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An Analysis of Reliability-Technical Losses In 33 kV Radial Distribution/transmission system In Far Western Region of Nepal

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"An Analysis of Reliability-Technical Losses In 33 kV Radial Distribution/transmission system In Far Western Region of Nepal "** submitted by **Kapil Joshi** in partial fulfillment of the requirements for the degree of Master of Science in Power System Engineering.

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ABSTRACT

This thesis presents a model approach for minimizing the transmission and distribution line power loss along with the analysis of reliability of the lines in electric power systems. Distribution power loss is a measure of the energy lost during the distribution of electricity from the sending end point to the receiving end users. This loss can be noteworthy and has a straight impact on the proficiency and economics of the power system. The proposed approach utilizes a combination of control algorithms and optimization techniques to effectively minimize the distribution power loss. Experiments on realistic power system models prove the effectiveness of the proposed method in reducing distribution power loss and improving the overall efficiency of the power system. This thesis also presents a model for improving the reliability of electric power systems through reducing distribution power loss. Reliability of power systems is a critical aspect as power outages can have significant economic and societal impacts. The proposed approach utilizes a combination of control algorithms, different calculation indexes, optimization techniques and redundancy strategies to minimize the distribution power loss and improve the overall reliability of the power system. The method is tested on realistic power system models, and results show the significant improvement in reliability metrics such as system availability and frequency of power outages. This approach can be a valuable tool for power system operators to enhance the reliability of power systems and ensure continuity of power supply to end-users

Integration of new substation in the real distribution network has several benefits such smoothing the power supply, i.e. increased reliability, improvement of nodal voltage profile, loss reduction in active power and reactive power, support of reactive power.

In this thesis, insertion of substation in Punarbas Nagarpalika in a suitable location was done. DigSILENT software is used for modeling and calculation of system. The software is check with reference IEEE 33 bus data for the technical analysis. RBTS 2 bus reference is used to check the corrective ness of software for the reliability purpose. The aim of thesis is to supply the Punarbas feeder from newly in inserted substation which is feed from Dhangadhi and analyze how it changes technical lossesand reliability indexes. The required data for line length, substation loading, failure rate, repair rate are collected from Belauri DCS, Lalpur substation, Sudurpaschim provincial office. The unavailable data are assumed with the reference data available. With available data the model of the system was created in the system. Mainly 4 cases are

analyzed. Case 1, Reconfiguration of existing line from Bansha-Jhalari to Bansha-Kalwapur-Jhalari. Little loss decreases and also reliability of system increases. Case 2, supply Punarbas feeder only, the simulation shows the total loss of the system is decreases from 26% to 6.65%. Also the reliability of the system increases as all the positive indexes are increasing and negative indexes are decreasing. Energy not served was decreased from 3387 MWh per year to 1102 MWh per year i.e. almost 68%.Third case was to supply all the DCS load from new substation. For this new line connecting from Punarbas to Belauri was assumed. The failure rate and repair rate for this line was assumed with reference of old lines. Calculation is done for both technical losses and reliability indexes. The system total loss is further decrease and reliability of the system further increase.

All system old line and new line are interconnected and the objective of the thesis is check in the modeled system. The modeled system was run to find the results. It was found that the system loss slightly increases also the reliability of the system slightly decreases that case 2. Hence modeling different cases, analyzing the results it the technical losses reduction and Reliability of the system increasing was done successfully and the insertion of the substation is found acceptable. Economical analysis of the ENS and power loss are calculated using different methods. It shows that the cost received from technical loss are very high with compared to that of energy not served cost. The case of new substation supplying all the power gives the minimum loss and most feasible out of all cases.

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LIST OF ABBREVIATION

Abbreviation	Full Form
ANSI	Branch Current to Bus Voltage
BCBV	Branch Current to Bus Voltage
BIBC	Bus Injection to Branch Current
CT	Current Transformer
CTI	Coordination Time Interval
DC	Distribution Center
DER	Distributed Energy Resources
DG	Distributed Generation
DLF	Direct Load Flow
DN	Distribution Network
DOCR	Directional Overcurrent Relay
DR	Distributed Resources
DR	Distributed Resources
ECI	Equivalent Current Injection
ETAP	Electrical Transient Analyzer Program
GA	Genetic Algorithm
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
MVA	Mega Volt Ampere
MVAR	Mega Volt Ampere Reactive
MW	Mega Watt
NEA	Nepal Electricity Authority
OCR	Overcurrent Relay
PCC	Point of Common Coupling
PPA	Power Purchase Agreement
PU	Per Unit
PS	Plug Setting
SFCL	Superconducting Fault Current Limiter
TCC	Time Current Characteristics
TMS	Time Multiplier Setting

LIST OF SYMBOL

Symbol	Name
Pu	Per unit
I_L	Load current
P_L	Active power load
Q_L	Reactive power load
I	Current
V	Node voltage
X_l	Leakage reactance of alternator
X_f	Field reactance of alternator
X''	Sub-transient reactance of alternator
E_g	No load voltage of generator
X_{dw}	Damper winding reactance of alternator
z	Impedance of the branch
N_{br}	Number of branches
RN	Relay / Number
t_{op}	Time of operation of relay
sec	Second
P_{DG}	Power injected by DG
Q_{DG}	Reactive power injected by DG
$I(F)$	Fault current
$V(F)$	Fault Voltage

CHAPTER 1: INTRODUCTION

1.1 Background

Nepal Electricity Authority (NEA) is an unbundled structure. NEA has full responsibility over distribution system. The total loss in system is, from generation, transmission and distribution. The generation and transmission losses are quite upto standard while the losses in the distribution system is relatively high with respect to transmission and generation losses. Distribution system comes under DCSD directorate which consists of 7 provincial office and 2 division office along various part of Country so that it covers all the supply area of the country. Since NEA is Non-profit organization, it has to supply electricity to every household that demands electricity. In Rural area of country, the density of the load is very less so, distribution lines are very long with compared to that of urban. As the load\demand at particular area increases the lines length of respective area are elongated to recover\fulfil the demand. As the line increases radially, the power losses in the line also increases. Along with that, voltage level difference can be noticed at consumer end. As the line length increases radially, the voltage level at the receiving end keeps decreasing such that it falls beyond acceptance level. Also in country like tree touching and other various factors affect the losses.

In an Power System engineering, the electricity outputted by generation units is used by end users via the different levels of distribution and transmission system. This system is like the end step in delivering electrical power, and its main job is to meet the electric needs of particular Clints. We generally can think of it as the crucial link between the high transmission system and the end users. Nowadays, Electric power is an essential component of our lives, and we can't think modern life without it. So, when there are any interruptions in the distribution system, it causes significant losses for consumers.

The reliability of the distribution system refers to how dependable and consistent it is. It's an important area of study within the power system field. Many different factors can affect the reliability of the distribution system. For example, failure in the electric power lines, element failures in the distribution field, interruptions in the electric power supply, and many others external causes for example, wind, rain, floods and landslides, can all have an impact. The measure of reliability for the consumers in the distribution network is also a measure of how well the utility company provides its service. To improve reliability, they should aim to minimize power outages as much as possible, regularly maintain the system, and use fast-acting protection systems. To tackle issues such as excessive load, inadequate voltage regulation, and frequent system disruptions caused by factors like wind and landslides, distribution systems have the option of undergoing redesign or reconfiguration. The dependability and excellence of electricity supply are intimately linked with a nation's progress and economic advancement, as well as customer contentment. Insufficient capacity and occurrences of faults and failures are among the elements that can impact the reliability of the system.

The electric power industry has been making significant changes in its structure, function, and regulation to ensure better power quality and reliability. Compared to the reliability of the Generation and Transmission System, the reliability of the Distribution System (DSR) is more complex. Hence, it is of utmost importance to conduct reliability analysis during the design phases and different development stages of intricate components and equipment. and systems to identify and address any weaknesses to understand reliability, it's important to enlighten in quality, security and adequacy, These aspects play a significant role in ensuring that the distribution system operates effectively and provides a dependable supply of electricity to consumers.

From the extensive research it has been established that, any power source\SS if placed within the system, will have positive impacts on reliability, power loss, voltage profile [8]. There is highest possibility that if new source is place at some certain point in system will provides good voltage level at the receiving end of consumers and increase the reliability of the existing system along with minimizing the technical losses. This research aims to show how the existing system Voltage is maintained and how the reliability indexes are changes into the network for which effective algorithm will be developed to calculate the technical losses and reliability indexes [9].

To integrated S\S into the network one suitable location is assumed, methodology for voltage calculation and calculation for reliability index of existing and modified system is adopted [10]. This methodology will ensure how the voltage profiles increases and reliability of the system improves in the distribution network. Work will also analyze the impacts of the different possible connection from the newly inserted S\S and old existing system.

Both the problem i.e., calculation of voltage profile at the different point and technical losses of the system and evaluating the reliability indexes is solved using DigSILENT software. All the calculations are done and results are then presented using DigSILENT software [11].

1.2 Problem Statement

Belauri DCS is located at southern end of Kanchanpur district. Existing MV (33kV) in is feeded from Lalpur 132\33\11 S\S, which is almost 45 kM away from the Belauri S\S. 33 kV lines of bare conductor and run through the forest area which causes the frequent tripping of the line. Also due to long radial length of the 33kV line the voltage at receiving 33kV busbar is very low, which cause low voltage in 11kV and eventually after long feeder the voltage at far end consumer in significantly low. It will be very hard for the utility to cope the ever-growing power demand. As the load\demand at particular area increases the lines length of respective area are elongated to recover\fulfil the demand. As the line increases radially, the power losses in the line also increases. Along with that, voltage level difference can be noticed at consumer end. To overcome this situation utility such as Nepal Electricity Authority (NEA) has planned to enhance the capacity of existing transmission line and increase the power delivery up to distribution substation. For this NEA has started constructing transmission line and substations inside the city. Further, NEA has also planned to increase its distributing capability by restructuring distribution lines.

To solve the problem of voltage drop, technical loss a systematic approach is needed that not only solves the voltage regulation, active and reactive power but also optimizes the reliability indexes of the existing distribution system. The research objectives are set as per the idea and elaborated in next section.

1.3 Research Objective

The prime objective of this work is to insert the new substation in the existing system of the distribution network and reconfiguring the 33 kV line to be feed to all consumers under Belauri DCS.

In order to accomplish the key objective, following detailed objectives are set;

1) To analyze the impact of 33\11 Substation on existing distribution network and propose the necessity of 33 kV line and redesigning 11kV feeders.
2) To develop the model for existing and new distribution network and calculating various technical aspects like, voltage level, active and reactive power.
3) To analyze the availability and unavailability of the network and comparing the reliability indexes for both existing distribution network and new proposed distribution network.

1.4 Scope and Limitations

Scope of this work is to develop an algorithm for a distribution network to integrate new substation to the system and calculate the various technical value and indexes as per the requirement. This research aims to develop a new S\S at certain point and show how the system improves with the installation of the new substation. Technical losses will be tested on IEEE 33 bus Distribution Network and for reliability indexes RBTS 2 bus system is used. At the end of this thesis, a methodology will be developed to calculate the technical losses and reliability indexes for the distribution system. Overall methodology is applied to the real network of Belauri DCS to check its practicability. The effectiveness of the methodology is then established. This work will be very useful to the distribution utility to analyze the importance of S\S to the system.

Limitations of the study is research wo that the location of the substation has to be selected at a particular site, so we cannot optimize the location of new substation. Also existing 11kV lines are assumed to be same. All loads are assumed at the far end of the feeder. Also, for calculation of reliability indexes proper data are unavailable. All the interruption are assumed are OC\Earth fault. Also, all other necessary data are assumed as per requirement of the research [12].

1.5 Outline of the Report

This thesis constitutes five chapters including the current chapter. Until now this chapter has briefly introduced about the background and necessity of substation installation and calculation of technical losses and reliability indexes. Also, research objectives are formulated with scope and limitations.

The rest of the report has been organized as follows.

Chapter two gives the overview of the literature associated with the research work. This chapter provides the theoretical background and highlights on the research conducted on the similar field. From this research gap on the subject matter is found and used to perform further research.

Chapter three explains the methodology adopted for the research work. This chapter provide brief algorithm /flowchart to achieve the specific objectives and collectively directs the research to attain the main objectives.

Chapter four presents the results obtained during the various study as per the scope of the work. Adopted methodology and results are discussed in detail in this chapter.

Chapter five summarizes the research work and highlights the contribution of this work. This chapter also proposes direction for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Distribution Network

Distribution networks are designed to transfer the electricity from source towards the load at the consumer ends. While the transmission networks are often operated with loops or radial structures, the distribution networks are operated radially. In the radial feeder, flow of current is only in one direction. Being a simple and economical to design and construct, radial feeders have major drawback of low reliability and poor voltage regulations with high technical losses. Substation when connected to the radial feeder compensates the above drawback but also will have impacts on following aspects:

i) Increased reliability
ii) Improved voltage regulation
iii) Reduced active and reactive power loss
iv) Peak shaving capabilities
v) Provision of ancillary services, including reactive power

Among these, new substation for grid support in terms of Technical losses, voltage profile and reliability indexes are briefly discussed.

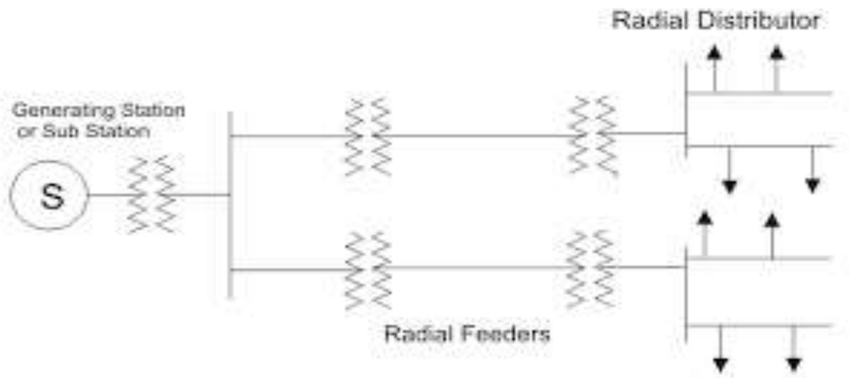


Figure 2.1 Simplified Distribution network

2.2 Load Flow Analysis of Network

The Newton Raphson method is used for calculation of voltage at each node, currents at each branch and also the total power loss of the network. The Newton-Raphson load flow analysis is used to find the steady-state operating conditions of the power system. The method is iteratively approximating the solution to the system of non-linear equations that describe the power flow in the system. It starts with an initial guess for the solution ($V_{0)}$ and then uses the Jacobian matrix (J) to update the guess until it converges to the final solution (V_n).

The basic equation of the Newton-Raphson method is as follows:

$$V_{n+1} = [J]^{-1} F(V_n) \qquad \text{-eq. (2.1)}$$

Where: V_{n+1} is the updated guess for the solution

Vn is the previous guess of the solution

$[J]^{-1}$ is the inverse of the Jacobian Matrix

$F(V_n)$ is the vector of non linear equations describing the power flow in the system.

The Newton-Raphson method is considered to be fast and accurate method for the load flow analysis, but it may converge to a non-physical solution in some cases. It is an iterative method and will continue until the change in voltages becomes negligible.

2.3 Voltage level and the Power loss in Radial Network

The practical system used in this thesis is redial network. The radial length and load in a distribution can have a significant impact on the power loss in the system. As the redial length of the distribution system increases, the power loss in the system also increases. This is because the longer the length of the distribution system, the greater the resistance in the distribution lines, which leads to more power loss due to ohmic losses [9]. The load in the distribution system also affects the power loss in the system. As the load on the system increases, the current flowing through the distribution lines increases, which in turn increases the power due to ohmic losses.

Furthermore, the voltage level of distribution system also affects the power loss. Lower voltage level increases the current and power in the system [13]. It is important to note that power loss in the distribution system affects the efficiency of the overall power system and it is also important to minimize power loss to reduce system cost [14].

2.4 Terminologies of Reliability.

Availability (A): The measure of the duration of power system is in fully operation at any time. That means it is the duration of operation of a component at any time [15].

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} = \frac{\text{MTBF} - \text{MTTR}}{\text{MTBF}} \qquad \text{eqn-(2.2)}$$

Unavailability (U): The measure of the duration of power system is in fully operation at any time.

$$U = \frac{\boldsymbol{\lambda}}{\boldsymbol{\lambda} + \boldsymbol{\mu}} = 1 - \text{Availability (A)} \qquad \text{eqn-(2.3)}$$

Failure Rate (λ):

$$\lambda = \frac{\mathbf{1}}{\boldsymbol{MTTF}} = \frac{\boldsymbol{No\ of\ outage\ on\ component\ in\ a\ given\ period}}{\boldsymbol{Total\ time}\ \textbf{component is in operation}} \qquad \text{eqn-(2.4)}$$

Repair Rate (μ):

$$\mu = \frac{\mathbf{1}}{\mathbf{MTTR}} = \frac{\text{No of operation on component in a given period}}{\text{Total time component is in operation}} \qquad \text{eqn-(2.5)}$$

Mean Time Between Failures (MTBF): In repairable systems, MTBF is the expected time between the occurrences of two consecutive fault/interruption and measures the reliability of these components. By which we know the total time of operation.

$$\text{MTBF} = \frac{\mathbf{1}}{\boldsymbol{\omega}\mathbf{F}} = \frac{\textbf{Total system operating hours}}{\textbf{No of failures}} = \text{MTTF} + \text{MTTR} \qquad \text{eqn-(2.6)}$$

Where,

ωF refers to the frequency of system failures, which represents the number of times the system transitions from an operational state to an unsuccessful or failed state in a steady manner..

Mean Time to Repair (MTTR) or Mean Down Time (MDT): It refers to the average duration required for the maintenance of an electric section or component before it is restored to normal operation if the component is out of service. This metric measures the average time taken to repair and bring the component back into regular operation. $MTTR = \frac{FOR}{NF} = \frac{\text{Total duration of outage}}{\text{Frequency of outage}}$ eqn-(2.7)

Mean Time to Failure/Mean Up Time (MTTF):

$$MTTF = \frac{SH}{NF} \quad \text{eqn-(2.8)}$$

Where, Hours (H) = 24 * No of days

Operation Hour (OH) = FOR+H

Service Hours (SH) = H-OH

No of times of forced outage = NF

Forced outage rate = FOR

2.5 Reliability Indexes.

Reliability indexes in the distribution system are used to evaluate the performance of the system and identify areas for improvement. These indexes provide a quantitative measure of the system's ability to deliver power to consumers and can be used to track changes in performance over time. Reliability indexes help us to identifying system weaknesses, prioritizing our investment, meeting regulatory requirements and also helps improving consumer satisfaction [17]. These terms are numerical constraints that mirror the capability of the system as essential by consumer. we have indices as below:

1. System Average Interruption Duration Index (SAIDI): SAIDI is a metric that represents the average duration of disruptions experienced by an average customer over a predefined period of time. It is typically expressed in minutes or hours. SAIDI provides an understanding of the average outage duration that customers may encounter within a power system..

   $$SAIDI = \frac{\sum Customer\ Total\ Interruption\ or\ Outage\ Duration}{\text{Total No of Clints Served or Supplied}} = \frac{\sum R\ i\ N\ i}{Nt} \quad \text{eqn-(2.9)}$$

2. System Average Interruption Frequency Index (SAIFI): SAIFI is a metric that measures the average frequency of interruptions experienced by an interrupted customer over a predefined period of time. It is typically expressed as the

number of interruptions per customer. SAIFI provides insights into the average occurrence of disruptions that customers may face within a power system.

$$\text{SAIFI} = \frac{\sum \text{Total No of Clints Interrupted or Outage Total}}{\text{Total No of Clint Served or Supplied}} = \frac{\sum N\ i}{Nt} \qquad \text{eqn-(2.10)}$$

3. Customer Average Interruption Duration Index (CAIDI) represents the average interruption time for an interrupted customer during a predefined period or time frame. It is calculated by dividing the total interruption duration by the number of interruptions for a specific customer. CAIDI essentially measures the mean time taken to restore the system after an interruption, providing insights into the average restoration time for customers.

$$\text{CAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total No of Customers Interrupted}} = \frac{\sum \text{R i N i}}{\sum Ni} = \frac{\text{SAIDI}}{\text{SAIFI}} \qquad \text{eqn-(2.11)}$$

4. Customer average interruption frequency index (CAIFI): The average frequency of the sustained interruptions for interrupted customers is called CAIFI. In this case; number of times are not calculated for once counted customers.

$$\text{CAIFI} = \frac{\sum \text{Total No of Interruptions}}{\text{Total No of Customers Interrupted}} = \frac{\sum N\ i}{Cn}\text{n} \qquad \text{eqn-(2.11)}$$

5. Average Service Availability Index (ASAI): ASAI represents the percentage of time, during a specified period, that electricity is available to customers. It measures the average reliability and continuity of the power supply, indicating the duration of uninterrupted service for customers.

$$\text{ASAI} = \frac{\textit{Customer Hours Service Availability}}{\text{Clints Hours Service Demanded}} = \frac{Nh - \sum R\ i\ N\ i}{\text{Nh}} = \frac{SAIDI}{\text{SAIFI}} = \frac{8760 - SAIDI}{8760}$$

6. Average Service Unavailability Index (ASUI): ASUI represents the percentage of time, during a specified period, that electricity is unavailable for customers. It measures the average duration of power outages, indicating the reliability of

the power system in meeting customer demand.ASUI = $\frac{Duration\ of\ Outage\ in\ hours}{\text{Total hours Demanded}} = 1 - \text{ASAI}$

7. Energy Not Served to consumers (ENS): KWhr/yr

   ENS = ∑ LiUsys,i

   Where, Li = Middling load connected to i_{th} load point

   Ni = No of clints at load point i.

   Usys,i = Yearly outage duration at i_{th} load point

2.6 Cost and Reliability of the system.

In electrical distribution systems there should be balance between the cost of upgrading and maintaining the system, and the availability of power it provides to customers. A system is said to be reliable system if it is able to consistently deliver electricity to end users consumers without any interruption or failure[32]. However, increasing the reliability of a system often comes at a cost, such as the cost of upgrading equipment or adding redundancy to the system.

On one hand, investing in a more reliable system can lead to cost savings in the long run by reducing the frequency and duration of power outages[25]. It can also improve customer satisfaction and increase business continuity. On the other hand, investing in a more costly system can lead to higher costs for customers and may not provide a significant enough increase in reliability to justify the expense.

Ultimately, the decision on cost vs reliability in electrical distribution systems will depend on a variety of factors, including the specific needs of the customer, the overall budget, and the potential risks and costs of power outages[29]. It is important for utilities and distribution companies to consider these factors and strike a balance between cost and reliability in order to provide a high-quality and reliable service to customers [18].

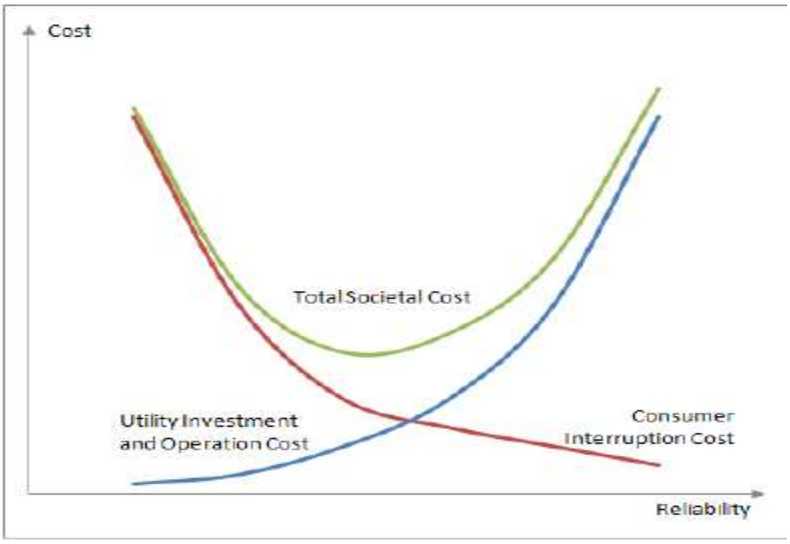


Figure 2.6 Reliability Vs Cost

2.7 Review of related research works.

Comparative analysis of distribution reliability presented by Robert E. Goodin [18] focus on comparative analysis was conducted to examine the impact of using different outdoor distribution devices on improving distribution reliability. The study primarily focuses on three commonly used devices: line reclosures, automatic sectionalizers, and manual switches. By evaluating the effectiveness of each device individually or in combination, the analysis aims to quantify the level of reliability improvement achievable.

Hag-Kwen Kim [19] focuses on aging power systems. Ageing of components is an important fact in power system reliability assessment. It results from a number of different reasons, deterioration, erosion, or damage of equipment. Regardless of reasons, most equipment may develop aging trend over time. As a result, aging may become the cause of load curtailments because of higher system failure probability. So it is necessary to examine ageing characteristics in system reliability or in economic evaluation.

S. Khounnouvong [20] proposed the use of protective equipment such as a re-closer and disconnects switching for reliability improvement in an electrical distribution system of Laos .The theoretical strategy was to add protective equipment to reduce the number of customers affected by outages to a minimum and to improve the stability of the power system. He added reclosures and disconnect switch in each feeder and evaluate the result. SAIDI values reduces significantly after the improvement of the system.

Y. Jibril and K.R. Ekundayo [21] studied outages on the 33kV feeders of the Kaduna Electricity distribution network for 16 months and concluded that Mogadishu feeder experienced the highest number of failures even though it is not the least available which means that outages are due to temporary outages or transient fault and the duration is usually short. Therefore the feeder should be look upon to, so that any weak equipment should be replaced, wooden poles should be replaced with concrete poles.

According to Oleboge K.P. Mokoka [11], Simulation can be performed using two popular software tools, namely DIgSILENT Power Factory and NEPLAN, both of which offer a range of features such as load-flow analysis, short-circuit calculations, reliability analysis, protection coordination, and stability calculations. To evaluate the performance and reliability of these software tools, a sample feeder was simulated in both NEPLAN and DIgSILENT. Mokoka conducted the simulation and compared the results obtained from each software. After careful analysis, it was concluded that the results generated by both software tools were similar..

According to Andreas Sumper [22] , System reliability is expressed by interruption indices. The variation of the interruption indices between countries and companies concludes that the factors influencing on these indices are inherited and inherent. Finally, decreasing fault rates, restoration time and number of affected customers will result in lower interruption indices and increase distribution system reliability.

A Ghods [23] Studied 24 KV distribution network and suggested the method to improve system reliability by changing network topology. He made a double circuit line for incoming feeder and changed the feeder route of some section. Significant improvement in ENS, SAIFI, CAIDI and ASAI is observed.

R E Brown [24] examined the impact of distribution substation reliability on overall distribution system reliability assessment. Important features to include in a substation reliability model are maintenance states, protection system, system reconfiguration and operational failures. Impact of substation on the reliability of its customers is not the function of substation alone. In fact, customer reliability variation of different substation is due to external events and how substation responds differently to these events.

The definition of sustained and momentary interruption may play a role in reliability analysis. Generally, SAIFI SAIDI CAIFI and ENS are calculated based on sustained interruption. Momentary interruptions include all reclosing operations that occur within five minutes of the first interruption. If reclosures or circuit breaker operates two, three, or four times and then holds (within five minutes of the first operation), those momentary interruptions shall be considered one momentary interruption event [25]and should not be included for calculation of SAIFI and SAIDI.

Onime Franklin [26] Studied the distribution feeder of Nigeria, the main cause of outage was load shedding. Out of total outage noted (1503) interruptions in ireukpen feeder in year 2012, the frequency of planned outage, load schedule, earth fault and supply failure was 265, 689,496 and 53 respectively. The duration of scheduled and forced outage was 2336 and 1038 hours respectively. He suggested reconfiguration of overhead distribution lines to reduce the frequency of forced outage and to improve reliability of the system.

2.8 DigSILENT

"DIgSILENT" is an abbreviation for "DIgital SImuLation of Electrical NeTworks." It is considered to be one of the first power system analysis software tools worldwide, featuring a graphical single-line interface that combines various functions, editing capabilities, and both static and dynamic calculation features.

PowerFactory, on the other hand, was developed by experienced engineers and programmers who possess extensive knowledge in programming and electrical power system analysis. The software's accuracy and reliability have been confirmed through numerous applications by organizations involved in power system operation and planning. PowerFactory serves as an integrated engineering tool that offers a comprehensive range of power system study functions within a single executable program. Its key features include the ability to modify, define, and associate cases, perform core mathematical routines, and generate outputs and documentation. Additionally, it provides an interactive interface for managing single-line graphics and data cases.

The software incorporates a database comprising various power system components and base cases, allowing for streamlined calculations and design tasks based on geometric or empirical evidence. It also enables integration with power system grid arrangements and facilitates online SCADA access. Furthermore, PowerFactory offers a generic interface that can be utilized with computer-based mapping systems.

CHAPTER 3: METHODOLOGY

Main aim of the research study is to build a new substation in the existing system and evaluate technical losses and reliability indexes of the distribution network. To achieve the main objective, methodology starts with literature review of various related topics, case studies, review of existing practices and study of the available related standards. Research methodology that will be applied to achieve the specific as well as main objective of the research work adopted in this research work is listed below.

1. Modeling of the distribution network under study.
2. Determination of states (voltage, loss etc.) of the DN existing network
3. Calculation of technical losses, voltage profile of the existing system.
4. Analyze the reliability indexes for the existing system.
5. Placement of substation in the existing network.
6. Calculate load flow and reliability assessment for the new system.
7. Reconfiguration of different arrangement for loss reduction, voltage profiles increasement and upgrading the reliability indexes values.
8. Evaluation of the all distribution system in DigSILENT.

These steps are elaborated in the respective section below.

3.1 Modeling of the distribution network under study

Modeling of the distribution network under study is the first step to the research work. Data inputs such as characteristics of source, distribution lines, protection system. relays and circuit breakers, loads etc. were made input to the DigSILENT software. Only line resistance and reactance were considered for modeling of the distribution line. Loads are assumed to be balanced in all scenarios and it was considered lumped at the point of connection of distribution transformer[34]. Same data was used to model distribution network in DigSILENT to establish the validity of the calculations. Details of the network and software used in the research work is explained in detail in Section 3.7 and 3.8.

3.2 Load Flow Analysis of Distribution Network

The voltage at each node, currents at each branch and also the total power loss of the network is determined by performing load flow analysis. The Backward/Forward Sweep Load Flow technique algorithm is used in this research. Figure below shows the basic procedure to determine the voltage at each node and the line flow earlier described in the Section 2.2. Ultimately losses in the system is determined by the obtained data. DigSilent is used to solve the power flow equations by iterative technique. Digsilent is a high level programming environment, as well as interactive Data analysis, mathematical modelling and data acquisition platform. Result obtained from the above procedure is checked with result of IEEE 33 bus system. This shows the effectiveness of the procedure of the load flow for further use.

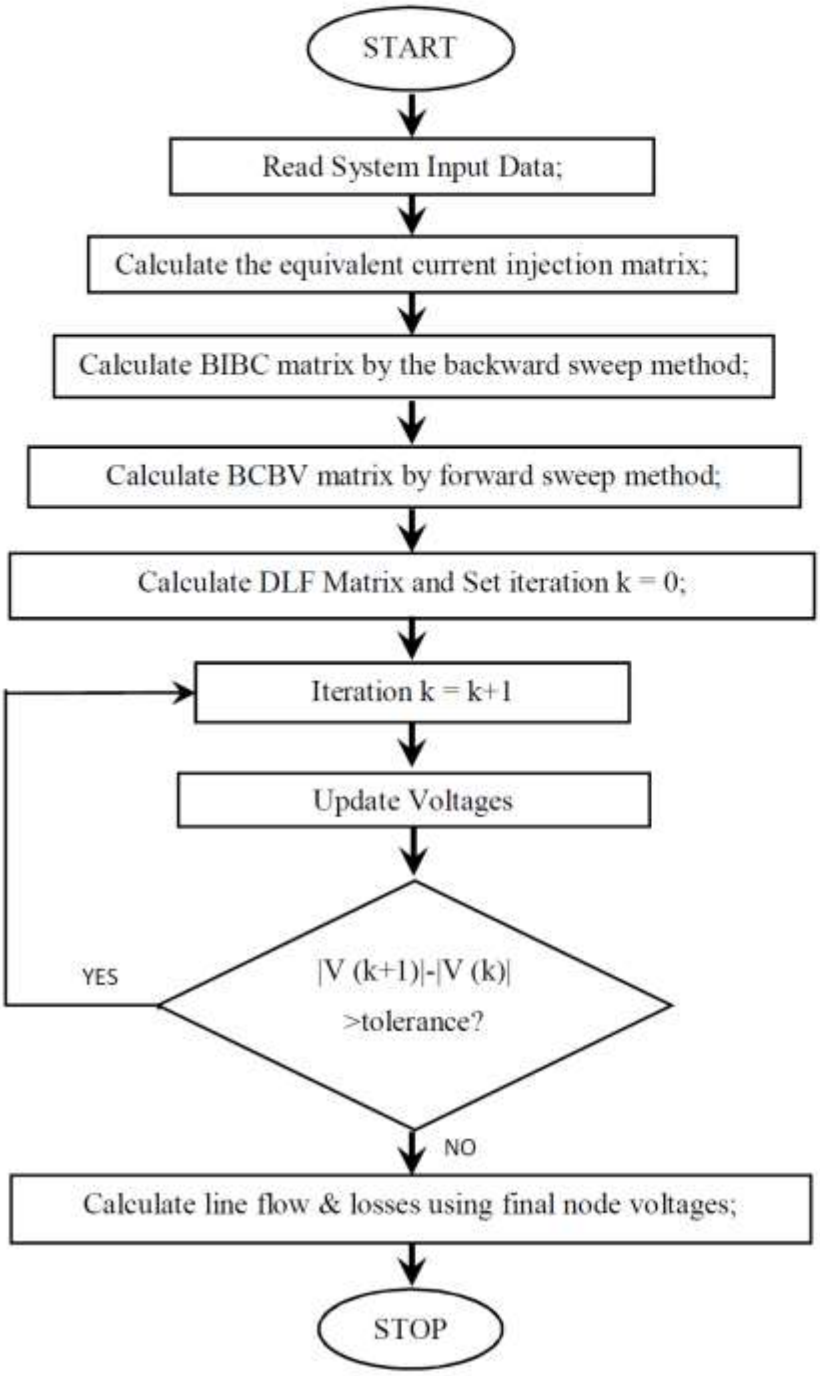


Figure 3.2 Flowchart for load flow analysis of distribution network

3.3 Data Collection

The data available for the distribution are very limited in country like Nepal. There is not proper practice of keeping or updating data mainly in DCS. Nevertheless, some useful data are obtained from the DCS which will be very useful for this research work. Data thus collected from distribution systems are used in order to monitor, analyze, and optimize the performance of the system.

Substations: Power is in and out from the substation. In DCS substation keeps the proper data of power received, power dispatched, incoming power factor, power factor of outgoing feeder, loading of busbar, loading of feeder. Along with it substation also keep records of line tripping, shutdown demanded for maintenance, system outage. Furthermore, transformer tapping, temperature of equipment. Voltage, current of incoming and outgoing lines are kept with line in substation.

For this research, the system voltage for incoming 33 kV (132\33) is received from Lalpur substation. Kalwapur substation also provides the data of voltage and loading of its feeder and incomer. Receiving end 33 voltage at Belauri substation are achieved from Belauri Substation. Voltage, Current and power factor of 33 kV incomer, 11 kV incomer and 3 outgoing feeder was collected from Belauri substation.

Belauri DCS: Line arrangement of the existing system is collected from Belauri DCS. The configuration of line, its length, tapping points, laterals of lines are also received from Belauri DCS. Conductor type, Disconnecting switch, Transformer size and loading, along with all possible available data are collected from Belauri DCS.

For reliability purpose all the data are received from Belauri substation. Total no of line tripping, shutdown demanded by staff for maintenance, system failure, temporary system tripping all data are collected. From the collected data scheduled outage and system outages are segregated for reliability index calculations.

Sudurpaschim provincial office: The cost for new built substation is received from sudurpaschim provincial office. The cost of Patan Melauli substation is taken as reference for cost analysis of substation costing. Also, for 33 kV line construction cost estimate from same office is taken as reference.

3.4 Reliability Analysis using DigSILENT

Reliability assessment is a process that involves using statistical methods to determine the overall number of electric interruptions experienced by loads within a power system over a specific operating period. The interruptions can be described by many indices that consider characteristics such as:

- The total number of clints [N].
- The total connected load, expressed in [kW].
- The time of the interruptions, generally stated in [h] = ’hours’.
- The total amount of power intermittent, normally expressed in [kW].
- The frequency/ number of interruptions, expressed in [1/a] = ’per annum’.
- Repair times are usually indicated by [h] = ’hours’.

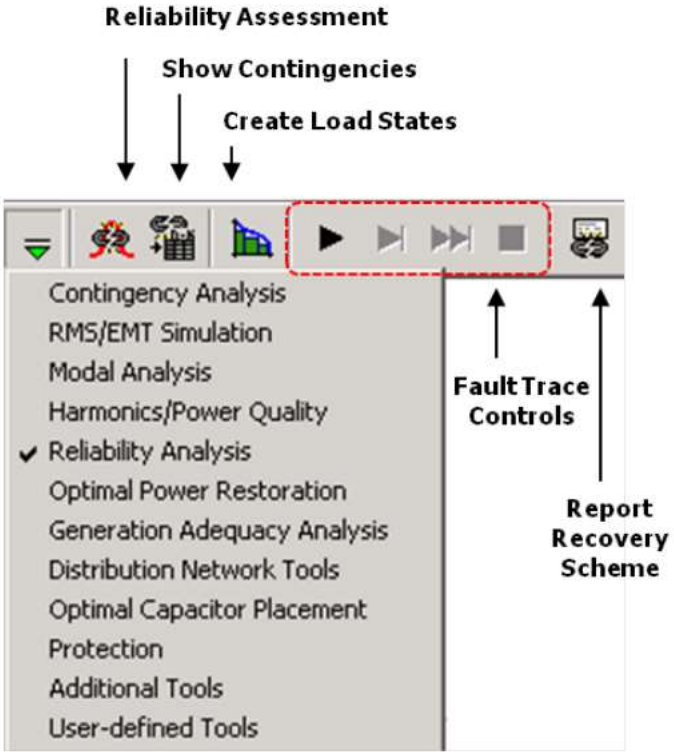


Figure 3.4 Reliability Assessment

Reliability analysis, also known as the Reliability Assessment tool, encompasses a set of factors and indices that are used to evaluate the reliability of a system. These features include the modeling of failures and their effects, the consideration of various loads and their impact on the system, the formation of the system's overall state, the analysis of failure effects, the application of statistical methods, and the generation of comprehensive reports. Through this tool, a thorough assessment of system reliability can be conducted.

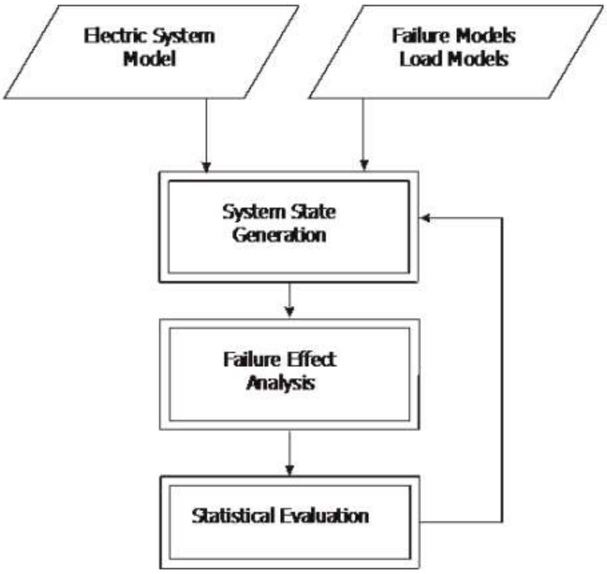


Figure 3.5 Reliability Assessment in DIGSILENT

To establish the necessity of re-coordination of protection system, impact due to DG integration on the network shall be studied carefully. To demonstrate impact on the network, firstly network will be coordinated without considering integration of DG.

3.5 Modeling of the system

Digsilent can be a valuable tool for performing technical analysis and reliability analysis on power systems, but it is important to have a good understanding of power systems and the specific analysis that we are trying to perform before using this particular software [30].

3.5.1 Modeling of Test System 1

The standard IEEE 33 bus system is modeled in the DIgSILENT. The data for the reference system are available in the reference paper. All the bus are connected accordingly as shown in the reference paper. Following with that all the load of particular load end are modeled. The line length and the line resistance along with reactance are also inserted. After all the available data are putted in the model system, the model system is run. The obtained results are compared to the reference result.

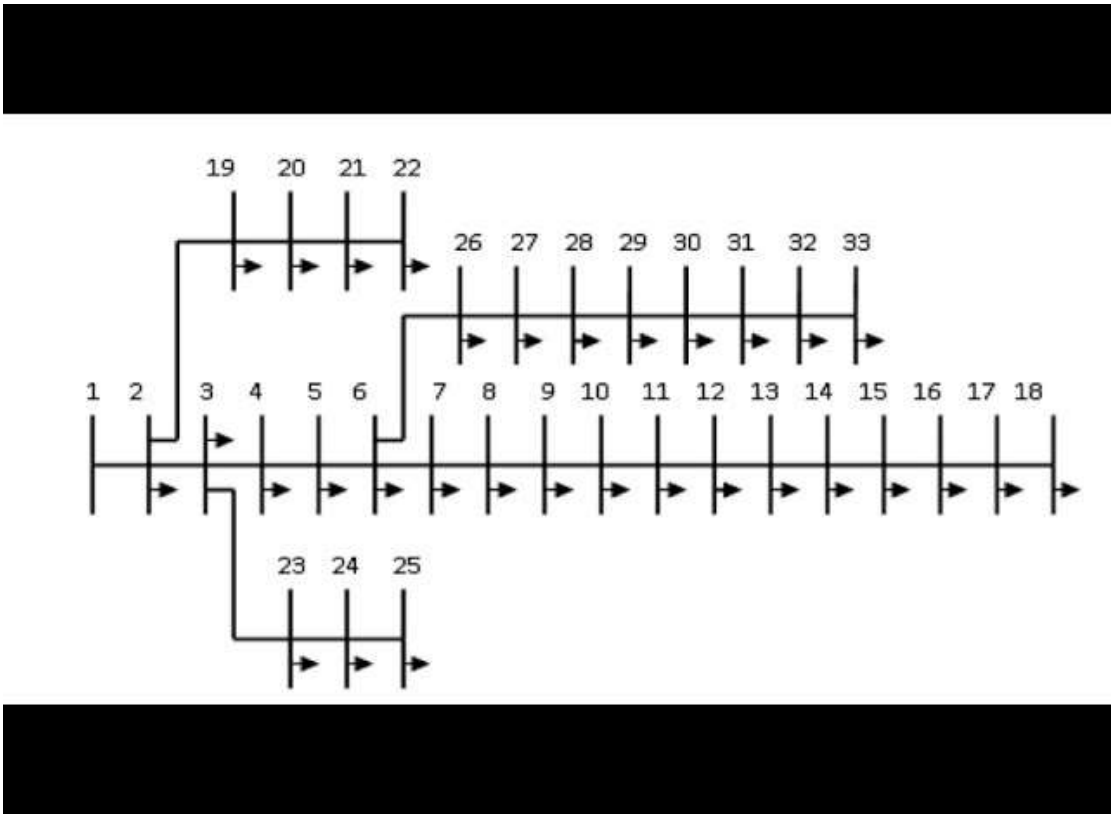


Figure 3.5.1 Modeling of Test System 1

3.5.2 Modeling Test System 2

For the reliability analysis, the RBTS 2 bus system is used as reference. The reference paper provides all line length of particular line segment. It also submit the load at the receiving end of the respective node. The failure rate , along with repair and replacement rate are also given. The standard system was modeled in the working software and the available data are place accordingly. The result thus obtained was compared with standard result.

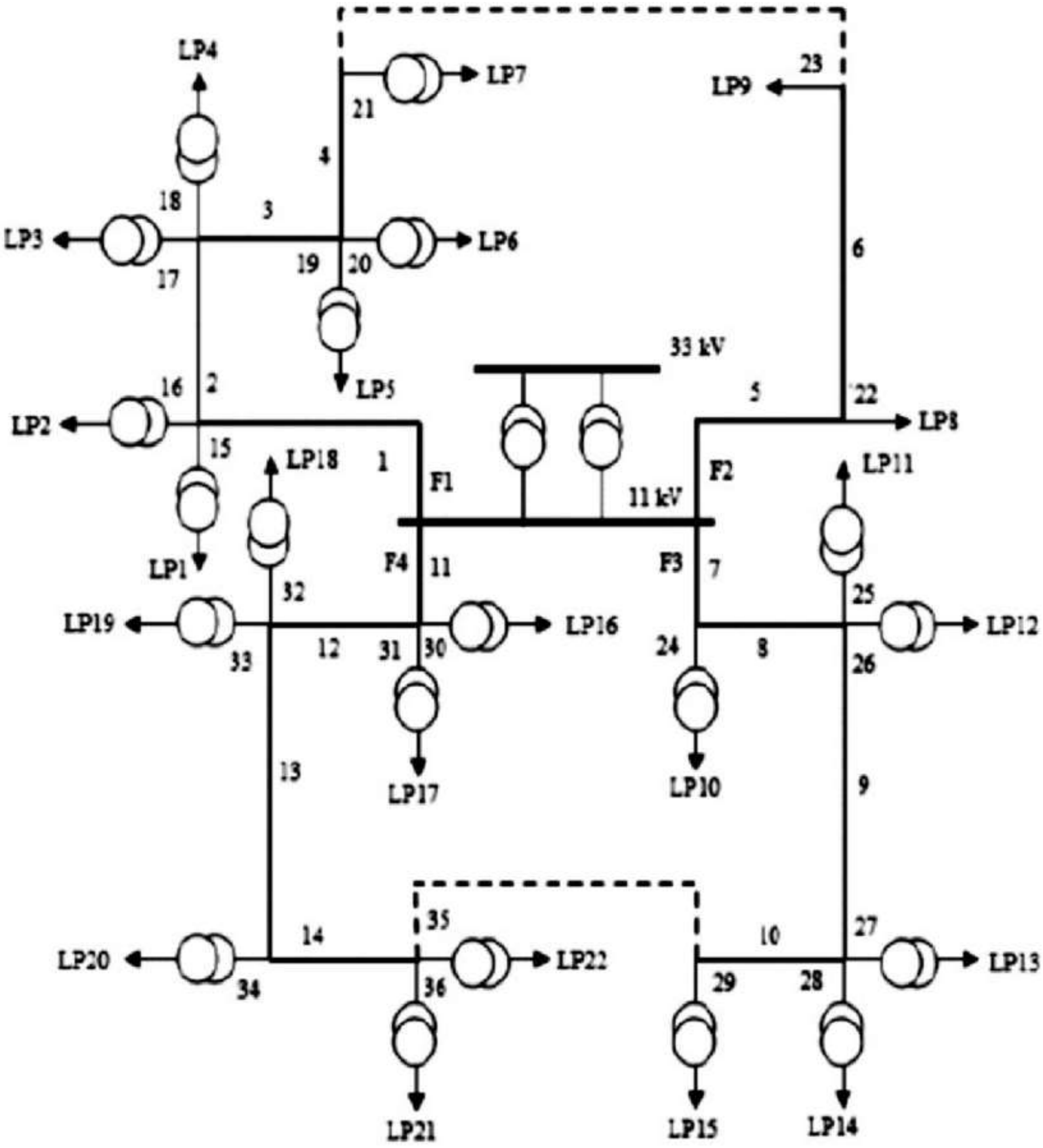


Figure 3.5.2 RBTS 2 BUS System

3.5.3 Modeling of real system.

The real system Lalpur-Jhalari-Belauri is modeled in the DIgsilent. Lalpur is taken as the slack bus and other as the load bus. All the line are drawn similar to the real field. The data of line length, Conductor type, loading, voltage current power factor etc. are modeled in the system. The failure rate of particular component is inserted. Calculation is done for technical losses and reliability assessment. Further new substation is inserted in the system. Its technical data are also modeled in the system. Furthermore, calculation of new system is done and results are analyzed.

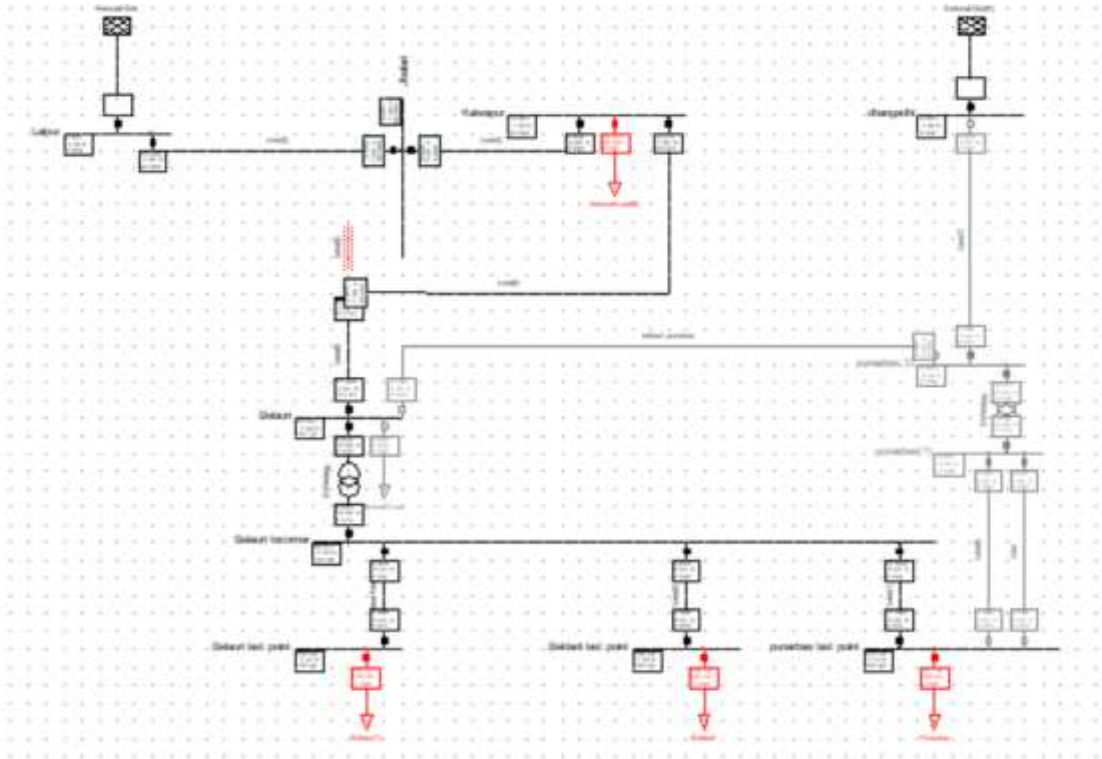


Figure 3.5.3 Modelling of Real System

3.6 Overall Implementation

Methodology for integration of utility substation methodology for integration is describes in this step and the calculation of technical losses and reliability assessment of the system is done. The steps involved are:

1. Read the modeled system data and run base\existing case.
2. Run for load flow, Calculate the technical data needed for the analysis. Volatge, Technical losses are calculated.
3. Run reliability assessment and calculate all the reliability indexes of the system.
4. Insert new substation in the model.
5. Run Load flow
6. Run Reliability assessment.
7. Display results.

The entire process is shown in the Figure 3.2. Here, the placement algorithm is only implemented to determine the technical losses and reliability analysis of the system with insertion of new substation in the network. The main research objective as stated earlier is to optimize technical losses and reliability indexes of the active distribution system.

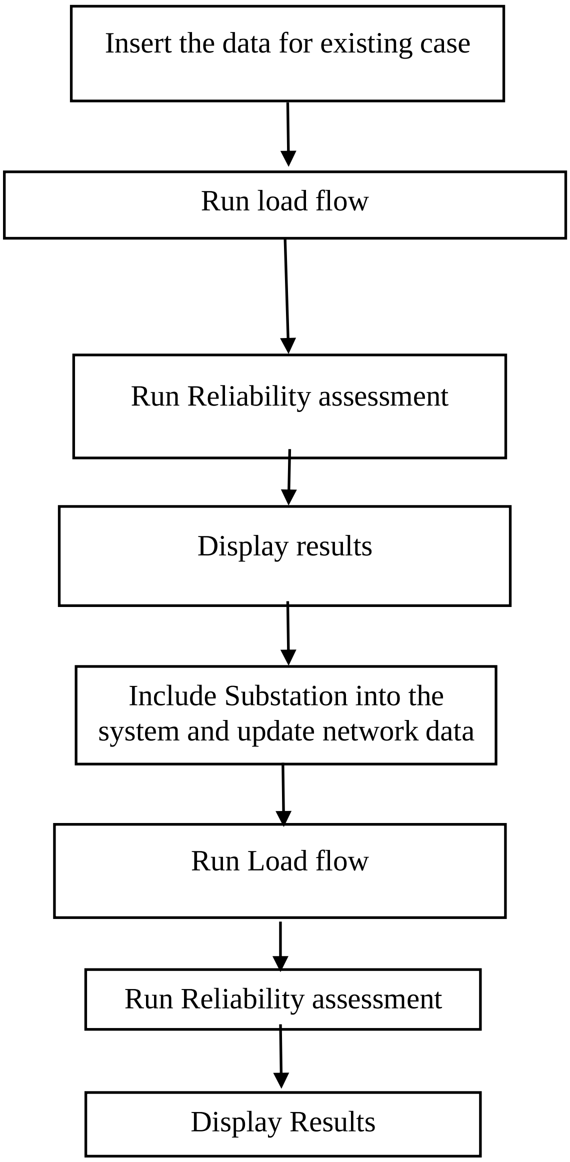


Figure 3.6 Flowchart for integration of substation in system

3.7 Cost Analysis

3.7.1 Revenue Losses due to system losses (RL)

The electrical distribution system is directly linked with the consumers and revenue is collected through them. Every system consists of power loss. Power losses are the energy per hour that can't not serve to the consumer. They are supplied from the sending end but not received by the consumers.

$P_{sending\ end} = P_{receiving\ end} + P_{loss}$

Power loss cost can be calculated by multiplying the total losses by number of hours per year.

$Revenue_{loss} = P_{loss} \text{x days x hours} * \text{rate}$

3.7.2 Payback Period

Simple Payback Period (SPBP): For the improvement of the system investment in new infrastructure must be done. New substation, its equipment, civils works and the lines are installed in the new designed system. Payback period is the ratio of investment to the annual benefits gained from its usage. As this does not include any interest rates, we assume 10 % as MARR, a discounted payback period (n) is also evaluated as in the following formula:

$$n = -\frac{\ln(1-(r\ x\ Investment)(BGA-(\Upsilon\ x\ Investment)))}{\ln(1+r)} \qquad (3.7)$$

3.7.3 Net Present Value

The difference between present value of the benefits gained and costs incurred in an

investment is termed as the net present value of the system. This is an important economic measure as it includes the time factor with the interest rate. It is always unique irrespective of the cash flow patterns. The formula to calculate NPV is as

below. The investment is deemed to be profitable for a positive NPV and conversion; a negative NPV indicates a financial loss

$$NPV = (BGA)[\frac{(1+r)^n - 1}{r(1+r)^n}] - Investment \quad (3.8)$$

3.7.4 Benefit Cost Ratio (BCR)

BCR is a profitability index which is most easily interpreted by any investor. The ratio of benefits gained by adding battery system to the costs associated with it is termed as its BCR. As the BCR must be greater than unity for any project to be viable.

We have:

$$\text{BCR} = \left(\frac{Benefits\ Gained}{Investment\ x (CRF + \Upsilon)}\right) \quad (3.9)$$

Benefits and Operation and maintenance cost (γ) are in annuity whereas initial investment is in present worth, which has to be converted to annuity by multiplying with Capital Recovery Factor (CRF).

3.8 System under Consideration

3.8.1 Lines

The power is delivered to Belauri and Jhalari (Kalwapur 33\11 SS) from Lalpur 132\33\11 substation through dog conductor. Before reaching Kalwapur 33\11 SS the 33 kV line is tapped to Belauri. Also the new line is constructed from Kalwapur to the junction point Bansa, where old 33kV feeder to Belauri meet at a point. The newly constructed line is of Dog conductor. From Bansha to Belauri the lines are also of dog conductor.

Table 3.1 Lines

Section	Conductor	kM
Lalpur- Jhalari	Dog	16
Jhalari-Kalwapur	Dog	1.75
Jhalari- Bansha	Rabbit	6
Kalwapur-Bansha	Dog	5
Bansha -Belauri	Dog	22
Dhangadhi- Punarbas	Dog	15

Punarbas-Belauri	Dog	10
Belauri feeder	Rabbit\weasel	15
Beldadi Feeder	Rabbit\weasel	25
Punarbas Feeder	Dog	29

3.8.2 Peak Load

Peak load of various load center is collected. The graph of peak current of respective month are plotted.

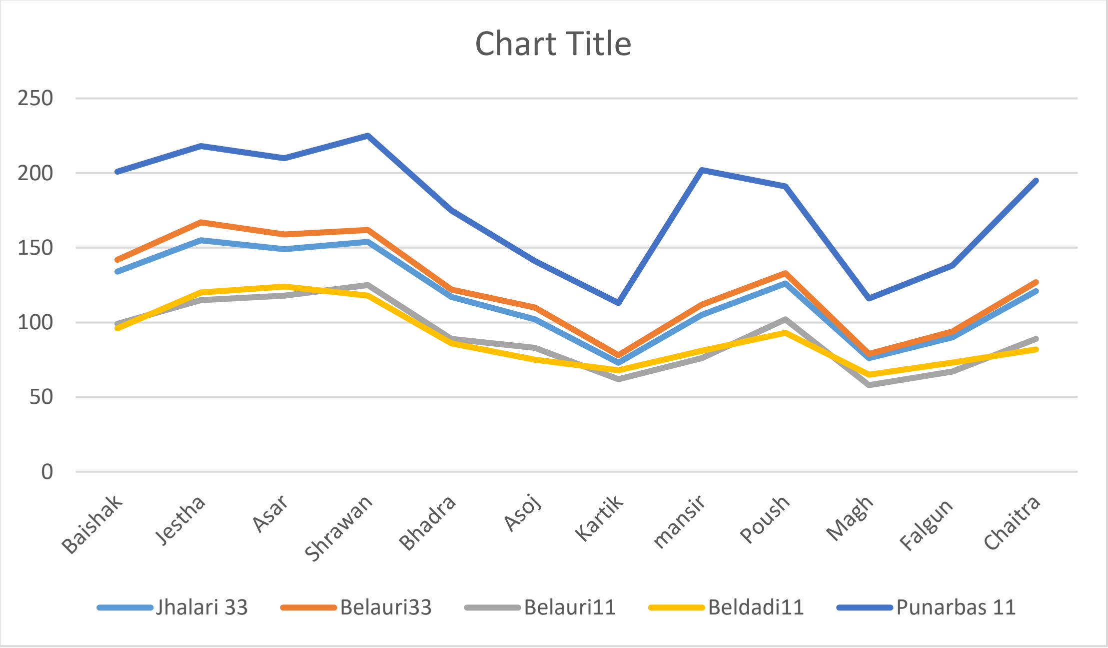


Figure 3.8.2 Peak Load

3.8.3 Load Curve :

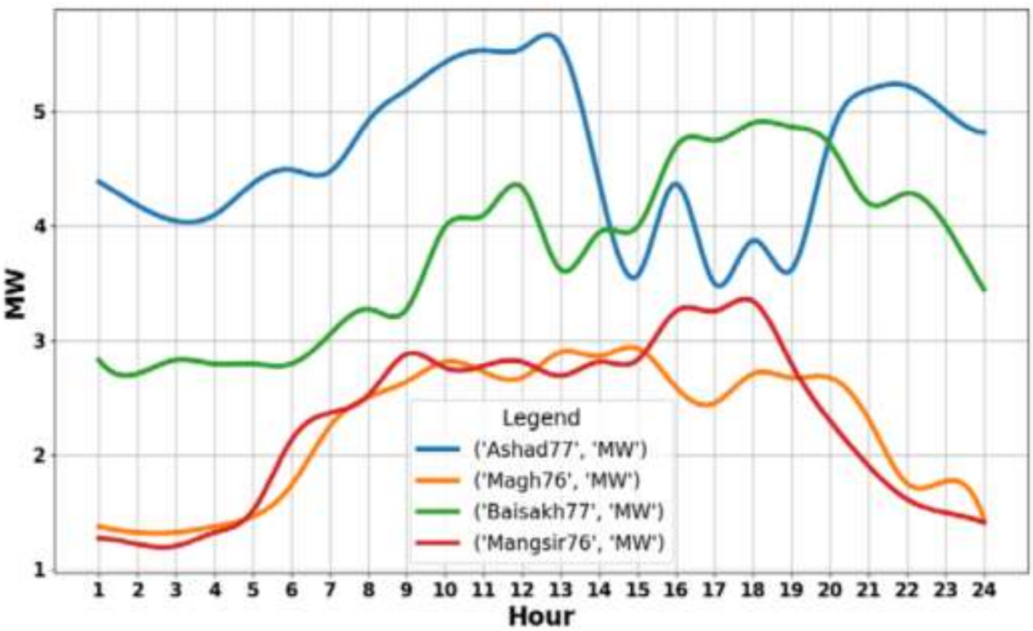


Figure 3.8 Load curve

3.8.4 Number of consumers:

Total number of consumers under Belauri DCS is 28108. In which Punarbas feeder have maximum number of consumers around 48%. Beldadi have around 27% consumers. And remaining 25% lies under Belauri feeder.

3.8.5 Types of Faults and its Details:

In a power system, various types of faults can occur, including: Single line to ground fault (LG): This fault happens when a single line comes into contact with the ground.

Line to Line fault (LG): This fault occurs when two lines contact with each other.

Double line to ground fault (LLG): In this fault, two lines simultaneously make contact with the ground.

Three-phase fault (LLL): This fault involves all three phases coming into contact with each other.

Three-phase to ground fault (LLLG): Here, all three phases are connected to the ground.

Specifically, within the distribution system, line-to-line faults are often categorized as overcurrent (O/C) faults. These faults can arise due to various reasons, including:

- Short circuits between lines.
- Animals, such as rats or lizards, causing shorts in control panels.
- Breakage or damage to jumpers or lines, resulting in contact with other live lines.
- Wind causing line collision.
- Overloading of lines.
- Birds running and coming into contact with two live lines.

Line-to-ground faults, on the other hand, are classified as earth faults (E/F) and occur due to:

- Contact between a live line and the ground due to any cause.
- Breakage or cutting of jumpers/lines, leading to contact with a pole/ground live line.
- Damaged or compromised insulators.
- Branches or trees touching the line, especially during windy conditions.
- Damaged cross arms and also other structure made of wood.
- Leaks in overhead or underground, including ABC cables and covered conductor.
- Sagging lines coming into contact with trees, the ground, or buildings.

These various types of faults highlight the potential causes and scenarios that can lead to interruptions or faults within a power system. According to the log sheet of Belauri SS, the line faults are divided into only two types. Scheduled shutdown and forced outage. For the reliability purpose we considered only forced outage over 1 year period.

Table 3.2 Types of fault and default

Line	No of faults	Repair time	Failure rate	Mean Time to Repair

Lalpur- Jhalari	14	880	14	62.85
Jhalari -Belauri	83	8878	83	107
Belauri Feeder	62	1274	62	21
Beldadi feeder	75	2843	75	38
Punarbas feeder	81	2367	81	30

CHAPTER 4: RESULTS AND DISCUSSION

This chapter presents the results and discussion of the thesis works in detail. As mentioned previously, Digsilent is used as a calculation software for both technical loss calculation and reliability assessment. The load flow methodology is tested in IEEE 33 bus system and reliability assessment is tested in RBTS 2 bus system. Finally, the method is successfully implemented in the practical network – 33kV supply to Belauri DCS. Following cases are considered in this analysis:

I. **Three Feeder Test Network**
   i) Base Case 1: 33 Bus System (load flow analysis)
   ii) Base case 2: RBTS 2 bus network (Reliability assessment)

II. **Practical Network – 33kV to Belauri DCS**
   i) Case 1: Analysis of technical losses and reliability assessment in existing system
   ii) Case 2: Analysis of Technical and reliability assessment in modified system

The general outlines for this section are as follows.

- First of all, base case of IEEE 33 bus system is determined. This includes determination of total active power loss of the system, node voltages, branch currents etc.
- Base case of RBTS 2 bus system is modeled in the software. Reliability assessment for all the reliability indexes for the given failure and repair rate are calculated.
- Results from both the test system are matched with the results obtained in the reference papers and calculated the deviation percentage from the actual results.
- Results are calculated are found that the results are under tolerance level so the methodology is ready for the work.

After testing the methodology in the test network, it is applied to the practical network – Belauri 33 kV, to check the effectiveness and practicability of the methodology.

4.1 Base Case: System without Modification

Base case analysis as stated above consists two parts, i) To determine the existing state of the system i,e load flow analysis of the network and ii) reliability of the exsting network.

4.1.1 Load flow of the network

Load flow of Existing case analysis is successfully performed in the IEEE 33 bus distribution network. Network data is provided in the required format to DigSILENT and load flow analysis is conducted as described in the Section 3.2. Base voltage is taken as 12.66 kV and Base MVA as 100 MVA.

Branch current, node voltage obtained in the load flow analysis is tabulated in Table 4.1.

Table 4.1 Branch Current, node voltage for base case

Node/ Branch	**Voltage**	**Voltage**	**Degree**
	(p.u.)	(kV)	(Radian)
1	1	12.66	0
2	0.997	12.62	0.01
3	0.983	12.44	0.1
4	0.975	12.35	0.16
5	0.968	12.25	0.23
6	0.950	12.02	0.14
7	0.946	11.98	-0.10
8	0.932	11.8	-0.25
9	0.926	11.72	-0.32
10	0.920	11.65	-0.39
11	0.919	11.64	-0.38
12	0.918	11.62	-0.37
13	0.912	11.54	-0.46

14	0.909	11.51	-0.54
15	0.908	11.49	-0.58
16	0.906	11.48	-0.6
17	0.904	11.45	-0.68
18	0.904	11.44	-0.69
19	0.996	12.62	0.00
20	0.993	12.57	-0.06
21	0.992	12.56	-0.08
22	0.992	12.55	-0.1
23	0.979	12.40	0.07
24	0.973	12.31	-0.02
25	0.969	12.27	-0.07
26	0.948	12.00	0.18
27	0.945	11.96	0.23
28	0.934	11.82	0.31
29	0.925	11.72	0.39
30	0.922	11.67	0.50
31	0.918	11.62	0.41
32	0.917	11.61	0.39
33	0.916	11.60	0.38

Same network is also modeled reference paper and results are compared. Summary of the load flow analysis of the base case as obtained from reference and DigSILENT are summarized below.

Table 4.2 Base Case Results for 33 bus test network

Description	Result in reference	Result Obtained
Total active power loss MW	0.21	0.21
Maximum node voltage	1	1
Minimum node voltage	0.904	0.904
Node for minimum voltage	18	18
Reactive power loss MVAR	0.14	0.14
Total Active power MW	3.71	3.71
Total Reactive power MVAR	2.3	2.3
External Infeed MW	3.92	3.92
External Infeed Mvar	2.44	2.44

All the branch currents, node voltages with active and reactive loss of the system obtained with refence calculation was verified with DIGsilent with very low error margin.

4.1.2 Reliability assessment of the system.

Reliability assessment of the test system is successfully performed in the RBTS 2 bus distribution network. Network data is provided in the required format to DigSILENT and reliability assessment is conducted as described in the Section 3.2.

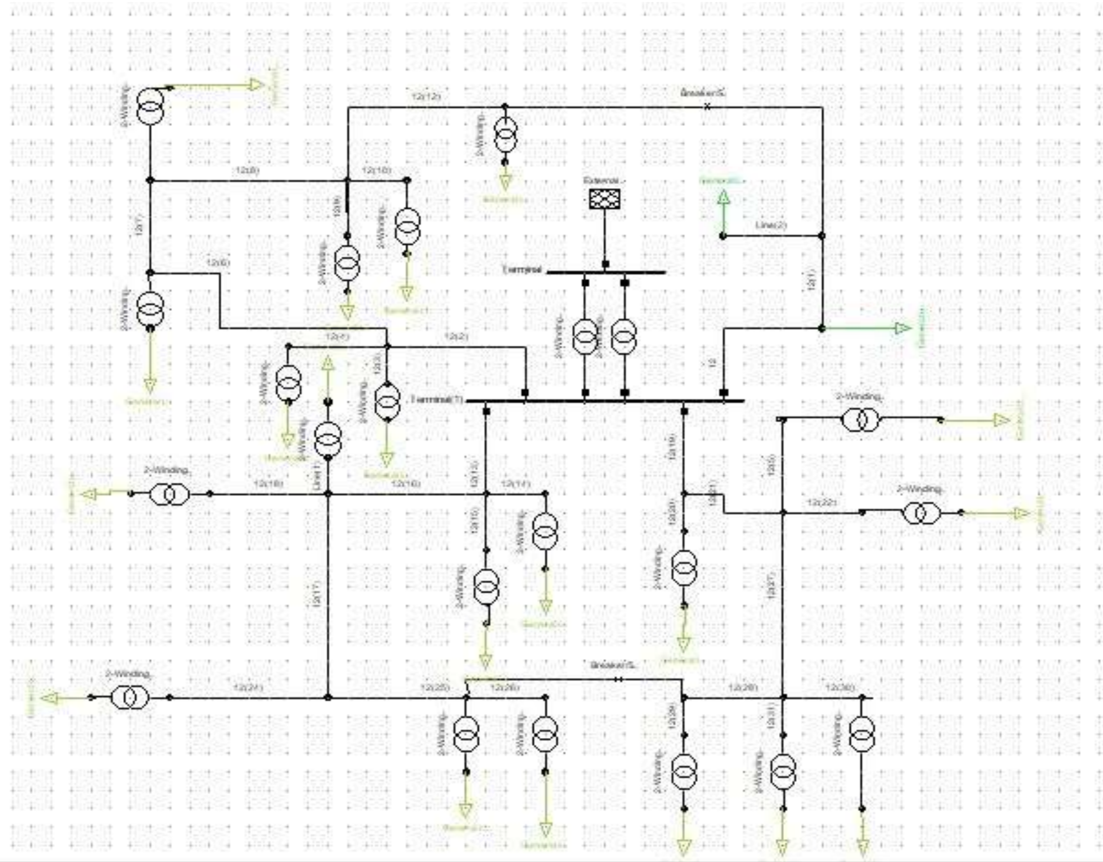


Figure 4.1 Reliability assessment of the system

Results:

```
System Summary

System Average Interruption Frequency Index     :  SAIFI  =    0.602849 1/Ca
Customer Average Interruption Frequency Index   :  CAIFI  =    0.602849 1/Ca
System Average Interruption Duration Index      :  SAIDI  =   22.475    h/Ca
Customer Average Interruption Duration Index    :  CAIDI  =   37.281    h
Average Service Availability Index              :  ASAI   =    0.9974343793
Average Service Unavailability Index            :  ASUI   =    0.0025656207
Energy Not Supplied                             :  ENS    =  231.051    MWh/a
Average Energy Not Supplied                     :  AENS   =    0.121    MWh/Ca
```

Table 4.3 Reliability assessment of the system

	IEEE Result (std)	simulation	% Deviation from standard
SAIFI	0.602	0.6029	-0.133
SAIDI	22.5	22.475	0.111
CAIDI	37.48	37.281	0.531
ASAI	0.99743	0.99743	0.000
ASUI	0.00256	0.002565	-0.195
ENS	231.263	231.051	0.092
AENS	0.121	0.121	0.000

The RBTS 2 bus network is also modeled as shown in fig and results are compared. Summary of the reliability assessment of the base case as obtained from reference and DigSILENT are summarized in the table .

To test the effectiveness of the calculation, and the verification of the software, case B: no disconnects - no fuses - no alternative supply - repair of transformers of the reference is taken as a base case. The feeder radial length are available with failure rate and repair rate. Failure rate and repair rate of transformer and busbar are also provided in the paper. The system is modeled as in the base case and reliability assessment is done and results are obtained. The Result are almost similar with deviation of less than 1%. So it can concluded that this software can be used for the calculation of reliability indexes for the distribution system. Real System network

The real field network in model Lalpur-Jhalari-Kalwapur-Bansha-Belauri line is taken as real system network. Two different case are analyzed with the available data in the system i.e. i. Lalpur-Jhalari-Bansha-Belauri as the existing system which is running right now, ii. New line is being constructed from kalwapur to bansha, so reconfiguration of line from Jhalari to Bansha is shifted to Kalwapur to Bansha.

4.1.3 Real existing system

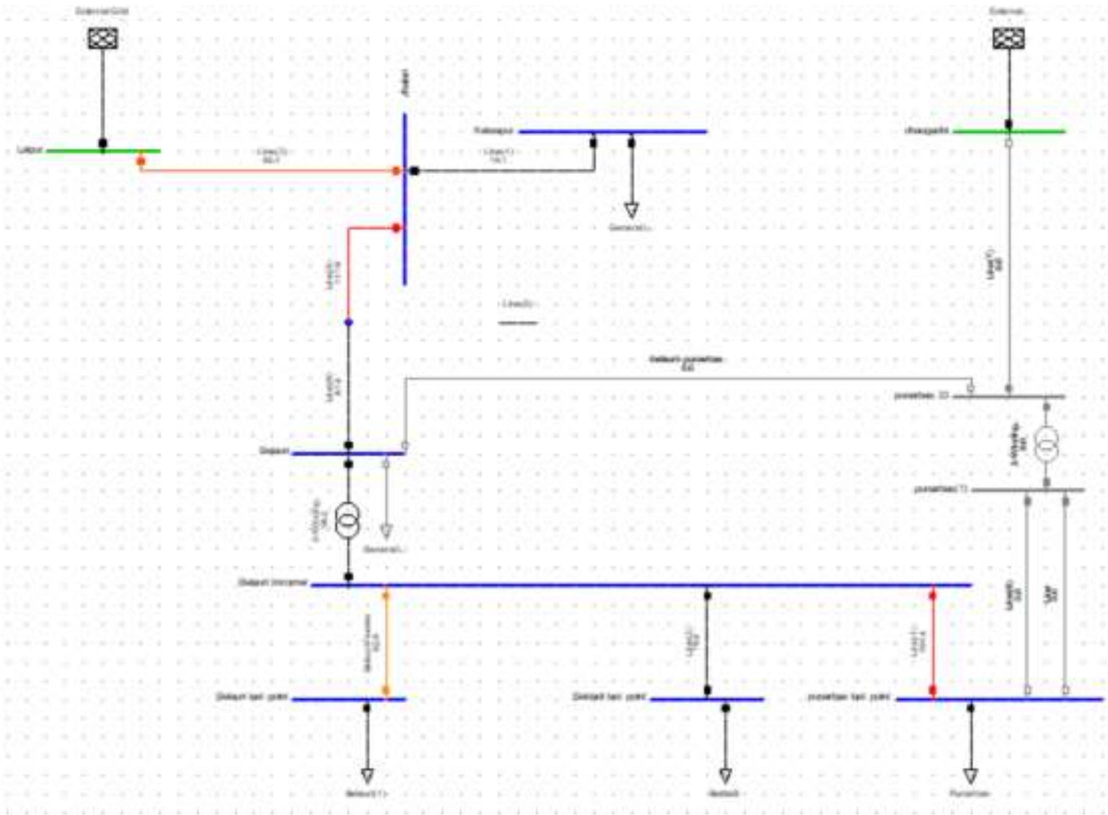


Figure 4.2 Load flow of existing System

Load flow results shows that, Jhalari-Bansha 33kV line overloaded. Also punarbas feeder 11kV is also overloaded. The other results are listed as below

Table 4.4 Load Flow Result

Node/ Branch	Voltage(pu)	Current (kA)	Angle(rad)
1	1	0.303	0
2	0.9	0.236	-2.08
3	0.9	0.067	-2.14
4	0.75	0.236	-5.13
5	0.74	0.707	-6.3
6	0.72	0.166	-6.46
7	0.69	0.159	-6.76
8	0.59	0.383	-6.76

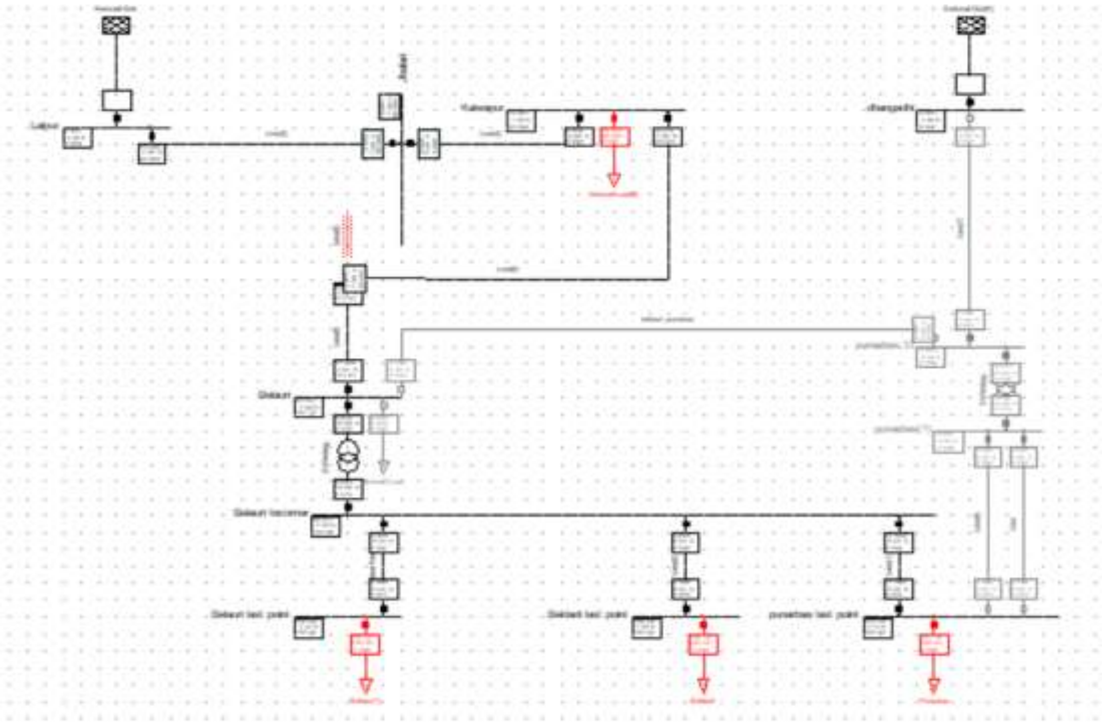
There is huge voltage deviation from the reference point of view. In normal loading condition it is tolerable but in peak load condition the voltage at receiving end consumers is very low. Also power loss is very high around 26% loss. Reliability of system is calculated with both case , RBTS failure rate and repair rate and compare with real system failure rate.

Table 4.5 RBTS failure rate and repair rate

Index	RBTS Failure and repair rate	Real Failure and Repair rate
SAIFI (1/Ca)	3.077	114.587
CAIFI (1/Ca)	3.077	114.587
SAIDI (h/Ca)	15.531	389.001
CAIDI (h)	5.047	3.395
ASAI	0.9982	0.955
ASUI	0.00177	0.0444
ENS (MWh/a)	140.695	3387.427
AENS (MWh/Ca)	0.007	0.121
ASIFI (h/a)	2.534	86.394
ASIDI (1/Ca)	12.7694	307.442

4.1.4 Real system with Reconfiguration.

New 33 kV feeder is under construction at the moment from Kalwapur to Bansha a tapping point where old line meets.



4.3 Modelling of real system with reconfiguration

With simple reconfiguration of line, there can be seen noticeable decrease in the loss. The disconnected segment is of rabbit conductor, which will be replaced by dog from other end as shown in fig. And, after reliability analysis there is seen significant change in the reliability indexes also. This is due to the fact that the disconnected segment has high failure rate and high repair hour.

Table 4.6 Real System with Reconfiguration

	Without reconfiguration	With Reconfiguration
SAIFI (1/Ca)	114.587	108.26
CAIFI (1/Ca)	114.587	108.26
SAIDI (h/Ca)	389.001	302.435
CAIDI (h)	3.395	2.794
ASAI	0.955	0.9654
ASUI	0.0444	0.034
ENS (MWh/a)	3387.427	2700.898
MW loss	3.89	3.44
Loss %	26	23.79

4.2 Insertion of substation

With reconfiguration there is seen high technical loss in the line also the reliability indexes are also poor. As mention in chapter 3, insertion of substation is done in Punarbas Nagarpalika. One feasible place is selected and 2 feeders are constructed and re-connected to existing old feeder nearby. The size of the substation will be 6/8 MVA will be supplied from Dhangadhi SS.

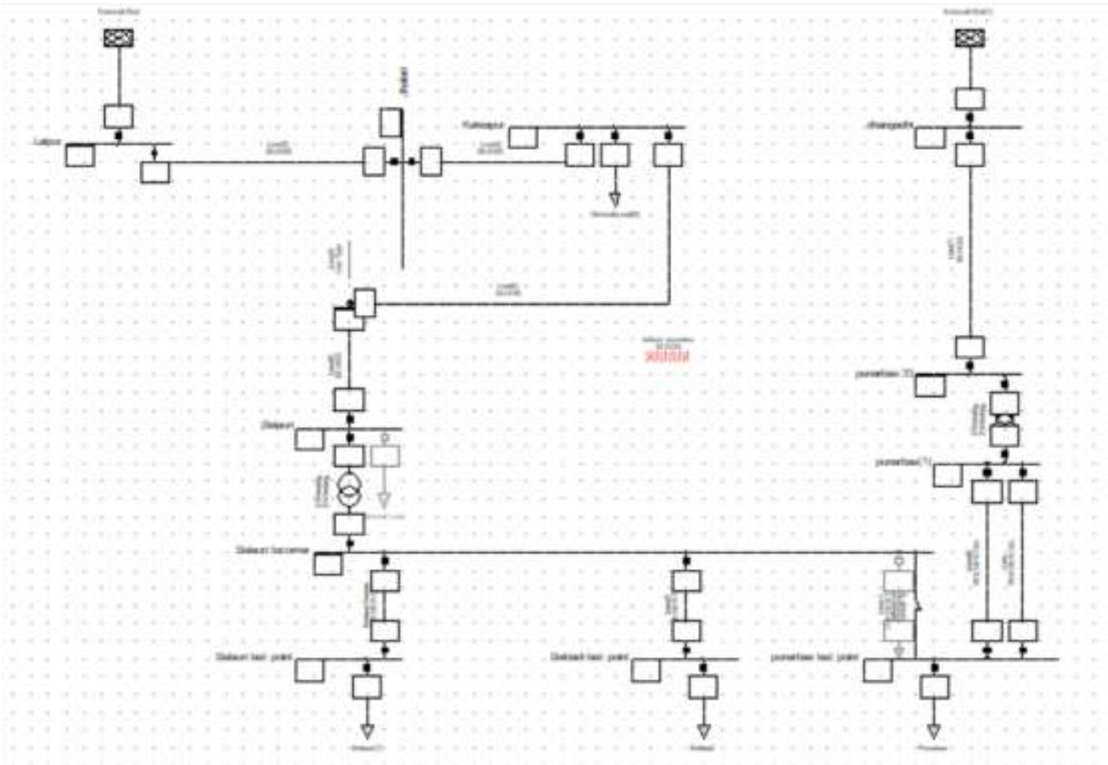


Figure 4.4 Modelling of system with insertion of substation

Three different cases are analyzed in this section. With the insertion of substation in the system.

Case 1. New Substation supply to particular feeder

Case 2. New Substation Supply to whole distribution network

Case 3. New Substation and existing system interconnected.

For all these case, technical analysis and reliability assessment is done

4.2.1 Integration of Substation and supply to particular feeder only

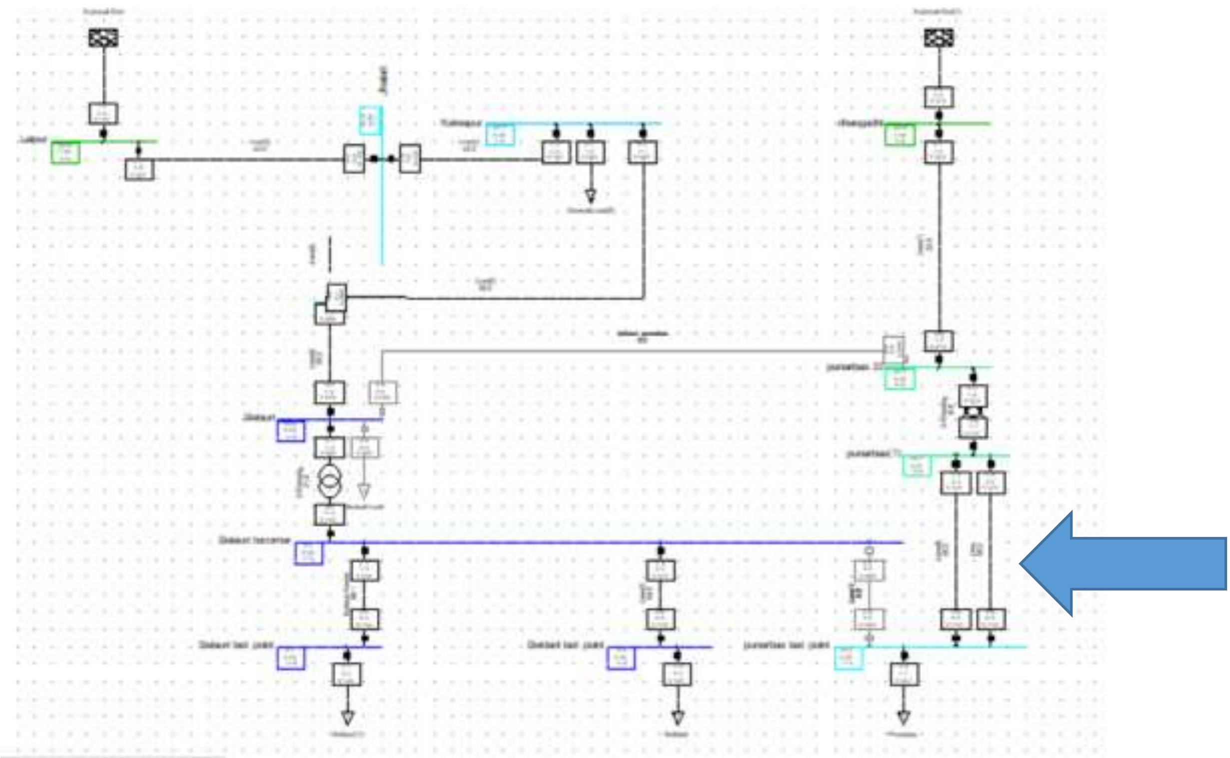


Figure 4.5 Calculation of system with insertion of substation

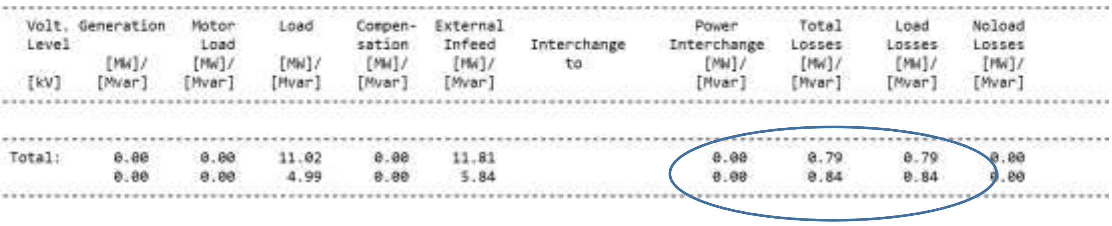
The size of inserted substation is 6/8 MVA. This newly inserted substation has two feeder busbar. This substation is located in between the line segment of Punarbas feeder. So two feeder will be assumed to have half of length of previous feeder. Now the system is modeled in the Digsilent, load flow and reliability assessment calculation was done. The optimization problem is to minimize the technical loss and increase the reliability of the system.

Table 4.7 Voltage and branch currents after adding substation into the network

Node/ Branch	Voltage	Angle
	(p.u.)	(radian)
Lalpur	1	0
Dhangadhi	1	0

Kalwapur	0.95	-1.28
Belauri Incomer33	0.9	-2.53
Punarbas Incomer 33	0.98	-0.62
Belauri feeder	0.88	-3.00
Beldadi feeder	0.86	-3.2
Punarbas feeder	0.97	-1.13

Voltage level increases significantly with the insertion of the substation. The total loss of the system is also decrease to 0.79MW. Loss percent decrease to 6.689% from earlier calculate 26%



Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen- sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
Total:	0.00 0.00	0.00 0.00	11.02 4.99	0.00 0.00	11.81 5.84		0.00 0.00	0.79 0.84	0.79 0.84	0.00 0.00

Figure 4.6 Loss of system with insertion of substation

For reliability purpose, the failure rate of busbar and transformer in taken from reference system. The failure rate of Dhangadhi-Punarbas line is taken half of Bansha-Jhalari rate and repair rate is taken as half of Bansha-Jhalari line because of easy accessibility. The reliability of system increases with inserted substation. Total energy not served decreases from 3387.427 MWh per year to 1102MWh per year. Other reliability indexes are shown in table.

Table 4.8 Reliability indexes after adding substation into the network

	Existing case	With inserted SS
SAIFI (1/Ca)	114.587	47.314
CAIFI (1/Ca)	114.587	47.314
SAIDI (h/Ca)	389.001	103.423
CAIDI (h)	3.395	2.186
ASAI	0.955	0.98819
ASUI	0.0444	0.0118
ENS (MWh/a)	3387.427	1102.346

4.2.2 New Substation supplies to whole feeder

Similar to the Case 4.3.1, Now the system is modeled in such a way that it will provide the power of whole DCS. The connection line between new Punarbas SS to to existing SS is about 10 km. The failure rate and repair time for this line segment is taken as of Dhangadhi-Punarbas line because it has similar access and geographical condition. Arrangement done for this model.

a) Belauri -Punarbas 33kV line connected
b) Belauri-Bansha line is turned off.
c) Bansha-Jhalari line turned off
d) Kalwapur-Bansha is also turned off.

Both technical analysis load flow and reliability analysis was done and the results are listed in the table

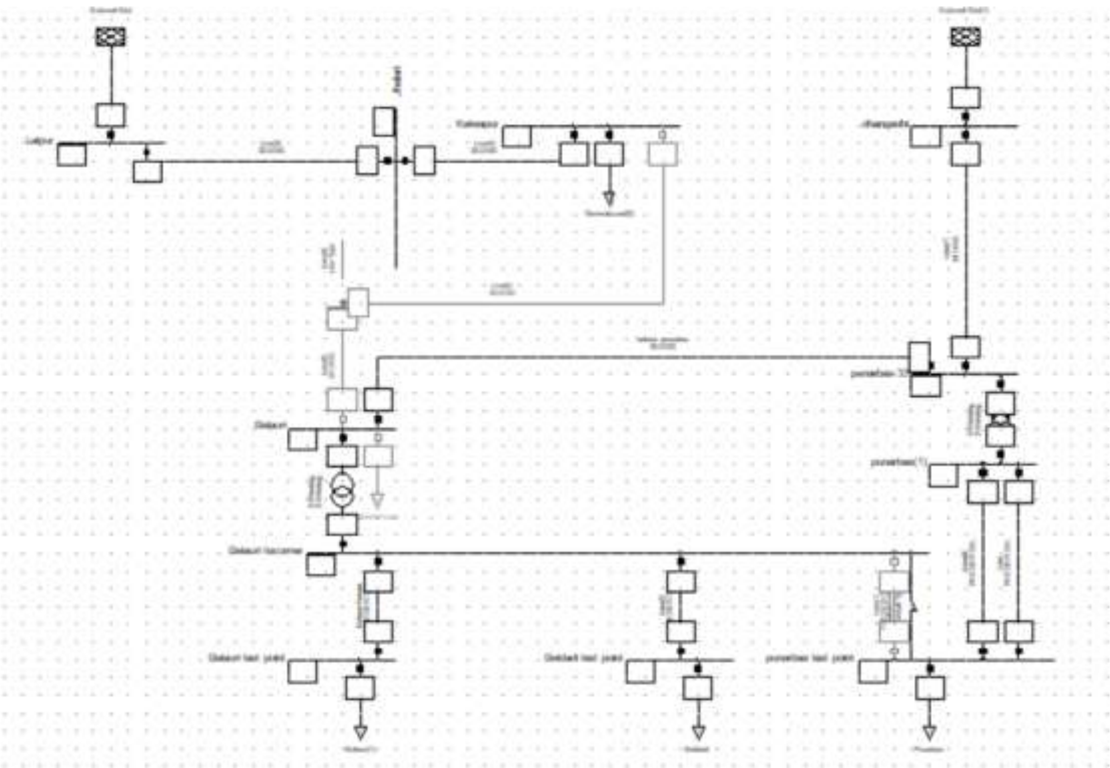


Figure 4.5 Modelling of system with new substation supplies all feeders

Table 4.9 Values of Reliability indexes substation to all feeder.

	Existing system	New SS to All DCS feeders
SAIFI (1/Ca)	114.587	41.08
CAIFI (1/Ca)	114.587	41.08
SAIDI (h/Ca)	389.001	39.962
CAIDI (h)	3.395	0.973
ASAI	0.955	0.9954
ASUI	0.0444	0.004
ENS (MWh/a)	3387.427	615.653
MW infeed	14.92	11.67
MW loss	3.89	0.65
Loss %	26	5.57

4.2.3 New Substation and Old system combined to feed whole feeder

Now for further analysis of the system we try connect the whole system with each other. Kalwapur -Belauri is connected to the Belauri substation and Dhangadhi -Punarbas line is connected to the new Punarbas substation. Also, Punarbas to Belauri is also connected. Arrangement of switch are done to connect lines to each other. For this interconnected system, voltage level is calculated at particular nodes, technical actice loss is calculated.

With the interconnection of lines, it is assumed that the reliability of the system might be increased. Whereas the results shows as in the table.

Table 4.10 Voltage and angles in combined mode into the network

Node/ Branch	**Voltage**	**Angle**
	(p.u.)	(radian)
Lalpur	1	0
Dhangadhi	1	0
Kalwapur	0.946	-1.28
Belauri Incomer33	0.898	-2.53
Punarbas Incomer 33	0.951	-2.53
Belauri feeder	0.88	-3.00

Beldadi feeder	0.857	-3.2
Punarbas feeder	0.97	-1.13

Table 4.11 Values of reliability indexes for combined mode .

	Existing system	Interconnected
SAIFI (1/Ca)	114.587	47.314
CAIFI (1/Ca)	114.587	47.314
SAIDI (h/Ca)	389.001	96.728
CAIDI (h)	3.395	2.044
ASAI	0.955	0.988
ASUI	0.0444	0.011
ENS (MWh/a)	3387.427	1047.34
MW infeeded	14.92	11.81
MW loss	3.89	0.79
Loss %	26	6.689

4.3 Comparison of different cases

4.3.1 Voltage profile in different case

With the insertion of substation and different cases of the analyzing the real field we summarize the following results. The results are tabulated for different cases and graph is shown.

Change in voltage level in particular node of the system for various case.

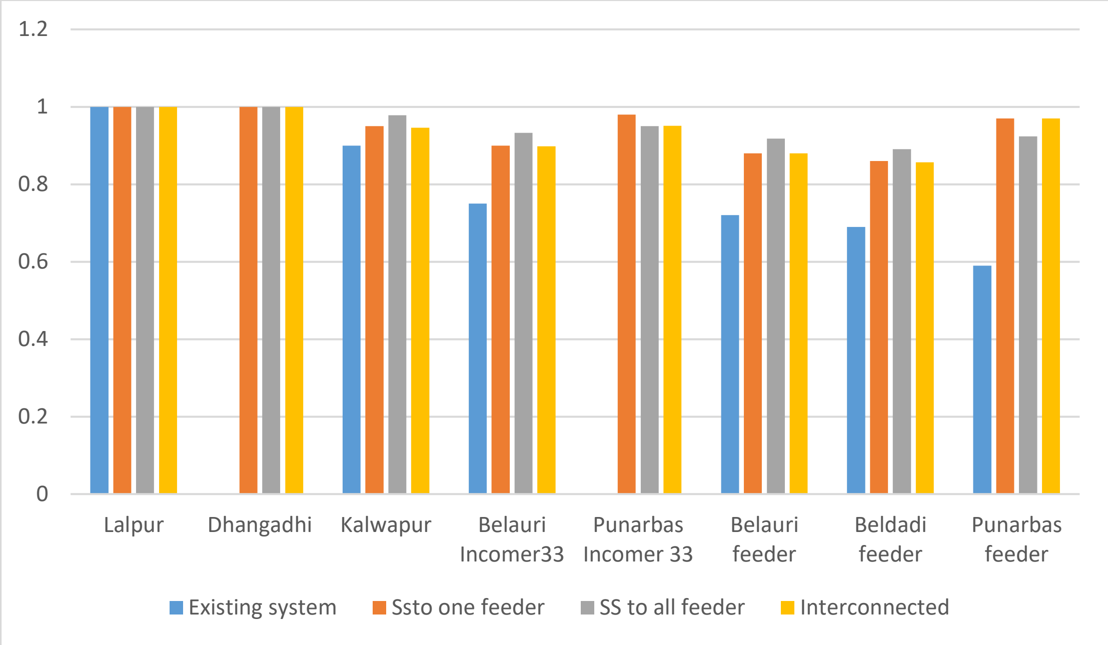


Figure 4.5 Comparison of Voltages in various Cases

4.3.2 Determination of Reliability indexes for various case

For different case of system modeling the calculation of reliability assessment is done and the system results are tabulated as follows.

Table 4.12 Reliability Indexes for different case

Reliability indexes	Existing system	Refiguration	With inserted SS	New SS to All DCS feeders
SAIFI (1/Ca)	114.587	108.26	47.314	41.08
CAIFI (1/Ca)	114.587	108.26	47.314	41.08
SAIDI (h/Ca)	389.001	302.435	103.423	39.962
CAIDI (h)	3.395	2.794	2.186	0.973
ASAI	0.955	0.9654	0.98819	0.9954
ASUI	0.0444	0.034	0.0118	0.004
ENS (MWh/a)	3387.427	2700.898	1102.346	615.653
MW infeeded	14.92	14.46	11.89	11.67
MW loss	3.89	3.44	0.79	0.65
Loss %	26	23.79	6.65	5.57

4.4 Cost Analysis and Saving

Technical losses and the reliability indexes are calculated. The power loss in the line is calculated for each case. The power loss minimization is the revenue saved which was earlier wasted in the form of system losses.

Also Energy not served index gives us the idea about the energy which are not served due to power failure in the system. Minimizing it, we will collect revenue for the shed power in the system. In this thesis we tried to accumulated both the cost, calculated the necessary data and presented the result as annual saving in the system.

4.4.1 Cost of per unit Energy (Purchase/Sell)

As per NEA annual report 2021/22 the average cost of energy purchase (kwh) is Rs. 6.1 and average selling cost of energy (kwh) is Rs. 9.3[41]. Hence there is profit of 3.2 in each unit of energy.

4.4.2 Relation between Peak load loss and Average Loss

As mention in earlier in this chapter, the calculation of the system losses for various cases are done with the available peak load. But the system will not have the peak load all the time. There is certain time in which peak load is available and other time the load will not be the near to the peak load, which in further also affect the loss calculated from the system. So the certain multiplying factor was calculated by taking square of currents. The percentage decrease of square of current of every hour with reference to the peak load is calculated. Since loss is directly proportion to the square of current, the average percentage decrease in loss can be calculated with reference of peak load loss. We add all the hourly loss and divide with the 24 hour peak load loss and found that the average loss to peak load ratio is 0.35.

One day complete 24 hour load from Belauri substation is taken of Belauri 33 kV line from Kalwapur and calculation is done as shown in table.

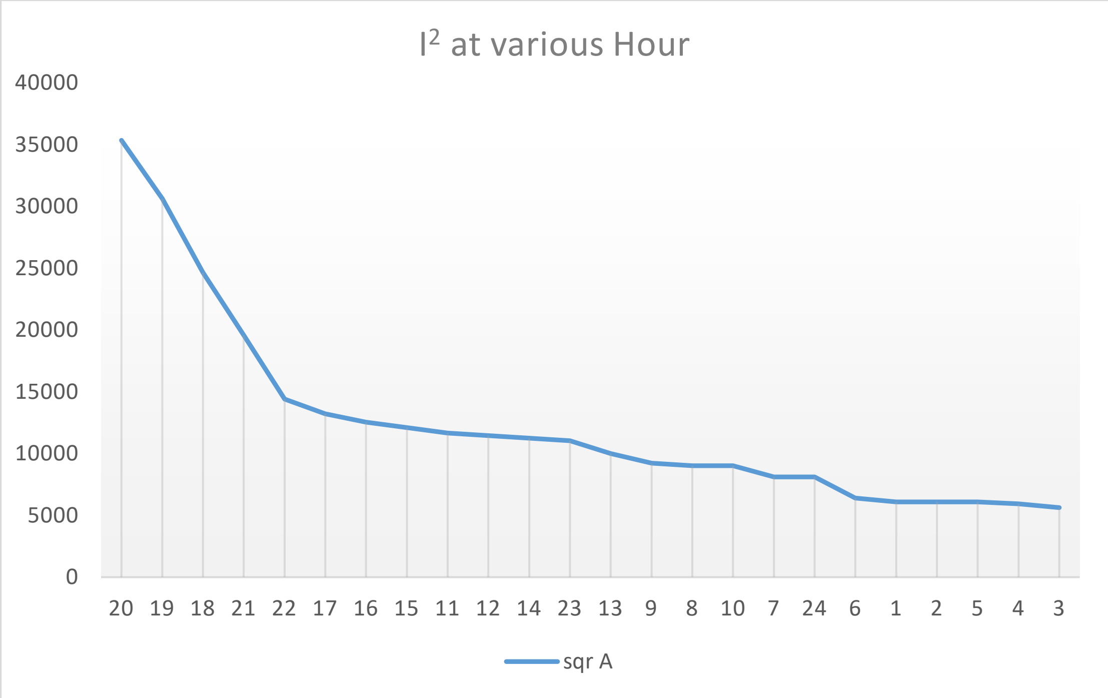


Figure 4.9 Variation of current at various Hour

Since loss is directly proportional to the square of current , the percentage decrease in the loss for particular hour can be calculated by calculating percentage decrease in square of current with respect to the peak load current .

Table 4.13 Average load loss and Peak load loss

S.N	Time(hrs)	I	I^2	I^2 Decrease wrt to Peak	Decrease in system loss
1	20	188	35344	0%	1
2	19	175	30625	-13%	0.866
3	18	157	24649	-30%	0.697
4	21	140	19600	-45%	0.555
5	22	120	14400	-59%	0.407
6	17	115	13225	-63%	0.374
7	16	112	12544	-65%	0.355
8	15	110	12100	-66%	0.342
9	11	108	11664	-67%	0.330
10	12	107	11449	-68%	0.324
11	14	106	11236	-68%	0.318
12	23	105	11025	-69%	0.312
13	13	100	10000	-72%	0.283
14	9	96	9216	-74%	0.261

15	8	95	9025	-74%	0.255
16	10	95	9025	-74%	0.255
17	7	90	8100	-77%	0.229
18	24	90	8100	-77%	0.229
19	6	80	6400	-82%	0.181
20	1	78	6084	-83%	0.172
21	2	78	6084	-83%	0.172
22	5	78	6084	-83%	0.172
23	4	77	5929	-83%	0.168
24	3	75	5625	-84%	0.159

Here to loss according to peak load = 1*24=24

But according to calculation loss = 8.418

So Average load loss/peak load loss = **0.35**.

4.4.3 Calculation for cost saved

ENS Energy not supplied is one of the parameters which can be minimized so that the energy to consumers should be sold. Decrease in ENS save revenue.

Cost saved due to Decrease in ENS= Decrease in ENS (kwh/a) *8760*profit per kwh

Where,

profit per kwh = 3.2

Also Decrease in loss of system save the energy which was earlier wasted due to losses in the system. This saving can be calculated as:

Cost saved due to decrease in loss = Loss reduced (kw) *8760*profit per kwh*average/peak loss

Where,

profit per kwh = 3.2

Average /peak load = 0.35

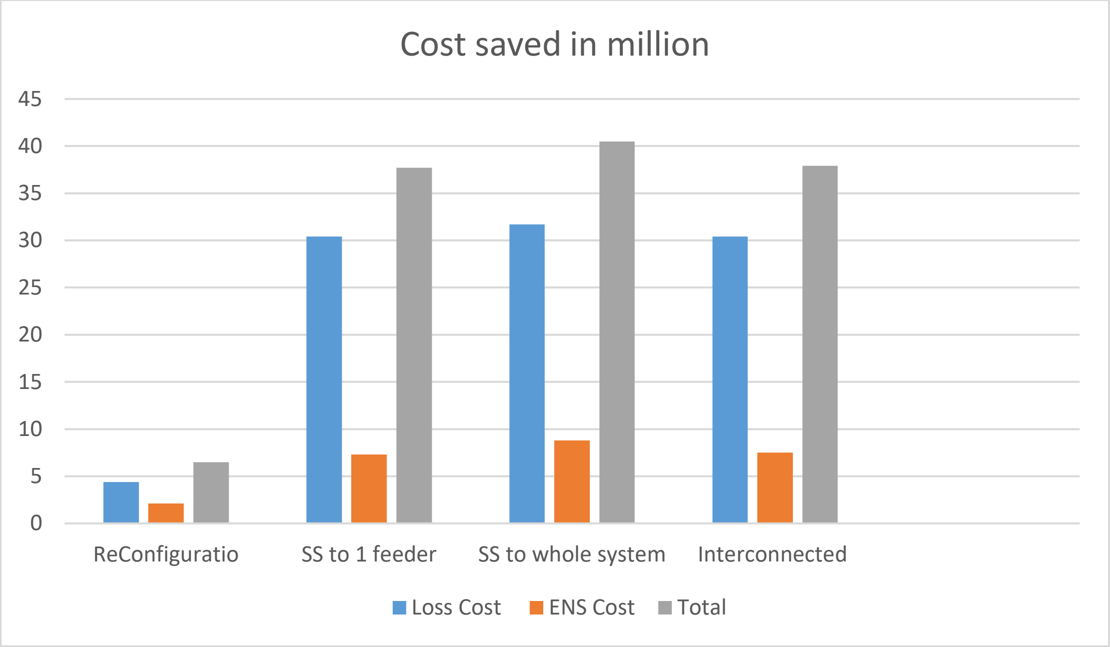


Figure 4.10 Cost analysis and Saving in various Cases

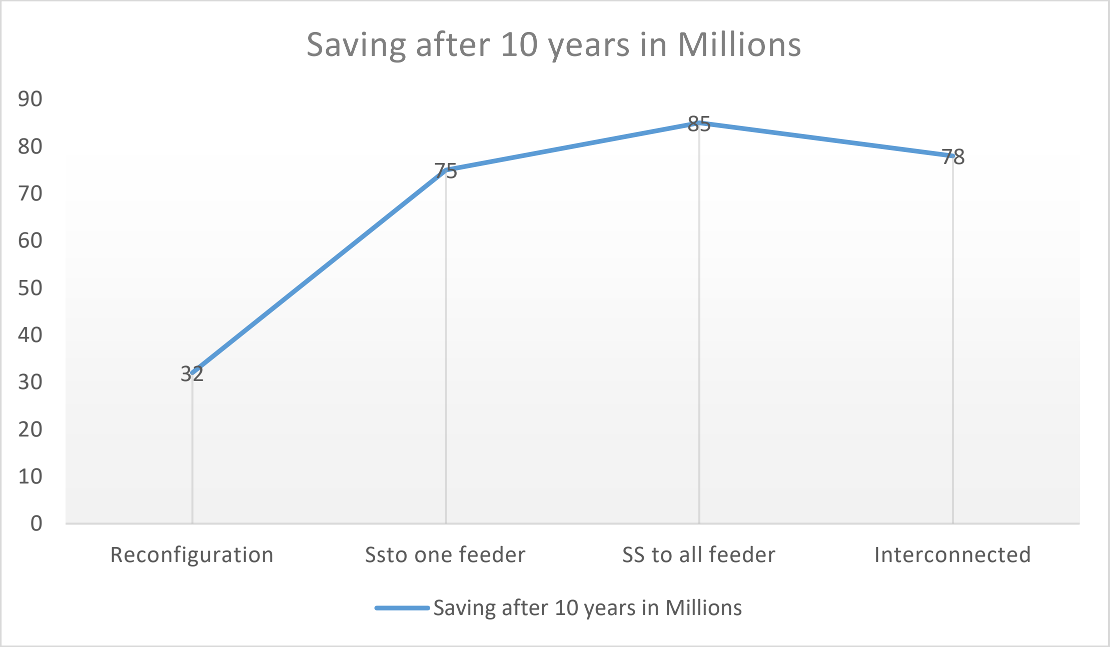


Figure 4.11 Saving After 10 years in Millions

4.5 Summary of the results

Analysis of various model are performed with the main objective to integrate substation and analyze the main objective in the system. Firstly, we modeled IEEE refence 33 bus in the digsilent, the result shown by software was analyze with the reference output. This show the system is operating optimally, as evidenced by the consistency of node voltages and the alignment of total active and reactive power values with the reference data. This suggests that the power distribution within the system is well-balanced and meets the desired specifications. Secondly, we modeled RBTS 2 bus reference system in digsilent. The required reliability assessment is done and the reliability indexes are analyzed. The deviation of reference results to generated results generated by digsilent is in acceptance range. So, this software DigSILENT was chosen for the analysis in the real field.

In this work, insertion of substation in Punarbas Nagarpalika in a suitable location was done. Before inserting the substation in system, we first reconfigure the existing 33 kV line. We connected the 33 kV line from Kalwapur substation where separate circuit breaker was already installed and dismantled the existing tapping from Jhalari. This case shows little decrease in the loss but have greater significance in reliability, this is due to high fault under Bansha-Jhalari line also, Jhalari tapping causing extra time for line supply. The second case was to supply the Punarbas feeder from newly inserted substation which is feed from Dhangadhi. The total loss of the system is decreases from 26% to 6.65%. Also, the reliability of the system increases as all the positive indexes are increasing and negative indexes are decreasing. Energy not served was decreased from 3387 MWh per year to 1102 MWh per year.

Third case was to supply all the DCS load from new substation. The connection from the old Kalwapur bansha was disconnected. Calculation is done for both technical losses and reliability indexes. The system total loss is further decrease and reliability of the system further increase. This is due to long length of existing line and higher failure rate. Also, the repair time for old line is very high with compared to the new line as new line will be constructed alongside road, while old through field and forest.

Further Case 4, all system old line and new line are interconnected and the objective of the thesis is check in the modeled system. The modeled system was run to find the results. It was found that the system loss slightly increases also the reliability of the system slightly decreases that case 3. Reliability decreases due to high failure rate of old system being connected to the line. Technical losses are due to more voltage drop in old line. The results shows that the voltage of high load feeder ie. Punarbas is increases but the feeder voltage of Belauri and Beldadi decrease. This causes the increasing in technical loss. Hence modeling different cases, analyzing the results it the technical losses reduction and Reliability of the system increasing was done successfully and the insertion of the substation is found acceptable.

From economic point of view all case are studied. In case 1- reconfiguration of 33 kV line to Belauri from Lalpur through Jhalari tapping was reconfigured through Kalwapur substation. Old line is of 0.5 (rabbit) conductor and new line will be of dog, so it decreases loss by only certain margin but reliability increases quite significantly, which show annual saving of around 6.5 million. In case 2 new substation is inserted and one feeder - Punarbas is feeded from it, decreases loss significantly and increases reliability very much, which show the annual saving of 37.7 million. In third case whole system is supplied from the new constructed substation. which shows further decrease in loss and further increases in reliability and have saving of Rs. 40.3 million. And final case was interconnecting all the old lines and new substation and certain increase in loss than case 3 and certain decrease in reliability than previous case which shows the annual saving of NRs. 37.5 million. After all calculation and cost analysis case 3 ie new substation suppling power to all the consumers under Belauri DCS is most feasible out of all cases.

CHAPTER 5: CONCULSION AND FUTURE WORKS

5.1 Conclusion

Analysis of various model are performed with the main objective to integrate substation and analyze the main objective in the system. Firstly, we modeled IEEE refence 33 bus in the digsilent, the result shown by software was analyze with the reference output. system is operating optimally, as evidenced by the consistency of node voltages and the alignment of total active and reactive power values with the reference data. This suggests that the power distribution within the system is well-balanced and meets the desired specifications. Secondly, we modeled RBTS 2 bus reference system in digsilent. The required reliability assessment is done and the reliability indexes are analyzed. The deviation of reference results to generated results generated by digsilent is in acceptance range. So, this software DigSILENT was chosen for the analysis in the real field.

In this work, insertion of substation in Punarbas Nagarpalika in a suitable location was done. The first case was to supply the Punarbas feeder from newly in inserted substation which is feed from Dhangadhi. The total loss of the system is decreases from 26% to 6.65%. Also, the reliability of the system increases as all the positive indexes are increasing and negative indexes are decreasing. Energy not served was decreased from 3387 MWh per year to 1102 MWh per year.

Second case was to supply all the DCS load from new substation. The connection from the old Kalwapur bansha was disconnected. Calculation is done for both technical losses and reliability indexes. The system total loss is further decrease and reliability of the system further increase. This is due to long length of existing line and higher failure rate. Also, the repair time for old line is very high with compared to the new line as new line will be constructed alongside road, while old through field and forest.

Further Case three, all system old line and new line are interconnected and the objective of the thesis is check in the modeled system. The modeled system was run to find the results. It was found that the system loss slightly increases also the reliability of the system slightly decreases that case 2. Reliability decreases due to high failure rate of old system being connected to the line. Technical losses are due to more voltage drop in old line. The results shows that the voltage of high load feeder ie. Punarbas is increases but the feeder voltage of Belauri and Beldadi decrease. This causes the increasing in technical loss. Hence modeling different cases, analyzing the results it the technical losses reduction and Reliability of the system increasing was done successfully and the insertion of the substation is found acceptable.

5.2 Future Works

This thesis work has attempted to analyze the impact of insertion of the substation in the real field. This works as mention shows how the voltage at every nodes increases, how technical losses decrease and reflect that the reliability of the system will increase., hence it can be taken as reference for the research work that are oriented in insertion of substation in high losses load center. However, there are still many area where future improvement can be done. The areas for probable future work based on the outcomes of the thesis.

- Reliability of the protection devices in the distribution network such as fuse, relay, disconnected, reclosure etc can be taken in account.
- This work is mainly oriented on 33 kV line loss, proper modeling of distribution transformer should be done total loss calculation and reliability analysis.
- Economic analysis with proper distribution network can be done.
- Optimization of the substation can be done, which will provide the minimum losses.
- Analysis the system in the unbalanced system.

REFERENCES

[1] B. E. A. Sultana, "Review on reliability improvement and power loss reduction in distribution system via network reconfiguration." Renewable and sustainable energy reviews 66 : 297-310.," *2016.*

[2] Sanford, F. (1947). "Electric distribution fundamentals. McGraw-Hill Book Co..".

[3] Allan, R. N., & Ochoa, J. R. (1988)." Modeling and assessment of station originated outages for composite systems reliability evaluation. IEEE Transactions on Power Systems, 3(1), 158-165.".

[4] Ringlee, R. J., & Goode, S. D. , " On procedures for reliability evaluations of transmission systems. IEEE Transactions on Power Apparatus and Systems, (4), 527-536.," 1970.

[5] Kim, H. K. (2010). "Reliability modeling and evaluation in aging power systems (Doctoral dissertation, Texas A & M University).".

[6] Billinton, R., &Billinton, J. (1989). "Distribution system reliability indices. IEEE Transactions on Power Delivery, 4(1), 561-568.".

[7] Franklin, O., & Gabriel, A. (2014)." Reliability Analysis of Power Distribution System in Nigeria: A Case Study of Ekpoma Network, Edo State. Interl. J. Elect. Elect. Engg, 2(3), 175-182".

[8] Brown, R. E., & Taylor, T. M. (1999). "Modeling the impact of substations on distribution reliability. IEEE Transactions on Power Systems, 14(1), 349-354".

[9] Allan, R. N., Billinton, R., Sjarief, I., Goel, L., & So, K. S. (1991). "A reliability test system for educational purposes-basic distribution system data and results. IEEE Transactions on Power systems, 6(2), 813-820.".

[10] H. E. Kassem, M. Badr and S. A. Ahmed, "Reduction of energy losses in electrical distribution systems," 22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013), Stockholm, 2013, pp. 1-4, doi: 10.1049/cp.2013.0589.".

[11] Mokoka, O. K., & Awodele, K. O. (2013, September). "Reliability Evaluation of distribution networks using NEPLAN & DIgSILENT power factory. In AFRICON, 2013 (pp. 1-5). IEEE.".

[12] Allan, R., & Billinton, R. (1993). "Power system reliability and its assessment. III. Distribution systems and economic considerations. Power Engineering Journal, 7(4), 185-192".

[13] Bollen, M. H. (2000). "Understanding power quality problems. Piscataway, NJ, USA: IEEE, 1, 1-35.".

[14] C. M. P. Dos Santos, "Determination of Electric Power Losses in Distribution Systems," 2006 IEEE/PES Transmission & Distribution Conference and Exposition: Latin America, Caracas, Venezuela, 2006, pp. 1-5, doi: 10.1109/TDCLA.2006.311585.".

[15] Rohani, H., & Roosta, A. K. (2014). "Calculating Total System Availability.".

[16] Torell, W., & Avelar, V. (2004). "Mean time between failure: Explanation and standards. white paper, 78.".

[17] P. B. Albrecht, " "reliability test system. IEEE Transactions on power apparatus and systems"," *IEEE,* vol. 98(6), pp. 2047-2054., 1979.

[18] Brown, R. E. (2008). "Electric power distribution reliability. CRC press.".

[19] Goodin, R. E., Fahey, T. S., & Hanson, A. (1999). "Distribution reliability using reclosers and sectionalisers. ABB, Inc., Lake Maryu, FL, USA.".

[20] H. Kim and C. Singh, "Reliability Modeling and Simulation in Power Systems With Aging Characteristics," in IEEE Transactions on Power Systems, vol. 25, no. 1, pp. 21-28, Feb. 2010, doi: 10.1109/TPWRS.2009.2030269.".

[21] Khounnouvong, S., Premrudeepreechacharn, S., & Ngamsanroaj, K. (2015, October). "Reliability improvement of the electrical distribution system of the Thanaleng Substation in Vientiane capital, Laos. In North American Power Symposium (NAPS), 2015 (pp. 1-6).".

[22] Jibril, Y., & Ekundayo, K. R. (2013). "Reliability Assessment of 33kV Kaduna Electricity Distribution Feeders, Northern Region, Nigeria. In Proceedings of the World Congress on Engineering and Computer Science (Vol. 1).".

[23] Sumper, A., Sudria, A., & Ferrer, F. (2005). "International reliability analysis in distribution networks. CITCEA Report for ENDESA RED. Spain, 32-36.".

[24] Ghods, A., Khaboury, D. A., & Zakerifar, R. (2009, October). "Case study of distribution network reliability analysis based on probabilistic method. In North American Power Symposium (NAPS), 2009 (pp. 1-7). IEEE.".

[25] Brown, R. E., & Taylor, T. M. (1999). "Modeling the impact of substations on distribution reliability. IEEE Transactions on Power Systems, 14(1), 349-354.".

[26] Allan, R. N. (2013). "Reliability evaluation of power systems. Springer Science & Business Media".

[27] Franklin, O., & Gabriel, A. (2014). "Reliability Analysis of Power Distribution System in Nigeria: A Case Study of Ekpoma Network, Edo State. Interl. J. Elect. Elect. Engg, 2(3), 175-182".

[28] Bam, L., & Jewell, W. (2005, June). "Power system analysis software tools. In Power Engineering Society General Meeting, 2005. IEEE (pp. 139-144). IEEE.".

[29] "Manual, DIgSILENT Power Factory. "Version 14.1. 6." DIgSILENT GmbH.".

[30] C Singh and R Billinton, "System Reliability Engineering.: Hutchison, 1977.".

[31] Li, W., Zhou, J., Xie, K., & Xiong, X. (2008). "Power system risk assessment using a hybrid method of fuzzy set and Monte Carlo simulation. IEEE Transactions on Power Systems, 23(2), 336-343.".

[32] O. J. Ayamolowo, C. A. Mmonyi, S. O. Adigun, O. A. Onifade, K. A. Adeniji and A. S. Adebanjo, "Reliability Analysis of Power Distribution System: A Case Study of Mofor Injection Substation, Delta State, Nigeria," 2019 IEEE AFRICON, Accra, Ghana, 2019, pp.".

[33] Suthapanun, C., Jirapong, P., Bunchoo, P., &Thararak, P. (2015, June). "Reliability assessment tool for radial and loop distribution systems using DIgSILENT PowerFactory. In Electrical Engineering/Electronics, Computer, Telecommunications and Information T".

[34] Dorji, T. (2009)." Reliability Assessment of Distribution Systems:-Including a case study on Wangdue Distribution System in Bhutan (Master's thesis, Institutt for elkraftteknikk).".

[35] Sanford, F. (1947). "Electric distribution fundamentals. McGraw-Hill Book Co..".

[36] Zahir Hossain Khan,"Improving reliability performance of medium voltage network. university of kape town 2015".

[37] Burke, J. J. (1994). "Power distribution engineering: fundamentals and applications. CRC Press..".

[38] Hewitson, L., & Balakrishnan, R. (2005) "Practical power system protection [electronic resource]. LG Ox [2]ford: Newnes.".

[39] "IEEE Guide for Collecting, Categorizing, and Utilizing Information Related to Electric Power Distribution Interruption Events, IEEE Standard 1782-2014, Aug. 2014, pp. 1–98".

[40] "IEEE Standards Association. (2012). IEEE Std 1366™-2012. IEEE Guide for Electric Power Distribution Reliability Indices, IEEE Power & Energy Society, IEEE, 3, 10016-5997.".

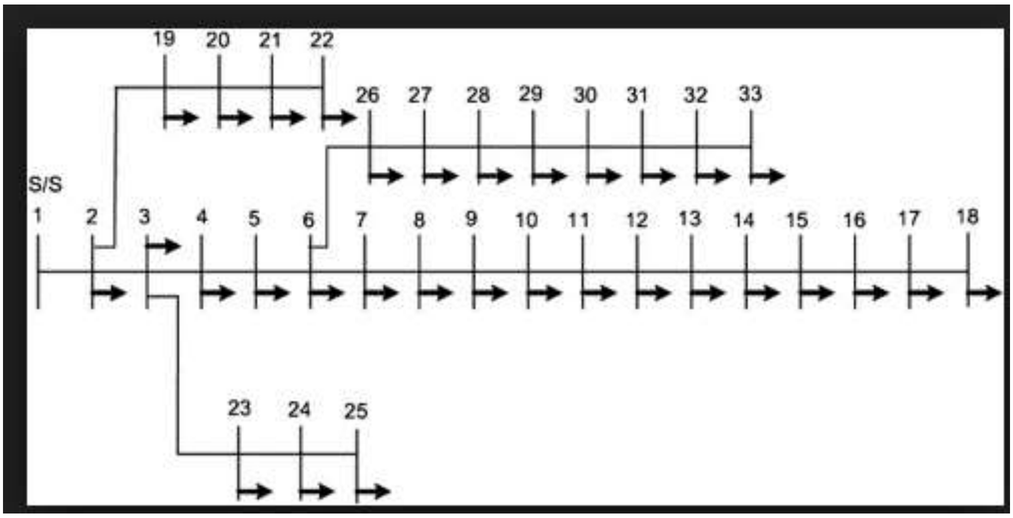
[41] "NEPAL ELECTRICITY AUTHORITY A YEAR IN REVIEW-FISCAL YEAR 2021/2022".

[42] Mokoka, O. K., & Awodele, K. O. (2013, September). " Reliability Evaluation of distribution networks using NEPLAN & DIgSILENT power factory. In AFRICON, 2013 (pp. 1-5). IEEE.".

ANNEXURE A: Network Details of 33 Bus Test Network

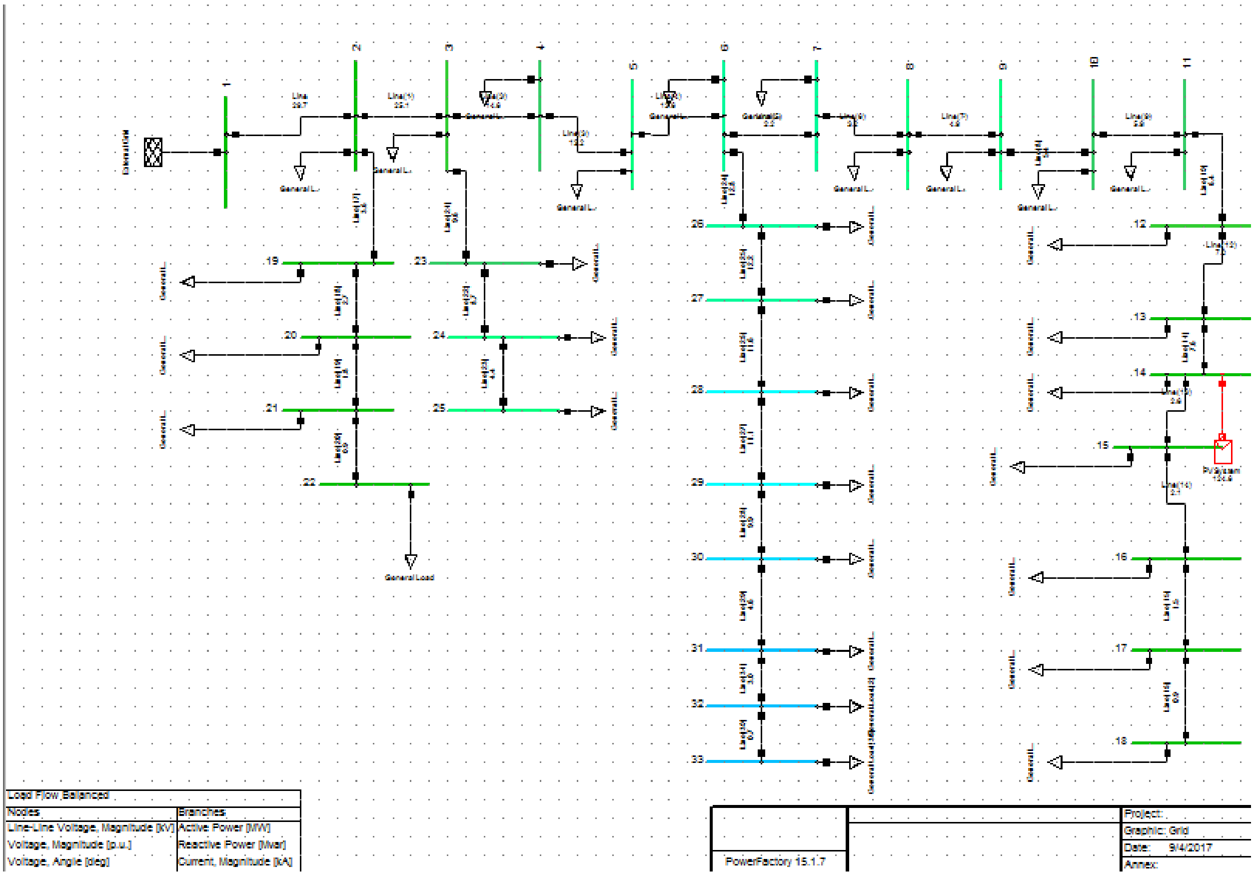
IEEE 33 Bus Radial distribution system:

Total connected Load = 3.715 MW, 2.3 MVar, Base: 100 MVA, Voltage level= 12.66 kV

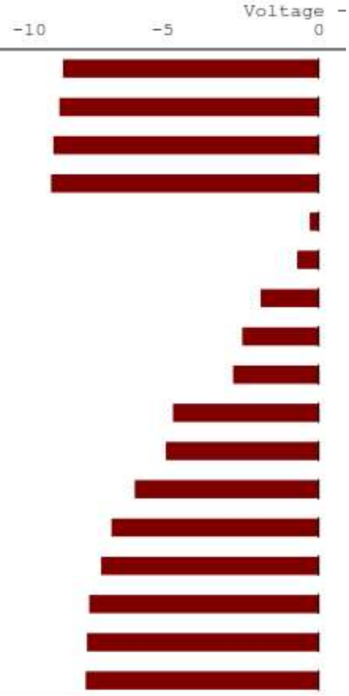


Branch nom	Sen. node	Rec. node	Active Power of Rec. node KW	Reactive Power of Rec. node KVAr	Resistance ohms	Reactance ohms
1	1	2	100	60	0.0922	0.0470
2	2	3	90	40	0.4930	0.251 1
3	3	4	120	80	0.3660	0.1 864
4	4	5	60	30	0.3811	0.1941
5	5	6	60	20	0.8190	0.7070
6	6	7	200	100	0.1872	0.6188
7	7	8	200	100	1.7114	1.2351
8	8	9	60	20	1.0300	0.7400
9	9	10	60	20	1.0440	0.7400
10	10	11	45	30	0.1966	0.0650
11	11	12	60	35	0.3744	0.1238
12	12	13	60	35	1.4680	1.1550
13	13	14	120	80	0.5416	0.7129
14	14	15	60	10	0.5910	0.5260
15	15	16	60	20	0.7463	0.5450
16	16	17	60	20	1.2890	1.7210
17	17	18	90	40	0.7320	0.5740
18	2	19	90	40	0.1640	0.1565
19	19	20	90	40	1.5042	1.3554
20	20	21	90	40	0.4095	0.4784
21	21	22	90	40	0.7089	0.9373
22	3	23	90	50	0.4512	0.3083
23	23	24	420	200	0.8980	0.7091
24	24	25	420	200	0.8960	0.7011
25	5	26	60	25	0.2030	0.1034
26	26	27	60	25	0.2842	0.1447
27	27	28	60	20	1.0590	0.9337
28	28	29	120	70	0.8042	0.7006
29	29	30	200	600	0.5075	0.2585
30	30	31	150	70	0.9744	0.9630
31	31	32	210	100	0.3105	0.3619
32	32	33	60	40	0.3410	0.5302
33*	21	8			2.0000	2.0000
34*	22	12			2.0000	2.0000
35*	9	15			2.0000	2.0000
36*	25	29			0.5000	0.5000
37*	33	18			0.5000	0.5000

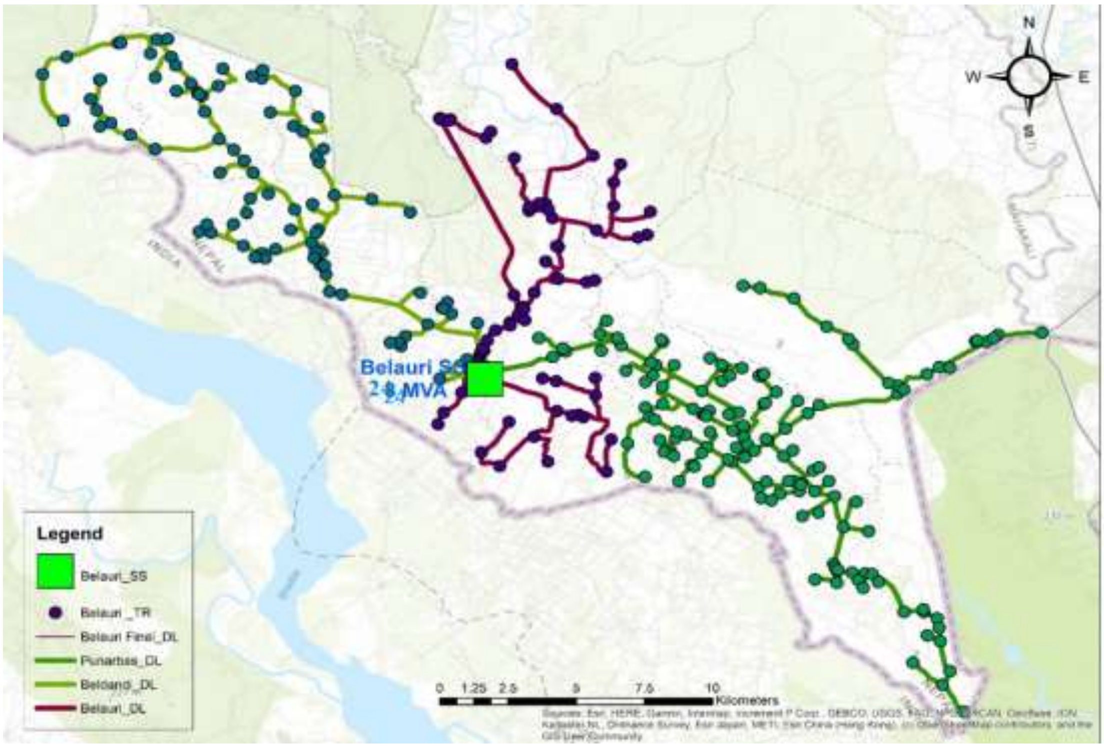
Load flow Analysis of IEEE 33 Bus using Digsilent Power factory(Base case):



Grid: Grid	System Stage: Grid				Study Case: Study Case
	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	
	12.66	0.908	11.49	-0.57	
16	12.66	0.906	11.47	-0.60	
17	12.66	0.904	11.45	-0.68	
18	12.66	0.904	11.44	-0.69	
19	12.66	0.996	12.61	0.01	
21	12.66	0.992	12.56	-0.08	
23	12.66	0.979	12.40	0.07	
24	12.66	0.972	12.31	-0.02	
25	12.66	0.969	12.27	-0.06	
26	12.66	0.947	11.99	0.18	
27	12.66	0.945	11.96	0.24	
28	12.66	0.933	11.82	0.32	
29	12.66	0.925	11.71	0.40	
30	12.66	0.922	11.67	0.50	
31	12.66	0.917	11.61	0.42	
32	12.66	0.917	11.60	0.40	
33	12.66	0.916	11.60	0.39	



ANNEXURE B: Network Details of Belauri DCS



Belauri 11 kV Feeder

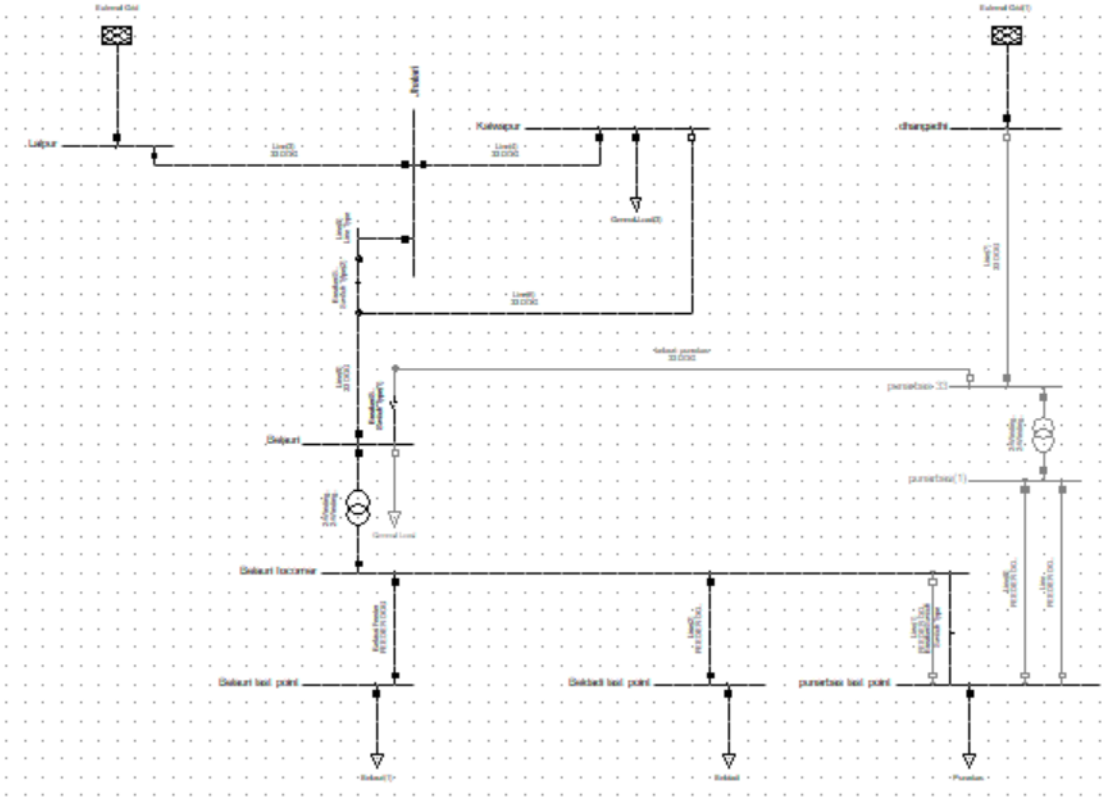
Figure A.1 GIS plot of Belauri 11kV Feeders [14]

ANNEXURE C: Google mapping of 33kV lines to Belauri DCS

Figure A.2 Google mapping of Belauri 33kV line

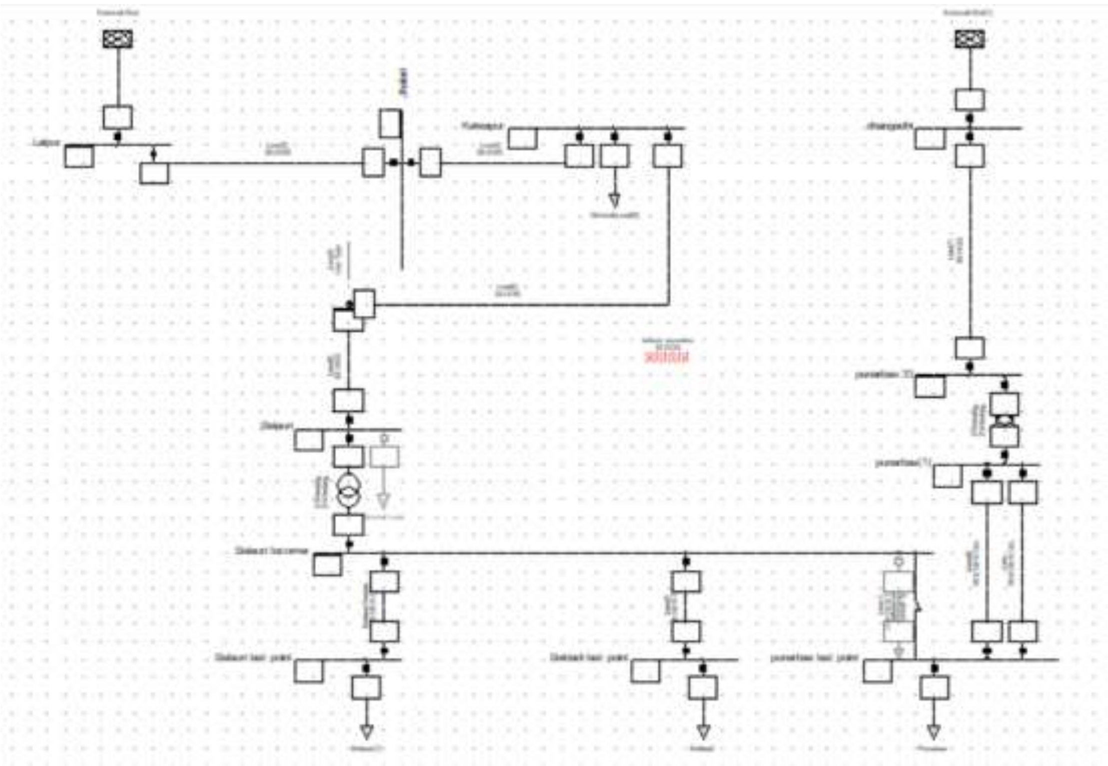
ANNEXURE D: DIGSILENT Model for Base Case

-

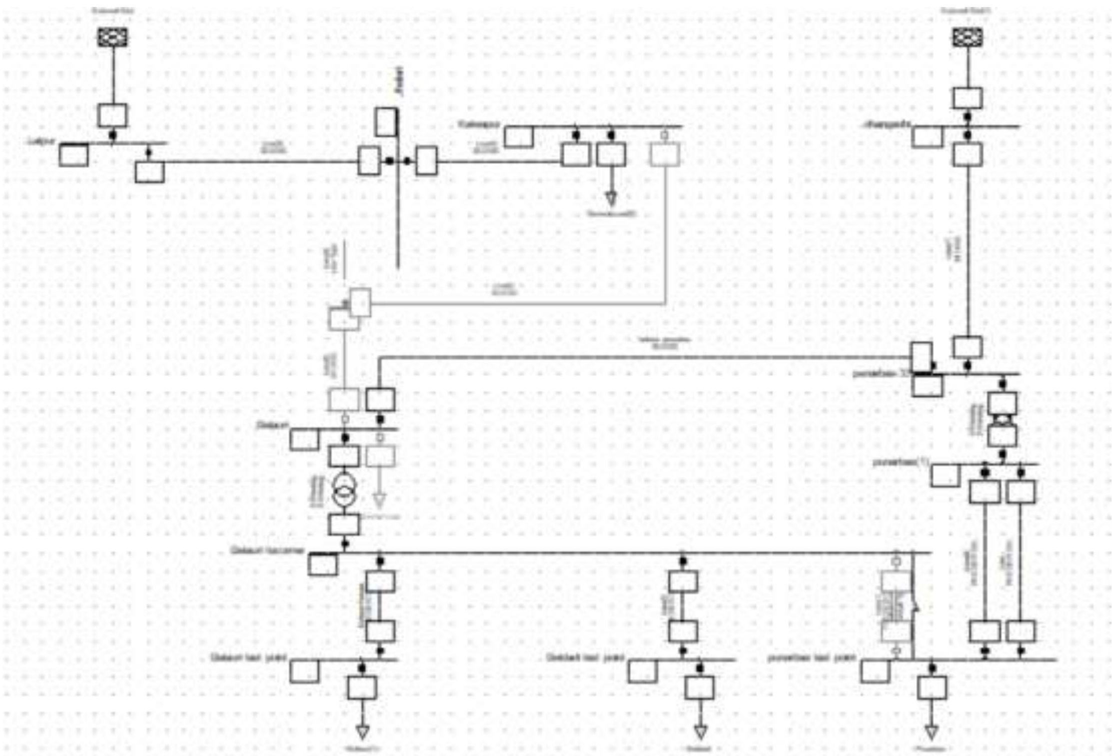


	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] -10 -5 0
Lalpur	33.00	1.000	33.00	0.00	|
Kalwapur	33.00	0.898	29.64	-2.14	<<<<<<<<<<<<<<<<<<<<<<<<|
dhangadhi	33.00	1.000	33.00	0.00	|
punarbas 33	33.00	0.000	0.00	0.00	<\\\\\\\\\\\\\\\\\\\\\\\|
punarbas(1)	11.00	0.000	0.00	0.00	<\\\\\\\\\\\\\\\\\\\\\\\|
Belauri Incomer	11.00	0.741	8.15	-6.30	<\\\\\\\\\\\\\\\\\\\\\\\|
Belauri	33.00	0.748	24.68	-5.13	<\\\\\\\\\\\\\\\\\\\\\\\|
Jhalari	33.00	0.901	29.72	-2.08	<<<<<<<<<<<<<<<<<<<<<<<<|
punarbas last point	11.00	0.588	6.46	-8.07	<\\\\\\\\\\\\\\\\\\\\\\\|
Beldadi last point	11.00	0.693	7.62	-6.76	<\\\\\\\\\\\\\\\\\\\\\\\|
Belauri last point	11.00	0.724	7.96	-6.46	<\\\\\\\\\\\\\\\\\\\\\\\|

ANNEXURE E: Insertion of SS



```
Study Case: Study Case
------------------------------------------------------------------------------------------------
System Summary
------------------------------------------------------------------------------------------------
System Average Interruption Frequency Index         :  SAIFI  =   47.314290 1/Ca
Customer Average Interruption Frequency Index       :  CAIFI  =   47.314290 1/Ca
System Average Interruption Duration Index          :  SAIDI  =  103.423    h/Ca
Customer Average Interruption Duration Index        :  CAIDI  =    2.186    h
Average Service Availability Index                  :  ASAI   =    0.9881937713
Average Service Unavailability Index                :  ASUI   =    0.0118062287
Energy Not Supplied                                 :  ENS    = 1102.346    MWh/a
Average Energy Not Supplied                         :  AENS   =    0.039    MWh/Ca
Average Customer Curtailment Index                  :  ACCI   =    0.000    MWh/Ca
Expected Interruption Cost                          :  EIC    =    0.000    M$/a
Interrupted Energy Assessment Rate                  :  IEAR   =    0.000    $/kWh
System energy shed                                  :  SES    =    0.000    MWh/a
Average System Interruption Frequency Index         :  ASIFI  =   37.440994 1/a
Average System Interruption Duration Index          :  ASIDI  =  100.048673 h/a
Momentary Average Interruption Frequency Index      :  MAIFI  =    0.000000 1/Ca
------------------------------------------------------------------------------------------------
```



ANNEXURE F: Economic Analysis

NEPAL ELECTRICITY AUTHORITY
Attariya Regional Office
33/11 KV Sub-Station at Patan, Baitadi

Summery Of Detail Abstract Of Civil Works Cost Estimate .

Title: Construction Of 6/8 MVA 33/11 Kv Civil Structure Works At Patan, Baitadi

S.No	Civil Structure Works	Amount Rs.
I	Land Development ,Boundary wall and Retaining structures	13211206.52
II	Construction Of Control Building .	11031670.85
III	Construction Of Conduit Trench .	930364.56
IV	Construction Of Switch Yard Equipment supports and pedestals .	3608274.00
V	Construction of Staff Quarter.	9544018.34
VI	Construction of Guard House .	1587217.05
A	Sub Total	**39912751.32**
B	13% VAT	**5188657.67**
C	Grand total	**45101408.99**

C. Cost Estimate for Spare Part & Maintenance Equipments/Instruments

S.N.	Description	Unit	Qty	Supply Price, (CIP, Site) L/C (NRs.) Unit Rate	Supply Price, (CIP, Site) L/C (NRs.) Amount	Local Taxes & Duties: With 15% Custom Duties	Local Taxes & Duties: Amount with Custom Duties	Local Taxes & Duties: VAT @13% NRs.	Local Taxes & Duties: Amount with VAT NRs.	Total
A	B	C	D	E	F = D*E	G = F*15%	H = F + G	I = H*13%	J = H+I	J
	C. Spare parts & Maintenance Equipments/Instruments									
3.1	**For Transformers**									
3.1.a	33 kV Bushing with Current Transformers	Nos	1	113,971.89	113,971.89	17,095.78	131,067.67	17,038.80	148,106.47	148,106.47
3.1.b	Dial type Thermometer	Nos	1	62,220.20	62,220.20	9,333.03	71,553.23	9,301.92	80,855.14	80,855.14
3.2	**For 33 kV Circuit Breaker**			-		-	-	-	-	-
3.2.a	Complete set of replacable vacuum chambers	Nos	4	145,342.89	581,371.55	87,205.73	668,577.29	86,915.05	755,492.34	755,492.34
3.2.b	Bushing	Nos	4	54,152.62	216,610.48	32,491.57	249,102.05	32,383.27	281,485.32	281,485.32
3.2.c	Tripping, closing and auxilliary coils	Set	4	16,754.21	67,016.82	10,052.52	77,069.34	10,019.01	87,088.36	87,088.36
3.3	**For 33 kV Disconnecting Switch**			-		-	-	-	-	-
3.3.a	Porcelain insulator	Nos	3	24,952.49	74,857.48	11,228.62	86,086.10	11,191.19	97,277.30	97,277.30
3.3.b	Main contact assemblies including grounding blades	Set	3	18,768.22	56,304.67	8,445.70	64,750.37	8,417.55	73,167.92	73,167.92
3.3.c	Auxilliary contacts	Set	3	20,533.37	61,600.10	9,240.01	70,840.11	9,209.21	80,049.32	80,049.32
3.4	**For 33 kV Control & Relay panel**			-		-	-	-	-	-
3.4.a	Indicating Lamps	%	200	233.19	46,638.22	6,995.73	53,633.95	6,972.41	60,606.37	60,606.37
3.4.b	Fuse for each type	%	200	287.57	57,513.50	8,627.03	66,140.53	8,598.27	74,738.79	74,738.79
3.4.c	Colour cap for each colour for indicating lamp	%	40	121.30	4,852.05	727.81	5,579.86	725.38	6,305.24	6,305.24
3.4.d	Over current/Earth fault relay	Nos	2	124,081.72	248,163.43	37,224.51	285,387.95	37,100.43	322,488.38	322,488.38
3.5	**For 12 kV Circuit Breakers**			-		-	-	-	-	-
3.5.a	Complete set of replacable vacuum chambers	Nos	7	106,773.29	747,413.03	112,111.95	859,524.98	111,738.25	971,263.23	971,263.23
3.5.b	Tripping, closing and auxilliary coils	Set	5	24,382.59	121,912.93	18,286.94	140,199.87	18,225.98	158,425.86	158,425.86
3.5.c	Indicating Lamps	%	400	184.04	73,617.28	11,042.59	84,659.87	11,005.78	95,665.66	95,665.66
3.5.d	Fuse for each type	%	400	132.80	53,121.56	7,968.23	61,089.79	7,941.67	69,031.47	69,031.47
3.5.e	Colour cap for each colour for indicating lamp	%	80	173.59	13,886.90	2,083.03	15,969.93	2,076.09	18,046.02	18,046.02
3.5.f	Over current/Earth fault relay	Nos	4	130,219.98	520,879.90	78,131.99	599,011.89	77,871.55	676,883.43	676,883.43
3.5.g	Current Transformer (For incoming feeder)	Nos	4	60,610.86	242,443.45	36,366.52	278,809.97	36,245.30	315,055.27	315,055.27
3.5.h	Current Transformer (For outgoing feeder)	Nos	4	60,610.86	242,443.45	36,366.52	278,809.97	36,245.30	315,055.27	315,055.27
3.5.i	11 kV Potential Transformer	Set	2	92,116.76	184,233.52	27,635.03	211,868.55	27,542.91	239,411.46	239,411.46
3.6	**Maintenance Equipments/Instruments**			-		-	-	-	-	-
3.6.a	Laptop(i5 8th gen, 8gb RAM, 1.6 GHz, Intel UHD 620 graphics)	Nos	1	140,506.53	140,506.53	21,075.98	161,582.51	21,005.73	182,588.23	182,588.23
3.6.b	Multimeter (AC and DC)	Nos	1	13,446.66	13,446.66	2,017.00	15,463.65	2,010.28	17,473.93	17,473.93
3.6.c	500 V Battery operated Meggar	Nos	1	87,475.94	87,475.94	13,121.39	100,597.33	13,077.65	113,674.99	113,674.99
	Total of C				**4,032,501.54**	**604,875.23**	**4,637,376.77**	**602,858.98**	**5,240,235.75**	**5,240,235.75**

Cost Estimate for 33/11 kV, [illegible] MVA Substation

1.23	Gantry Structure including all accessories complete	Ton	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.24	1.5 Ton Air conditioners including accessories complete	Set	3	206,460.92	619,382.75	92,907.41	712,290.16	92,397.72	[illegible]	[illegible]
1.25	250 W Mercury Vapour Lamp including copper ballast capacitor and other control gears including accessories complete	Set	4	35,313.29	141,253.16	21,187.97	162,441.13	21,117.35	183,558.48	183,558.48
1.26	Steel Tubular Street Light Pole	Nos	4	52,900.92	211,603.67	31,740.55	243,344.22	31,634.75	274,978.97	274,978.97
1.27	11 m Steel tubular pole with channels, clamps and 9 kV Lightning Arrestor (including earthing) including accessories complete	Set	5	52,900.92	264,504.59	39,675.69	304,180.27	39,543.44	343,723.71	343,723.71
1.28	32" Color TV LED including accessories complete	Nos	1	35,313.29	35,313.29	5,296.99	40,610.28	5,279.34	45,889.62	45,889.62
1.29	400 V A.C.And DC Disribution Board including accessories complete	Nos	2	208,461.34	416,922.68	62,538.40	479,461.08	62,329.94	541,791.02	541,791.02
1.30	Grounding materials to complete the specified scope of works including all accessories complete	Lot	1	216,928.37	216,928.37	32,539.26	249,467.63	32,430.79	281,898.42	281,898.42
1.31	Kiosk box	Set	1	26,142.50	26,142.50	3,921.38	30,063.88	3,908.30	33,972.18	33,972.18
1.32	Lightning Mast with including all accessories complete	Set	2	312,232.43	624,464.85	93,669.73	718,134.58	93,357.50	811,492.07	811,492.07
	Total of A				47,944,397.19	7,191,659.58	55,136,056.77	7,167,687.38	62,303,744.15	62,303,744.15

NEPAL ELECTRICITY AUTHORITY
Distribution and Consumer Service Directorate
Attariya Regional Office
Attariya, Kailali

Cost Estimate (Revised)

Design, Supply, Delivery, Installation and Testing & Commissioning of 33/11 kV, 6/8 MVA Substation

Location : Melauli, Baitadi

S.N.	Description	Unit	Qty	Supply Price, (CIP, Site) L/C (NRs.) Unit Rate	Supply Price, (CIP, Site) L/C (NRs.) Amount	Construction and Installation works L/C (NRs.) Unit Rate	Construction and Installation works L/C (NRs.) Amount	Local Taxes & Duties: Custom Duties @ 15% NRs.	Local Taxes & Duties: VAT @13% NRs.	Total
	SUMMARY									
1	Supply and Delivery of Materials	Lot	1	46,409,738.33	46,409,738.33	-	-	6,961,460.25	6,938,255.88	60,309,454.95
2	Construction, Installation, Testing and Comissioning of Electrical Goods	Lot	1	-	-	1,787,352.87	1,787,353.87	-	232,355.87	2,019,708.74
3	Spare Part & Maintenance Equipments/Instruments	Lot	1	4,032,501.54	4,032,501.54	-		604,875.23	602,858.98	5,240,235.75
4	Civil Works (land development, boundary wall, retaining wall, Control Building, staff quarter, switchyard foundation and guard house)	Lot	1			42,083,496.99	42,083,496.99		5,470,854.61	47,554,351.60
	Grand Total				50,442,239.86		43,870,849.86	7,566,335.98	13,244,325.34	115,123,751.05

Prepared By

Checked By

Approved By

An Analysis of Reliability-Technical Losses In 33 kV Radial Distribution

By Kapil Joshi

An Analysis of Reliability-Technical Losses In 33 kV Radial Distribution

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68 Saheli Ray, Aniruddha Bhattacharya, Subhadeep Bhattacharjee. "Differential Search Algorithm for Reliability Enhancement of Radial Distribution System", Electric Power Components and Systems, 2015
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72 G. Manikanta, Ashish Mani, H. P. Singh, D. K. Chaturvedi. "Placing distributed generators in distribution system using adaptive quantum inspired evolutionary algorithm", 2016 Second International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), 2016
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