

SYSTEM LOSS STUDY AND ANALYSIS OF PACHRUKHI SUB-ZONAL OFFICE UNDER NARAYANGANJ PALLI BIDYUT SAMITI-2

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

We hereby declare that this project “**System Loss Study And Analysis of Pachrukhi Sub-Zonal Office Under Narayanganj Palli Bidyut Samiti -2**” represents our work which has been done in the field work of Pachrukhi Sub-Zonal Office under Narayanganj Palli Bidyut Samiti-2 in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. we have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

Signature of the candidates



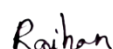
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Dedicated
To
Our Parents

TABLE OF CONTENTS

LIST OF FIGURES	vii
LIST OF TABLES	viii
LIST OF ABBREVIATIONS	ix
LIST OF SYMBOLS	x
ACKNOWLEDGMENT	xi
ABSTRACT	xii
CHAPTER 1.....	1
INTRODUCTION.....	1
1.1 Introduction.....	1
1.2 Problem Statement.....	3
1.3 Objectives.....	4
1.4 Brief Methodology.....	6
1.5 Implementation Schedule.....	8
Chapter 2.....	9
Literature Review.....	9
2.1 Introduction.....	9
2.2 Related Research.....	10
2.3 Compare and Contrast.....	11
2.4 Summary.....	12
Chapter 3.....	13
Materials and Methods.....	13
3.1 Introduction.....	13
3.2 Methods and Materials.....	13
3.3 Design Specifications. Standards and Constraints.....	18
3.4 Circuit Diagram.....	26
3.5 Analysis of the System.....	31
3.6 Summary.....	35
Chapter 4.....	36
Results and Discussions.....	36
4.1 Results.....	36

4.2 Technical Losses.....	36
4.3 Total Losses	37
4.4 Non-Technical Losses.....	43
4.5 Proposed Solution	46
4.6 Discussions	51
Chapter 5	52
Project Management	52
5.1 Task, Schedule and Milestones.....	52
5.2 Resources and Cost Management	53
5.3 Lesson Learned	53
Chapter 6	54
Impact assessment of the project	54
6.1 Economical, Societal and Global Impact.....	54
6.2 Environmental and Ethical Issues.....	55
6.3 Utilization of Existing Standards	55
6.4 Other Concerns	56
Chapter 7	57
Conclusions and Recommendations	57
7.1 Conclusions.....	57
7.2 New Skills and Experiences Learned	58
7.3 Future Recommendations	60
References.....	63
Appendix A.....	66
Turnitin Report.....	66
Appendix B	67
Complex Engineering Problem Solving and Engineering Activities	67

LIST OF FIGURES

<i>Figure No</i>	<i>Figure Name</i>	<i>Page No.</i>
Fig. 1.1	Methodology of our study	6
Fig. 3.1	Advanced Metering Infrastructure (AMI)	15
Fig. 3.2	Dry Type & Oil Type Transformer	17
Fig. 3.3	Single Line Diagram (SLD) of Pachrukhi Sub-Zonal Office.	26
Fig. 3.4	Energy Audit Methodologies.	29
Fig. 3.5	Fault Detection Mechanisms.	31
Fig. 4.1	Loss Calculation	38
Fig. 4.2	Total Loss & Non-Technical Loss	41

LIST OF TABLES

<i>Table No</i>	<i>Fig. Name</i>	<i>Page No.</i>
Table 1.1	Implementation Schedule of this study	8
Table 3.1	Difference Between Dry Type & Oil Type Transformer	16
Table 5.1	Task Distribution	46
Table 4.1	Monthly & Average Loss Calculation Of Pachrukhi Sub-Zonal Office	35
Table 4.2	Energy Purchase as per Billing Meter Of Pachrukhi Sub-Zonal Office	36
Table 4.3	Energy Resale Unit of Pachrukhi Sub Zonal Office	37
Table 4.4	Non-Technical Loss Calculation Of Pachrukhi Sub-Zonal Office	40

LIST OF ABBREVIATIONS

BREB	Bangladesh Rural Electrification Board
PBS	Palli Bidyut Samiti
AMI	Advanced Metering Infrastructure
DERs	Distributed Energy Resources
ROW	Right of Way
PPP	Public-Private Partnership
SLD	Single Line Diagram
ABS	Air-Break Switch
ACR	Automatic Circuit Recloser
VR	Voltage Regulator
KPIs	Key Performance Indicators
SCADA	Supervisory Control and Data Acquisition
AVR	Automatic Voltage Regulators
APFCs	Automatic Power Factor Controllers
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
BPDB	Bangladesh Power Development Board
IEA	International Energy Agency
GIS	Geographic Information Systems
ACSR	Aluminum Conductor Steel-Reinforced
HTLS	High-Temperature Low-Sag
AAAC	All Aluminum Alloy Conductors
XLPE	Cross Linked Polyethylene
ABC	Aerial Bundled Cables

LIST OF SYMBOLS

<i>Symbol</i>	<i>Name of the symbol</i>

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ABSTRACT

This research addresses the issue of energy loss in electrical distribution networks by analyzing and mitigating system loss at the Pachrukhi Sub-Zonal Office under Narayanganj Palli Bidyut Samiti-2. System loss, encompassing technical and non-technical components, significantly impacts energy distribution efficiency and sustainability. The study aims to identify root causes, measure consequences, and propose practical remedies to enhance operational effectiveness. Real-time data from the Pachrukhi Zonal Office was analyzed to assess transformer efficiency, distribution line performance, and client-related issues. The research has been carried out in a structured approach, including data collection and its analysis. Using advanced analytical tools, The results have shown that the total system loss is about (4.99%). Technical losses (1.3%) due to line resistance and non-technical losses (3.68%) from unauthorized consumption were quantified. Some of the key recommendations include modernization of the distribution infrastructure, installation of AMI, and strengthening of monitoring systems. These are likely to increase the reliability and economy of the electrical distribution system significantly by reducing the system loss. This paper furthers our understanding of the system loss dynamics in rural electrification settings and provides utility companies and policymakers with a framework that can be employed in the maximization of electricity distribution. Solving these problems will lead to sustainable development goals and ensure better resource utilization.

Keywords: System Loss, Energy Efficiency, Technical Loss, Non-Technical Loss, Daffodil International University.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electrical distribution systems are crucial in order to ensure that the end users can access electricity reliably. System losses remain a critical issue, affecting economic viability and operational efficiency at transmission and distribution. These include technical losses, which result mainly from internal inefficiencies within the network components, and non-technical losses usually because of theft of electricity, meter tampering, and other billing errors. The losses in distribution system are considered to account for approximately 6% of our countries in distribution system. Energy demand has trend to increase while sources have long distances from loads. In distribution system, line losses have much value at end line and will decrease when loads have constant distribution and they are near the source. Line losses have lower value when lead lines have higher size. Both load distribution and lead line size have effect on distribution line losses [1]. In distribution system, from generation, transmission and distribution have technical loss. Technical loss occurred at transmission lines, power transformer, feeder and terminal which it depends on current in lines (I^2R). In addition, it have loss which caused by wrong measurement and act under cover using, called non-technical loss. In each year, Manufacturer lose benefit enormously so they find method for decrease losses.

The Bangladesh Rural Electrification Board (BREB) has been in the forefront of increasing access to electricity through its rural electrification program in Bangladesh [2]. The Pachrukhi Sub-Zonal Office under Narayanganj Palli Bidyut Samiti-2 (PBS) often experiences system malfunctioning. The system losses are mainly categorized into technical losses and non-technical losses. Affective electrical component inefficiencies arising due to technical losses include resistive loss in conductors, transformer, and other system components.

However, the non-technical losses are attributed to human factors such as theft of electricity, meter tampering, billing errors, and administrative inefficiencies. This case study, therefore, attempts to provide workable insights and recommendations for

reducing overall system losses in the Pachrukhi Sub-Zonal Office through the analysis of these loss types. The Pachrukhi Sub-Zonal Office of the Narayanganj PBS-2 is responsible for ensuring the distribution of electricity within the intricate area comprising rural and peri-urban areas. Due to increasing inequalities in energy over time, this office gradually experienced much hardship in ensuring regular and effective power supply.

Energy and environmental policies are being shaped at the national and international levels in response to a wide range of challenges. Rural Electrification Program (REP) in Bangladesh started its journey in 1978, primarily with the technical assistance of National Rural Electrification Cooperative Association (NRECA) of United States of America with an aim to provide the electricity outside the urban strata. The program is based on the concept of member owned, Palli Bidyut Samity (PBS) similar to the rural electric cooperatives that exist in the United States. Seventy-eight PBSs have been organized to date in Bangladesh [3]. At present 80 PBS are running their power distribution program under the supervision of BREB [2]. Recent works identify the implementation of AMI, distribution automation, and new loss detection algorithms to minimize system losses. Works carried out in South Asia estimate that smart grid technologies, along with real-time monitoring systems, can reduce nontechnical losses as high as 30% [4]. Optimization of voltage regulation, transformer loading, and sizing of conductors improves efficiency in distribution in the case of technical losses [5]. Past studies that identified the various aspects of system losses emanating from both technical inefficiencies in the distribution network and non-technical problems relating to electricity theft and billing irregularities have made it imperative to address them through a mix of technological intervention, such as renovation of infrastructure, and administrative measures regarding strengthening of monitoring and enforcement systems [6]. Such a case study will be ideal in the Pachrukhi Sub-Zonal Office because it is strategically critical in the Narayanganj PBS-2 areas and has massive operational challenges in its domain.

Because system loss results in higher cost accumulation and lower revenue, it directly relates to the financial stability of electricity providers. For instance, technical losses can make up a huge bulk of the overall energy loss since they pertain to internal inefficiencies within conductors, transformers, and other electrical components. Once more, this points toward infrastructure maintenance and improvement in ways of

making substantial cost savings by dealing with inefficiencies. Non-technical losses, such as electricity theft and incorrect billing, further damage trust between consumer and provider. By recognizing and fixing such issues, utilities can make their financial performance better while forging closer bonds with customers. High system losses, which often lead to outages and service interruptions, badly affect the stability and reliability of electrical distribution networks. These problems not only harm the reputations of consumers but also power companies. Reduction of losses and operational efficiency will ensure a stable supply of electricity while satisfying customer and statutory requirements.

From the point of view of the environment, system losses reduction also coincides with global sustainability goals. While energy is lost in transmission and distribution, the need for power generation increases, and since generation most often uses fossil fuel, greenhouse gas emissions increase, hence deteriorating the environment. Utilities can reduce losses to decrease their carbon footprint and further the cause of sustainable energy practices. Another motivation for this research is regulatory standard supervision. Bangladeshi and international governments and regulatory bodies strongly emphasize the importance of energy conservation and efficiency. Utility providers, through support of these priorities, can be in a position to reflect responsible and forward-thinking businesses while also assuring them of compliance. In addressing the system losses, the Pachrukhi Sub-Zonal Office will have set the benchmark for similar efforts in other Narayanganj PBS-2 zones.

But, above all, it stands out for the strategic relevance of Pachrukhi Sub-Zonal Office being a critical node within the regional electrical distribution, its operation has influences at the general system level. This study tries to point out a standard concerning seeking to manage system losses, by identifying problems and proffering solutions to increase the sustainability of the sector under specified conditions.

1.2 Problem Statement

Electricity distribution is important in the process of economic development as well as social development. The major problem facing many distribution systems, which include the Narayanganj PBS-2 Pachrukhi Sub-Zonal Office, is the reduction of system losses. These losses could be technical or non-technical and reduce efficiency in the

supply of power, thus putting financial burdens on both the utility company and its customers.

Technical losses are pinpointed to the intrinsic inefficiencies in the distribution system, such as inefficiencies of transformers, conductor resistivity, and less-than-ideal network configurations. These are generally more critical in industrial or highly populated areas where infrastructure may be older, maintenance minimal, and loads heavy. These losses would occur in any electrical system as well, but they are normally too great to be tolerated, requiring major system redesign or reconfiguration.

Non-technical losses due to problems of unauthorized connections, tampered meters, theft of electricity, and faulty billing. These are further reducing the utility revenue base along with breakdown in consumer trust, thus causing injustice to the users. From above, it is indicated that high non-technical losses in Pachrukhi Sub-Zonal Office do have a problem in both governance and operational issues that demand immediate attention.

Whereas for combined technical and non-technical losses, the system loss percentage surpasses the efficiency of operation's acceptable levels. Thus, a situation that influences negatively against the potential by the Distribution Utility to maintain such financial stability needed for investment towards infrastructure extension to reliably feed in a growth in energy demand.

1.3 Objectives

The study will try to improve the electrical distribution system by proper observation; hence, it is titled "System Loss Study and Analyses of Pachrukhi Sub-Zonal Office under Narayanganj PBS-2." Five major objectives of the study are:

- Assess and quantify system losses: To identify the actual amount of both technical and non-technical losses within the power distribution network of the Pachrukhi Sub-Zonal Office, with a view to finding out the extent and causes of inefficiency.
- Technical loss breakdown: The transformer, transmission lines, and other electrical equipment losses are to be analyzed, keeping in view the characteristics such as conductor resistance, load imbalance, and deterioration in power factor.

- **Analyze Non-Technical Losses:** Assess the business losses due to inappropriate metering, unauthorized connections, billing errors, and theft of electricity in order to realize which areas need improvement.
- **Provide Workable Mitigation Strategies:** Provide practical solutions that will help reduce system losses and improve operational efficiencies, such as updating infrastructure, improving the monitoring system, and using the latest metering technology.
- **Promote Sustainable Energy Practices:** This will help in developing a more sustainable and efficient power distribution system, minimizing energy waste, improving customer satisfaction, and meeting the business objectives of a smaller environmental footprint.

This setup offers a structured, precise, and directed approach toward accomplishing the objectives of the study and addressing key issues revolving around system loss analysis.

1.4 Brief Methodology

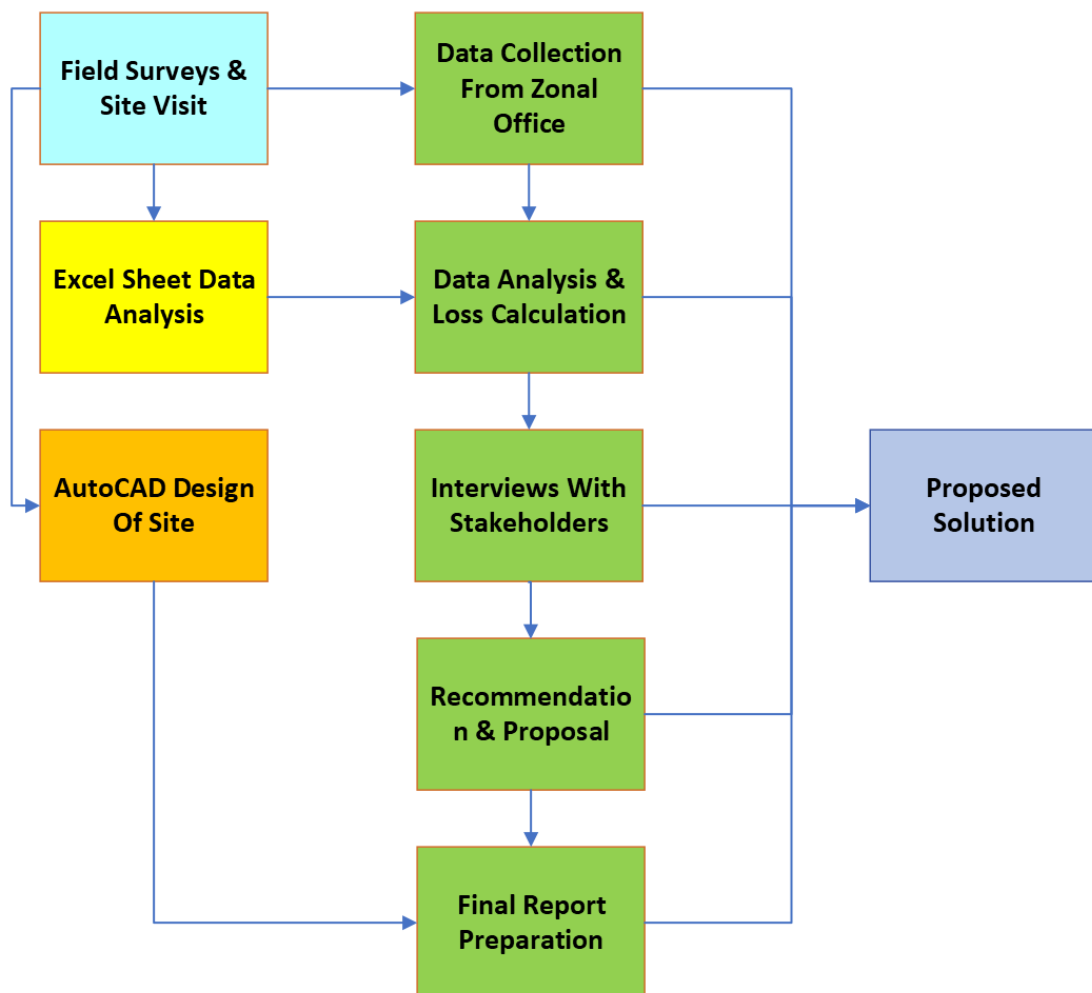


Fig. 1.1: Methodology of our study

Fig. 1.1 shows a formalized process for research and solution development. It is one that begins with the site visits and field surveys, leads into the stakeholder involvement and design, and ends in a final report along with a proposed solution.

1. **Field Surveys & Site Visit:** This first step involves the collection of data and observation on site. This step most probably includes learning about the prevailing situation, identification of problems, and understanding the context in which the problem under research falls.
2. **Data Collection from Zonal Office:** Additional information-statistical data, historical documents, or any other supporting document-would be collected from the relevant zonal offices.

3. **Excel Sheet Data Analysis & Loss Calculation:** Organize data collected by using spreadsheet software, compute statistical analysis, and visualize trends, patterns, or potential losses.
4. **AutoCAD Design of Site:** Site design and visualization for this thesis shall be done in AutoCAD. This would include detailed site drawings and models that help in understanding spatial relationships, communicating design concepts, and planning interventions.
5. **Interviews with Stakeholders:** The consultations with the relevant parties are carried out. To be certain that the suggested solution has a focus, and is for, the beneficiaries it affects, this phase tries to map out and understand all the concerns of the stakeholders.
6. **Recommendation & Proposal:** Based on the analysis, design, and feedback of the stakeholders, we have come up with a recommendation and proposal for solving the issue at hand in this study. This could be including specific strategies, interventions, or solutions.
7. **Final Report Preparation:** This final stage will include compiling the thesis, analysis, design, and recommendations into one report. The report would be used for documentation of the thesis and as a deliverable to the stakeholders.

Strengths of the Methodology

- **Systematic Approach:** Fig. 1.1 ensures that each step is dealt with methodically to approach the thesis in a structured and orderly way.
- **Data-Driven:** In this strategy, there is a strong emphasis on data gathering and analysis as the main foundation for decisions based on evidence.
- **Stakeholder-Centric:** The inclusion of interviews with stakeholders in the given research will let one get into the consideration the stakeholders' needs and points regarding the issue, for raising the chances of successful implementation.
- **Visual Communication:** To help understand and, in turn, to communicate with others, this diagram depicts the case study process.

In general, the methodology presented in this diagram appears reasonably valid for analysis and the formulation of conscious strategies for the delivery of solutions.

1.5 Implementation Schedule

Phase/Task	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Thesis Planning	✓											
Literature Review		✓										
Problem Definition and Objectives			✓	✓								
Field Surveys & Site Visits					✓	✓						
Data Collection						✓	✓					
Data Analysis and Loss Calculation							✓	✓	✓			
Proposed Solution								✓	✓	✓		
Thesis Writing									✓	✓		
Review and Feedback										✓	✓	
Final Documentation											✓	✓

Table 1.1: Implementation Schedule of this study

This project timeline is graphically portrayed in Fig. 1.2. It's in Gantt chart format: the duration of the project broken down horizontally into months and the phase or tasks listed vertically, while the amount of time allocated to each task-when placed inside the grid-is indicated by checkmarks. This work lays the foundation: organization of the thesis, definition of the research problem and objectives, literature review-all within the first four months. In the mid-phase-which covers months 5-8-the practical work will deal with field surveys, site visits, data collection, and preliminary data analysis, including loss calculations. The last stage is from months 9-12, which will involve synthesis of results, development of solutions, writing the thesis document, incorporation of reviews and feedback, and doing the final documentation. With this approach, it should be pretty easy to follow the progress and ensure orderly passage through the different phases of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electrical distribution networks need system loss analysis for more reliable, efficient, and sustainable power systems. The technical losses area related to the material properties and its resistance to the flow of the electrical current that is dissipated as heat. The most obvious examples are the power dissipated in distribution lines and transformers due to their internal electrical resistance. In addition, technical losses are easy to be simulated and calculated [7]. On the other hand, non-technical losses are caused by clandestine connections, frauds in energy meters, diversity of readings and deficiencies (or losses) in the processes of energy measurement [8].

Handling system losses is not only an operational requirement but also a crucial step especially in view trying to reach the future power energy sustainability goals of Bangladesh's increasing energy demand. Finding and minimizing system losses has become a top priority as the government seeks to increase rural electrification and cut down on energy waste. The difficulties in controlling distribution losses in a rural area are best illustrated by the Pachrukhi Sub-Zonal Office of Narayanganj PBS-2. The region, like many others, has to bear the brunt of high technical losses due to deteriorating infrastructure, apart from non-technical losses increased by socio-economic factors such as lesser consumer awareness and electricity theft. Therefore, the reduction of technical losses leads to a real gain in energy and reduced capital-intensive investments. On the other hand, the reduction of non-technical losses not only improves the financial balance of the company concerned, but also the load curve by subjecting consumption to the tariff regulation [9].

This literature review will analyze the current methodologies and best practices in system loss analysis and mitigation with a focus on the Pachrukhi Sub-Zonal Office. This review intends to explore relevant case studies, models, and frameworks that identify sustainable and efficient ways of improving the effectiveness of rural electricity distribution systems and advancing the interests of the global energy transition.

2.2 Related Research

A number of studies on technical and non-technical aspects of system losses in Bangladesh's electrical distribution networks have been conducted in the last couple of years. A study highlighted key issues of concern regarding the utilization of the country's natural gas and the need for a well-balanced energy mix that would cater to the country's attainment of sustainable development in one comprehensive study relating to the power sector of Bangladesh. The authors presented a summary of both present and possible aspects of the sector, taking into account the forecast on future energy requirements and highlighted the essence of energy security [10].

The Asian Development Bank Report, 2023, informs that the Dhaka Power System Expansion and Strengthening Project will be developed to extend the electrical distribution system in the city. In order to reduce system losses and operational efficiency to provide reliable electricity to new and existing customers, the main project components include substation construction and installation of underground cables [11]. A 2023 article reviewed improvements in Bangladesh's electrical distribution system and recommended several measures to enhance efficiency, sustainability, and dependability. The study concluded that the application of advanced technologies and new infrastructure can reduce system losses significantly [12]. A new proposal for the calculation of technical and non-technical losses, the Equivalent Operational Impedance was proposed in [13]. Several analyzes involving IEEE test systems and real distribution feeders, under different operating conditions, were carried out later [14,15], in which it was possible to observe the good precision of the method for calculating losses.

These papers all lead to a point where it becomes highly indispensable to carry out more research and establish policies for reduction in system losses within the electrical distribution network in Bangladesh. This underlines the importance of strategic planning, technological enhancement, and expansion in infrastructural development of an improved power sector.

2.3 Compare and Contrast

The system loss in electrical distribution networks has been one of the critical areas of research due to its impact on cost, reliability, and energy efficiency. There are two major categories: technical losses brought on by the physical properties of electrical components and non-technical losses brought on by external factors such as theft and billing errors. Comparing these points of view shows just how sophisticated an approach is needed in order to reduce system inefficiencies.

Technical losses are influenced by load patterns, conductor resistance, and transformer inefficiencies. Advanced technologies have been proposed to reduce these losses, including installing high-efficiency transformers, integrating Distributed Energy Resources (DERs), and reconfiguring networks [16]. One study, focused on how the management of reactive power and load balancing can effectively reduce technical losses [17].

Non-technical losses, An Study observed a significant improvement in the load profile characterization, with the advancement of smart meters and an increase in amount and data quality, which reduces the predictive error and enables calculation in real-time. Hence, the statistical load modeling through the smart-meters database can make load sampling obsolete [18]. (Lewis, 2015) found that Electricity theft is a big challenge because it influences the supply of electricity from power generation units by overloading/ short-circuiting their networks. This regularly results in a disturbance (for example an incomplete or complete loss) in the power supply to genuine consumers [19]. Sharma and Abhyankar presented an efficient method of loss allocation with Shapley value and network laws. They had provided a solution with a cooperative game theory approach. They used Shapley value for balanced radial and weekly meshed distribution system to solve the analytical solution provided by the proposed method. They used the network data and power flow solutions without any assumptions in their proposed method [20].

However, resource limitations in developing countries often limit extensive implementation. The losses in the context of Pachrukhi Sub-Zonal Office under Narayanganj PBS-2 call for customized solutions, considering socio-economic factors, regional load characteristics, and existing infrastructure. International comparisons were made from studies carried out abroad, which provided the basis for developing strategies with regard to local needs and resources.

2.4 Summary

A literature review reveals that the losses in electrical distribution systems depend on both technical and non-technical factors. Technical losses include intrinsic inefficiencies of electrical infrastructure such as resistive losses in conductors and transformers, whereas the most significant causes of nontechnical losses include energy theft and meter tampering supplemented by human error. Various studies have proved that AMI, routine maintenance, and real-time monitoring systems are some of the effective ways to substantially reduce both types of losses. Without integrating modern technology and proper enforcement of the law, no effective solution could be foreseen regarding these problems at Pachrukhi, Narayanganj PBS-2, and other rural and semi-urban areas. This information forms part of system loss analysis by the Pachrukhi Sub-Zonal Office.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter fully discusses the methodologies adopted, equipment and supplies required, and the design techniques involved in conducting a comprehensive system loss study and analysis of Pachrukhi Sub-Zonal Office under Narayanganj PBS-2. It starts with the description of methodology followed by the data collection methodologies, various analytical equipment, and computational approaches executed for estimating the technical and nontechnical losses of the distribution network. The major elements of the analysis, transformers, feeders, meters, and conductors, are described in greater detail later in this chapter, along with their specifications and operating parameters.

Furthermore, it addresses the issues on limitation of network capacity, variability in load, and economic viability, besides the design principles and optimization techniques for reduction of system losses. Special emphasis is given to advanced techniques such as energy audit methodologies and fault detection mechanisms. Our thesis, based on the analysis of loss calculation, using data provided by the Pachrukhi Sub-Zonal Office, did not use Easy Power, ETAP, or comparable platforms for simulation of electrical distribution network software.

The experimental setup is described in detail, including steps of data collection, simulation, and result validation. Real-world operational data is analyzed step by step to find loss patterns, evaluate system performance, and produce useful insights. This chapter develops the theoretical background necessary for the system losses specific to Pachrukhi Sub-Zonal Office by integrating theoretical perspectives into practice.

3.2 Methods and Materials

Methodology Overview

The methodology to be used in this study will be hybrid, with the combination of analytical techniques, field data collection, and theoretical analysis. The steps in the methodology are as follows:

1. **Field Surveys & Site Visit:** Information is gathered at the site for identifying problems and understanding the context of the study.

2. **Data Collection:** Record and statistical data collection from zonal offices.
3. **Data Analysis:** Use of Excel in analyzing data to find patterns and trends, and estimation of loss.
4. **AutoCAD Design:** The design and visualization of the site in AutoCAD.
5. **Stakeholder Interviews:** Interviews for the gathering of a range of views.
6. **Recommendations:** Ideas and solutions to be generated from stakeholder contribution and analysis.
7. **Final Report:** This involves writing down all the conclusions, designs and recommendations into a comprehensible report.

Materials and Tools

Some of the vital instruments and resources this study relies on are highlighted here:

1. **Energy Meters:**



Fig. 3.1: Advanced Metering Infrastructure (AMI) [18].

Energy meters measure input and output in various sections of the distribution network. They offer critical data regarding energy flow and, hence, can make correct calculations related to efficiency, losses, and consumption. Electric meters are typically fed from the same electric feed that they are monitoring. Flow meters are typically powered by stored energy, i.e., batteries; therefore, have utilization constraints. These constraints are more evident in communication since power is needed for transmitting and receiving signals. Meters also have embedded controllers to manage the metering sensor, a display unit, and a communication module which is generally a wireless transceiver [18]. These functionalities support effective load management, detection of abnormalities, and loss reduction within the system.

2. **Transformers:** The study of transformers is done to establish their efficiency and losses of energy within them. Different variables are established such as

copper losses (due to resistance in windings) and core losses (due to magnetic hysteresis and eddy currents). Energy is wasted in transformers, especially when their performance is not checked.

Aspect	Dry-Type Transformers	Oil-Filled Transformers
Cooling Mechanism	Cooled by inert gas or air.	Cooled by synthetic fluids or mineral oil.
Safety	Less chance of fire because non-flammable liquids are used	More danger of fire because of the oil.
Applications	Installation indoor, commercial buildings and industries	High voltage systems, utility grids, outdoor substations
Environmental Impact	Non-Toxic; does not have a risk to an oil spill	Risk to an oil spill and contamination not environmental-friendly
Maintenance	Very less maintenance is required.	Requires regular check-up and testing of oil.
Cooling Efficiency	Only for small-scale power consumption; Less efficient	Highly Efficient; suitable for heavy applications
Cost	Higher initial cost	Lower initial cost
Durability	Less durable in extreme conditions or under high load	More durable with proper maintenance
Size and Weight	Lighter weight and smaller size; easier indoor installation	Space requirements more significant as bigger and heavier.
Overload Capacity	Lower overload handling capacity	Higher overload handling capacity

Table 3.1: Difference Between Dry Type & Oil Type Transformer [21,22].

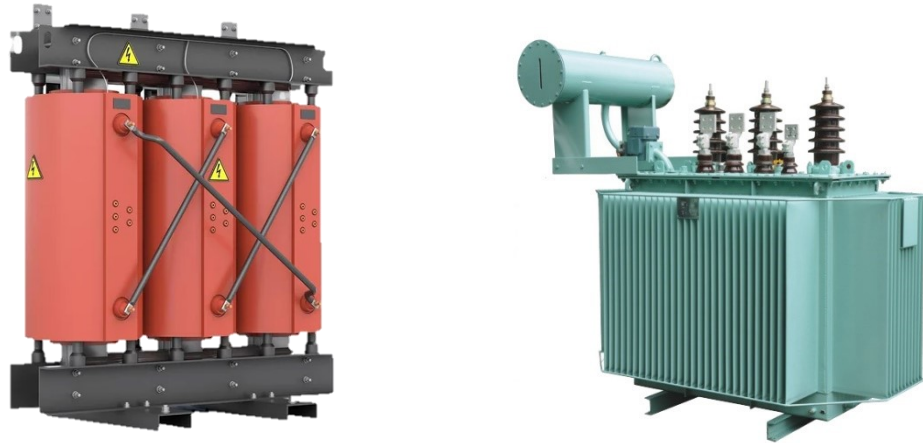


Fig. 3.2: Dry Type & Oil Type Transformer

Generally, oil-immersed transformers are much better for high-efficiency applications and the capability to withstand heavy loads because of their very minimal system loss. The high-power and high-voltage applications, such as utility grids and outdoor substations, are ideally suited because of their excellent cooling efficiency, which minimizes overheating and reduces copper losses. Additionally, their higher overload capacity ensures stable performance under varying load conditions, which further reduces energy loss due to inefficiencies. However, for applications involving indoor installations or very densely populated areas where safety, low maintenance, and environmental friendliness are of essence, dry-type transformers are more suitable. Even though these may suffer somewhat greater losses than oil-filled transformers in high-load situations, long-term cost savings may result from their low maintenance needs [21,22]. Oil-filled transformers would be most suitable for the purpose of reducing system losses in a distribution network at places of high demand, like the Pachrukhi Sub-Zonal Office, because they can perform efficiently even under extreme operating conditions. Long-term dependability is assured, and their performance will be further enhanced with routine quality checks of oil and other forms of maintenance performed regularly.

3. **Load Profiles:** Load profiles identify the trend of energy utilization and are collected from the distribution network. These profiles reflect information on daily or seasonal variations, off-peak consumptions, and peak demands. Inefficiencies can be traced more precisely, and their load management plans

can also be developed with the help of a load profile analysis. A load profile is very important to minimize system loss.:

- a. **Understanding Energy Demand Patterns:** Utilities can identify peak demand periods and adjust operations to reduce system stress and energy losses by examining load profiles, which provide detailed information on the changes in electricity demand during the day, week, or season.
- b. **Optimal Transformer Loading:** Overloading or underloading of transformers results in energy losses in the form of core losses or copper losses (**I^2R losses**). Load profiles are utilized to select the proper size and capacity of the transformer, which ensures its effectiveness in operation with reduced losses.
- c. **Efficient Network Planning:** The design and optimization of the distribution network matching the demand patterns are guided by the load profiles. This reduces over dimensioning of the equipment and prevents overloading from causing excessive energy dissipation.
- d. **Balancing Phases in the Network:** Inequalities in load between phases create equipment inefficiencies and energy losses. On the other hand, imbalances are made so much more visible by load profiles, which allow corrective measures in balancing the loads and lowering the losses.
- e. **Improved Power Factor Management:** Load profiles provide insight into low power factors that increase reactive power flow and system losses. Such can be minimized using capacitors or other methods.
- f. **Demand Response Strategies:** The analysis of load profiles allows demand-side management programs to be implemented. Losses in energy and congestion of the system are minimized by shifting customers from peak to off-peak hours of use.
- g. **Loss Localization:** Load profiles help in identifying feeders, transformers, or sections in the distribution network that present higher losses. Targeted maintenance or upgrades can then be performed with a view to reducing such losses.
- h. **Preventing Overgeneration:** Load profiles help balance generation and demand in systems that integrate renewable energy, therefore preventing over energy losses through mechanisms of curtailment or overgeneration.

- i. **Economic Benefits:** By reducing system losses through load profile analysis, energy efficiency and operating costs are improved for both the utility and the customers.
4. **Excel (Spreadsheet):** Used for data representation and analysis.
5. **Software:** The Single Line Diagram (SLD) of the Pachrukhi Sub-Zonal Office is designed in AutoCAD.

These will ensure that the distribution network's technical and non-technical losses are systematically analyzed.

3.3 Design Specification, Standards and Constraints

System Design Overview

The proposed system design is developed with the intent of diminishing both technical and nontechnical losses within the electric distribution network. It is an embodiment of advanced technology that, merged with strategic planning, significantly enhances monitoring systems, network performance optimization, and power delivery reliability. This integrates high-efficiency components of real-time data communication along with reliable monitoring solutions aiming at minimal energy waste and increased operational transparency for easier sustainable energy management.

The system addresses many losses reduction issues: renewal of important network elements; deployment of accurate metering solutions; and development of modern communication infrastructures. In its design process, national and international standards are considered in order to assure compatibility, safety, and adherence to best practice. It is a must to have the reduction of system loss within a power distribution network in order to guarantee that electricity delivery is effective with lower operating costs and increased reliability. The following recommendations give certain tactics and actions that will reduce the non-technical and technical losses of the system:

1. **Establish Load Centers Based on Requirements:** During planning, load centers are to be created with due care and in line with the demand in the locality. This includes looking at load density and geographical distribution with the aim of ensuring that effective energy transmission is achieved at minimal losses brought about by long-distance power delivery. Overall stability and dependability of the distribution network increase when load centers are positioned appropriately, as they reduce energy waste and voltage drops.
2. **Construct 33/11 kV Substations According to Demand:** Construction of 33/11 kV substations should be done based on demand so that proper voltage regulation and optimum distribution of power take place. These form vital nodes in the system where medium-voltage distribution voltage levels are stepped down from 33 kV to 11 kV. Building substations in areas of high demand, the system thereby cuts down on energy losses resulting from overloading and consequently long distances of transmission.
3. **Build New 33 kV and 11 kV Feeder Lines Based on Demand:** Where demand is increasing, constructing new 33 kV and 11 kV feeder lines will expand the network and ensure that the loads are managed effectively. A feeder line which is properly designed minimizes overloading, thus distributing power throughout the network. It will further ensure a consistent flow of electricity to customers due to reduced losses from old, overloaded lines.
4. **System Loss = I^2R (Importance of Maintenance and Load Adjustments):** The formula for the system loss, I^2R , basically shows the amount of resistance (R) and how the flow of current (I) results in dissipating energy. In order for these kinds of losses to be as low as possible, distribution lines and transformers shall undergo regular maintenance to hold resistance to the lowest degree. Proper adjustments and balancing also avoid the excess flow of current and, hence, reduce loss and improve efficiency in the system.

5. **Ensure Proper Right of Way (ROW) Clearance:** Safety and effectiveness of the power line solely depend upon maintaining the clearance between the Right of Way (ROW). Building vegetation and other obstacles near about the power lines lead to malfunctioning, blackout, or even accidents. Effective ROW management guarantees a continuous supply of power across the distribution lines and avoids energy leakage, thus reducing technical losses.
6. **Conduct Proper Inspection and Maintenance of Power Lines:** On-time inspections and maintenance are very vital to locate and fix wear and tear, loose connections, or environmental damages. Assuring integrity in the system, preventive maintenance reduces losses arising due to malfunctioning or inefficiency in the lines. For efficient line inspection, modern instruments such as drones and thermal imaging may be utilized.
7. **Change Transformer Overloads and Adjust Accordingly:** The leading cause of technical losses within distribution systems is overloaded transformers. The continuous assessment of load and quick replacement or upgrade of transformers reduce the possibility of equipment breakdowns and prevent wastage of energy. Properly sized transformers ensure good load sharing and improve overall network performance.
8. **Check and Replace Faulty Meters:** Broken meters result in faulty energy readings, which can be quite costly for companies and irritating to consumers. Regular meter testing and replacement ensure correct billing, as well as dependable information on energy consumption. Use of modern, precise meters such as Class 1.0 meters contributes to lowering non-technical losses.
9. **Prevent Illegal Electricity Usage and Theft:** The two major reasons for non-technical losses are illegal connections and theft of electricity. Advanced metering systems, regular audits, and the use of tamper-proof meters will help reduce thefts. Increasing consumer awareness about financial and legal consequences related to these losses is another important way to reduce losses.

10. **Enhance Phase Balancing, Power Factor Improvement, and Load Management:** Suitable phase balancing reduces energy losses and equipment stress by evenly distributing power in all phases. The installation of capacitor banks increases the power factor, hence reducing reactive power losses. Efficient load management ensures effective and sustained use of energy, particularly at locations where there is a problem with grounding or voltage conditions.
11. **Voltage Levels (Operate at 11 kV in the Distribution Network):** Operate at 11 kV in the Distribution Network. To reduce the losses at medium voltage transmission of power, it is a normal practice to operate at 11 kV in the distribution network. This voltage level reduces the chances of voltage drops while ensuring efficient energy supply within longer distances. The end user can always be guaranteed of a consistent and reliable supply of power from well-maintained 11 kV lines.
12. **Transformer Efficiency (Maintain a Minimum Standard of 95%):** To minimize technical losses, it should be at least a minimum of 95% at full load operation. High-efficiency transformers provide the best energy transfer because of minimal dissipation of energy due to heating and other inefficiencies. It also cuts down network operating costs and enhances its long-term viability.
13. **Energy Meter Accuracy (Utilize Class 1.0 Meters):** Class 1.0 meters will ensure accurate and reliable measurement of energy consumption. Since the customers are billed based on these readings, these meters are ideal for billing since they can have a maximum margin of error of 1%. Correct meters will assist in determining the system loopholes and thus permit enhancement in network management.
14. **Communication Infrastructure (Deploy IoT-Enabled Devices):** Implementation of IoT-Enabled Devices in a Network will, therefore, facilitate monitoring and analysis in real time. These tools will enable operators to easily identify inefficiencies or issues by providing them with basic information related to transformer operation, feeders, and meters. Moreover, the usage of IoT technology in systems enhances overall dependability and effectiveness, thereby performing high-level analytics like load forecasting and predictive maintenance.

By implementing these comprehensive measures, the system can significantly reduce technical and non-technical losses, ensuring a sustainable and efficient power distribution network.

Standards

The following national and international guidelines are followed in the design:

- **IEC 62053:** provides the standards for electricity metering equipment.
- **IEEE 1547:** Interconnection standards for distributed energy resources.
- **REB Guidelines:** The REB Guidelines ensure that the local law motivates an efficient and viable distribution of electricity to Rural Bangladesh. It offers elaborative details on designing the operation and maintenance of a power system to bear the burden related to specific challenges emerging because of rural electrification.

Key aspects of REB Guidelines include:

- a. **Network Planning:** Network planning focuses on the establishment of adequate load centers, building sub-stations, and ensuring feeder lines are of a capacity to meet demand within rural areas.
- b. **Technical Standards:** These are standards on technical loss reduction by using high-efficiency transformers, appropriate sizing of conductors, and routine maintenance on systems.
- c. **Consumer Engagement:** Facilitates initiatives like consumer education and the usage of AMI to minimize or eliminate non-technical losses in case of theft/abuse.
- d. **Affordability and Access:** Aims to have electricity accessible and its supply to be affordable by rural areas while the infrastructure is meeting the reliability and quality standards.

Since REB is following the guideline provided, the system ascertains compatibility with present infrastructure and policies besides tuning towards national goals for rural electrification. Similarly, guidelines may assist Bangladesh in developing a sustainable energy network.

Constraints

The number of factors inhibit effective monitoring and loss reduction in a system. The constraints, though not insurmountable, can be addressed through careful planning, prudent resource allocation, and involvement of the stakeholders. The subsequent provides an elaborate explanation of the principal restrictions:

1. Financial Limitations: Modern technologies and infrastructures are developed within the limits that financial constraints allow. The high cost of modern equipment like smart meters, high-efficiency transformers, and IoT-enabled devices itself restricts the extent of deployment in most cases.

Key Challenges:

- a. **Limited Resources:** Large-scale modernization projects are difficult to get funded, with most utilities and rural electrification boards having very limited operating budgets.
- b. **High Initial Costs:** The major challenge in deploying smart grid technologies without immediate returns in sight is the cost of putting in place energy meters and related communication systems.
- c. **Maintenance Expenses:** Besides installation, the maintenance of such complex systems, training of staff, and replacement of old components are added burdens on the budget.

Mitigation Strategies: The mitigation strategies to overcome the financial barriers may be a public-private partnership, foreign grants, and government subsidiaries. High-priority areas may be focused on and the changes made in a step-by-step manner to make optimum use of the available resources.

2. Infrastructure Challenges: One of the biggest obstacles to deploying modern monitoring and control systems is, in fact, the availability of appropriate and modern communication infrastructure especially in rural areas. In fact, many rural areas are bereft even of the basic network required for real-time data transmission or even IoT devices.

Key Challenges:

- a. **Inadequate Communication Networks:** IoT-based devices require proper cellular networks and internet connectivity. In fact, the concept of real-time monitoring and fault detection is just not possible without these.
- b. **Aging Electrical Infrastructure:** There exist rural power systems with obsolete transformers, conductors, and distribution lines that cannot adequately answer to the needs of up-to-date technologies.
- c. **Geographic challenges:** The electrical as well as communication systems installation in remote and inaccessible regions is very difficult.

Mitigation Strategies: Governments and utilities could invest in upgrading the present electrical infrastructure along with investments in expanding communications networks such as fiber optics or satellite-based systems, routing around the infrastructure issues. Partnerships with telecommunication providers may also provide implementation of necessary communication frameworks.

3. Consumer Behavior: The main social problem revolves around resistance to the adoption of new metering procedures and systems. This is because consumers, especially in rural areas, may be skeptical about new technologies for either not understanding such sophisticated systems, fear of increased prices, or even invasion of privacy.

Key Challenges:

- a. **Lack of Awareness:** Customers may object to the advanced metering systems on account of unawareness about the benefits associated with this, such as correct billing and fewer outages.
- b. **Cultural Resistance:** Deep-seated beliefs and a general aversion to changing long-established customs can sometimes act as barriers to the adoption of new technologies.
- c. **Mistrust of Utilities:** Consumers may mistrust the intentions of utility-driven programs based on past bad experiences such as incorrect billing or denial of service.

- d. **Illegal Activities:** Any systems allowing for quick and easier identification and termination of thievery in the areas where stealing is frequent are significantly impaired if that activity involves consumers engaging in this illegal activity.

Mitigation Strategies: Utilities to overcome customer resistance can implement awareness programmes on the benefits of advanced metering systems. It also builds trust and convinces people to accept by offering incentives, such as early adopter discounts, in a transparently cost-benefit explained manner.

In conclusion, overcoming monitoring and loss reduction challenges requires strategic financial planning, infrastructure modernization, and consumer engagement. Partnerships, phased upgrades, and awareness campaigns can address these barriers, ensuring improved system efficiency and a more reliable energy infrastructure.

3.4 Circuit Diagram

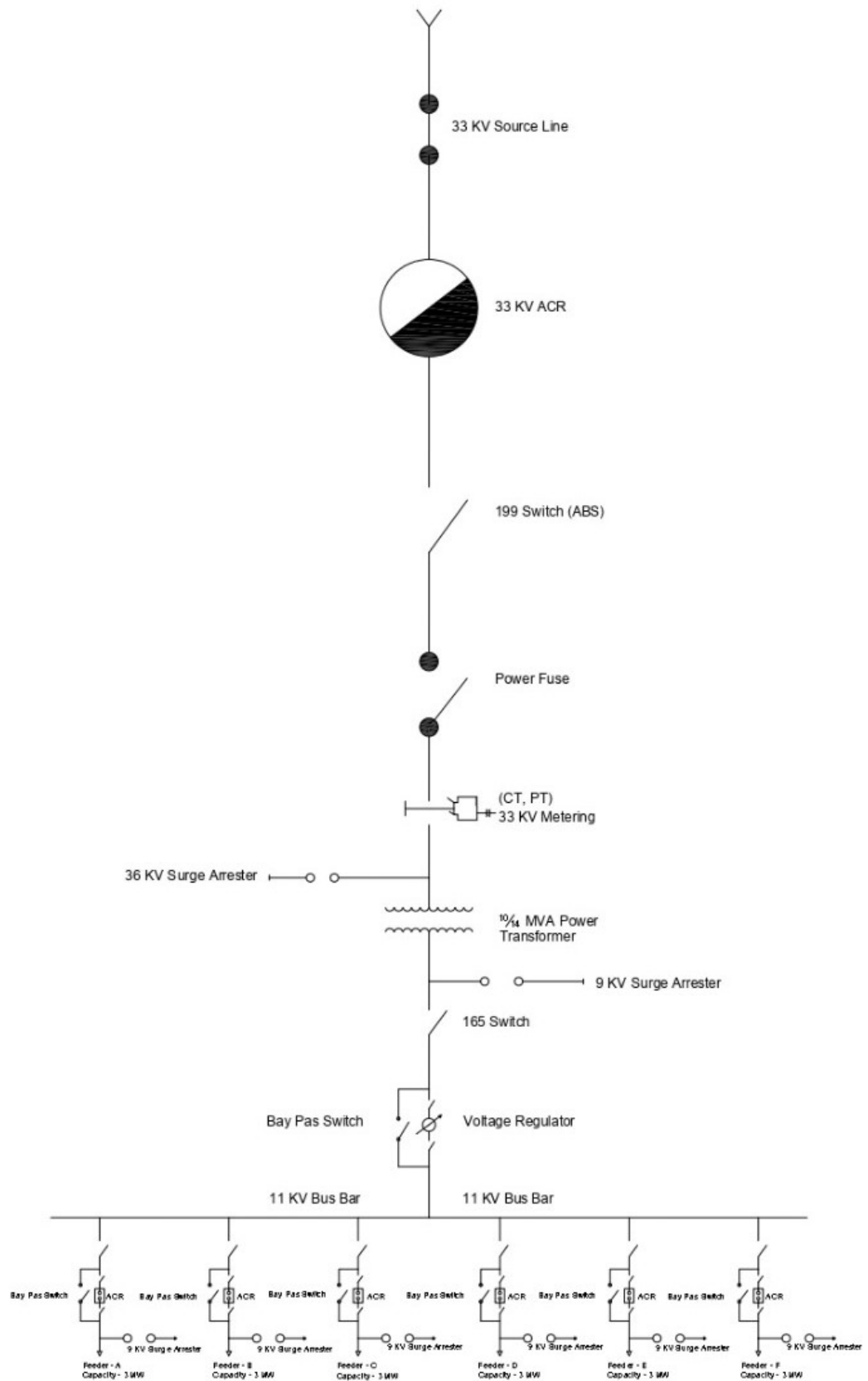


Fig. 3.3: Single Line Diagram (SLD) of Pachrukhi Sub-Zonal Office.

Distribution Line: A distribution line is an electrical circuit specifically intended to transmit and distribute electric power to end-users, including stores, houses, factories, and other consumer places. The system is characterized by its extensive network of branches and its many connections to the service. There are two classifications of distribution lines based on voltage:

- The primary distribution voltages are 11 KV, 6.6 KV, and 3.3 KV.
- Secondary distribution includes two voltage levels: 400V and 220V.

SLD shows a simplified model of a typical power distribution system in the Pachrukhi Sub-Zonal area. It depicts the major components and their relationships, which are essential to understand in the perspective of possible losses in the system.

Key Elements and Their Significance:

ABS 199: Most likely an abbreviation of Air-Break Switch (ABS) with a rated voltage of 199kV, this switch can be used for either connecting or isolating sections within an electrical grid.

- **Impact on the System Loss Study:**
 - a. **Switching Losses:** In operation (Open or Closed), ABS 199 may temporarily disrupt the power system. These may lead to energy losses as well as voltage fluctuations.
 - b. **Outage Losses and Maintenance:** Repair and maintenance of the ABS 199 result in a temporary disruption of the supply that costs energy for the customers.

ACR 33kV: ACR 33kV is an abbreviation for **Automatic Circuit Recloser** at 33kV. An ACR is a protective device that isolates a line automatically when it detects any form of damage and then attempts to re-energize that section.

Importance to the System Loss Analysis:

- a. **Fault Clearance:** Since faults (short circuits) at 33kV must be quickly isolated, ACR 33 kV is required. Also, by reducing the section of power outages the loss of energy by consumers also decreases.
- b. **Selective Protection:** By isolating the defective area alone while sustaining power to other parts of the system, an ACR 33 kV aids in selective clearance of fault.

33kV Bus Bar: The 33kV Bus Bar is the main incoming supply point at the sub-station level. The system losses at this stage may be due to:

- **Corona Loss:** There is a corona discharge at higher voltages on the bus bar that may cause energy losses.
- **Switching Losses:** Temporary losses may occur due to the switching operation on the bus bar.

33kV Metering: The metering point at 33kV is essential for accurate energy accounting. Inaccurate metering may result in huge revenue losses for the utility.

CT (Current Transformer) and PT (Potential Transformer): Are types of instrument transformers used in electrical power systems for measurement, protection, and control. They step down high currents and voltages to lower, standardized levels, enabling safe monitoring and operation of high-voltage systems.

CT (Current Transformer)

- **Purpose:** Steps down high current to a measurable level.
- **Connection:** In series with the power line.
- **Application:** Current measurement, protection, and relays.

PT (Potential Transformer)

- **Purpose:** Steps down high voltage to a safe level.
- **Connection:** In parallel with the power line.
- **Application:** Voltage measurement, energy metering, and protection.

Power Transformer: The main step-down transformer, the power transformer, steps down the voltage from **33 kV to 11 kV** for distribution within the sub-zone. The transformer suffers loss due to:

- **Copper Losses:** Those are the resistive losses in the transformer windings.
- **Core Losses:** These are the hysteresis and eddy current-related losses in the transformer core.
- **Stray Losses:** These are losses due to flux leakage.

Lightning arrester: Protects electrical systems by diverting high-voltage surges caused by lightning to the ground, preventing equipment damage and interruptions.

Importance in System Loss Analysis:

- **Reduces Energy Losses:** Prevents faults from surges, ensuring stable operation.
- **Protects Equipment:** Safeguards transformers, breakers, and insulators.
- **Lowers Maintenance Costs:** Reduces damage and repair frequency.
- **Enhances Reliability:** Minimizes outages and downtime.
- **Prevents Fault Propagation:** Contains surge effects locally.
- **Supports Insulation Coordination:** Avoids insulation breakdown.

Lightning arresters are crucial for minimizing losses and maintaining efficient power delivery.

11kV Bus Bar: The 11kV feeders are sourced from this distribution bus bar. Following could be the reason for losses at this location:

- **Corona Loss:** Same as in the case of 33kV bus bar.
- **Switching Losses:** There are some temporary losses due to changes in operations of feeders.

11kV Feeders: A set of lines feeding the consumers of the sub-zone is termed as 11kV feeders. Following are some of the principal feeder losses:

- **Resistive Losses:** This is caused by the resistance of the feeder conductors.
- **Corona Loss:** This occurs if the voltage of feeder lines is high enough.

VR (Voltage Regulator): Voltage regulators installed on feeders are meant for keeping voltage within reasonable limits; otherwise, the losses are higher.

Study and Analysis Implication in the System Loss:

- **Data Collection:** To undertake proper system loss study, data with high degree accuracy shall be collected at feeder metering, 33kV metering, and load data at various feeder sections.
- **Loss Estimation:** SLD provides a structure to predict losses at various system components by using the appropriate models of losses.
- **Reduction Measures for Losses:** Based on the loss analysis, measures can be implemented to reduce losses, such as:
 - a. Improvement in transformer efficiencies is one of the loss reductions measures according to the loss analysis.
 - b. Adoption of better feeder configurations for minimizing the line losses.

- c. Advanced metering system installations are required for improving energy accounting.
- d. Voltage Optimization Techniques Implementation.

The system loss study would require much more detailed data on feeder configurations, load characteristics, and other pertinent parameters for an in-depth analysis. Measures within this framework are categorized based on the foundations of institutional theory. New strategies for analyzing barriers during the implementation of a sustainability effort are provided by the separation of ex-ante and ex-post barriers. A thorough framework for future analysis and reference is provided by classifying development activities and practices based on their mandatory or collaborative nature and including economic, social, and environmental outcomes. Finally, additional future analysis is suggested for academics to address in the future based on the findings of the BREB's sustainable supply chain practices in the development projects, the literature review and methodology of this report, and more.

3.5 Analysis of the System

Energy Audit Methodologies: Energy audit is the detailed process of identification of the exact location where energy efficiency in a system can be improved. It involves studies on energy consumption and identification of areas where energy waste can be minimized.



Fig. 3.4: Energy Audit Methodologies.

1. Audit Criteria & Team Selection:

- Audit goals and scope need to be specified as the very first step of the whole procedure. That is the decision on which particular area is to be audited; which energy sources are to be dealt with such as gas, electricity, etc.; and what will be achieved with the audit.

- A suitable audit team is selected according to the scope of the audit. It will include energy engineers, auditors, and other relevant staff with relevant experience in energy management.

2. Audit Planning:

- The audit methodology, schedule, budget, and resources needed are documented in an audit plan.
- Checklists are prepared to make sure that necessary data are collected and also all audit procedures are consistently applied.

3. Data Collection:

- A preliminary walk-through of the site gives insight into how well the facility is known, particularly in key energy-consuming areas.
- Data collection consists of gathering energy bills, discussion of current documents, field measurements-actual consumption of power, temperature, and humidity, among others.

4. Data Analysis & Preliminary Analysis:

- Energy analysis is done to identify the trend of energy consumption, benchmarking energy use against best industry practices, and identification of potential areas for improvement.

5. Identifying Energy Efficiency Potentials:

- Annotated data provided within this report provides all the fields where savings on energy use can be done, that might either be incompatible equipment, improved procedures, or the embedding of energy-efficient technologies.

6. Cost-Benefit Analysis:

- It gives the financial viability of recommended energy-saving strategies through the cost-benefit analysis, with priorities to help in economical options.

7. Report Writing & Action Planning:

- The audit report would include a detailed summary of the findings, recommendations, and an action plan.
- Course of action required to be undertaken for the implementation of proposed energy-saving measures.

8. Implementation & Post-Audit Activities:

- The suggested energy-saving measures are implemented.
- Post-audit activities include tracking energy savings, evaluating the success of the measures instituted, and modification of the action plan accordingly.

This flowchart is a step-by-step method of conducting an energy audit to make sure that all the key processes are covered and the audit is executed correctly and in a systematic manner.

Fault Detection Mechanisms

Energy systems need fault detection to remain operationally efficient with minimum downtime. Well, the following techniques can be used in finding mistakes and inefficiencies in energy systems, with a special emphasis on complex mechatronic systems like programmable logic controllers, compressors, and pneumatic systems:

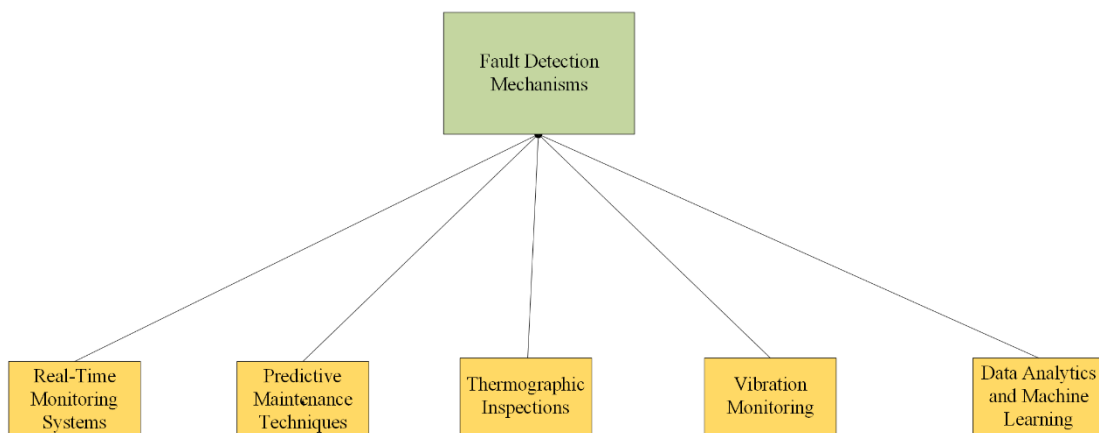


Fig. 3.5: Fault Detection Mechanisms.

1. **Real-Time Monitoring Systems:** Improved monitoring systems closely monitor a variety of important parameters in key performance indicators (KPIs), including energy consumption, temperature, pressure, and flow rates. Any variation from the normal operating scale may trigger an alarm due to malfunction or inefficiency in any one of those parameters. Such systems are also integrated into **Supervisory Control and Data Acquisition (SCADA)** systems where operators may monitor and operate from a distance.
2. **Predictive Maintenance Techniques:** This type of system makes use of sensor data and machine learning algorithms to forecast when a certain system or component is most likely to fail. It is informed by past performance data and trends. In this way, such a system avoids unplanned downtime by predicting the problems before they can occur and thus enabling proactive maintenance.
3. **Thermographic Inspections:** Thermographic inspections use thermal-imaging cameras in order to locate hot components, indicative of potential worn-out bearings, inadequate connections, or electric problems of any sort. Electrical overloads and mechanical friction inside motors-in two conditions liable to induce energy inefficiency-become noted.
4. **Vibration Monitoring:** This is one of the best methods for finding out issues with rotating machinery like compressors, pumps, and motors. Unusual vibration levels may indicate a variety of mechanical problems that can lead to equipment failure or increased power consumption.
5. **Data Analytics and Machine Learning:** Machine learning models integrated with data-based techniques to identify unusual patterns. These systems process large amounts of data about system behavior and can project probable failures or inefficiencies long before they begin to substantially affect energy use.

Failure modes in electrical machines include insulation failure in the stator or rotor windings, brush gear failure, slip ring failure, and mechanical modes such as bearing failure or stator/rotor mechanical integrity failure. Condition monitoring based on visual inspection, current signal measurement, vibration monitoring, wear debris monitoring, acoustic measurements, and thermal monitoring that can minimize the downtime and increase the efficiency of the system has been extensively. For example, practical sensors to detect rotor failure without having rotor-based sensors include analysis of the stator current with signal processing methods or artificial intelligence

techniques. Electrical faults in stator windings can be detected by measuring axial leakage flux and stray flux or extracting features from the stator current signals to detect faults.

3.6 Summary

This chapter represents different approaches, materials, and design strategies employed to execute the system loss study of Pachrukhi Sub-Zonal Office under Narayanganj PBS-2. The said structure of the study is done by describing the technique of data collection, analysis, and computation methodologies to estimate the losses. Further, it provides additional information related to important components, such as meters, feeders, and transformers with their specifications and operational parameters. It discusses the design principles and the optimization techniques that consider some network limitations such as network capacity, load variability, and economic viability. The fault detection system and methodologies for energy audit, which is of great importance, are discussed here within this chapter. A detailed explanation of the experimental setup contains the description of methodology for data collection, simulation, and validation. The chapter concludes with the single line diagram of distribution network highlighting important parts in the perspective of system loss analysis, namely power transformer, ABS 199, ACR 33kv, 33kV bus bar and 11kV feeders along with explanation of each in the same perspective.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results

The result section describes the results of the system loss study conducted at Pachrukhi Sub-Zonal Office under Narayanganj PBS-2. This includes both technical and nontechnical losses in the distribution network. This section will most probably present data in understandable and well-organized graphs, tables, and charts showing load profiles and energy consumption patterns. These could be divided into two classes of outcome: the non-technical ones-which involve theft and improper metering-and technical losses due to transformer or line losses. It would certainly give very good insight into decision-making by implementing effective and efficient loss-reduction measures through pointing out specific areas where such energy losses have taken place owing to an overloaded transformer or ill-maintained lines.

4.2 Technical Losses

Technical losses in an electricity distribution system are those that take place in the course of transmission and distribution from the source of generation to the end user. These losses actually cause energy dissipation during the transfer of electricity from source to consumer due to several systemic factors.

Mechanism and Loss Zones:

1. Distribution Substation:

- **Transformer Losses:** The voltage-reducing power transformers have huge losses.
 - a. **Copper Losses:** These result from the resistive effect of the transformer windings due to current flow in them.
 - b. **Core Losses:** Since in a transformer, the core is magnetized and de-magnetized, therefore, some energy will get dissipated out as heat.
- **Voltage Regulator Losses:** These are losses developed within voltage regulators, which are used to maintain a constant level of voltage.

- **Station Service Losses:** The losses associated with substation auxiliary equipment, such as fans, lighting, and control systems.
2. **Distribution Transformer:** Distribution transformers have further voltage reduction for locally feeding, which also experiences losses in the form of copper and core loss as that of the main substation transformer.
 3. **Primary (HT) Lines:** The main loss of high voltage lines, those operating at 11 kV and above, is due to the resistance of the conductors. These losses depend on the line length and the magnitude of the current flowing through it.
 4. **Secondary (LT) Lines:** Even the low-voltage lines, normally carrying 400V, also suffer from the problem of resistive losses. These losses are considerable because of higher current and lower voltage, especially in places with high loads and a high population density.
 5. **Service Meter:** Although usually neglected, service meters can be contributing to small losses because of their internal resistance and power consumptions by their internal circuitries.

As revealed through the data from AMI, in Pachrukhi Sub-Zonal Office under Narayanganj Polli Biddut-2, the technical losses are at a rate of 1% within the zone. This percentage includes the loss of the whole zone's generated electricity at the time of transmission and distribution due to conductor resistance losses, transformer losses, voltage regulator losses, primary (HT) lines, and secondary (LT) lines. Usage of AMI data allows the evaluation of such losses at a resolution much finer than that possible by traditional techniques.

4.3 Total Losses

We calculated the average and total system losses in the zone using data sheets that we received from the Pachrukhi Sub-Zonal Office under Narayanganj PBS-2. In order to analyze the gathered data for finding out the trend of energy use, locating lossy areas, and calculation of the number of losses, it was required.

Total Loss Calculation:

$$Total\ Loss = \frac{purchase - (sales + Resales)}{purchase} \times 100 \quad [23]$$

The overall loss percentage in the Pachrukhi Sub-Zonal Office under Narayanganj PBS-2 can be computed by using the following formula. It contrasts the total quantity of

energy that a distribution firm buys with the total quantity of energy that is sold to customers as well as resold to other firms. The distinction between bought energy and accounted-for energy is the total unaccounted-for energy representing the complete loss. The difference between them is then divided by the total amount of energy purchased, multiplying with 100 gives the total loss percentage. This calculation helps in estimating the overall energy losses-technical and non-technical-occurring in the distribution system.

Year - 2024						
Month	Purchase (kWh)	Sales (kWh)	Resale (kWh)	Total (kWh)	%Total Loss	Comment
January	5365595	5011372	261100	5272472	1.74	
February	4968930	4672214	271101	4943315	0.52	
March	5722266	5345374	358898	5704272	0.31	
April	6417571	5140423	343499	5483922	14.55	Loss High
May	6082057	5471812	289903	5761715	5.27	
June	5993155	4612250	268216	4880466	18.57	Loss High
July	6406518	5608813	290463	5899276	7.92	Loss High
August	6468725	6011687	274576	6286263	2.82	
September	6216073	5760726	279223	6039949	2.83	
October	6829841	6442567	303221	6745788	1.23	
November	6627449	6227449	232753	6460202	2.52	
December	5230720	4867123	281511	5148634	1.57	
Average Loss Calculation					4.99	Loss High

Table 4.1: Monthly & Average Loss Calculation of Pachrukhi Sub-Zonal Office

The table below gives the monthly analysis of operational or energy losses for 2024. For every month, it has the following:

- **Purchase:** Total quantity of goods or energy received.
- **Sales:** Total number of units sold.
- **Resale:** Units sold again have secondary transactions.
- **Total:** The summation of all the relevant numbers.
- **%Loss:** A percentage of loss which is deduced from the data.
- **Comment:** Excessive or within reasonable bounds.

If we count January month, then we find some data from our data sheet, like:

Purchase = 5365595 kWh

Sales = 5011372 kWh

Resale = 261100 kWh

$$\text{Total Loss} = \frac{5365595 - (5011372 + 261100)}{5365595} \times 100$$

$$\text{Total Loss} = \frac{5365595 - 5272472}{5365595} \times 100$$

$$\text{Total Loss} = \frac{5365595 - 5272472}{5365595} \times 100$$

$$\text{Total Loss} = \frac{5365595 - 5272472}{5365595} \times 100$$

$$\text{Total Loss} = 0.0174 \times 100$$

$$\text{Total Loss} = 1.74\%$$

This calculation helps us to find out the total monthly losses. The above information has been provided by Narayanganj Polli Biddut-2's Pachrukhi Sub-Zonal Office. We get the following information from the data sheet and engineers from Narayanganj PBS-2 which is given below:

Purchase Data:

Narayanganj PBS-2							
Pachrukhi Sub-Zonal.							
Sub: Energy Purchase as per Billing Meter.					Month of October-2024		
Name	Name of S/S, 33 KV Consumer & Pole Metering.	Present Reading	Previous Reading	Diff	M.F	Total	Net Consumption
Pasruki S/S	U-1	1850	845	1005.00	4763	4786815	4786815
	U-2	5570	5363	207.00	4763	985941	985941
33 KV Consumer	Akter Textial	979	807	172.00	1587	272964	272964
	EPZ	161	46	115.00	1587	182505	182505
Narsingdi PBS-1 to Narayanganj PBS-2(11KV)	Danga (Atlapur) (Indivisul)	-	-	220575	1	226089	226089
	Dupertek-2 (16012811)	204111	200155	3956	1	4055	44771
	Abartech (19470063)	3998	3883	115	79.375	9356	
	Irrigation(15706752)	14325	14325	0	1	0	
	Charigaon (93198112)	441098	431491	9607	1	9847	
Dupertek-1 (15570446)	4332	4200	132	159	21513		
Nasingdi PBS-1 to Narayanganj PBS-2(PSZ) 11KV	Joariakanda (15650963)	4278	3857	421	530	228708	202904
(বাঁদ)Narayanganj PBS-2(PSZ)	Khalpar (9001890)	4570	4475	95	265	25804	
Nasingdi PBS-1 to Narayanganj PBS-2 (PSZ)11KV	Asuhat-2 (903448)	443483	433483	3000	1	3075	106705
	Asuhat-3 (17205215)	18099	17930	169	1	173	
	Rasulpur-1 (19470074)	1559	1182	377	265	102403	
	Rasulpur-2 (24031616004870)	10786	9758	1028	1	1054	
Kanchan Sub-Zonal to Pachrukhi Sub-zonal) 11KV. (বাঁদ)Pachrukhi Sub-zonal.	Tarial Pole Meter(15556857)	5886	5873	13	1587	21147	21147
Total=(Others PBS)							601616
Sub Total=							6829841

Table 4.2: Energy Purchase as per Billing Meter of Pachrukhi Sub-Zonal Office

From this table, we can identify that our purchase unit is 682984 kWh, given by PBS-2.

The sale unit is given by the PBS engineer, while resale unit is given by 303221 kWh.

নারায়ণগঞ্জ পল্লী বিদ্যুৎ সমিতি-২									
ছনপাড়া, সাতগ্রাম, আড়াইহাজার, নারায়ণগঞ্জ।									
								মাসের নাম: অক্টোবর/২০২৪ইং	
০১। বিষয়:- পাঁচরুখী সাব জোনাল হইতে নরসিংদী পবিস-১ এর বিদ্যুৎ ব্যবহার।									
গ্রাহকের নাম	হিসাব নং	মিটার নং	বর্তমান রিডিং	পূর্বের রিডিং	পার্থক্য	গুণিতক	লস	মোট	মন্তব্য
রশিদের বাড়ী(ছনপাড়া)	নরসিংদী পবিস- ১	8954711	297212	282771	14441	1.000	1.025	14802	
কান্দাইল(বাস স্ট্যান্ড ভিক্টো:)	নরসিংদী পবিস- ১	14086003	5413	4492	921	265.000	1.025	250167	
স্বরূপাব ও দঃস্বরূপাব	নরসিংদী পবিস- ১	9000118	2621	2350	271	79.375	1.025	22048	
স্বরূপাব ও বাগবাড়ী	নরসিংদী পবিস- ১	22444897	117833	112799	5034	1.000	1.025	5160	
ইন্ডিভিজুয়াল	আশুহাট(১৫৯- ৭১৫০)	13982132	0	0	0	1.000	1.025	11044	
	আশুহাট(১৫৯- ৭১৫৫)	এস০০১৫৯০৮৭	0	0	0				
	আশুহাট(১৫৯- ৭৫৪০)	13953532	178900	177330	1570				
	আশুহাট(১৫৯- ৭৫৫০)	2022021193	36990	34308	2682				
	রসুলপুর(০৮- ১২০৫)	2022031180	30496	24846	5650				
	রসুলপুর(০৮- ১১০৭)	এস০০০৬৯০৯৮	2459	2455	4				
	রসুলপুর(০৮- ১১০৫)	21399820	11059	10917	142				
	বিলপার(৭৮৬- ৭০২০)	21399820	1848	545	869				
Total=								303221	বিল হবে

Table 4.3: Energy Resale Unit of Pachrukhi Sub-Zonal Office

Average Loss: The average yearly loss is 4.99%. While this may appear to be moderate, the high losses in April, June, and July are immense contributors to annual performance.

The average loss calculates by,

$$\text{Average Loss} = \frac{\text{Sum of total loss}}{\text{Months of year}} \%$$

$$\text{Average Loss} = \frac{59.85}{12} \%$$

$$\text{Average Loss} = 4.98\% \cong 4.99\%$$

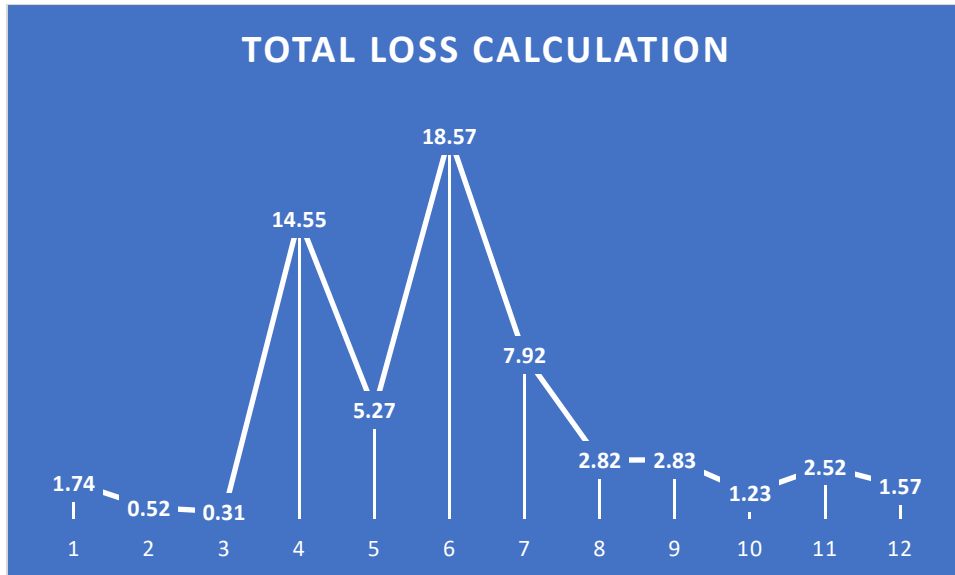


Fig. 4.1: Loss Calculation 12 months of 2024.

The following line chart indicates the percentage of losses of the 12 months of 2024. Each of the different points represents one month: from January to December, represented by numerical labels running from 1 to 12 along the x-axis.

1. Low percentages of loss in some months:

- a. January:** The year opens with a relatively small and bearable decline of 1.74% in the month.
- b. February:** February presents a significant decline, at a loss of 0.52%, the lowest percentage ever noted in the year.
- c. March:** The low loss of 0.31% suggests excellent operational effectiveness.

2. High Percentage Loss Months:

- a. April:** The increase in April is quite steep, and the loss jumps to 14.55%.
- b. June:** The percentage of loss at the end of the year is 18.57%.
- c. July:** The loss is less than that in June but is still quite high at 7.92%.

3. Stabilization Period:

- a. August to November:** The loss percentages during the stabilization period, extending from August to November, show a regular gain and stabilize between 2.52% and 2.83%.
- b. December:** Represents a net loss of only 1.57%, showing recovery toward the close of the year.

Trends and Patterns: The chart shows three distinct phases.

1. **Initial Stability (Months 1–3):** Low losses between months one through three are representative of operational control.
2. **Mid-Year Spikes (Months 4–7):** Increased rates of loss indicate ineffectiveness or disruptions.
3. **Late-Year Recovery (Months 8–12):** A downward trend suggests effective mitigation measures.

Views and Recommendations:

1. **Peak Losses:** To represent the causes of such remarkable losses in April, June, and July, focused audits need to be carried out.
2. **Improvement Zones:** Losses are in control from August onwards, which indicates that corrective measures are effective.
3. **Future Strategy:**
 - a. Take cautionary measures to avoid mid-year peaks.
 - b. Enhance prediction and tracking systems to identify any potential issues early.

4.4 Non-Technical Losses

Non-technical losses of energy in transmission and distribution are those caused by elements unrelated to the technical aspects of the system, such as the physical or technical characteristics of the network that include line resistance and transformer inefficiencies. Normally, these losses are due to human intervention, operational inefficiencies, or external influences.

Examples of Non-Technical Losses

1. **Electricity Theft:**
 - Illegal connections to the electrical network.
 - Tampering with meters in order to reduce consumption records.
2. **Billing and Metering Errors:**
 - Inaccurate or faulty energy meters.
 - Errors in processing, recording, or reading electricity consumption data.
3. **Unpaid Bills:**
 - Customers who do not pay their electricity bills in time or at all.
 - Large customers who do not pay their dues in time.

4. Fraudulent Activities:

- Corruption in utility companies, including employee-consumer collusion to falsify readings or evade billing.

5. Inaccurate Data:

- Inaccurate billing or unrecorded electricity use due to poorly maintained customer databases.

6. Unauthorized Usage:

- Use by people or organizations who aren't formally listed as clients.

Calculation Of Non-Technical Losses:

$$\text{Non – Technical Loss} = (\text{Technical Loss} – \text{Total Loss})\% \quad [24]$$

$$\text{Non – Technical Loss} = 2.50 – 1.74\%$$

$$\text{Non – Technical Loss} = 0.76\%$$

Year - 2024			
Month	Total Loss%	Technical Loss%	Non-technical Loss%
January	1.74	2.50	0.76
February	0.52	2.50	1.98
March	0.31	2.50	2.19
April	14.55	2.50	12.05
May	5.27	2.50	2.77
June	18.57	2.50	16.07
July	7.92	2.50	5.42
August	2.82	2.50	0.32
September	2.83	2.50	0.33
October	1.23	2.50	1.27
November	2.52	2.50	0.02
December	1.57	2.50	0.93
Average Loss Calculation	4.99		3.68

Table 4.4: Non-Technical Loss Calculation of Pachrukhi Sub-Zonal Office

The average non-technical loss calculates by,

$$\text{Average non technical Loss} = \frac{\text{Sum of total non technical loss}}{\text{Months of year}} \%$$

$$\text{Average non technical Loss} = \frac{44.11}{12} \%$$

Average Loss = 3.675% \cong 3.68%

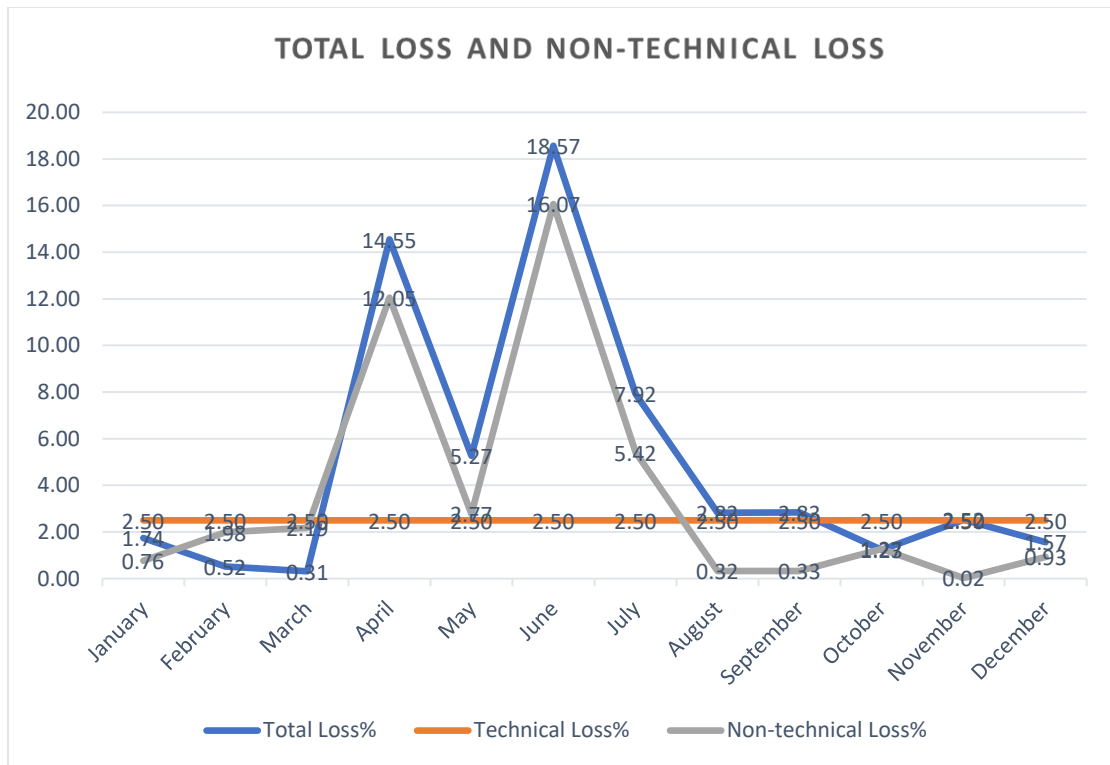


Fig. 4.2: Total Loss & Non-Technical Loss

The table and graph have segregated the data for each month into three categories, including Total loss%, Technical loss%, and Non-Technical loss%. In the last row, a calculated average for the whole year is provided. Here's an elaboration:

1. Low Non-Technical Loss at the Beginning of the Year:

- The minimum Loss starts at 0.76% in January, then by March, loss has gradually increased to 2.19%

2. Peaks of April and June are significant:

- **April:** Non-technical inefficiency increases tremendously during the month, going up as high as 12.05% evident from the loss incurred.
- **June:** The highest loss throughout the year-16.07%-which indeed signals a serious problem as relates to non-technical performance.

3. Gradual Decline After June:

- A Progressive Reduction After June, the losses decrease month by month to 5.42% in July, then remain constant for successive months.

- The non-technical loss continuously fell to 1.27% by October and, in November, reached its lowest value, having fallen only a scant 0.02%

4. Stability Towards the Year's End:

- This trend increases slightly in December at 0.93% but remains way lower compared to this year's peaks at the beginning.

Principal Findings:

- **Critical Months:** The worst months among these are April and June, with losses of 12.05% and 16.07%, respectively.
- **Improvement Trend:** From June onward, the losses show a constant downward trend consistently, perhaps due to the seasonality effect or some corrective measures taken.
- **Minimal Values:** The best months by non-technical loss value are January, November, and December, with loss less than 1.00%

4.5 Proposed Solution

Considering that the government standards of acceptability Technical losses have set it as 2.5%, which generally acts as a yardstick for proper energy distribution, Narayanganj PBS-2 has gone one extra step in taking on initiative measures and striving for still stricter limits ranging between 1.25 and 1.50%. The previous statement explains how these types of system performances improve if infrastructure, routine repairs and maintenance, and best methods are used in managing the load. The calculated average total loss was 4.99% which is much less than the government standard of 6.0%, but they failed to maintain their PBS standard 3.60%. If they want to maintain their PBS standard then they need to take immediate action to reduce their average loss of 1.39%. This implies that Narayanganj PBS-2 is improving in operational procedures to contain losses. With the PBS standard for total losses set at 3.60%, Narayanganj PBS-2 has thus established an internal benchmark that is much more efficient in operations.

This holistic analysis of the total loss identifies those non-technical losses, representing theft, illegal use, meter tampering, and incorrect billing, amounts to 3.68% of the total non-technical losses. The value for the nontechnical loss has come out as a huge scope for improvement due to its leading proportion among total losses. The non-technical ones are a bit more difficult to handle because they involve human error and other external factors, but stringent anti-theft legislation, advanced metering systems,

awareness campaigns, and careful observation can reduce them. While the average total loss of 4.99% at Narayanganj PBS-2 is below the government standard of 6.0%, achieving the internal benchmark of 3.60% will require focused efforts on reducing the 3.68% non-technical loss. Their efforts to keep technical losses within 1.25% to 1.50% serve as a model of efficiency, but addressing non-technical issues will be pivotal in achieving their ambitious goals and setting a standard for operational excellence.

Solutions:

Technical Loss: The technical losses occurring in Narayanganj PBS-2 can be reduced by the use of modern technologies, frequent maintenance, and improvement in the technical field. The following recommendations may be proposed for its reduction:

Modernize Infrastructure for Distribution

- Replacement of old, faulty, or undersized conductors by more large-capacity conductors will reduce resistance and loss of energy.
- Reduce overload/under-load transformer losses by proper sizing of transformers in relation to load demand.
- Amorphous core transformers or other low-loss transformers can be utilized to achieve the same.

Regular Maintenance and Monitoring

- Transformers, distribution lines, and other equipment must be routinely inspected for defects such as corroded parts, broken insulators, and loose connections, and repaired.
- Cooling systems of the transformers to be cleaned and serviced regularly for efficient functioning.
- Leakages to ground or faulty connections to be located and repaired.

Adopt Advanced Technologies

- The voltage levels could be retained within the optimal limits and avoid network overloading using Automatic Voltage Regulators (AVR).
- Install sensors and smart meters monitoring data in real time can help in observing areas that have high technical losses
- Deploying energy-efficient devices like capacitor banks would improve the power factor thereby reducing the losses due to reactive power

Demand Management and Load Balancing

- The load should be well distributed across phases to avoid overloading/under-loading issues.
- Demand side management techniques will be applied, such as load shedding schemes and time-of-use tariffs to help regulate peak load demands.
- Load flow studies to be conducted in order to find weak points and enhance the distribution of loads.

Enhance Voltage Regulation

- Step-down transformers and voltage regulators would be utilized in maintaining the voltage of the distribution system within limits.
- Load-tap-changing sophisticated transformers would also be employed to vary voltage levels corresponding to changes in demand.

Improve Metering Accuracy

- Update old and incorrect meters with new, more accurate digital or smart meters to correctly measure the energy supplied.
- Calibrate the existing meters periodically to avoid any discrepancy in reading.

Installation of Power Factor Correction Equipment

- Encourage capacitor banks at customer sites. This should especially be done for the largest customers, both commercial and industrial. Since capacitors compensate for reactive power, the current flow and, hence, the losses in the overall network reduce.
- Automatic Power Factor Controllers (APFCs) for real-time power factor correction depending on different loads are recommended.

Load Balancing and Equipment Sizing

- Steer clear of unbalanced loads that will lead to a drop in the power factor by helping clients with properly balancing the load across phases.
- Motor, transformer, and other equipment correct sizing to ensure maximum efficiency by reduced excessive reactive power consumption is advised.

Conductor Issue:

The major reason for this high technical loss in the BREB system can be reduced to a great extent by replacing conductors with more efficient ones. In the literature, the idea of selecting the optimal conductor sizes had been investigated years ago [25–27]. The concept of selecting Aluminum Conductor Steel Reinforced (ACSR) sizes based on economic considerations was introduced in [25]. Later, various optimization techniques

such as analytical, numerical, and heuristic-based methods were used to solve the problem of optimal conductor size selection [28–32]. However, throughout these studies, one can note that the optimal conductor selection problem is always thought of as a solution for power loss reduction in distribution systems without considering today's challenges with the connection of DG units and the problems that have arisen with them. Accordingly, much consideration must be given to obtaining criteria for designing a practical system that is able to handle the different load uncertainties and DG penetration variations. The general approach for replacement of conductors in the system along with the cost for the same in Bangladesh is described below.

Replace Old Conductors with ACSR or AAAC

- **Technical Benefit:**
 - The immediate technical advantage of using ACSR or AAAC for the replacement of old conductors is that it will reduce the resistance and energy loss, especially on long distances.
 - AAAC is resistant to corrosion in coastal areas, while ACR provides very high tensile strength over longer spans.

Use Aerial Bundled Cables (ABC) in Theft-Prone Areas

- **Technical Benefit:**
 - Loss of non-technical is minimized along with the prevention of pilferage of connections.
 - Improved reliability and safety

Optimize Conductor Sizing

- **Technical Benefit:**
 - Conductors of the right size reduce thermal losses and overloading.

Implement XLPE Insulated Conductors

- **Technical Benefit:**
 - Due to superior insulation characteristics, line losses are reduced.
 - Suitable for underground distribution in densely populated areas.

Introduce Low-Loss Conductors

- **Technical Benefit:**
 - Improved technologies like HTLS conductors allow higher current carrying capacity and lower losses.

Non- Technical Loss:

Here, we have proposed some methods to reduce the non-technical loss. Our main loss will reduce if we can reduce these non-technical losses also. because non-technical losses are dominating the losses.

- a. Decreased on meter tampering.
- b. Service drop bypass bound
- c. Ratio alteration and CT/PT bypass bind
- d. Locate meter boards being separated or bypassed
- e. Identify and cut parallel connections.
- f. Direct hooking is a severe and dangerous problem. The most disturbing situation of the BREB line is direct hooking. Too many losses occurred due to this. This problem should be reduced as much as possible.
- g. Find out the broken or bent poles and change them.
- h. Reduction of missing or loose logs.
- i. Ensure the wire is neutral.
- j. Check the whole system for loose connection.
- k. The fuse barrel, cut-out, and lightning arrester among others shall be properly functioning.

4.6 Discussions

The distribution system of Narayanganj PBS-2 will only be improved when the technical and non-technical losses are reduced. Efficient load balancing, demand management strategies such as time-of-use tariffs, and load flow studies would assure network stability along with waste reduction. Voltage regulation improvements, such as load-tap-changing transformers and sophisticated voltage regulators, assist in maintaining ideal levels and reducing losses. Changing to smart meters and making sure that the meters are accurate will also avoid inconsistencies and illegal use. The power factor correction, with capacitor banks and automatic controllers, maximizes the performance by reducing the reactive power losses. Non-technical losses, such as direct hooking, service drop bypass, and meter tampering, must be dealt with in order to overcome theft and unauthorized use. System reliability is improved through upkeep of infrastructure, replacing damaged parts, and ensuring the operation of vital equipment.

CHAPTER 5

PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

The project timeline gives a step-by-step approach toward thesis preparation: initial planning and literature review in early 2024, followed by site visits and surveys that should be finalized in the middle of the year; definition of problems and objectives is then determined, while data collection, analysis, and loss calculation will take place between August and October; after the development of the proposed solution, writing of the thesis commences in November. In early 2025, the timeline is finally complete, with due time for preparation of the thesis defense.

Task	Start Date	End Date	Milestone
Thesis Planning	05-Jan-2024	02-Feb-2024	Planning to make thesis
Literature Review	04-Feb-2024	04-Mar-2024	Completion of literature review
Site Visits & Surveys	04-Apr-2024	30-Jun-2024	Visit the site for surveys
Problem Definition & Objectives	02-Jul-2024	08-Aug-2024	Problem finding and objective making
Data Collection, Analysis & Loss Calculation	10-Aug-2024	28-Oct-2024	Collecting data, make analysis & complete our required calculation
Proposed Solution & Thesis Writing	01-November-2024	17-Dec-2024	Find solution & Thesis written done
Thesis Defense Preparation	20-Dec-2024	5-Jan-2025	Defense Preparation

Table 5.1: Task Distribution

The major milestones on this timeline are the completion of the literature review, visits to the sites, formulation of the problem and objectives, data analysis, formulation of a solution, and thesis defense preparation. It's a very ambitious timeline and needs very careful planning regarding time management if it has to be executed successfully.

5.2 Resources and Cost Management

Here, cost-effectiveness and resource management will be the two most feasible options for reduction in the failure rate of the systems and long-term sustainability of operations at the Pachrukhi Sub-Zonal Office. There is a strategic need for investment in material, human, and financial resources to overcome problems caused by both technical and nontechnical losses. There is no doubt that modern equipment, upgraded transformers, and AMI investments bring down losses. Regular training programs for staff raise technical competence and operational efficiencies, reducing errors and maintenance costs. In addition, special measures for reducing electricity theft and accelerating the billing process are some other ways to help in revenue protection through reduced non-technical losses. With regard to a balanced resource utilization and cost management policy, the zonal office would ensure improvement in operational reliability with financial health as depicted in the performance metrics.

5.3 Lesson Learned

The case study on system loss conducted at the Pachrukhi Sub-Zonal Office of Narayanganj Polli Biddut-2 provided ample knowledge on the issues regarding power distribution and loss management. Indeed, identification of loss patterns is all about precision in data collection and analysis a lesson well learned. The dependence of technical and non-technical losses on each other requires regular monitoring and timely maintenance to maintain the overall system inefficiencies at low percentages. Advanced technologies such as smart metering and automation systems are ideal examples that can drastically cut down non-technical losses. Beyond the improved efficiency made possible, these tools leverage real-time identification of issues like energy theft and busted meters. According to them, investment in these kinds of technologies is quite necessary if long-term sustainability and reliability of the power distribution network are to be ascertained. It further emphasized that stakeholder cooperation and participation would add to any effort at loss reduction. In the same vein, awareness creation and community involvement at the level of the consumer in campaigning against the negative impact of electricity theft, encouraging morals to take the forefront for the reduction of non-technical losses, are highly relevant. Training of staff and capacity building for the organization are equally imperative in order for optimum performance of the system and for addressing new challenges effectively.

CHAPTER 6

IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

These are the major impacts of the system loss study and analyses under Narayananj PBS-2 at Pachrukhi Sub-Zonal Office on society, the economy, and international relations. Economically, it maximizes the use of resources, reduces energy waste, and improves revenue collection, which may further translate to lower utility costs and a lower increase in electricity rates for the consumers. It improves the living standards and contributes to regional economic development by increasing the reliability of electricity distribution, ensuring social benefits due to a steady supply to homes, businesses, and essential services.

The socioeconomic characteristic of an area represents the extent of development and also helps to take suitable policies for further expansion. The socioeconomic environment also significantly determines the nature and extent of participation of people in the development programs. A group of people must not be same from one another in many aspects. Social status and economic condition are dissimilar from one to another. Consumption pattern, employment patterns, combination of crop cultivation, taking credit, decision making and livelihood status, etc. are greatly affected by the socioeconomic characteristics of farm households. For this reason, the socioeconomic background of the respondents is important. The major socioeconomic characteristics are family size and composition, education, occupation, land possession pattern, income and consumption.

This situation promotes justice and equity within the community because non-technical losses comprise electricity theft. Therefore, this will raise confidence in utility providers. Less loss translates into less wasteful energy production, which is part of the global goals to ensure low carbon emissions. Consequently, this is a path toward sustainability that supports important global climate change objectives. In fact, this offers an economic efficiency advance of a value greater than what this project could attain, aside from empowering the environment and community.

6.2 Environmental and Ethical Issues

Some of the important ethical and environmental issues arising from the system loss analysis of the Narayanganj PBS-2 Pachrukhi Sub-Zonal Office are: Inefficient energy distribution causes more energy generation; it degrades the environment and increases the carbon emission rate. Therefore, directly reducing the carbon footprint in the region by increasing installation, improving infrastructure, management strategies, and equipment to bring down system losses can play to the advantage of battling climate change.

Inequality in billing, defective metering, and theft of electricity are all morally wrong issues concerning justice and transparency. Non-technical losses due to tampering and unauthorized connections generally pass on an unfair distribution of loads to customers because of the financial losses experienced by the utility. Without proper measures taken regarding the supervision, legislation, and public awareness for each of these ethical dilemmas, distribution network integrity impacts threaten equitable access to electricity for all. Application of such ethical power system management techniques is a serious matter because, in establishing trust, much depends on them in the development of the sustainable energy sector.

6.3 Utilization of Existing Standards

The current System Loss Study and Analysis, by the best standards available in the industry at best, assisted to a large extent by the integration of advanced technology, the study categorically states that the methodology adopted in quantifying the system losses is per the international standards as laid down by prestigious internationally accepted guidelines and standards laid down by such renowned organizations as the **International Electrotechnical Commission (IEC)**. In fact, these standards outline the rules for the proper measurement of both technical and nontechnical losses for achieving methodical and comparable analyses. The results that conform to established norms have better acceptability and are easily reproducible in larger industrial practices. The research also applies the guidelines of the **Institute of Electrical and Electronics Engineers (IEEE)**, such as standards operating procedures and design for power distribution systems. Application of standards is allowed to measure the actual efficiency of the main infrastructures such as conductors, meters, and transformers, as

well as all losses at every point or stage in the distribution circuits. In view of the above, the present research has tried to estimate the losses by following a rational procedure by which potential causes of energy losses can easily be identified. While this agrees with international best practices, the application of these standards ensures the study remains relevant to its local regional environment, that is, Pachrukhi Sub-Zonal Office. This has been in conjunction with and following recommendations set forth by the **Bangladesh Power Development Board (BPDB)**, giving this study a regional perspective for energy loss control. All these have been useful for acquiring relevant insights into the special problems that the Pachrukhi Sub-Zonal Office has faced and the way those factors may be addressed from an operational reality in Bangladesh regarding the power sector. The study has taken extra care to make the recommendations for reduction of system losses realistic and feasible by harmonizing the analysis with the BPDB standards, besides following the national regulatory frameworks. This therefore provides a path to long-term sustainability in power distribution by creating feasible plans that can lower operating expenses while boosting system efficiency.

6.4 Other Concerns

It has been found in the study and analysis conducted by the Pachrukhi Sub-Zonal Office of Narayanganj PBS-2 that, along with the short-term steps taken to reduce the losses, some basic issues are to be found and resolved. The major problems are located as inefficiencies in lines and distribution transformers, and technical losses due to aged infrastructure. The other major issue is the high percentage of nontechnical losses resulting from meter tampering and electricity theft. Additionally, because a higher percentage of the metering systems are faulty, an upgrade is highly needed. Lack of adequate training for the staff and financial problems within the organization also make it impossible to have better loss reduction strategies. In short, what is needed is a multi-faceted approach: process enhancements, technological development, and of course, more stringent enforcement of the law regarding illegality.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Efficiency enhancement is never easy and painless but highly rewarding in any system. The study and analysis conducted for improving the efficiency in the Pachrukhi Sub-Zonal Office, Narayanganj under PBS-2 revealed that such primary causes of the system loss are mainly a combination of technical and nontechnical elements. The technical loss consists of dissipation of electricity inherent in the transformers, conductors, and switchgear. Non-technical losses-theft of electricity, meter tampering, errors in the billing system, and other frauds-add significantly to the overall losses. The study indicated that the percentage of non-technical losses in total system losses is very high and has even exceeded the 6-7% benchmark value considered acceptable for efficient power distribution systems. According to the International Energy Agency (IEA), non-technical losses should generally be reduced to less than 2% with sound governance and the appropriate technological solution, while technical losses in typical rural networks should not exceed 2.5% ("Energy Efficiency in Distribution Systems," 2022). While non-technical losses in the case of the Pachrukhi Sub-Zonal Office have been observed between 3.68% and 6.00%. Thus, it is now imperative that rigid action be taken against such defaults. Counterbalancing the technical losses means that the infrastructure has to be modernized. In fact, a number of studies believe that replacing inefficient conductors and transformers with their energy-efficient counterparts may reduce technical losses by up to 15% (World Bank, "Reducing Electricity Distribution Losses," 2021). In reducing energy waste, balancing the load, upgrading conductor sizes, and performing periodic maintenance of different network components have become quite essential. Supervisory Control and Data Acquisition (SCADA) systems, among other digital utilities, can be applied to give an upper hand in terms of real-time monitoring and fault detection, hence increasing general operational efficiency. However, given that the problem requires solving in terms of administrative, technological, and community-based approaches, the AMI facilitates meter tampering reduction to curbing real-time energy consumption monitoring. Geographic Information Systems (GIS) maps will enable specifying those areas where losses have

been noted to be highest in value, to expand visibility into the network for specific interventions. Besides, serious punishments and consumer education can serve as a deterrent for electricity theft and facilitate efficient use of energy. The research findings indeed prove that any reduction in system loss requires an integrated approach, not just a technical one. It aims at integration of modern technologies, strict policy implementation, and promotion of customer engagement for enhancement in energy efficiency, better financial performance, and reliability of services at the Pachrukhi Sub-Zonal Office. This will help the nation achieve its targets regarding distribution of sustainable energy with the least loss of energy, besides helping in operational objectives of the zonal office.

Other future recommendations concern the inclusion of renewable sources of energy onto the grid to stop relying on conventional power, and the use of smart grid technologies that would make the grid resilient and efficient. The cooperation with stakeholders and continuous training of the staff will also be required for the long-term benefits.

7.2 New Skills and Experiences Learned

The technical, analytical, and professional skills gained during this study and analysis have enriched our knowledge base and experience. The next section enumerates the main skills gained during this project.

Improved capabilities in analysis: The energy input and energy bills with system losses were, per se, a very simplified part of the whole work. In this regard, the process taught us to work with advanced computational-visualization tools such as Excel in computing and visualizing specific data patterns that indicate how to distinguish between technical and nontechnical losses of electricity. It also gave me a deeper understanding of how energy flows through a distribution network, which helped me to precisely pinpoint the inefficiencies.

Data Management Skills: Managing and evaluating large data is one of the most significant skills. We enhanced our ability to handle data, ensuring accuracy and performing calculations by using systematic techniques. This included the use of

formulas, tabulation of raw data, and graphical representations, all of which are core electrical engineering projects.

Understanding Power Distribution Systems: The valuable understanding of the complexity that accompanies the operating of the power distribution system was immense from the case study. To deliver the energy in the process, there involves several components that include: feeders, distribution lines, and transformers. So, their interrelationship is key to knowing how each function in finding or detecting system losses.

Loss Reduction Technique Knowledge: We identify the most viable means of checking losses in technical as well as non-technical areas. Better infrastructure, improved metering, and stringent monitoring techniques are some of the strategies applied. In designing Green and efficient power distribution systems, these aspects play a salient role.

Practical capability of working with software: The project included data processing with the help of some software and creation of diagrams in it. We have studied AutoCAD for creating single-line diagrams and practically worked in Excel to develop charts and conduct complex calculations. Such software tools enhance technical documentation and decision-making based on real data.

Professional Reporting and Collaboration: During our thesis, we worked with various experts to collect data and corroborate the findings. All this experience enhanced our power of expressing difficult concepts in simple and lucid language. Our technical writing skills were further enhanced by generating comprehensive professional reports that presented the findings clearly and lucidly.

Practical Problem-Solving: We developed problem-solving skills via a set of very realistic challenges, such as data gaps and irregularities in loss patterns. In so doing, we developed practical solutions for the issues identified, which included recommendations for changes in infrastructure or policy that would reduce non-technical losses.

In the final analysis, the knowledge and skills learned from this research greatly enhanced our capabilities in dealing with complex problems in power distribution

systems. These will not only enhance our technical capabilities but also allow us to work in the field of electrical engineering and energy management.

7.3 Future Recommendations

To decrease the system losses and increase overall efficiency and reliability in the network of the power distribution system at the Pachrukhi Sub-Zonal Office under Narayanganj PBS-2, the following recommendations can be provided:

Advanced Metering Infrastructure (AMI) deployment: An AMI system with smart meters will be installed to reduce non-technical losses. Since smart meters have real-time consumption data, they permit accurate billing and, therefore, reduce the possibility of manual meter reading errors. They also provide automated alerts to utility companies for anomaly identification like theft or tampered electricity. This integration of the AMI system with central data management systems will definitely ensure due monitoring and regulation of energy consumption by customers, offering more process transparency and, hence, revenue losses in the future. Also, investments in AMI support demand-side management by better tariff structures.

Infrastructure up-gradation and maintenance: It is said that aging infrastructure is the main cause of the technical loss. The deteriorated portions of the distribution network, namely, transformers, cables, and insulators, should be identified and replaced in a scheduled manner. It can also be reduced in transmission by using high-efficiency conductors like low-loss transformers and Aluminum Conductor Steel-Reinforced (ACSR) cables. In addition, leakage current losses can be reduced by enhancing the insulation of cables and insulating exposed joints. The renovation of substations with Automatic Voltage Regulators (AVR) and capacitor banks will ensure voltage stability, thus reducing power outages.

Optimization and Reconfiguration of Network: The distribution network layout shall be optimized in order to reduce unnecessary line length and voltage drops. Low-voltage transmission distances should be minimized and feeder line reconfiguration should be implemented to effectively balance the load distribution and substantially reduce resistive losses. The substation should be located close to the area with the highest demand in order to minimize transmission loss. For the purpose of locating any bottleneck and further improvement of the network architecture, the employment of load flow analysis tools is necessary. Proactive approach will provide resilience and energy efficiency in the distribution system.

Data Acquisition and Integration for SCADA Systems: Real time network monitoring and control is possible through the SCADA technological tool. This tool will facilitate prompt fault detection and repair, thus avoiding unplanned outages and loss of energy in relation to the distribution network. The demand management tool will help in distributing energy to the consumer efficiently, hence cutting down the load balance losses during peak hours in conjunction with SCADA. Even predictive analytics can improve decision-making when SCADA systems identify patterns in system inefficiencies.

Segmentation of Losses and Detailed Energy Audit: Detailed energy audits will locate the inefficiencies in the system in minute details. Technical and nontechnical losses must be segregated to take up appropriate problem-solving action. Auditing will find the operational bottlenecks, poor network architecture, and broken equipment contributing to the technical losses. Similarly, audits may find irregularities in billing, unauthorized connections, and meter tampering for non-technical losses. These should be the basis of plans of action in terms of focused and effective mitigation strategies.

Consumer Awareness and Participation Programs: Public participation is a must for reducing non-technical losses. Consumer awareness programs will help educate the public about the socio-economic evils of electricity theft and promote the judicious use of electricity. Incentives on following energy-saving procedures and declaring illegal connections will lead to more participation. Besides ensuring smoother operations, well-defined grievance redressal procedures can ensure increased cooperation and mutual trust between the utility and its clients.

Adoption of Renewable and Distributed Energy Resources (DERs): Integrating renewable energy sources into the network, such as rooftop solar photovoltaic systems and small-scale wind turbines, will reduce energy losses and lessen the demand pull on the main grid. Microgrids can be utilized for integrating these into the existing distribution network, especially in rural or unserved areas. Such measures decrease reliance on conventional sources of power, while at the same time promoting environmental sustainability. Policies that promote net metering and feed-in tariff mechanisms will further incentivize consumers toward renewable energy.

Workforce Development and Capacity Building: While the process of reduction of losses is being affected, technical know-how and skills have to be enhanced for the staff members. Training of the staff on state-of-the-art technologies, best practices of energy management, and techniques of loss prevention has to be regularly imparted. Workshops and Certificate Programs on SCADA, AMI, and Energy Auditing will help the staff eventually operate and manage the systems better. Smarter workforce: The improvements in the distribution network shall be implemented and sustained by a more skilled workforce.

Predictive maintenance through data analytics: The utility should invest in various data analytics tools to enable predictive maintenance. By analyzing the historical trend of a particular feeder section, failures can be predicted to avoid downtime and energy losses caused by prolonged outages. This ensures that predictive models allow for an extended usefulness of assets by scheduled maintenance or replacement.

Enhancing Policy Support and Regulatory Frameworks: In any effort at loss reduction, there has to be a clear policy and framework issuance by government and regulatory authorities. Some of the key examples in this regard include strict punishments for electricity theft, incentives related to the implementation of energy-efficient technologies, and compulsive energy audits for utilities. Cooperation with local authorities in enforcing regulations and guaranteeing compliance will further increase their effectiveness.

Thus, the Pachrukhi Sub-Zonal Office can implement these far-reaching, focused recommendations to greatly reduce system losses and contribute toward operational efficiency, while guaranteeing reliable and affordable electricity services. In addition to improved financial performance, the measures will make the methods of energy distribution greener.

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APPENDIX A

TURNITIN REPORT

203-33-1315

ORIGINALITY REPORT

16%	14%	10%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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2	Sherif M. Ismael, Shady H. E. Abdel Aleem, Almoataz Y. Abdelaziz, Ahmed Faheem Zobaa. "Practical Considerations for Optimal Conductor Reinforcement and Hosting Capacity Enhancement in Radial Distribution Systems", IEEE Access, 2018 Publication	2%
3	Submitted to Daffodil International University Student Paper	2%
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APPENDIX B

**COMPLEX ENGINEERING PROBLEM SOLVING AND
ENGINEERING ACTIVITIES**

Complex Engineering Problems (P) Solving		
	Attributes	Statements
P1	Depth of knowledge required	The thesis required in-depth knowledge of the power system analysis, methods of data analysis, and legal and financial frameworks that control power distribution.
P2	Range of conflicting requirements	It was quite challenging to satisfy the needs of stakeholders with a balance of technical, economic, and social factors within the constraints of time and resources.
P3	Depth of analysis required	Detailed analysis of data using the most advanced techniques was required for finding the causes of losses and investigating areas where system improvement is possible.
P4	Familiarity of issues	The research should be based on the knowledge of the local context about the power system, socioeconomics, customer behavior, and field staff's issues.
P5	Extent of applicable codes	The relevant standards and innovative color-coding-based strategies had to be followed because certain codes were not being followed.
P6	Extent of stakeholder involvement and conflicting requirements	Involving a variety of stakeholders resulted in differing viewpoints and competing demands, which necessitated careful evaluation of all interests.
P7	Interdependence	The entire process, in fact, entailed understanding the interaction between technical, economic, and social factors, which could only be iteratively advanced across interdependent stages of research.

Complex Engineering Activities (A) Solving		
	Attributes	Statements
A1	Range of resources	Among many other resources, software tools, data access, technical know-how, and field resources for data collection and analysis were required in the process.
A2	Level of interaction	A high level of engagement was required with a diverse range of stakeholders, including engineers and technicians, customers, and regulatory bodies, to inform, enlighten, and validate that the project matched the needs of the stakeholders.
A3	Innovation	The project advocated for the creative methods to be used in system modeling, data analysis, and loss reduction techniques in meeting the particular difficulties faced by the Pachrukhi Sub-Zonal Office.
A4	Consequences of society and environment	The project considered how losses in the system would be affecting society and the environment, including financial consequences among consumers, waste of energy affecting the environment, and how sustainable solutions would be warranted.
A5	Familiarity	The project was well-implemented with prior knowledge in data analysis methods, power system analysis, and local context from the Pachrukhi Sub-Zonal Office.

