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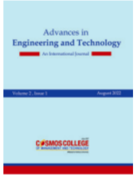

Impact Study of the Hetauda-Dhalkewar-Inaruwa Transmission Line on the Operation of Integrated Nepal Power System

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Abstract

Despite Nepal's abundant hydroelectric resources, a substantial disparity exists between its electricity supply and demand. This discrepancy is exacerbated by the absence of high-voltage transmission lines, hindering efficient power evacuation from a handful of generating plants. This not only incurs financial losses for the utility but also compromises the reliability of the power supply. A prime example is the protracted delay in the construction of the 576 KM long Hetauda-Dhalkebar-Inaruwa 400kV double-circuit Transmission Line, primarily due to challenges posed by local residents unwilling to relinquish their land.The Integrated Nepal Power System (INPS) heavily relies on power generation concentrated in the central mid-hills region. The construction of the Hetauda-Dhalkebar-Inaruwa (HDITL) 400kV double-circuit Transmission Line is crucial for routing power to industrialize these areas, potentially bolstering the national GDP and generating employment opportunities. Furthermore, it is essential to connect the current hydropower output of around 2300 MW to the INPS system via a high-voltage transmission line to maximize its utilization.

The HDITL project not only reduces line losses but also enhances grid stability. It facilitates energy export and direct transmission of high-generation power, such as the 456 MW from Upper Tamakoshi, thus saving approximately 400 MW of power and preventing losses for both the Government of Nepal (GoN) and the Nepal Electricity Authority.

This research not only calculates the reduction in power and energy losses with the commissioning of HDITL but also assesses its monetary benefits. Utilizing INPS data and Digsilent Power Factory 15.1 for power flow analysis, the study estimates that HDITL can prevent a power loss of about 26.276 MW. Furthermore, it demonstrates that HDITL significantly improves the total generation power factor in INPS, from 0.88 to 0.99, and enhances the voltage profile, underscoring its critical role in Nepal's energy infrastructure development.

Keywords: transmission line, integrated Nepal power system, line loss, voltage sag, transmission management

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1. Introduction

The first hydropower plant built during Chandra Shumsher's rule is the foundation of the history of the Nepalese Power System. The 500 KW Pelton wheel generator, built in the Pharping hydropower plant with support from the British government in 1911, supplied electricity for the electrification of Singha Durbar, the royal palace. The theoretical total Potential Capacity of Hydropower is estimated to be 83,000 MW. Substantial economical Hydropower potential is 43,000 MW. The energy acquired from Independent Power Producers (IPPs) and NEA subsidiaries was 4,286 GWh and 1,976 GWh, respectively, increasing 38.57% and 1,235.14% from 3,093 GWh and 148 GWh in FY 2020/21 (Marg et al., 2021).

Establish numerous strong HV cross-border links to alleviate Nepal's current power crisis by importing power from India. The same cross-border TL links permit further power export to India when Nepal anticipates surplus power needed to build South Asia's Regional Power Grid Requires Regional Cooperation (Shyam & Yadav, n.d.)

As part of the construction of the Hetauda-Dhalkebar-Inaruwa(HDI) 400-kV double-circuit transmission line, which is essential to strengthen Nepal's domestic power transmission system and facilitate electricity trade between Nepal and India. Nepal Electricity Authority (NEA) has stressed the importance of addressing obstacles to the project and has encouraged residents to take necessary steps to remove them, to avoid any further problems (The Himalayan, n.d.). The 400-kV double-circuit Hetauda-Dhalkebar-Inaruwa (HDI) transmission line plays an important role in the steady, affordable, and trustworthy transfer of electrical energy by minimizing transmission losses and enhancing the INPS's (Integrated Nepal Power System) power quality. To trade excess energy in the day-ahead energy market, Nepal used the 400KV Dhalkewar-Muzaffarpur line, which connects to the Hetauda-Dhalkebar-Inaruwa (HDI) transmission line, improving the system's ability to transport electricity while also lowering line losses. The NEA - Hetauda-Dhalkebar-Inaruwa Transmission Line is a high-voltage transmission line that is a vital component of Nepal's power infrastructure. While Nepal has enormous potential for hydroelectricity plant production, the country still faces energy deficiency during the dry season due to maximum power projects being of the river (ROR) type. Nearly one-third of the generation-only energy is produced as compared to the wet season. Because of the lack of storage-type power plants. As a result, to reduce this difficulty, the Indian power system must be interconnected in a synchronous mode of operation. Despite having a considerable hydro potential, Nepal now experiences a power shortage because of a serious imbalance between the supply and demand for energy in the nation. The average annual increase in the annual peak electricity consumption is 9% (Mishra, Karki, & Gyawali, 2014) The majority of the generation for the Integrated Nepal Power System (INPS) is centered in the country's central mid-hills, which stretches from Syangja-Baglung in the west to Dolakha-Ramechhap in the east. The Duhabi-Biratnagar industrial corridor, for example, has a high electricity demand, which must be met by supplying it from Hetauda via the Dhalkebar substation. The Khimti-Dhalkebar Transmission Line (KDTL) is being built to transport electricity produced in the Tamakoshi-Bhotekoshi basin to Nepal's eastern region (Mishra, Karki, & Gyawali, 2014).The main objective of the thesis is to determine the impact of the high voltage 400 kV transmission line (HDITL) on INPS.

2. Materials and methods

2.1 Research Approach

The research methodology is based on a thorough examination of the technical, as well as the financial, aspects of transmission lines, including line loss reduction, voltage regulation, and voltage profile enhancement. The outcomes of the INPS system simulation modeling were carried out with the aid of the dig-silent Power Factory 15.1 software. Through simulation, validation, and comparison analysis, the specific line loss, loadability curve, short circuit analysis, and load flow in dig- silent are examined. Different case studies are conducted in the case of the Nepalese power system, which is integrated and connected to the HDI line. The analysis of the influence on the INPS network's load flow, voltage profile loadability, and implementation of the final result and counsel.

2.2 Research Methodology

The research approach is separated into many stages, which are briefly mentioned below. Figure 1 depicts a flowchart of the process.

- Literature review

Various publications and journals were read and analyzed to comprehend the present state of distribution feeders. The concept of data and information collecting came from several writings. The mathemat-ical formulation was investigated and analyzed. The parameters required for computation and simula-tion were carefully explored, and these parameters were meticulously examined.

- Data Collection

The data of Standard INPS system connected load install capacity transmission line, conductor types voltage rating, etc was collected.

- Simulation and Algorithm

PowerFactory is a major power system analysis software tool that may be used to examine genera-tion, transmission, distribution, and industrial systems.It includes typical functions as well as very sophisticated and advanced applications like wind power, distributed generation, real-time simulation, and performance monitoring for system testing and supervision. PowerFactory is simple to use, completely Windows compatible, and combines dependable and adaptable system modeling skills with cutting-edge algorithms and a one-of-a-kind database idea. PowerFactory is also well suited to highly automated and integrated solutions in your commercial applications due to its flexibility in scripting and interface.

- Load Flow study

Load flow and simulation of the system were carried out.

- Simulation

Following the results, the system with an impact of HDI 400 kV Transmission line length of 576 km was developed. The analysis was performed using technical characteristics of the INPS such as voltage pro-file, voltage regulation, losses, voltage drop, percentage impedance loading, and financial factors before and after analysis. Following a thorough examination, the final result was confirmed and concluded based on the techno-financial parameters before and after the HDL injection of INPS into the System. Report Writing, Presentation, and Research paper publication. The final report and presentation were both completed.

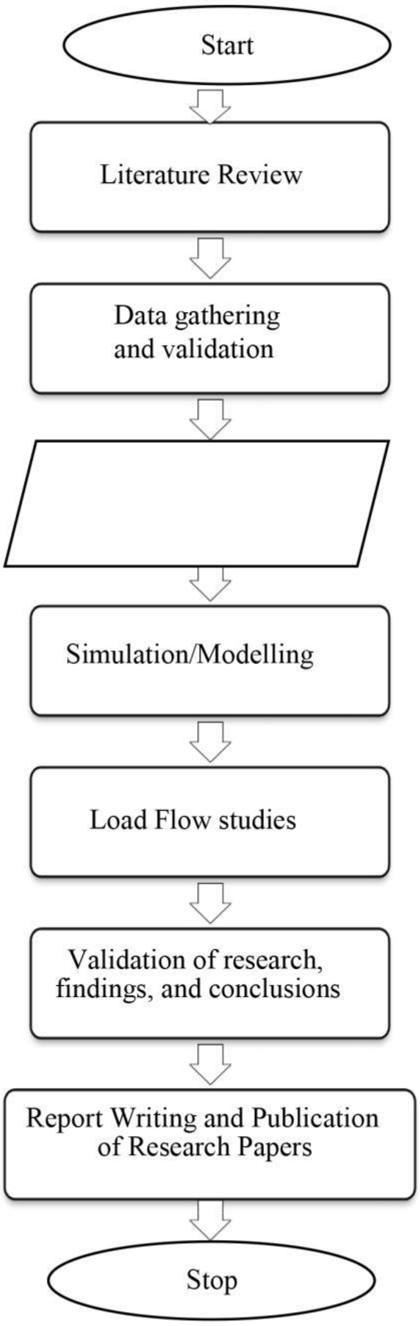


Figure 1 Research methodology

2.3 Flowchart of the proposed method

The flowchart of Newton- Raphson method starts with read line data, Bus data and the tolerance of ΔP and ΔQ. First assume all the buses except the slack bus, Bus voltage 1PU and angle 0_0.Then check the con-vergence criteria if the systems is converged then calculate the bus parameter and line parameter in load flow study if not then go to the next step for checking the bus count that is all of the bus count is done or not. If not then the increase the bus count and find the jacobian matrix then after find the error vector matrix with the help of jacobian matrix then, update the old assume voltage and phase angle after the all the bus count is done then calculate the bus and the line parameter. The flow chart for the proposed N-R method is shown in Figure 4: General Methodology of the Load Flow study.

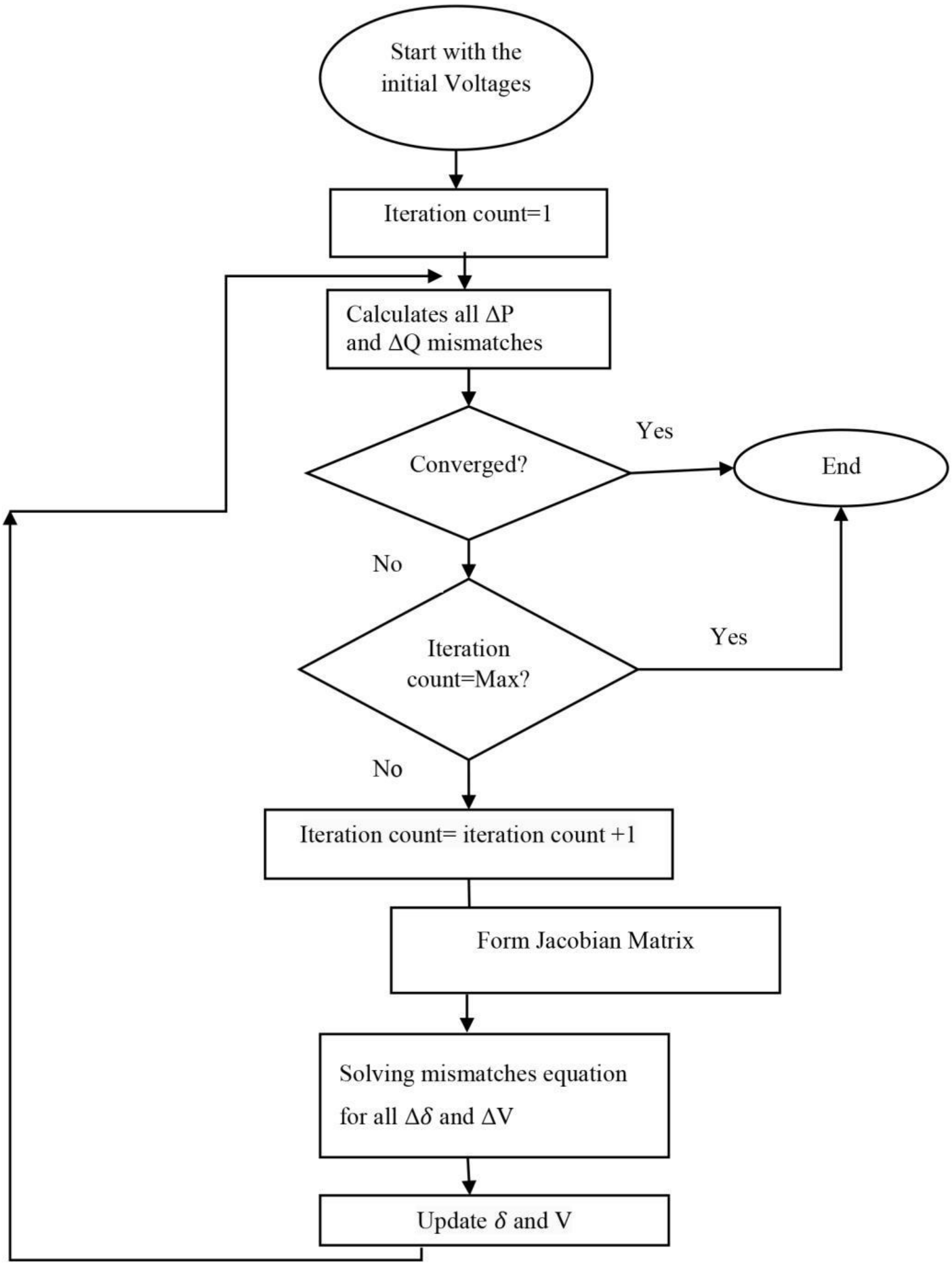


Figure 2: General Methodology of the Load Flow study

2.4 Load flow study to find the line losses

The goal of load flow analysis is to determine a power system's steady-state operating conditions, which include calculating voltages, currents, and power flows at various buses and transmission lines. The equations provided are used in load flow analysis to calculate power flows and network losses.

The equations are broken down as follows:

The voltage at Each Bus (Vi): The first step in load flow analysis is to determine the magnitude and angle of the voltage at each bus in the power system. These voltages are denoted as Vi, where "i" represents the bus number. For generator buses, the voltage magnitude Vi is typically assumed to be constant and specified for load buses. Vi is calculated for each bus based on the complex power injection and admittance (Y) at that bus:

$$(P + jQ) / (V * Y^*) = V_i \qquad (1)$$

Where:

Vi is the complex voltage at bus i. P and Q are the active and reactive power injections at bus i. V is the voltage magnitude at bus i. Y* is the complex conjugate of the bus admittance.

Power Loss in Lines (SLoss): The algebraic sum of the line power flows in both directions determines the power loss in a transmission line between buses i and j. This is denoted as SLoss:

$$S_{loss} = S_{ij} + S_{ji} \qquad (2)$$

Sloss represents the power lost as heat due to transmission line resistance. It takes into account both active and reactive power losses.

2.5 Financial analysis tools

2.5.1 Payback period (PBP)

The payback period is the number of years required to recover the investment made in a project.

$$Payback\ period\ (PBP) = minimum\ year + \frac{Unrecover\ amount}{Next\ year\ cash\ flow} \qquad (3)$$

2.5.2 Internal rate of return (IRR)

A financial analysis tool used to determine the profitability of possible investments is the internal rate of return (IRR). In a discounted cash flow analysis, the IRR is the discount rate that reduces all cash flows’ net present values (NPV) to zero (*Internal Rate of Return (IRR) Rule: Definition and Example*, n.d.).

$$NPV = \sum_{1}^{n} A_i \,/(1 + r\,)^n \quad (4)$$

3. Results and discussions

3.1 Grid loss estimation

3.1.1 Study Case I considers an INPS without a HDI 400 kV transmission line

As indicated in Figure, the first study case is intended to be applied to an integrated Nepalese power system (INPS) without an HDI 400Kv transmission line. The B.S. 2079/080 power demand and generation scenario has been analyzed. The load flow solution calculates power loss. Provided it consists of 30 generators, 58 load buses, 9 transformers, and 160 lines (branches) as shown in Figure 5.

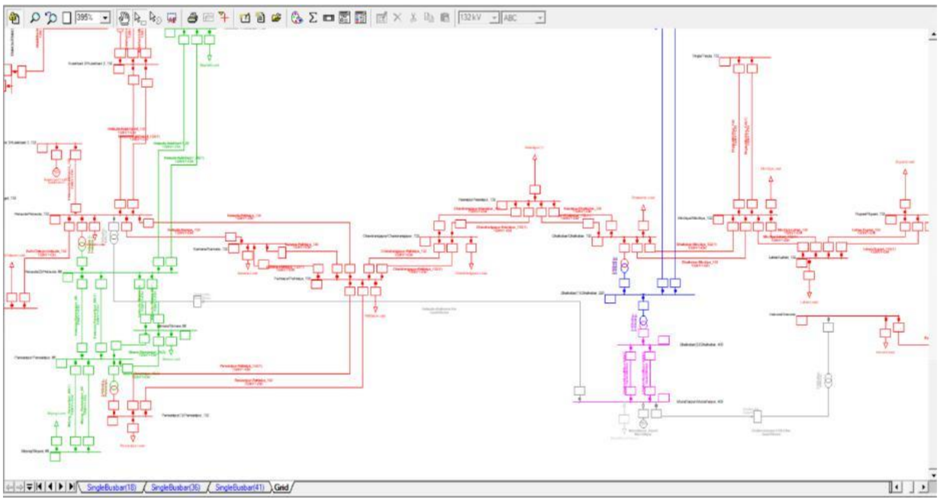


Figure 5: INPS system without HDI line

3.1.2 Study Case II considers an INPS with a HDI 400 KV transmission line

As indicated in Figure, the first study case is intended to be applied to an integrated Nepal power system (INPS) with HDI 400Kv transmission line. The B.S. 2079/080 power demand and generation scenario has been analyzed. The load flow solution calculates power loss. Provided it consists of 30 generators, 58 load buses, 11 transformers, and 162 lines (branches) as shown in Figure 4.

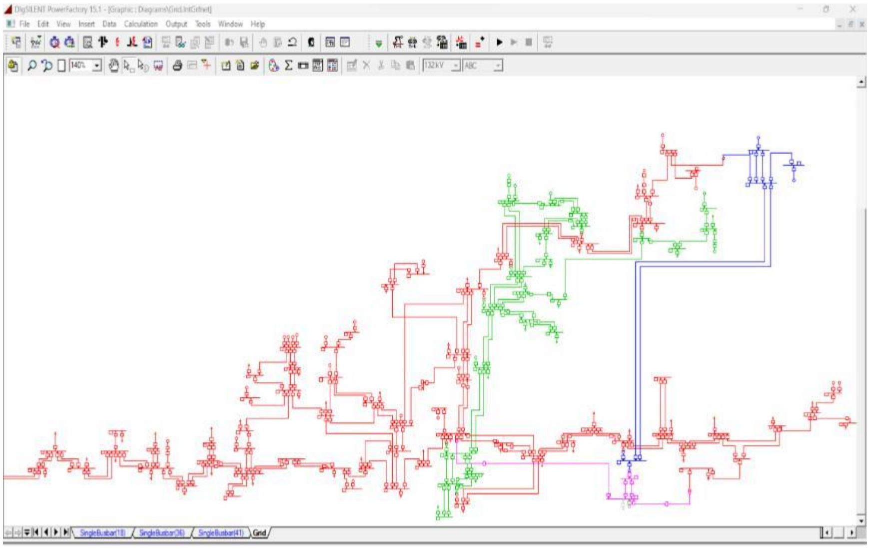


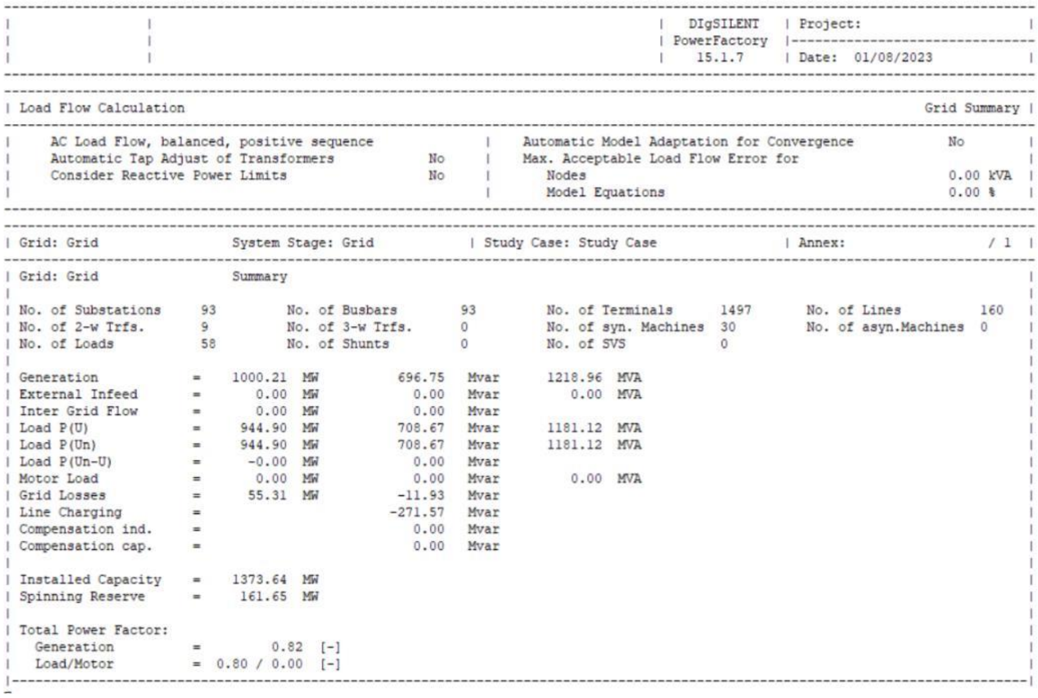
Figure 4: INPS with HDI 400KV Transmission Line

3.1.3 Load Flow

When the INPS data were analyzed and provided as input data to the constructed model, it was effective in finding the best solution.

3.1.4 Results for the Line test system without HDI transmission

Using the software Dig-silent Power Factory 15.1, INPS load flow has been run without the use of HDI trans-mission line. Load flow provides information on power loss. On a total generated power of 1000.21 MW, INPS transmission losses totaled 55.31 MW. Table 1 displays the results of the power flow.



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|                 |                                                                   |   DIgSILENT   | Project:                       |
|                 |                                                                   | PowerFactory  |--------------------------------
|                 |                                                                   |    15.1.7     | Date:  01/08/2023              |
----------------------------------------------------------------------------------------------------------------------------------
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| Load Flow Calculation                                                                                              Grid 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                                   0.00 %    |
----------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------
| Grid: Grid                System Stage: Grid           | Study Case: Study Case               | Annex:                     / 1  |
----------------------------------------------------------------------------------------------------------------------------------
| Grid: Grid                Summary                                                                                               |
|                                                                                                                                 |
| No. of Substations     93         No. of Busbars         93         No. of Terminals       1497       No. of Lines            160  |
| No. of 2-w Trfs.       9          No. of 3-w Trfs.       0          No. of syn. Machines   30         No. of asyn.Machines   0    |
| No. of Loads           58         No. of Shunts          0          No. of SVS             0                                      |
|                                                                                                                                 |
| Generation          =    1000.21  MW          696.75   Mvar      1218.96  MVA                                                    |
| External Infeed     =       0.00  MW            0.00   Mvar         0.00  MVA                                                    |
| Inter Grid Flow     =       0.00  MW            0.00   Mvar                                                                     |
| Load P(U)           =     944.90  MW          708.67   Mvar      1181.12  MVA                                                    |
| Load P(Un)          =     944.90  MW          708.67   Mvar      1181.12  MVA                                                    |
| Load P(Un-U)        =      -0.00  MW            0.00   Mvar                                                                     |
| Motor Load          =       0.00  MW            0.00   Mvar         0.00  MVA                                                    |
| Grid Losses         =      55.31  MW          -11.93   Mvar                                                                     |
| Line Charging       =                        -271.57   Mvar                                                                     |
| Compensation ind.   =                           0.00   Mvar                                                                     |
| Compensation cap.   =                           0.00   Mvar                                                                     |
|                                                                                                                                 |
| Installed Capacity  =    1373.64  MW                                                                                             |
| Spinning Reserve    =     161.65  MW                                                                                             |
|                                                                                                                                 |
| Total Power Factor:                                                                                                             |
|   Generation        =         0.82  [-]                                                                                         |
|   Load/Motor        =  0.80 / 0.00  [-]                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------|
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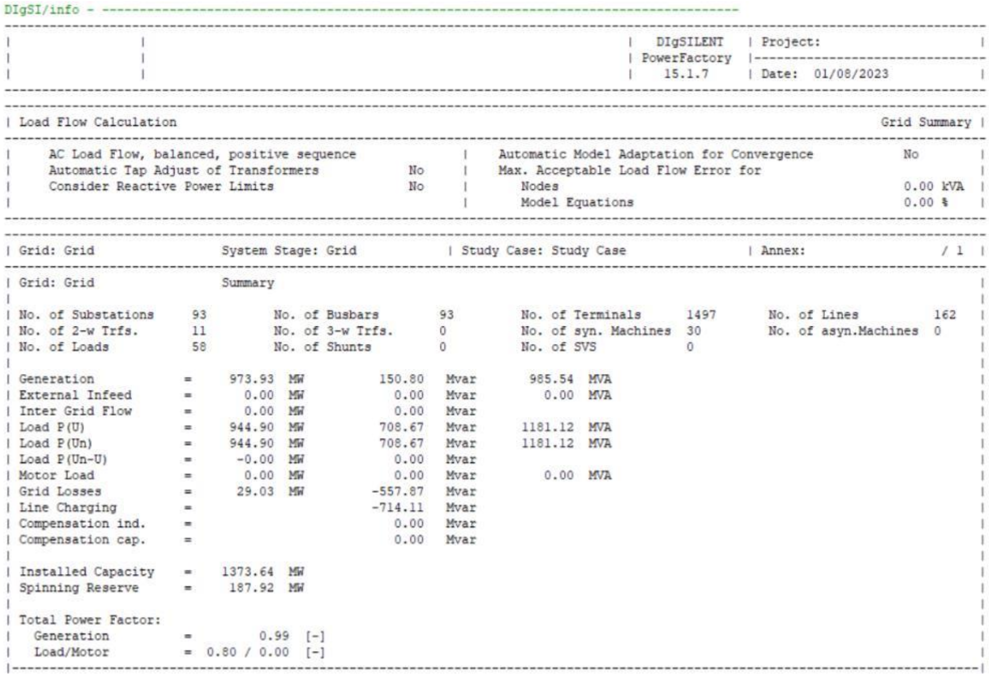
Figure 7: Summary sheet of INPS system without HDI line

3.1.5 Results for the Line test system with HDI transmission on INPS

Using the software Dig-silent Power Factory 15.1, INPS load flow has been run with the use of HDI transmission line. Load flow provides information on power loss. On a total generated power of 973.93 MW, INPS transmission losses totaled 29.03 MW, and the installed capacity was found to be 1373.64 with a spinning reserve of 187.92 along with an improved total load factor of the generation of 0.99. Table 1 displays the results of the power flow.



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DIgSI/info - ------------------------------------------------------------------------------
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|                 |                                                                   |   DIgSILENT   | Project:                       |
|                 |                                                                   | PowerFactory  |--------------------------------
|                 |                                                                   |    15.1.7     | Date:  01/08/2023              |
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| Load Flow Calculation                                                                                              Grid 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                                   0.00 %    |
----------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------
| Grid: Grid                System Stage: Grid           | Study Case: Study Case               | Annex:                     / 1  |
----------------------------------------------------------------------------------------------------------------------------------
| Grid: Grid                Summary                                                                                               |
|                                                                                                                                 |
| No. of Substations     93         No. of Busbars         93         No. of Terminals       1497       No. of Lines            162  |
| No. of 2-w Trfs.       11         No. of 3-w Trfs.       0          No. of syn. Machines   30         No. of asyn.Machines   0    |
| No. of Loads           58         No. of Shunts          0          No. of SVS             0                                      |
|                                                                                                                                 |
| Generation          =     973.93  MW          150.80   Mvar       985.54  MVA                                                    |
| External Infeed     =       0.00  MW            0.00   Mvar         0.00  MVA                                                    |
| Inter Grid Flow     =       0.00  MW            0.00   Mvar                                                                     |
| Load P(U)           =     944.90  MW          708.67   Mvar      1181.12  MVA                                                    |
| Load P(Un)          =     944.90  MW          708.67   Mvar      1181.12  MVA                                                    |
| Load P(Un-U)        =      -0.00  MW            0.00   Mvar                                                                     |
| Motor Load          =       0.00  MW            0.00   Mvar         0.00  MVA                                                    |
| Grid Losses         =      29.03  MW         -557.87   Mvar                                                                     |
| Line Charging       =                        -714.11   Mvar                                                                     |
| Compensation ind.   =                           0.00   Mvar                                                                     |
| Compensation cap.   =                           0.00   Mvar                                                                     |
|                                                                                                                                 |
| Installed Capacity  =    1373.64  MW                                                                                             |
| Spinning Reserve    =     187.92  MW                                                                                             |
|                                                                                                                                 |
| Total Power Factor:                                                                                                             |
|   Generation        =         0.99  [-]                                                                                         |
|   Load/Motor        =  0.80 / 0.00  [-]                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------|
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Figure 8: Grid summary with HDI transmission line On INPS

3.1.6 Comparison of Grid power losses with the highest ten transmission lines

The impact of a high voltage 400 kV transmission line on the operation of INPS is that significantly reduced the line losses. The top ten lines (branches) are compared and get damak- godak 132 kV line loss reduced with the HDI line connected to INPS from 4719.415 kW to 574.7908 kW. Likewise, another line duhabi- damak 132 kV line loss was reduced from 3210.955 kW to 2.84 kW. The dhalkewar- mirchiya 132 kV line loss was reduced from 2517.547 kW to 126.08 kW. The rupani – duhabi 132 kV line loss was reduced from 2553.933 kW to 508.45 kW. Similarly, the top ten line nawalpur- dhalkewar 132 kV loss was reduced from 372.2739 kW to 90.45 kW.

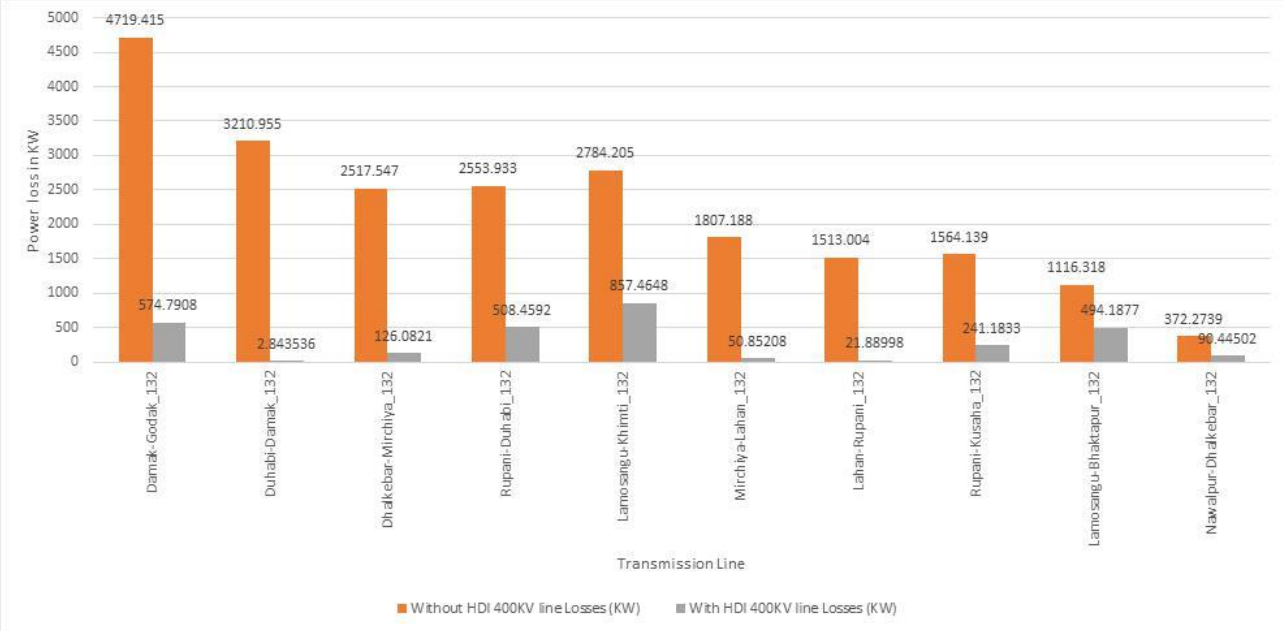
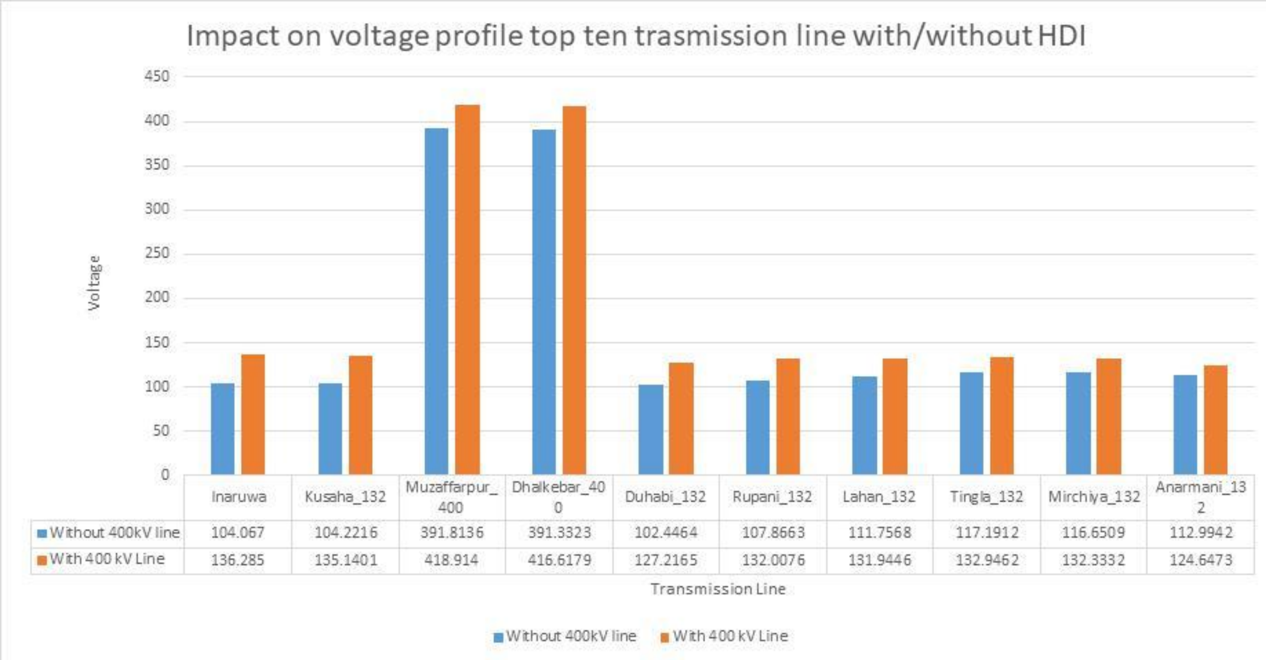


Figure 9: Highest Power losses in the ten branches (Lines)

3.2 Voltage profile improvement connected to HDI 400 kV line



	Inaruwa	Kusaha_132	Muzaffarpur_400	Dhalkebar_400	Duhabi_132	Rupani_132	Lahan_132	Tingla_132	Mirchiya_132	Anarmani_132
Without 400kV line	104.067	104.2216	391.8136	391.3323	102.4464	107.8663	111.7568	117.1912	116.6509	112.9942
With 400 kV Line	136.285	135.1401	418.914	416.6179	127.2165	132.0076	131.9446	132.9462	132.3332	124.6473

Figure 10: The impact on the voltage profile of the top ten transmission lines

3.3 Impact on % of Line loading on Highest 10 Branches

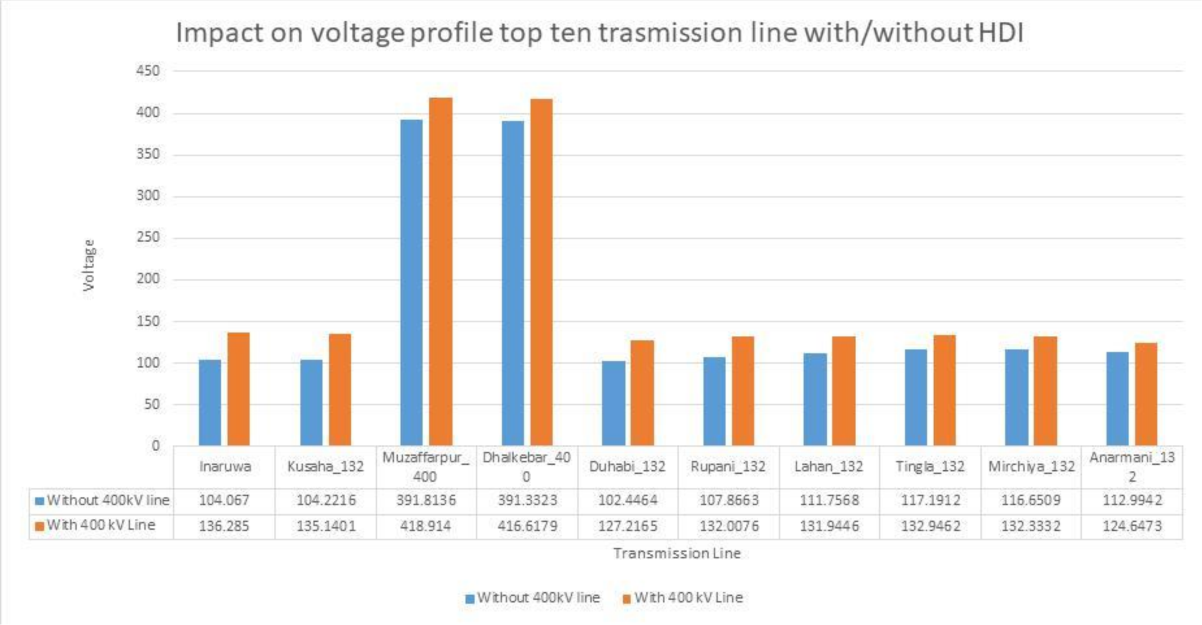


Figure 11: Impact on HDI line on Line loading

3.4 Financial analysis of the HDI 400 kV transmission line

3.4.1 Payback period (PBP)

Rainy season PPA rate	4.8	per kWh
Dry season PPA rate	8.4	Per kWh
Weighted average PPA rate	6.6	per kWh

Substation costs and transmission line Costs(million)		
	USD	NPR
For the construction of 400 kV GIS substation at Dhalkebar	17.58	220.33
construction of 400 kV GIS substation at Hetauda and Inaruwa	28.4	410.5
Hetauda-Dhalkebar-Inaruwa 400kV Transmission Line	170	
	$ 215.98	630.83
In NPR@ 1 USD= 132 NPR in 21/09/2023)	28,698.34	630.83
Total Investment	**29,329.17 NPR**	

Year	Cash flow(in million) NPR	PVF, 10%	PV	Cumulative PV
0	-29329.17	1.00	-29329.17	-29329.17
1	7008.00	0.91	6370.91	-22958.26
2	7008.00	0.83	5791.74	-17166.52
3	7008.00	0.75	5265.21	-11901.31

4	7008.00	0.68	4786.56	-7114.75
5	7008.00	0.62	4351.42	-2763.33
6	7008.00	0.56	3955.83	1192.50

PBP= 5.70 years

Figure 12 Payback period of HDI line

The project's payback period was found to be 5.70 years when 10% of the project's discounted rate was con-sidered.

3.4.2 Internal rate of return (IRR)

Simple IRR calculation

The internal rate of return for the project was found to be 11% when the project's MARR was thought to be 10%, indicating that it is an investment that will yield a positive IRR.

Year	0	1	2	3	4	5	6
Cash flow(in million) NPR	-29329.17	7008.00	7008.00	7008.00	7008.00	7008.00	7008.00
	IRR=11.38%						

Incremental Internal rate of return(IRR)

The internal rate of return was found that it was 16.94% after the annual profit increased by 5%. which is more the MARR, which indicates that the project being financially feasible..

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Cash flow(in million) MNPR	-29329	7008	7008	7008	7008	7008	7008
Incremented by 5% annually Cash flow(in million) NPR	-29329	7358.4	7726.32	8112.64	8518.27	8944.18	9391.39
	IRR=16.94%						

3.4.3 NPV Profile

The NPV vs discount rate graph plots with equal annual income and incremented by 5 %. The graph of NPV profile shown in Figure 13: NPV profile

Figure 13: NPV profile

4. Conclusions and recommendations

4.1 Conclusions

The major cessations or findings of this analysis or research work are listed below:

- Comparing the Test model on INPS with and without HDITL, the Result shows that Transmission loss saving by connecting HDITL to INPS is 26.28MW, and energy loss saving per year will be 149638.3 MWh assuming 0.65 loss of load factor.
- The system spinning reserve also increased to 187.92 MW from 161.65MW with connecting HDITL.

- Research done in KDTL results shows that Transmission loss saving by connecting KDTL to INPS is 15.639MW and energy loss saving per year will be 89048.46 MWh assuming 0.65 loss of load factor. power demand and generation scenario of B.S. 2070/071 has been considered
- Comparing the finding of research on KDTL (15.639MW loss saving based) with, the finding on the research of HDITL. It shows the findings obtained in this research work to be valid.
- Study shows that problems like voltage sag and line loss in INPS can be reduced and power transfer capability increased using a High-voltage Transmission line.
- The simulation result shows a significant improvement in the total system power factor of generator 0.99 from 0.82 with connecting HDITL.
- Analysis carried out in this research shows that there is a great reduction in transmission line power loss of About 26.28MW and energy loss saving per year will be 149638.3 MWh.
- The project seems financially feasible according to factors like the payback period, the IRR method, and the NPV profile.
- The issue of generating power below its maximum capacity can be addressed by effectively utilizing high-voltage transmission lines and substations. By efficiently managing the transmission and dis-tribution of power, surplus energy can be exported to other areas, contributing to a more optimized power generation process.

4.2 Recommendations

The study can be expanded to include load growth patterns and load models. In addition to optimally placing capacitor banks and injecting DERs into the system, feeder reconfiguration can help reduce losses. Similar research can be conducted for the Khimti-Dhalkebar 220 kV Transmission Line to determine the impact on INPS and analyze grid losses with and without KDTL. Further harmonics and contingency analysis of INPS before and after HDI transmission line injection can be performed on solar and wind power plants and can be implemented to improve system reliability.

5. Conflict of interest

“No conflict of interest”.

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Appendix

APPENDIX A: List of hydropower and installed capacity

The following are the results of the integration of performing research hydropower and installed capacity data obtained from the Load dispatch center, as specified in Section 3.5:

Table A-1: Hydropower and their installed capacity connected with INPS system

S.N.	Name of hydropower	Installed Capacity (MW)
1	Solu Khola Dudhkoshi(86)	86.000
2	Super Dordi (54)	54.000
3	Likhu-IV(52.4)	52.400
4	Upper Marsyangdi "A"(50)	50.000
5	Upper Bhotekoshi Khola(45)	45.000
6	Super Madi (44)	44.000
7	Mistri Khola(42)	42.000
8	Upper Kalanga Gad(38.46)	38.460
9	Upper Balefi (36)	36.000
10	Nyadi(30)	30.000
11	Likhu Khola A(29.04)	24.200
12	Lower Likhu(28)	28.000
13	Dordi(27)	30.000
14	Upper Madi(25)	25.000
15	Kabeli B-1(25)	25.000
16	Singati Khola(25)	25.000
17	Upper Dordi (25)	25.000
18	Solu Khola(23.5)	23.500
19	Upper Chaku A(22.2)	22.200
20	Tallo Hewa Khola(22.1)	22.100
21	Sanima Mai Khola(22)	22.000
22	Bagmati Khola Small(22)	22.000
23	Lower Modi (20)	20.000
24	Middle Modi (18)	18.000
25	Kalanga Gad(15.33)	14.900
26	Hewa Khola A(14.9)	14.900
27	Thapa Khola(13.6)	13.600

28	Madkyu Khola(13)	13.000
29	Dordi12)	12.000
30	Jhimruk Khola(12)	12.000
31	Upper Khimti(12)	12.000
32	Upper Mai Khola (12)	22.00
33	Namarjun Madi(11.88)	11.880
34	Lower Khare(11)	11.000
35	Lower Modi 1(10)	10.000
36	Makari Gad(10.0)	10.000
37	Mithila Solar PV Electric Project(10)	10.000
38	Other IPP Total	85.000
39	Kabeli Corridor	240.000
	Total IPP	922.140
1	Upper Tamakoshi(456)	456.000
2	Khimti Khola(60)	60.000
3	Chilime(22.1)	22.100
	Total NEA SUBSIDIARIES	538.100
1	KGA(144)	144
2	Middle MRS(70)	70
3	MRS(69)	69
4	U Trisuli 3A(60)	60
5	CHM(30)	30
6	NEA SOLAR(25)	25
7	TRI(24)	24
8	GDK(15)	15
9	DEVI(14.1)	14.1
10	MODI(14)	14
11	SUN(10.05)	10.05
12	PUWA(6.2)	6.2
13	Other NEA Small	8.5
	Total ROR	**489.85**
1	KL1(60)	60
2	KL2(32)	32
3	KL3(14)	14
	Total STORGE	**106**
1	MULTI F(39)	39
2	HTD DIE(14.41)	14.4
3	MRS DI()	2
	Total THERMAL	**55.4**
	TOTAL SYSTEM LOAD (ACTUAL)	**2111.49**

Table A-2: Line length and other details connected with the INPS system

S.N.	Name of hydropower	Installed Capacity (MW)
1	Solu Khola Dudhkoshi(86)	86.000
2	Super Dordi (54)	54.000
3	Likhu-IV(52.4)	52.400
4	Upper Marsyangdi "A"(50)	50.000
5	Upper Bhotekoshi Khola(45)	45.000
6	Super Madi (44)	44.000
7	Mistri Khola(42)	42.000
8	Upper Kalanga Gad(38.46)	38.460
9	Upper Balefi (36)	36.000
10	Nyadi(30)	30.000
11	Likhu Khola A(29.04)	24.200
12	Lower Likhu(28)	28.000
13	Dordi(27)	30.000
14	Upper Madi(25)	25.000
15	Kabeli B-1(25)	25.000
16	Singati Khola(25)	25.000
17	Upper Dordi (25)	25.000
18	Solu Khola(23.5)	23.500
19	Upper Chaku A(22.2)	22.200
20	Tallo Hewa Khola(22.1)	22.100
21	Sanima Mai Khola(22)	22.000
22	Bagmati Khola Small(22)	22.000
23	Lower Modi (20)	20.000
24	Middle Modi (18)	18.000
25	Kalanga Gad(15.33)	14.900
26	Hewa Khola A(14.9)	14.900
27	Thapa Khola(13.6)	13.600
28	Madkyu Khola(13)	13.000
29	Dordi12)	12.000
30	Jhimruk Khola(12)	12.000
31	Upper Khimti(12)	12.000
32	Upper Mai Khola (12)	22.00
33	Namarjun Madi(11.88)	11.880
34	Lower Khare(11)	11.000
35	Lower Modi 1(10)	10.000
36	Makari Gad(10.0)	10.000
37	Mithila Solar PV Electric Project(10)	10.000
38	Other IPP Total	85.000
39	Kabeli Corridor	240.000
	Total IPP	922.140
1	Upper Tamakoshi(456)	456.000

2	Khimti Khola(60)	60.000
3	Chilime(22.1)	22.100
	Total NEA SUBSIDIARIES	538.100
1	KGA(144)	144
2	Middle MRS(70)	70
3	MRS(69)	69
4	U Trisuli 3A(60)	60
5	CHM(30)	30
6	NEA SOLAR(25)	25
7	TRI(24)	24
8	GDK(15)	15
9	DEVI(14.1)	14.1
10	MODI(14)	14
11	SUN(10.05)	10.05
12	PUWA(6.2)	6.2
13	Other NEA Small	8.5
	Total ROR	489.85
1	KL1(60)	60
2	KL2(32)	32
3	KL3(14)	14
[redacted]	Total STORGE	106
1	MULTI F(39)	39
2	HTD DIE(14.41)	14.4
3	MRS DI()	2
	Total THERMAL	**55.4**
	TOTAL SYSTEM LOAD (ACTUAL)	**2111.49**

S.N.	**Name of the Line (From Ith bus to Jth bus)**	**Type**	**Length in KM**	**Type of Phase Conductors**
1	Anarmani-Damak_132	132kV 1-Ckt	**27**	Bear 132
2	Attariya-Pahalmanpur_132	132kV 1-Ckt	**38**	Bear 132
3	Attariya-Pahalmanpur_132(1)	132kV 1-Ckt	**38**	Bear 132
4	Balaju-Chapali_132	132kV 1-Ckt	**11**	Bear 132
5	Balaju-Chapali_132(1)	132kV 1-Ckt	**11**	Bear 132
6	Balaju-Lainchour_66	132kV 1-Ckt	**2**	Panther 66
7	Balaju-Trishuli_66	132kV 1-Ckt	**29**	Dog 66
8	Balaju-Trishuli_66(1)	132kV 1-Ckt	**29**	Dog 66
9	Baneshwor-Bhaktapur_66	132kV 1-Ckt	**11**	AAAC Silvasa
10	Bardghat-Kawasoti_132	132kV 1-Ckt	**34**	Panther132
11	Bhaktapur-Banepa_132	132kV 1-Ckt	**11**	Wolf 66
12	Bharatpur-Damauli_132(1)	132kV 1-Ckt	**39**	Wolf 132
13	Bharatpur-Purbi Chitwan_132	132kV 1-Ckt	**35**	Panther132
14	Bhotekoshi HP-Lamosangu_132	132kV 1-Ckt	**31**	Dog 132

15	Birjung_Parwanipur_66	132kV 1-Ckt	**12**	Wolf 66
16	Birjung_Parwanipur_66(1)	132kV 1-Ckt	**12**	Wolf 66
17	Butwal-Kaligandaki_132	132kV 1-Ckt	**58**	Duck 132
18	Butwal-Kaligandaki_132(1)	132kV 1-Ckt	**58**	Duck 132
19	Butwal-Lumbini_132	132kV 1-Ckt	**22**	Bear 132
20	Butwal-Lumbini_132(1)	132kV 1-Ckt	**22**	Bear 132
21	Butwal-New Butwal_132	132kV 1-Ckt	**43**	Bear 132
22	Butwal-New Butwal_132(1)	132kV 1-Ckt	**43**	Bear 132
23	Chandranigapur-Nawalpur_132	132kV 1-Ckt	**25**	Bear 132
24	Chandranigapur-Nawalpur_132(1)	132kV 1-Ckt	**25**	Bear 132
25	Chandranigapur-Pathlaiya_132	132kV 1-Ckt	**32**	Bear 132
26	Chandranigapur-Pathlaiya_132(1)	132kV 1-Ckt	**32**	Bear 132
27	Chapali-Bhaktapur_132	132kV 1-Ckt	**12**	Bear 132
28	Chapali-Bhaktapur_132(1)	132kV 1-Ckt	**12**	Bear 132
29	Chapali-New Chabel_66	132kV 1-Ckt	**5**	AAAC Silvasa
30	Chapali-New Chabel_66(1)	132kV 1-Ckt	**5**	Dog 66
31	Chilime-Trishuli_66	132kV 1-Ckt	**39**	Wolf 66
32	Damak-Godak_132	132kV 1-Ckt	**34.55**	Bear 132
33	Devighat-Okhaltar_66	132kV 1-Ckt	**26.5**	Dog 66
34	Devighat-Okhaltar_66(1)	132kV 1-Ckt	**26.5**	Dog 66
35	Dhalke-Muzaffafpur 400kV	400kV 1-Ckt	**39**	Quad Moose
36	Dhalke-Muzaffapur 400kV	400kV 2-Ckt	**39**	Quad Moose
37	Dhalkebar-Mirchiya_132	132kV 1-Ckt	**32**	Bear 132
38	Dhalkebar-Mirchiya_132(1)	132kV 1-Ckt	**32**	Bear 132
39	Duhabi-Damak_132	132kV 1-Ckt	**43**	Bear 132
40	Gandak_Bardaghat_132	132kV 1-Ckt	**14**	Panther132
41	Hetauda-Kamane_132	132kV 1-Ckt	**8**	Bear 132
42	Hetauda-Kulekhani 1_66	132kV 1-Ckt	**16**	Wolf 66
43	Hetauda-Kulekhani 1_66(1)	132kV 1-Ckt	**16**	Wolf 66
44	Hetauda-Kulekhani 3_132	132kV 1-Ckt	**2**	Bear 132
45	Hetauda-Kulekhani-II_132	132kV 1-Ckt	**8**	Bear 132
46	Hetauda-Kulekhani-II_132(1)	132kV 1-Ckt	**8**	Bear 132
47	Hetauda-Parwanipur_66	132kV 1-Ckt	**52**	Wolf 66
48	Hetauda-Parwanipur_66(1)	132kV 1-Ckt	**52**	Wolf 66
49	Hetauda-Pathlaiya_132	132kV 1-Ckt	**37**	Bear 132
50	Hetauda-Simara_66	132kV 1-Ckt	**44**	Wolf 66
51	Hetauda-Simara_66(1)	132kV 1-Ckt	**44**	Wolf 66
52	Indrawati-Panchkhal_66	132kV 1-Ckt	**28**	Dog 66
53	Jhimruk-Lamahi_132	132kV 1-Ckt	**50**	Dog 132
54	Kaligandaki-Syangja_132	132kV 1-Ckt	**48**	Duck 132
55	Kamane-Pathlaiya_132	132kV 1-Ckt	**29**	Bear 132
56	Kamane-Pathlaiya_132(1)	132kV 1-Ckt	**29**	Bear 132
57	Kawasoti-Bharatpur_132	132kV 1-Ckt	**36**	Panther132

58	Kawasoti-NewBharatpur_132(1)	132kV 1-Ckt	**31**	Single Bison 132
59	Khimti-Likhu A_132	132kV 1-Ckt	**2.8**	Bear 132
60	Kohalpur-Bhurigaon_132	132kV 2-Ckt	**50**	Bear 132
61	Kohalpur-Bhurigaon_132(1)	132kV 1-Ckt	**50**	Bear 132
62	Kulekhani 1-Suichatar_66	132kV 1-Ckt	**29**	Wolf 66
63	Kulekhani 1-Suichatar_66(1)	132kV 1-Ckt	**29**	Wolf 66
64	Kulekhani 2-Matatirtha_132	132kV 1-Ckt	**36**	Bear 132
65	Kulekhani 2-Matatirtha_132(1)	132kV 1-Ckt	**36**	Bear 132
66	Kusaha-Duhabi_132	132kV 1-Ckt	**29**	Bear 132
67	Kusum-Hapure_132	132kV 1-Ckt	**20**	Bear 132
68	Kusum-Kohalpur_132	132kV 1-Ckt	**48**	Bear 132
69	Kusum-Kohalpur_132(1)	132kV 1-Ckt	**48**	Bear 132
70	Lahachowk-New Modi_132	132kV 1-Ckt	**40**	Bear 132
71	Lahachowk-New Modi_132(1)	132kV 1-Ckt	**40**	Bear 132
72	Lahan-Rupani_132	132kV 1-Ckt	**27**	Bear 132
73	Lahan-Rupani_132(1)	132kV 1-Ckt	**27**	Bear 132
74	Lainchour-New Chabel_132	XLPE 66	**7**	Dog 66
75	Lamahi-Ghorahi_132	132kV 1-Ckt	**13**	Bear 132
76	Lamahi-Ghorahi_132(1)	132kV 1-Ckt	**13**	Bear 132
77	Lamahi-Kusum_132	132kV 1-Ckt	**47**	Bear 132
78	Lamahi-Kusum_132(1)	132kV 1-Ckt	**47**	Bear 132
79	Lamahi-Shivapur_132	132kV 1-Ckt	**51**	Bear 132
80	Lamahi-Shivapur_132(1)	132kV 1-Ckt	**51**	Bear 132
81	Lamki-Bhurigaon_132	132kV 1-Ckt	**33**	Bear 132
82	Lamki-Bhurigaon_132(1)	132kV 1-Ckt	**33**	Bear 132
83	Lamosangu-Bhaktapur_132	132kV 1-Ckt	**48**	Bear 132
84	Lamosangu-Bhaktapur_132(1)	132kV 1-Ckt	**48**	Bear 132
85	Lamosangu-Khimti_132	132kV 1-Ckt	**46**	Bear 132
86	Lekhnath-Damauli_132	132kV 1-Ckt	**45**	Wolf 132
87	Lekhnath-Lahachowk_132	132kV 1-Ckt	**3**	Bear 132
88	Lekhnath-Lahachowk_132(1)	132kV 1-Ckt	**3**	Bear 132
89	Lekhnath-Pokhara_132	132kV 1-Ckt	**7**	Dog 132
90	Lekhnath-UMadi(132)	132kV 1-Ckt	**1**	Bear 132
91	LikhuIV-N Khimti_220(2)	Twin Moose220	**19**	Twin Bison 220
92	Mahendranagar-Attariya_132	132kV 1-Ckt	**37**	Bear 132
93	Mahendranagar-Attariya_132(1)	132kV 1-Ckt	**37**	Bear 132
94	Malekhu-Marsyangdi_132	132kV 1-Ckt	**36**	Bear 132
95	Marsyangdi-New Marsyangdhi_132	132kV 1-Ckt	**5**	Cardinal 132
96	Marsyangdi-New Marsyangdhi_132.	132kV 1-Ckt	**5**	Cardinal 132
97	Marsyangdi-Suichatar_132	132kV 1-Ckt	**84**	Duck 132
98	Matatirtha-Malekhu_132	132kV 1-Ckt	**36**	Bear 132
99	Matatirtha-Samundratar_132(2)	132kV 1-Ckt	**52**	Bear 132
100	Matatirtha-Suichatar_132	132kV 1-Ckt	**36**	Bear 132

101	Matatirtha-Suichatar_132(1)	132kV 1-Ckt	**36**	Bear 132
102	Middle Marsyangdi-Damauli_132(1)	132kV 1-Ckt	**18**	Bear 132
103	Mirchiya-Lahan_132	132kV 1-Ckt	**27**	Bear 132
104	Mirchiya-Lahan_132(1)	132kV 1-Ckt	**27**	Bear 132
105	Motipur-Butwal_132	132kV 1-Ckt	**38**	Bear 132
106	Motipur-Butwal_132(1)	132kV 1-Ckt	**38**	Bear 132
107	Motipur-Sandikharka_132	132kV 1-Ckt	**37**	Bear 132
108	Motipur-Sandikharka_132(1)	132kV 1-Ckt	**37**	Bear 132
109	N Khimti-Dhalkebar_220	220kV Tower 1-Ckt	**75**	Twin Bison 220
110	N Khimti-Dhalkebar_220(1)	220kV Tower 1-Ckt	**75**	Twin Bison 220
111	Nawalpur-Dhalkebar_132	132kV 1-Ckt	**45**	Bear 132
112	Nawalpur-Dhalkebar_132(1)	132kV 1-Ckt	**45**	Bear 132
113	New Bharatpur-Bharatpur_132	132kV 1-Ckt	**5**	Duck 132
114	New Bharatpur-Marsyangdi_132	132kV 1-Ckt	**20**	Duck 132
115	New Bharatpur-Marsyangdi_132(1)	132kV 1-Ckt	**20**	Duck 132
116	New Butwal-Bardghat_132	132kV 1-Ckt	**43**	Bear 132
117	New Butwal-Bardghat_132(1)	132kV 1-Ckt	**43**	Bear 132
118	New Marsyangdhi-Mid Marsyangdi_132	132kV 1-Ckt	**40**	Cardinal 132
119	New Marsyangdhi-Mid Marsyangdi_132(1)	132kV 1-Ckt	**40**	Cardinal 132
120	New Marsyangdi-Damauli_132	132kV 1-Ckt	**18**	Bear 132
121	Okhaltar-Chapali_132	132kV 1-Ckt	**2.8**	Dog 66
122	Okhaltar-Chapali_132(1)	132kV 1-Ckt	**2.8**	Dog 66
123	Pahalmanpur-Lamki_132	132kV 1-Ckt	**35**	Bear 132
124	Pahalmanpur-Lamki_132(1)	132kV 1-Ckt	**35**	Bear 132
125	Panchkhal-Banepa_66	132kV 1-Ckt	**8**	Wolf 66
126	Parwanipur-Pathlaiya_132	132kV 1-Ckt	**17**	Bear 132
127	Parwanipur-Pathlaiya_132(1)	132kV 1-Ckt	**17**	Bear 132
128	Patan-Baneshwor_66	132kV 1-Ckt	**2.7**	AAAC Silvasa
129	Pokhara-New Modi_132	132kV 1-Ckt	**37**	Bear 132
130	Purbi Chitwan-Hetauda_132	132kV 1-Ckt	**40**	Panther132
131	Rupani-Duhabi_132	132kV 1-Ckt	**58**	Bear 132
132	Rupani-Kusaha_132	132kV 1-Ckt	**29**	Bear 132
133	Samundratar-Trishuli_132	132kV 1-Ckt	**6**	AAAC Upas
134	Samundratar-Trishuli_132(1)	132kV 1-Ckt	**6**	AAAC Upas
135	Shivapur-Motipur_132	132kV 1-Ckt	**23**	Bear 132
136	Shivapur-Motipur_132(1)	132kV 1-Ckt	**23**	Bear 132
137	Simara-Parwanipur_66(2)	132kV 1-Ckt	**8**	Wolf 66
138	Simara-Parwanipur_66(3)	132kV 1-Ckt	**8**	Wolf 66
139	Suichatar-Balaju_132	132kV 1-Ckt	**4.9**	Bear 132
140	Suichatar-Balaju_66	132kV 1-Ckt	**7**	Wolf 66
141	Suichatar-Balaju_66(1)	132kV 1-Ckt	**7**	Wolf 66
142	Suichatar-Patan_66	132kV 1-Ckt	**7**	Wolf 66

143	Suichatar-Patan_66(1)	132kV 1-Ckt	**7**	Wolf 66
144	Suichatar-Teku_66(1)	132kV 1-Ckt	**4.1**	Bear 66
145	Sunkoshi-Panchkhal_66	132kV 1-Ckt	**29**	Wolf 66
146	Syangja-Lekhnath_132(1)	132kV 1-Ckt	**70**	Bear 132
147	Syaule-Attariya_132	132kV 1-Ckt	**131**	Bear 132
148	Tamakoshi-N Khimti_220	220kV Tower 1-Ckt	**47**	Twin Bison 220
149	Tamakoshi-N Khimti_220(1)	220kV Tower 1-Ckt	**47**	Twin Bison 220
150	Teku-K3_66	XLPE 66	**2.8**	Twin Moose 400
151	Teku-K3_66(1)	132kV 1-Ckt	**4.1**	Bear 66
152	Teku-K3_66(2)	XLPE 66	**2.8**	Bear 66
153	Tingla-Mirchiya_132	132kV 1-Ckt	**90**	Bear 132
154	Tingla-Mirchiya_132(1)	132kV 1-Ckt	**90**	Bear 132
155	Trishuli-Devighat_66	132kV 1-Ckt	**4.56**	Wolf 66
156	UMarsyangdhi-MMarsyangdi_132(2)	132kV 1-Ckt	**40**	Cardinal 132
157	UMarsyangdhi-Nyadi_132	132kV 1-Ckt	**6**	Bear 132

APPENDIX B: Interest rate of top 20 commercial Bank in Nepal

S. No.	**Name of Bank**	**General Saving Max. Interest (% p.a.)**	**Interest Rate Fixed Deposit (% p.a.)**	
			Individual	**Institutional**
1	Machhapuchchhre Bank Limited	7.85	9	7
2	Citizens Bank International Limited	7.4	9.99	7.99
3	Laxmi Sunrise Bank Limited	7.4	9.99	7.99
4	Prime Commercial Bank Limited	7.93	10.93	8.93
5	Kumari Bank Limited	7.4	10.01	7.51
6	Nepal SBI Bank Limited	6.4	9.99	7.99
7	Himalayan Bank Limited	7.4	9.99	7.99
8	Prabhu Bank Limited	7.5	9.5	7.5
9	Sanima Bank Limited	7.2	9.52	7.52
10	Siddhartha Bank Limited	7	9.5	7.5
11	Global IME Bank Limited	7	9.99	7.99
12	NMB Bank Limited	7.98	10.98*	7.99
13	Agricultural Development Bank Limited	7	9.51	7.51
14	Nepal Investment Mega Bank Limited	7.4	9.99	7.99
15	Everest Bank Limited	6.75	9.5	7.5
16	Nabil Bank Limited	7.9	10.49	8.49
17	Nepal Bank Limited	6.66	8.99	6.99
18	Standard Chartered Bank Nepal Limited	6.45	8.95	6.95
19	Rastriya Banijya Bank	6.66	8.99	6.99
20	Nepal Bank Limited	7.95	9.29	7.29
Average Interest Rate(%)		**7.2615**	**9.6906842**	**7.6805**

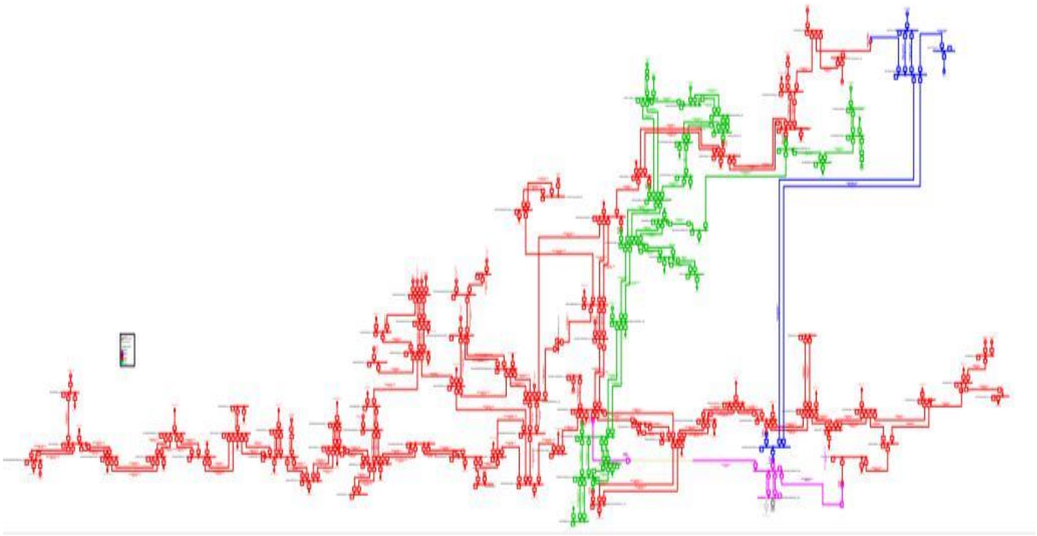

Figure 14 Overall INPS network simulation model drawn in Dig-silent software