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Impact Analysis of Marsyangdi Corridor 220kV Transmission Line on the Operation of Integrated Nepal Power System

By

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a project report entitled " **Impact Analysis of Marsyangdi Corridor 220kV Transmission Line on the Operation of Integrated Nepal Power System**" submitted by Mr. Gaurav Sapkota in partial fulfillment of the requirements for the degree of Master of Science in Energy Systems Planning and Management.

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ABSTRACT

Despite having an enormous hydropower potential and being one of the early adopters of hydropower as a source of energy, Nepal has not been able to make significant strides in this sector. Since most of the hydropower generating station are located in central hilly regions and majority of load centre are location in Terai region of Nepal, the transportation of power remains a huge challenge in Nepal. Additionally, there is significant power loss in the power system itself. Currently, Nepal is focusing on developing high voltage transmission line to evacuate the power as well as decrease the existing loss in the system. Marsyangdi Corridor 220kV Transmission Line Project (MCTLP) is a project that aims to develop 113 km of double circuit line from Dharapani in Manang to Aaptari in Chitwan to evacuate the power produces in Marsyangdi river basin and its tributaries. The construction of this high voltage line is expected to significantly ease the burden on current Middle Marsyangdi-Markichowk and Damauli-Bharatpur transmission line along with decreasing the overall loss in the system.

This research aims to determine the current status of Integrated Nepal Power System (INPS) by creating a simulation model of current INPS in Digsilent PowerFactory 15.1 software and performing a load flow calculation for steady state condition. Then, the Marsyangdi Corridor 220kV Transmission Line will be modelled and the corresponding electrical parameters will be determined after the load flow. The results obtained are then analyzed on both technical and financial parameters

The research concludes that the construction of MCTLP transmission line can decrease the loss on transmission system by 45.34 MW. Furthermore, the voltage profile and line loading of the transmission line was also improved. The payback period for the project is found to be 11.48 years.

Keywords: Transmission Line, Digsilent Powerfactory 15.1, Payback Period, IRR, NPV, Financial Risk Analysis

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LIST OF SYMBOLS AND ABBREVIATIONS

LDC	:	Load Dispatch Centre
MCTLP	:	Marsyangdi Corridor Transmission Line Project
RPGCL	:	Rastriya Prasaran Grid Company Limited
IPP	:	Independent Power Producers
NEA	:	Nepal Electricity Authority
NVVN	:	NTPC Vidhyut Vyapar Nigam
BPDB	:	Bangladesh Power Development Board
EIB	:	European Investment Bank
GoN	:	Government of Nepal
INPS	:	Integrated Nepal Power System
TL	:	Transmission Line
MW	:	Mega Watt
kV	:	Kilo Volt
MVA	:	Mega Volt Ampere
DER	:	Distributed Energy Resources
LOLF	:	Loss of Load Factor
PPA	:	Power Purchase Agreement
kWh	:	Kilo Watt Hour
km	:	Kilometers
AC	:	Alternating Current
DC	:	Direct Current
Δ	:	Small Change in Value
ε	:	Maximum Permissible Error
P	:	Active Power

Q	:	Reactive Power
V	:	Voltage
δ	:	Phase Angle
p.u.	:	per unit
PDF	:	Probability Density Function
IRR	:	Internal Rate of Return
MARR	:	Minimum Attractive Rate of Return
NPV	:	Net Present Value
PBP	:	Payback Period
FY	:	Fiscal Year

CHAPTER ONE: INTRODUCTION

1.1 Background

Hydropower development in Nepal started during the early 1900s with the establishment of Shree Chandra Hydro-Electric Power Station, now known as 'Pharping Hydropower Plant'. Despite being one of the early adopters of hydropower energy, Nepal was not able to make huge strides in this sector. The high investment cost required meant that Government alone could not develop these power plants. Electricity Act, 1992 has made provisions for the private entities to enter the market. However, there is a severe issue of making arrangements for these hydropower plants to connect with the national grid of Nepal, Integrated Nepal Power System.

In the FY 2023/24, the total generation capacity has reached 3,157 MW among which 2991 MW is generated through hydropower resources. The independent power producers (IPPs) are responsible for 1915 MW of total hydropower generation capacity while NEA hydropower plant contributes 583MW and NEA Subsidiary contributes 493 MW of power. [1] The total energy that was available in the system was 13,966GWh in the fiscal year 2023/24. The energy acquired from IPPs and NEA Subsidiaries was 6,564 GWh and 2,597 GWh which is more than 65% of the total available energy. [1]

Similarly, for the evacuation of power generated through these plants, NEA has constructed 6,508 circuit km of transmission lines and increased substation capacity to 13,050 MVA in FY 2023/24. [1]

Currently, 137 projects with combined installed capacity of 3,906MW are being developed by IPPs after obtaining financial closure with NEA and a further 136 projects with combined installed capacity of 3,899MW are at various stages of development with financial closure yet to be done with NEA. [1]

NEA has also entered into agreement with Haryana Discom and Bihar State Power Holding Company limited to supply 200 MW of power each to these entities. NEA also engages in electricity trading through various channels to cater for the demand of Nepali citizens. Furthermore, a Tripartite Agreement between NEA, NTPC Vidhyut Vyapar Nigam (NVVN) and Bangladesh Power Development Board (BPDB) is also being agreed upon for the sale of 40 MW of power from Nepal to Bangladesh through India. [1]

Transmission lines are the backbones to support all these developments of IPP projects and trade agreements. The hydropower potential in the Marsyangdi Basin is estimated to be in the range of 1568.96MW to 2191.68MW. [2] Marsyangdi Corridor 220kV Transmission Line Project (MCTLP) aims to evacuate power generated by the hydropower plants in the Marsyangdi river basin along with its tributaries such as Dordi, Chepe, etc. The evacuated power is further connected to load center in Kathmandu at Matatirtha substation through Marsyandi-Kathmandu 220kV Transmission Line. The transmission line project will develop 113km long double circuit transmission line from Dharapani 220kV substation in Dharapani, Manang to New Bharatpur 220kV substation in Aaptari, Chitwan, encompassing a total of 5 districts, Manang, Lamjung, Gorkha, Tanahun and Chitwan. A total of 5 substation will be built along this transmission line. [3] The project is financed by European Investment Bank (EIB), Nepal Government (GoN) and NEA with the overall estimated cost of the project to be around NRs. 16 billion. [4]

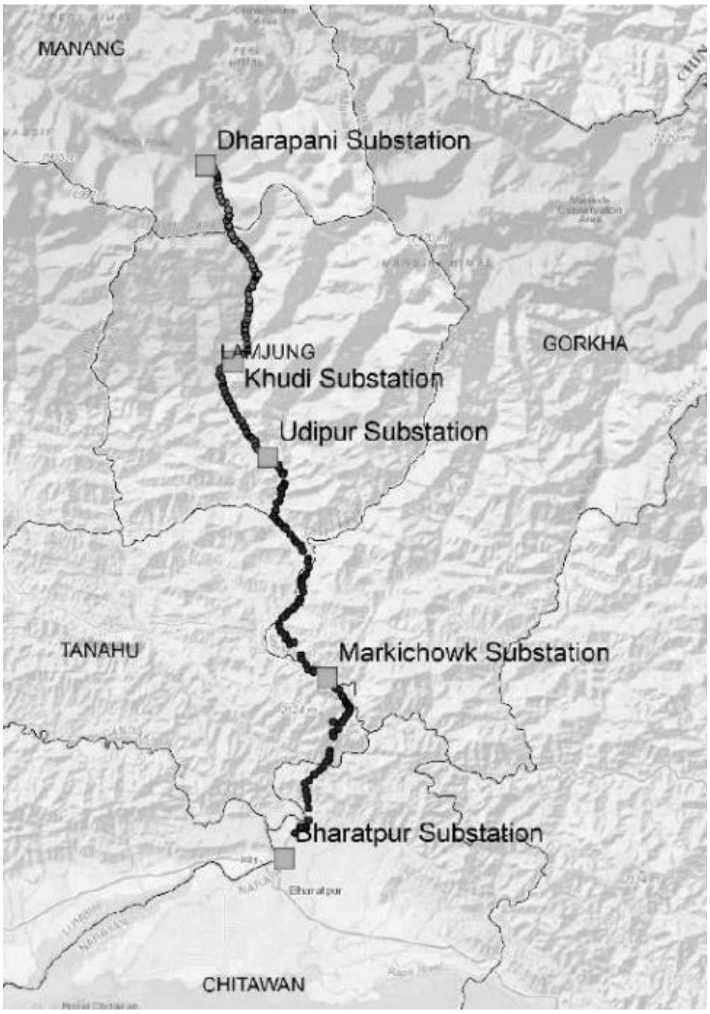

Figure 1: Project Location Map

Table 1: Substations of MCTLP along with their capacity.

S.N.	Substation	Capacity	Load
1.	Dharapani	100 MVA	30 MVA
2.	Khudi	160 MVA	50 MVA
3.	Udipur	160 MVA	50 MVA
4.	Markichowk	-	-
5.	Bharatpur	320 MVA	

Table 2: Transmission Line of MCTLP along with Conductor Used and Distance.

S.N.	Tranmission Line	Conductor Used	Distance
1.	Dharapani – Khudi	ACSR Moose	28 km
2.	Khudi – Udipur	ACCC Drake	18 km
3.	Udipur – Bharatpur	ACCC Drake	67 km
		Total	113 km

The double-circuit 220kV transmission line of Marsyangdi Corridor will play an important role in evacuating the electrical energy in a safe, reliable and affordable way by minimizing transmission losses and enhancing power quality. [4] The abundance of power that can be generated in this area can not only cater for needs within the country but can also be used to trade the excess energy to different regions in South Asia. [5]

The design of MCTLP features several high-capacity and low resistance conductors, improved insulators, modern monitoring and protection device such that low power losses and optimal power control is achieved.

However, the influence of this transmission line is far beyond just its technical characteristics. The plethora of hydropower plants that would develop as a result of this transmission line would be helpful in the overall development of the region as many new infrastructures and job opportunities are to be available. The reliable and consistent power supply throughout this region can boost the local industries and enhance the socioeconomic growth in the area. [6]

However, the project that has been developed with the goal of evacuating 1,600MW of electricity is facing several delays mainly due to coronavirus pandemic and local's intervention and geographical challenges. [7] Various officials including Managing Director of NEA and Chief District Officer of Lamjung have urged the stakeholders to provide necessary support and escalate the process of development of transmission line and substations. [4] The overall physical progress of the project is about 60% till the end of FY 2023/24. [1]

1.2 Problem Statement

Only 43,000 MW of hydroelectricity generation is economically feasible out the 83,000 MW stated by Dr. Hari Man Shrestha in his Ph.D. dissertation. [8] Nepal government has planned to commission electricity projects of capacity 15,000MW within 2028. [9] To properly reap the benefits of this enormous hydropower potential, there needs to be significant improvement in current scenario of transmission line network in Nepal. [10] Along with the enormous potential in hydropower sector, there lies a challenge to be able to evacuate and utilize the produced energy. Without sufficient transmission line, there is no point in developing only hydropower plants. Construction of high voltage transmission line will enable reliable and affordable transmission of generated energy from the power stations to the load centre. The benefits of building these high voltage transmission lines are listed below:

- **Evacuation of Available Energy:** High voltage transmission network can easily evacuate more generated energy from the area to respective load centre.
- **Lower Energy Loss:** High voltage transmission lines ensures that lower current flows in the lines for the same amount of power which in turns leads to lower energy losses.
- **Enhance Grid Stability:** A large and improved transmission network is more reliable than small ones as it can manage voltage fluctuations and grid failures more effectively.
- **Facilitate Economic Growth:** Reliable and affordable electricity is the basis of industrial development in any area which in turns helps to create job opportunities along with infrastructural development thus facilitating economic growth.

However, these transmission line project require huge capital investment and proper financial assessment along with associated risk of the line should be done.

1.3 Objectives

1.3.1 Main objective

The main objective of this research paper is to analyze the impact of the Marsyangdi Corridor 220kV Transmission Line Project on the operation of INPS.

1.3.2 Specific Objectives

The specific objectives of the research are listed below.

- To determine the power loss in the transmission line network with and without the MCTLP.

- To determine the transmission network line loading with and without MCTLP and compare them.
- To determine the voltage profile at substation with and without MCTLP and compare them.
- To perform financial analysis of the transmission line project.
- To perform financial risk analysis of the transmission line project.

1.4 Assumptions and Limitations

- The transformers used in the system are considered to be 100% efficient.
- Muzaffarpur Bus is classified as Slack/Reference Bus.
- The load for each substation is assumed to be 67% of maximum demand.
- All the generating station are operated at their rated capacity.
- Some of the hydropower of generating capacity less than 5 MW are lumped into a single hydropower for modelling.

CHAPTER TWO: LITERATURE REVIEW

2.1 Related Literatures

Only 43,000 MW of hydroelectricity generation is economically feasible out the 83,000 MW stated by Dr. Hari Man Shrestha in his Ph.D. dissertation. [8] Nepal government has planned to commission electricity projects of capacity 15,000MW within 2028. [9] To properly reap the benefits of this enormous hydropower potential, there needs to be significant improvement in current scenario of transmission line network in Nepal. Unregulated voltage, high distribution loss, major dependency on ROR projects and monopoly power system model are the biggest issue in Nepalese power system. [10] The imbalance between the supply and demand has resulted in Nepal not being fully able to reap the benefits of enormous hydropower potential. Majority of hydropower projects are location in central mountainous region of Nepal which are away from the major load centers. This makes transportation of generated energy from the stations to load centre inefficient resulting in significant power loss. The introduction of Khimti-Dhalkebar 220kV TL in the INPS can reduce the power loss in the transmission network by 15.639MW. This results in energy saving of 89048.466 MWh per year when assuming loss of load factor (LOLF) to be 0.65. [11] In addition to the decrease in power loss, the addition of new high voltage transmission links can improve the voltage profile of the system. [12] The development of transmission line is an essential tool in development of hydropower plants and solving Nepal's energy crisis. [13]

The construction of transmission line is subjected to various uncertainties. While making investment in the transmission line, various risk and their impacts need to properly addressed. Pandey and Nakarmi through their research, use Monte-Carlo simulation to examine the financial risk associated with transmission line network in Nepal. The electricity demand in Kathmandu valley was predicted using linear regression model and was compared with power transmitted from Chilime-Trishuli transmission line project. The study proved the economic viability of independent transmission lines in Nepal. [14]

Nepal frequently experiences system failures and low voltage delivery in different regions of the country due to the insufficient and poorly planned infrastructure of transmission network. Acharya and Shrestha use a computer model to simulate a steady-state power flow to determine the optimum operation of the transmission line.

The optimum operation of the generating stations and substation along with acceptable line loading through regional and sub-regional control are backbone for meeting the electricity requirement within the country along with exporting the generated energy to neighboring markets. [15]

Continuous addition of generators in the system along with aging transmission infrastructure poses a significant challenge in the power sector of Nepal. Matatirtha-Hetauda 132kV, Damauli-Bharatpur 132kV, Marsyangdi-Bharatput 132kV, etc. are mostly operated in full capacity in order to provide power supply during certain conditions, which results in power interruptions. Another significant challenge is the power evacuation from new generating stations due to various limitation of current transmission network. [3]

The transmission line wheeling charge should be determined such that it is economically beneficial to both the transmission line utility and the consumer using it. The cost for transmission line network should be recovered from the wheeling charge. The wheeling charge can be determined by using a combination of marginal pricing method and one of the embedded cost transmission pricing method such as Postage Stamp Method and MW-Mile methods. [16] MW-mile method is not sufficient to recover the total cost of transmission line network and Postage stamp method should be adopted for the recovery of total cost of transmission system network. [17]

The table below provides a brief synopsis of all the relevant works.

Table 3: Summary of Literature Review

S.N.	**Topic**	**Major Conclusion**
1.	"Impact Study of Khimti-Dhalkebar 220kV Transmission Line on the Operation of Integrated Nepal Power System" [11]	15.639MW of power loss can be reduced and voltage stability of the INPS system is increased due to Khimti-Dhalkebar 220kV Transmission Line. [11]
2.	"Impact Analysis of 220kV and 400kV Transmission Lines on the Integrated Nepal Power System" [12]	The commissioning of 220kV and 400kV transmission line on current system along with optimal capacitor placement can decrease the line losses by 17.12 MW along with voltage profile improvement. [12]

3.	"Impact Study of Hetauda-Dhalkebar-Inaruwa Transmission Line on the Operation of Integrated Nepal Power System" [6]	The operation of Hetauda-Dhalkebar-Inaruwa 400kV Transmission Line results in the net decrease of power loss by 26.276 MW along with increase in generation power factor and voltage profile. [6]
4.	"Operation of Integrated Nepal Power System on Injection of Upper Tamakoshi Hydroelectric Power Plant" [15]	Secure and reliable operation of INPS is possible with the optimal use of generating stations along with reduction of transmission loss. The optimal operation of INPS is possible through control of INPS in regional and sub-regional level. [15]
5.	"A Year Book: Fiscal Year 2023/2024" [3]	Continuous addition of generators in the system along with ageing transmission infrastructure poses a significant challenge in the power sector of Nepal. Most of the transmission line are mostly operated in full capacity to provide power supply which results in power interruption. [3]
6.	"Financial Risk Assessment of Transmission Line Projects in Nepal: A Case Study of Chilime-Trishuli Transmission Line Project" [14]	On evaluation of the financial risk of individual transmission network, it is seen that independent transmission company is feasible in the context of Nepal. [14]
7.	"Assessment of Run-of-River Hydropower Potential Using SWAT Modeling and GIS in Marsyangdi River Basin" [2]	The hydropower potential in the Marsyangdi river basin is estimated to be in the range of 1568.96 MW to 2191.68 MW. [2]
8.	"Load Flow Analysis of Bhutan Power System Network Using Digsilent	The result of the load flow analysis done using Digsilent PowerFactor software conforms to the real-world date and hence the results of the software are reliable. [18]

	PowerFactory Software" [18]	
9.	"Present Situation and Future Roadmap of Energy, Water Resources and Irrigation Sector" [9]	The paper provides the current scenario of energy sector in Nepal along with future planning in this sector. [9]
10.	"Cumulative Impact Assessment (CIA) of Marsyangdi Corridor 220kV Transmission Line Project" [19]	This provides the list of prospective hydropower plants that can be connected to the MCTLP line upon its completion. [19]
11.	"Evaluation of Transmission Pricing Methodologies for Nepal Power System in Restructured Environment" [16]	The wheeling charge should be fixed such that the cost of transmission line network is recovered as well as consumers get enough incentive to use the network. Marginal pricing along with one of the embedded cost transmission pricing method is the best one for pricing of transmission line network. [16]
12.	"Wheeling Charges Methodology for Deregulated Electricity Markets Using Tracing-Based Postage Stamp Methods" [17]	MW-mile method is not sufficient to recover the total cost of transmission line network and Postage stamp method should be adopted for the recovery of total cost of transmission system network. [17]
13.	"Study on Transmission Pricing Mechanisms for Nepal Power System Network" [20]	The wheeling charge of the transmission line network is dependent on profit margin and estimated payback period in addition to usage of network. [20]

2.2 Current Status of Transmission Network in Nepal

Energy is transmitted from the generated stations to the consumers via different types of transmission lines. These transmission lines are classified into different groups according to the voltage level. The voltage level used in Nepal are 400V, 11kV, 33kV, 66kV, 132kV, 220kV and 400kV. 400V, 11kV and 33kV voltage level are mostly used in distribution system whereas 66kV, 132kV, 220kV and 400kV are used in transmission system. The length of transmission system in 66kV, 132kV, 220kV and 400kV are 514.46 circuit km, 3967.87 circuit km, 1105 circuit km and 384 circuit km respectively. [3]

Total installed capacity of generating stations has reached 3,157MW out of which 473MW of projects were commission in FY 2023/24. The total available energy in the system has also increased from 12,369 GWh to 13,966 GWh which is an increase of 12.91% over the one-year period. [1]

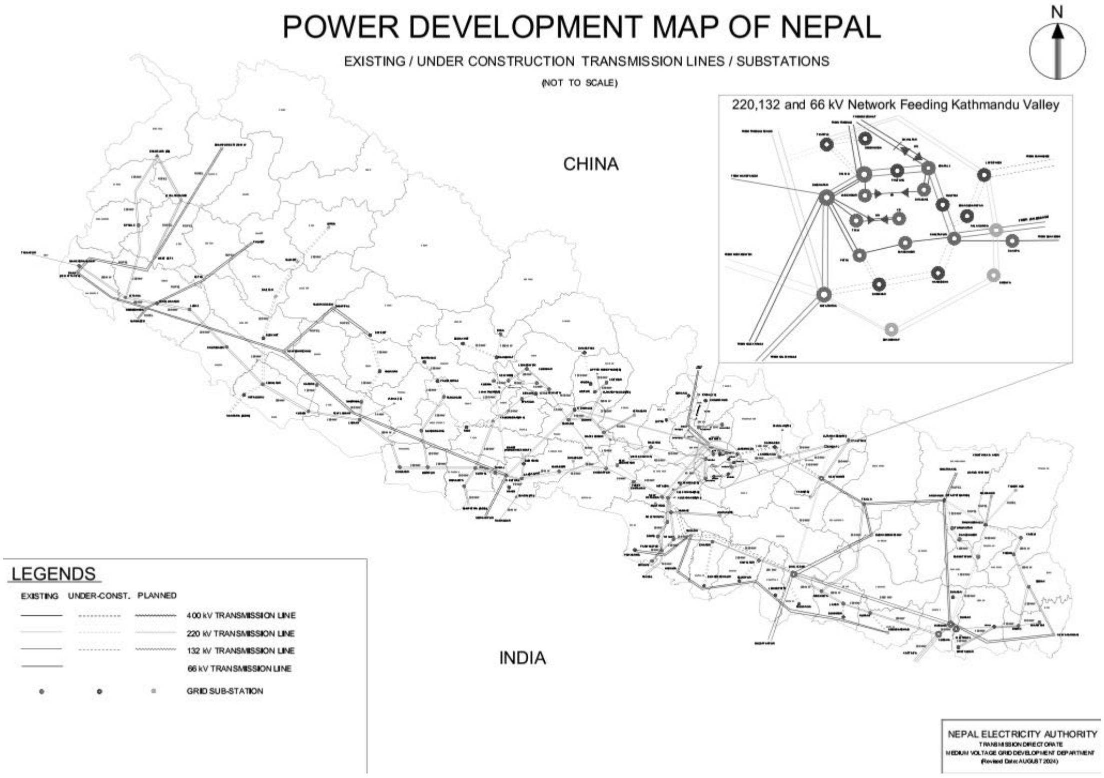

Figure 2: Power Development Map of Nepal [1]

2.3 Related Technical Terminologies

2.3.1 Load Dispatch Centre

All the generating stations are connected to each other and to load centre parallelly through an interconnected power system. This interconnected power system has to be controlled in such a way that all the different component are operated in synchronous manner. Load Dispatch Centre (LDC) is the body which is responsible for the smooth integration and operation of all the system components. LDC takes into account the constraint in the transmission line and operating system to ensure smooth operation of the interconnected system. The major functions of LDC are:

- Ensure reliable, affordable and quality service of electricity to the consumers as per the prevailing Grid Code and standards.
- Safeguard the fair operation of IPPs by determining the standard operating procedures.
- Schedule different generating station and substations so as to manage energy requirement within the country and cross-border exchange.
- Restoration of power system after any unforeseen disturbances in the system or blackouts.
- Demand Forecasting and estimation.

2.3.2 Integrated Nepal Power System

Integrated Nepal Power System (INPS) refers to the electrical power system in Nepal, where every generating stations, substations and load centre are connected for the reliable, affordable and quality supply of electrical energy from the generating stations to the consumers. INPS should be reliable and adequate for the proper supply of electricity. Any faults in INPS results in blackout in the region which might have significant impact on both utility and consumers.

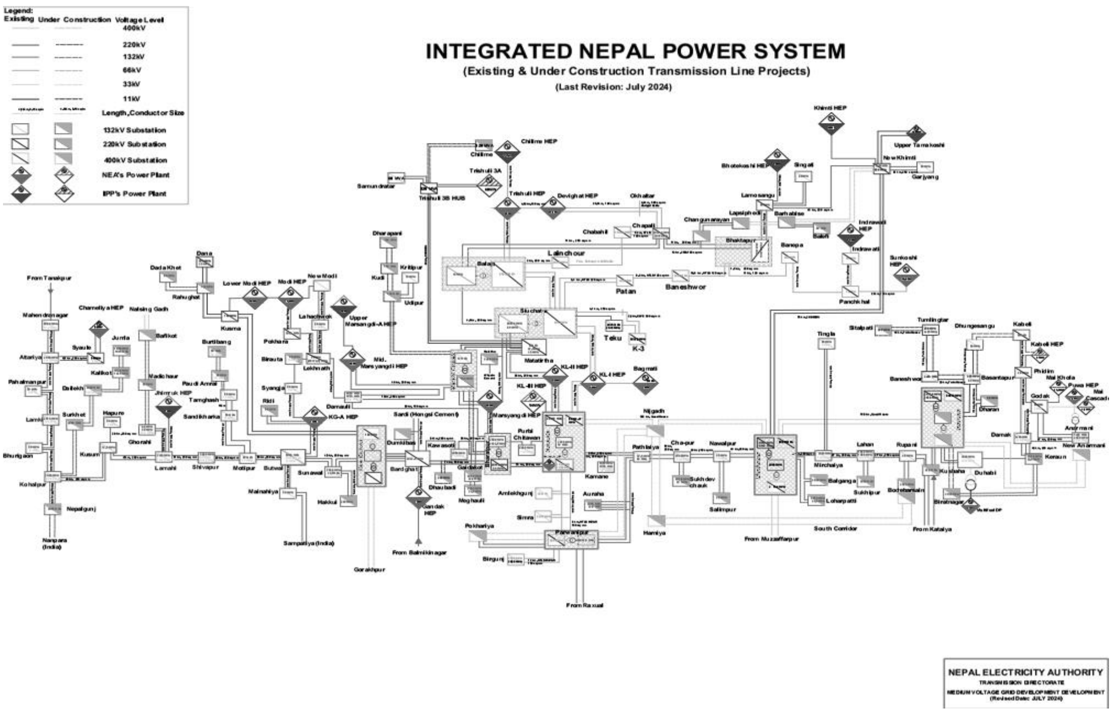

Figure 3: Integrated Nepal Power System [1]

The data for INPS and its components have been collected using both primary sources and secondary sources. The primary sources include official from LDC, NEA and

MCTLP. The secondary sources include the annual reports published by NEA and its different directorate.

The obtained data was then modelled into Digsilent PowerFactory 15.1 software and then a simulation of load flow was conducted to obtain the current scenario of INPS.

2.3.3 Digsilent PowerFactory Software

Digsilent PowerFactory is a power system analysis software which in used for the analysis of different power system components such as generation, transmission and distribution system. The software uses an enhanced non-decoupled Newton-Raphson algorithm which is aided by multiple commands and controller model to yield accurate and reliable solution for both balanced and unbalance load conditions. The key features of Digsilent PowerFactory software in load flow analysis are listed in below: [21]

- Analysis of load flow for AC and DC grids under balanced and unbalanced conditions.
- Rapid and reliable load flow solution from any initial conditions using cutting-edge numerical solvers.
- Implementation of primary and secondary control mechanisms, including inertial response.
- Allocation of slack across distributed loads and generation, accounting for interchange schedules.
- Incorporation of active and reactive power constraints, along with generator capability curves
- Accurate modelling of induction machines
- Voltage dependent load models
- User-definable load flow controller models
- Simple load/generation scaling, as well as automated feeder load scaling (balanced and unbalanced)
- Consideration of temperature dependency

2.3.4 Monte Carlo Simulation

Monte Carlo simulation calculates separate discrete results such that all the possible outcomes are covered by randomly selecting sets of value from input probability distribution. This computerized mathematical model helps individuals to make proper risk assessment during quantitative analysis and decision making. [14]

2.3.5 Probability Distribution Function

Probability distribution function is used to model how probabilities are distributed for a random variable over a range of possible values. For continuous random variable, probability is modelled using continuous distribution function called probability density functions (PDF). [14] The continuous distribution function used in our research is Triangular Distribution function. Triangular distribution function is a continuous probability function which has triangular shaped PDF and is defined by three parameters. Those parameters are:

a. The minimum value (lower bound)
b. The mode (most likely value)
c. The maximum value (upper bound)

2.3.6 Load Flow Analysis

The load flow analysis the study of power system under steady state condition to determine the electrical performance such as real and reactive power flow, power losses, voltage magnitudes and angle at different nodes of the system. Load flow studies is important for the future planning to prepare for many probable situations. [18]

Load flow analysis is done using a set of equation that determine the relationship between the voltage, current and power in different node of a power system network. Load flow analysis can be done using various numerical technique such as Gauss-Seidel method, Newton-Raphson method and Fast Decoupled load flow method. Digsilent PowerFactory uses in Newton-Raphson method for the load flow analysis.

2.3.7 Newton-Raphson Method

For a transmission system with 'n' number of buses, the equation for the load flow in bus i where i = 1, 2, 3, …, n can be written as:

Active Power (P_i) = $\sum_{j=1}^{n}|V_i||V_j||Y_{ij}|\cos(\theta_{ij}+\delta_j-\delta_i)$ ---------- (i)

Reactive Power (Q_i) = $-\sum_{j=1}^{n}|V_i||V_j||Y_{ij}|\sin(\theta_{ij}+\delta_j-\delta_i)$ ------ (ii)

where, V_i = Magnitude of Voltage in Bus 'i',

δ_i = Angle of voltage in Bus 'i',

V_j = Voltage in Bus 'j',

δ_j = Angle of voltage in Bus 'j'

Y_{ij} = Magnitude of admittance between Bus 'i' and Bus 'j'

θ_{ij} = Angle of admittance between Bus 'i' and Bus 'j'

The equations (i) and (ii) are solved using iterative process to obtain the electrical parameter at each bus.

Newton- Raphson method enjoy of benefit of fast convergence to the solution and requires less iterations than other methods. However, it is comparatively difficult and requires large computer memory.

2.3.8 Slack Bus

The magnitude and phase angle of voltage are defined for this bus so that we can take this as reference to solve the load flow equations. The phase angle of voltage is usually considered to be zero. The active and reactive power of this bus is determined using load flow equations. There is only one bus of this type in a system. Muzaffarpur is used as slack bus in our model.

This bus is also generally referred to as swing bus or reference bus. This bus is necessary in computation because real and reactive power flow or loss in the system cannot be known in advanced. Hence, it is necessary to have one bus where complex power is not specified so that it can supply the difference in complex power throughout the system. It is generally at generator bus.

2.3.9 PV Bus

This bus is also generally referred to as Generator Bus or Voltage Controlled Bus. In this bus, the voltage magnitude and active power is specified. The voltage magnitude is maintained at the constant value and reactive power and phase angle of the voltage is determined using iterative process.

2.3.10 PQ Bus

This bus is also generally referred to as load bus. In this bus, active and reactive power are known and magnitude and phase angle of the voltage is to be computed using iterative process.

2.3.11 Wheeling Charge

Wheeling charge in power system network refers to the fee levied by the entity that own the transmission network for the transfer of electrical energy from one location to another. Wheeling charge can be determined by using one of the following methods.

a. **Postage Stamp Method:** This method allocates the total system costs to the generator on the basis of load it shares during the peak period. This method is very simple to calculate but it ignores actual distance the power flows. It can be calculated using the formula: [16]

$$\text{Wheeling Charge} = TC \times \frac{P_g}{P_{peak}}$$

where, TC = Total Transmission Cost

P_t = Power Generated by Generator

P_{peak} = System Peak Load

b. **Contract Path Method:** This method allocates the wheeling charge based on distance the electricity has to flow. However, it does not consider actual power flow through the line. [17]

Wheeling Charge = Rate per km x Transmission Distance

c. **MW-Kilometre Method:** This method allocates the wheeling charge on the account of both distance and magnitude of power flow. This method is complex than other methods but is more equitable. [20]

Wheeling Charge = $\sum$ (MW Flow x Distance x Per Unit Cost)

d. **Market-Based Pricing:** This method allocates charges based on market conditions i.e., demand and supply. It is more common in deregulated markets and includes real-time or day-ahead pricing mechanisms. [20]

To calculate the wheeling charge in this research, we use postage stamp method.

2.4 Related Financial Terminologies

2.4.1 Payback Period

Payback period can be defined as the length of time in which an investment pays back its original cost. This method assumes that all the cash outflow occurs right at the beginning of the project's life and is followed by a stream of inflows. The project is accepted when the calculated payback period is less than or equal to some pre-specified payback period. Otherwise, the project is rejected. [22] There are two types of payback period:

- **Simple Payback Period**: It is the number of years required to recover the original investment in the project. Although it is simple to calculate and understand, this does not consider time value of money. [22]
- **Discounted Payback Period**: In this method, each of future cash flow is discounted to the present values and then the number of years necessary to recover the investment is calculated. [22]

2.4.2 Internal Rate of Return

IRR can be defined as the breakeven interest rate at which the present value of a project's cash outflows is equal to the present value of its cash inflow. Higher value of IRR makes the project more desirable. If IRR is greater than the Minimum Acceptable Rate of Return (MARR), then the project is accepted, otherwise the project is rejected. For comparing multiple investment, the project with higher IRR is accepted. [22]

2.4.3 Net Present Value

Net Present Value (NPV) is the difference between the present worth of cash inflows and the present worth of cash outflows for a certain discount rate. It is widely applied in finance and accounting to determine the value of a business, capital project, new initiatives and any anything that involves cash flow. The project is accepted if NPV is positive and rejected if NPV is negative. For comparing multiple investment, the project with higher NPV is selected. [22]

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research Approach

The research approach of this thesis is built upon the evaluation of technical parameters including power loss, line loading and voltage profile and financial parameters such as payback period, internal rate of return and net present value. The model of INPS was modelled in Digsilent PowerFactory 15.1 software to obtain different technical parameters. Then, the data of Marsyangdi Corridor 220kV Transmission Line Project will be entered into the model to determine the same technical parameters and the changes will be analyzed. Furthermore, financial analysis of the line will be done and its financial viability will be calculated.

3.2 Research Methodology

- **Literature Review**

  Various relevant research paper, journals, reports and various website were studied to get the idea of past efforts that were made in the similar topics and the expected results thereof. The data and computation required to obtain the results were carefully examined.

- **Data Collection**

  The required data for the INPS system was collected using annual report published by Nepal Electricity Authority and its Transmission Directoriate. Further data was collected through primary sources by enquiring with official of NEA, Load Dispatch Centre and Marsyangdi Corridor 220kV Transmission Line Project.

- **Modelling and Simulation of Load Flow**

  The obtained data was modelled in Digsilent PowerFactory 15.1 software and load flow study was simulated to obtain different electrical parameters for base scenario. Then, the model of MCTLP was added to obtain electrical parameter for another scenario.

- **Comparison of Results**

  The results obtained through both the modelled were compared. The comparison was made for total power loss in the system, loading and power loss in transmission line network and voltage profile at different busbars.

- **Analysis of Result and Conclusion**

  The results obtained was analyzed and different calculation were made to obtain the technical and financial parameters for the project. A robust conclusion was drawn from the analysis.

- **Final Documentation and Publication**

  All the data, finding and simulation was compiled and a complete report for the thesis was prepared.

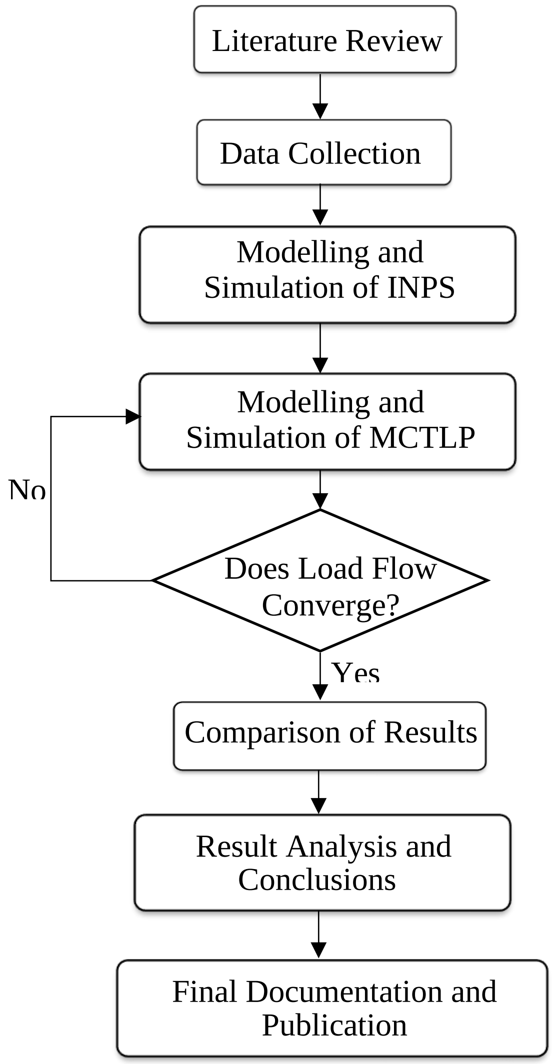

Figure 4 : Flowchart of Research Methodology

3.3 Flowchart of Newton-Raphson Method

The proposed method of load flow analysis is Newton-Raphson Method. First of all, all the buses except the slack bus are assumed to have a voltage of 1 p.u. and angle 0^0 and all the load flow calculation are done using the load flow equations. Then, the procedure follows the given flowchart unless convergence is obtained.

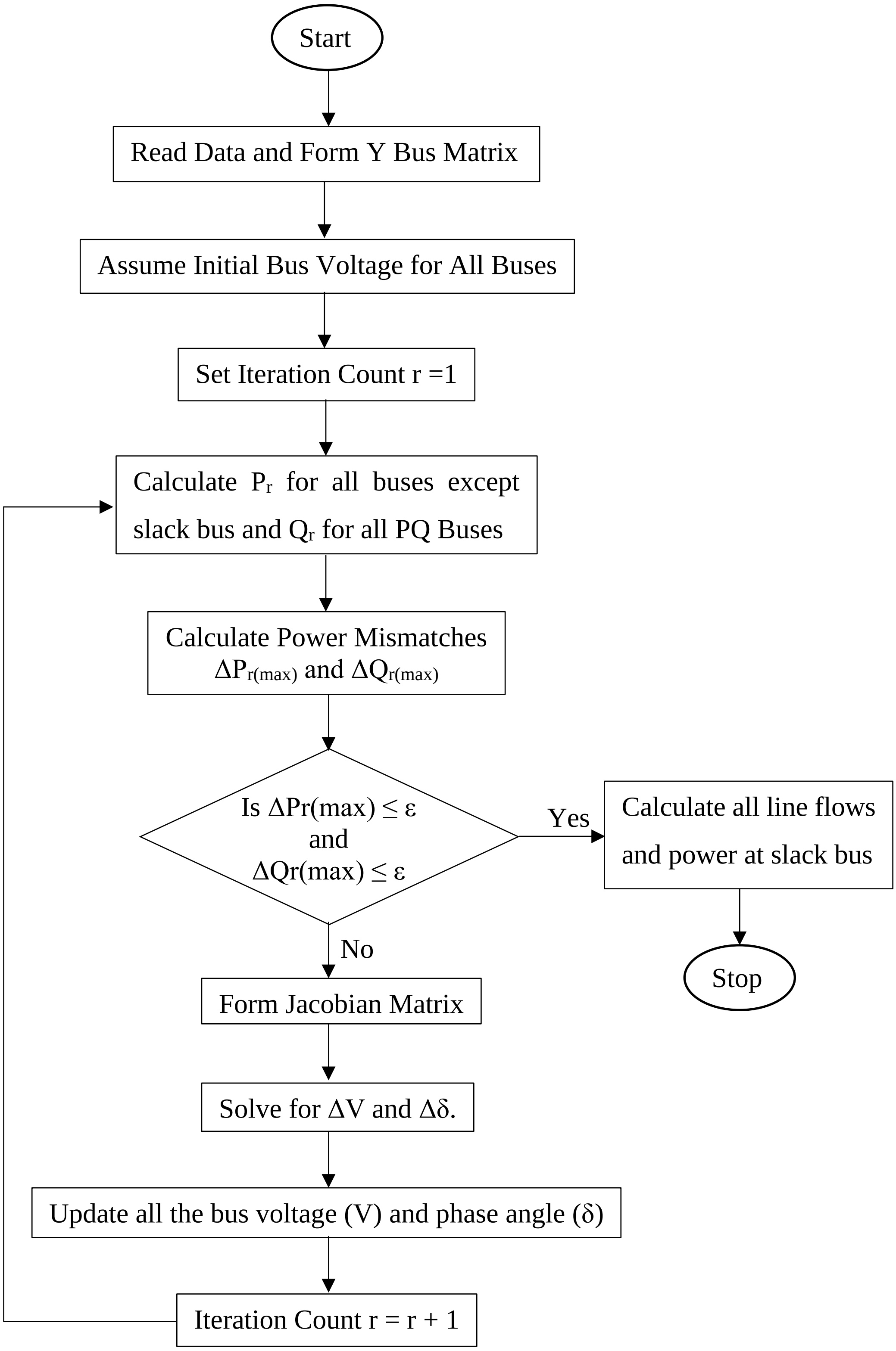

Figure 5: Flowchart of Newton-Raphson Method

3.4 Computational Method Used in Analysis

The research was conducted through performing the simulation of the INPS model in the Digsilent PowerFactory 15.1 software. The data then obtained was transferred into Microsoft Excel 2016 for further analysis and obtaining results. Different methods such as payback period, internal rate of return (IRR) and Net Present Value (NPV) will be used for financial analysis of the project.

3.5 Case Study Considered in the Analysis

The list of the hydropower along with their location and installed capacity connected to the Integrated Nepal Power System is presented in Appendix A, Substation and their maximum demand is presented in Appendix B. Transmission line along with their respective line length in circuit km is presented in Appendix C.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Study Case I: Base INPS Model

The figure illustrated below shows the model of INPS without the Marsyangdi Corridor 220kV Transmission line. The INPS model is updated for the power demand and generation scenario up to FY 2023/24. The load flow is conducted to determine power loss. The INPS model includes 147 generators, 114 substations, 15 transformers, and 187 lines as illustrated below.

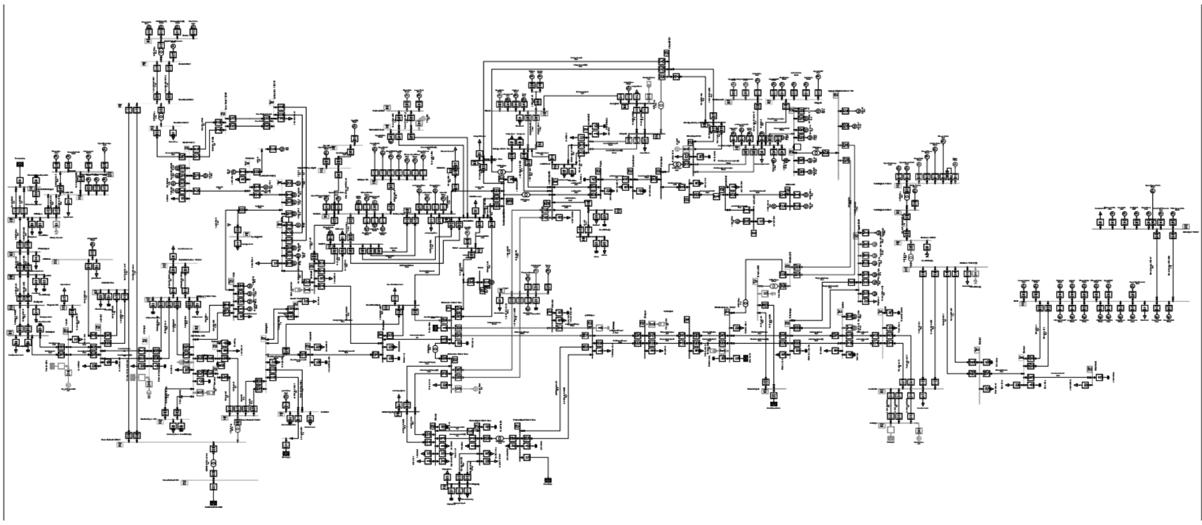

Figure 6: INPS system without Marsyangdi Corridor Transmission Line

4.2 Load Flow of Base INPS Model

The load flow of the INPS model was conducted in Digsilent PowerFactory 15.1 and it was able to obtain the solution.

4.3 Results for the Load Flow of Base INPS Model

The result obtained from the load flow analysis of INPS model using the Dig-silent Power Factory 15.1 software is presented in figure below. The total loss on the transmission line was found to be 203.98 MW while a total of 2966.87 MW was generated. The lines with most losses are Khimti-Dhalkebar followed by New Bharatpur-Hetauda, Bhaktapur-Lamosanghu, Hetauda-Pathlaiya and Middle Marsyangdi-New Marsyangdi respectively. The lines which have the highest loading are New Chabahil-Chapali, Dumbikas-Bardaghat, Hetauda-Kamane, Khimti-Dhalebar and New-Bharatpur respectively. The details of line losses and line loading can be found in appendix D.

		DIgSILENT PowerFactory 15.1.7	Project:
			Date: 3/2/2025

Load Flow Calculation		Total System Summary	
AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	0.00 kVA
		Model Equations	0.10 %

Total System Summary		Study Case: Study Case		Annex: / 1			
No. of Substations	10	No. of Busbars	114	No. of Terminals	213	No. of Lines	187
No. of 2-w Trfs.	15	No. of 3-w Trfs.	0	No. of syn. Machines	147	No. of asyn.Machines	0
No. of Loads	86	No. of Shunts	44	No. of SVS	0		

Generation	=	2966.87	MW	514.18	Mvar	3011.09	MVA
External Infeed	=	-546.19	MW	360.37	Mvar	654.37	MVA
Load P(U)	=	2216.69	MW	1050.75	Mvar	2453.12	MVA
Load P(Un)	=	2216.69	MW	1050.75	Mvar	2453.12	MVA
Load P(Un-U)	=	-0.00	MW	0.00	Mvar		
Motor Load	=	0.00	MW	0.00	Mvar	0.00	MVA
Grid Losses	=	203.98	MW	865.28	Mvar		
Line Charging	=			-295.46	Mvar		
Compensation ind.	=			27.96	Mvar		
Compensation cap.	=			-1069.43	Mvar		
Installed Capacity	=	3183.21	MW				
Spinning Reserve	=	212.33	MW				
Total Power Factor:							
Generation	=	0.99	[-]				
Load/Motor	=	0.90 / 0.00	[-]				

Figure 7: Grid Summary Report of Base INPS Model

4.4 Study Case II: INPS Model with MCTLP

The figure illustrated below shows the model of INPS with the inclusion of Marsyangdi Corridor 220kV Transmission line. The model includes the substation and transmission line of the transmission line project. The load flow is conducted to determine power loss. The INPS model includes 147 generators, 124 substations, 22 transformers, and 202 lines as illustrated below.

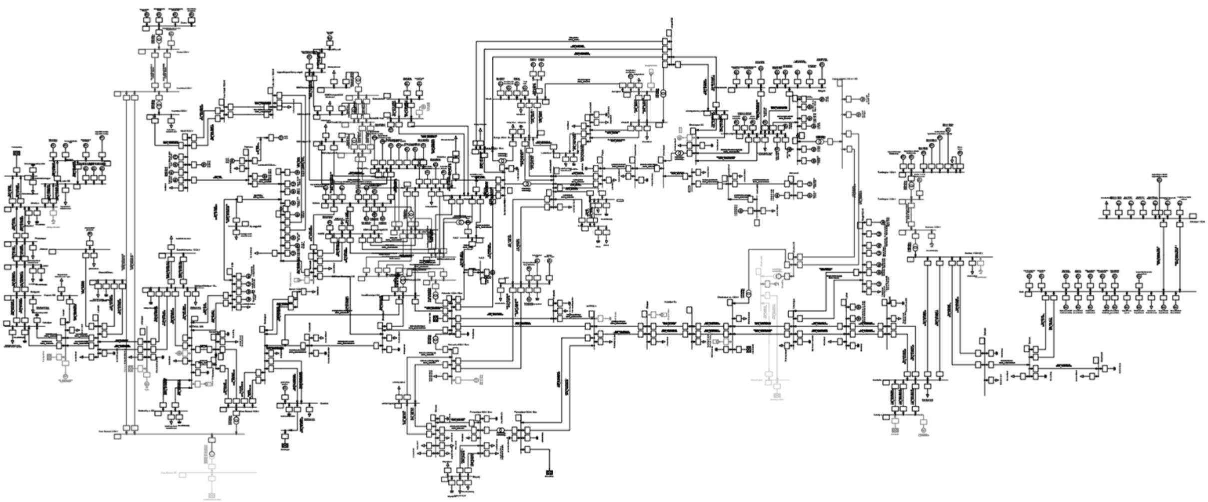

Figure 8: INPS System with Marsyangdi Corridor Transmission Line

4.5 Load Flow of INPS Model with MCTLP

The load flow of the INPS model was conducted in Digsilent PowerFactory 15.1 and it was able to obtain the solution.

4.6 Results for the Load Flow of INPS Model with MCTLP

The result obtained from the load flow analysis of INPS model using the Dig-silent Power Factory 15.1 software is presented in figure below. The total loss on the transmission line was found to be 158.64 MW while a total of generation of 2966.87 MW of electrical power remained the same. The lines with most losses are Khimti-Dhalkebar followed by Bhaktapur-Lamosanghu, Duhabi-Damak, Hetauda-Pathlaiya and Syaule-Attaria respectively. The lines which have the highest loading are New Chabahil-Chapali, Dumbikas-Bardaghat, Khimti-Dhalkebar, Lainchaur-New Chabahil, Bhaktapur-Lamosanghu and Hetauda-Kamane respectively. The details of line losses and line loading can be found in appendix E.

		DIgSILENT PowerFactory 15.1.7	Project:
			Date: 3/2/2025

Load Flow Calculation			Total System Summary
AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	0.00 kVA
		Model Equations	0.10 %

Total System Summary				Study Case: Study Case		Annex:	/ 1
No. of Substations	20	No. of Busbars	124	No. of Terminals	357	No. of Lines	202
No. of 2-w Trfs.	22	No. of 3-w Trfs.	0	No. of syn. Machines	147	No. of asyn.Machines	0
No. of Loads	89	No. of Shunts	44	No. of SVS	0		

Generation	= 2966.87 MW	262.99 Mvar	2978.50 MVA
External Infeed	= -513.15 MW	312.20 Mvar	600.66 MVA
Load P(U)	= 2295.08 MW	1088.71 Mvar	2540.21 MVA
Load P(Un)	= 2295.08 MW	1088.71 Mvar	2540.21 MVA
Load P(Un-U)	= -0.00 MW	0.00 Mvar	
Motor Load	= 0.00 MW	0.00 Mvar	0.00 MVA
Grid Losses	= 158.64 MW	619.10 Mvar	
Line Charging	=	-330.67 Mvar	
Compensation ind.	=	28.93 Mvar	
Compensation cap.	=	-1161.55 Mvar	
Installed Capacity	= 3183.21 MW		
Spinning Reserve	= 212.33 MW		
Total Power Factor:			
Generation	= 1.00 [-]		
Load/Motor	= 0.90 / 0.00 [-]		

Figure 9: Grid Summary Report of INPS Model with MCTLP

4.7 Comparison of Study Cases

4.7.1 Comparison of Total System Loss

The commissioning of Marsyangdi Corridor 220kV resulted in the change of loss from 203.98 MW to 158.64 MW which is a reduction of 45.34 MW.

4.7.2 Comparison of Line Losses and Line Loading

The line which experienced a significant reduction in loss and loading is New Bharatpur-Hetauda line which had the loss reduction of 9.35 MW and line loading was also reduced from 135.65% to 53.67%. The details of difference in loss and loading are presented in appendix F.

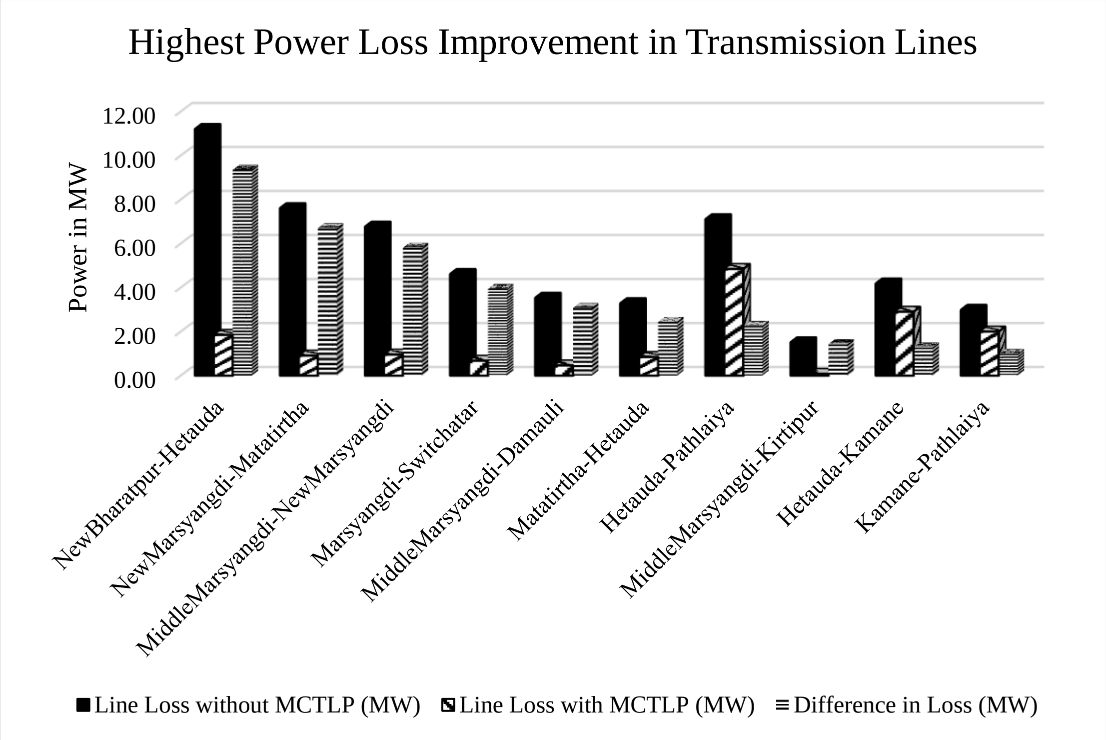

Figure 10: Highest Power Loss Improvement in Transmission Line

Figure 10 Figure 10: Highest Power Loss Improvement in Transmission Linepresents the top 10 transmission line that experienced the highest decrease in power loss after the connection of MCTLP in the INPS model. As mentioned earlier, New Bharatpur-Hetauda experienced a significant reduction in power loss by 9.35 MW. It was followed by New Marsyangdi-Matatirtha, Middle Marsyangdi-New Marsyangdi, Marsyangdi-Switchatar, Middle Marsyangdi-Damauli, Matatirtha-Hetauda, Hetauda-Pathlaiya, Middle Marsyangdi-Kirtipur Hetauda-Kamane and Kamane-Pathlaiya transmission lines respectively which had a reduction in loss of 6.70MW, 5.81 MW, 3.94 MW, 3.07 MW, 2.44 MW, 2.26 MW, 1.43 MW, 1.28 MW and 0.99 MW respectively. It is to be noticed that most of the transmission lines that are located near the MCTLP line experienced better results.

Figure 11 presents the top 10 transmission line that experienced the highest decrease in line loading after the connection of MCTLP in the INPS model. As mentioned earlier, New Bharatpur-Hetauda experienced a significant reduction in line loading by 81.97%. It was followed by Middle Marsyangdi-Kirtipur, Middle Marsyangdi-New Marsyangdi, Upper Marsyangdi-Middle Marsyangdi, New Marsyangdi-Matatirtha, KulekhaniI-Hetauda, Matatirtha-Hetauda, Middle Marsyangdi-Damauli Damauli-Bharatpur and Marsyangdi-Switchatar transmission lines respectively which had a reduction in loading of 79.68%, 67.40%, 54.94%, 46.84%, 43.34%, 43.02%, 42.83%, 38.13% and 28.05% respectively. It is to be noticed that most of the transmission lines that are located near the MCTLP line experienced better results.

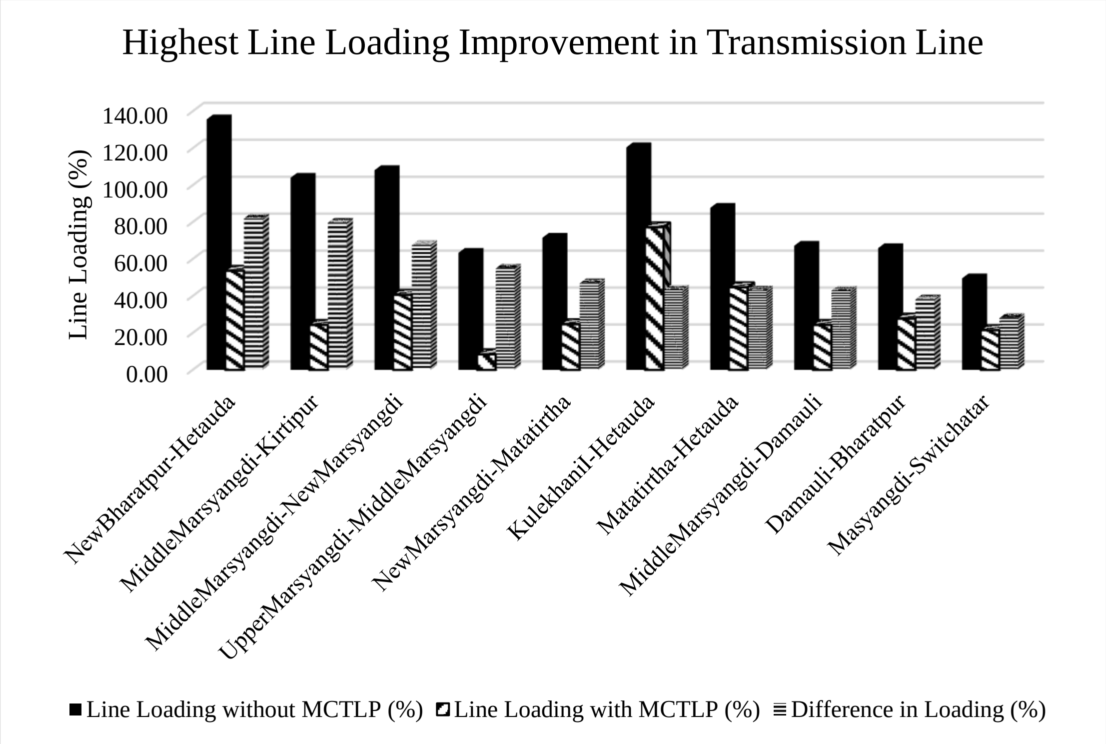

Figure 11: Highest Line Loading Improvement in Transmission Line

4.7.3 Comparison of Voltage Profile

The voltage profile of substation has also significantly improved with the addition of MCTLP line. The detailed report of voltage profile can be found in appendix G.

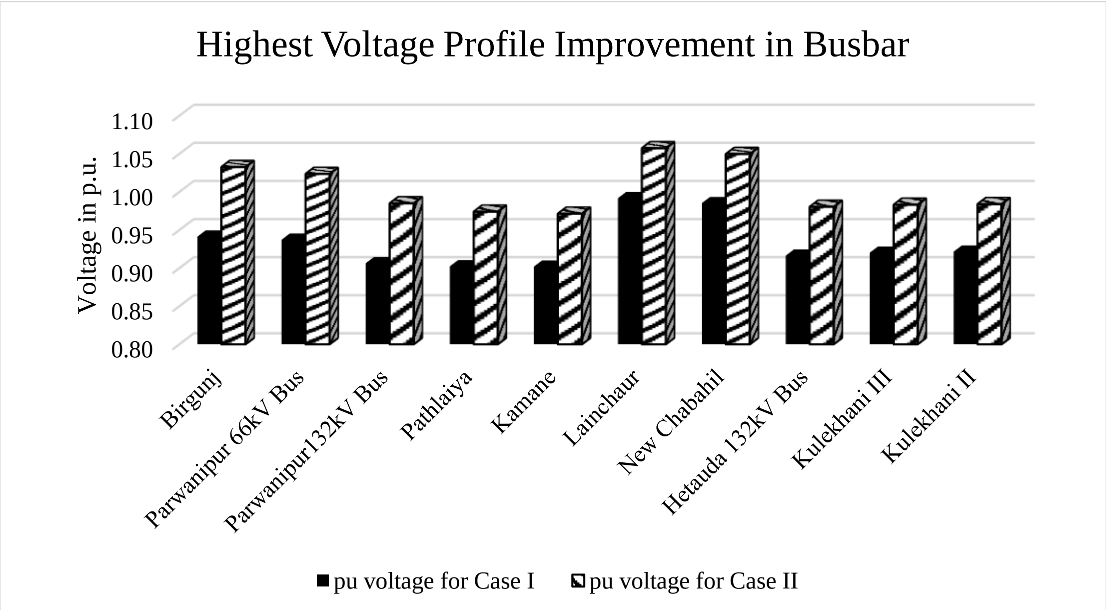

Figure 12: Highest Voltage Profile Improvement in Busbar

The above figure represents the top 10 busbar that experienced the highest improvement in busbar per unit voltage after the connection of MCTLP in the INPS model. The highest improvement can be seen in Birgunj 66kV Busbar as it has reached 1.03 from 0.94 showing an increase of 0.09 p.u. which is equivalent to 6.02kV. This was followed by Parwanipur 66kV, Parwanipur 132kV, Pathaiya 132kV, Kamane 132kV, Lainchaur 66kV, New Chabahil 66kV, Hetauda 132kV, Kulekhani II 132kV and Kulekhani III 132kV which have an improvement of 6.02kV (0.09p.u.), 10.38kV (0.08p.u.), 9.47kV (0.07p.u.), 9.17kV (0.07p.u.), 4.32 (0.07p.u.), 4.26kV (0.06p.u.), 8.45kV (0.06p.u.), 8.32kV (0.06p.u.) and 8.24kV (0.06p.u.) respectively. The biggest voltage profile improvement can be seen in the Terai region and Kathmandu valley as they are the places with most concern for voltage imbalances.

4.8 Study Case III: Addition of Hydropower in INPS Model with MCTLP

The figure illustrated below shows the model of INPS with the inclusion of Marsyangdi Corridor 220kV Transmission line and connection of associated hydropower within the model. The list of hydropower that are added to the model is presented in Appendix H. The load flow is conducted to determine power loss. The INPS model includes 158 generators, 124 substations, 22 transformers, and 202 lines as illustrated below.

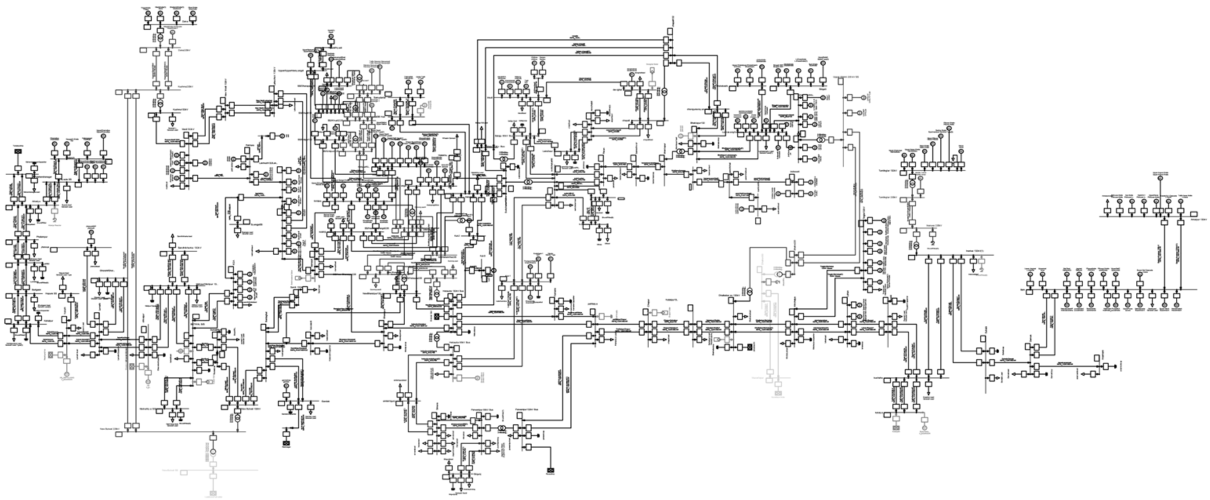

Figure 13: INPS System with Marsyangdi Corridor Transmission Line and Hydropower

4.9 Load Flow of INPS Model with MCTLP and Hydropower

The load flow of the INPS model was conducted in Digsilent PowerFactory 15.1 and it was able to obtain the solution.

4.10 Results for the Load Flow of INPS Model with MCTLP and Hydropower

The result obtained from the load flow analysis of INPS model using the Dig-silent Power Factory 15.1 software is presented in figure below. The total loss on the transmission line was found to be 207.52.81 MW while a total of generation of increased by 840.34 MW to 3807.21 MW due to addition of new generators. The loss percentage is found to be 5.45% which is fairly similar to Case II where loss percentage was 5.34%. Hence, the model is found to be satisfactory.

```
|                  | DIgSILENT      | Project:         |
|                  | PowerFactory   |------------------|
|                  | 15.1.7         | Date:  3/5/2025  |

Load Flow Calculation                                              Total System Summary

   AC Load Flow, balanced, positive sequence        | Automatic Model Adaptation for Convergence     No
   Automatic Tap Adjust of Transformers        No   | Max. Acceptable Load Flow Error for
   Consider Reactive Power Limits              No   |    Nodes                                 0.00 kVA
                                                    |    Model Equations                       0.10 %

Total System Summary                   | Study Case: Study Case             | Annex:              / 1

No. of Substations     20     No. of Busbars      124     No. of Terminals      393     No. of Lines          202
No. of 2-w Trfs.       22     No. of 3-w Trfs.      0     No. of syn. Machines  158     No. of asyn.Machines    0
No. of Loads           95     No. of Shunts        44     No. of SVS              0

Generation          =    3807.21  MW        982.19   Mvar     3931.86  MVA
External Infeed     =    -581.01  MW        388.05   Mvar      698.68  MVA
Load P(U)           =    3018.68  MW       1439.17   Mvar     3344.19  MVA
Load P(Un)          =    3018.68  MW       1439.17   Mvar     3344.19  MVA
Load P(Un-U)        =      -0.00  MW          0.00   Mvar
Motor Load          =       0.00  MW          0.00   Mvar        0.00  MVA
Grid Losses         =     207.52  MW        958.56   Mvar
Line Charging       =                      -316.29   Mvar
Compensation ind.   =                        27.54   Mvar
Compensation cap.   =                     -1055.04   Mvar

Installed Capacity  =    4023.55  MW
Spinning Reserve    =     212.33  MW

Total Power Factor:
  Generation        =         0.97  [-]
  Load/Motor        =  0.90 / 0.00  [-]
```

Figure 14: Grid Summary Report of INPS Model with MCTLP and Hydropower.

4.11 Financial Analysis of the Project

4.11.1 Assumption for Determining Cash Flow of Project

Total overall cost of the project is estimated to be NRs. 16 billion. The total capital asset is considered to be 80% of the overall cost. The PPA rate is taken to be the weighted average of wet season and dry season PPA rate published by NEA where 70% of energy is produced in dry season and 30% of energy is produced in wet season. The total energy loss saving is calculated by assuming loss of load factor to be 0.65. The wheeling charge of the transmission line network is calculated using postage-stamp method. The discount rate and MARR is calculated by taking the weighted average base interest rate of A-class commercial banks in Nepal. The depreciation rate is assumed to be 5% on total capital asset of project. The operation and maintenance cost and insurance of the project is assumed to be 5% and 0.25% respectively of the total investment cost. Annual operation and maintenance cost is going to increase by 1% every year. The lifecycle of the project is expected to be 35 years. The details of cash flow calculation are shown in table below.

Table 4: Calculation of Cash Flows of Project

Total Investment in Project in NRs. (millions) **[A]**	16,000.00	
Fixed Assets in NRs. (millions)	12,800.00	80% of Total Investment
Working Capital in NRs. (millions)	3,200.00	
System Peak Demand **[B]**	3,807.21	MW
PPA Rate for Wet Season in NRs.	4.80	per kWh
PPA Rate for Dry Season in NRs.	8.40	per kWh
Weighted Average PPA Rate in NRs.	5.88	per kWh
Addition of New Generators **[C]**	840.34	MW
Loss After Addition of New Generators	48.88	MW
Initial Reduction in Loss	45.34	MW
Per Year Saving in NRs. (millions)	(118.52)	
Wheeling Charge in NRs. (millions per year) **[A*C/B]**	4.20	per MW
Per Year Earning from Wheeling Charge in NRs. (millions)	3,531.57	
Total Cash Inflow in NRs. (millions)	3,413.05	
Discount Rate/MARR	6.63%	
Depreciation Rate	5%	of Fixed Asset
Operation and Maintenance Cost	5%	of Investment Cost
Insurance	0.25%	of Fixed Asset
Life Span of Transmission Line Project	35	years

4.11.2 Calculation of Free Cash Flow

The calculation of free cash flow for the project from year 0 to year 35 is presented in table below.

Table 5: Calculation of Free Cash Flow of Project

Year	Revenue	O&M Cost	Depreciation	Insurance Cost	Net Cash Flow
0					(16,000.00)
1	3413.05	800.00	640.00	32.00	1941.05
2	3413.05	808.00	608.00	30.40	1966.65
3	3413.05	816.08	577.60	28.88	1990.49
4	3413.05	824.24	548.72	27.44	2012.65
5	3413.05	832.48	521.28	26.06	2033.22
6	3413.05	840.81	495.22	24.76	2052.26
7	3413.05	849.22	470.46	23.52	2069.85
8	3413.05	857.71	446.94	22.35	2086.06
9	3413.05	866.29	424.59	21.23	2100.95
10	3413.05	874.95	403.36	20.17	2114.58
11	3413.05	883.70	383.19	19.16	2127.00
12	3413.05	892.53	364.03	18.20	2138.28

13	3413.05	901.46	345.83	17.29	2148.47
14	3413.05	910.47	328.54	16.43	2157.61
15	3413.05	919.58	312.11	15.61	2165.75
16	3413.05	928.78	296.51	14.83	2172.94
17	3413.05	938.06	281.68	14.08	2179.22
18	3413.05	947.44	267.60	13.38	2184.63
19	3413.05	956.92	254.22	12.71	2189.21
20	3413.05	966.49	241.51	12.08	2192.98
21	3413.05	976.15	229.43	11.47	2196.00
22	3413.05	985.91	217.96	10.90	2198.28
23	3413.05	995.77	207.06	10.35	2199.86
24	3413.05	1005.73	196.71	9.84	2200.78
25	3413.05	1015.79	186.87	9.34	2201.05
26	3413.05	1025.95	177.53	8.88	2200.70
27	3413.05	1036.21	168.65	8.43	2199.76
28	3413.05	1046.57	160.22	8.01	2198.25
29	3413.05	1057.03	152.21	7.61	2196.20
30	3413.05	1067.60	144.60	7.23	2193.62
31	3413.05	1078.28	137.37	6.87	2190.53
32	3413.05	1089.06	130.50	6.53	2186.96
33	3413.05	1099.95	123.98	6.20	2182.92
34	3413.05	1110.95	117.78	5.89	2178.43
35	3413.05	1122.06	111.89	5.59	2173.51

All the cost and revenue are expressed in NRs. (millions)

4.11.3 Calculation of Payback Period (PBP)

The calculation of payback period is presented in the table below.

Table 6: Calculation of Payback Period

Year	Cash Flow	PVF, 6.63%	PV	Cumulative PV
0	-16000.00	1.00	-16000.00	-16000.00
1	1941.05	0.94	1820.30	-14179.70
2	1966.65	0.88	1729.58	-12450.12
3	1990.49	0.82	1641.65	-10808.48
4	2012.65	0.77	1556.66	-9251.81
5	2033.22	0.73	1474.74	-7777.07
6	2052.26	0.68	1395.95	-6381.12
7	2069.85	0.64	1320.33	-5060.78
8	2086.06	0.60	1247.89	-3812.89
9	2100.95	0.56	1178.62	-2634.27
10	2114.58	0.53	1112.47	-1521.81
11	2127.00	0.49	1049.39	-472.42
12	2138.28	0.46	989.33	516.91

All the Cash Flow and PV are expressed in NRs. (millions)

Hence,

Payback Period = 11 + (472.42/989.33) = 11.48 years

The payback period of the MCTLP project was found to be 11.48 years.

4.11.4 IRR Calculation

The IRR of Marsyangdi Corridor Transmission Line Projetct was calculated to be 12.69% which exceeds the discount rate of 6.63%. Hence, the project is considered to be financially viable.

4.11.5 Net Present Value

The calculation of NPV of the MCTLP project is presented in the table below.

Table 7: Calculation of Net Present Value

Year	Cash Flow	PVF, 6.63%	PV
0	(16,000.00)	1.00	-16000.00
1	1941.05	0.94	1820.30
2	1966.65	0.88	1729.58
3	1990.49	0.82	1641.65
4	2012.65	0.77	1556.66
5	2033.22	0.73	1474.74
6	2052.26	0.68	1395.95
7	2069.85	0.64	1320.33
8	2086.06	0.60	1247.89
9	2100.95	0.56	1178.62
10	2114.58	0.53	1112.47
11	2127.00	0.49	1049.39
12	2138.28	0.46	989.33
13	2148.47	0.43	932.21
14	2157.61	0.41	877.93
15	2165.75	0.38	826.43
16	2172.94	0.36	777.59
17	2179.22	0.34	731.32
18	2184.63	0.31	687.53
19	2189.21	0.30	646.11
20	2192.98	0.28	606.96
21	2196.00	0.26	569.99
22	2198.28	0.24	535.08
23	2199.86	0.23	502.16
24	2200.78	0.21	471.12
25	2201.05	0.20	441.86
26	2200.70	0.19	414.31
27	2199.76	0.18	388.37

28	2198.25	0.17	363.96
29	2196.20	0.16	341.00
30	2193.62	0.15	319.41
31	2190.53	0.14	299.12
32	2186.96	0.13	280.06
33	2182.92	0.12	262.15
34	2178.43	0.11	245.34
35	2173.51	0.11	229.55
		NPV	**12,266.47**

All the Cash Flow and PV are expressed in NRs. (millions)

The net present value of project is found to be NRs. 12,266.47 million. Hence, the project is found to be financially feasible.

4.12 Risk Analysis of Financial Parameters

4.12.1 Case I: Considering Addition of New Generator

The aforementioned IRR and NPV are calculated for base case scenario of generating 840.34MW. However, not all hydroelectric plants are completed and under operation. Hence, there will be a certain risk that all the hydropower may not be completed and connected to the MCTLP line. Hence, to compute the risk of transmission line, we assume that new generators that will be connected to the transmission line network follows a triangular distribution function where the minimum value will be 80 MW, most likely value will be 840.34 MW and maximum value will be 1600 MW.

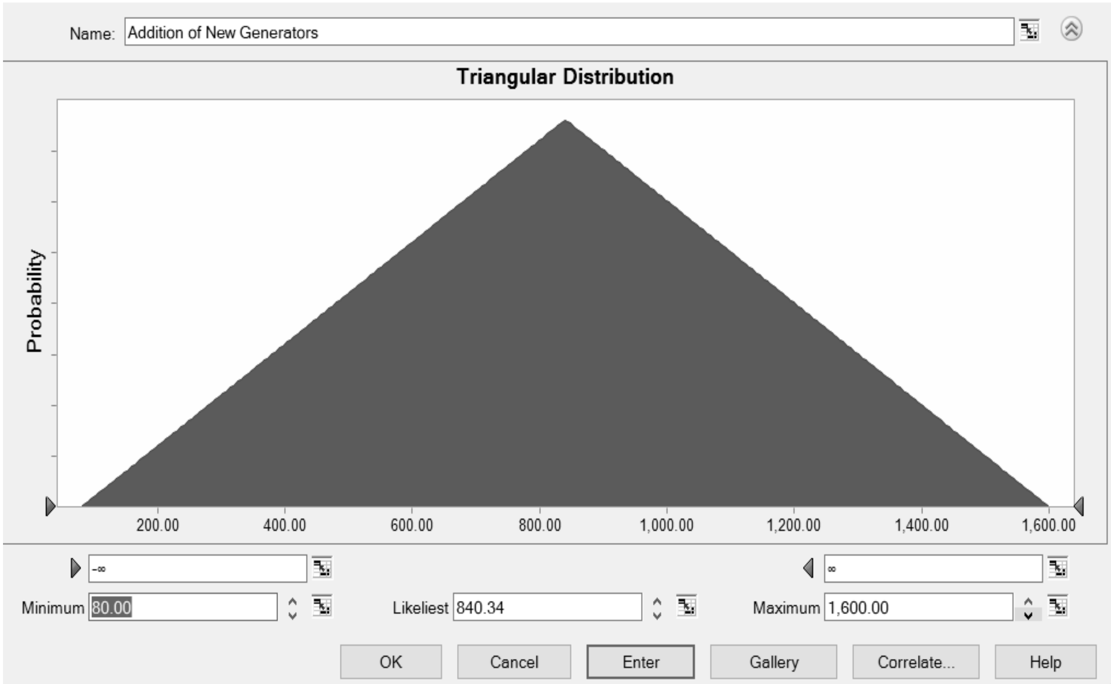

Figure 15: Probability Distribution Function of Addition of New Generators

Also, the loss after addition of new generators is considered to vary linearly with the addition of new generators and linear regression model is used to determine the same. The simulation will be done in Crystal Ball analysis for 10,000 trails and the obtained NPV and IRR will be analyzed.

The results obtained from the trails are presented in Figure 16 and Figure 17. Figure 16 shows that the value of NPV ranges from NRs. (9,051.76) million to NRs. 20,223.49 million. The probability that the net present value will be better than the base case scenario of NRs. 12,266.47 million is found to be 49.91%.

Figure 17 presents the range of values of IRR to be in between 1.09% and 16.39%. The probability that the IRR will be greater than the MARR of 6.63% is found to be 93.97%.

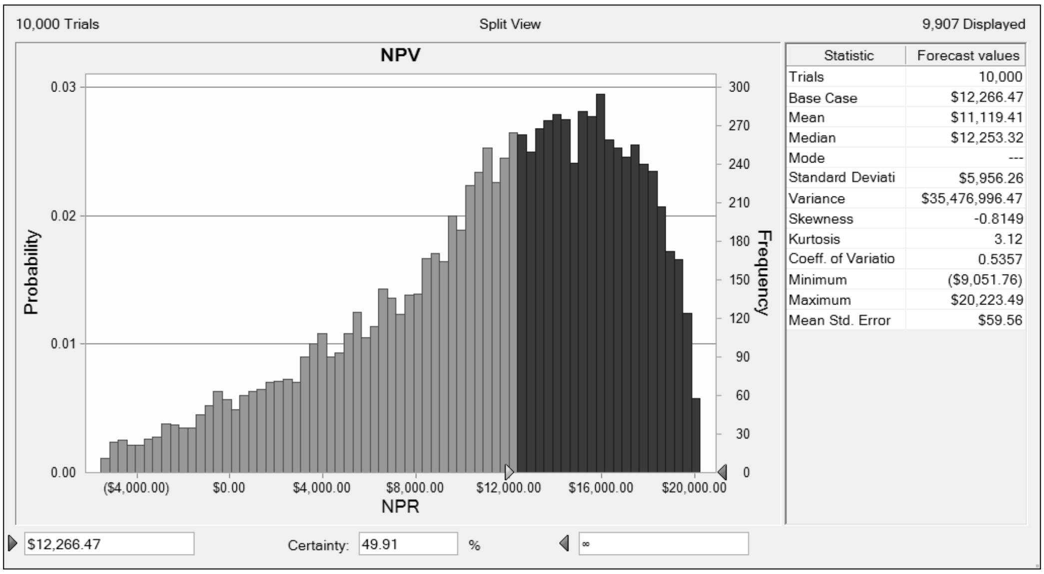

Figure 16: Results for NPV After 10,000 Trails for Case I

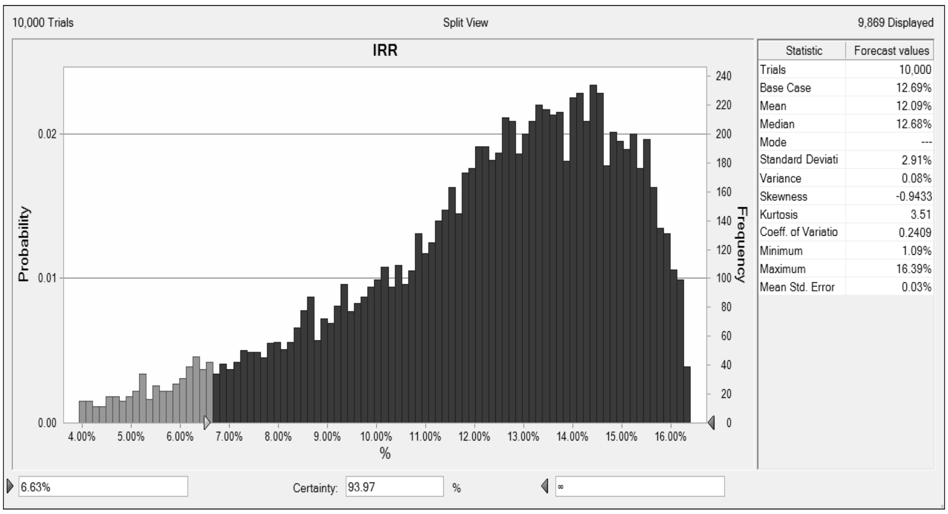

Figure 17: Results for IRR After 10,000 Trails for Case I

4.12.2 Case II: Considering Interest Rate

The aforementioned IRR and NPV are calculated for base case scenario of discount interest rate 6.63%. However, the interest rate keeps on fluctuating. Hence, to compute the risk of transmission line, we assume that interest rate follows a triangular distribution function where the minimum value will be 6.63%, most likely value will be 8% [14] and maximum value will be 12%. The simulation will be done in Crystal Ball analysis for 10,000 trails and the obtained NPV will be analyzed.

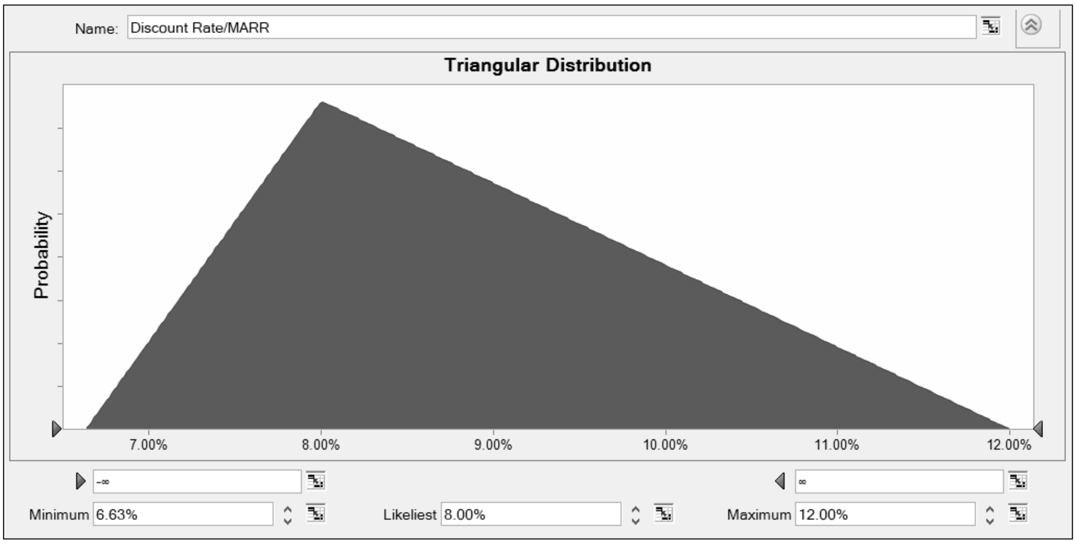

Figure 18: Probability Distribution Function of Discount Rate

The results obtained from the trails in presented in Figure 19. It shows that the value of NPV ranges from NRs. 975.72 million to NRs. 12,230.36 million. The probability that the net present value will be positive is found to be 100%.

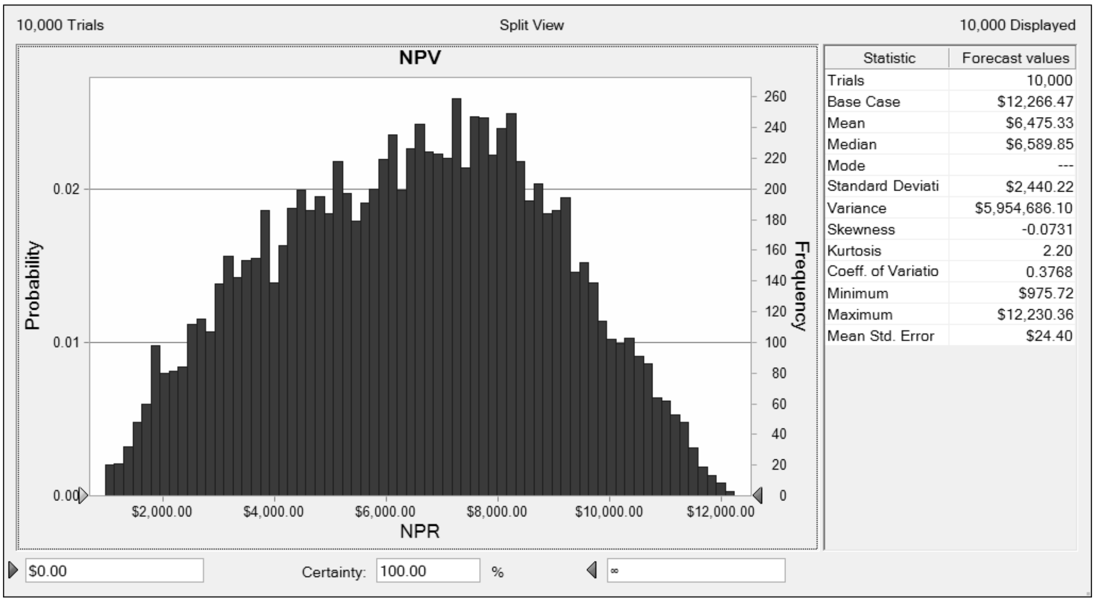

Figure 19: Results for NPV After 10,000 Trails for Case II

4.12.3 Case III: Considering Both Case I and Case II

The financial parameter of transmission line is susceptible to risk of both addition of new generator and interest rate. Hence, when we consider both to fluctuate over a period of time and calculate the financial risk through simulation. The probability distribution function of addition of new generators and interest rate is taken the same as in Figure 15 and Figure 18. The simulation will be done in Crystal Ball analysis for 10,000 trails and the obtained NPV will be analyzed.

The results obtained from the trails in presented in Figure 20. It shows that the value of NPV ranges from NRs. (11,462.89) million to NRs. 19,115.01 million. The probability that the net present value will be positive is found to be 84.36%.

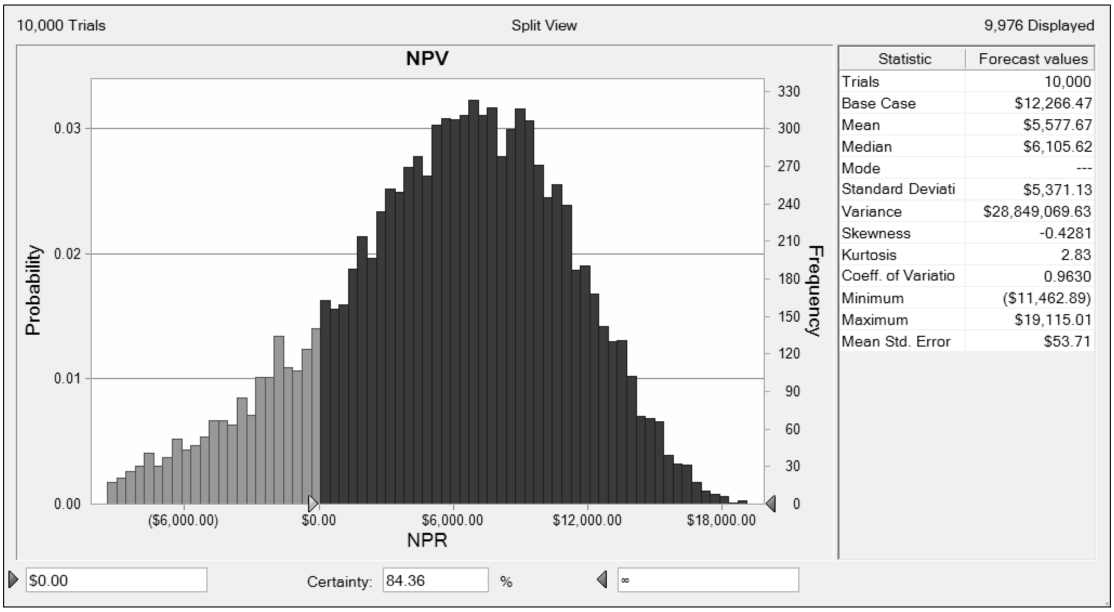

Figure 20: Results for NPV After 10,000 Trails for Case III

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The major conclusions of the study are listed below:

- On simulation of INPS model with the introduction of MCTLP 220kV Transmission line, the loss in the line decreased from 203.98 MW to 158.64 MW. This means a net reduction in power loss of 45.34 MW.
- The energy saving per year was found to be 258,165,960 kWh when taking the loss of load factor to be 0.65.
- The earning for NEA after construction of MCTLP was found to be NRs. 3,413.05 million per year.
- The line loading on transmission line was found to be considerably improved after the inclusion of MCTLP on INPS model. Better profile was obtained for transmission line that are in the vicinity of MCTLP.
- The voltage profile of substation improved considerably upon the introduction of MCTLP into the INPS model.
- The transmission line of MCTLP can effectively incorporate the planned hydropower in the Marsyangdi river basin and connect them to national grid.
- The project was found to be financially acceptable with its payback period being 11.48 years. The IRR also was found to be 12.69% which is greater than the MARR calculated. The Net Present Value of the project is also found to be positive at NRs. 12,266.47 million.
- When the financial risk assessment was calculated for on basis of addition of new generators, the probability of NPV being NRs. 12,266.47 million or more was found to be 49.91% and the probability of IRR being more than MARR of 6.63% was found to be 93.97%.
- When the financial risk assessment was calculated for on basis of change in interest rate, the probability of NPV being positive was found to be 100%.
- When the financial risk assessment was calculated for on basis of both addition of new generators and change in interest rate, the probability of NPV being positive was found to be 84.36%.
- While comparing the findings of this research with relevant research, the findings are found to be concurrent. Hence, the findings of the research work are valid.

- It is clearly seen that addition of new high voltage transmission line is beneficial to the nation as a whole as it reduces energy loss, increases quality of electricity and reliability. Since affordability, reliability and quality energy are requirement of a better and prosperous society, it is necessary to invest in these high voltage transmission line.

5.2 Recommendations

Distributed Energy Resources (DERs) can be introduced at strategic location to further enhance the voltage profile and decrease the line loss in the line.

Furthermore, addition of capacitor in transmission line network can also aid in lowering losses. The placement of capacitor of optimum size at appropriate location can significantly improve the performance of transmission line.

Reliability analysis and contingency analysis can be performed on the INPS model before and after the introduction of MCTLP to find the other benefits of construction of high voltage transmission line network.

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APPENDIX A: List of Hydropower, Location and Installed Capacity

Table 1: List of Hydropower with their location and installed capacity.

S.N.	Name of Hydropower	Location	Installed Capacity (MW)
Hydropower Plants of NEA			
1	Kaligandaki A	Syangja	144
2	Middle Marsyangdi	Lamjung	70
3	Marsyangdi	Tanahun	69
4	Kulekhani I	Makwanpur	60
5	Upper Trishuli 3A	Rasuwa	60
6	Kulekhani II	Makwanpur	32
7	Chameliya	Darchula	30
8	Trishuli	Nuwakot	24
9	Gandak	Nawalparasi	15
10	Modikhola	Parbat	14.8
11	Devighat	Nuwakot	14.1
12	Kulekhani III	Makwanpur	14
13	Sunkoshi	Sindhupalchowk	10.05
14	Puwa Khola	Illam	6.2
15	Chatara	Sunsari	3.2
16	Paunati	Kavre	2.4
17	Seti	Pokhara	1.5
18	Fewa	Pokhara	1
19	Sundarijal	Kathmandu	0.96
20	Pharping	Kathmandu	500
Hydropower of NEA Subsidiary Companies			
1	Chilime	Rasuwa	22.10
2	Upper Tamakoshi	Dolkha	456.00
3	Upper Sanjen	Rasuwa	14.80
Hydropower of Independent Power Producers			
1	Solu Khola (Dudhkoshi)	Solukhumbu	86.00
2	Likhu-1	Solukhumbu/ Ramechap	77.00
3	Middle Tamor	Taplejung	73.00
4	Nilgiri Khola-2 Cascade	Myagdi	71.00
5	Khimti Khola	Dolakha	60.00
6	Super Dordi 'Kha'	Lamjung	54.00
7	Likhu-2	Solukhumbu/ Ramechap	52.47
8	Likhu-IV	Ramechhap	52.40
9	Upper Marsyangdi "A"	Lamjung	50.00
10	Upper Bhotekoshi Khola	Sindhupalchowk	45.00
11	Super Madi	Kaski	44.00

12	Mistri Khola	Myagdi	42.00
13	Upper Chameliya	Darchula	40.00
14	Upper Kalangagad	Bajhang	38.46
15	Upper Balephi A	Sindhupalchowk	36.00
16	Nyadi	Lamjung	30.00
17	Likhu Khola A	Solukhumbu/ Ramechap	29.04
18	Lower Likhu	Ramechhap	28.10
19	Dordi Khola	Lamjung	27.00
20	Upper Madi	Kaski	25.00
21	Kabeli B-1	Taplejung, Panchthar	25.00
22	Singati Khola	Dolakha	25.00
23	Upper Dordi A	Lamjung	25.00
24	Solu Khola	Solukhumbu	23.50
25	Upper Chaku A	Sindhupalchowk	22.20
26	Tallo Hewa Khola	Panchthar	22.10
27	Mai Khola	Ilam	22.00
28	Bagmati Khola Small	Makawanpur/ Lalitpur	22.00
29	Lower Modi	Parbat	20.00
30	Upper Solu	Solukhumbu	19.80
31	Middle Modi	Parbat	18.00
32	Kalangagad	Bajhang	15.33
33	Hewa Khola A	Panchthar	14.90
34	Maya Khola	Sankhuwasabha	14.90
35	Upper Mailun	Rasuwa	14.30
36	Ghar Khola	Myagdi	14.00
37	Thapa Khola	Myagdi	13.60
38	Madkyu Khola	Kaski	13.00
39	Jhimruk Khola	Pyuthan	12.00
40	Upper Khimti	Ramechhap	12.00
41	Dordi-1 Khola	Lamjung	12.00
42	Namarjun Madi	Kaski	11.88
43	Lower Khare	Dolakha	11.00
44	Upper Sanigad	Bajhang	10.70
45	Down Piluwa	Sankhuwasabha	10.30
46	Lower Modi 1	Parbat	10.00
47	Makarigad	Darchula	10.00
48	Upper Mai Khola	Ilam	9.98
49	Kabeli B-1 Cascade	Panchthar	9.94
50	Iwa Khola	Taplejung	9.90
51	Upper Ingwa khola	Taplejung	9.70
52	Sipring Khola	Dolakha	9.66

53	Super Mai 'A'	Illam	9.60
54	Mai Beni	Illam	9.51
55	Mid Solu Khola	Solukhumbu	9.50
56	Andhi Khola	Syangza	9.40
57	Super Chepe	Gorkha Lamjung	9.05
58	Rudi Khola A	Lamjung and Kaski	8.80
59	Chepe Khola Small	Lamjung	8.63
60	Naugadh gad Khola	Darchula	8.50
61	Upper Hewa Khola Small	Sankhuwasabha	8.50
62	Ankhu Khola - 1	Dhading	8.40
63	Mai sana Cascade	Ilam	8.00
64	Upper Naugad Gad	Darchula	8.00
65	Taksar Pikhuwa	Bhojpur	8.00
66	Super Mai	Illam	7.80
67	Jogmai	Ilam	7.60
68	Indrawati - III	Sindhupalchowk	7.50
69	Upper Khorunga	Terhathum	7.50
70	Upper Midim	Lamjung	7.50
71	Yambling Khola	Sindhupalchowk	7.27
72	Mai Cascade	Ilam	7.00
73	Molung Khola	Okhaldhunga	7.00
74	Upper Mardi	Kaski	7.00
75	Upper Khimti II	Ramechhap	7.00
76	Upper Suri	Dolakha	7.00
77	Chepe khola A	Lamjung	7.00
78	Rudi Khola B	Lamjung and Kaski	6.60
79	Sapsup Khola	Khotang	6.60
80	Suri Khola	Dolakha	6.40
81	Lower Jogmai	Illam	6.20
82	Daraudi Khola A	Gorkha	6.00
83	Upper Phawa	Taplejung	5.80
84	Upper Mai C	Ilam	5.10
85	Tadi Khola (Thaprek)	Nuwakot	5.00
86	Mailung Khola	Rasuwa	5.00
87	Upper Hugdi Khola	Gulmi	5.00
88	Pikhuwa Khola	Bhojpur	5.00
89	Ghalemdi Khola	Myagdi	5.00
90	Ghatte Khola	Dolakha	5.00
91	Rukumgad	Rukum	5.00
92	Lower Tadi	Nuwakot	4.99
93	Richet Khola	Gorkha	4.98
94	Puwa - 2	Illam	4.96

95	Siuri Khola	Lamjung	4.95
96	Phawa Khola	Taplejung	4.95
97	Mardi Khola	Kaski	4.80
98	Padam Khola	Dailekh	4.80
99	Upper Piluwa Khola 2	Sankhuwasabha	4.72
100	Upper Chirkhwa	Bhojpur	4.70
101	Upper Machha Khola Small	Gorkha	4.55
102	Mai Khola	Ilam	4.50
103	Bijayapur 2 Khola Small	Kaski	4.50
104	Hewa Khola	Sankhuwasabha	4.46
105	Bijayapur-1	Kaski	4.41
106	Radhi Khola	Lamjung	4.40
107	Baramchi Khola	Sindhupalchowk	4.20
108	Khudi Khola	Lamjung	4.00
109	Sabha Khola	Sankhuwasabha	4.00
110	Puwa Khola -1	Ilam	4.00
111	Sardi Khola	Kaski	4.00
112	Upper Chhyangdi Khola	Lamjung	4.00
113	Super Mai Cascade	Illam	3.80
114	Charanawati Khola	Dolakha	3.52
115	Gelun	Sindhupalchowk	3.20
116	Piluwa Khola Small	Sankhuwasabha	3.00
117	Chaku Khola	Sindhupalchowk	3.00
118	Bhairab Kunda	Sindhupalchowk	3.00
119	Upper Puwa -1	Illam	3.00
120	Midim Karapu	Lamjung	3.00
121	Upper Rawa	Khotang	3.00
122	Upper Syange Khola	Lamjung	2.40
123	Chhandi	Lamjung	2.00
124	Pati Khola Small	Parbat	1.00

APPENDIX B: List of Substation and Maximum Demand

Table 2: List of Substation and Maximum Demand

S.N.	Substation	Max Demand (MVA)
1	Amarpur	16.16
3	Godak	11.66
4	Damak	67.37
5	Anarmani	85.04
6	Duhabi	235.47
7	Kusaha	22.5
8	Inaruwa	92.7
10	Tumlingtar	21
11	Dhungesanghu	
12	Tingla	17.83
13	Lahan	38.87
14	Mirchaiya	53.5
15	Rupani	40.24
16	Dhalkebar	117.06
17	Chandranigahapur	102.43
18	Nabalpur	46.18
19	Garjyang	
20	New Khimti	
21	Singati	
22	Lamosanghu	16.74
23	Indrawati	6.68
24	Pathlaiya	9.83
25	New Parwanipur	237.31
26	Birjung	96.93
28	New Bharatpur	20
29	Bharatpur	98.65
30	Kamane	47.79
31	Hetauda	102.76
32	New Hetauda	
33	Amlekhgunj	2.13
34	Simara	15.49
35	Balaju	101.85
36	Chapali	125.05
37	Siuchatar	103.11
38	New Chabel	80.48
39	Lainchaur	41.38
40	Patan	95.34
41	Teku	73.16
42	K-3	40.58

43	Baneshwor	56.47
44	Bhaktapur	183.13
45	Banepa	37.61
46	Paanchkhal	6.68
47	Matatirtha	42
48	Samundratar	
49	Trishuli 3B Hub	
50	Damauli	37.49
51	Pokhara	56.01
52	Lekhnath	14.86
53	New Marsyangdi	8.14
54	Syangja	11.95
55	Dana	
56	Kushma	
57	New Modi	
58	Lahachowk	14.4
59	Kirtipur	
60	Butwal	142.21
61	Bardaghat	26.98
62	Gandak	39.97
63	Chanauta	43.66
64	New Butwal	
65	Sunwal	60
66	Kawasoti	39.55
67	Motipur	29.26
68	Sandhikharka	11.89
69	Mainahiya	73.16
70	Tamghas	
71	Lamahi	66.08
72	Ghorahi	66.08
73	Kusum	2
74	Hapure	19
75	Kohalpur	54.19
76	Bhurigaun	2.11
77	Attariya	40.23
78	Lamki	21.95
79	Mahendranagar	33.61
80	Pahalmanpur	11.19
81	Syaule	7.54
82	Chilime Hub	

APPENDIX C: List of Transmission Line and Length

Table 3: List of Transmission Line and Line Length

S.N.	Name	Length (km)
1	Attari-Phalam	35.19
2	Attari-Phalam(1)	35.19
3	Balanch-Syaule	70
4	Balanch-Syaule(1)	70
5	Bard-NB	10
6	Bard-NB1	10
7	Bardaghat-Sardi	20
8	Bardaghat-Sardi(1)	20
9	Bardghat-New Bharatpur	70
10	Bhaktapur-Lamosanghu	48.3
11	Bhaktapur-Lamosanghu(1)	48.3
12	Bharatpur-Kawasoti	28.7
13	Burigaon-Kohal	55.29
14	Burigaon-Kohal(1)	55.29
15	But-Sun	13
16	But-Sun1	13
17	Butwal-Mainahiya	18
18	Butwal-Mainahiya(1)	18
19	Butwal-Motipur	38
20	Butwal-Motipur1	38
21	Chapali-Balaju	10
22	Chapur-Nabalpur	34.75
23	Chapur-Nabalpur1	34.75
24	Dhalkebar-Mirchaiya	31.5
25	Dhalkebar-Mirchaiya(1)	31.5
26	Duhabi-Damak	48.9
27	Dumkibas-Bardaghat	12
28	Dumkibas-Kawasoti	45.8
29	Gandak-Bardaghat(1)	14
30	Godak-Amarpur 132kV	56.5
31	Godak-Amarpur 132kV(1)	56.5
32	Hetauda-pathlaiya	37
33	Inarwa-Duhabi	10
34	Inarwa-Duhabi1	10
35	Inruwa-Tumlingtar220kV	106
36	Kohal-Kusum	48.3
37	Kul-3(1)	0.5
38	Kusaha-Inarwa	13.1
39	Kusaha-Inarwa(1)	13.1

40	Kusma-Dana220kV	39
41	Kusma-Dana220kV(1)	39
42	Kusma-Modi132kV	6
43	Kusum-Hapure132kV	22
44	Lahachowk-Lekhnath1	22
45	Lahachowk-Lekhnath2	22
46	Lahan-Rupani	27
47	Lahan-Rupani1	27
48	Lamahi-Ghorahi	13
49	Lamahi-Ghorahi1	13
50	Lamahi-Jhimruk	49.49
51	Lumki-Burigaon	33.9
52	Lumki-Burigaon(1)	33.9
53	MMRS-Kirtipur	17
54	Mahen-Attari	51.4
55	Mahen-Attari(1)	51.4
56	Mata-Hetauda	36.24
57	Modi-New Modi	0.8
58	Modi-New Modi(1)	0.8
59	Motipur-Sandhikhark	57
60	Motipur-Sandhikhark1	57
61	Motipur-Shivpur	23
62	Motipur-Shivpur(1)	23
63	NB-Sunwal	20
64	NB-Sunwal1	20
65	NMRS-Matatirtha	84
66	NMRS-Matatirtha2	84
67	Nabalpir-Dhalke1	34.75
68	Nabalpur-Dhalke	34.75
69	New Modi-Lahachok	20
70	New Modi-Lahachok(1)	20
71	NewBharatpur-Hetauda	74
72	NewButwal-Kusuma	88
73	NewButwal-Kusuma1	88
74	Newbharatpur-mars	25
75	Nyadi-UpperMarsyan	6
76	Pathlaiya-Chapur	30.68
77	Phalam-Lumki	28.9
78	Phalam-Lumki(1)	28.9
79	Rupani-Kusaha	34.9
80	Rupani-Kusaha1	34.9
81	Samun-Matatirtha	49
82	Samun-Matatirtha(1)	49

83	Samun-Trishuli3B	26
84	Samun-Trishuli3B_2	26
85	Singati-Lamosanghu	40
86	Syangja-Kga-Lekhnath	0.2
87	Syaule-Attaria Ckt	60
88	Syaule-Attaria Ckt(1)	60
89	Teku-K3	2.3
90	Teku-Swichatar2	4.1
91	Tingla-Mirchaiya	90
92	Tingla-Mirchaiya(1)	90
93	UpperMarsyan-MMarsyan	21
94	Whasin 132kv	0.2
95	amlekh-simara	12.9
96	amlekh-simara(1)	12.9
97	balaju-chapali	10
98	balaju-chapali(1)	10
99	balaju-lainchaur	2
100	balaju-switchatar132	4.4
101	balaju66-trisuli	29
102	balaju66-trisuli(1)	29
103	banepa-panchkahl	8.03
104	baneshwor-bhaktapur	14
105	bhaktapur-changu	3.65
106	bhaktapur-changu(1)	3.65
107	bhaktapurbanepa	13.57
108	bharatpur-mars(1)	0.5
109	birgunj-parwani	9
110	birgunj-parwani(1)	9
111	butwal-kga	58
112	butwal-kga(1)	58
113	chapali-changu	8.24
114	chapali-changu(1)	8.24
115	chapali-devighat	29.3
116	chapali-devighat(1)	29.3
117	chilime-trisuli	39
118	damak-anarmani	26.7
119	damauli-bharatpur	39
120	damauli-nmrs	23
121	damauli-nmrs(1)	23
122	dhalke-muzza	39
123	dhalke-muzza(1)	39
124	gandak-bardaghat	14
125	hetauda-amlekhgunj	20.17

126	hetauda-amlekhgunj(1)	20.17
127	hetauda-bharatpur	70.85
128	hetauda-kamane	18.5
129	hetauda-kul2(1)	5.24
130	hetauda-kul2(1)_a	3
131	ilam-damak	35
132	ilam-damak(1)	35
133	kamane-pathlaiya	18.5
134	kga-lekhnath	55
135	kga-lekhnath_a	41
136	khimti-dhalke	75
137	khimti-dhalke(1)	75
138	kohal-kusum	48.3
139	ku1-switch66	32.86
140	kul1-switch66	32.86
141	kule2-matatirtha	67.6
142	kulekhani1-hetauda	15.05
143	kulekhani1-hetauda(1)	15.05
144	kushaha-kataiya	15
145	kushaha-kataiya2	15
146	kushaha-kataiya3	15
147	kusum-lamahi	47.5
148	kusum-lamahi(1)	47.5
149	lainchaur-newchabil	2.3
150	lainchaur-newchabil(1)	2.3
151	lamahi-shivpur	51
152	lamahi-shivpur(1)	51
153	lamosanghu-bhotekoshi	31
154	lamosanghu-khimti	45.84
155	lekhnath-damauli	45
156	mars-switchatar	40
157	mars-switchatar_a	84
158	matatirtha-switchatar	4.4
159	matatirtha-switchatar(1)	4.4
160	mirchaiya-lahan	27.68
161	mirchaiya-lahan(1)	27.68
162	mmrs-damauli	42.69
163	newchabil-chapali	5
164	newchabil-chapali(1)	5
165	nmrs-mmrs(1)	31.5
166	nrms-mrs	5
167	nrms-mrs2	5
168	panchkahl-sunkoshi	27.44

169	panchkhal-indrawati	28
170	patan-baneshwor	2.8
171	pathlaiya-Chapur	30.68
172	pathlaiya-parwani	16.59
173	pathlaiya-parwani(1)	16.59
174	pkr-lekhnath	7
175	pkr-modi	37
176	ramnagarimpline	0.1
177	seti-pkr	0.1
178	simara-parwani66	9.6
179	simara-parwani66(1)	9.6
180	switch-patan	6.5
181	switch66-balaju66	4.4
182	switch66-balaju66(1)	4.4
183	switch66-k3	6.9
184	switch66-teku	4.1
185	swtch-patan	6.5
186	teku-k3	2.3
187	trisuli-devighat	4.56

APPENDIX D: List of Transmission Line, Line Loss and Loading for Case I

Table 4: Line Loss and Line Loading of Transmission Line for Case 1

S.N.	Name	Line Loss (MW)	Line Loading (%)
1	Attari-Phalam	1.42	58.55
2	Attari-Phalam(1)	1.42	58.55
3	Balanch-Syaule	2.53	55.34
4	Balanch-Syaule(1)	2.53	55.34
5	Bard-NB	0.83	83.81
6	Bard-NB1	0.83	83.81
7	Bardaghat-Sardi	0.01	7.47
8	Bardaghat-Sardi(1)	0.01	7.47
9	Bardghat-New Bharatpur	2.82	69.93
10	Bhaktapur-Lamosanghu	8.38	121.20
11	Bhaktapur-Lamosanghu(1)	8.38	121.20
12	Bharatpur-Kawasoti	0.98	68.28
13	Burigaon-Kohal	1.63	50.29
14	Burigaon-Kohal(1)	1.63	50.29
15	But-Sun	0.04	15.53
16	But-Sun1	0.04	15.53
17	Butwal-Mainahiya	0.06	16.48
18	Butwal-Mainahiya(1)	0.06	16.48
19	Butwal-Motipur	0.20	21.40
20	Butwal-Motipur1	0.20	21.40
21	Chapali-Balaju	0.00	2.86
22	Chapur-Nabalpur	0.09	20.83
23	Chapur-Nabalpur1	0.17	21.01
24	Dhalkebar-Mirchaiya	0.52	37.60
25	Dhalkebar-Mirchaiya(1)	0.52	37.60
26	Duhabi-Damak	5.17	94.78
27	Dumkibas-Bardaghat	3.30	194.27
28	Dumkibas-Kawasoti	3.10	96.36
29	Gandak-Bardaghat(1)	0.00	5.01
30	Godak-Amarpur 132kV	0.60	30.08
31	Godak-Amarpur 132kV(1)	0.60	30.08
32	Hetauda-pathlaiya	7.11	127.61
33	Inarwa-Duhabi	0.00	0.63
34	Inarwa-Duhabi1	0.00	0.63
35	Inruwa-Tumlingtar220kV	1.90	45.03
36	Kohal-Kusum	0.67	34.51
37	Kul-3(1)	0.00	11.68
38	Kusaha-Inarwa	0.02	11.37
39	Kusaha-Inarwa(1)	0.02	11.37

40	Kusma-Dana220kV	0.23	25.83
41	Kusma-Dana220kV(1)	0.23	25.83
42	Kusma-Modi132kV	0.08	34.07
43	Kusum-Hapure132kV	0.02	9.93
44	Lahachowk-Lekhnath1	0.00	0.75
45	Lahachowk-Lekhnath2	0.00	0.77
46	Lahan-Rupani	0.01	5.93
47	Lahan-Rupani1	0.01	5.93
48	Lamahi-Ghorahi	0.04	15.73
49	Lamahi-Ghorahi1	0.04	15.73
50	Lamahi-Jhimruk	0.05	14.30
51	Lumki-Burigaon	1.04	51.02
52	Lumki-Burigaon(1)	1.04	51.02
53	MMRS-Kirtipur	1.51	104.03
54	Mahen-Attari	0.04	7.97
55	Mahen-Attari(1)	0.04	7.97
56	Mata-Hetauda	3.29	87.74
57	Modi-New Modi	0.00	6.25
58	Modi-New Modi(1)	0.00	0.03
59	Motipur-Sandhikhark	0.01	5.07
60	Motipur-Sandhikhark1	0.01	5.07
61	Motipur-Shivpur	0.07	16.66
62	Motipur-Shivpur(1)	0.07	16.66
63	NB-Sunwal	0.03	11.13
64	NB-Sunwal1	0.03	11.13
65	NMRS-Matatirtha	3.80	71.57
66	NMRS-Matatirtha2	3.80	71.57
67	Nabalpir-Dhalke1	0.25	25.17
68	Nabalpur-Dhalke	0.25	25.17
69	New Modi-Lahachok	0.00	3.38
70	New Modi-Lahachok(1)	0.00	3.38
71	NewBharatpur-Hetauda	11.20	135.65
72	NewButwal-Kusuma	1.16	40.53
73	NewButwal-Kusuma1	1.16	40.53
74	Newbharatpur-mars	0.38	36.09
75	Nyadi-UpperMarsyan	0.04	23.66
76	Pathlaiya-Chapur	0.40	33.21
77	Phalam-Lumki	1.07	56.02
78	Phalam-Lumki(1)	1.07	56.02
79	Rupani-Kusaha	0.03	8.32
80	Rupani-Kusaha1	0.03	8.32
81	Samun-Matatirtha	1.81	67.35
82	Samun-Matatirtha(1)	0.00	1.90

83	Samun-Trishuli3B	0.19	19.94
84	Samun-Trishuli3B_2	0.19	19.94
85	Singati-Lamosanghu	1.78	61.32
86	Syangja-Kga-Lekhnath	0.00	5.74
87	Syaule-Attaria Ckt	4.06	75.63
88	Syaule-Attaria Ckt(1)	4.06	75.63
89	Teku-K3	0.00	12.08
90	Teku-Swichatar2	0.09	52.61
91	Tingla-Mirchaiya	1.90	35.20
92	Tingla-Mirchaiya(1)	1.90	35.20
93	UpperMarsyan-MMarsyan	0.99	63.37
94	Whasin 132kv	0.00	10.50
95	amlekh-simara	0.24	52.63
96	amlekh-simara(1)	0.24	52.63
97	balaju-chapali	0.00	3.79
98	balaju-chapali(1)	0.00	3.79
99	balaju-lainchaur	0.00	0.06
100	balaju-switchatar132	0.09	40.47
101	balaju66-trisuli	1.76	100.22
102	balaju66-trisuli(1)	1.76	100.22
103	banepa-panchkahl	0.09	38.40
104	baneshwor-bhaktapur	0.99	101.65
105	bhaktapur-changu	0.17	62.77
106	bhaktapur-changu(1)	0.17	62.77
107	bhaktapurbanepa	0.05	23.13
108	bharatpur-mars(1)	0.01	40.06
109	birgunj-parwani	0.56	95.87
110	birgunj-parwani(1)	0.56	95.87
111	butwal-kga	3.23	55.10
112	butwal-kga(1)	3.23	55.10
113	chapali-changu	0.38	62.73
114	chapali-changu(1)	0.38	62.73
115	chapali-devighat	0.06	19.32
116	chapali-devighat(1)	0.06	19.32
117	chilime-trisuli	2.64	99.82
118	damak-anarmani	0.56	42.38
119	damauli-bharatpur	1.16	65.91
120	damauli-nmrs	0.23	23.57
121	damauli-nmrs(1)	0.23	23.57
122	dhalke-muzza	1.68	70.67
123	dhalke-muzza(1)	1.68	70.67
124	gandak-bardaghat	0.00	5.01
125	hetauda-amlekhgunj	0.40	54.12

126	hetauda-amlekhgunj(1)	0.40	54.12
127	hetauda-bharatpur	0.00	3.36
128	hetauda-kamane	4.18	138.44
129	hetauda-kul2(1)	0.34	73.79
130	hetauda-kul2(1)_a	0.14	62.67
131	ilam-damak	2.75	81.64
132	ilam-damak(1)	2.75	81.64
133	kamane-pathlaiya	2.99	117.03
134	kga-lekhnath	0.71	26.54
135	kga-lekhnath_a	0.70	30.48
136	khimti-dhalke	11.65	137.37
137	khimti-dhalke(1)	11.65	137.37
138	kohal-kusum	0.67	34.51
139	ku1-switch66	0.86	62.36
140	kul1-switch66	0.86	62.36
141	kule2-matatirtha	1.20	39.02
142	kulekhani1-hetauda	1.49	120.52
143	kulekhani1-hetauda(1)	1.49	120.52
144	kushaha-kataiya	0.00	0.52
145	kushaha-kataiya2	0.00	0.52
146	kushaha-kataiya3	0.00	0.52
147	kusum-lamahi	0.50	30.12
148	kusum-lamahi(1)	0.50	30.12
149	lainchaur-newchabil	0.00	0.07
150	lainchaur-newchabil(1)	0.21	111.75
151	lamahi-shivpur	0.03	8.46
152	lamahi-shivpur(1)	0.03	8.46
153	lamosanghu-bhotekoshi	1.04	53.54
154	lamosanghu-khimti	3.68	114.41
155	lekhnath-damauli	0.77	50.23
156	mars-switchatar	1.81	49.56
157	mars-switchatar_a	2.81	42.77
158	matatirtha-switchatar	0.10	43.01
159	matatirtha-switchatar(1)	0.10	43.01
160	mirchaiya-lahan	0.04	11.92
161	mirchaiya-lahan(1)	0.04	11.92
162	mmrs-damauli	3.53	67.18
163	newchabil-chapali	1.24	202.65
164	newchabil-chapali(1)	1.24	202.65
165	nmrs-mmrs(1)	6.77	108.14
166	nrms-mrs	0.02	14.34
167	nrms-mrs2	0.02	14.34
168	panchkahl-sunkoshi	0.05	16.56

169	panchkhal-indrawati	0.20	31.57
170	patan-baneshwor	0.00	0.09
171	pathlaiya-Chapur	0.40	33.21
172	pathlaiya-parwani	1.48	87.08
173	pathlaiya-parwani(1)	1.48	87.08
174	pkr-lekhnath	0.02	20.01
175	pkr-modi	0.04	7.57
176	ramnagarimpline	0.00	0.00
177	seti-pkr	0.00	2.01
178	simara-parwani66	0.00	0.30
179	simara-parwani66(1)	0.00	0.30
180	switch-patan	0.28	78.86
181	switch66-balaju66	0.17	75.36
182	switch66-balaju66(1)	0.17	75.36
183	switch66-k3	0.08	40.75
184	switch66-teku	0.09	52.61
185	swtch-patan	0.28	78.86
186	teku-k3	0.00	14.11
187	trisuli-devighat	0.00	0.15

APPENDIX E: List of Transmission Line, Line Loss and Loading for Case II

Table 5: Line Loss and Line Loading of Transmission Line for Case II

S.N.	Name	Line Loss (MW)	Line Loading (%)
1	Attari-Phalam	1.41	58.43
2	Attari-Phalam(1)	1.41	58.43
3	Balanch-Syaule	2.53	55.37
4	Balanch-Syaule(1)	2.53	55.37
5	Bard-NB	0.80	82.46
6	Bard-NB1	0.80	82.46
7	Bardaghat-Sardi	0.01	7.35
8	Bardaghat-Sardi(1)	0.01	7.35
9	Bardghat-New Bharatpur	2.73	68.94
10	Bhaktapur-Lamosanghu	7.90	117.69
11	Bhaktapur-Lamosanghu(1)	7.90	117.69
12	Bharatpur-Kawasoti	0.91	66.19
13	Burigaon-Kohal	1.63	50.21
14	Burigaon-Kohal(1)	1.63	50.21
15	But-Sun	0.05	19.05
16	But-Sun1	0.05	19.05
17	Butwal-Mainahiya	0.06	16.35
18	Butwal-Mainahiya(1)	0.06	16.35
19	Butwal-Motipur	0.20	21.13
20	Butwal-Motipur1	0.20	21.13
21	Chapali-Balaju	0.00	3.20
22	Chapur-Nabalpur	0.01	6.39
23	Chapur-Nabalpur1	0.02	6.37
24	Dhalkebar-Mirchaiya	0.50	36.80
25	Dhalkebar-Mirchaiya(1)	0.50	36.80
26	Dharapani-Khudi1	0.00	3.75
27	Dharapani-Khudi2	0.00	3.75
28	Duhabi-Damak	5.19	95.05
29	Dumkibas-Bardaghat	3.24	192.54
30	Dumkibas-Kawasoti	3.05	95.80
31	Gandak-Bardaghat(1)	0.00	5.01
32	Godak-Amarpur 132kV	0.62	30.72
33	Godak-Amarpur 132kV(1)	0.62	30.72
34	Hetauda-pathlaiya	4.85	105.43
35	Inarwa-Duhabi	0.00	0.68
36	Inarwa-Duhabi1	0.00	0.68
37	Inruwa-Tumlingtar220kV	1.84	44.36
38	Khudi-Udipur1	0.01	6.99
39	Khudi-Udipur2	0.01	6.99

40	Kirtipur-Udipur1	0.01	7.66
41	Kirtipur-Udipur2	0.07	7.66
42	Kohal-Kusum	0.67	34.39
43	Kul-3(1)	0.00	10.93
44	Kusaha-Inarwa	0.02	11.93
45	Kusaha-Inarwa(1)	0.02	11.93
46	Kusma-Dana220kV	0.23	25.82
47	Kusma-Dana220kV(1)	0.23	25.82
48	Kusma-Modi132kV	0.08	34.56
49	Kusum-Hapure132kV	0.02	9.85
50	Lahachowk-Lekhnath1	0.00	0.77
51	Lahachowk-Lekhnath2	0.00	0.80
52	Lahan-Rupani	0.01	5.47
53	Lahan-Rupani1	0.01	5.47
54	Lamahi-Ghorahi	0.04	15.62
55	Lamahi-Ghorahi1	0.04	15.62
56	Lamahi-Jhimruk	0.05	14.22
57	Lumki-Burigaon	1.03	50.96
58	Lumki-Burigaon(1)	1.03	50.96
59	MMRS-Kirtipur	0.08	24.35
60	Mahen-Attari	0.04	7.94
61	Mahen-Attari(1)	0.04	7.94
62	Mata-Hetauda	0.85	44.73
63	Modi-New Modi	0.00	6.25
64	Modi-New Modi(1)	0.00	0.03
65	Motipur-Sandhikhark	0.01	5.03
66	Motipur-Sandhikhark1	0.01	5.03
67	Motipur-Shivpur	0.07	16.45
68	Motipur-Shivpur(1)	0.07	16.45
69	NB-Sunwal	0.04	13.56
70	NB-Sunwal1	0.04	13.56
71	NMRS-Matatirtha	0.45	24.73
72	NMRS-Matatirtha2	0.45	24.73
73	Nabalpir-Dhalke1	0.12	17.46
74	Nabalpur-Dhalke	0.12	17.46
75	New Modi-Lahachok	0.00	3.38
76	New Modi-Lahachok(1)	0.00	3.38
77	NewBharatpur-Hetauda	1.74	53.67
78	NewBharatpur-NewHetauda1	0.64	33.02
79	NewBharatpur-NewHetauda2	0.64	33.02
80	NewButwal-Kusuma	1.17	40.66
81	NewButwal-Kusuma1	1.17	40.66
82	NewMarsyangdi-Matatirtha1	0.16	14.97

83	NewMarsyangdi-Matatirtha2	0.16	14.97
84	NewMarsyangdi-NewBharatpur1	0.07	17.26
85	NewMarsyangdi-NewBharatpur2	0.07	17.26
86	Newbharatpur-mars	0.10	18.33
87	Nyadi-UpperMarsyan	0.04	24.23
88	Pathlaiya-Chapur	0.14	19.75
89	Phalam-Lumki	1.06	55.91
90	Phalam-Lumki(1)	1.06	55.91
91	Rupani-Kusaha	0.03	9.32
92	Rupani-Kusaha1	0.03	9.32
93	Samun-Matatirtha	1.40	58.91
94	Samun-Matatirtha(1)	0.00	1.92
95	Samun-Trishuli3B	0.15	17.79
96	Samun-Trishuli3B_2	0.15	17.79
97	Singati-Lamosanghu	1.69	59.90
98	Syangja-Kga-Lekhnath	0.00	5.74
99	Syaule-Attaria Ckt	4.03	75.42
100	Syaule-Attaria Ckt(1)	4.03	75.42
101	Teku-K3	0.00	12.23
102	Teku-Swichatar2	0.08	50.99
103	Tingla-Mirchaiya	1.85	34.73
104	Tingla-Mirchaiya(1)	1.85	34.73
105	Udipur-NewMarsyangdi1	0.17	22.14
106	Udipur-NewMarsyangdi2	0.17	22.14
107	UpperMarsyan-Khudi132	0.10	66.34
108	UpperMarsyan-MMarsyan	0.02	8.44
109	Whasin 132kv	0.00	9.99
110	amlekh-simara	0.24	52.05
111	amlekh-simara(1)	0.24	52.05
112	balaju-chapali	0.00	4.23
113	balaju-chapali(1)	0.00	4.23
114	balaju-lainchaur	0.00	0.07
115	balaju-switchatar132	0.08	38.55
116	balaju66-trisuli	1.80	101.31
117	balaju66-trisuli(1)	1.80	101.31
118	banepa-panchkahl	0.08	36.79
119	baneshwor-bhaktapur	0.98	101.47
120	bhaktapur-changu	0.17	63.21
121	bhaktapur-changu(1)	0.17	63.21
122	bhaktapurbanepa	0.04	21.88
123	bharatpur-mars(1)	0.00	18.00

124	birgunj-parwani	0.59	98.45
125	birgunj-parwani(1)	0.59	98.45
126	butwal-kga	3.24	55.19
127	butwal-kga(1)	3.24	55.19
128	chapali-changu	0.39	63.16
129	chapali-changu(1)	0.39	63.16
130	chapali-devighat	0.06	18.28
131	chapali-devighat(1)	0.06	18.28
132	chilime-trisuli	2.64	99.82
133	damak-anarmani	0.55	41.96
134	damauli-bharatpur	0.20	27.78
135	damauli-nmrs	0.05	10.81
136	damauli-nmrs(1)	0.05	10.81
137	dhalke-muzza	1.48	66.36
138	dhalke-muzza(1)	1.48	66.36
139	gandak-bardaghat	0.00	5.01
140	hetauda-amlekhgunj	0.39	53.44
141	hetauda-amlekhgunj(1)	0.39	53.44
142	hetauda-bharatpur	0.00	3.52
143	hetauda-kamane	2.90	115.31
144	hetauda-kul2(1)	0.16	50.16
145	hetauda-kul2(1)_a	0.06	39.74
146	ilam-damak	2.70	80.88
147	ilam-damak(1)	2.70	80.88
148	kamane-pathlaiya	2.00	95.80
149	kga-lekhnath	0.69	26.18
150	kga-lekhnath_a	0.68	30.12
151	khimti-dhalke	11.65	137.48
152	khimti-dhalke(1)	11.65	137.48
153	kohal-kusum	0.67	34.39
154	ku1-switch66	0.28	35.82
155	kul1-switch66	0.28	35.82
156	kule2-matatirtha	0.29	19.56
157	kulekhani1-hetauda	0.61	77.18
158	kulekhani1-hetauda(1)	0.61	77.18
159	kushaha-kataiya	0.00	0.53
160	kushaha-kataiya2	0.00	0.53
161	kushaha-kataiya3	0.00	0.53
162	kusum-lamahi	0.50	30.05
163	kusum-lamahi(1)	0.50	30.05
164	lainchaur-newchabil	0.00	0.07
165	lainchaur-newchabil(1)	0.24	119.08
166	lamahi-shivpur	0.03	8.42

167	lamahi-shivpur(1)	0.03	8.42
168	lamosanghu-bhotekoshi	0.99	52.00
169	lamosanghu-khimti	3.52	111.96
170	lekhnath-damauli	0.72	48.58
171	mars-switchatar	0.34	21.51
172	mars-switchatar_a	0.33	14.79
173	matatirtha-switchatar	0.14	52.29
174	matatirtha-switchatar(1)	0.14	52.29
175	mirchaiya-lahan	0.04	11.28
176	mirchaiya-lahan(1)	0.04	11.28
177	mmrs-damauli	0.46	24.34
178	newchabil-chapali	1.38	213.70
179	newchabil-chapali(1)	1.38	213.70
180	nmrs-mmrs(1)	0.96	40.65
181	nrms-mrs	0.01	8.93
182	nrms-mrs2	0.01	8.93
183	panchkahl-sunkoshi	0.05	15.84
184	panchkhal-indrawati	0.18	30.20
185	patan-baneshwor	0.00	0.09
186	pathlaiya-Chapur	0.14	19.75
187	pathlaiya-parwani	1.45	86.21
188	pathlaiya-parwani(1)	1.45	86.21
189	pkr-lekhnath	0.02	20.86
190	pkr-modi	0.04	7.56
191	ramnagarimpline	0.00	0.00
192	seti-pkr	0.00	2.01
193	simara-parwani66	0.00	0.33
194	simara-parwani66(1)	0.00	0.33
195	switch-patan	0.26	75.86
196	switch66-balaju66	0.13	66.99
197	switch66-balaju66(1)	0.13	66.99
198	switch66-k3	0.07	39.64
199	switch66-teku	0.08	50.99
200	swtch-patan	0.26	75.86
201	teku-k3	0.00	14.28
202	trisuli-devighat	0.00	0.16

APPENDIX F: Comparison of Line Loss and Line Loading for Both Cases

Table 6: Comparison of Line Loss and Line Loading for Both Cases

S.N.	Name	Difference in Loss (MW)	Difference in Loading (%)
1	Attari-Phalam	0.01	0.12
2	Attari-Phalam(1)	0.01	0.12
3	Balanch-Syaule	0.00	-0.03
4	Balanch-Syaule(1)	0.00	-0.03
5	Bard-NB	0.03	1.36
6	Bard-NB1	0.03	1.36
7	Bardaghat-Sardi	0.00	0.12
8	Bardaghat-Sardi(1)	0.00	0.12
9	Bardghat-New Bharatpur	0.09	0.98
10	Bhaktapur-Lamosanghu	0.48	3.51
11	Bhaktapur-Lamosanghu(1)	0.48	3.51
12	Bharatpur-Kawasoti	0.06	2.10
13	Burigaon-Kohal	0.01	0.07
14	Burigaon-Kohal(1)	0.01	0.07
15	But-Sun	-0.02	-3.52
16	But-Sun1	-0.02	-3.52
17	Butwal-Mainahiya	0.00	0.12
18	Butwal-Mainahiya(1)	0.00	0.12
19	Butwal-Motipur	0.01	0.27
20	Butwal-Motipur1	0.01	0.27
21	Chapali-Balaju	0.00	-0.33
22	Chapur-Nabalpur	0.08	14.44
23	Chapur-Nabalpur1	0.16	14.65
24	Dhalkebar-Mirchaiya	0.02	0.80
25	Dhalkebar-Mirchaiya(1)	0.02	0.80
26	Duhabi-Damak	-0.02	-0.27
27	Dumkibas-Bardaghat	0.06	1.73
28	Dumkibas-Kawasoti	0.05	0.57
29	Gandak-Bardaghat(1)	0.00	0.00
30	Godak-Amarpur 132kV	-0.02	-0.63
31	Godak-Amarpur 132kV(1)	-0.02	-0.63
32	Hetauda-pathlaiya	2.26	22.18
33	Inarwa-Duhabi	0.00	-0.05
34	Inarwa-Duhabi1	0.00	-0.05
35	Inruwa-Tumlingtar220kV	0.06	0.68
36	Kohal-Kusum	0.01	0.12

37	Kul-3(1)	0.00	0.75
38	Kusaha-Inarwa	0.00	-0.57
39	Kusaha-Inarwa(1)	0.00	-0.57
40	Kusma-Dana220kV	0.00	0.01
41	Kusma-Dana220kV(1)	0.00	0.01
42	Kusma-Modi132kV	0.00	-0.49
43	Kusum-Hapure132kV	0.00	0.09
44	Lahachowk-Lekhnath1	0.00	-0.03
45	Lahachowk-Lekhnath2	0.00	-0.03
46	Lahan-Rupani	0.00	0.46
47	Lahan-Rupani1	0.00	0.46
48	Lamahi-Ghorahi	0.00	0.10
49	Lamahi-Ghorahi1	0.00	0.10
50	Lamahi-Jhimruk	0.00	0.08
51	Lumki-Burigaon	0.00	0.06
52	Lumki-Burigaon(1)	0.00	0.06
53	MMRS-Kirtipur	1.43	79.68
54	Mahen-Attari	0.00	0.03
55	Mahen-Attari(1)	0.00	0.03
56	Mata-Hetauda	2.44	43.02
57	Modi-New Modi	0.00	0.00
58	Modi-New Modi(1)	0.00	0.00
59	Motipur-Sandhikhark	0.00	0.05
60	Motipur-Sandhikhark1	0.00	0.05
61	Motipur-Shivpur	0.00	0.20
62	Motipur-Shivpur(1)	0.00	0.20
63	NB-Sunwal	-0.01	-2.42
64	NB-Sunwal1	-0.01	-2.42
65	NMRS-Matatirtha	3.35	46.84
66	NMRS-Matatirtha2	3.35	46.84
67	Nabalpir-Dhalke1	0.13	7.71
68	Nabalpur-Dhalke	0.13	7.71
69	New Modi-Lahachok	0.00	0.00
70	New Modi-Lahachok(1)	0.00	0.00
71	NewBharatpur-Hetauda	9.46	81.97
72	NewButwal-Kusuma	-0.01	-0.12
73	NewButwal-Kusuma1	-0.01	-0.12
74	Newbharatpur-mars	0.28	17.76
75	Nyadi-UpperMarsyan	0.00	-0.57
76	Pathlaiya-Chapur	0.26	13.46
77	Phalam-Lumki	0.00	0.10
78	Phalam-Lumki(1)	0.00	0.10
79	Rupani-Kusaha	-0.01	-1.00

80	Rupani-Kusaha1	-0.01	-1.00
81	Samun-Matatirtha	0.41	8.44
82	Samun-Matatirtha(1)	0.00	-0.02
83	Samun-Trishuli3B	0.04	2.15
84	Samun-Trishuli3B_2	0.04	2.15
85	Singati-Lamosanghu	0.08	1.42
86	Syangja-Kga-Lekhnath	0.00	0.00
87	Syaule-Attaria Ckt	0.02	0.21
88	Syaule-Attaria Ckt(1)	0.02	0.21
89	Teku-K3	0.00	-0.15
90	Teku-Swichatar2	0.01	1.63
91	Tingla-Mirchaiya	0.05	0.47
92	Tingla-Mirchaiya(1)	0.05	0.47
93	UpperMarsyan-MMarsyan	0.97	54.94
94	Whasin 132kv	0.00	0.51
95	amlekh-simara	0.01	0.58
96	amlekh-simara(1)	0.01	0.58
97	balaju-chapali	0.00	-0.44
98	balaju-chapali(1)	0.00	-0.44
99	balaju-lainchaur	0.00	0.00
100	balaju-switchatar132	0.01	1.92
101	balaju66-trisuli	-0.04	-1.09
102	balaju66-trisuli(1)	-0.04	-1.09
103	banepa-panchkahl	0.01	1.61
104	baneshwor-bhaktapur	0.00	0.18
105	bhaktapur-changu	0.00	-0.44
106	bhaktapur-changu(1)	0.00	-0.44
107	bhaktapurbanepa	0.01	1.26
108	bharatpur-mars(1)	0.01	22.07
109	birgunj-parwani	-0.03	-2.59
110	birgunj-parwani(1)	-0.03	-2.59
111	butwal-kga	-0.01	-0.09
112	butwal-kga(1)	-0.01	-0.09
113	chapali-changu	0.00	-0.42
114	chapali-changu(1)	0.00	-0.42
115	chapali-devighat	0.01	1.03
116	chapali-devighat(1)	0.01	1.03
117	chilime-trisuli	0.00	0.00
118	damak-anarmani	0.01	0.42
119	damauli-bharatpur	0.95	38.13
120	damauli-nmrs	0.19	12.77
121	damauli-nmrs(1)	0.19	12.77

122	dhalke-muzza	0.20	4.30
123	dhalke-muzza(1)	0.20	4.30
124	gandak-bardaghat	0.00	0.00
125	hetauda-amlekhgunj	0.01	0.68
126	hetauda-amlekhgunj(1)	0.01	0.68
127	hetauda-bharatpur	0.00	-0.17
128	hetauda-kamane	1.28	23.14
129	hetauda-kul2(1)	0.18	23.63
130	hetauda-kul2(1)_a	0.08	22.93
131	ilam-damak	0.05	0.75
132	ilam-damak(1)	0.05	0.75
133	kamane-pathlaiya	0.99	21.24
134	kga-lekhnath	0.02	0.36
135	kga-lekhnath_a	0.02	0.36
136	khimti-dhalke	0.00	-0.11
137	khimti-dhalke(1)	0.00	-0.11
138	kohal-kusum	0.01	0.12
139	ku1-switch66	0.58	26.54
140	kul1-switch66	0.58	26.54
141	kule2-matatirtha	0.91	19.46
142	kulekhani1-hetauda	0.88	43.34
143	kulekhani1-hetauda(1)	0.88	43.34
144	kushaha-kataiya	0.00	-0.01
145	kushaha-kataiya2	0.00	-0.01
146	kushaha-kataiya3	0.00	-0.01
147	kusum-lamahi	0.00	0.07
148	kusum-lamahi(1)	0.00	0.07
149	lainchaur-newchabil	0.00	0.00
150	lainchaur-newchabil(1)	-0.03	-7.33
151	lamahi-shivpur	0.00	0.04
152	lamahi-shivpur(1)	0.00	0.04
153	lamosanghu-bhotekoshi	0.06	1.54
154	lamosanghu-khimti	0.16	2.45
155	lekhnath-damauli	0.05	1.65
156	mars-switchatar	1.47	28.05
157	mars-switchatar_a	2.47	27.97
158	matatirtha-switchatar	-0.05	-9.29
159	matatirtha-switchatar(1)	-0.05	-9.29
160	mirchaiya-lahan	0.00	0.64
161	mirchaiya-lahan(1)	0.00	0.64
162	mmrs-damauli	3.07	42.83
163	newchabil-chapali	-0.14	-11.04
164	newchabil-chapali(1)	-0.14	-11.04

165	nmrs-mmrs(1)	5.81	67.49
166	nrms-mrs	0.01	5.41
167	nrms-mrs2	0.01	5.41
168	panchkahl-sunkoshi	0.00	0.72
169	panchkhal-indrawati	0.02	1.38
170	patan-baneshwor	0.00	0.00
171	pathlaiya-Chapur	0.26	13.46
172	pathlaiya-parwani	0.03	0.88
173	pathlaiya-parwani(1)	0.03	0.88
174	pkr-lekhnath	0.00	-0.85
175	pkr-modi	0.00	0.00
176	ramnagarimpline	0.00	0.00
177	seti-pkr	0.00	0.00
178	simara-parwani66	0.00	-0.03
179	simara-parwani66(1)	0.00	-0.03
180	switch-patan	0.02	3.00
181	switch66-balaju66	0.04	8.37
182	switch66-balaju66(1)	0.04	8.37
183	switch66-k3	0.00	1.11
184	switch66-teku	0.01	1.63
185	swtch-patan	0.02	3.00
186	teku-k3	0.00	1.88
187	trisuli-devighat	0.00	-0.01

APPENDIX G: Comparison of Voltage Profile in Busbar for Both Cases

Table 7: Comparison of Voltage Profile in Busbar for Both Cases

S.N.	Name	Nominal Voltage (kV)	Voltage Magnitude for Case I (p.u.)	Voltage Magnitude for Case II (p.u.)	Voltage Profile Improvement (p.u)
1	Amarpur 132kV	132	1.00	1.00	0.00
2	Anarmani	132	0.94	0.95	0.01
3	Attariya	132	0.94	0.94	0.00
4	BUTWAL S/S	132	0.98	0.99	0.01
5	Balaju 66kV Bus	66	0.94	0.96	0.03
6	Balaju132Kv Bus	132	0.92	0.96	0.05
7	Balanch	132	1.00	1.00	0.00
8	Banepa	66	0.93	0.98	0.05
9	Bardaghat	132	0.98	1.00	0.02
10	Bhaktapur132	132	0.92	0.96	0.04
11	Bharatpur	132	0.93	0.98	0.05
12	Birgunj	66	0.94	1.03	0.09
13	Burigaon	132	0.93	0.94	0.01
14	Chapur	132	0.90	0.96	0.06
15	ChilimeHydroSS	66	1.00	1.00	0.00
16	Damak	132	0.96	0.97	0.01
17	Dana 132kV	132	1.06	1.06	0.00
18	Dana220kV	220	1.06	1.06	0.00
19	Dhalke400	400	0.99	0.99	0.00
20	Dhalkebar ss 132kV	132	0.95	0.98	0.03
21	Duhabi	132	0.96	0.98	0.02
22	Gandak	132	0.98	1.00	0.02
23	Ghorahi Bus	132	0.94	0.95	0.01
24	Hapure SS	132	0.93	0.94	0.01
25	Hetauda 132kV Bus	132	0.92	0.98	0.06
26	Hetauda 66kV Bus	66	0.94	0.97	0.04
27	Ilam	132	0.99	1.00	0.01
28	Inariwa 132kV(1)	132	0.96	0.98	0.02
29	Inaruwa 220kV	220	0.97	0.98	0.02
30	Jhimruk	132	0.96	0.97	0.01
31	KGA	132	1.00	1.00	0.00
32	Kamane	132	0.90	0.97	0.07
33	Khimti132(1)	132	1.04	1.06	0.02
34	Khimti132(2)	132	1.01	1.01	0.00
35	Kirtipur SS	132	1.01	1.00	-0.01
36	Kohalpur	132	0.94	0.94	0.01
37	Kulekhani I	66	1.00	1.00	0.00

38	Kulekhani II	132	0.92	0.98	0.06
39	Kulekhani III	132	0.92	0.98	0.06
40	Kushma132kV	132	1.04	1.04	0.00
41	Kushma220kV	220	1.05	1.05	0.00
42	Lahachok 132kV	132	1.04	1.04	0.00
43	Lahan	132	0.97	0.99	0.02
44	Lainchaur	66	0.99	1.06	0.07
45	Lamahi	132	0.95	0.95	0.01
46	Lamosanghu	132	0.97	1.00	0.02
47	Lekhnath132(1)	132	1.03	1.03	0.00
48	Lekhnath132(2)	132	0.97	1.00	0.03
49	Lumki	132	0.93	0.93	0.01
50	M-Mars	132	1.00	1.00	0.00
51	Mahendranagar	132	0.93	0.94	0.00
52	Mainahiya SS	132	0.98	0.99	0.01
53	Matatirtha	132	0.92	0.97	0.05
54	Mirchaiya	132	0.96	0.98	0.02
55	Modi132kV	132	1.04	1.04	0.00
56	Motipur 132kV Bus	132	0.97	0.98	0.01
57	Muzzafapur	400	1.00	1.00	0.00
58	NMRS	132	0.95	0.99	0.04
59	Nabalpur	132	0.92	0.96	0.04
60	New Butwal 132kV	132	0.99	1.01	0.01
61	New Butwal 220kV	220	1.03	1.03	0.00
62	New Modi 132kV	132	1.04	1.04	0.00
63	New-Butwal SS	400	1.03	1.03	0.00
64	NewBharatpur	132	0.93	0.98	0.05
65	Nyadi	132	1.03	1.01	-0.02
66	Parwanipur 66kV	66	0.94	1.02	0.09
67	Parwanipur132kV	132	0.91	0.98	0.08
68	Patan	66	0.92	0.95	0.03
69	Phalampur	132	0.93	0.93	0.00
70	Pokhara	132	1.03	1.03	0.00
71	Ramnagarimp	132	0.98	1.00	0.02
72	Rupani	132	0.97	0.98	0.02
73	Samudartar	132	1.00	1.00	0.00
74	Sandhikharka 132kV	132	0.96	0.97	0.01
75	Sardi 132kV	132	0.98	1.00	0.02
76	SetiHydroSS	132	1.03	1.03	0.00
77	Simara	66	0.93	0.97	0.04
78	Singati	132	0.99	1.01	0.02
79	Sunwal SS	132	0.99	1.00	0.01
80	SunwalSS(2)	132	0.99	1.00	0.01

81	Switchatar132kv	132	0.92	0.97	0.05
82	SyangjaSS	132	1.02	1.02	0.00
83	Syaule SS	132	0.97	0.98	0.00
84	Teku	66	0.93	0.96	0.03
85	Tingla132kV	132	1.00	1.00	0.00
86	Trishuli3B Hub	132	0.99	1.00	0.01
87	Tumlingtar 132kV	132	1.05	1.06	0.02
88	Tumlingtar 220kV	220	1.02	1.04	0.02
89	Upper Khimti 220	220	1.00	1.00	0.00
90	UpperMarsyangdi	132	1.03	1.00	-0.02
91	amlekhgunj	66	0.93	0.97	0.04
92	baneshwor	66	0.94	0.99	0.05
93	bhaktapur	66	0.94	0.98	0.05
94	bhotekoshi	132	1.00	1.00	0.00
95	changunarayan	132	0.92	0.96	0.04
96	chapali	66	0.97	1.04	0.06
97	chapali132	132	0.92	0.96	0.04
98	damauli	132	0.95	0.99	0.03
99	devighat	66	0.99	1.05	0.06
100	dhalke220	220	0.98	0.98	0.01
101	indrawati	66	0.97	1.01	0.05
102	k-3	66	0.93	0.96	0.03
103	kataiya	132	0.96	0.98	0.02
104	kawasoti	132	0.95	0.99	0.04
105	kushaha	132	0.96	0.98	0.02
106	kusum	132	0.94	0.95	0.01
107	marsyangdi	132	0.95	0.99	0.04
108	newchabil	66	0.99	1.05	0.06
109	panchkhal	66	0.94	0.99	0.05
110	pathlaiya	132	0.90	0.97	0.07
111	shivapur	132	0.96	0.97	0.01
112	sunkoshi	66	0.95	1.00	0.05
113	switchatar66	66	0.93	0.96	0.03
114	trisuli	66	1.00	1.00	0.00

APPENDIX H: List of Hydropower to be Connected to MCTLP

Some of the major hydropower to be connected to Marsyangdi Corridor 220kV Transmission Line Project are:

Table 8: List of Major Hydropower to be Connected to MCTLP [19]

S.N.	Name of Hydropower	Installed Capacity (MW)	Connection To
1.	Upper Marsyangdi A HEP	50	Khudi S/S
2.	Marsyangdi Besi HEP	50	Dharapani
3.	Manang Marsyangdi	282	Dharapani
4.	Tallo Manang Marsyangdi HEP	140	Dharapani
5.	Upper Marsyangdi 1 HEP	138	Khudi
6.	Dordi-1 HEP	12	Udipur
7.	Nyadi Khola HEP	30	Khudi
8.	Nyadi-Phidi HEP	21.40	Khudi
9.	Super Nyadi HEP	40.27	Khudi
10.	Upper Khudi HEP	26	Khudi
11.	Himchuli Dordi HEP	57	Udipur
12.	Narkhola HPP	61.11	Dharapani
13.	Lower Nyadi	12.6	Khudi
	Total	**920.38**	

APPENDIX I: Base Rate of "Class A" Commercial Bank of Nepal

Table 9: Base Rate of Commercial Banks of Nepal [23]

S.N.	Bank	Base Rate
1	Standard Chartered Bank	5.11%
2	Rastriya Banijya Bank	5.44%
3	Everest Bank	5.63%
4	Nepal Bank Limited	6.12%
5	Nabil Bank	6.17%
6	Nepal Investment Mega Bank	6.41%
7	Agricultural Development Bank	6.63%
8	NMB Bank	6.73%
9	Global IME Bank	6.74%
10	Sanima Bank	6.76%
11	Prabhu Bank	6.87%
12	Machhapuchhre Bank	6.90%
13	Siddhartha Bank	6.90%
14	Nepal SBI Bank	6.97%
15	Himalayan Bank	7.06%
16	Kumari Bank	7.12%
17	Laxmi Sunrise Bank	7.13%
18	Prime Commercial Bank	7.16%
19	Citizens Bank International	7.29%
20	NIC Asia Bank	7.53%

9% Overall Similarity

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