Erection of 12 meter Steel Tubular pole (GI)	no.	80	35,000.00	39,550.00	3,164,000.00	
1.3	Supply and Fitting of Disc Insulator	set	30	1,650.00	1,864.50	55,935.00	
1.4	Supply and Fitting of Pin Insulator	no.	450	350.00	395.50	177,975.00	
1.5	Supply and Installation of stay set	set	10	4,000.00	4,520.00	45,200.00	
1.6	Supply and Fitting of 2300 mm MS Channel	set	160	2,650.00	2,994.50	479,120.00	
	Sub Total 1:					**7,312,230.00**	
2	**400 Sq.mm XLPE Cable**						
	Supply, Installation, Testing & Commisioning of following :						
2.1	11 kV 400 Sq.mm. 3 Core, Aluminium Conductor, XLPE Insulated Armoured Cable	Rm.	100	4,000.00	4,520.00	452,000.00	
2.2	11 kV Heat Shrinkable Type Cable Termination Kit (Indoor) for above Cable.	Set	2	7,000.00	7,910.00	15,820.00	
2.3	11 kV Heat Shrinkable Type Long Sleeve Cable Termination Kit (Outdoor) for above Cable.	set	2	7,000.00	7,910.00	15,820.00	
2.4	12 " HDPE Pipe	M	60	1,000.00	1,130.00	67,800.00	
	Sub Total 2:					**551,440.00**	

S.N.	Particulars	Unit	Quanty	Rate (Rs.)	Rate with 13% VAT	Amount (NRs.)	Remarks
3	**HV Circuit Breaker**						
3.1	Supply, installation, testing & commisioning of indoor type cubical single panel, metal clad, dead front, fully drawout switchgear with motor operated spring closing mechanism (with over-current and earth fault protection relay facilities) as well as 3 phase 4 wire CT/PT (accuracy class:- 5P20 for relay & 0.5 for metering) operated Tri-vector energy meter for 12 kV, 3 phase, 50 Hz supply system, 630 A, 25kA (for 3 sec.) interrupting capacity VCB having following. Make:- Crompton / Siemens / ABB / Areva / Schneider / Alshom or Equivalent The switchgear panel having trip ckt supervision relay, auxiliary (O/C, E/F, S/C) relays with shunt trip coil as per requirement, CTs (two core, capacity:- 200-300-400-500/1 A), suitable PTs for the above system (arranged in seperate compartment top most point of the VCB cabinet-fixed type), measuring & indication instruments, digital multifuntction energy meter, master trip relay, antipumping relay, IDMT relay, 9kV LA panel mounting and all other necessary assosories as per IEC standard. Indicating Lamps to indicate OPEN, CLOSE, TRIP, SPRING CHARGED, TRIP CIRCUIT with protection as per requirements (IEC Standard).	Set	2	1,200,000.00	1,356,000.00	2,712,000.00	
3.2	Two set of 100Ah, 12V tubular battery (autocut system) with suitable two set 24V battery charger.	Set	2	60,000.00	67,800.00	135,600.00	
3.3	Chemical earthing using copper electrode, 50 kg back-fill compound chemical, 1 swg or equivalent down coductor and other necessary works acording to specification. (earthing resistance should be less than 5 Ohm by adding necessary parallel electrode)	Set	2	25,000.00	28,250.00	56,500.00	
3.4	Lightining arrestor with rod earthing for cable	set	2	6,000.00	6,780.00	13,560.00	
	Sub Total 3:					**2,917,660.00**	
4	Supply and Fitting of 400 A heavy duty 11 kV isolator switches all compelete	set	2	25,000.00	28,250.00	**56,500.00**	
	Grand Total:					**10,837,830.00**	

APPENDIX F: Detail Cost Estimate of Creating Ring Main Between Feeders

S.N.	Particulars	Unit	Quanty	Rate (Rs.)	Rate with 13% VAT	Amount (NRs.)	Remarks
1	Supply and Stringing of 100 Sq.mm 11kV Grade Covered Conductor	Rm.	150	750.00	847.50	127,125.00	
2	Supply and Erection of 12 meter Steel Tubular pole (GI)	no.	10	35,000.00	39,550.00	395,500.00	
3	Supply and Fitting of Disc Insulator	set	30	1,650.00	1,864.50	55,935.00	
4	Supply and Fitting of Pin Insulator	no.	50	350.00	395.50	19,775.00	
5	Supply and Installation of stay set	set	4	4,000.00	4,520.00	18,080.00	
6	Supply and Fitting of 2300 mm MS Channel	set	15	2,650.00	2,994.50	44,917.50	
7	GI Triangle Bracket for DS	Pcs.	15	2000.00	2260.00	33,900.00	
	Supply, Installation, Testing & Commisioning of following :						
8	11 kV 400 Sq.mm. 3 Core, Aluminium Conductor, XLPE Insulated Armoured Cable	Rm.	40	4,000.00	4,520.00	180,800.00	
9	11 kV Heat Shrinkable Type Long Sleeve Cable Termination Kit (Outdoor) for above Cable.	set	6	7,000.00	7,910.00	47,460.00	
10	Remaining Installation Charges	lot	1	500,000.00	565,000.00	565,000.00	
	Sub Total 1:					**1,488,492.50**	
10	Supply and Fitting of 400 A heavy duty 11 kV isolator switches all compelete	set	5	25,000.00	28,250.00	**141,250.00**	
	Grand Total:					**1,629,742.50**	

APPENDIX G: Electrical Transient Analyzer Program

Electrical Transient Analyzer Program

Reliability Analysis

	Total
Number of Buses:	230 (case 0)
	230 (case 1)
	231 (case 2)
	189 (case 3)

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	SPDT	Total
Number of Branches:	76	0	0	149	0	5	0	230 (case 0)
	76			149		5		230 (case 1)
	76			151		5		232 (case 2)
	39			146		6		191 (case 3)

	Synchronous Generator	Power Grid	Inverter	Total
Number of Sources:	0	1	0	1 (case 0)
		1		1 (case 1)
		2		2 (case 2)
		1		1 (case 3)

	Synchronous Motor	Induction Machines	Static Load	Lumped Load	Total
Number of Loads:	0	0	0	83	83 (case 0)
				83	83 (case 1)
				83	83 (case 2)
				46	46 (case 3)

System Frequency: 50 Hz
Unit System: Metric
Project Filename: Balaju Industrial Area

Bus Input Data

Bus		λA	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time
ID	kV	f / yr	λA%	hour	hour	Yes/No	hour
Bus (HT)	11.000	0.0010	80.00	2.00	2.00	No	10.00
Bus (LT)	0.400	0.0010	80.00	2.00	2.00	No	10.00

Branch Input Data

Cable/Line ID	Cable/Line Type	λA f / yr	λP f / yr	Momentary Rate λA%	MTTR hour	Switch Time hour	Replacement Avail. Yes/No	Replacement Time hour	Unit Length for λA & λP	Length	Unit
OH Line4	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	150.00	m
OH Line8	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	100.00	m
OH Line10	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line14	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	400.00	m
OH Line16	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	200.00	m
OH Line18	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	70.00	m
OH Line28	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	120.00	m
OH Line34	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	80.00	m
OH Line40	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	32.93	m
OH Line48	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	80.00	m
OH Line49	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	200.00	m
OH Line50	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	13.12	m
OH Line53	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	50.00	m
OH Line57	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	100.00	m
OH Line60	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line64	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	10.01	m
OH Line63	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	29.32	m
OH Line68	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	36.08	m
OH Line71	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line75	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	13.21	m
OH Line76	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line82	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
OH Line83	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	50.00	m
OH Line89	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line304	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
Line14	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	1.00	km
OH Line345	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line348	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	25.00	m
OH Line346	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	80.00	m
OH Line347	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
Line15	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	120.00	m
OH Line340	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line329	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
OH Line332	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	10.00	m
OH Line311	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line343	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line354	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line344	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	10.00	m
OH Line327	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	10.00	m
OH Line330	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	50.00	m

Cable/Line ID	Type	λA f / yr	λP f / yr	Momentary Rate λA%	MTTR hour	Switch Time hour	Replacement Avail. Yes/No	Replacement Time hour	Unit Length for λA & λP	Length	Unit
OH Line339	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	90.00	m
Line7	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line312	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line342	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	36.09	m
OH Line341	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	60.00	m
Line8	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	90.00	m
OH Line316	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	26.09	m
OH Line331	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	78.78	m
OH Line333	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line317	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line318	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	60.00	m
OH Line203	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line202	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	56.79	m
OH Line198	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line206	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	120.00	m
OH Line211	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	35.21	m
OH Line244	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	37.67	m
OH Line246	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	22.86	m
OH Line276	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
OH Line243	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	44.79	m
OH Line284	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	5.00	m
OH Line242	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	37.63	m
OH Line241	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	74.59	m
OH Line240	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
OH Line280	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	46.88	m
OH Line281	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	26.69	m
OH Line239	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	210.50	m
OH Line248	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
Line11	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	60.00	m
OH Line262	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	15.81	m
OH Line279	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	52.13	m
OH Line300	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	12.80	m
OH Line260	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
OH Line289	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	65.00	m
OH Line264	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	13.13	m
OH Line278	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	5.00	m
OH Line290	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
OH Line259	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	40.00	m
OH Line359	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	35.21	m
OH Line362	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	30.00	m
Line9	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	90.00	m
Line10	Line	0.0500	0.0500	80.00	8.00	8.00	No	8.00	km	20.00	m
UG Cable18	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	70.00	m

Cable/Line		λA	λP	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time	Unit Length		
ID	Type	f / yr	f / yr	λA%	hour	hour	Yes/No	hour	for λA & λP	Length	Unit
UG Cable5	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	150.00	m
Cable55	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	15.00	m
Cable56	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	30.00	m
Cable57	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	15.00	m
Cable58	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	20.00	m
Cable59	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable60	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable61	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	80.00	m
Cable62	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	20.00	m
Cable63	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	60.00	m
Cable64	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable65	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable66	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	40.00	m
Cable67	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	40.00	m
Cable68	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	30.00	m
Cable69	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable70	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable71	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable37	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable33	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable34	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	35.00	m
Cable35	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable (Coke)	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable36	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable38	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable39	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	15.00	m
Cable31	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable (ABC)	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable24	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	35.00	m
Cable23	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable36 (UG)	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	70.00	m
Cable32	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	40.00	m
Cable50	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
UG Cable52	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	80.00	m
Cable30	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	20.00	m
Cable28	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable27	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	100.00	m
Cable26	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	70.00	m
Cable25	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	15.00	m
UG Cable44	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	75.00	m
Cable40	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable41	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable18	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	40.00	m

Cable/Line		λA	λP	Momentary Rate	MTTR	Switch Time	Replacement		Unit Length		
							Avail.	Time			
ID	Type	f / yr	f / yr	λA%	hour	hour	Yes/No	hour	for λA & λP	Length	Unit
Cable16	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable53	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	40.00	m
Cable52	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	30.00	m
Cable20	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	20.00	m
Cable47	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	45.00	m
Cable45	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable54	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable22	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	60.00	m
Cable46	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable51	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	20.00	m
Cable49	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	100.00	m
Cable48	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	25.00	m
Cable44	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	10.00	m
Cable43	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	60.00	m
Cable4	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	70.00	m
Cable7	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	75.00	m
Cable14	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	50.00	m
Cable42	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	30.00	m
3*400 UG Cable - 1	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	988.00	m
3*400 UG Cable - 2	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	988.00	m
3*300 UG Cable	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	30.00	m
3*400 UG Cable - 3	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	988.00	m
3 *400 UG Cable	Cable	0.0200	0.0200	80.00	25.00	30.00	No	8.00	km	80.00	m

Transformer		λA	λP	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time
ID	Type	f / yr	f / yr	lA%	hour	hour	Yes/No	hour
T (Number)	2W XFMR	0.0150	0.0000	80.00	200.00	200.00	No	10.00

Switching Device Input Data

Switching Device			λA	λP	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time
ID	Type	Status	f / yr	f / yr	λA%	hour	hour	Yes/No	hour
SW (Number)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
Link Switch (4)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
NEA VCB (BID 1)	HVBreaker		0.0030	0.0045	80.00	54.20	54.20	No	3.90
BID S/S VCB - 2	HVBreaker		0.0030	0.0045	80.00	54.20	54.20	No	3.90
BID S/S VCB - 1	HVBreaker		0.0030	0.0045	80.00	54.20	54.20	No	3.90
BID S/S VCB - 3	HVBreaker		0.0030	0.0045	80.00	54.20	54.20	No	3.90
Link Switch (3)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
SW211	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
Link Switch (F3-2)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
Link Switch (F3 -1)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
Fuse (Number)	Fuse		0.0030	0.0020	80.00	30.00	30.00	No	10.00
Link Switch (2)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
Link Switch (1)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
SW (F2, F3)	Switch		0.0030	0.0020	80.00	50.00	50.00	No	10.00
NEA VCB (BID 2)	HVBreaker		0.0030	0.0045	80.00	54.20	54.20	No	3.90

Switching Device			λA	λP	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time
ID	Type	Status	f / yr	f / yr	λA%	hour	hour	Yes/No	hour
New VCB (Proposed)	HVBreaker		0.0030	0.0045	80.00	30.00	54.20	No	3.90
CB (Number)	LVBreaker		0.0030	0.0045	80.00	50.00	50.00	No	10.00

Load Input Data

Load					No. of	λA	Momentary Rate	MTTR	Replacement Avail.	Replacement Time
ID	Type	Connected Bus ID	kW	Sector	Loads	f / yr	λA%	hour	Yes/No	hour
LT Industries (4)	LumpLd	Bus20	85.00	None	1	0.0200	80.00	50.00	No	10.00
LT Industries (3)	LumpLd	Bus18 (S/S 2)	170.00	None	1	0.0200	80.00	50.00	No	10.00
LT Industries (2)	LumpLd	Bus18 (S/S 2)	170.00	None	1	0.0200	80.00	50.00	No	10.00
LT Industries (1)	LumpLd	Bus18 (S/S 2)	85.00	None	1	0.0200	80.00	50.00	No	10.00
LT Industries (5)	LumpLd	Bus20	170.00	None	1	0.0200	80.00	50.00	No	10.00
LT Industries (6)	LumpLd	Bus20	170.00	None	1	0.0200	80.00	50.00	No	10.00
DDC	LumpLd	Bus24	551.65	None	1	0.0200	80.00	50.00	No	10.00
Annapurna Pet Bottles P L	LumpLd	Bus611	181.05	None	1	0.0200	80.00	50.00	No	10.00
BID Complex	LumpLd	Bus39	85.00	None	1	0.0200	80.00	50.00	No	10.00
Quality Feed & Cold - 1	LumpLd	Bus51	119.00	None	1	0.0200	80.00	50.00	No	10.00
Naman Cutting Plastic Ind	LumpLd	Bus52	145.35	None	1	0.0200	80.00	50.00	No	10.00
Kohinoor Cold Storage - 3	LumpLd	Bus61	238.85	None	1	0.0200	80.00	50.00	No	10.00
Kohinoor Cold Storage - 2	LumpLd	Bus63	212.50	None	1	0.0200	80.00	50.00	No	10.00
Himalayan Multiplast - 2	LumpLd	Bus71	340.00	None	1	0.0200	80.00	50.00	No	10.00
Himalayan Multiplast - 1	LumpLd	Bus73	340.00	None	1	0.0200	80.00	50.00	No	10.00
S/S 1 - F1	LumpLd	Bus83	85.00	None	1	0.0200	80.00	50.00	No	10.00

Nepal Argano Rubbers P L	LumpLd	Bus94	183.60	None	1	0.0200	80.00	50.00	No	10.00
Kohinoor Cold Storage - 1	LumpLd	Bus96	277.95	None	1	0.0200	80.00	50.00	No	10.00
Himal Oxygen Pvt. Ltd.	LumpLd	Bus104	369.75	None	1	0.0200	80.00	50.00	No	10.00
Kiran Shoes Manufacturers	LumpLd	Bus106	850.00	None	1	0.0200	80.00	50.00	No	10.00
National Ice-cream P. L.	LumpLd	Bus113	255.00	None	1	0.0200	80.00	50.00	No	10.00
Nebico Pvt. Ltd.	LumpLd	Bus118	1360.00	None	1	0.0200	80.00	50.00	No	10.00
Monaj Offset Press P. L.	LumpLd	Bus124	136.00	None	1	0.0200	80.00	50.00	No	10.00
High Plast Poly Product	LumpLd	Bus130	272.00	None	1	0.0200	80.00	50.00	No	10.00
Wow Snacks Pvt. Ltd.	LumpLd	Bus136	72.25	None	1	0.0200	80.00	50.00	No	10.00
Modern Slipper P. L. 2	LumpLd	Bus141	637.50	None	1	0.0200	80.00	50.00	No	10.00
Hisi Polythene & Plastic	LumpLd	Bus148	212.50	None	1	0.0200	80.00	50.00	No	10.00
Balaju Yantrashala P. L.	LumpLd	Bus150	119.00	None	1	0.0200	80.00	50.00	No	10.00
Plastic Udhyog P. L.	LumpLd	Bus156	178.50	None	1	0.0200	80.00	50.00	No	10.00
Nepal Polypipe P.L.	LumpLd	Bus492	170.00	None	1	0.0200	80.00	50.00	No	10.00
S/S 1 - F2	LumpLd	Bus83	170.00	None	1	0.0200	80.00	50.00	No	10.00
S/S 1 - F3	LumpLd	Bus83	170.00	None	1	0.0200	80.00	50.00	No	10.00
Monaj Printing House P.L.	LumpLd	Bus124	42.50	None	1	0.0200	80.00	50.00	No	10.00
Bolltlers Nepal Ltd.	LumpLd	Bus527	1062.50	None	1	0.0200	80.00	50.00	No	10.00

Hilltake Plastic & Pipe	LumpLd	Bus531	212.50	None	1	0.0200	80.00	50.00	No	10.00
Maa Pathivara Process Ind	LumpLd	Bus529	510.00	None	1	0.0200	80.00	50.00	No	10.00
Balaju Auto Works P.L.	LumpLd	Bus542	89.25	None	1	0.0200	80.00	50.00	No	10.00
Eco Rolling Mill	LumpLd	Bus544	85.00	None	1	0.0200	80.00	50.00	No	10.00
Mars Polymer Products P L	LumpLd	Bus513	148.75	None	1	0.0200	80.00	50.00	No	10.00
Nayeesa Plastic Udhyog	LumpLd	Bus523	234.60	None	1	0.0200	80.00	50.00	No	10.00
BSET (College)	LumpLd	Bus538	191.25	None	1	0.0200	80.00	50.00	No	10.00
Nepal Gas Udhyog P.L.	LumpLd	Bus525	201.45	None	1	0.0200	80.00	50.00	No	10.00
Balaju Metal Inds. P.L.	LumpLd	Bus546	119.00	None	1	0.0200	80.00	50.00	No	10.00
Kathmandu Maida Mill P.L.	LumpLd	Bus534	248.20	None	1	0.0200	80.00	50.00	No	10.00
Shree Polythene & Plastic	LumpLd	Bus536	170.00	None	1	0.0200	80.00	50.00	No	10.00
Shree Bindabasini Plastic	LumpLd	Bus517	170.00	None	1	0.0200	80.00	50.00	No	10.00
Balaji Highloft Non-oven	LumpLd	Bus521	212.50	None	1	0.0200	80.00	50.00	No	10.00
Atlas Pet Plas Inds. P.L.	LumpLd	Bus519	170.00	None	1	0.0200	80.00	50.00	No	10.00
Abhinash Industry P.L.	LumpLd	Bus501	88.40	None	1	0.0200	80.00	50.00	No	10.00
Guheshwori Rolling Mill	LumpLd	Bus499	145.35	None	1	0.0200	80.00	50.00	No	10.00
Hilltake Industries P. L.	LumpLd	Bus515	684.25	None	1	0.0200	80.00	50.00	No	10.00
Gadhimai Plastic Udhyog 1	LumpLd	Bus567	170.00	None	1	0.0200	80.00	50.00	No	10.00
Aqua Minerals Nepal P.L.	LumpLd	Bus505	170.00	None	1	0.0200	80.00	50.00	No	10.00

5 Industries	LumpLd	Bus507	85.00	None	1	0.0200	80.00	50.00	No	10.00
Valley Cold Store P. L.	LumpLd	Bus503	340.00	None	1	0.0200	80.00	50.00	No	10.00
J & R Enterprises P.L.	LumpLd	Bus329	297.50	None	1	0.0200	80.00	50.00	No	10.00
Nepal Chalchitra Company	LumpLd	Bus327	93.50	None	1	0.0200	80.00	50.00	No	10.00
Surya Food Processing	LumpLd	Bus331	89.25	None	1	0.0200	80.00	50.00	No	10.00
Gadhimai Plastic Udhyog-2	LumpLd	Bus343	170.00	None	1	0.0200	80.00	50.00	No	10.00
Shyamlal & Sons Inds. P L	LumpLd	Bus345	106.25	None	1	0.0200	80.00	50.00	No	10.00
Shakya Al Inds. P.L.	LumpLd	Bus353	266.05	None	1	0.0200	80.00	50.00	No	10.00
BSET (College) - 2	LumpLd	Bus355	34.43	None	1	0.0200	80.00	50.00	No	10.00
RK Plastic P.L. - 2	LumpLd	Bus360	680.00	None	1	0.0200	80.00	50.00	No	10.00
RK Plastic P.L. - 1	LumpLd	Bus385	403.75	None	1	0.0200	80.00	50.00	No	10.00
Quality Feed & Cold - 2	LumpLd	Bus446	639.20	None	1	0.0200	80.00	50.00	No	10.00
Aadhunik Dairy P.L.	LumpLd	Bus479	147.05	None	1	0.0200	80.00	50.00	No	10.00
Himalayan Polymers Inds.	LumpLd	Bus481	318.75	None	1	0.0200	80.00	50.00	No	10.00
MN Plastic Udhyog	LumpLd	Bus477	103.70	None	1	0.0200	80.00	50.00	No	10.00
Shree Bindabasini - 1	LumpLd	Bus398	212.50	None	1	0.0200	80.00	50.00	No	10.00
National Plastic Ind. P L	LumpLd	Bus450	212.50	None	1	0.0200	80.00	50.00	No	10.00
Gokul Industries P.L.	LumpLd	Bus463	137.70	None	1	0.0200	80.00	50.00	No	10.00
Valley Feed Industries	LumpLd	Bus444	127.50	None	1	0.0200	80.00	50.00	No	10.00

Load					No. of	λA	Momentary Rate	MTTR	Replacement Avail.	Replacement Time
ID	Type	Connected Bus ID	kW	Sector	Loads	f / yr	λA%	hour	Yes/No	hour
Modern Slipper Ind. PL -1	LumpLd	Bus422	425.00	None	1	0.0200	80.00	50.00	No	10.00
Jagdamba Polytank Inds.	LumpLd	Bus416	297.50	None	1	0.0200	80.00	50.00	No	10.00
Sarvottam Plastic & Pro.	LumpLd	Bus468	85.00	None	1	0.0200	80.00	50.00	No	10.00
Shree Asian Pipe & Plymrs	LumpLd	Bus383	510.00	None	1	0.0200	80.00	50.00	No	10.00
British Color Ind. P. L.	LumpLd	Bus420	72.25	None	1	0.0200	80.00	50.00	No	10.00
Bhawani Plasto Udhyog	LumpLd	Bus381	340.00	None	1	0.0200	80.00	50.00	No	10.00
Triveni Top Kitchen Inds.	LumpLd	Bus379	106.25	None	1	0.0200	80.00	50.00	No	10.00
Jay Hanuman Foods P.L.	LumpLd	Bus448	340.00	None	1	0.0200	80.00	50.00	No	10.00
Prashanna Plastic Udhyog	LumpLd	Bus418	143.65	None	1	0.0200	80.00	50.00	No	10.00
Nepal Frozen Centre P.L.	LumpLd	Bus377	137.70	None	1	0.0200	80.00	50.00	No	10.00
Shankar Oxygen Gas P.L.	LumpLd	Bus442	531.25	None	1	0.0200	80.00	50.00	No	10.00
CAP1	St Load	Bus18 (S/S 2)	0.00	None	1	0.0200	80.00	50.00	No	10.00
CAP3	St Load	Bus20	0.00	None	1	0.0200	80.00	50.00	No	10.00
CAP5	St Load	Bus83	0.00	None	1	0.0200	80.00	50.00	No	10.00

Source Input Data

Source			λA	Momentary Rate	MTTR	Switch Time	Replacement Avail.	Replacement Time
ID	Type	Connected Bus ID	f / yr	λA%	hour	hour	Yes/No	hour
132/66/11 kV Balaju S/S	Power Grid	Bus Main	0.6430	80.00	155.00	200.00	No	200.00
66/11 kV Lainchour S/S	Power Grid	Bus RL	0.6430	80.00	2.00	2.00	No	10.00

APPENDIX H: Paper Acceptance Mail (Publication)

Notifications ×

[IOEGC15] Editor Decision

2024-06-09 08:48 AM

Mitra Kumar Rai; Nava Raj Karki, Shahabuddin Khan:

We have reached a decision regarding your submission to 15th IOE Graduate Conference, "Reliability Assessment of Power Distribution System of Industrial Estate: A Case Study in Balaju Industrial Estate".

Our decision is to: **Accept Submission**

[*This email is auto-generated from 15th IOE Graduate Conference web portal*]

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Date: July 7, 2024

To Whom It May Concern:

This is to certify that the paper titled "***Reliability Assessment of Power Distribution System of Industrial Estate: A Case Study in Balaju Industrial Estate***" (Submission# **25**) submitted by **Mitra Kumar Rai** as the first author, which had been accepted for presentation after the peer-review process, has successfully been presented at the 15th IOE Graduate Conference held during May 17 & 18, 2024. Kindly note that the final revision of the papers and publication process of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon timely response to further edits during the publication process.

Bhim Kumar Dahal, PhD
Convener,
15th IOE Graduate Conference

IOE Graduate Conference
[Placeholder for
Publication
Information]

Reliability Assessment of Power Distribution System of Industrial Estate: A Case Study in Balaju Industrial Estate

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Abstract
The main task of distribution system is to provide acceptable reliability, economic and quality service of electricity according to the demanded load value. To fulfill this task more accurately, the reliability assessment of the distribution system can be performed and measured using a wide variety of reliability indices. This study evaluates the reliability indices of industrial distribution network, Balaju Industrial District, and deals with the reliability of four different network configurations (Case 0-1-2-3) to increase reliability and achieve more realistic results. Using ETAP, distribution networks are designed, comparisons are made. Reliability changes achieved by network configuration have demonstrated the importance of optimal configuration planning to improve the uninterrupted and sustainable energy quality of the system. In addition, cost of electricity outage, i.e. unserved energy cost, is estimated in this paper based on industrial consumer survey for the financial analysis from the reliability point of view. Outage cost is estimated by production loss method, backup generation method and willingness to pay method. The weighted average of production loss method and backup generation method has estimated overall cost of unserved energy of BID distribution system as Rs. 28.26 per kWh, this value has been used for ECOST calculation during reliability worth analysis. The base is taken case 0 which is the existing distribution system. Cases 1, 2 and 3 are separating of two 11kV feeders by separate VCBs, adding redundant power supply and interconnections between three 11kV feeders, i.e. creating ring main, respectively. Results have concluded that all three modifications improve the reliability of the system with financial gain. As these modifications have their own importances for the reliability enhancement from the industries point of view, this paper recommends the utility office, BIDMO, for the implementation of the modifications.

Keywords
Distribution Power System Reliability, Reliability Indices, Industrial Consumer Surveys, Cost of Unserved Energy, System Modifications

1. Introduction

The main task of electrical distribution power system is to provide consumers with affordable, quality and acceptable reliable and uninterrupted energy. Industrial consumers are critical consumers as they have to suffer economic losses due to insecure and unreliable power supply. Due to power outages, manufacturing industries have different losses, such as raw materials and finished products loss, idle workers costs loss, increase in maintenance cost, penalty due to not meeting the demand, etc. So, power security and reliable supply play vital role for manufacturing industrial processes. Occurrences of faults, schedule maintenance power shutdown, no proper management of supply-demand, etc. causes power outages to consumers. Some of the industries may have backup system to cover load, partial load or full load, during grid outage. Mostly, backup system is diesel generator. But the electricity prices from the generators may be higher than the prevailing electricity tariff. According to Nepal Electricity Authority, it has managed sufficient power capacity to meet the demand of country by its own generation, IPPs' generation and power purchase from India. But NEA is facing problems in transmission system and distribution system through which power is up to consumers utilization. Upgrading and construction of these systems are ongoing but delay in work completions due to many problems, such as public disturbances, disputes in land acquisition and forest, etc. So, due to poor and old infrastructures of transmission and distribution systems, they are not capable of meeting the day-by-day increasing demand of the consumers. This has also caused unexpected power outages in Nepal. NEA is rapidly working in enhancement and reinforcement of distribution systems.

Using the statistical and reliability theory of distribution networks, reliability indices are carried out on energy sustainability. Commonly used reliability indices, including SAIDI, SAIFI, ASAI, CAIDI, EENS, EIR, etc., are used to measure system reliability. In the unlikely event of energy supply, consumers can reduce losses by anticipating and reducing the likelihood of downtime during the day ahead or the day ahead of the planning process to avoid power outages. This economic gain is achieved by keeping EENS value at a minimum, which is achieved by using required ESS in unexpected power cuts[1]. Unexpected situations that reduce system reliability adversely affect system planning, which can lead to system failures, sudden load changes and adverse environmental conditions. Energy sustainability is very important as it does not experience disruptions such as power outages and the planning is directly affecting both costs and system reliability.

In this study, reliability assessment with worth analysis of the power distribution system of Balaju Industrial District. Ten industrial estates are in operation under the government company, Industrial District Management Limited. This research is also focused on the outage cost estimation. BID has three number of underground dedicated feeders, each nearly one kilometer long from Balaju substation of NEA with 7 MVA, 4.5 MVA and 3.5 MVA approved loads serving 157 customers under BIDMO. Almost 84% are industrial consumers and remaining are commercial and non-commercials types.

Research based on estimation of cost of unserved energy by customer survey approach in Kathmandu valley was previously done[2]. In this paper, the average outage cost for the industrial customer was estimated at Rs. 38.42 per kWh which is significantly higher than electricity rates and indicated the urgent need of enhancing the supply reliability. Only 1.31% of total consumers are industrial customers which contributes nearly 38.44% of revenue collection in Nepal (NEA report, F/Y 2022/2023). So, the concerned authorities have to focus on the secure and reliable supply to productive industries which has direct positive impact in the economic growth, i.e. GDP, of country. Paper on cost of unserved energy in Karnataka, India had used analytical methodologies to estimate the outage cost for industrial and agricultural sectors[3]. According to this paper, economic loss due to power outages in industrial sector varies between 0.04% to 0.17% of total state domestic product (SDP) depending upon size of industries. Among three analytical methods, it is found that the cost of unserved energy is Rs.22.1/kWh (from production loss method), Rs.2.63/kWh (from backup generation method) and Rs.4.89/kWh (from WtP method) in Indian currency. Neto et al., 2006 had calculated the reliability indices of radial feeder connecting the distributed generation on the distribution network aiming to achieve goals like loss minimization, interruption costs reduction and voltage profile correction[4]. Alekya et al. 2011 had analyzed and compared the reliability of rural, urban and industrial distribution feeder on basis of cost benefit analysis under manual control, under partial automated control and under fully automated control[5]. Integration of renewable distributed generation units into distribution networks for reliability improvement is gaining widespread popularity. The reliability assessment of distribution system with hybrid DG systems was undertaken considering optimal restoration strategies and system uncertainties[6].

2. Methodology

The methodology of reliability assessment of distribution power system of BID includes the following steps shown in figure below.

2.1 Industrial Consumers' Survey for Estimation of Cost of Unserved Energy

In general, the term unserved energy refers to supply interruptions or blackouts. It can be described as an estimate of the electricity that would otherwise have been used by customers but for a power cut and the cost of related to the unserved energy refers to the cost of expected energy not served. These supply interruptions may originate from various parts of the supply chain. This cost also refers to cost of alternative electricity supply during outage. Survey in productive industries of BID is done to estimate the cost of unserved energy. Following three analytical

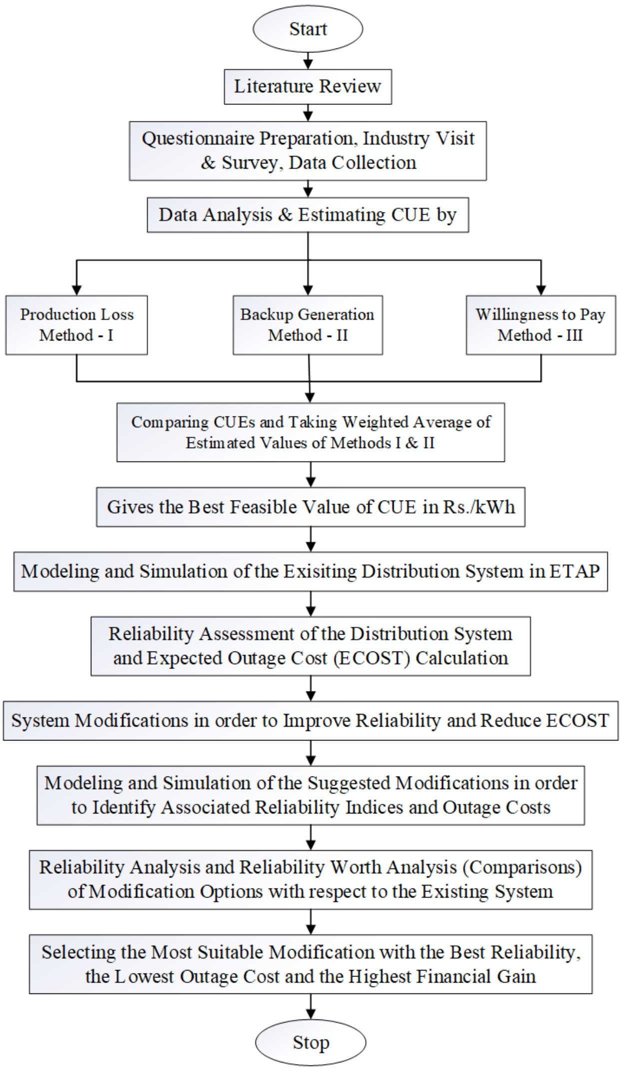


Figure 1: Flow Chart of Reliability Assessment Process

methods are used for data collection during survey for the estimation of outage cost.

2.1.1 Production Loss Method

In this method, data collected from industries from survey are raw materials and finished products loss, cost of idle workers due outage, increment of maintenance cost, penalty for not meeting the demand, annul electricity consumed, etc. and value of production loss per hour of electricity outage is calculated for the estimation of outage cost. Calculation of production loss per unit of power outage of the i^{th} industry, unit is Rs./kWh, is given by,

$$L_i = \frac{\left(\frac{production\ loss\ value\ in\ Rs.}{annual\ outage\ hours}\right)_i}{\left(\frac{annual\ electricity\ consumed\ from\ grid}{annual\ hours\ of\ electrcity\ available\ from\ grid}\right)_i} \tag{1}$$

The weighted average of L_i in Rs./kWh is represented by L and calculated as,

$$L = \frac{\sum_i L_i U_i}{\sum U_i} \tag{2}$$

Here, U is the annual energy consumption from NEA supply and its unit is kWh.

2.1.2 Backup Generation Method

This method is applied for those industries having fully operated backup supply in case of power outage. It provides clear and transparent value of a unit of electricity by backup power supply. Collected data from survey includes capacity of backup supply, its capital cost, annual maintenance cost, fuel consumption per hour, etc. Cost of backup power generation for the i^{th} industry using j^{th} backup unit in Rs. / kWh is given by,

$$C_{ij} = \frac{(C_A + M_A + F_A)_{ij}}{(total\ unit\ of\ electricity\ generated\ annually)_{ij}} \tag{3}$$

Where C_A, M_A and F_A are annual capital cost, annual maintenance cost and annual fuel cost respectively. Here, annual capital cost is the product of capital cost of backup power supply system in Rs. and capital recovery factor.

If 'r' is annual interest rate and 'n' is total life of j^{th} backup supply system in year, then capital recovery factor is given by,

$$R_j = \frac{r}{1-(1+r)^{-nj}} \tag{4}$$

The weighted average of economic cost of backup power generation in unit Rs. / kWh is calculated by,

$$C = \frac{\sum_{ij} C_{ij} U_{ij}}{\sum_{ij} U_{ij}} \tag{5}$$

Here, U is the annual energy generated by backup system, unit is kWh.

2.1.3 WtP Method

It is willingness to pay method. It gives industries' perception to pay higher tariff than prevailing electricity rates for secure and reliable electricity supply. This method is bidding process for electricity rates. In this method, current electricity price is taken as the minimum rate. During survey, questions "Are you willing to pay more per kWh?" and "What is your bid value for this?" are asked to industry. The mid-price between the highest accepted rate and the lowest rejected rate is the bid value. For example, if industry says 'Yes' to Rs.10 per kWh but no to Rs.11 kWh, the bid has taken as Rs. 10.5 kWh. All the industries may not participate in this method, i.e. may be not ready to pay higher cost of electricity than the prevailing rate.

2.1.4 Distribution System Cost of Unserved Energy and Economic Loss due to Power Outages

The weighted average value of outage costs estimated by production loss method and backup generation method gives the industrial distribution system cost of unserved energy given as below:

$$CUE = \frac{LU_l + CU_g}{\sum U_i} \quad (6)$$

Where L is CUE estimated from production loss method, U_l is Annual energy consumption of industries having production losses due to power cuts, C is CUE estimated from backup generation method, C_g Annual energy consumption of industries surveyed during method II and U_i Annual energy consumption of each responding industry. The annual expected energy not served (EENS) of distribution system is estimated from its average load and annual outage duration as given below:

$$EENS = \sum AverageLoad * OutageDuration \quad (7)$$

Also, EENS is the summation of the products of average load of distribution system and unreliability of the system. The unit of EENS is MWh/year. After the estimation of cost of unserved energy and expected energy not served, then we can calculate the annual economic loss in Rs. due to power outages in distribution system given by,

$$ECOST = Expected\,Energy\,Not\,Served * Outage\,Cost \quad (8)$$

2.2 Reliability Indices Evaluation

There are two index groups to evaluate the reliability performance of distribution system, viz., the system index and the customer load point index. The definition and evaluation of reliability indices are as follows:

1. System Average Interruption Frequency Index (SAIFI)

   It is defined as the average number of interruptions customer has experienced during study period. It is the ratio of total number of interrupted customers by total number of customers served.

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i}\ f/cust.yr. \quad (9)$$

2. System Average Interruption Duration Index (SAIDI)

$$SAIDI = \frac{\sum U_i N_i}{\sum N_i}\ hr/cust.yr. \quad (10)$$

3. Customer Average Interruption Duration Index (CAIDI)

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i}\ hr/cust.int. \quad (11)$$

4. Average Service Availability Index (ASAI)

$$ASAI = \frac{\sum N_i * 8760 - \sum U_i N_i}{\sum \lambda_i N_i}\ pu \quad (12)$$

5. Average Service Unavailability Index (ASUI)

$$ASUI = 1 - ASAI\ pu \quad (13)$$

6. Energy Index of Reliability (EIR)

$$EIR = \frac{TotalEnergyServed}{TotalEnergyServed + EENS}\ pu \quad (14)$$

7. Energy Index of Unreliability (EIU)

$$EUI = 1 - EIR\ pu \quad (15)$$

2.3 Modeling, Simulation and Data Analysis

In this paper, industrial distribution system modeling and simulation for reliability assessment is done is ETAP software and EXCEL is used for results analysis.

Series of sets of different electrical components, such as, transformers, protection devices, fuses, circuits breakers, capacitor banks, lightning arresters, cables, conductors, insulators, disconnectors, isolators, metering units, loads, etc. Real field data of these components has been taken for the modeling, simulation and data analysis.

2.4 ETAP as the Modeling Tool

ETAP is the most comprehensive analysis platform for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. It creates and tests electrical power systems in a full simulation environment with access to tools for designing and adjusting all kinds of objects and structures with real-time load flow analysis, reliability analysis, short-circuit analysis, motor acceleration analysis, harmonic analysis and transient stability analysis. ETAP is developed with various features which aim to provide users with intelligent power visual monitoring, system optimizations, energy management, automation and forecasting. ETAP is a fully functional analysis tool which can be used for analyzing any of the AC/DC electrical power system.

ETAP is trustworthy, consistent and dependable tool for reliability assessment. Advanced distribution reliability assessment provides engineers with an efficient and effective tool for estimating the performance of power system. Using flexible input parameters, results can be quickly obtained for both radial and looped systems. Powerful calculation techniques allow engineers to choose the depth of system design and the associated results.

It helps to make confident decisions with reliable results. In ETAP, we can model reliability characteristics of each component, implement user-defined parameters and settings, calculate load point reliability indices, bus reliability indices, system reliability indices and reliability energy Indices, etc. It is also useful for plotting and reporting. Reporting includes graphical display of reliability results, load point and bus reliability indices, system reliability indices, EENS and ECOST sensitivity analysis, access databases of output results, export output reports to our favorite word processor, export one-line diagrams with results to third party CAD systems.

Due to all reliability assessment related features, ETAP software is chosen as the modeling tool in this thesis. Furthermore, similar other analysis like load flow analysis, short circuit analysis, transient stability analysis, etc. of distribution system of Balaju Industrial Estate can be done in the created design or model of Balaju Industrial Estate as actual in the real field.

3. Results and Discussion

3.1 Distribution System Modeling

There are 3, 11kV dedicated feeders from 132kV Balaju S/S, NEA to BID S/S – each around 1 km long underground radial feeder supplying power to 157 different consumers inside the industrial estate. This radial distribution system up to 11kV 400/5 A metering units at BID premises is owned by NEA, Balaju DCS. These feeders after entering into BID S/S is owned and operated by BIDMO. Large industries having approved load > 100 kVA have their own step-down transformers (11/0.4 kV), whereas small and cottage industries have power supply from the BIDMO owned transformers. These existing distribution system with its networks details are shown in figures 2, 3, 4, 5 and 6 below.

3.2 Distribution System Outage Duration

For system outage record details, data have been obtained from NEA, Kathmandu Grid Division, Balaju S/S, Balaju DCS and BIDMO S/S log sheets. Last one-year trip data are used (from 2079 Magh to 2080 Magh) for the calculation of average outage duration. Details are shown below in table 1.

The average outage duration of the whole distribution system is found to be 100 hr./yr. During the one-year study period, NEA has cut-off power supply of BID five times during peak time of dry season. Electrical line was cut-off 3 hours per day (per time). This was like undeclared load shedding in the industrial estate.

3.3 Reliability Assessment of Different Network Configurations

Following four cases are studied.

3.3.1 Case 0: Existing Distribution System

ETAP simulation of the existing and operating distribution system of Balaju Industrail Estate is shown in Figure 7.

3.3.2 Case 1: Separating 4.5 MVA Feeder and 3.5 MVA Feeder in NEA S/S by Installing Separate VCB

There are only two VCBs, one for the 7 MVA feeder and other for 3.5 MVA and 4.5 MVA feeders in Balaju S/S, NEA. Due to having only one VCB for two feeders, problems have been faced by the respective industries. If there is fault in any one feeder in between NEA S/S and BID S/S, both feeders (one

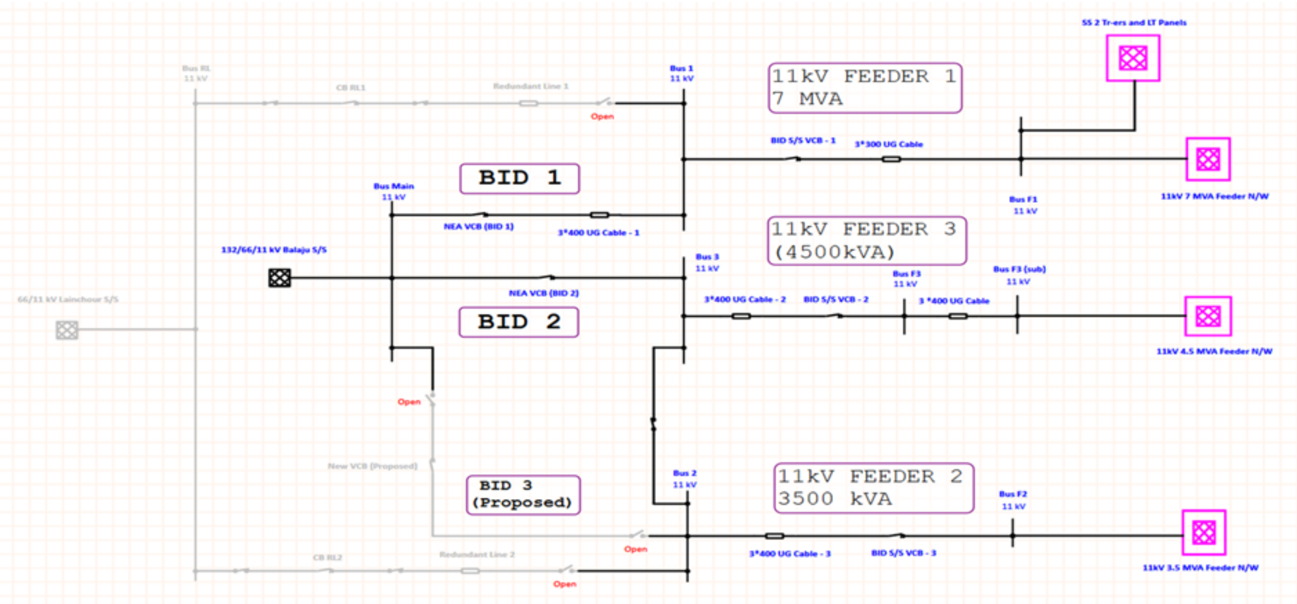


Figure 2: Existing Distribution System of BID

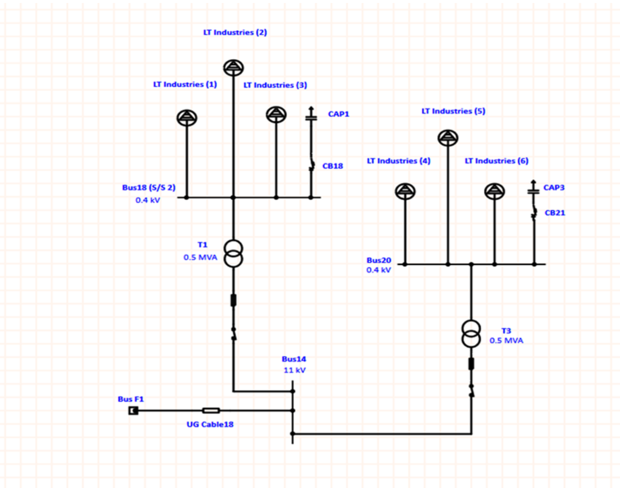


Figure 3: Composition of S/S Transformers and LT Panels Network

healthy and other faulted) have to be kept in shutdown during the maintenance period. If there occurs problem in the NEA VCB, both feeders suffer tripping. If we have to take NEA shutdown for the maintenance (VCB maintenance, NEA metering unit maintenance, etc.) of any one feeder, another feeder also suffers shutdown. In case of high stage faults in any one feeder, BID VCB including NEA VCB trip causing the healthy feeder electricity outage too. In this case, industries related to the healthy feeder have to face unwanted electricity interruption resulting financial losses, sometimes equipment damages also. Hence, idea of separate VCB for separate feeders has been proposed in this case for study from the reliability point of view. ETAP simulation of this case is shown in Figure 8.

3.3.3 Case 2: Adding Redundant Power Supply

In this case, redundant supply is suggested to add with an existing distribution system from 66kV Lainchour substation to improve the reliability. The suggested redundant supply is able to supply whole distribution system load in case of main radial distribution system is no longer able to supply the power. ETAP simulation of this case is shown in Figure 9.

3.3.4 Case 3: Creating Ring Main Between Feeders

In general, all the feeders are not shutdown simultaneously and if happens, only for very short period. Also, faults do not occur simultaneously in all feeders. It's generally one time in one feeder. Depending upon to faults type, feeder shutdown period may be very long and the critical industries, such as, medical oxygen plants, cold storages, dairy plants, food and drinking water plants, etc. suffer. For the continuous supply of power to these critical industries, ring main between feeders is created installing isolators as one or two feeders are always in operation. In this case, power is supplied only to the critical industries considering the loading capacity of operating feeder or feeders. ETAP simulation of this case is shown in Figure 10.

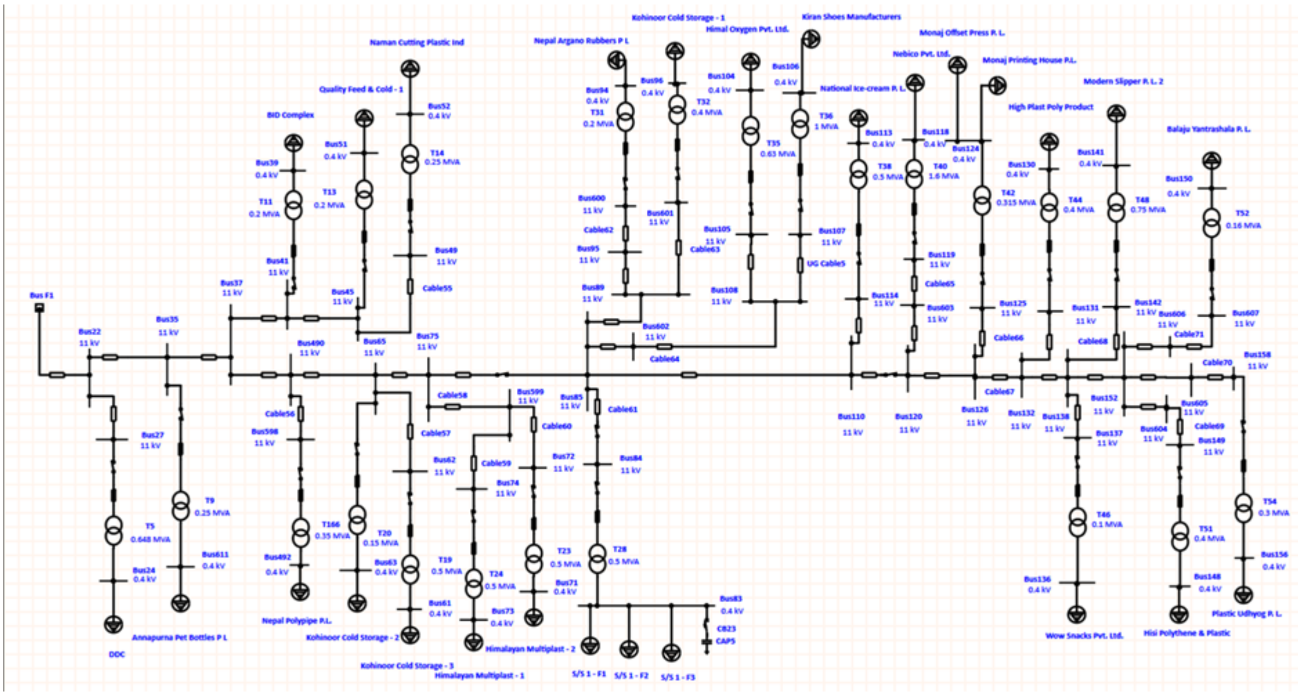


Figure 4: 11kV 7 MVA Feeder Network

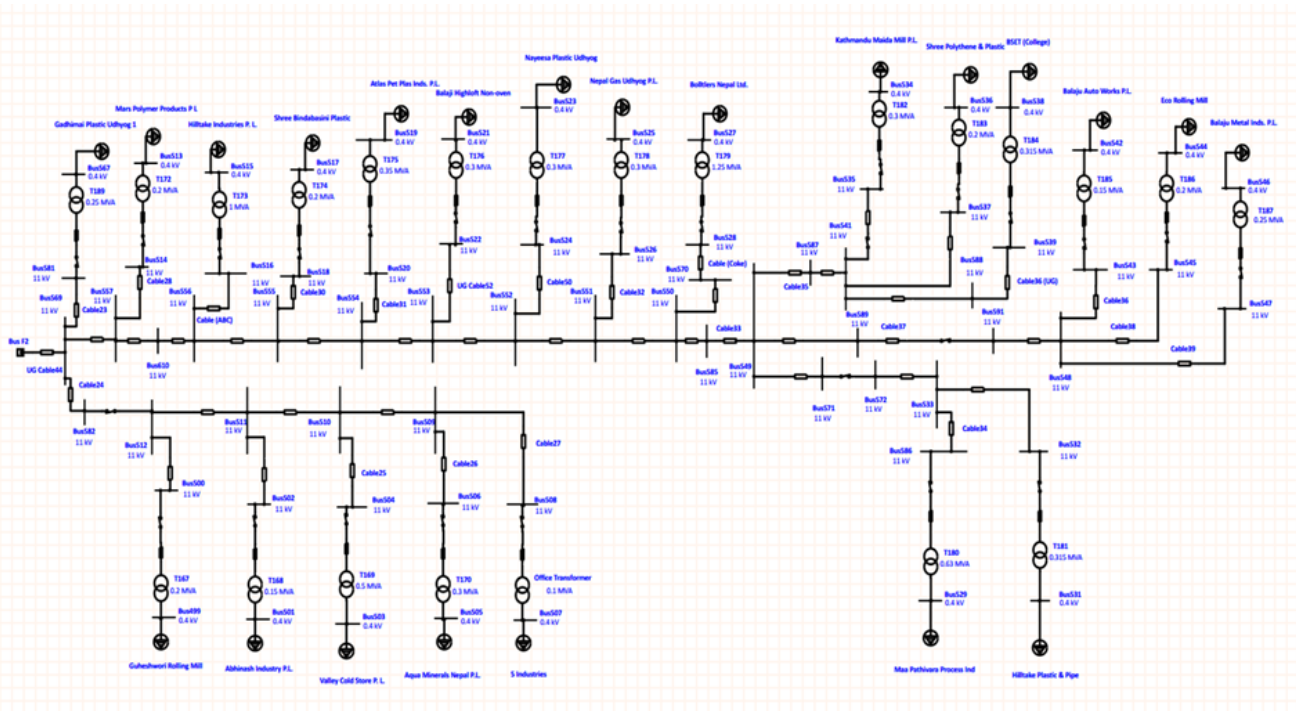


Figure 5: 11kV 3.5 MVA Feeder Network

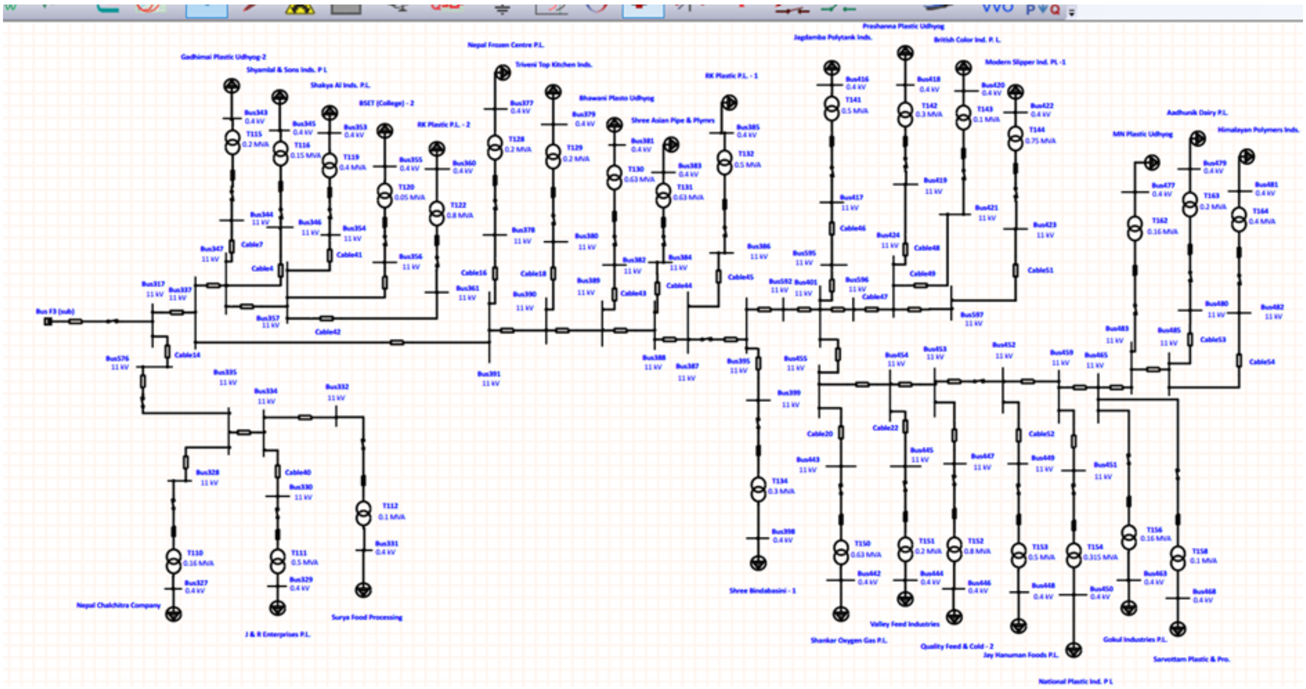


Figure 6: 11kV 4.5 MVA Feeder Network

3 BID Feeders	No. of Auto Trip Fault Types					No. of Manual Trips for Maintenance	No. of Undeclared Load Shedding in Dry Season	Electricity Outage Duration, minutes		
	Three Phase OC Protection			Earth Fault Protection						
	Low Stage: 3I >	High Stage: 3I >>	Instantaneous Stage: 3I >>>	Low Stage: Io >	High Stage: Io >>			Auto	Manual	Load Shedding
NEA S/S VCB	9	16		74	20	48	15	2228	1952	2700
BID S/S VCB	35	42		230	53	244		4315	6816	
Total:-	**44**	**58**		**304**	**73**	**292**	**15**	**6543**	**8768**	**2700**
Total Outage Duration (hrs./yr.):								**300.1833333**		
Average Outage Duration of the whole distribution System (hrs./yr.):								**100**		

Table 1: Tripping and Outage Duration Details

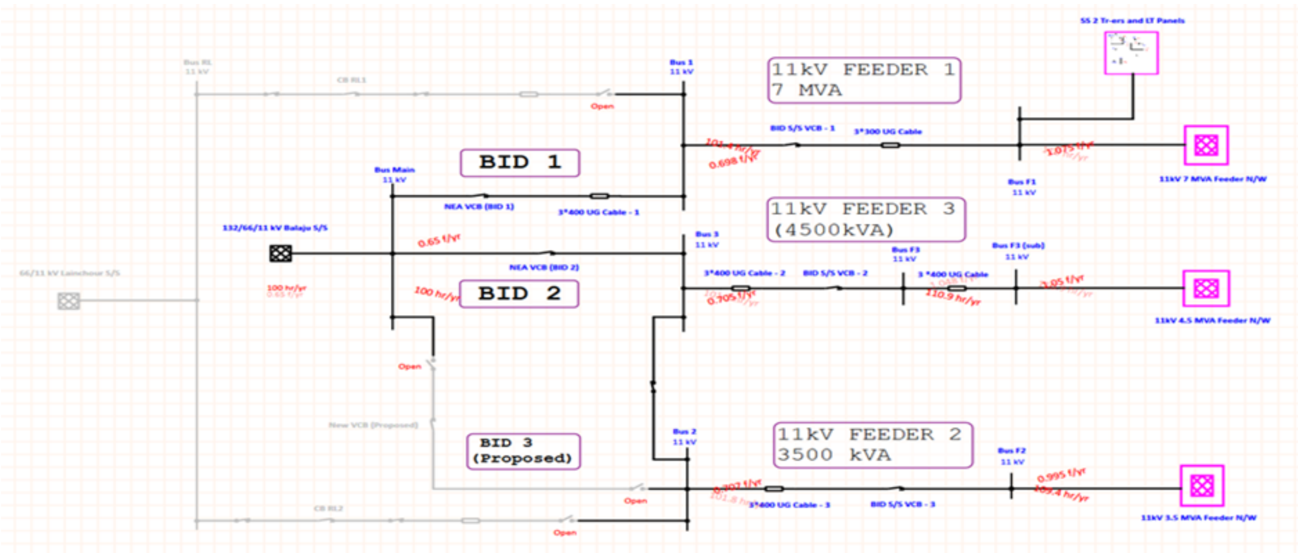


Figure 7: Simulation of Existing Distribution System

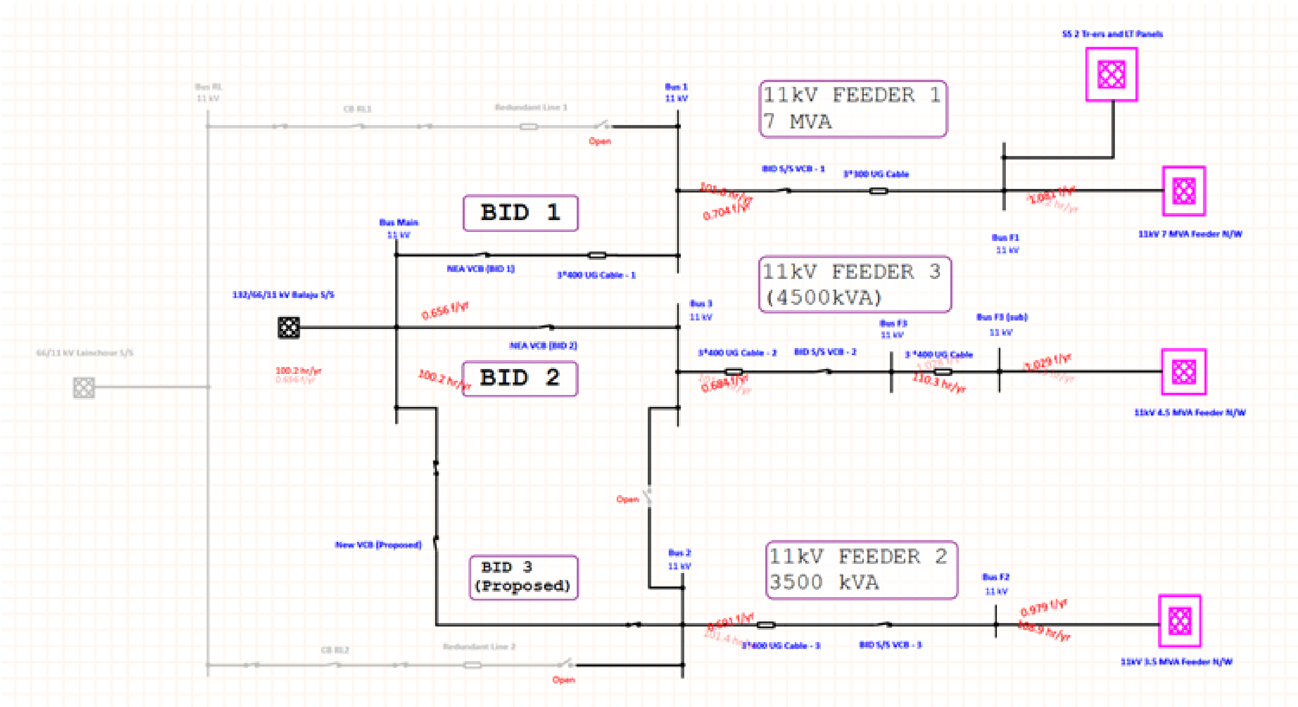


Figure 8: Modeling and Simulation of Case 1

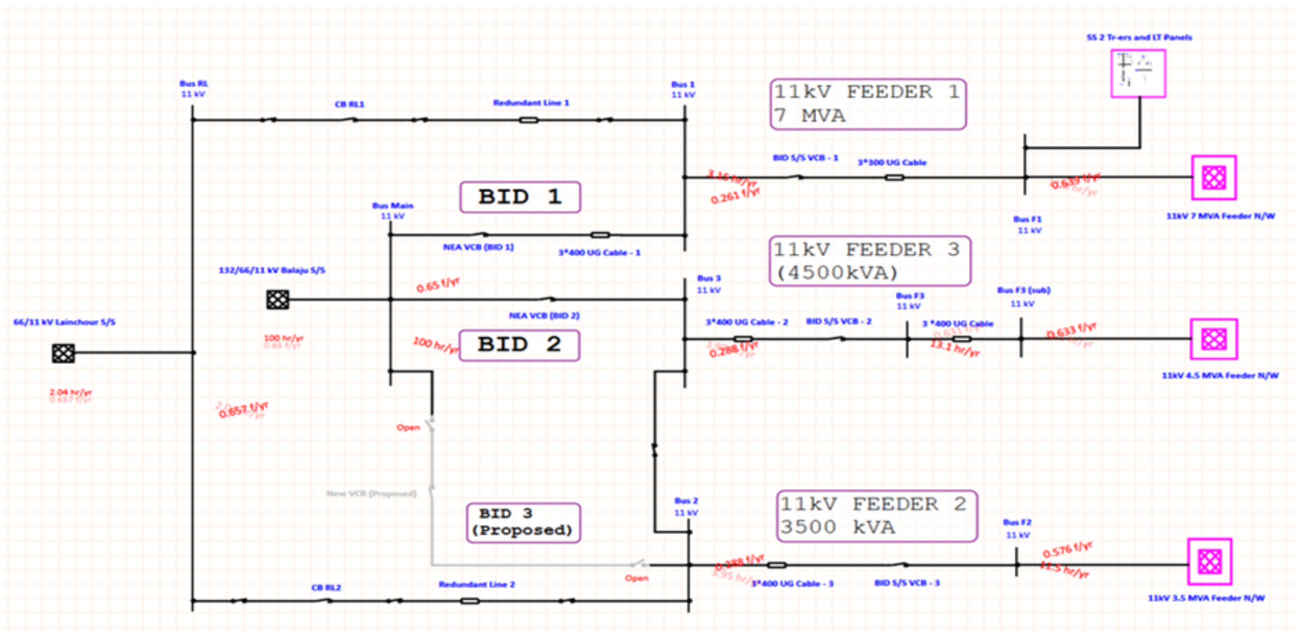


Figure 9: Modeling and Simulation of Case 2

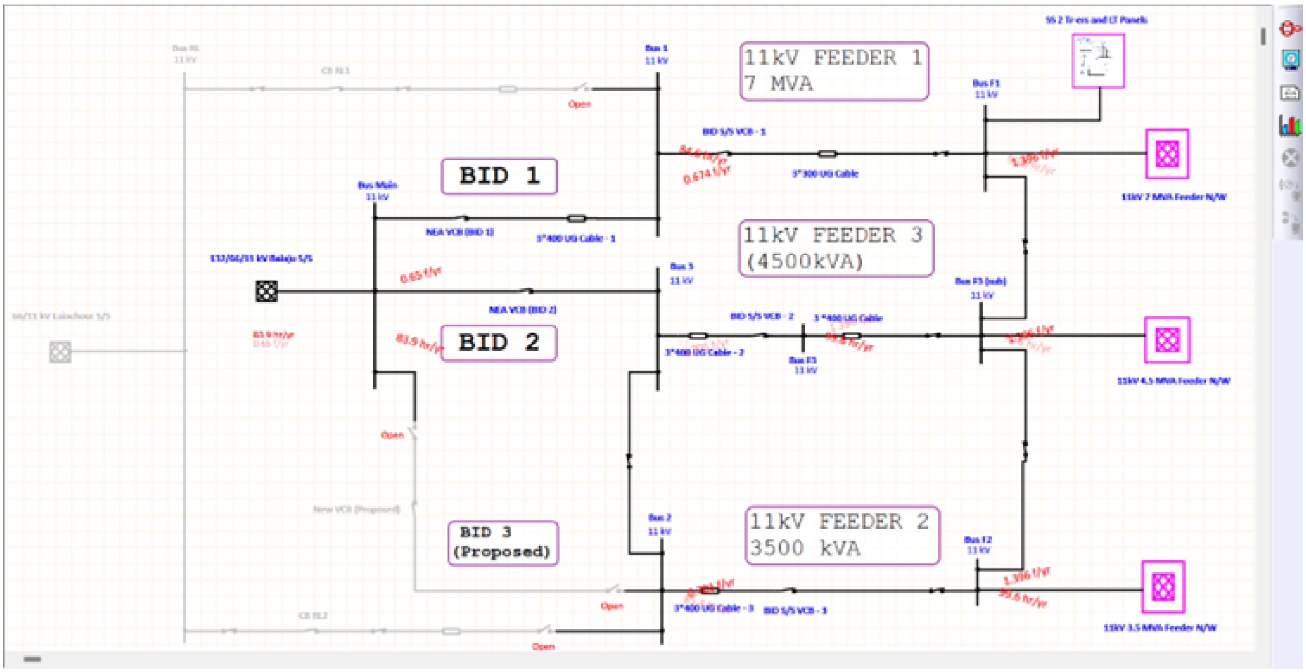


Figure 10: Modeling and Simulation of Case 3

3.3.5 Reliability Assessment Results

ETAP modeling and simulation results are shown in table 2.

Graphs of ASAI, EIR and EENS of all cases are shown in Figures 11, 12 and 13.

Above results show that cases 1, 2 and 3 have improved the system reliability compared to existing system (case 0). Also, EENS has decreased. It can be noticed that system EENS decreases with the increase in its reliability. Case 2 of adding redundant supply in the existing system is the most reliable network configuration compared to all cases.

3.4 Outage Cost

3.4.1 Estimation of Outage Cost

For the estimation of cost of unserved energy, questionnaire regarding to production loss methods, backup generation method and willingness to pay method is prepared and survey of productive industries in BID is done. 114 manufacturing industries participated well in the survey and collected data are used for the estimation of outage cost. Production loss method, backup generation method and willingness to pay method have estimated CUE as Rs. 27.68 per kWh, Rs. 50.93 per kWh and Rs. 11.03 per kWh respectively.

The weighted average of method-I and method-II gives the overall cost of unserved energy as Rs. 28.26 per kWh and is used for ECOST evaluation during economic losses analysis in all cases explained above.

3.4.2 Comparisons of Estimated Outage Costs

Karki et al. 2010 (Estimation of cost of unserved energy: a customer survey Approach) has estimated the average outage cost for the industrial customer Rs 38.42 per kWh is obtained using weighted average method. The outage cost was computed based on the information obtained from the survey regarding loss of raw materials, loss of profit, wages paid to idle workers, penalty for not meeting the delivery deadline, cost of standby supply, etc. Three years of outage data were obtained for two selected feeders in urban, semi-urban and semi-rural areas of Kathmandu valley.

But in case of Balaju Industrial Estate by productive industries survey method, the outage cost obtained using weighted average method is estimated as Rs. 28.26 per kWh.

The earlier estimated value of outage cost is higher by 26.45%. Following points are to be noted worth considering.

1. At that time, Nepal had been suffering from severe power shortages and consumers had to face up to 16-hour load shedding in a day during dry season. The study has also focused on the poor infrastructure of distribution system

Cases	SAIFI (f/cus.yr)	SAIDI (hr/cus.yr)	CAIDI (hr/cust.int)	ASAI (p.u.)	ASUI (p.u.)	AENS (MWhr/cus.yr)	EENS (MWhr/yr)	EIR (p.u.)
Case 0: Grid Only	1.1224	114.9161	102.387	0.9869	0.01312	29.2704	2429.443	0.9377
Case 1: Separate VCB (BID 3)	1.1136	95.4164	85.685	0.9891	0.01089	24.3008	2016.963	0.9478
Case 2: Grid+ Redundant Supply	0.6971	16.9443	24.307	0.9981	0.00193	4.2910	356.151	0.9904
Case 3: Ring Main (Interconnections between Feeders)	1.4305	96.7756	67.651	0.9890	0.01105	25.6832	1053.011	0.9720

Table 2: Results of Reliability Assessment

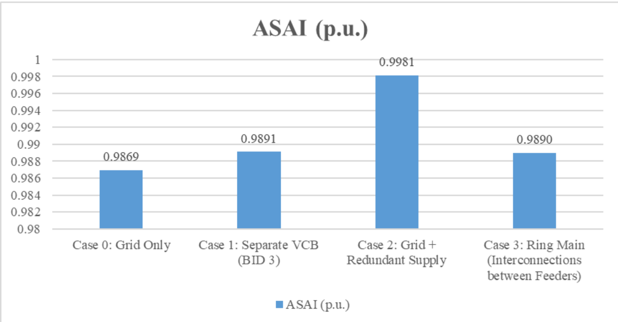


Figure 11: ASAI for All Cases

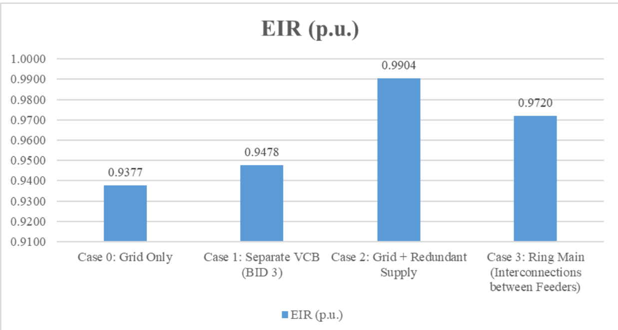


Figure 12: EIR for All Cases

of Kathmandu valley and indicated the urgent need of enhancing supply reliability.

2. The earlier survey was done in different areas of Kathmandu valley. But thesis survey is based on the typical industrial estate, Balaju industrial estate, owned by the Nepal Government which has improved and better electrical distribution system for industries i.e. reliable supply than outside the industrial estate.

3.4.3 Physical Possibility of System Modifications

All the suggested system reconfiguration schemes, i.e. case 1, case 2 and case 3, are practically and physically

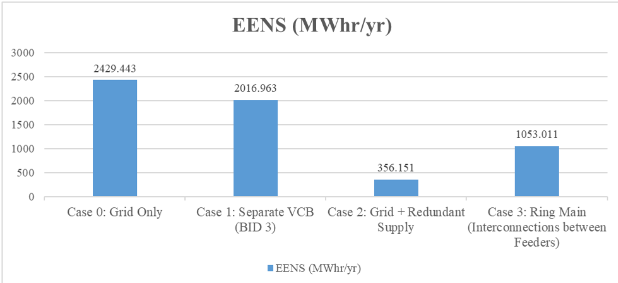


Figure 13: EENS for All Cases

possible with investments according to the estimations. The modification costs of each case are shown in table 3.

3.5 Economic Analysis from Reliability Point of View

For the reliability worth analysis of the different cases, ECOST, NEA Income Loss and BIDMO Income Loss are calculated using the above estimated values of CUE, EENS, annual energy billing amount and annual energy served. Annual energy billing and annual energy consumption of BID are Rs. 31,42,29,554.30 and 36596869 units respectively. Calculation and analysis are given in table 4 given below.

Ten percent of NEA income loss is the BIDMO income loss as ten percent discount is given to industrial estates, undertaking of government of Nepal, by NEA only in case of payment within seven days of meter reading. Industrial estates pay electricity within prescribed time period because this rebate is also their main income source.

From the above results, it is seen that reliability indices of cases 1, 2 and 3 improve significantly compared to case 0. But it is necessary to estimate the investments to be made for network modifications for

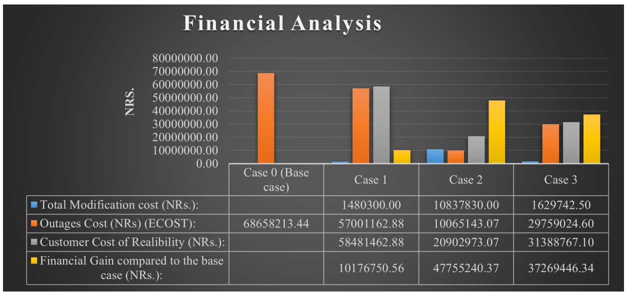
S.N.	Equipment Descriptions	Estimated total cost of units including supply, installation, testing & commisioning (NRs.)		
		Case 1	Case 2	Case 3
1	11 kV Distribution Feeder		7,312,230.00	
2	400 Sq.mm XLPE Cable		551,440.00	
3	HV Circuit Breaker (Including cost of battery, its charger and Cu plate earthing)	1,480,300.00	2,917,660.00	
4	Disconnect / Isolator Switches		56,500.00	141,250.00
5	Materials and their installations for Isolators (only in case of Case 3)			1,488,492.50
	Total Modification cost (NRs.):	**1,480,300.00**	**10,837,830.00**	**1,629,742.50**

Table 3: Summary of System Modification Costs (Estimation)

Cases	ECOST (Rs./yr)	NEA Revenue Loss (Rs./yr)	BIDMO Income Loss (Rs./yr)	NEA Revenue Loss (%)	BIDMO income Loss (%)	Percentage Reduction in ECOST
Case 0: Grid Only	68,658,213.44	21,075,418.03	2,107,541.80	6.7070	0.6707	
Case 1: Separate VCB (BID 3)	57,001,162.88	17,497,154.03	1,749,715.40	5.5683	0.5568	16.98%
Case 2: Grid + Redundant Supply	10,065,143.07	3,089,609.93	308,960.99	0.9832	0.0983	85.34%
Case 3: Ring Main (Interconnections between Feeders)	29,759,024.60	9,134,870.43	913,487.04	2.9071	0.2907	56.66%

Table 4: All cases ECOSTs, income losses and reductions in ECOST

higher reliability and evaluate financial burdens, whether we have financial gain or don't have. Estimations are based on the prevailing norms. The results of economic analysis of reliability are shown in figures 14 and 15 below.



	Case 0 (Base case)	Case 1	Case 2	Case 3
Total Modification cost (NRs.):		1480300.00	10837830.00	1629742.50
Outages Cost (NRs) (ECOST):	68658213.44	57001162.88	10065143.07	29759024.60
Customer Cost of Realibility (NRs.):		58481462.88	20902973.07	31388767.10
Financial Gain compared to the base case (NRs.):		10176750.56	47755240.37	37269446.34

Figure 14: Results in Amount (Rs.) for all cases

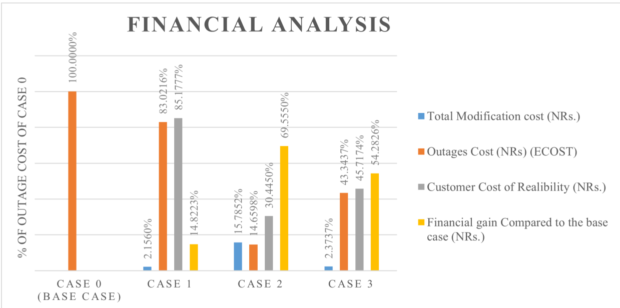


Figure 15: Results in Percentage of Outage Cost for all cases

3.5.1 Reliability Worth Analysis of Case 1

After separating 3500 kVA and 4500 kVA feeders by adding another separate VCB in NEA S/S, reliability of system is slightly improved and outage cost is reduced. This modification requires one number of VCB with its accessories. The investment is NRs. 14,80,300.00. The outage cost reduces to 83% of the base case i.e., NRs. 5,70,01,162.88 (reduced by 17%). Economic benefit (gain) in this case is NRs. 1,01,76,750.56.

3.5.2 Reliability Worth Analysis of Case 2

After adding redundant lines with the existing distribution system, reliability of system is significantly improved and outage cost is reduced. The added redundant lines have similar loading capacity as that of the existing feeders which are able to supply power in the industrial estate in case of main distribution system fails. Suggested network configuration requires double circuit 11kV overhead lines, 2 number of HV breakers, XLPE cable, isolator switches, etc. which needs an investment of NRs. 1,08,37,830.00. From the analysis, outage cost reduces to 14.66% of the base case i.e., NRs. 1,00,65,143.07 (reduced by around 85%). Economic benefit is NRs.4,77,55,240.37. This is the most suitable configuration.

3.5.3 Reliability Worth Analysis of Case 3

For creating the ring main between three 11kV feeders, installations of isolators with other required materials, such as, poles, conductors, insulator, etc., are necessary and the investment is NRs. 16,29,742.50. In this case, economic gain is NRs. 3,72,69,446.34 which is around 54% of the outage cost of case 0.

3.5.4 Importance and Comparison of the above Cases

All the three modification cases have their own importances. Case 1 for separating 3500 kVA and 4500 kVA feeder is in the favor of consumers related to the healthy feeder by remedying unwanted tripping and reducing outage duration. Case 2 of adding redundant double circuit lines is in the favor of whole industrial estate because it plays a role of emergency backup supply from the 66kV Lainchour S/S in case of failure of Balaju S/S. Case 3 is in the favor is critical industries, which require continuous supply of power, during the shortage of full power required by whole industrial estate. In each case, we observe improvement in reliability and also financial gain by comparing investments and savings. Cases 1 and 3 can be implemented very easily within short period with low cost compared to case 2.

4. Conclusion

The results obtained from the reliability assessment of distribution system of Balaju Industrial Estate seem to be very useful as suggest different ways to improve the reliability which ultimately results in financial gain to industrial consumers and respective utility offices. Results give information about planning, upgrading, designing, maintenance programming of distribution system to enhance reliability. Real data collected help to identify the weak parts of the industrial distribution system, then viable solutions are recommended to increase reliability and achieve the best performance of the system. ASAIs of all configurations, existing distribution system, separating two feeders by separate VCB, adding redundant supply and creating ring main, are 0.9869 pu, 0.9891 pu, 0.9981 pu and 0.9890 pu respectively. Adding redundant supply is the most reliable configuration. Other two modifications also have better reliability than the existing system.

In this paper, cost of unserved energy is also estimated by the three analytical methods for the reliability worth analysis and the overall cost is found Rs. 28.26 per kWh, higher than the prevailing electricity rate. Using this CUE and EENS of four different configurations, investment and return analysis is done and concluded that redundant supply with existing distribution system configuration has the highest financial gain and is the most suitable configuration.

All the suggested options for reliability enhancement have their own importances and result in improved reliability with financial gains, therefore, these modifications are recommended for implementation to the concerned utility offices, BIDMO and NEA.

Acknowledgments

The authors acknowledge the supports by Industrial District Management Limited, Balaju Industrial District Management Office and Balaju Distribution Centre, NEA. We would like to thank NEA officials and the industries of Balaju Industrial Estate for their cooperation and providing necessary data.

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