Federal Democratic Republic of Nepal
Nepal Electricity Authority

DATA COLLECTION SURVEY ON TRANSMISSION AND DISTRIBUTION NETWORK DEVELOPMENT IN NEPAL

FINAL REPORT

July 2019

Japan International Cooperation Agency

NEWJEC Inc.
The Kansai Electric Power Co., Inc.

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Data Collection Survey on Transmission and Distribution Network Development in Nepal

FINAL REPORT

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Abbreviations

Symbol	Abbreviations
ABC	Aerial Bundled Conductor
ACSR	Aluminum Conductor Steel Reinforced
ADB	Asian Development Bank
BESS	Battery Energy Storage System
DoED	Department of Electricity Development
DS/REMP	Distribution System / Rural Electrification Master Plan
EA	Electricity Act, 1992
EIA	Environmental Impact Assessment
ER	Electricity Rules, 1993
ETFC	Electricity Tariff Fixation Commission
F/S	Feasibility Study
GIS	Gas Insulated Switchgear
IEC	International Electrotechnical Commission
IMP	Integrated Master Plan for Evacuation of Power from Hydro Projects in Nepal
INPS	Integrated Nepal Power System
INR	India Rupee
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
LDC	Load Dispatch Center
LRMP	Loss Reduction Master Plan
MCC	Millennium Challenge Corporation
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoI	Ministry of Industry

Symbol	Abbreviations
NEA	Nepal Electricity Authority
NERC	Nepal Electricity Regulatory Commission
NPR	Nepalese Rupee
PTDEP	Power Transmission and Distribution Efficiency Enhancement Project
PPA	Power Purchase Agreement
REC	Rural Electrification Community
ROW	Right of Way
RPGCL	Ratriya Prasaran Grid Co. Ltd
SDGs	Sustainable Development Goals
S/S	Substation
Sw/S	Switching Station
THDP	The Hydropower Development Policy
TSDP	Transmission System Development Plan of Nepal
TSMP	Transmission System Master Plan of NEA
VUCL	Vidhyut Utpadan Co., Ltd.
WB	World Bank
WEC	Water and Energy Commission
WRSN	Water Resource Strategy Nepal

CHAPTER 1

BACKGROUND AND OBJECTIVES

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1.1 BACKGROUND OF THE STUDY

Looking at the electric power demand and supply in the Federal Democratic Republic of Nepal (hereinafter referred to as "**Nepal**"), the power generation capacity as of July 2018 was 1,069MW, about 440MW lesser than the peak demand of that year. The shortfall is made up for by the power imported from India. Efforts have been made to increase power generation capacity through the development of large-scale hydraulic power plants with the aid of donors and active participation of private operators as IPPs. However, in the power transmission and distribution sector, the power loss rate is 20.45% (FY2018)[1], which is higher than its neighboring countries, and this contributes to the increase in supply and demand gap. Moreover, the power demand in Nepal has been increasing at an annual rate of 7-8% and is expected to further increase with the target electrification rate of 99% by 2030. In this situation, there is an urgent need to develop the transmission and distribution network, in order to achieve efficient and stable power supply across a wide area, as well as, to increase power generation capacity.

In the field of power transmission and distribution, in July 2018, the government of Nepal (**GoN**) established the "Transmission System Development Plan of Nepal" (**TSDP**) and announced a plan to develop 132kV or higher-voltage transmission and distribution networks by 2040. The plan to develop transmission and distribution network of voltage less than 132kV (66kV, 33kV and 11kV) is being developed as the "Nepal Distribution System/ Rural Electrification Master Plan" with the aid of the Asian Development Bank (**ADB**). The power transmission and distribution sector has issues such as (1) insufficient distribution network in urban areas to meet the power demand and (2) many areas remain unelectrified. Although the World Bank (**WB**) and ADB have been actively providing assistance to this sector, the demand is not met, and there is still a great need for development.

This study is to clarify the current state and issues in the power transmission and distribution sector and to examine and make suggestions in a concrete manner for financial assistance (Official Development Assistance (**ODA**) loans and grant aid) and technical cooperation from Japan International Cooperation Agency (**JICA**), in view of forming future projects for the power sector.

Under these circumstances, JICA implemented the Data Collection Survey on Transmission and Distribution Network Development in Nepal (**Study**) and created a joint venture of NEWJEC Inc. and Kansai Electric Power Co. Inc. to form the **JICA Study Team**.

[1] NEA. 2018. Annual Report 2017/2018

1.2 PURPOSE AND SCOPE OF THE STUDY

Category	Contents	Notes
Purpose	Clarify the development status and plans in the power transmission and distribution sector, for the major cities of Nepal and identify the need for assistance (financial assistance and technical cooperation) concerning the development of transmission and distribution network. Also, clarify the issues concerning the improvement of power supply, which has to be achieved by 2040. The expected outcomes are described below. 1) Collection of basic information for the formation of financially assisted projects, suggestion of potential projects for financial assistance and clarification of issues 2) Suggesting the need for technical cooperation by analyzing the structure and the maintenance capability of the relevant organizations, and clarification of issues	1) Collect and analyze generally available documents and materials in advance using the Internet, etc. to work efficiently. 2) Assuming that the materials and analysis results are insufficient, interview many relevant parties. 3) Perform tasks in an efficient manner, by making the maximum use of the results of the studies conducted by JICA and other donors and the relevant materials available from the government of Nepal. When using relevant materials, check the consistency of the contents and clarify the missing information, the additional required information, etc.
Target areas and scope	Transmission and distribution networks of 132kV or less in major cities of Nepal (Kathmandu, Pokhara, Lalitpur, Birgunj, Biratnagar, Bhairahawa, Simla and Bharatpur)	1) Select a few cities including Kathmandu Valley from the 8 cities listed on the left as candidates for ODA loan assistance. 2) If other cities are found to have great need for power transmission and distribution based on future demand and supply balance and trends of assistance from other donors, add these cities to the 8 cities listed on the left.
Relevant organizations, study subjects, etc.	1) Ministry of Energy, Water Resources and Irrigation (MoEWRI) 2) Nepal Electric Authority (NEA) 3) Ratriya Prasaran Grid Co. Ltd. (RPGCL)	In this study, NEA is assumed to be the implementing organization. However, considering the possibility that RPGCL will be in charge of all power transmission projects in the future, collect information from all relevant organizations and assess the current situation.
Scope of operations	1) Collection, analysis, etc. of relevant materials and information; and preparation of Inception Report 2) Collection and analysis of information from relevant local ministries, agencies and other organizations, other donors, etc. 3) Collection of information concerning candidates for loan assistance 4) Consideration of Quality infrastructure that can be utilized 5) Consideration of a plan to introduce large-capacity storage batteries 6) Proposal of candidates for loan assistance and clarification of issues 7) Suggestion of technical cooperation need	When considering the utilization of Quality infrastructure, consider whether the technological superiority of "quality infrastructure" matches the needs of the recipient country. Explain the results of trial calculation of lifecycle cost, etc. as needed to obtain full consent from the implementing organization and other relevant organizations.

1.3 STUDY TEAM MEMBERS

The study will be conducted by the following study team members (JICA Study Team).

Table 1.3-1 JICA Study Team

Name	Responsibility	Organization
Kenichiro Yagi	Team leader / Power development planning	NEWJEC Inc.
Shinichi Muroya	Transmission and Substation facility planning	Kansai Electric Power Co. Inc.
Shinichi Kawabe	Distribution facility planning	NEWJEC Inc.
Kazuki Konishi	Power system analysis	Kansai Electric Power Co. Inc
Yukihiro Mikumo	Economic and financial analysis / Organizational structure	NEWJEC Inc.

CHAPTER 2

CURRENT STATE OF THE ELECTRIC POWER SECTOR IN NEPAL

CHAPTER 2 CURRENT STATE OF THE ELECTRIC POWER SECTOR IN NEPAL

2.1 POLICIES AND ORGANIZATIONAL STRUCTURE OF THE ELECTRIC POWER SECTOR IN NEPAL

2.1.1 Current Situation and Issues in Power Sector

In Nepal, the development, implementation, monitoring and evaluation of energy policies are supervised by Ministry of Energy, Water Resources and Irrigation (**MoEWRI**), and the affiliated organization, Department of Electricity Development (**DoED**) is in charge of practical works of the Electric power industry. MoEWRI is a ministry that was established after the Ministry of Energy took over the Ministry of Irrigation as determined by the Government of Nepal Work Allocation Regulations - 2074, which was implemented under the second Oli administration in March 2018. And, the Nepal Electricity Regulatory Commission (**NERC**), the Water and Energy Commission (**WEC**), and others were established as government agencies for power sector by the government.

The Nepal Electricity Authority (**NEA**) has jurisdiction over the overall power sector, and deals with procurement, sales, supply, infrastructure development and maintenance of power. The "Power Act" enacted in 1992, allows private power operators to be a part of wholesale power sector, since then, many IPPs and Vidhyut Utpadan Co., Ltd. (**VUCL**, Electricity Generating Authority of Nepal) are in charge of the power generation. In addition, the Government of Nepal aims to separate transmission and distribution in the future. Based on this policy, Ratriya Prasaran Grid Co. Ltd. (**RPGCL**) was established in 2015 as a Power Transmission Corporation. The relationship between the ministries and organizations related to the electric power industry is shown in Figure 2.1-1.

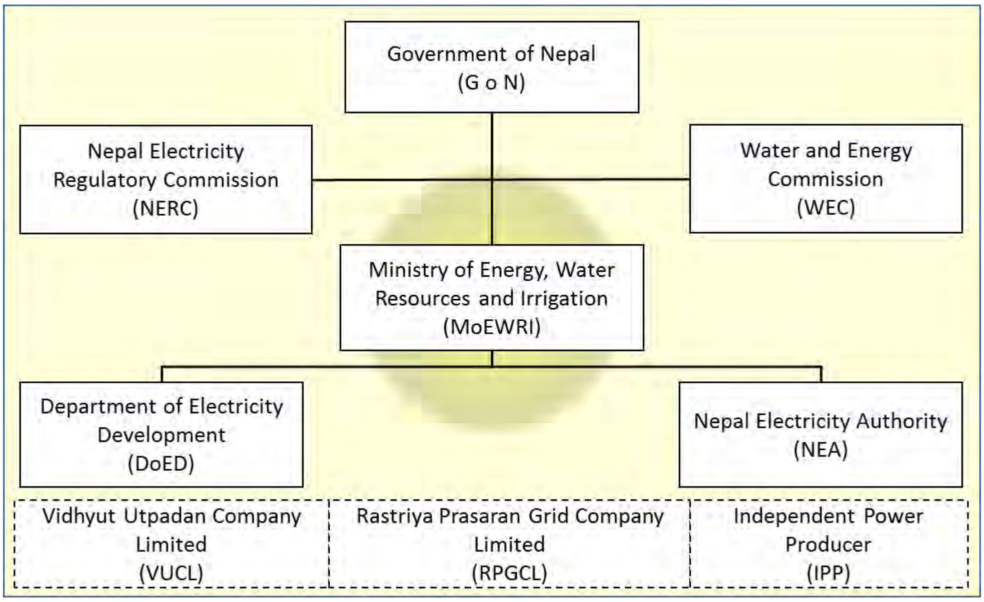


Figure 2.1-1 Organizations related to the Electric Power Industry in Nepal

In terms of policy, the government of Nepal established "The Hydropower Development Policy" (**THDP**) in 2001, and set the goal as economic development, including the development of rural areas by developing inexpensive electric power, using the abundant water resources[1] of the country.

In the next year, 2002, the government started to formulate the first comprehensive water resource strategy named as "Nepal Water Resource Strategy" (**WRSN**) under the support of World Bank, the International Development Association and Canadian International Development Agency. Although some full-scale water resource development plans have been formulated by the government, the development of the same have not progressed as planned and power shortage has not yet been resolved.

On the other hand, in order to supply electricity to the demand site stably, it is indispensable to develop a transmission / distribution network, along with measures to expand the generation capacity. In order to promote this development plan, "Transmission System Master Plan of NEA" (**TSMP**) was formulated in 2015. And "Integrated Master Plan for Evacuation of Power from Hydro Projects in Nepal" (**IMP**) and development plans such as TSDP etc. were formulated in 2016. In accordance with the future development of power generation facilities, it is necessary to implement the plan, in order to improve and expand the power transmission network and distribution network in a timely manner.

[1] It is said that the capacity of Hydroelectric power in Nepal might be 83,000 MW, and the capacity of economically developable hydroelectric power might be 42,000 MW. But only about 2.5% of capacity have been developed as of 2016.

2.1.2 The Organization Map and Management Structure of Project Implementing Organization

NEA is a state owned utility, an organization engaged in power generation, transmission and distribution. NEA was established in 1985, by integrating the Power Dept. with the Electricity Bureau of the Ministry of Water Resources, under the Electricity Authority Act enacted in 1984.

NEA has a Board of Directors chaired by the Minister of Energy, Water Resources and Irrigation; and the Board of Directors consists of seven members: Secretary of Energy, Secretary of Finance, Federation of Chambers of Commerce, Representatives of Consumers, Electric Power Specialist and President of NEA. In the board meetings, important matters related to the operation of NEA such as, power business or power purchase agreement (**PPA**) are discussed.

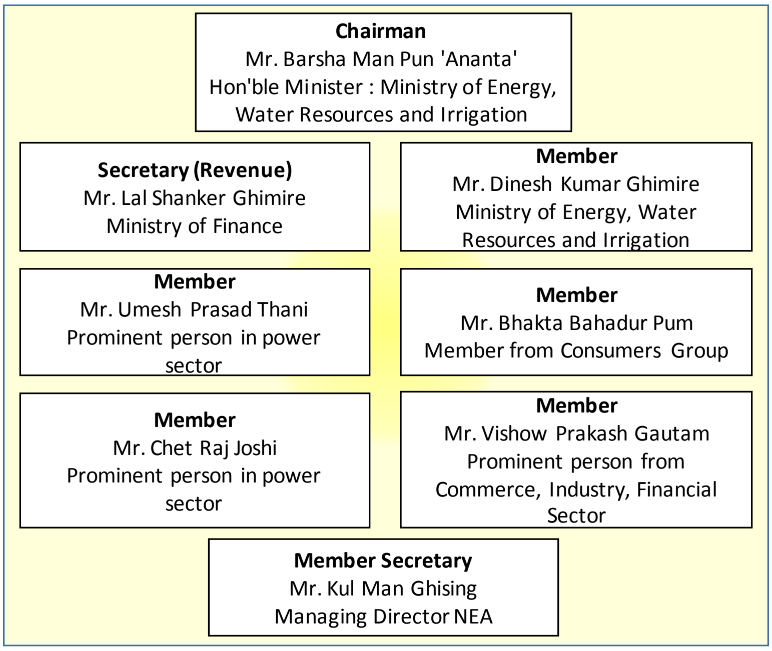


Figure 2.1-2 Organization Structure of NEA Board of Directors

The NEA as an organization has a Managing Director, who works under the Board of Directors, and the practical tasks are carried out by eight directorates, who work under the Managing Director. The Managing Director has a Steering Committee, which makes decisions on NEA's management. The organizational structure of NEA is shown in Figure 2.1-3.

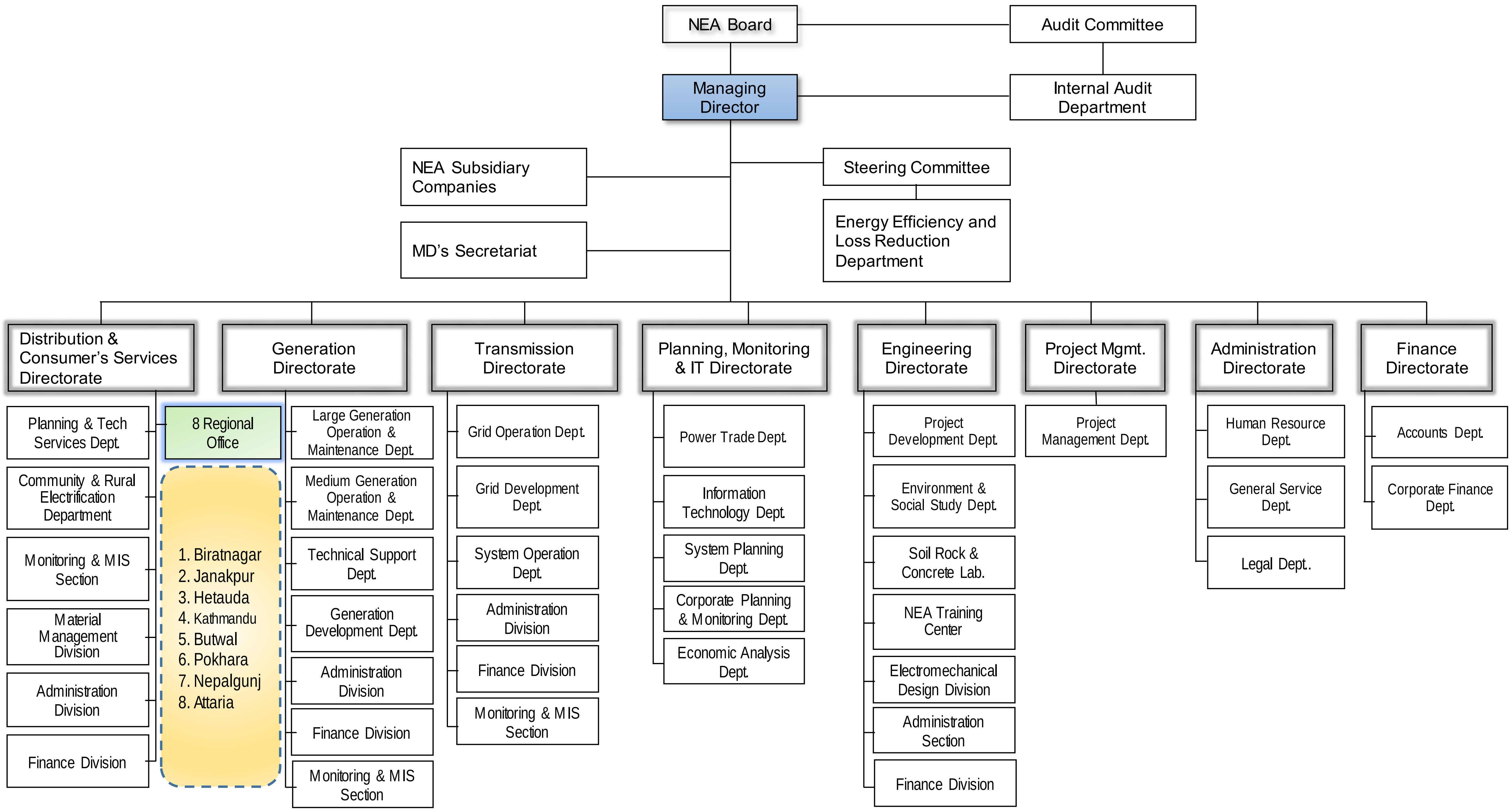


Figure 2.1-3 Organizational Structure of NEA

In this organization, "Distribution & Consumer Service Directorate", "Transmission Directorate" and "Project Management Directorate" are considered to play an important role in the transmission and distribution projects.

The role of each directorate is described below.

(1) Distribution & Consumer Services Directorate（DCSD）

DCSD plans, constructs, maintains and operates substations and distribution facilities, which are up to 33 kV. In addition to supplying electricity to new customers, the DSCD also carries out billing and collects electricity charges from its users. DCSD is the largest business unit in NEA, and 70% of the total number of staff members belong to this directorate, and it has 6 departments and 8 branch offices.

"Planning Technology Service Department" is in charge of technical support, in terms of expansion planning and preparation of the distribution system. The main business contents of this department are shown below.

- Planning and implementation of rural electrification and substation rehabilitation
- Programming of TOD meters and measuring instruments, data collection and analysis
- Monitoring and analysis of distribution system losses by area
- Support in project design and implementing loss reduction in the distribution system
- Modernization of facilities related metering, billing and fee collection
- Implementation of distribution plan for integrated power demand and loss reduction

Community & Rural Electrification Department is a department established in 2003 to efficiently implement a community rural electrification program led by the Government of Nepal. This department supplies electricity to the Rural Electrification Community (REC), and supports the operation and management of distribution in the area. NEA provides service up to 11 kV line, REC is in charge of 400 / 230V line.

Table 2.1-1 Departments of DCSD

6 Departments		
1. Planning & Tech. Services Dept.	2. Community & Rural Electrification Department	3. Finance Division
4. Administration Division	5. Material Management Division	6. Monitoring & MIS Section

This department is the largest department in NEA, and there are many organizations under its umbrella. Its organizational structure and the structure of branch offices located throughout the country are shown in Figure 2.1-4 and Figure 2.1-5.

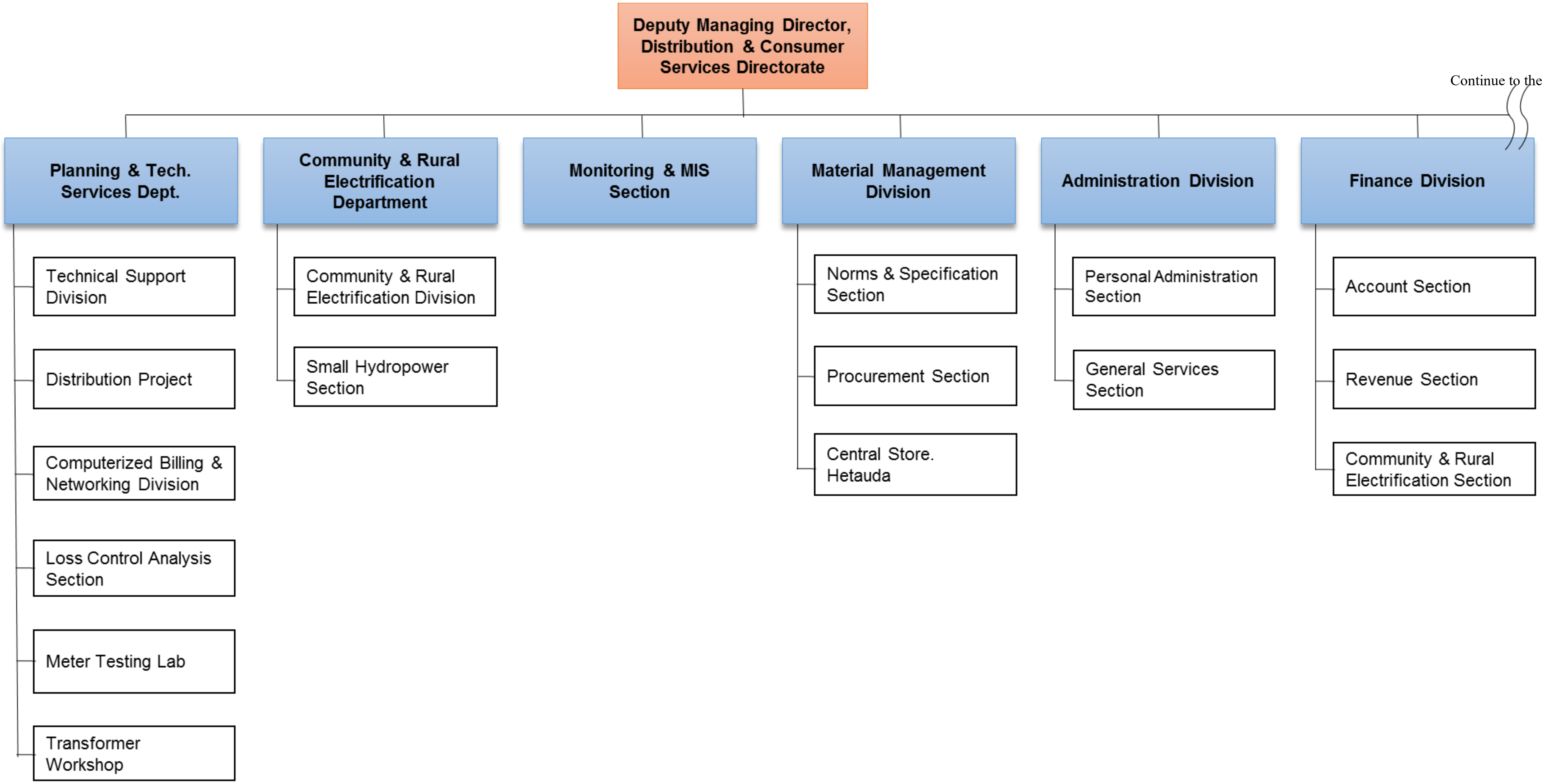


Figure 2.1-4 Organizational Structure of DCSD (Part 1)

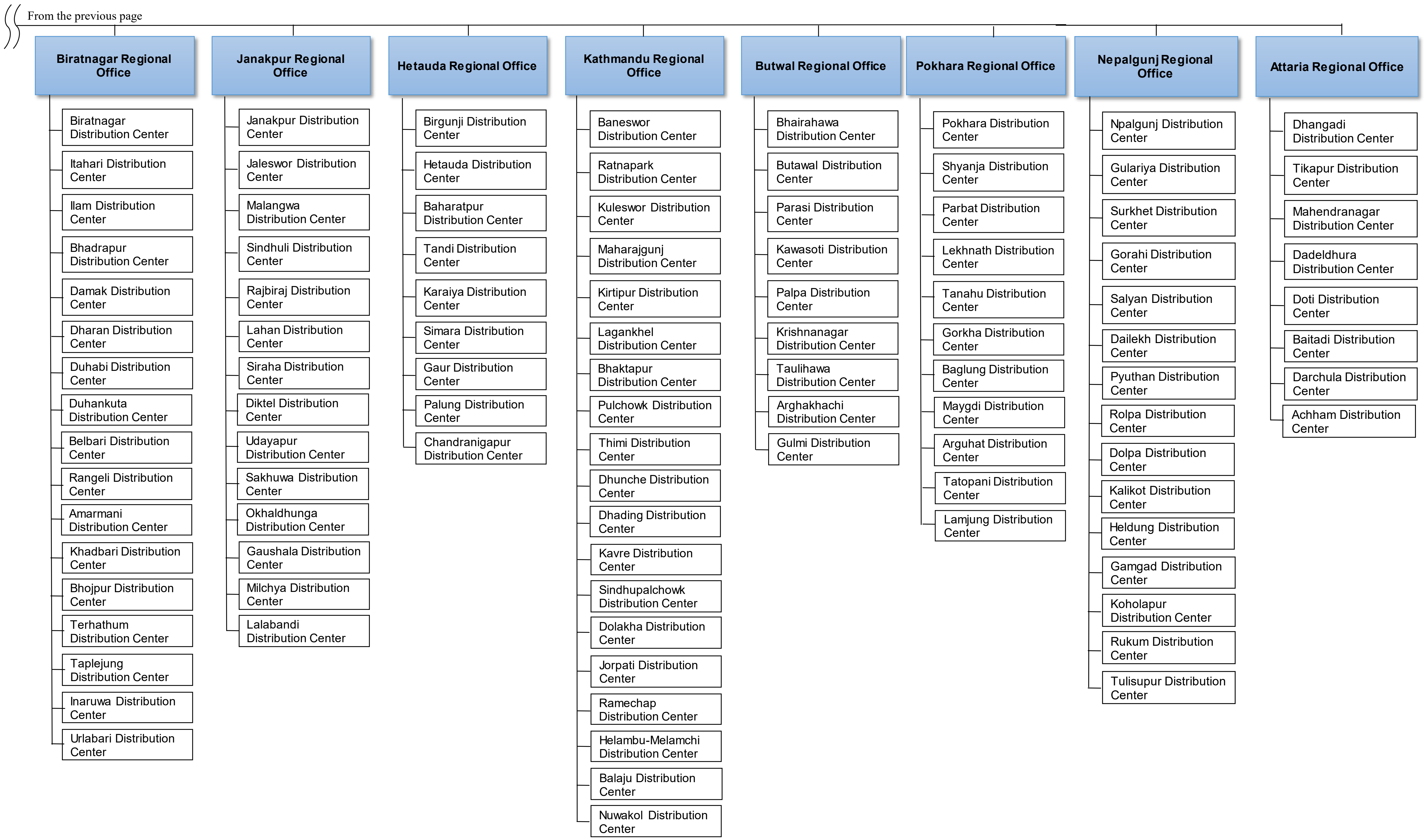


Figure 2.1-5 Organizational Structure of DCSD (Part 2)

(2) Generation Directorate

This department is responsible for the construction of a new power plant and the maintenance and operation of the power plant, when it is operated by the NEA. The business related tasks are mainly carried out by power development department, technical support department, power plant operation and maintenance department. Currently, the following three hydroelectric power plant construction projects are being implemented by this department.

- ✓ Kulekhani III Hydroelectric Project(14MW)
- ✓ Rahughat Hydroelectric Project(40 MW)
- ✓ Upper Trishuli 3'A' Hydroelectric Project(60MW)

Table 2.1-2 Departments of Generation Directorate

7 Departments		
1. Large Generation Operation & Maintenance Dept.	2. Medium Generation Operation & Maintenance Dept.	3. Technical Support Dept.
4. Generation Development Dept.	5. Administration Division	6. Finance Division
7. Monitoring & MIS Section	-	-

(3) Transmission Directorate

This Directorate is responsible for the construction and operation of high-voltage transmission lines, and it consists of Grid Operation Department, Grid Development Department, System Operation Department, Administration Division, Finance Division and Monitoring & MIS Section. The Grid Operation Department, Grid Development Department, System Operation Department, have their own organizations and project sites under their umbrella, and their structure is shown in Table 2.1-3.

The Grid Operation Department is mainly responsible for high-quality transmission of power from distant power stations to various load centers. It also provides connection service between IPP and mass consumers at different voltages, by signing a connection contract in accordance with the NEA Grid Code.

Another major task of the Grid Operation Department is the daily maintenance work, which involves tasks such as operation of substations and transmission lines of 66kV or more, expansion of facilities, replacement and repair work, etc., and the Grid Branch (Pokhara, Duhabi, Attariya, Kathmandu, Hetauda, and Butwal) work under this department to fulfill these responsibilities.

Table 2.1-3 Organizational Structure of Transmission Directorate

Transmission Directorate		
1. Grid Operation Department	2 Grid Development Department	3. System Operation Department
Pokhara Grid Branch	Butwal – Kohalpur 132kV Transmission Line 2nd Circuit	Load Dispatch Center
Duhabi Grid Branch		
Attariya Grid Branch	Chapali 132kV Substation	
Kathmandu Grid Branch	Illam - Damak 132kV Transmission Line from Kabeli Corridor	
Hetauda Grid Branch		
Butwal Grid Branch		

The Grid Branch Office, mentioned above, operates substations with the organizational structure shown in Figure 2.1-6. Engineers are deployed under the Branch Chief (Chief Engineer), and each Engineer manages the operation of the substation. In actual operation, two operators manage for eight hours in one shift, and the substations are continuously managed for 24 hours a day by three shifts. When problems occur, the Maintenance Group assists in problem resolution and restoration of the substations.

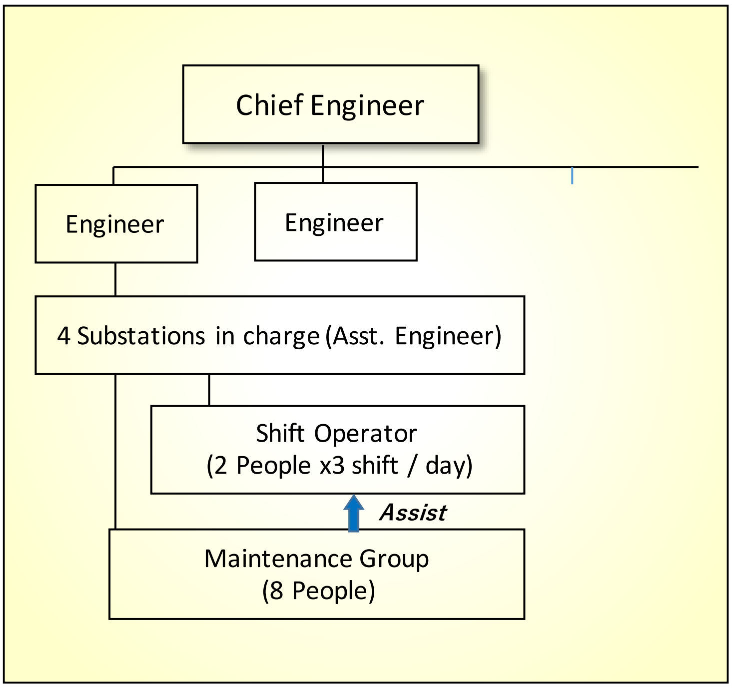


Figure 2.1-6 Organizational Structure of Grid Branch

Grid Development Dept. is in charge of developing projects, which shall expand the power supply capacity and the target area. The projects recently completed by the Grid Development Dept. are shown below.

- Butwal – Kohalpur 132kV Transmission Line 2nd Circuit
- Chapali 132kV Substation
- First Section Illam-Damak 132kV Transmission Line from Kabeli Corridor

The System Operation Dept. operates the Load Dispatch Center. The Load Dispatch Center operates the Integrated Nepal Power System (INPS), by using the SCADA system on a 24-hour basis. This system improves the overall availability of power plants and transmission lines and helps to quickly restore the power system during power outage.

(4) Planning, Monitoring & IT Directorate

This department consists of the Power Trade Dept., the System Planning Dept., the Corporate Planning & Monitoring Dept. and Monitoring Department, the Information Technology Dept. and the Economic Analysis Dept. The Power Trade Dept. is responsible for purchasing power from IPPs and power generation companies in India. The system planning dept. is in charge of planning, for the expansion of transmission and distribution systems. The Transmission Directorate and the Distribution & Consumer's Services Directorate are also involved in the expansion plan.

Table 2.1-4 Organizational Structure of Planning, Monitoring & IT Directorate

5 Departments		
1. Power Trade Dept.	2. Information Technology Dept.	3. System Planning Dept.
4. Corporate Planning & Monitoring Dept.	5. Economic Analysis Dept.	-

(5) Engineering Service Directorate

This Directorate consists of Project Development Dept., Environment & Social Study Dept., Soil Rock & Concrete Lab., NEA Training Center, Electromechanical Design Division, Administration Section and Finance Division

Table 2.1-5 Organizational Structure of Engineering Service Directorate

7 Departments		
1. Project Development Dept.	2. Environment & Social Study Dept.	3. Soil Rock & Concrete Lab.
4. NEA Training Center	5. Electromechanical Design Division	6. Administration Section
7. Finance Division	-	-

(6) Project Management Directorate

This Directorate consists of only the project management department, and mainly manages the execution of the projects, which are implemented with the support of ADB.

(7) Administration Directorate

This Directorate is comprised of Human Resources Development Department, General Service Department and Legal Department; and it is mainly responsible for the labor management of NEA personnel, legal management and human resource development.

Table 2.1-6 Organizational Structure of Administration Directorate

3 Departments		
1. Human Resource Dept.	2. General Service Dept.	3. Legal Dept.

(8) Finance Directorate

This Directorate consists of the accounting department and the finance department. The accounting department manages the balance sheet of the NEA, and the corporate finance department mainly carries out all the financing activities and the financial activities of NEA.

Table 2.1-7 Organizational Structure of Finance Directorate

2 Departments	
1. Account Dept.	2. Corporate Finance Dept.

2.1.3 Financial Condition of Implementing Agency

As a result of the field survey, financial statements that reflect actual values for 2018, the latest year, were obtained. The trends, which can be read from the financial statements, are shown below.

(1) Balance Sheet

The current ratio rose to around 46% from around 30% in 2016, and the same rose to around 76% from 2017 to 2018. The capital adequacy ratio was around 10% in the past, but has increased from 23% to 28% since 2017.

Table 2.1-8 Balance Sheet of NEA （2009～2018）

（Unit：NRs. in million）

Particulars	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Assets										
Non Current Assets										
Property, Plant & Equipment	112,984.5	90,341.2	88,521.1	86,439.1	84,238.7	83,873.5	85,460.7	84,725.5	83,105.6	81,238.5
Capital Work in Progress	77,607.0	80,272.3	66,684.1	58,052.4	46,993.9	39,843.2	29,905.5	22,832.0	17,040.5	13,550.5
Investments	29,941.5	25,845.4	21,755.1	17,550.9	12,288.3	6,807.6	5,049.2	4,855.1	3,445.7	2,501.1
Total Non-Current Assets	220,533.1	196,458.9	176,960.2	162,042.3	143,520.9	130,524.2	120,415.3	112,412.6	103,591.8	97,290.1
Current Assets										
Inventories	7,543.7	4,218.0	3,376.4	3,169.8	2,859.4	3,043.0	3,033.8	2,502.9	2,432.0	2,159.1
Trade and other Receivables	15,547.0	13,585.9	11,186.8	9,927.5	9,015.6	7,930.0	6,693.2	6,871.2	6,097.7	4,854.0
Cash and Cash Equivalents	34,494.6	24,823.8	15,361.6	10,621.6	6,121.6	4,715.0	2,697.5	2,016.6	1,244.7	1,724.8
Prepaid, Loans & Advances and Deposit	6,453.6	5,875.9	3,804.3	3,783.0	3,644.7	3,300.6	4,222.7	2,976.8	4,585.6	2,495.1
Total Current Assets	64,039.0	48,503.5	33,729.1	27,501.8	21,641.3	18,988.6	16,647.1	14,367.5	14,360.0	11,233.0
Total Assets	284,572.1	244,962.4	210,689.4	189,544.2	165,162.2	149,512.8	137,062.5	126,780.1	117,951.8	108,523.1
Equity and Liabilities										
Capital and Reserves										
Share Capital	102,437.6	82,411.3	58,527.9	49,275.1	44,510.8	37,364.9	31,422.4	25,694.8	38,651.8	33,659.5
Reserves and Accumulated Profits										
Reserve	1,988.7	1,833.3	2,089.2	2,021.9	1,908.5	1,721.4	1,706.0	1,677.6	1,631.3	1,497.9
Accumulated Profits (Loss)	(25,586.6)	(28,168.1)	(34,608.5)	(25,751.4)	(20,238.6)	(13,238.2)	(9,867.0)	0.0	(21,022.4)	(14,098.8)
Total Equity	78,839.7	56,076.4	26,008.6	25,545.5	26,180.7	25,848.2	23,261.5	27,372.4	19,260.7	21,058.5
Non-Current Liabilities										
Borrowings	120,261.1	110,681.7	111,303.6	98,253.1	82,691.7	75,034.9	68,909.2	62,631.9	58,231.7	53,788.5
Deferred Tax	693.2	693.2	693.2	693.2	693.2	693.2	693.2	693.2	693.2	693.2
Total Non-Current Liabilities	120,954.4	111,374.9	111,996.9	98,946.3	83,384.9	75,728.1	69,602.4	63,325.1	58,924.9	54,481.7
Current Liabilities										
Borrowings	-	-	-	-	700.0	1,200.0	3,500.0	790.0	1,280.0	250.0
Sundry Creditors and Other Payables	58,833.3	54,085.3	51,324.5	45,742.9	37,637.2	33,019.2	29,137.1	27,826.0	32,909.5	29,402.2
Provisions	25,944.7	23,425.8	21,359.5	19,309.5	17,259.5	13,717.3	11,561.5	7,466.7	5,576.8	3,330.8
Total Current Liabilities	84,778.0	77,511.1	72,683.9	65,052.4	55,596.7	47,936.6	44,198.6	36,082.7	39,766.3	32,983.0
Total Liabilities	205,732.4	188,886.0	184,680.8	163,998.6	138,981.6	123,664.7	113,801.0	99,407.7	98,691.1	87,464.7
Total Equity and Liabilities	284,572.1	244,962.4	210,689.4	189,544.2	165,162.2	149,512.8	137,062.5	126,780.1	117,951.8	108,523.1
Current ratio	75.5%	62.6%	46.4%	42.3%	38.9%	39.6%	37.7%	39.8%	36.1%	34.1%
Capital adequacy ratio	27.7%	22.9%	12.3%	13.5%	15.9%	17.3%	17.0%	21.6%	16.3%	19.4%

(2) Profit and Loss Statement

The profit and loss statement shows a surplus since 2017, and the income has increased.

Table 2.1-9 Profit and Loss Statement of NEA（2009～2018）

（Unit：NRs. in million）

Particulars	2018*	2017	2016	2015	2014	2013	2012	2011	2010	2009
Net Sales Revenue	55,358.2	46,795.8	31,824.2	30,168.8	28,205.7	25,354.6	20,088.6	17,946.8	17,164.6	14,405.9
Cost of Sales										
Generation	1,678.5	1,463.9	1,333.1	1,384.0	1,886.5	1,604.3	1,147.7	929.6	1,541.3	1,119.7
Power Purchase	34,130.7	28,332.8	22,332.4	19,210.2	17,041.5	13,572.5	11,948.4	10,493.7	9,746.6	7,691.3
Royalty	1,428.8	967.4	883.1	892.5	888.7	890.5	941.6	854.8	849.8	796.1
Transmission	1,883.1	1,822.8	1,094.6	579.6	519.5	416.7	421.4	346.0	337.7	328.2
Gross profit	16,237.1	14,208.8	6,181.0	8,102.5	7,869.5	8,870.6	5,629.6	5,322.8	4,689.3	4,470.7
Other Income	6,615.5	4,907.3	3,249.3	3,116.3	2,156.9	1,868.4	1,695.4	1,382.9	1,188.3	1,601.7
Distribution Expenses	7,645.0	7,041.6	5,671.4	5,341.5	4,575.2	4,088.0	3,685.2	3,004.2	3,091.2	2,575.1
Administrative Expenses	2,043.0	1,601.6	1,218.6	1,339.0	1,239.2	1,327.5	973.4	866.7	789.5	651.7
Interest Expenses	3,221.8	3,546.2	5,079.7	4,670.2	4,234.5	4,039.7	3,885.5	3,594.0	3,668.7	2,492.6
Depreciation	4,210.3	3,755.2	3,554.4	3,471.0	3,296.6	3,228.7	3,175.8	3,031.3	2,902.9	2,361.2
Loss (Gain) on Foreign Exchange	277.5	(410.7)	746.5	(523.2)	(52.8)	(652.1)	896.6	85.0	28.7	814.0
Provisions & write offs	-	-	-	-	-	-	(549.8)	(323.7)	(112.4)	(959.7)
Provision under Employees' Benefits Plan	2,500.0	2,050.0	2,050.0	2,050.0	3,542.1	2,112.7	4,106.7	1,890.0	2,246.0	1,246.0
Provisions for Employees' Bonus	57.9	30.1	-	-	-	-	-	-	-	-
Net Profit/(Loss) before Tax	2,897.1	1,502.3	(8,890.2)	(5,129.8)	(6,808.4)	(3,405.4)	(9,947.9)	(6,089.2)	(6,961.8)	(5,027.8)
Provision for Income Tax	-	-	-	-	-	-	-	-	-	-
Total Profit Available for Appropriation	2,897.1	1,502.3	(8,890.2)	(5,129.8)	(6,808.4)	(3,405.4)	(9,947.9)	(6,089.2)	(6,961.8)	(5,027.8)
Appropriation for Corporate Social Responsibility Fund	29.0	15.0	-	-	-	-	-	-	-	-
Appropriation for Insurance Fund	20.0	20.0	-	-	-	-	-	-	-	-
Profit/(Loss) Transferred to Statement of Financial Position	2,848.1	1,467.3	(8,890.2)	(5,129.8)	(6,808.4)	(3,405.4)	(9,947.9)	(6,089.2)	(6,961.8)	(5,027.8)

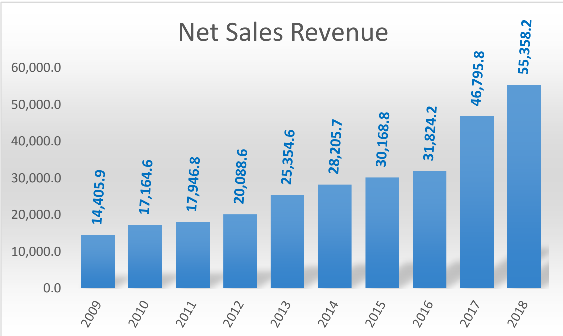


Figure 2.1-7 Net Sales Revenue of NEA

As mentioned above, the main reasons for the remarkable improvement in profits are the reduction of transmission and distribution losses and the improvement of electricity rate recovery rates.

NEA carried out a campaign to thoroughly eliminate non-technical losses due to wrong weighing or electricity stealing at each regional office, and NEA succeeded in reducing transmission and distribution losses by implementing the projects to optimize the distribution system with the assistance of WB and ADB.

In addition, NEA implemented an incentive program to give a fixed rate of rebate to customers who paid online, and this enabled NEA to carry out the on-time payment and reduction of collection costs. Eventually, NEA succeeded in the improvement of the collection rate of electricity bills by the installation of meters and implementation of staff instruction for charge collection.

Also, the following factors are considered to contribute to the recent improvement of financial conditions.

- Power sales increased due to expansion and commencement of IPP power supply
- Low price electricity supply from India has increased.
- A profit margin was generated as the purchase price was dropped from 8 NPR/kWh to 6 NPR/kWh

In addition, the following points have been pointed out as positive sign for future financial situation.

- Recovery of Bhotekoshi hydropower plant is in progress, and the operation is scheduled to resume in 2019. An increase in power supply is expected by this.
- According to Dinesh Kumar Ghimire, who is the Minister of Energy, it is believed that the operation of Upper Tamakosi hydro power plant will be commenced this November (2019/4/11, Kathmandu Post). An increase in power supply is expected by this hydro power.

2.1.4 Other Related Organizations

As mentioned above, RPGCL, which was launched by the government in 2015, is an organization that is considered to play a role in implementing the power transmission and distribution project in the future.

RPGCL has Board of Directors, chaired by the Minister of Energy, and it consists of seven members (Secretary and Deputy Secretary of Energy, Secretary of Finance, Managing Director and Deputy Director of NEA and CEO of RPGCL). The board of directors discuss important matters related to the operation of business and contracts. The organizational structure of the Board of Directors (as of May 2019) is shown in Figure 2.1-8.

Figure 2.1-8 Structure of the Board of Directors in RPGCL

In RPGCL, as shown in Figure 2.1-9., the "Grid Planning & Engineering Dept." and "Grid Communication & Operating Dept." are responsible for the implementation of new development and maintenance of transmission lines under the CEO.

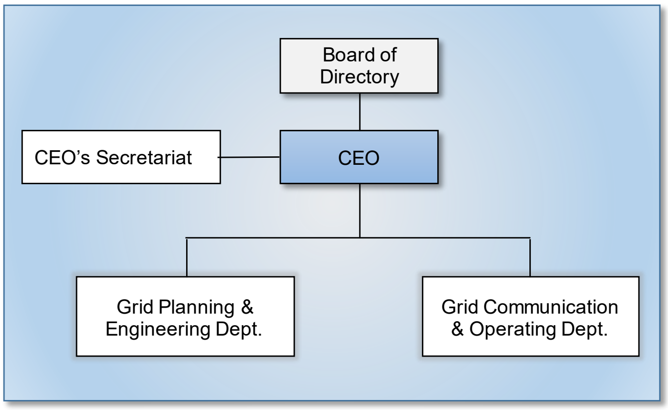


Figure 2.1-9 Management System of RPGCL

(1) Demarcation between RPGCL and NEA

RPGCL currently does not own assets, but in the future, plans to build a transmission line for IPP and connect it to the NEA's grid to create a business model that will generating income from the Wheeling Charge. Therefore, in the future, RPGCL will be in charge of operation, maintenance and implementation of facilities related to this. In addition, NEA is in charge of the grid on the load side for under 132 kV, and the distribution grid, which are not under the scope of RPGCL.

(2) Abilities of project development and maintenance management

RPGCL is a public utility funded by the government, and currently there is no training department for the development and transfer of skills and the sustainability of its staff. It will be established in the near future.

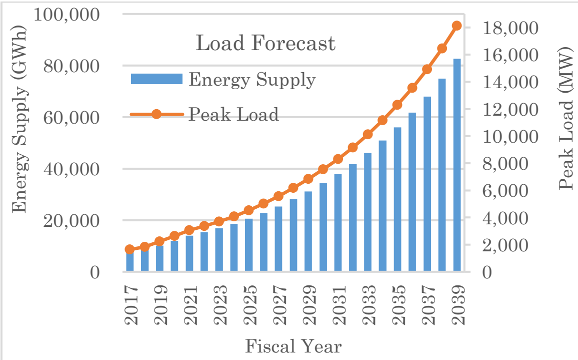
2.2 CURRENT STATE OF POWER TRANSMISSION AND DISTRIBUTION NETWORK AND DEVELOPMENT PLANNING

2.2.1 Current State of Electric Power Demand and Energy Utilization

The electrification rate in Nepal is about 76%[2] as of 2016, which is lesser than its neighboring countries. The Nepalese government has set a target in SDGs to increase the rate to 99% by 2030. However, there is a huge regional gap; the electrification rate is only 72% in rural areas while it is 97% in urban areas. As shown in Figure 2.2-1, the power demand in Nepal has been increasing at an annual average rate of 7-8%, and is expected to increase from 1,508 MW in 2018 to 18GW in 2040.

[2] ADB. 2017. NEPAL ENERGY SECTOR ASSESSMENT, STRATEGEY, AND ROAD MAP

Regarding the current state of the power supply, Table 2.2-1 shows that, although the power generation capacity has increased at an annual average rate of 3.9% from 2011 (706MW) to 2016 (856MW), this power generation capacity in the country covers only about 60% of the peak demand because demand grew at an even greater rate (annual average rate of 7.9%). The shortage is covered by imports from India, as well as, by having planned outage (load shedding) for long hours.[3] In order to reduce such a serious demand and supply gap, the Nepalese government has established multiple national policies and development plans for water resource development and taken other measures, including the liberalization of the power generation market to allow the entry of IPPs. However, the Nepalese government declared the end of load shedding to all consumer categories from May 2018.



Source: NEA Annual Report 2017/2018

Figure 2.2-1 Estimated Power Demand in Nepal

Table 2.2-1 Power Demand and Supply Capacity in Nepal

Item			FY 2011	2012	2013	2014	2015	2016	Annual Growth Rate(%)
Installed capacity(MW)			706	719	762	787	787	856	3.9
Peak demand(MW)			946	1,027	1,095	1,201	1,292	1,385	7.9
Supply capacity shortage(MW)			240	308	333	414	505	529	17.1
Electricity requirement(GWh)			4,833	5,195	5,446	5,910	6,335	6,920	7.4
Supply (GWh)	NEA	Hydro	2,122	2,357	2,273	2,288	2,366	2,168	0.4
		Thermal	3	2	19	10	1	0.1	0
		Total NEA	2,123	2,359	2,292	2,298	2,367	2,169	0.3
	IPPs		1,039	1,074	1,176	1,070	1,269	1,173	2.5
	Imports		694	746	790	1,319	1,370	1,758	20.4
	Total		3,858	4,179	4,258	4,687	5,006	5,100	5.7
Supply shortage(GWh)			975	1,018	1,188	1,223	1,329	1,820	13.3

Source: NEPAL ENERGY SECTOR ASSESSMENT, STRATEGEY, AND ROAD

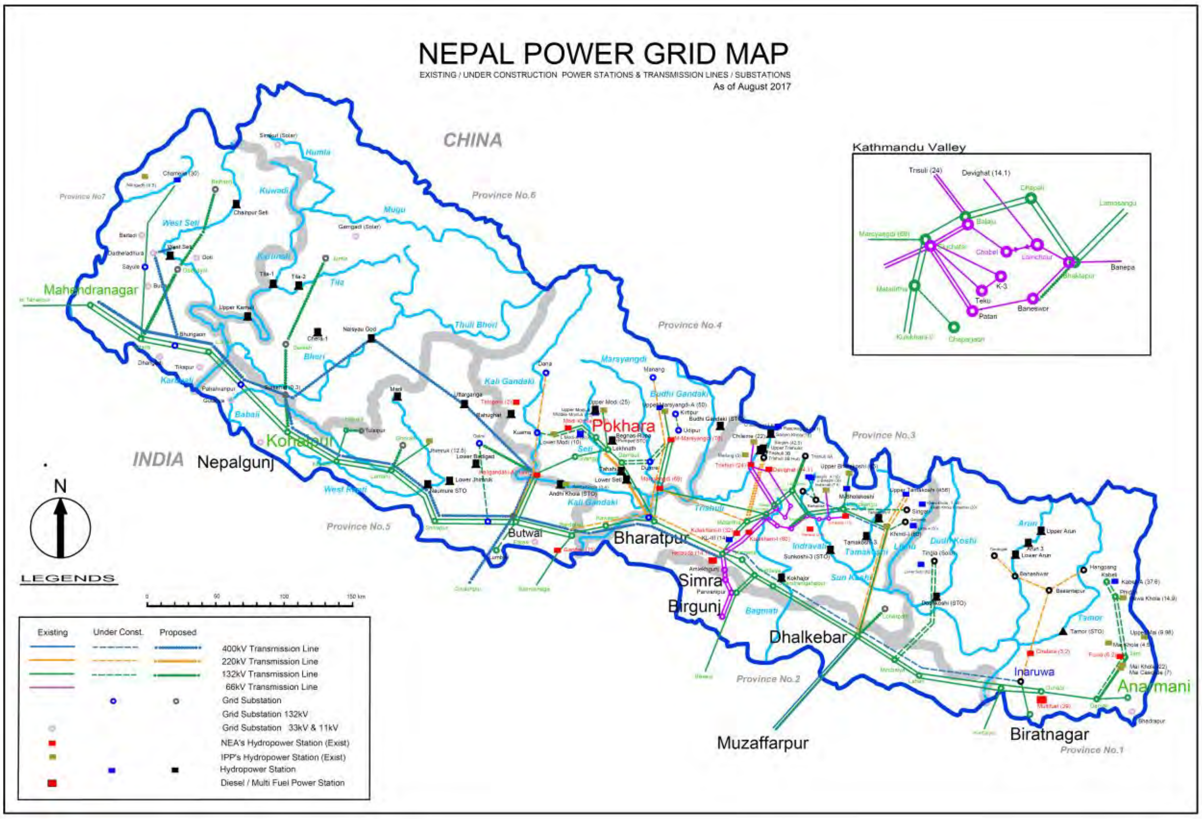
One of the causes for this situation is said to be the underdevelopment of power transmission and distribution network, which prevents the IPPs from investing in hydraulic power generation.

[3] Planned outage lasts for 11 hours a day in the dry season (Jan – Apr).

2.2.2 Current State of Transmission and Distribution Network

(1) Current state of transmission network

Figure 2.2-2 shows the overview of the transmission system in Nepal. The current transmission system consists of 400kV, 220kV, 132kV and 66kV transmission lines. The major transmission line is 132kV line running from east to west in the southern part of Nepal. The major 132kV transmission line connects Anarmani in the east and Majendtanager in the west. The major demand areas are located in the central hilly area, including the Kathmandu Valley and Terai region, and it also includes industrial areas such as Butwal, Birgunj and Biratnagar. Many hydropower plants are located in the northern and middle region of Nepal. Power generated by these hydropower plants is supplied to demand areas, mainly through 132kV transmission line.



Source: JICA Study Team based on NEA materials

Figure 2.2-2 Power Transmission Systems in Nepal (as of August 2017)

Table 2.2-2 shows capacity of power plants in the current transmission system of Nepal. The total capacity of power plants is 1,074,135kW. The hydropower plants contribute to about 95 % of the total capacity and the thermal and solar power plants contribute to about 5% of the total capacity. NEA owns about half of the hydropower plants in terms of capacity. Table 2.2-3 shows the existing hydropower plants owned by NEA. The Kaligandaki A power plant with largest capacity is the major plant in the current transmission system of Nepal. This plant is located in Syangja district of mid-western Nepal and supplies power to Lekhnath and Butwal substation.

Table 2.2-4 shows the list of transmission lines in the current system. Total length of 132kV transmission lines is 2,871km. Total length of 66kV transmission lines is 514km. The 66kV lines are present in some parts of the transmission system in Kathmandu city and region located south of Kathmandu. 400kV and 220kV network have only one transmission line respectively. In future, 400kV and 220kV network will be expanded, as the installed capacity of hydropower plants and power demand increase.

Table 2.2-5 shows the list of substations in the current system. The number of 132kV substations is 38 and the number of 66kV substations is 14. In future, 400kV and 220kV substations will be installed.

Power is supplied all over Nepal by the current transmission system. Nepal has seven provinces and six of the provinces are connected to the transmission system. However, province No.6 is still not connected to the system.

In the current 66kV and more transmission networks, there are five interconnection lines between Nepal and India. In addition, one interconnection lines are currently under construction. Power is exported from India through these interconnection lines when the power generated in Nepal is lesser than demand. In February 2016, 400kV transmission line for the interconnection was installed between Muzaffarpur in India and Dhalkebar, which is one of the five interconnection points. This interconnection line had been operated in 132kV since its completion. However, the voltage of the interconnection line was upgraded to 220kV in 2018. The line is planned to be operated in 400kV in the future.

Table 2.2-2 Capacity of power plants in the current transmission system of Nepal.

Type of Power Plant	Capacity(kW)
Major Hydropower Plants (NEA)	489,150
Small Hydropower Plants (NEA)	14,244
Small Hydropower Plants (NEA)-Isolated	4,536
Hydropower Plants (IPP)	512,695
Thermal Power Plants (NEA)	53,410
Solar Power Plants (NEA)	100
Total Installed Capacity	**1,074,135**

Source: NEA Annual Report 2017/2018

Table 2.2-3 Hydropower plants owned by NEA

Major Hydropower Plants		
S.No	Power Plants	Capacity(kW)
1	Kaligandaki A	144,000
2	Middle Marsyangdi	70,000
3	Marsyangdi	69,000
4	Trishuli	24,000
5	Sunkoshi	10,050
6	Gandak	15,000
8	Kulekhani I	60,000
7	Devighat	14,100
8	Kulekhani II	32,000
9	Puwa Khola	6,200
10	Modi Khola	14,800
11	Chameliya	30,000
Sub Total		489,150
Small Hydropower Plants		
12	Sundarijal	640
13	Panauti	2,400
14	Fewa	1,000
15	Seti(Pokhara)	1,500
16	Tatopani	2,000
17	Chatara	3,200
18	Tinau	1,024
19	Pharping***	500
20	Jomsom**	240
21	Baglung***	200
22	Khandbari**	250
23	Phidim**	240
24	Surnaiyagad	200
25	Doti***	200
26	Ramechahap	150
27	Terhathum**	100
28	Gamgad	400
Sub Total		14,244
Total		503,394

Small Hudropower Plants(Isolated)		
S.No	Power Plants	Capacity(kW)
1	Dhankuta***	240
2	Jhupra(Surkhet)***	345
3	Gorkhe(Illam)***	64
4	Jumla**	200
5	Dhanding***	32
6	Syangja***	80
7	Helambu	50
8	Darchula**	300
9	Chame**	45
10	Taplejung**	125
11	Manag**	80
12	Chaurjhari(Rukum)**	150
13	Syaprudaha(Rukum)**	200
14	Bhojpur**	250
15	Bajura**	200
16	Bajhang**	200
17	Arughat(Gorkha)	150
18	Okhaldhunga	125
19	Rupalgad(Dadeldhura)	100
20	Achham	400
21	Dolpa	200
22	kalokot	500
23	Heldung(Humla)	500
Total		4,536

Note
** Leased to Private Sector
*** Not in Normal Operation

Source: NEA Annual Report 2017/2018

Table 2.2-4 Transmission lines in the current system

S.No	400/220kV Tranmission Line	Configuration	Length Circuit (km)
1	Dhalkebar-Muzzaffarpur 400 kV Cross Border Line	Double	78
2	Khimti- Dhalkebar 220 kV Transmission Line	Single	75
	Total		153
S.No	132kV Tranmission Line	Configuration	Length Circuit (km)
1	Anarmani-Damak-Duhabi	Single	75.76
2	Duhabi-Kusaha-Lahan-Mirchaiya-Dhalkebar	Double	290
3	Dhalkebar-Chandranigahapur-Pathaliya	Double	206
4	Pathlaiya-Hetauda	Double	76
5	Pathlaiya-Parwanipur	Double	36
6	Kushaha-Katiya(India)	Single	15
7	Hetauda-KL2 P/S	Double	16
8	KL2 P/S-Siuchatar	Double	72
9	Suichatar-Balaju-Chapali-New Bhaktapur	Double	26.9
10	New Bhaktapur-Lamosangu	Double	96
11	Lamosangu-Khimti P/S	Single	46
12	Lamosangu-Bhotekoshi P/S	Single	31
13	Hetauda-Bharatpur	Single	70
14	Bharatpur-Marsyangdi P/S	Single	25
15	Marsyangdi P/S-Suichatar	Single	84
16	Bharatpur-Damau	Single	39
17	Bharatpur-Kawasoti-Bardghat	Single	70
18	Bardghat-Gandak P/S	Double	28
19	Bardghat-Butwal	Double	86
20	Butwal-KGA P/S	Double	116
21	KGA P/S-Lekhnath	Double	96
22	Lekhnath-Damauli	Single	45
23	Lekhnath-Pokhar	Single	7
24	Pokhara-Modikhola P/S	Single	37
25	Butwal-Shivapur-Lamahi	Double	230
26	Lamahi-Jhimruk P/S	Single	50
27	Lamahi-Kohalpur-Lumki-Attariya	Double	486
28	Attariya-Mahendranagar-Gaddachauki	Double	98
29	Marsyangdi -M. Marsyangdi	Double	78
30	Damak-Godak	Single	35
31	Kusum-Hapure	Single	22
32	Raxual-Parwanipur (Cross Border-Nepal Portion)	Single	16
33	Kusaha-Kataiya (Cross Border-Nepal Portion)	Single	13
34	Bhulbhule- Middle Marsyangdi P/S	Single	22
35	Chameliya Power Plant-Attaria	Single	131
	Total		2,871
S.No	66kV Tranmission Line	Configuration	Length Circuit (km)
1	Chilime P/S-Trishuli P/S	Single	39
2	Trisuli P/S-Balaju	Double	58
3	Trisuli P/S-Devighat P/S	Single	4.56
4	Devighat P/S-Chapali	Double	58.6
5	Chapali-New Chabel	Double	10
6	Chabel-Lainchor	Single	7
7	Balaju-Lainchor	Single	2
8	Balaju-Siuchatar-KL1 P/S	Double	72
9	KL 1 P/S-Hetauda-Birgunj	Double	144
10	Suichatar-Teku Single	Single	4.1
11	Suichatar-New Patan	Double	13
12	Teku-K3 (underground)	Single core	2.8
13	Suichatar-K3	Single	6.9
14	New Patan-New Baneswor-Bhaktapur	Single	16.5
15	Bhaktapur-Banepa-Panchkhal-Sunkoshi P/S	Single	48
16	Indrawati- Panchkhal Single	Single	28
	Total		514

Source: NEA Annual Report 2017/2018

Table 2.2-5 Substations in the current system

S.No	Substation		Capacity (MVA)		Remark
1	Dhalkebar		320		
Total			320		
132kV Substation					
S.No	Substation	Capacity (MVA)	S.No	Substation	Capacity (MVA)
1	Mahendranagar	25.0	20	Duhabi	189.0
2	Attariya	60.0	21	Anarmani	60.0
3	Lamki	30.0	22	Pokhara	60.0
4	Kohalpur	60.0	23	Lekhnath	22.5
5	Lamahi	93.0	24	Damauli	60.0
6	Shivapur	42.5	25	Lamosagu	30.0
7	Buwal	189.0	26	Bhaktapur	94.5
8	Bardghat	30.0	27	Balaju	45.0
9	Kawasoti	30.0	28	Suichatar	113.4
10	Bharatpur	97.5	29	Matatirtha	52.5
11	Hetauda	90.0	30	Hapure	30.0
12	Parwanipur	193.5	31	Chapali	129.0
13	Chandranigahapur	60.0	32	Mirchaiya	30.0
14	Pathlaiya	22.5	33	Damak	30.0
15	Kusum	12.5	34	Godak	30.0
16	Kamane	30.0	35	Phidim	16.0
17	Syangja	30.0	36	Syaule	30.0
18	Dhalkebar	93.0	37	Bhurigaon	30.0
19	Lahan	63.0	38	Pahalwanpur	30.0
Total			2,333		
66kV Substation					
S.No	Substation	Capacity (MVA)	S.No	Substation	Capacity (MVA)
1	Birgunj	85.0	8	Baneshwor	36.0
2	Amlekhgunj	7.5	9	Indrawati	7.5
3	Simra	30.0	10	Banepa	45.0
4	K-3	45.0	11	Panchkhal	10.0
5	Teku	45.0	12	Lainchour	45.0
6	Patan	54.0	13	New-Chabel	67.5
7	Balaju	45.0	14	Hetauda	20.0
Total			543		

Source: NEA Annual Report 2017/2018

(2) Current state of distribution network

Distribution network in Nepal consists of medium voltage (MV) (e.g. 11kV or 33kV) distribution networks (distribution primary system) and low voltage (LV) (e.g. 400V or 230V) distribution networks (distribution secondary system). Most of these networks, except those near the substation, are constructed and operated with overhead network. MV feeders are supplied from grid substation (132/11kV or 66/11kV), distribution substation (33/11kV), or switching station, and the electricity is distributed in the city by radial network.

Overhead MV feeder are generally three phase using ACSR (Aluminum Conductors Steel Reinforced) 100mm^2 (Code Dog), 50mm^2 (Code Rabbit), 30mm^2 (Code Weasel). Insulators used for the suspension poles are pin type insulators, and insulators used for the tension poles are suspension insulators. Both insulators types are made of porcelain, and very few glass insulators are used for distribution facilities.

Figure 2.2-3 Suspension Pole

Figure 2.2-4 Tension Pole

Poles used for the support of MV feeders are mostly steel or concrete poles, and very few wooden poles are present. These concrete poles are square columns. The spun concrete poles, which are generally used in Japan, are not seen. Most of these steel poles have deteriorated due to heavy rust, so NEA has to consider planned replacement of such poles.

Figure 2.2-5 Steel Pole

Figure 2.2-6 Concrete Pole

Three phase transformers are used as distribution transformers to step down from 11kkV to 400/230V, which is the supply voltage for domestic households etc. Standard three phase ratings used in Nepal are 50, 100, 200 kilovolt-ampere (kVA). These transformers are normally mounted on two poles which are assembled as H shape. In some cases, for a large consumer such as a big factory, supply is derived from a ground mounted transformer with large capacity, and in some areas supply is derived from single phase 15 kVA and 25 kVA pole mounted units.

Cutout fuses and a lightning arrester are installed on the primary side of the distribution transformer for protection (overcurrent protection, lightning overvoltage protection).

As mentioned above, NEA's Distribution Directorate (DCSD) is in charge of these distribution facilities, as well as sub-transmission and substation facilities up to 33 kV. The 33 kV sub-transmission lines are connected between the grid substation (132/33 kV), which is connected to the national grid, and the distribution substation (33/11 kV); and they are constructed using a steel tower system. The distribution substation (33/11 kV) ,which is supplied from these 33kV sub-transmission line, supplies to 11kV feeder, and is typically composed of two transformers.

Figure 2.2-7 Distribution transformer

Figure 2.2-8 33kV sub-transmission line

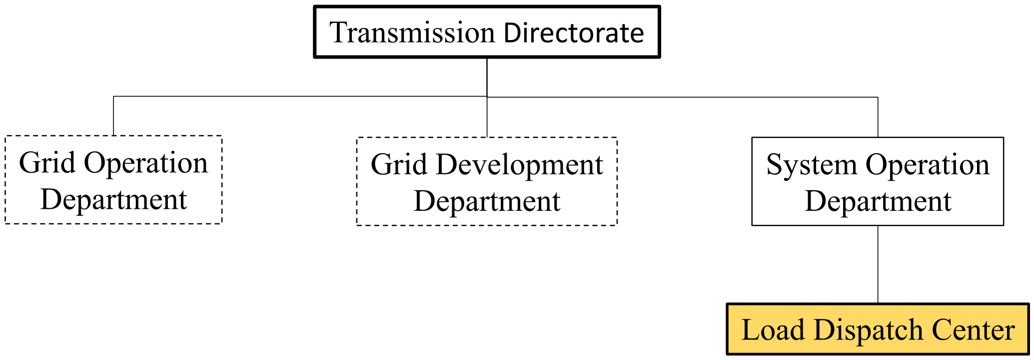
Majority of the distribution facilities in the major central areas in Nepal were constructed several decades ago, and despite the recent rapid and significant increase in power demand, systematic reinforcement and rehabilitation of distribution facilities have not been carried out for more than a decade. As a result, overloading of the distribution system and large losses occur, and it is important to improve them and improve the operational efficiency of the distribution network.

2.2.3 Operation State of Power System

(1) Structure of power system operation

In Nepal, Load Dispatch Center(LDC) controls and adjusts demand and supply for the entire power system. LDC is in Siucahatar of Kathmandu, and it belongs to the System Operation Department of Transmission Directorate. The organizational structure of Transmission Directorate is shown in Figure 2.2-9.

LDC supervises frequency and interconnected power flow from India in the system supervise board, and adjusts the output of the Hydro power plants owned by NEA and the import power from India as required. The output adjusting is done by each power plant via telephone from LDC.



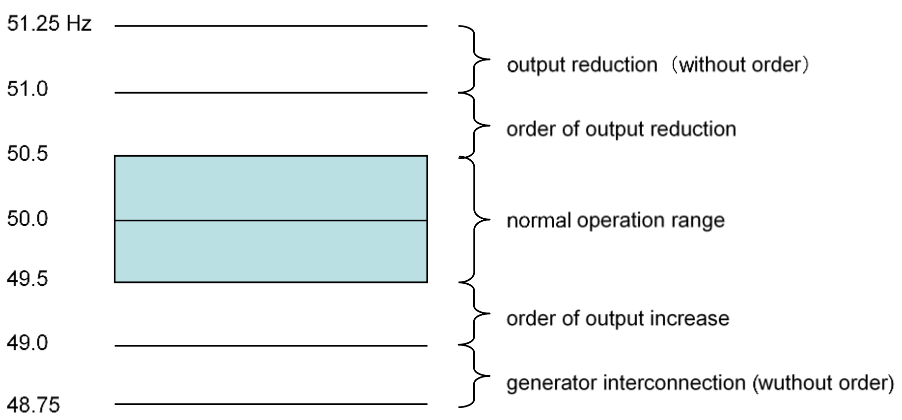
Source: JICA Study Team based on NEA materials

Figure 2.2-9 The organizational structure of Transmission Directorate

(2) Frequency control method

The frequency control method specified in NEA Grid Code is shown in Figure 2.2-10. In normal situation, the frequency is controlled between 49.5Hz and 50.5Hz. In the case where the frequency becomes less than 49.5Hz, LDC orders power plants to increase output, and in the case where the frequency becomes less than 49.0Hz, generators interconnect the available power plant without LDC's order. On the other hand, In the case where the frequency becomes more than 50.5Hz, LDC orders power plants to reduce output, and in the case where the frequency becomes more than 51.0Hz, the generators reduce the output without LDC's order.

If it is estimated in advance that the frequency can't be maintained within the above range, a planned outage will be implemented upon notification of the reason, amount, area, date and time. In Nepal, the maximum demand is increasing at an average annual growth rate of 7.9%, and until several years ago, the supply capacity against demand could not be secured, and planned outages were frequently implemented. However, in recent years, because of the expansion of the international interconnecting transmission line with India, the number of planned outages has been reduced significantly, and the power quality has been improved .



Source: JICA Study Team based on NEA materials

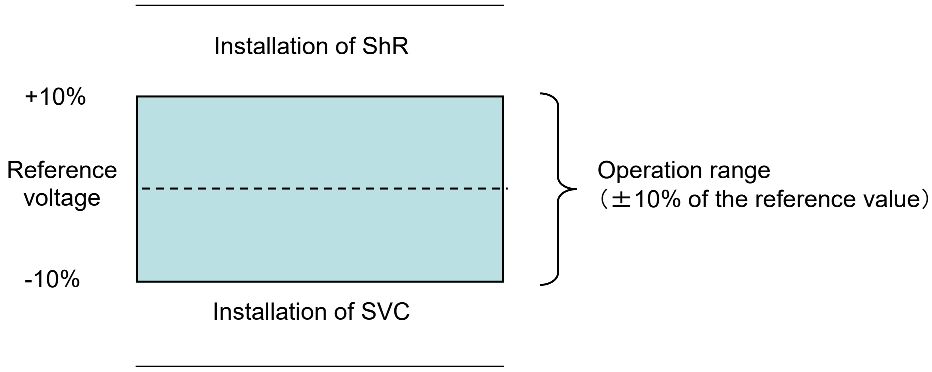
Figure 2.2-10 Frequency control method

Also, in the rainy season, the whole country is operated as one system, but in the dry season when the supply capacity is not sufficient, the system is divided into three in terms of operation, in order to prevent power outage across a wide area.

(3) Voltage control method

The voltage control method specified in NEA Grid Code is shown in Figure 2.2-11. LDC controls the grid voltage within ±10% of the reference value. Also, it is specified that each generator is installed with an Automatic voltage Regulator (AVR).

As a result of the power flow analysis, if the voltage cannot be secured within ±10% of the reference voltage, it is necessary to install phase modifying equipment such as Static Var Compensators (SVC) or Shunt Reactors (ShR).



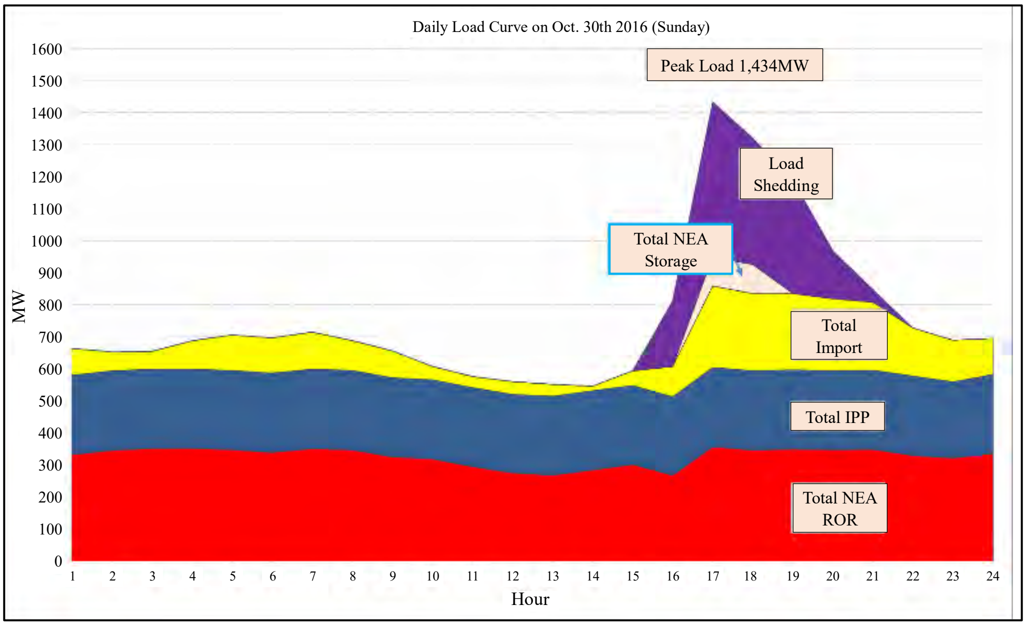
Source: JICA Study Team based on NEA materials

Figure 2.2-11 Voltage control method

(4) Power demand state

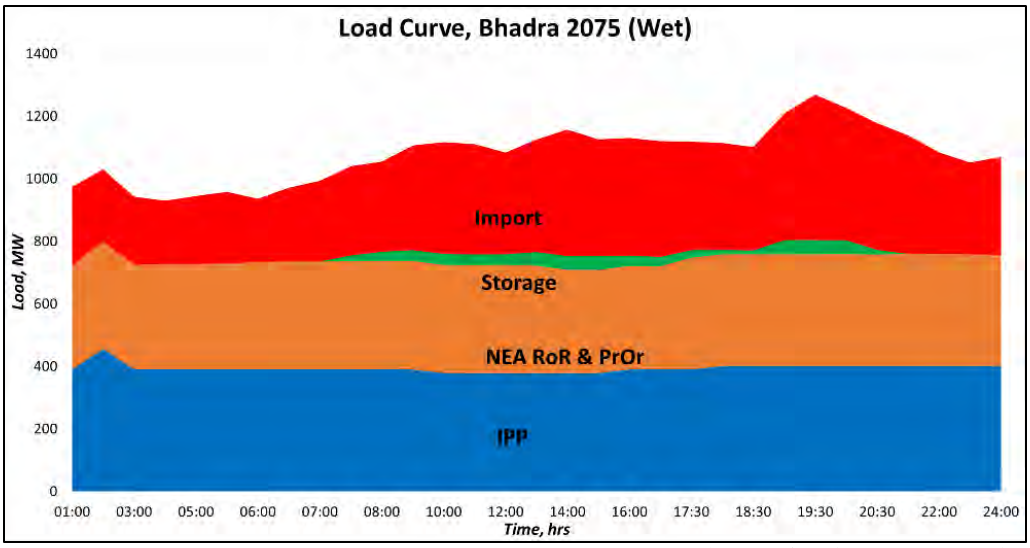
1) Improvement of power quality

The daily load curve in the whole of Nepal in 2016 is shown in Figure 2.2-12, and the daily load curve of the day in 2018, which recorded the maximum power demand, as received in this survey, is shown in Figure 2.2-13. In 2016, it was expected that the peak demand would be 1,434MW, but due to the shortage of supply capacity, planned outage had been implemented. On the other hand, in 2018, since the supply capacity was increased by interconnection transmission line with India, planned outage had not been implemented, and the power quality has been improved.



Source: JICA Study Team based on NEA materials

Figure 2.2-12 Daily load curve (In 2016)



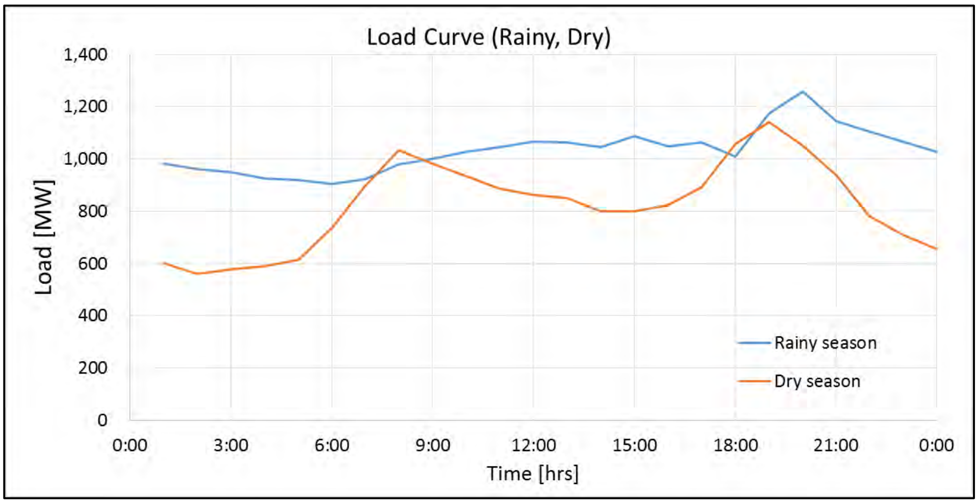
Source: JICA Study Team based on NEA materials

Figure 2.2-13 Daily load curve (In 2018)

2) Comparison of rainy season and dry season

Figure 2.2-14 shows the daily load curve in the rainy season (Aug. 2018) and in the dry season (Jan. 2019), which is based on the data from NEA in this survey.

On comparing the electricity demand in the rainy season and dry season, we can confirm that the maximum demand is 1,258.2MW and 1,140.2MW respectively, and the peak demand is in the evenings during both the seasons. In addition, in the dry season, it is confirmed that the electricity demand is low at midnight and daytime, when compared to the rainy season. In Nepal, the average maximum temperature reaches 30 degree during the rainy season. On the other hand, during the dry season, the average maximum temperature falls below 20 degree, and the climate is pleasant. This is considered as one of the reasons for the difference in the demand at midnight and daytime, between the rainy and dry season.



Source: JICA Study Team based on NEA materials

Figure 2.2-14 Daily load curve in whole Nepal (rainy season and dry season)

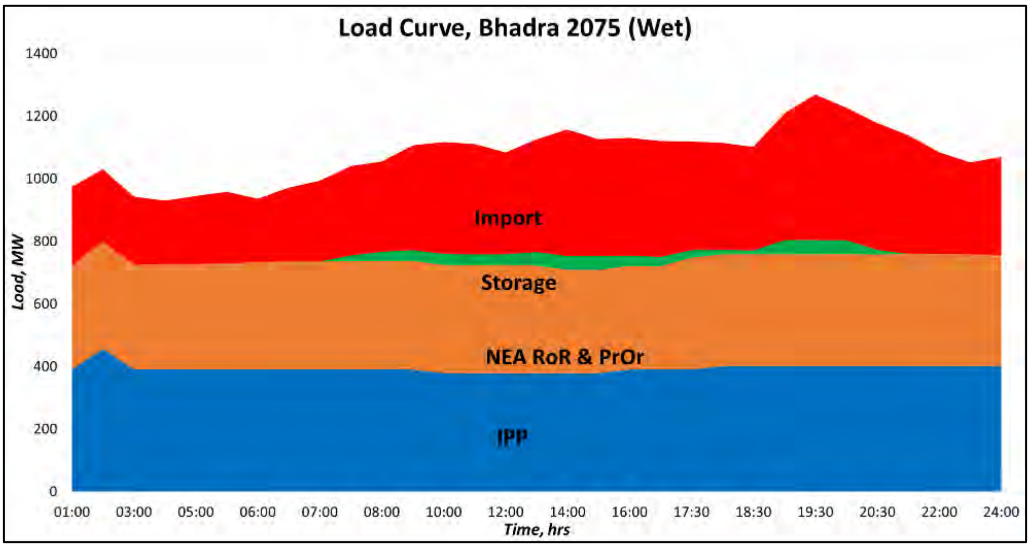
(5) Operation of interconnection line

Nepal has interconnection lines with India at a total of five locations, at four locations at 132kV and one location at 220kV, (400kV design, 220kV operation). And if it is difficult to supply only by domestic power plants in Nepal, the shortage in electricity is compensated by the imports from India through these interconnection lines. Among the five interconnection lines with India, the interconnection line between Dhalkebar substation (Nepal) and Muzaffarpur substation (India) located in the southeast of Nepal is a major one. This interconnection line started operating at 132kV in February 2016, and it was boosted to 220kV in August 2018. After that, through this interconnection line, about 240MW of electricity is always imported, and this line is helping to improve the power quality, as it is the only 220kV interconnection line in Nepal. In addition, this interconnection line is constructed with a 400kV design, and 400kV operation is planned in the future.

The tariff of the electricity, imported from India varies based on the interconnection point, it is either set to 4.18 Indian Rupee (about 6.69 Nepal Rupee) or 6.86 Indian Rupee (about 10.98 Nepal Rupee).

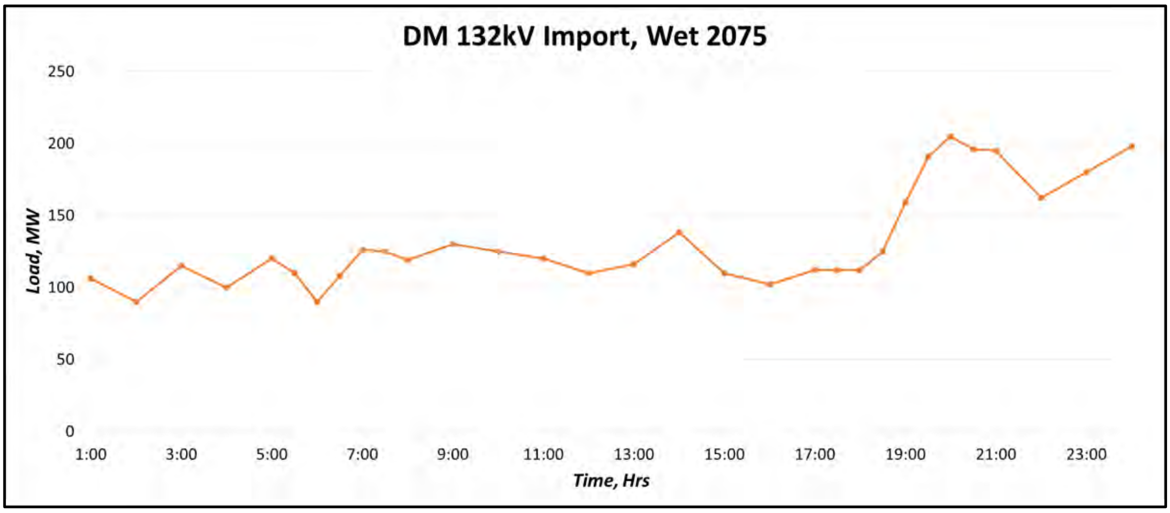
In the 220kV Dhalkebar-Muzaffarpur interconnection line, 4.18 Indian Rupee (about 6.69 Nepal Rupee) is set as the tariff . However, in the contract between Nepal and India, if the imported electricity of this interconnection line is more than a certain amount of excess or deficiency compared to the standard capacity, which is 240MW, the tariff will be set to three times the standard amount. This seems to prevent the reduction of stability such as frequency fluctuation on India side due to load fluctuation in Nepal. Therefore, in Nepal, the method of the supply and demand adjustment is different before and after the 220kV interconnection line had begun operating.

The daily load curve and the imported power from India before the operation of 220kV are shown in Figure 2.2-15 and Figure 2.2-16 respectively. From these figure, we can confirm that before operation of 220kV, the supply and demand adjustment was carried out by increasing and decreasing the amount of import electricity from India, and the hydropower owned by IPP and NEA was operated at a constant output as the base power source. It appears, that the contract mentioned above was not concluded between Nepal and India before the operation of 220kV, so the hydropower, which has low generation cost, was operated as base power source.



Source: JICA Study Team based on NEA materials

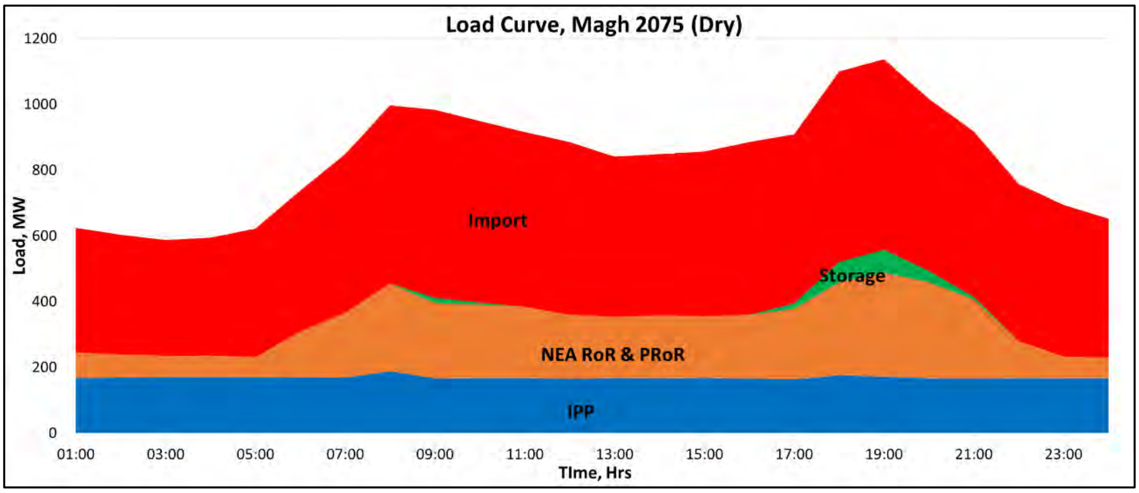
Figure 2.2-15 Daily load curve （before 220kV interconnection operation）



Source: JICA Study Team based on NEA materials

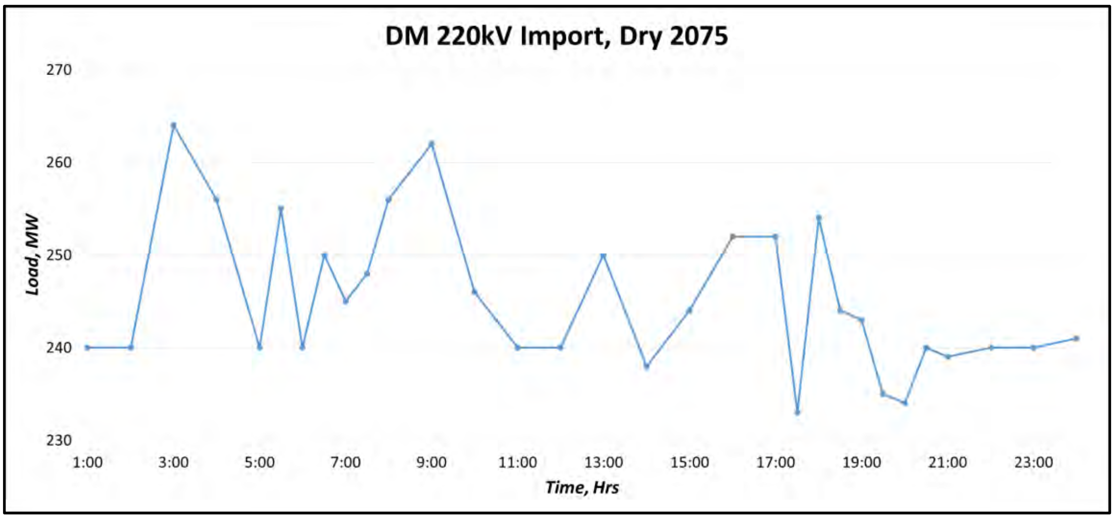
Figure 2.2-16 Imported electricity from India （before 220kV interconnection operation）

The daily load curve and the power, imported from India after the operation of 220kV are shown in Figure 2.2-17 and Figure 2.2-18 respectively. From these figure we can confirm that, after the operation of 220kV, although the IPP’s hydropower is operated at a constant output as the base power source, the output of the hydropower owned by NEA is increased or decreased to adjust supply and demand. And, the import electricity from India is also operated at a constant output. It appears that the contract mentioned above was concluded between Nepal and India only after the operation of 220kV. Therefore, that the adjustment of supply and demand is implemented by NEA's hydropower to avoid the increase in tariff.



Source: JICA Study Team based on NEA materials

Figure 2.2-17 Daily load curve (after 220kV interconnection operation)



Source: JICA Study Team based on NEA materials

Figure 2.2-18 Imported electricity from India (after 220kV interconnection operation)

(6) Power system analysis

The basic contents of power system analysis are power flow calculation, short circuit capacity calculation and stability calculation. And, it is also stated in NEA Grid Code to implement these analysis. The outline and purpose of each calculation are as follows.

・Power flow calculation

Power flow calculation is a calculation to analyze how the power flow supplied from each generator flows to each load through transmission lines or transformers in the power system. The voltage profile of each part of the power system and power flow profile of each substation and transformer from the generators output condition, the load condition, the transformer tap values, transmission line impedance and so on are obtained. It is used to study voltage balance and overloading of transmission and transformer equipment.

・Short circuit capacity calculation

Short circuit capacity: S [kVA] is obtained by the following equation using the three phase short circuit current: I_S [A] at the fault point and the line voltage: V[kV] before the fault.

$S=\sqrt{3}\, VI\_S[kVA]$

It is used to confirm with or without of rated breaking capacity exceed of circuit breaker, determining the specification of circuit breaker, and settling of the system protection relay.

・Stability calculation

Stability calculation is an analysis to confirm whether the stability of the generator's synchronous operation can be maintained against disturbances, such as load fluctuation and lightning strike to the transmission line. In general, stability is classified into steady state stability and transient stability. The former refers to a stability achieved against relatively small disturbances such as normal load fluctuation and system operation, and the latter refers to a stability achieved against relatively large disturbances such as lightning to the transmission line.

In NEA, power system analysis is done by SPD, and PSS/E is used as a tool. And, PSS/E is a power system analysis software, which is developed by Siemens, and is the most widely used software across the world in this field.

In this survey, PSS/E data of dry season peak, rainy season peak, and rainy season off peak for the years 2020,2025 and 2030 was received. And, The PSS/E data from NEA is only for 132kV or more.

2.2.4 Development Plan on Transmission and Distribution Network

(1) Development plan on transmission network

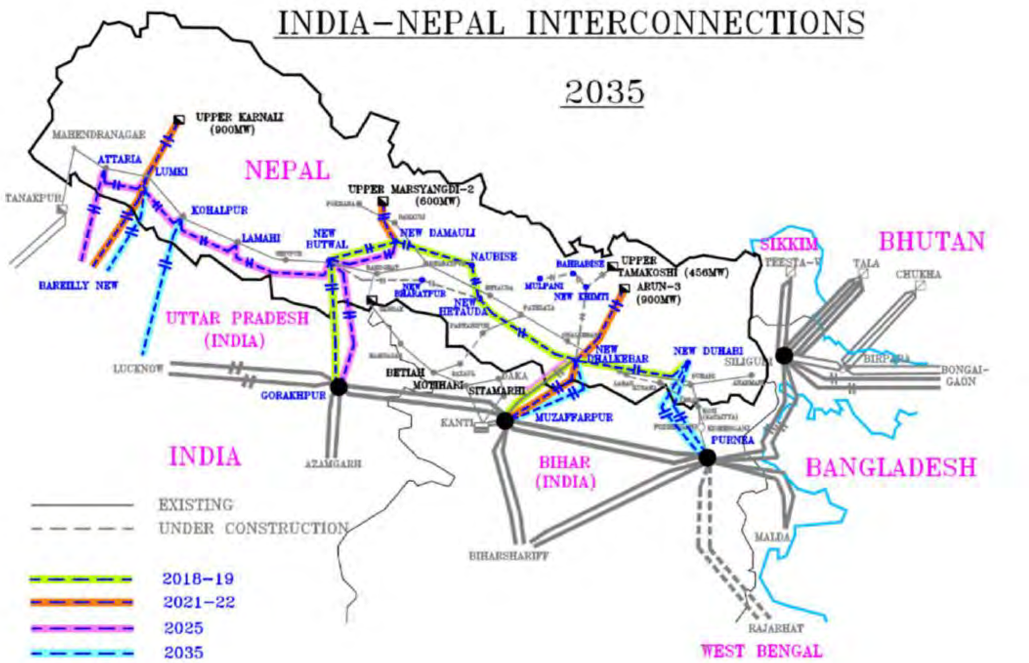
1) Development plan on transmission network（TSMP, IMP, TSDP）

NEA had been in charge of development plan for power transmission network of Nepal, but some planning works of NEA were transferred to RPGCL, which was established in 2015 when the electric power business reform was carried out with the support of ADB. NEA is currently in charge of development plan for 132kV and 66kV transmission network and distribution network. On the other hand, RPGCL is in charge of development plan for 400kV and 220kV transmission network.

As stated in section 2.1.1, Nepal has TSMP, IMP and TSDP for power transmission network. TSMP was formulated in 2015 and IMP was formulated in 2016, and both focus on power transmission network planning for the future scenario up to 2035. The two plans have similar proposals with the focus on configuration of transmission network, to export power to India. The two plans also propose construction of 400kV trunk transmission line, running from east to west in the Terai region, and a radial network, connecting major hydropower plants and the 400kV trunk transmission line. Figure 2.2-19 and Figure 2.2-20 show power transmission networks for 2035 as proposed in TSMP and IMP respectively.

Source: TSDP

Figure 2.2-19 Power transmission networks for 2035- proposed in TSMP



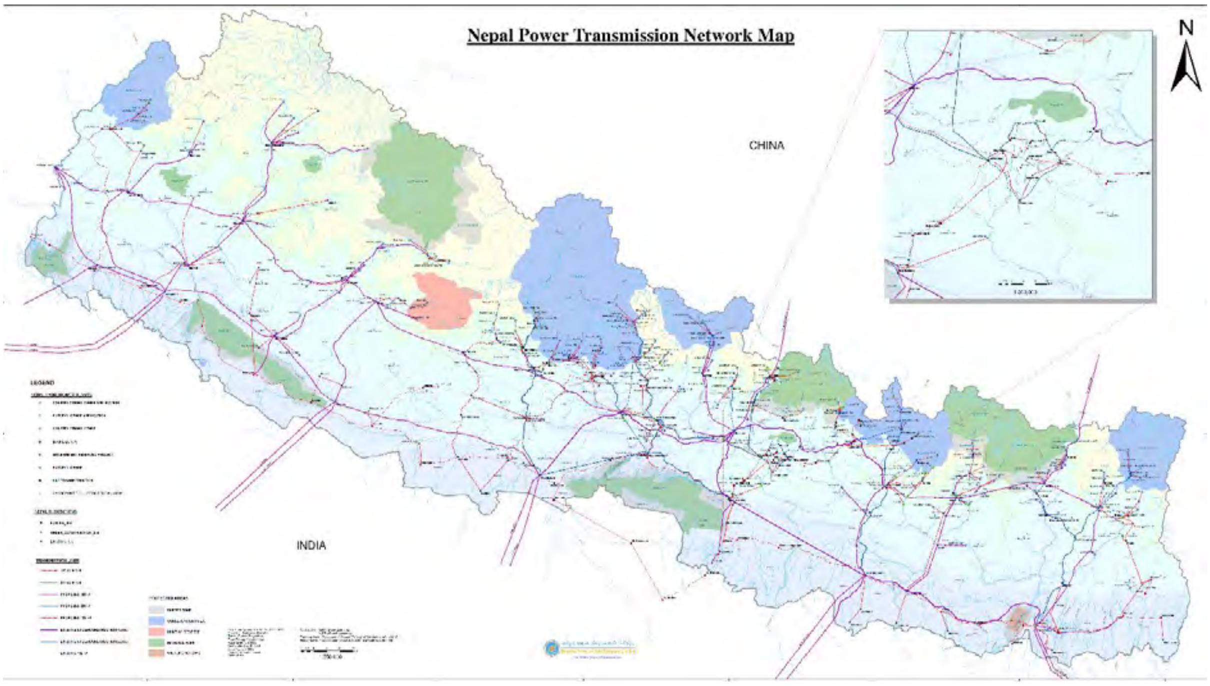
Source: TSDP

Figure 2.2-20 Power transmission networks for 2035- proposed in TSMP

TSMP and IMP assume that the peak domestic power demand in 2035 will be 6.2GW and 4.7GW respectively. On the other hand, according to the electricity demand forecast report made by WEC, the peak domestic power demand is expected to be 18GW by 2040 if the government of Nepal achieves the target of economic development with a GDP growth rate of 7.2%. Therefore, Nepal requires a power transmission network, which can supply power to the increasing domestic demand while exporting power to India and China. Under this situation, RPGCL published TSDP in 2018, which is new development plan for power transmission network in Nepal.

TSDP covers the period of 2020 – 2040, and it assumes that the total installed capacity of hydropower plants and power demand will increase to 38GW and 18GW respectively by 2040. Based on this assumption, TSDP proposes a power transmission network, which can supply power for domestic load stably while exporting power to India and China.

Figure 2.2-21 shows power transmission network for 2040 as proposed in TSDP. TSDP suggests installing a 400kV trunk transmission line along the hilly region, in addition to the 400kV trunk transmission line in Terai region as proposed in TSMP and IMP. TSDP also suggests constructing a mesh network by connecting these two 400kV lines with the radial lines along the river corridors. The power transmission network has six Nepal- India interconnection points in the Terai region and two Nepal-China interconnection points in the Himalaya region for the export of power.



Source: TSDP

Figure 2.2-21 Power transmission network for 2040 proposed in TSDP

Table 2.2-6 shows the overview of TSDP proposal. TSDP proposes the construction of numerous transmission lines and substations including 2,515km transmission lines and 14 substations for the 132kV transmission network, which is targeted in this data collection survey.

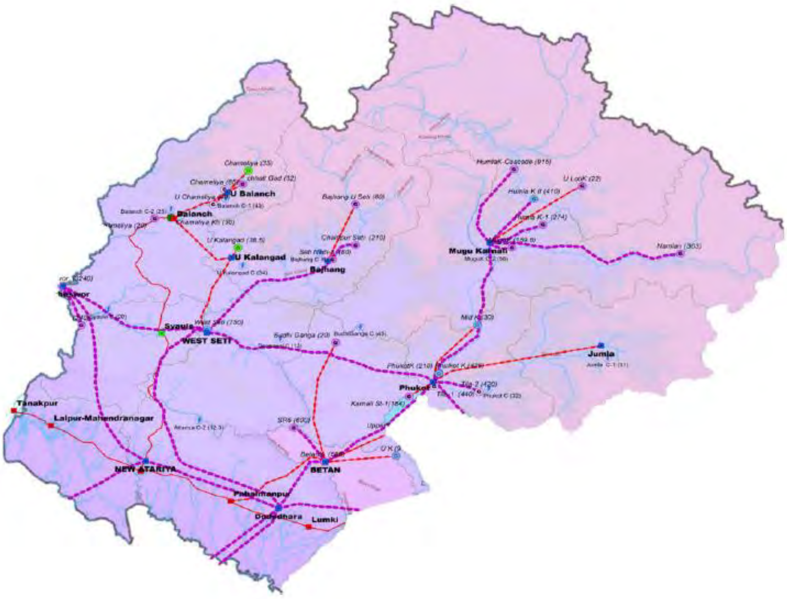
Table 2.2-6 Overview of TSDP proposal

Voltage (kV)	Transmission Line (km)	Substation (no.)
400	3,192	40
220	1,160	19
132	2,515	14
Total	6,867	73

The feature of TSDP is that the power transmission network is divided into 5 Zones. Demand forecast is conducted for each Zone, and the development plan for the power transmission network in each Zone is formulated. Overview of the plan for each zones is as follows.

a) Zone 1

Figure 2.2-22 the shows power transmission network of Zone 1 for 2040. Zone 1 covers Province No.7 and a part of Province No.6. Total installed capacity of hydropower plants and peak power demand in Zone 1 are expected to increase to 9.92GW and 2.3GW respectively by 2040. Attariya is the main substation for power supply. This substation is planned to supply power to the major load centers.



Source: TSDP

Figure 2.2-22 Power transmission network of Zone 1 for 2040.

b) Zone 2

Figure 2.2-23 shows the power transmission network of Zone 2 for 2040. Zone 2 covers Province No.5 and a part of Province No.6. Total installed capacity of hydropower plants and peak power demand in Zone 2 are expected to increase to 4.47GW and 2.3GW respectively by 2040. Hapure and Kohalpur are the main substations for power supply. These two substations are planned to supply power to the major load centers.

Source: TSDP

Figure 2.2-23 Power transmission network of Zone 2 for 2040

c) Zone 3

Figure 2.2-24 shows the power transmission network of Zone 3 for 2040. Zone 3 covers Province No.4 and a part of Province No.5 and includes Pokhara, Bharatpur and Bhairahawa, which are candidate cities for this data collection survey. Total installed capacity of hydropower plants in Zone 3 is expected to increase to 7.4GW by 2040. Peak power demand in Zone 3 is expected to increase to 2.3GW by 2040 due to the development of tourism and factories. Butwal, Bharatpur, Lekhnath and New Damauli are the main substations for power supply. These substations are planned to supply power to the major load centers.

Source: TSDP

Figure 2.2-24 Power transmission network of Zone 3 for 2040

d) Zone 4

Figure 2.2-25 shows the power transmission network of Zone 4 for 2040. Zone 4 covers Province No.3, located in the central region of Nepal and a part of Province No.2. Zone 4 includes Kathmandu, Lalitpur, Birgunj and Simra, which are candidate cities for this data collection survey. Total installed capacity of hydropower plants and peak power demand in Zone 4 are expected to increase to 8.03GW and 6.48GW respectively by 2040. Balaju, Bhaktapur Harisidhi and Matatirha are the substations, planned to supply power to Kathmandu Valley, which is the major load center.

Source: TSDP

Figure 2.2-25 Power transmission network of Zone 4 for 2040

e) Zone 5

Figure 2.2-26 shows the power transmission network of Zone 5 for 2040. Zone 5 covers Province No.1 and a part of Province No.2. Total installed capacity of hydropower plants and peak power demand in Zone 4 are expected to increase to 7.78GW and 2.85GW respectively by 2040. Railway and industrial load are expected to be the major loads, and the plan is to supply power to these loads from the Inaruwa substation.

Source: TSDP

Figure 2.2-26 Power transmission network of Zone 5 for 2040

In TSDP, load flow study and contingency analysis are conducted by using the computer model, which includes data of the existing and planned hydropower plants and transmission lines, demand forecast and so on. TSDP defines N-1 contingency as– a power outage that occurs in one of two circuits of a major transmission line. Criteria for N-1 contingency is– the power flow in the other sound circuit should be within 120% of the thermal capacity, and the other functioning transmission line should be operated within 100% of the thermal capacity. In addition, TSDP defines sever contingency as– an outage that occurs in both circuits of a major transmission line at the same time. Criteria for sever contingency is– the other functioning transmission line should be operated within 120% of the thermal capacity. Different scenarios are analyzed, taking into consideration the seasonal variation in the power generated by the hydropower plants, as most of the hydropower plants in Nepal are run-of-the-river (**RoR**) type plants. Based on the results of such analyses, TSDP proposes a reliable power transmission network which can meet the above criteria.

Results of domestic analysis, short circuit study and estimation of wheeling charge, and development plan from 2020 to 2035 are not described in the TSDP. They will be presented in another report.

2) Prioritized Projects planned by NEA

TSDP focuses mainly on 220kV and 400kV bulk power transmission network and the detailed data about the basis of development plan for 132kV and less power transmission network is not indicated in TSDP. However, when the development plan based on TSDP is carried out, the development of 132kV and less transmission network will also be needed, in order to supply power from the bulk power transmission network to the load centers.

Table 2.2-7 List of prioritized projects

No.	Contents	Objective
1	Inaruwa － Dharan 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Dharan)	Supplying power to demand areas
2	Kohalpur－Nepalgunj 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Janaki Gaupalika)	Supplying power to demand areas
3	Pathalaiya－Simraungadh 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Simraungadh)	Supplying power to demand areas
4	Bhumahi－Hakui 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Hakui)	Supplying power to demand areas
5	Dumkibas 132/33kV Substation Project	Supplying power to demand areas
6	Godak－Anarmani 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Anarmani Substation)	Increasing the transmission capacity to transmit the power generated by hydropower plants
7	Pokhara 132/11kV Substation Project (132/11kV Transformer should be installed at Birauta, Pokhara)	Supplying power to demand areas
8	Dhading 132/33kV Substation Project (132/33kV Transformer should be installed at Dhading)	Supplying power to demand areas
9	Ghorahi－Khungri－Banfikot 132kV Transmission Line and Substation Project	Increasing the transmission capacity to transmit the power generated by hydropower plants
10	Kohalpur－Surkhet－Dailekh 132kV Transmission Line and Substation Project	Supplying power to demand areas
11	Dhalkebar－Balganga 132kV Transmission Line and Substation Project	Supplying power to demand areas

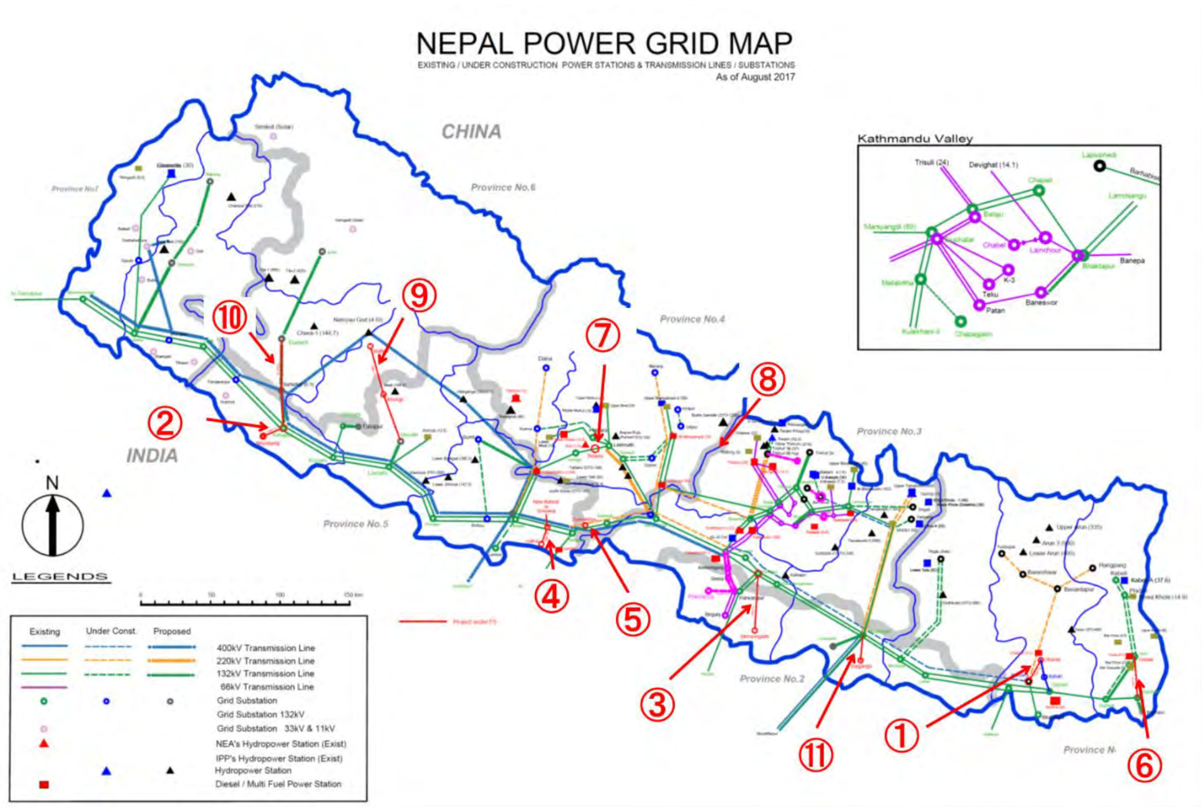
Source：NEA（Transmission Directorate）

NEA is carrying out development projects of power transmission network based on TSDP. However, if there are regions which require urgent development of power transmission network due to problems caused by increased demand and voltage drop, then the NEA formulates projects which is not planned in the TSDP. Table 2.2 7 shows the list of prioritized 132kV projects, as provided by NEA. With the exception of project

No.10, all these projects were not planned in TSDP. NEA selected them as projects with high urgency from the aspects of the necessity to increase the capacity, in order to transmit the power generated by hydropower plants from the north to the south and to supply power to the demand areas located in the hilly region and Terai region.

NEA is considering these prioritized projects by itself, but the donors to fund these projects at the implementation stage has not yet been decided.

Figure 2.2-27 shows the locations of the prioritized projects. Most of the projects are located around local cities. Only project No.7 is related to a target candidate of this data collection survey.



Source: JICA Study Team based on NEA materials

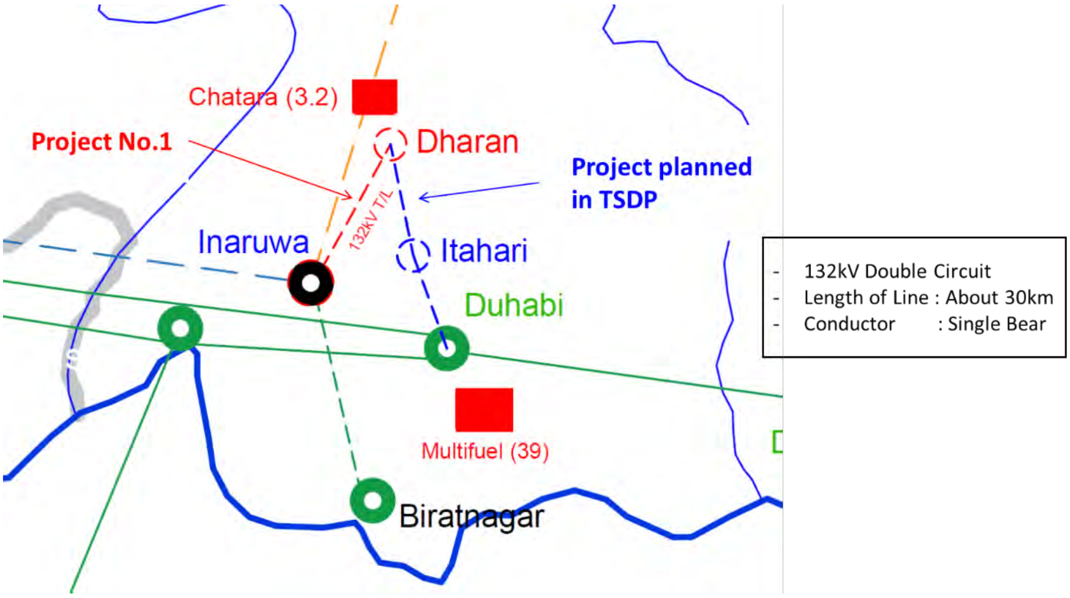
Figure 2.2-27 Locations of prioritized projects

The overview of each project is as follows.

① Inaruwa – Dharan 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Dharan)

This project aims to construct a new 132/33kV substation at Dharan and a new 132kV transmission line between Inaruwa substation and Dharan substation to supply power to Dharan, which is one of the major cities in the eastern part of the country. Inaruwa substation is the main substation, and it is scheduled to be completed in 2019 and the plan is to connect it to the 400kV transmission line, running from east to west, in the future. Figure 2.2-28 shows the overview of this project.

TSDP proposes 132kV double circuit transmission line connecting Duhabi, Itahari and Dharan. However, it is difficult to construct 132kV transmission line in Itahari, due to problems of land acquisition. So this project is proposed as an alternative to the project planned in TSDP.



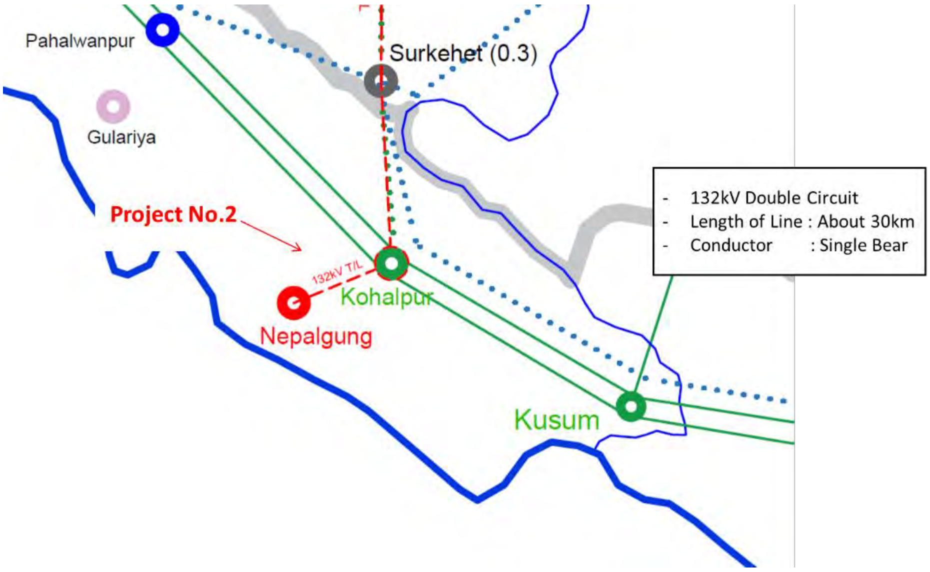
Source: JICA Study Team based on NEA materials

Figure 2.2-28 Overview of project No.1

② Kohalpur－Nepalgunj 132kV Transmission Line and Substation Project <u>(132/33kV Transformer should be installed at Janaki Gaupalika)</u>

Nepalgunj is located near the border of India in the southwest region of Nepal, and it is the center of commerce in the western part of Nepal. Many factories are operated in the industrial areas of Nepalgunj, and factories such as steel and cement factory are under construction in these areas. Nepalgunj is specified as a special economic zone, and is one of cities, whose power demand is expected to increase.

Currently, power is supplied to areas around Nepalgunj from the Kohalpur substation through 33kV transmission lines. However, the capacity of 33kV transmission line is expected to be insufficient, due to the increase in power demand in the future. Considering such a situation, this project aims to construct a new 132/33kV substation at Nepalgunj and a new 132kV transmission line between Kohalpur substation and Nepalgunj substation to increase the capacity of transmission line. Figure 2.2-29 shows the overview of this project.



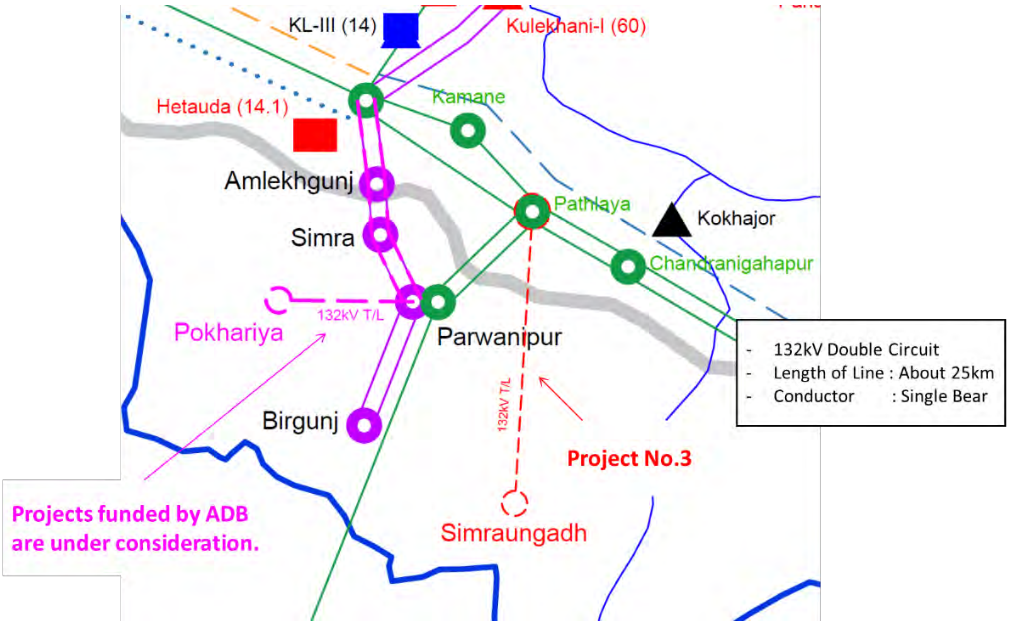
Source: JICA Study Team based on NEA materials

Figure 2.2-29 Overview of project No.2

③ Pathalaiya－Simraungadh 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Simraungadh)

This project aims to construct a new 132/33kV substation at Simraungadh and a new 132kV transmission line between Pathalaiya substation and Simraungadh substation to supply 53MW power to Simraungadh, which is the load center. After the completion of this project, power is planned to be supplied to areas near Simraungadh from the new substation through 33kV transmission line. Figure 2.2-30 shows the overview of this project.

On the other hand, Birgunj and Simra are located on the west of Simraungadh. Birgunj is a famous dry port and Simra is specified as a special economic zone. Power demand in areas around these cities is expected to increase. The following two projects, funded by ADB are under planning. One project aims to upgrade the 66kV transmission line between Hetauda substation and Parwanipur substation to 132kV line. The other project aims to construct a new 132kV transmission line between Parwanipur substation and Pokhariya substation. It is assumed that the common objective of these projects is to handle the increasing demand in the areas near Birgunj and Simra.

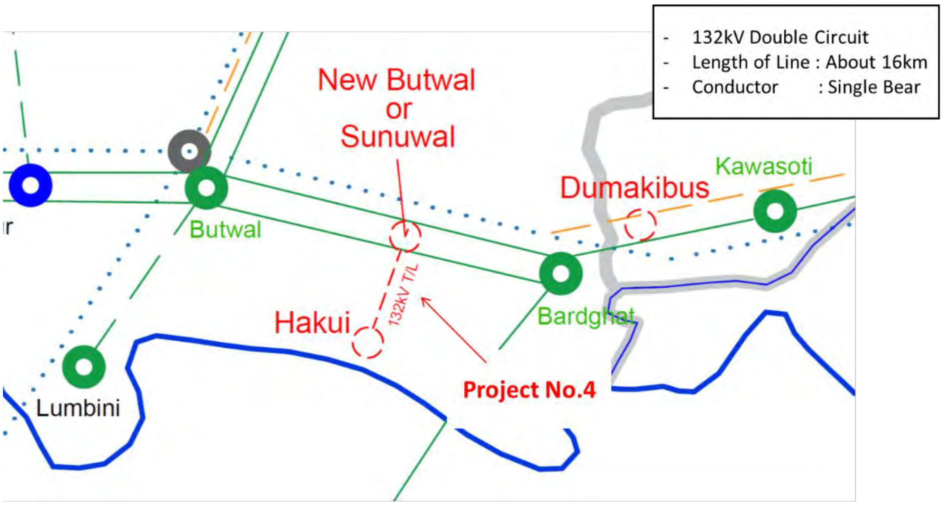


Source: JICA Study Team based on NEA materials

Figure 2.2-30 Overview of project No.3

④ Bhumahi－Hakui 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Hakui)

This project aims to construct a new 132/33kV at Hakui and a new 132kV transmission line between New Butwal substation or Sunuwal substation and Hakui substation, to supply 63MW power to Hakui. New Butwal substation is a main substation, which is under construction, and it is planned to be connected to the 400kV transmission line, running from east to west, in the future. Sunuwal substation is a new 132/33kV substation, which is under construction and it shall supply power to the cement industry area in Palpa, based on the memorandum of understanding, signed between NEA and Ministry of Industry (**MoI**). This project proposes to connect the new transmission line to either of the two substations. Figure 2.2-31 shows the overview of this project.

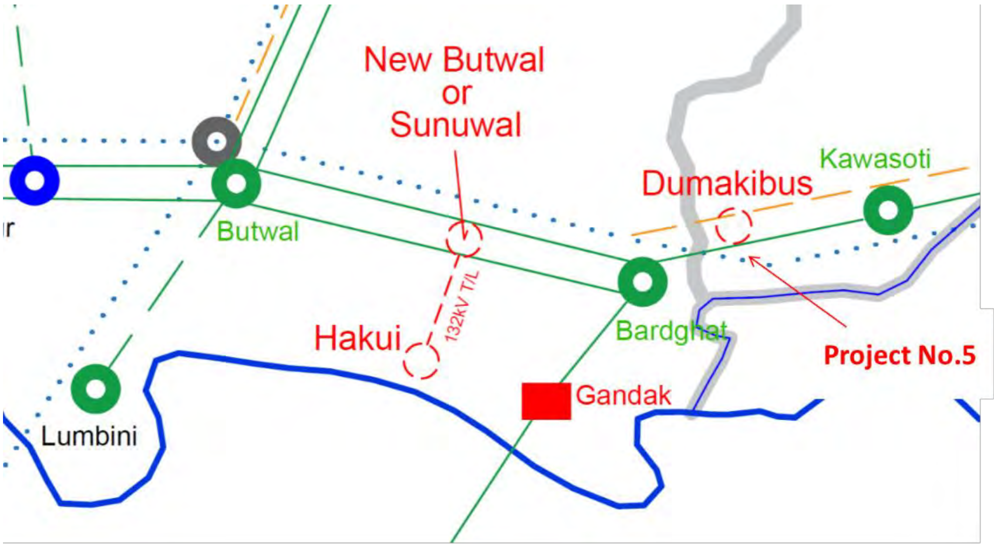


Source: JICA Study Team based on NEA materials

Figure 2.2-31 Overview of project No.4

⑤ Dumkibas 132/33kV Substation Project

This project aims to construct a new 132/33kV substation at Dumkibas, to supply power to the residential area and the industrial area, including the cement factories around Dumkibas. The new substation is planned to be connected to the existing 132kV single circuit transmission line between Bardgat substation and Kawasoti substation. Figure 2.2-32 shows the overview of this project.



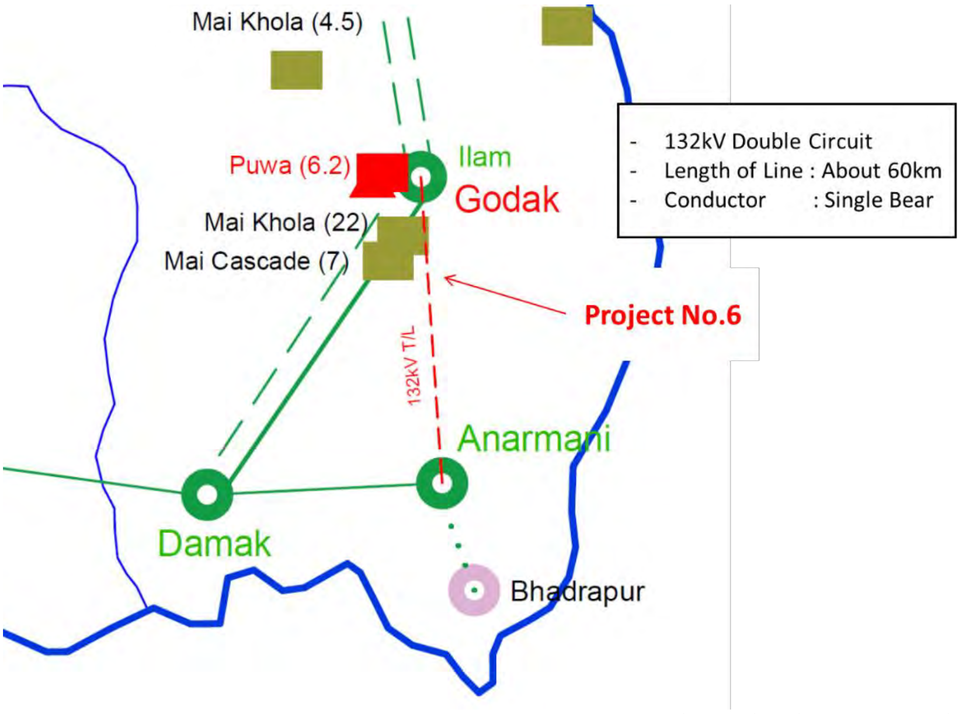
Source: JICA Study Team based on NEA materials

Figure 2.2-32 Overview of project No.5

⑥ Godak－Anarmani 132kV Transmission Line and Substation Project (132/33kV Transformer should be installed at Anarmani Substation)

Power generated by the hydropower plants in the northern area of the easternmost region of Nepal is supplied to load centers in the southern area, through the 132kV transmission line between Godak and Damak. However, the capacity of the existing transmission line is expected to be insufficient in the future, as the power generated by hydropower plants is increasing. Considering this situation, this project aims to install a new 132/33kV transformer at Anarmani substation and construct a new 132kV transmission line between Godak and Anarmani, in order to add another route to transmit the power generated by the hydropower plants in the northern area. Figure 2.2-33 shows the overview of this project.

132/33kV transformers of Damak substation are currently in over load condition, so this project also aims to shift some load from Damak substation to Anarmani substation.



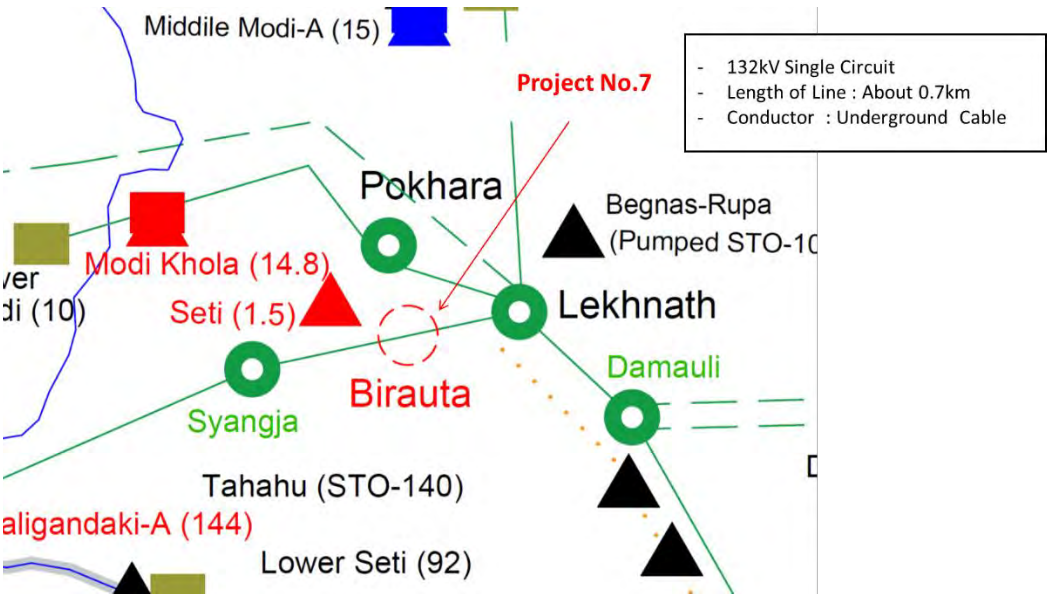
Source: JICA Study Team based on NEA materials

Figure 2.2-33 Overview of project No.6

⑦ Pokhara 132/11kV Substation Project (132/11kV Transformer should be installed at Birauta, Pokhara)

Pokhara is a major tourist spot and the second most populated city behind Kathmandu in Nepal. Power is currently supplied to Pokhara city from the existing Pokhara substation through 11kV distribution line. Electricity sales in Pokhara region increased by about 1.7 times in the last 5 years and the power demand in Pokhara is expected to increase in future. An international airport is planned to be constructed in Pokhara city, so power demand is also expected to increase rapidly due to the increase in tourists. Under this situation, there are concerns that the capacity of the existing transformers at Pokhara substation will be insufficient due to the increase in power demand. In addition, it is difficult to install more 11kV distribution lines from Pokhara substation because Pokhara substation already has eleven 11kV distribution lines, running towards city. Considering this situation, this project aims to construct a new 132/11kV substation at Birauta in Pokhara city and shift some distribution lines from Pokhara substation to Birauta substation. Figure 2.2-34 shows the overview of this project.

The new Birauta substation is planned to be connected to the existing 132kV transmission line between Lekhnath substation and Syangja substation.



Source: JICA Study Team based on NEA materials

Figure 2.2-34 Overview of project No.7

⑧ Dhading 132/33kV Substation Project (132/33kV Transformer should be installed at Dhading)

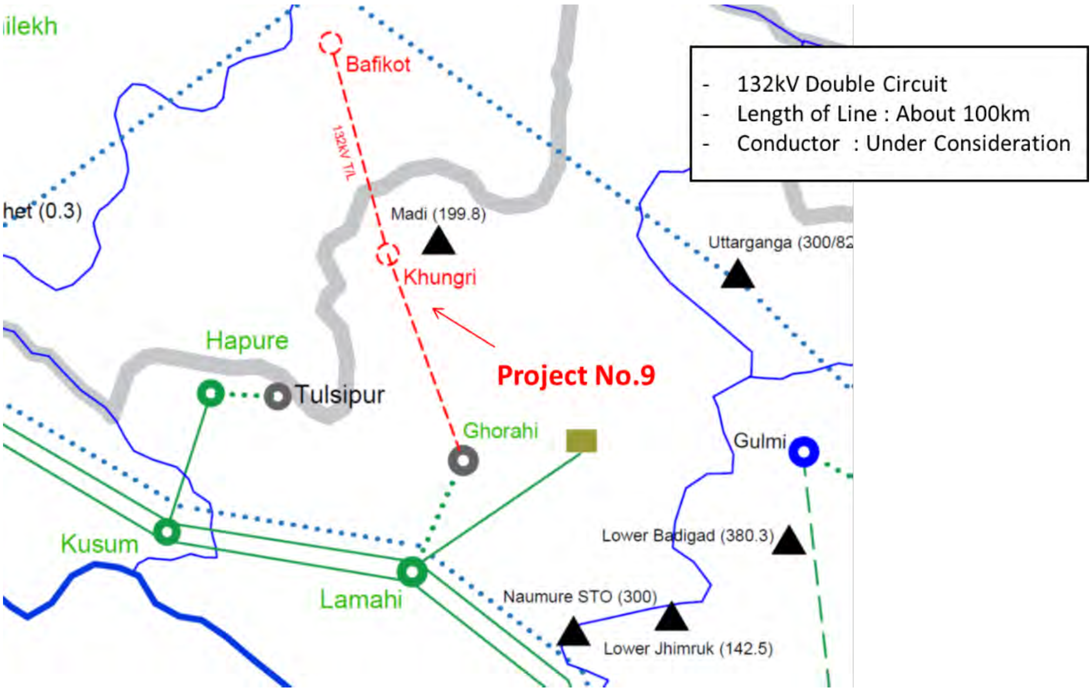
This project aims to construct a new 132/33kV substation to supply power to the industrial area in Dhading. The location of the new substation is under consideration and is not yet determined.

⑨ Ghorahi－Khungri－Banfikot 132kV Transmission Line and Substation Project

This project aims to construct a new 132kV transmission line connecting Ghorahi, Khungri and Banfikot. Figure 2.2-35 shows the overview of this project.

FS of the section between Ghorahi and Khungri is already finished and EIA is in progress. On the other hand, FS of the section between Khungri and Banfikot is in progress.

The Panther, Bear and Duck are generally used as conductors for the 132kV transmission line in Nepal, but in this project the adoption of Cardinal is under consideration to increase the capacity of transmission line.



Source: JICA Study Team based on NEA materials

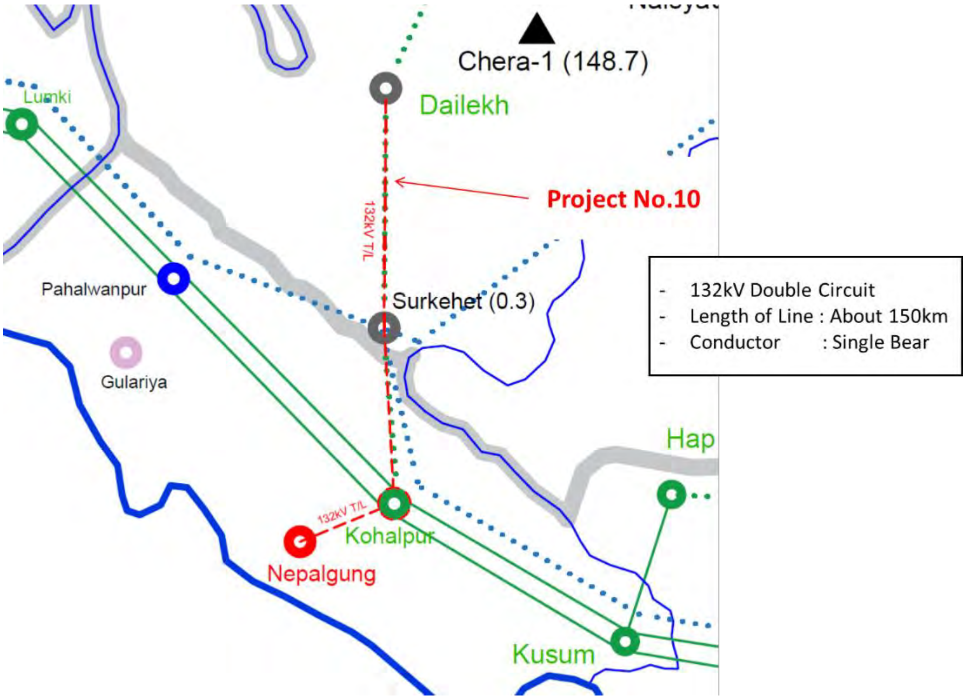
Figure 2.2-35 Overview of project No.9

⑩ Kohalpur－Surkhet－Dailekh 132kV Transmission Line and Substation Project

This project aims to install a new 132/33kV substation at both Surkhet and Dailekh and construct a new 132kV transmission line connecting Kohalpur, Surkhet and Dailekh. Province No.6 is currently not connected to 66kV and more transmission network. Power is supplied to Province No.6 through 33kV and less distribution lines.

The Capital city of Province No.6 is in Surkhet, and Dailekh is located to the north of Surkhet. It is assumed that the objective of this project is to handle the increasing power demand of Province No.6, by constructing a 132kV transmission line to supply power to Surkhet and Dailekh. Figure 2.2-36 shows the overview of this project.

132kV transmission line is planned to be extended to Jumla, located to the north of Dailekh, after the completion of this project.

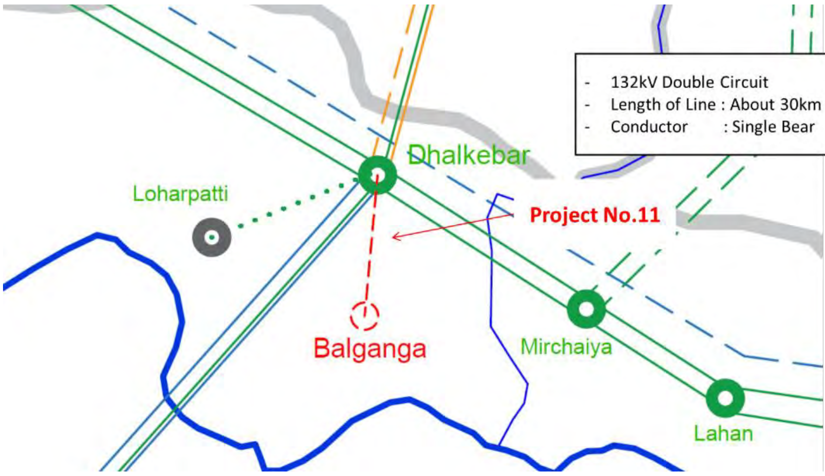


Source: JICA Study Team based on NEA materials

Figure 2.2-36 Overview of project No.10

⑪ Dhalkebar－Balganga 132kV Transmission Line and Substation Project

This project aims to construct a new 132kV substation at Balganga and a new 132kV transmission line between Dhalkebar substation and Balganga substation. Dhalkebar substation is a major substation in the eastern part of Nepal. The interconnection line between Nepal and India, which is designed to be operated in 400kV, is connected to Dhalkebar substation. Figure 2.2-37 shows the overview of this project.



Source: JICA Study Team based on NEA materials

Figure 2.2-37 Overview of project No.11

(2) Development plan of distribution network

In order to develop the distribution network, two master plan development projects are currently underway. One of them is the Distribution System / Rural Electrification Master Plan (DS / REMP), supported by ADB. The main purpose of DS / REMP is to improve the electrification ratio. The work is aimed to strengthen Nepal's power system including the on-grid and the off-grid, in order to achieve 100% electrification ratio by 2025. The DS / REMP project was started from province 4, which is scheduled to be completed by December 2019. After province 4, The DS / REMP will be prepared for another province.

The other development plan is the Loss Reduction Master Plan (LRMP), supported by WB. The LRMP analyzes the power supply and demand forecast, the load flow, the grid etc. of entire Nepal, and formulates a reinforcement project corresponding to the increase in power demand. The main feature of the project is to improve the power loss. Studies, which include not only the reinforcement of 11kV network but also the upgrading to 33kV and 66kV, are being considered. The LRMP is currently in the data collection phase and is scheduled for completion in 2020.

In addition to the above, as a transmission and distribution enhancement plan, the Power Transmission and Distribution Efficiency Enhancement Project (PTDEP), supported by ADB is underway. The purpose of PTDEP is to increase the supply capacity in the Kathmandu Valley, and a plan to upgrade the distribution system, including a radical revision of the distribution system such as upgrading the distribution primary voltage of 11kV to 22kV, is currently being considered.

As mentioned above, the large power loss in the transmission and distribution network is an issue of concern for Nepal. Power system loss in 2018 was 20.45%. The breakdown is 5.63% for transmission loss and 14.82% for distribution loss, and it is higher when compared with the neighboring countries. In order to improve this situation, DCSD is carrying out action items in the units of eight regional offices all over Nepal. The action items are classified into two categories. One is reduction of non-technical loss- main activities are periodic monitoring, introduction of electronic meters, and replacement of bare conductor with covered conductor (Aerial Bundled Conductor: ABC), in order to prevent improper weighing and stealing. The other is reduction of technical loss- main activity is the replacement of overloaded conductors and transformers with a larger capacity unit. In addition to the effects of these steady activities, further reduction of distribution loss can be expected if the distribution system is optimized by the above-proposed projects - the LRMP and PTDEP.

2.2.5 Development State of Power Transmission and Distribution Network

TD of NEA carries out projects for the development of 132kV, 220kV and 400kV transmission lines and substations. Table 2.2-8 shows the list of 132kV projects. These projects mainly aim at increasing the power supply to load centers and the transmission capacity to transmit the power generated by hydropower plants.

Table 2.2-8 List of 132kV projects

S.N.	Name of Project	Total Cost in Crore (NPR)	Donor
132kV Transmission Line Projects			
1	Thankot-Chapagaon-Bhaktapur 132kV Transmission Line	187.64	GoN
2	Kabeli Corridor 132kV Transmission Line	258.44	GoN
3	Singati-Lamosangu 132kV Transmission Line	89.23	GoN
4	Dumre-Damauli-Marsyangdi 132kV Transmission Line	153.99	GoN
5	Kohalpur-Mahendranagar 132kV Transmission Line	186.98	GoN, ADB
6	Ramechhap-Garjyang 132kV Transmission Line	114.45	GoN
7	Rupani 132/33kV S/S	49.00	GoN
8	Syaule 132kV S/S	54.51	GoN
9	Kusma-Lower Modi 132kV Transmission Line	25.77	GoN
10	Kusaha-Kataiya 132kV 2nd Circuit Transmission Line	53.00	GoN
11	Raxual-Parwanipur 132kV 2nd Circuit Transmission Line	45.00	GoN
12	Hetauda-Birgunj 66kV Transmission Line Capacity Increment Project	37.12	GoN
13	New Modi-Lekhnath 132kV Transmission Line	221.45	GoN,Exm of India
14	Solu Corridor 132kV Transmission Line	365.51	GoN,Exm of India
15	Burtibang-Gulmi-Paudi Amrai-Arghakhanchi-Motipur 132kV Transmission Line	300.86	GoN
16	Butwal-Gorusinghe-Lumbini 132kV Transmission Line	118.95	GoN
17	Kusaha-Biratnagar 132kV Transmission Line	188.79	GoN
18	Balefi-Barhabise 132kV Transmission Line	76.15	GoN
19	Dordi Corridor 132kV TL	85.29	GoN
20	East Chitwan 132kV S/S	64.08	GoN
21	Dhalkebar-Loharpatti 132kV Transmission Line	85.00	GoN
22	Chameliya-Syaule-Attariya 132kV 2nd Circuit Transmission Line Project	63	GoN
23	Dandakhet-Rahughat 132kV Transmission Line	280.00	GoN
24	Ghorahi-Khumdi-Madichaur 132kV Transmission Line	109	GoN
25	Nawalpur 132/33kV S/S	66.5	GoN
26	Bhaktapur Baneshwor-Patan 66kV Transmission Line	27.75	GoN
27	Emergency Restoration System (ERS)	13.35	GoN
28	Power Efficiency Project	5.36	GoN
29	Grid Substation Enhancement	128	GoN
30	Amarpur-Dhungesangu 132kV TL	82.65	GoN
31	Kohalpur-Surkhet-Dailekh 132kV TL	278.1	GoN
32	Keroun 132/33 kV S/S	83.67	GoN
33	Dhalkebar-Balganga 132kV TL	225	GoN
34	Lalbandi-Nawalpur-Salimpur 132kV TL	159	GoN
35	Inaruwa-Dharan 132kV TL (25km)	100	GoN
36	Kohalpur-Nepalgunj 132kV TL (20km)	90	GoN
37	Pathlaiya-Harniya 132kV TL(27km)	104	GoN
38	Bhumahi-Hakui 132kV TL(16km)	82	GoN
39	Godak-Anarmani 132kV TL(35km)	120	GoN
40	New Pokhara-Brauta 132/11 kV S/S	70	GoN
41	Bafikot-Khungri 132kV TL	172.7	GoN
42	Sunkoshi 132kV S/S	24.88	GoN
43	Sampatiya-Mainahiya 132kV TL	98.15	GoN
44	Godak-Soyak 132kV TL		GoN
45	Lamahi Ghorahi S/S Expansion	19	GoN

Source: NEA (Transmission Directorate)

Table 2.2-9 shows list of 220kV and 400kV projects. 220kV projects mainly aim to improve the reliability of power transmission system and increase the transmission capacity to transmit the power generated by hydropower plants. The 400kV projects aim to construct trunk transmission line and reinforce interconnection line between Nepal and India or China.

In order to promote cement industries, the government of Nepal has taken up the policy of developing transmission line networks leading up to the site of cement industries. Based on this policy, the NEA and MoI have signed a memorandum of understanding, which stipulates that the MoI shall provide the required funds and the NEA shall develop the transmission network for the cement industries. Table 2.2-10 shows the list of projects which aim to promote the cement industries.

Table 2.2-11 shows the projects, which the PMD of ENA plans or conducts with the assistance of ADB.

Table 2.2-9 List of 220kV and 400kV projects

S.N.	Name of Project	Total Cost in Crore (NPR)	Donor
220kV Transmission Line Project			
1	Khimti -Dhalkebar 220kV Transmission Line	192.5235	GoN
2	Hetauda-Bharatpur 220kV Transmission Line	282.8926	GoN, WB
3	Bharatpur-Bardaghat 220kV Transmission Line	149.4166	GoN, WB
4	Koshi Corridor 220kV Transmission Line	1288.51	GoN,Exm of India
5	Trishuli 3B Hub Project	175.5445	GoN, Kfw, EIB
6	Chilime-Trishuli 220kV Transmission Line	391.21	GoN, kFW, EIB
7	Lekhnath-Damauli 220kV Transmission Line	700.53	GoN, kFW
8	Borang-(Naubise) Ratamate 220kV Transmission Line	344	GoN
9	Tumlingtar-Sitalpati 220kV Transmission Line	281	GoN
10	Trishuli 3 B Ratamate 220kV Transmission Line	221	GoN
400kV Transmission Line Project			
1	Nepal-India Electricity Transmission and Trade Project (NIETTP) Hetauda-Dhalkebar-Duhabi 400kV Transmission Line	1689	GoN, WB
2	New Hetauda, Dhalkebar,Inaruwa400kV S/S Expansion	747.8	GoN
3	Bheri Corridor 400kV Transmission Line	202	GoN
4	Rasuwagadi-Chilime-Ratamate 400kV TL	1074	GoN
5	Arun-Inaruwa-Tingla-Mirchaiya 400kV Transmission Line Study Project	55.5	GoN,WB

Source: NEA (Transmission Directorate)

Table 2.2-10 List of projects for promotion of cement industry

S.N.	Name of Project	Total Cost in Crore (NPR)	Donor
Projects for Power Supply to Cement Industry			
1	Lamahi -Ghorahi 132kV TL	52.2	GoN
2	Bardaghat-Sardi 132kV TL	47.5	GoN
3	Sunuwal 132kV Substation	78.2	GoN
4	Kaligandaki-Ridi 132kV TL	103	GoN
5	Malekhu 132/33 kV S/S	Under Study Projects funded by GoN	
6	Simara SEZ 132kV TL		

Source: NEA (Transmission Directorate)

Table 2.2-11 List of projects planned or conducted by PMD of NEA

No.	Project name	Cost
Electricity Transmission Expansion and System Improvement Project (ETESIP)		
1	Tamakoshi- Kathmandu 220/400 kV Transmission Line Project	US$ 90 Million
SASEC Power System Expansion Project (SPSEP)		
1	Samundratar- Trishuli 3B 132kV Transmission Line	US$ 12.0 Million
2	Marsyangdi Corridor 220 Transmission Line Project	US$ 90 Million
3	Marsyangdi-Kathmandu 220 kV Transmission Line Project	US$ 56Million
4	Kaligandaki Corridor 220kV Transmission Line Projec	
5	Grid Substation Reinforcement and Capacity Expansion Project	
6	Distribution System Augmentation and Expansion Project	
7	Distribution System Master Plan Project	
8	Utility Scale Grid tied Solar Project	US$ 20Million (Grant)
Power Transmission and Distribution Efficiency Enhancement Project (PTDEEP):		
1	Kathmandu Valley Transmission Capacity Reinforcement Project	USD 189 Million
2	Lapsephedi and Changunarayan Substation Construction Project	
3	Kathmandu Valley Smart Metering Project	
4	Enhancement of Distribution Networks in Central & Northern Region of Kathmandu Valley	
5	Kathmandu Valley East & South Distribution System Enhancement Project	
Other Projects		
1	New Butwal Kohalpur, Surkhet and Upper Karnali 400 kV Transmission Line project	
2	Power Transmission and Distribution System Strengthening Project	US$ 240Million
3	Upgrading 220 kV Substations to 400 kV along the New Khimti–Barhabise–Kathmandu Transmission Line Section	US$ 64 Million
4	Automation of Existing Grid Substation	US$ 18 Million
5	Arun Hub-Tingla- Dhalkebar 400kV Transmission Line Project	US$ 230 Million
6	Tingla- New Khimti-Sunkoshi Hub-Dhalkebar 400kV Transmission Line Project	US$ 208 Million
7	Grid Connected Battery Energy Storage System (BESS)	
8	Kathmandu Valley 220kV Ring Main Project	US$ 150 Million

Source: JICA Study Team based on NEA Annual Report 2017/2018

2.3 BASIC INDICATORS RELATED TO POWER TRANSMISSION AND DISTRIBUTION NETWORK

The Electricity Act (EA: 1992) to regulate the overall electric power business, including development and management of hydro power generation, standardization and protection of power industry, was enacted as the law related to power sector in Nepal. In addition, Electricity Rules (ER: 1993) were enacted as the related rules, and the rules determine the Voltage / Frequency, the safety measures for the installation of electrical facilities or construction works.

Based on the above Electricity Act and Electricity Rules, NEA Grid Code specifies indicators related to power transmission and distribution network.

(1) Voltage

In Nepal, 400kV, 220kV, 132kV and 66kV are the voltage levels applied to the transmission line. 33kV and 11kV are the voltage levels applied to the distribution line. NEA Grid Code specifies the permissible voltage variation. According to the Grid Code, voltage variation during normal condition shall be within +/-5% of the normal voltage and the voltage variation during emergencies shall be within +/-10% of the normal voltage.

(2) Frequency

Operating standard frequency in Nepal is 50Hz. NEA Grid Code specifies the permissible frequency variation. According to the Grid Code, frequency variation during normal condition shall be within +/-2.5% of the normal frequency and the frequency variation during emergencies shall be within +/-10% of the normal frequency.

(3) Transmission Loss

Transmission Loss is calculated from the following formula.

Transmission Loss in percent = (Total Received Energy – Total Transmitted Energy – Total Station Loss) / Total Received Energy x 100

Here, the Total Received Energy is defined as the sum of active energy received by the grid owner from generators and so on at each metering point. Total Transmitted Energy is defined as the sum of active energy supplied by the grid owner to users and export at each metering point.

NEA Grid Code specifies that Transmission Loss shall not exceed 4.5% of the Received Energy.

2.4 BASIC MATTERS AND CONSIDERATIONS FOR PROJECT FORMATION IN THE POWER TRANSMISSION AND DISTRIBUTION NETWORK

2.4.1 Basic Matters for Project Formation in Power Transmission and Distribution Sector

In Nepal, standards for planning and design of electric power facilities are specified by the Grid Code and other standards. The following standards need to be paid attention to when projects are formulated in the power transmission and distribution sector.

(1) Maximum allowable load of transmission line and transformer

Grid Code specifies the maximum allowable load of transmission line and transformer as shown in Table 2.4-1. The "Single outage condition", mentioned in the Table, refers to a condition caused by fault of one component in the network such as a single circuit fault of transmission line and one bank fault of transformer. The "Severe outage condition", mentioned in the Table, refers to a severe condition caused by a rare fault such as a double or more circuit fault of transmission line.

Table 2.4-1 Maximum allowable load of transmission line and transformer

	Normal Condition	Single Outage Condition	Severe Outage Condition
Transmission Line	Less than 100% of thermal capacity at 85 degrees Celsius	Less than 120% of thermal capacity at 85 degrees Celsius	Less than 120% of thermal capacity at 85 degrees Celsius
Transformer	Less than 100% of rated capacity	Less than 120% of rated capacity	Less than 120% of rated capacity

Source: NEA Grid Code

(2) Standards for overhead transmission line

Right of way (ROW) is secured under the overhead transmission line in Nepal. It is prohibited to construct building in the ROW, also, the trees in the ROW must be chopped down. Width of ROW depends on the voltage of the transmission line as shown below[4].

- 400kV : 46m
- 220kV : 30m
- 132kV, 66V : 18m

The "NEA Over Head transmission Line Standards", prepared in 2014, define the standards of design and construction for the overhead transmission line. Main design standards described in "NEA Over Head transmission Line Standards" are as follows.

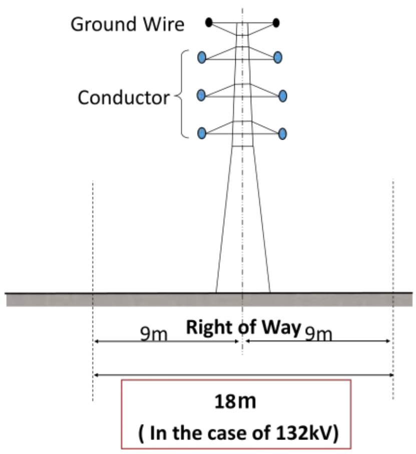


Figure 2.4-1 ROW of 132kV

1) Temperature and Wind velocity

In terms of geographical features, Nepal is divided into mountainous region in the north, hilly region in the central and the Terai plain in the south. There are large differences in elevation between these three regions, so the climate changes significantly depending on the region. If climate conditions for design are specified according to the region, facilities with different specifications increase and the number of required spare parts will also be more. It is not a desirable solution. Therefore, "NEA Over Head transmission Line Standards" specify the following conditions, which is applied all over Nepal.

[4] According to the information from NEA, width of ROW depends on the voltage of the transmission line.

・Temperature
Maximum temperature : 50 degrees Celsius
Minimum temperature : 0 degrees Celsius
Annual average temperature : 32 degrees Celsius

・Wind Velocity
Hilly area, Terai plain: 47m/s
Mountainous area : 55m/s

2) Clearance

The clearance required between the transmission line and the obstacles are shown in Table 2.4-2. This clearance is based on the condition of maximum conductor temperature and no wind. Taking into consideration the survey errors, a value of 0.2m is added to the clearance value, displayed as shown in the below Table.

Table 2.4-2 Required clearance between transmission line and obstacles

Obstacle	Required Vertical Clearance (m)		
	132kV	220kV	400kV
Natural Land	6.5	7	9
Cultivated Land	7	7.5	9.5
Tree	5	5	5
Building	5	5	5
Road	8	8	8
Highway	9	9	9
River and Water area	6.5	6.5	6.5
Telecommunication Line	3	4	5
Railway Track non electrified	18	18	18
Railway Track electrified	4	4.5	5
66kV Line and Lower	3.5	5	5.5
132kV Line	3.5	5	5.5
220kV Line	5	5	5.5
400kV Line	5.5	5.5	5.5

Source: NEA Over Head transmission Line Standards

3) Span

Spans applied for pre-design are shown in Table 2.4-3 to Table 2.4-8. The values of spans, displayed in the Table, are applied for pre-design, so these values can be changed at detail design stage.

Table 2.4-3 Span of 132kV transmission line in Plain Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	350	500	100
Tension small/medium Angle	350	500	-250
Tension Large Angle	350	500	-250

Source: NEA Over Head transmission Line Standards

Table 2.4-4 Span of 132kV transmission line in Hilly Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	350	700	100
Tension small/medium Angle	350	700	-500
Tension Large Angle	350	700	-500

Source: NEA Over Head transmission Line Standards

Table 2.4-5 Span of 220kV transmission line in Plain Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	400	600	100
Tension small/medium Angle	400	600	-300
Tension Large Angle	400	600	-300

Source: NEA Over Head transmission Line Standards

Table 2.4-6 Span of 220kV transmission line in Hilly Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	400	800	100
Tension small/medium Angle	400	800	-400
Tension Large Angle	400	800	-400

Source: NEA Over Head transmission Line Standards

Table 2.4-7 Span of 400kV transmission line in Plain Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	500	700	100
Tension small/medium Angle	500	700	-400
Tension Large Angle	500	700	-400

Source: NEA Over Head transmission Line Standards

Table 2.4-8 Span of 400kV transmission line in Hilly Terrain

Tower type	Wind Span (m)	Maximum Weight Span (m)	Minimum Weight Span (m)
Suspension	500	1000	100
Tension small/medium Angle	500	1000	-500
Tension Large Angle	500	1000	-500

Source: NEA Over Head transmission Line Standards

4) Conductor type

Conductors applied to the transmission line are shown in Table 2.4-9. Conductors applied to transmission line have to conform to IEC.

Table 2.4-9 Conductor type applied to transmission line

Conductor	Voltage (kV)	Cross Sec (mm^2)	Thermal Limit (MVA)
Single Panther	132	210	104
Single Bear	132	265	124
Single Duck	132	344	159
Single Duck	220	344	265
Twin Duck	220	22044	530
Single Bison	220	381	271
Twin Bison	220	22081	542
Triple Bison	220	32081	813
Twin Zebra	220	22028	662
Twin Moose	220	22028	691
Quad Moose	220	42028	1381
Single Bison	400	381	492
Twin Bison	400	20081	985
Triple Bison	400	30081	1477
Twin Moose	400	20028	1256
Triple Moose	400	30028	1883
Quad Moose	400	40028	2511
Twin Bersemis	400	20024	1454

Source: NEA Over Head transmission Line Standards

(3) Standards and criteria for distribution network

Planning and construction standards for distribution network are not clearly defined, but the specifications are defined for each project on project-by-project basis. However, Planning and Technical Service Department (PTSD) of DCSD is now managing the tasks pertaining to the preparation of construction standards and guidelines for the implementation of electrical installations and construction, for a voltage level of 33kV and below.

2.4.2 Issues in Project Management and Maintenance Management

(1) Organization to keep the capacity of project supervision and maintenance

NEA established a training center in the suburbs of Kathmandu in the Engineering Directorate for staff capacity development, technology transfer and sustainability.

On investigating about the actual situation of capacity development for NEA staff, we can confirm that the main responsibility of the NEA Training Center is divided into A) Transmission and distribution, B) Generation in Power house and C) Distribution and Consumer Services.

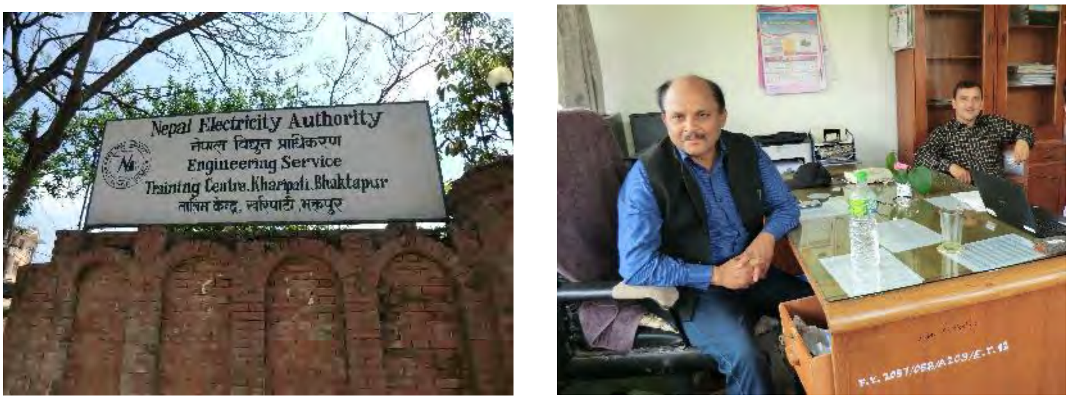


Figure 2.4-2 The Entrance of NEA Training Center and Management Staff

The NEA Training Center consists of the following four sections under the supervision of the Chief, who is the Management Head. And, the training center coordinates trainings according to each skill development field, such as the technical department, the accounting department etc.

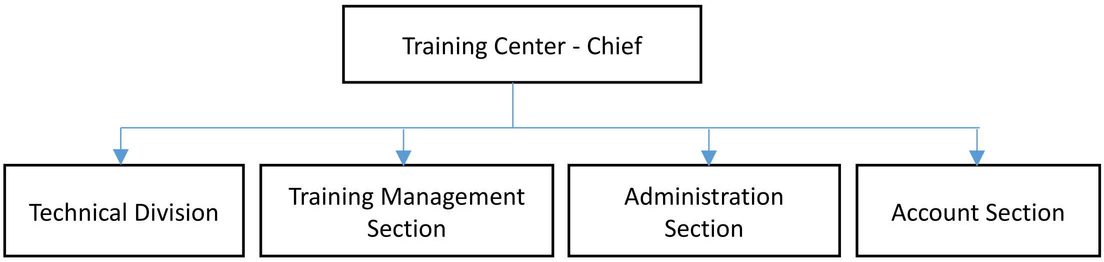


Figure 2.4-3 Organization Structure of NEA Training Center

Training is often carried out at NEA training center, but some trainings are carried out at the 8 Regional Offices in Nepal nationwide.

(2) Instructor on capacity development and maintenance

Most of the instructors are NEA's staff, and it is a fact that appropriate personnel are dispatched from each department as needed for the technical training. However, there are exceptions to this. There are trainings where the NEA staff is not the instructor. For example, in case of carrying out training related to work management practices to the staff of the management department, instructors from another organization called the "Staff college" are invited to carry out the training.

(3) Teaching materials for capacity development, training manuals, etc.

The training center prepares the training manuals, and the instructors prepare the lecture notes for each training. There are no textbooks in the actual lecture, and only the printed materials are distributed by the instructor. The training center also does not publish the textbooks, and after the training, the trainees are provided repeated OJT to acquire practical knowledge.

(4) Training monitoring and feedback

As a follow-up to the training, the office manager of the participant will report to the training center about the improvements observed at work after the training. The training center collects the information on how the participants are working at the workplace after the training, and use it to improve the training in the future.

(5) Issues in capacity development and maintenance

NEA has carried out many trainings on project supervision and trainings to develop the capabilities to maintain and manage the facilities well. However, the following points-of-evaluation and the points-for-improvement can be specified..

The following are the points-of-evaluation.

- Since trainings are held at eight regional offices throughout the whole country, there are equal opportunities for NEA staffs working at distant places, far from Kathmandu.

- The training center is well equipped for lectures and accommodation, and is suitable for short-term intensive training.

- Even when the trainees return to their respective job locations, it is followed by OJT.

The contents shown in Table 2.4-10 can be considered as the points to be improved, and the measures to maximize the outcome of capacity development are necessary.

Table 2.4-10 Points to Consider for Improvement in Training

The Points to be Improved	The Measures to Maximize The Outcome of Capacity Development
Since there are no textbooks, it can be considered that there are various lecture contents depend on lecturers, and there will be a variation in the technology or knowledge to be acquired. Also, there will be a possibility that the replacement of the content that becomes obsolete is not maintained.	➢ Preparing to create training texts ➢ Standardization of training content ➢ Regularly modify the training content by the review committee for content update
It can be considered that training is carried out without sufficient capacity assessment for the trainees. As a result, it can be thought that a difference is likely to be made in the level of learning of the students.	➢ Carrying out of capacity assessment ➢ Setting of outcome goals ➢ Development of education plan
Monitoring and feedback system is not standardized, therefore it is not easy to upgrade the training programs and the contents based on the accumulated data.	➢ Monitoring and analysis of proficiency ➢ Examination of task extraction and feedback ➢ Establishment of a feedback system ➢ Consideration in the improvement of training content
Most of the content is related to the collection of electricity bills and the handling of computer systems for their management, and there seems to be little content related to project development and maintenance.	➢ Consideration in the expansion of the curriculum for training project development and maintenance skills.

Source: JICA Study Team

2.5 STATE OF OTHER DONORS' ASSISTANCE FOR THE DEVELOPMENT OF POWER TRANSMISSION AND DISTRIBUTION NETWORK

As shown in Table 2.5-1, donors such as WB, MCC and ADB provide assistance to the power transmission and distribution sector in Nepal, in the form of grant aids, loan assistance, etc. Assistance from JICA should not overlap with these projects.

Table 2.5-1 Major Development Projects Supported by International Donors

Project	Donor	Contents	Cost	Period
Millennium Challenge Corporation: Nepal Compact[5]	MCC (USA)	Improvement of 300km high voltage transmission lines	US$ 398M	2017/9～
Distribution System / Rural Electrification Master Plan[6]	ADB	Development of 11kV distribution system and rural electrification master plan	-	2017/9.～
Power Transmission and Distribution Efficiency Enhancement Project[7]	ADB	Energy efficiency improvement through the improvement of the transmission and distribution system in Kathmandu Valley area	US$ 150M	2017/9 – 2022/6 (Loan3542-NEP))
Grid Solar and Energy Efficiency[8]	WB	Development of distribution master plan and construction of 33kV,11kV,400/230V distribution network and substation	US$130M	2014/12～2020/12 (P146344)
South Asia Subregional Economic Cooperation (SASEC) Power System Expansion Project[9]	ADB	1.Power transmission capacity increased, 2.Power distribution network improved, 3. Mini-grid-based renewable energy systems in off-grid areas increased, 4.Capacity development support to NEA and AEPC provided.	US$ 60M US$11.20M US$ 20M US$ 180M	2014/11～2022/6 (Grant 0397-NEP) 2014/7～2022/6 (Grant 0398-NEP) 2017/1～2022/6 (Grant 0520-NEP) 2014/7～2022/6 (Loan3139-NEP)
Electricity Transmission Expansion and Supply Improvement Project[10]	ADB	Improvement of transmission and distribution system and rehabilitation of small hydropower	US$ 19M US$ 56M	2012/3～2020/3 (Grant0270-NEP) 2012/3～2020/3 (Loan2808-NEP)
Nepal-India Electricity Transmission and Trade Project[11]	WB	Improvement of Nepal-India cross-border interconnections	US$ 182M	2011/6 – 2020/4 (P115767)

Source: JICA Study Team

5 https://www.mcc.gov/where-we-work/program/nepal-compact
6 http://gestoenergy.com/project/nepal-distribution-systemrural-electrification-master-plan/
7 https://www.adb.org/projects/50059-002/main
8 http://projects.worldbank.org/P146344?lang=en
9 https://www.adb.org/projects/44219-014/main
10 https://www.adb.org/projects/41155-013/main#project-pds
11 http://projects.worldbank.org/P115767/nepal-india-electricity-transmission-trade-project?lang=en

CHAPTER 3

CURRENT STATE OF MAJOR CITIES IN NEPAL

CHAPTER 3 CURRENT STATE OF MAJOR CITIES IN NEPAL

3.1 THE OUTLINE OF MAJOR CITIES IN NEPAL (GEOGRAPHICAL ENVIRONMENT, POPULATION TRANSITION, MAJOR INDUSTRY, INDUSTRIAL PARK AND REGIONAL DEVELOPMENT PLAN)

Based to the population size[1], the Metropolitan cities and Sub-metropolitan cities are decided to be the survey target, as they are the major cities in Nepal, and the target cities are organized by "Province" that is considered as top of administrative division. The list of cities and their population are shown in Table 3.1-1.

Table 3.1-1 Major Cities and Their Population

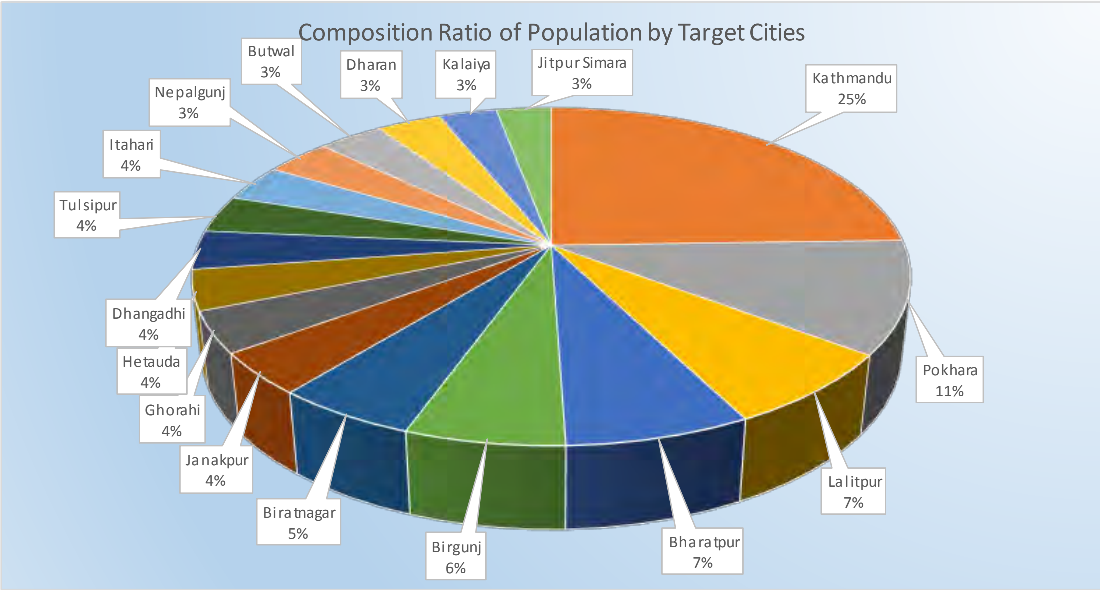
No.	Name of City	District	Province	Population (2011)
1	Kathmandu	Kathmandu	Province No. 3	975,453
2	Pokhara	Kaski	Gandaki Pradesh (Province No.4)	426,759
3	Lalitpur	Lalitpur	Province No. 3	284,922
4	Bharatpur	Chitwan	Province No. 3	280,502
5	Birgunj	Parsa	Province No. 2	240,922
6	Biratnagar	Morang	Province No. 1	214,663
7	Janakpur	Dhanusha	Province No. 2	159,468
8	Ghorahi	Dang	Province No. 5	156,164
9	Hetauda	Makawanpur	Province No. 3	152,875
10	Dhangadhi	Kailali	Sudurpashchim Pradesh (Province No.7)	147,741
11	Tulsipur	Dang	Province No. 5	141,528
12	Itahari	Sunsari	Province No. 1	140,517
13	Nepalgunj	Banke	Province No. 5	138,951
14	Butwal	Rupandehi	Province No. 5	138,741
15	Dharan	Sunsari	Province No. 1	137,705
16	Kalaiya	Bara	Province No. 2	123,659
17	Jitpur Simara	Bara	Province No. 2	117,496

Source: Nepal Central Bureau of Statistic (CBS)

The population of the target cities and their composition ratio are shown in Figure 3.1-1. According to the most recent survey by CBS (2011), the capital city of Kathmandu is the largest, accounting for 25% of the total population of the target cities, followed by Pokhara at 11%, and Lalitpur at 7% . Lalitpur is located near Kathmandu, and these two cities account for one third of the total population of target cities. Kathmandu shows a population growth rate (2001-2011) of 61.2% and Lalitpur shows a population growth rate of 38.6%, both are pretty high values. Also in other cities, the population is increasing at about 20%. Based on the national average population trend, the population growth rate is estimated to be 1.7% during 2011 to 2015. According to the latest information from World Bank (2016), the population growth rate has become stable at 1.1%, and the total population in Nepal is estimated to be 28.98 million. This confirms the remarkable population concentration in the urban areas of Nepal, and it is

[1] The classification criteria of cities are as follows. The big city has a population of over 300,000, and the big city has a population of over 100,000. (www.llrc.gov.np)

becoming increasingly important to prioritize the improvement of transmission and distribution network in the urban areas, which will be highly beneficial and will have a great effect on the development.



Source: CBS Nepal, World Bank

Figure 3.1-1 Composition Ratio of Population by Target Cities

The target cities to be studied are organized by Province, which is the administrative division of Nepal, as follows, and the location map is shown in Figure 3.1-2.

Province 1: Biratnagar

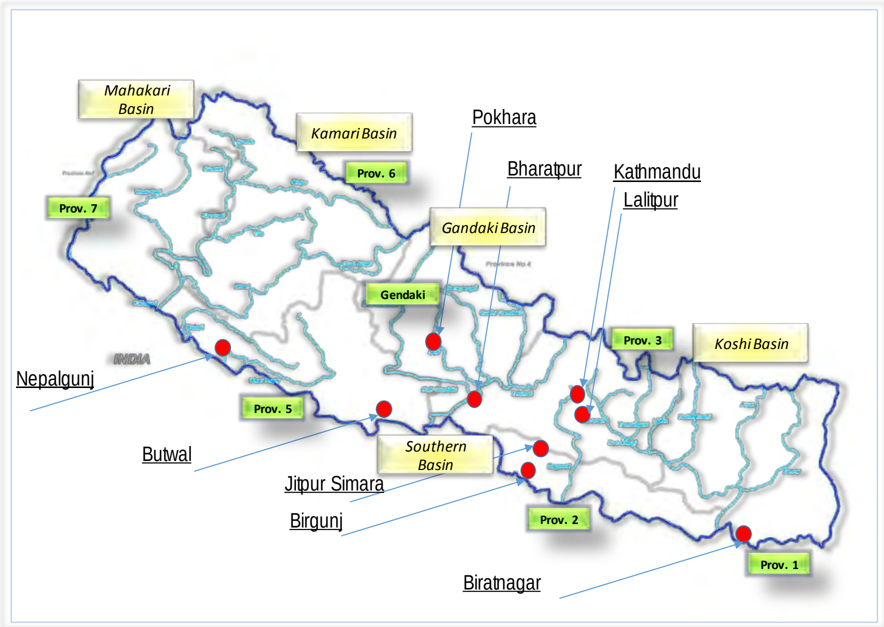
Province 2: Birgunj and Jitpur Simra

Province 3: Kathmandu, Lalitpur and Bharatpur

Gandaki Pradesh Province: Pokhara

Province 5: Butwal and Nepalgunj

These major target cities are located in the main basin (Gandaki, Koshi, Southern Basin) where the potential for hydro-energy is high, and further development of power resource will continue.

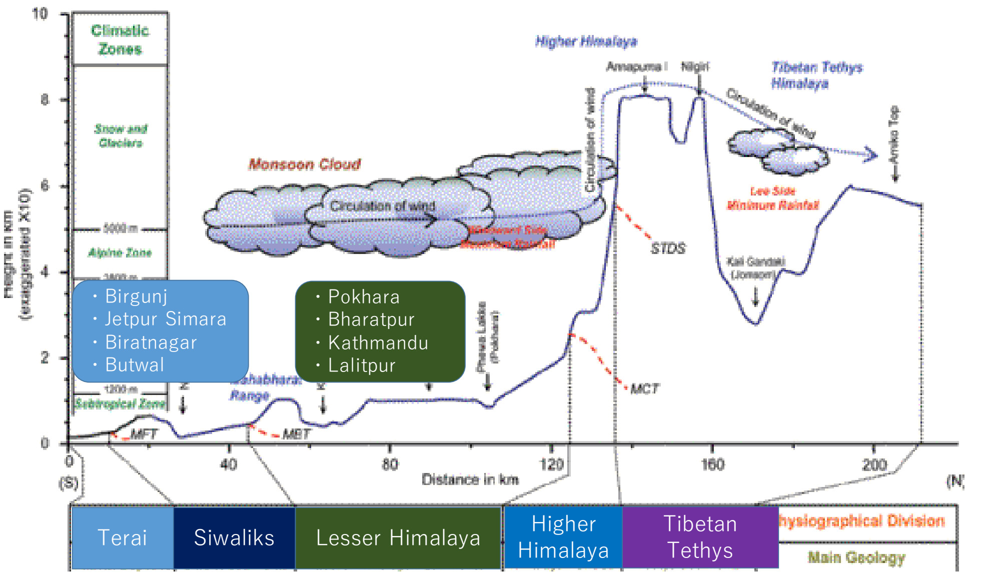


Source: JICA Study Team

Figure 3.1-2 Location of Target Cities

The terrain of Nepal can be divided into five zones extending in the east-west direction approximately based on altitude. Geographical Environment of Nepal is shown in Figure 3.1-3.

The five zones consist of the Tibetan Plateau (Tibetan Tethys: altitude 5,000 to 8,000 m), the High Himalaya Belt (Himalayan main ridge: altitude 3,000 to 5,000 m), Lesser Himalaya belt (mountainous area with altitude 1,000 to 3,000 m), Siwalik hill belt (altitude 800 to 1,500 m) and Terai plain (alluvial lowland leading to the Ganges river). Half of the eight target cities are located in the Terai plain, and the rest are located in the Lesser Himalaya belt.



Source: JICA Study Team based on "Dahal and Hasegawa (2008)"

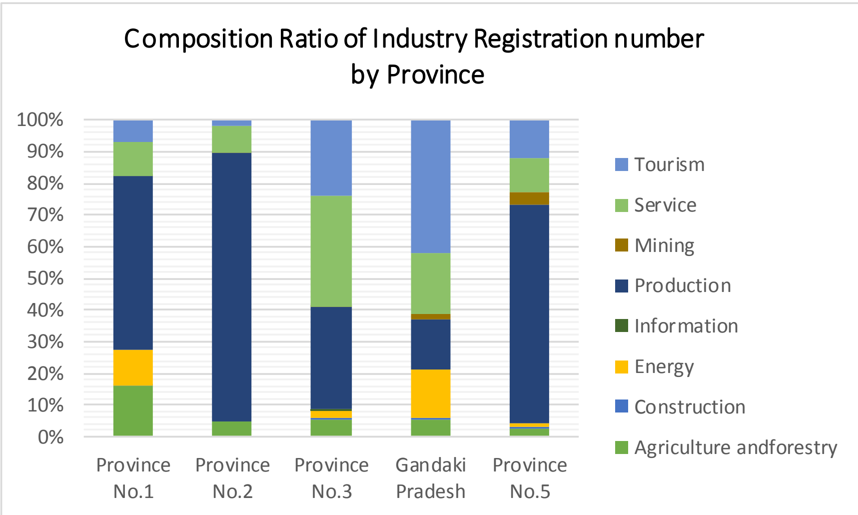
Figure 3.1-3 Geographical Environment of Target Cities

GDP in Nepal has grown by about 1.5 times in a span of about seven years, and according to the composition ratio, agriculture contributes to about 31.2% of the GDP. On the other hand, the composition ratio of manufacturing industry with high energy consumption propensity is as low as 14.8%, and it can be said that the industrialization progress has been delayed in Nepal. The composition ratio of location by industry and region is shown in Figure 3.1-4.

In Province 1, Province 2 and Province 5, the composition ratio of manufacturing industry is very high and the values are about 60 to 80% of the total value. The manufacturing industries are located in Biratnagar of Province 1, Birgunj and Jitpur Simra of Province 2, Bhairahawa and Butwal of Province 5, and these areas are designated as Special Economic Zones.

In Province 3, which includes Kathmandu and Lalitpur, the service industry and the manufacturing industry have almost the same ratio, and the value is about 30%.

In Gandaki Pradesh which includes Pokhara, a city famous for tourism, the composition ratio of tourism and service industry is 60% of the total value.



Source: MoF Nepal

Figure 3.1-4 Composition ratio of Industry registration Number by Province

Nepal's Special Economic Zone is a system launched by the Special Economic Zone Agency of the Ministry of Commerce, based on the “Special Economic Zone Act”, established in 2015 with the aim of promoting exports. The following tax exemptions and assistance will be provided to the companies established in the special zone.

- 100% exemption from income tax for the first 5 years and half for the subsequent 5 years
- 100% exemption from income tax for 10 years in the Special Economic Zone of mountainous areas
- For dividend payment, full tax exemption for the first five years and half tax exemption for the next three years are adopted
- VAT is exclusive
- There is a rebate system for leased land

A list of industrial parks is shown in Table 3.1-2. As of 2017, 4 sites with a total area of 2,511 ha are in the course of development, and 10 other sites (Lease contract is completed for 998 ha) are already in operation.

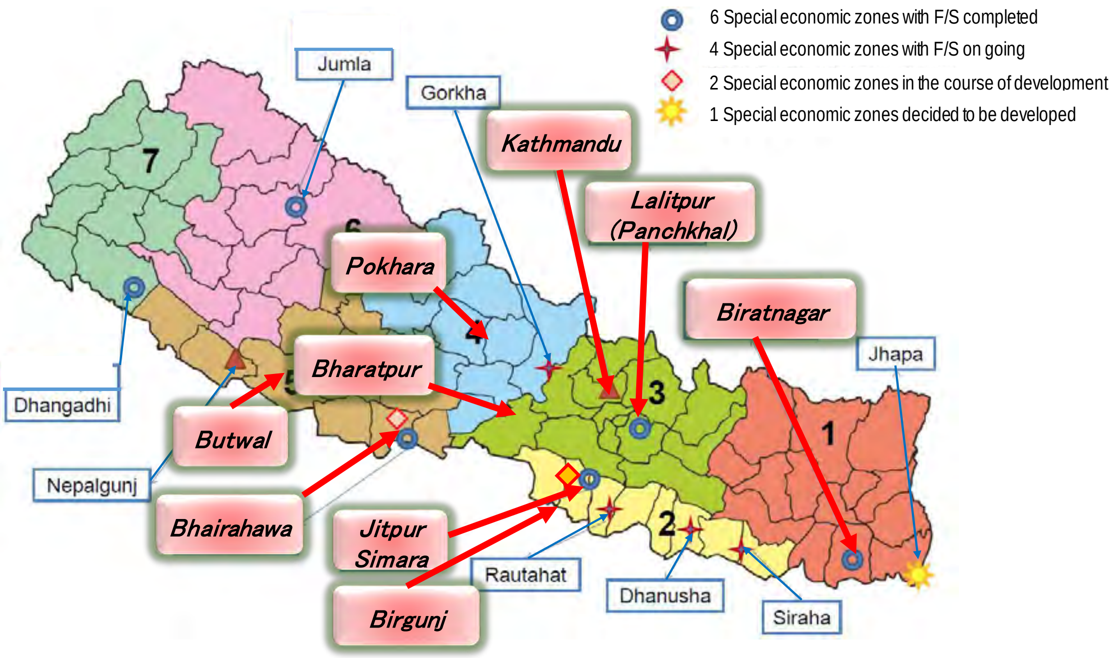
Table 3.1-2 A List of Industrial Parks

Industrial Park	District	Area(ha)	Status
Damak	Jhapa	1,510	Acquired (308ha)
Mayurdhaap	Hetauda	204	Acquired (136ha)
Motipur	Rupandehi	542	Acquired (553ha)
Naubasta	Banke	255	Acquired (230ha)
TOTAL		2,511	
10 other places are in operation		1,000	Lease contracted (998ha)

Source : Mikio TAMADA (Nepal Investment Board)

ESZ (Economic Special Zones) and their locations are shown in Figure 3.1-5.

In 2017, special economic zone was set up in the vicinity of the following cities, among the target cities: Bhairahawa, Jitpur Simra, Birgunj, Kathmandu, Lalitpur (Panchkhal) and Biratnagar. The feasibility study of 4 of these sites has been completed.



Source : Mikio TAMADA (Nepal Investment Board)

Figure 3.1-5 Special Economic Zones and Their Locations

3.2 BASIC INDICES RELATED TO TRANSMISSION AND DISTRIBUTION

The electricity sales (total and industrial) for the recent 5 years in the target cities, and their growth rates are shown in Table 3.2-1. Observing the total electricity sales of target cities in 2018, we can confirm that, Kathmandu, where industry and population are concentrated, is the largest, and it is followed by Butwal and Biratnagar in that order. As shown in Figure 3.2-1, the composition ratio of Kathmandu is 23.9%, and that of Butwal is 12.7%, and that of Biratnagar is 7.7% of the total sales. In the same way, observing the electricity sales in industrial by target cities, we can conclude that, the top 3 composition ratios are 19.5% of Jitpur Simra, 18.3% of Butwal and 14.6% of Birgunj.

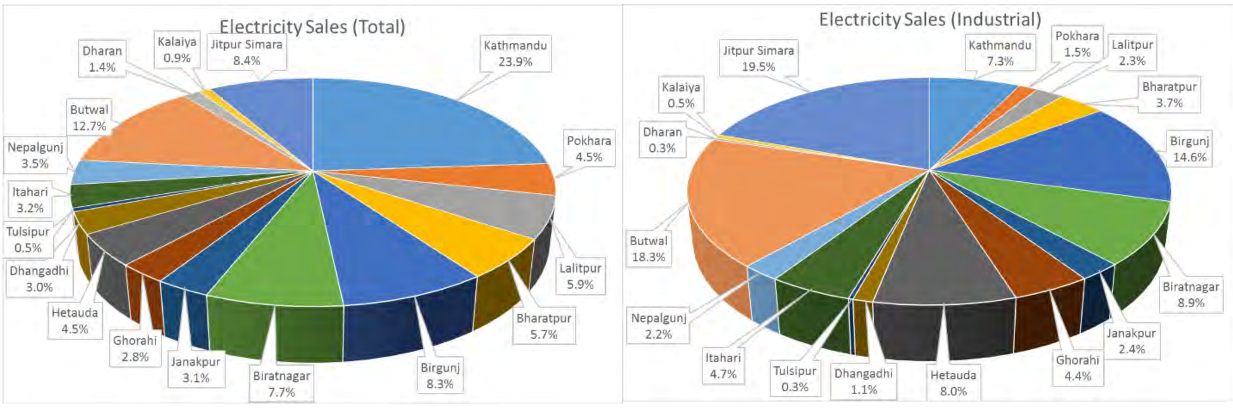
Observing the growth rate in total electricity sales of cities for the last 5 years, Ghorahi is prominent and is showing a growth rate of 231%, followed by 206% of Jitpur Simra and 194% of Butwal. Similarly, on observing the annual average growth rate, we can confirm that Ghorahi is prominent and is showing an annual average growth rate of 23%, followed by 15.6% of Jitpur Simra and 14.4% of Biratnagar. Observing the growth rate in the electricity sales in industrial by city, both the growth rate for the recent 5 years and the annual average are high for Ghorahi[2].

Table 3.2-1 Electricity Sales of Target Cities (Total, Industrial)

	Name of City	Province	Population (2011)	Electricity Sales (Total) (MWh)							Electricity Sales (Industrial) (MWh)						
				2070/071 (2014)	2071/072 (2015)	2072/073 (2016)	2073/074 (2017)	2074/075 (2018)	5 years Growth rate	Yearly Growth rate	2070/071 (2014)	2071/072 (2015)	2072/073 (2016)	2073/074 (2017)	2074/075 (2018)	5 years Growth rate	Yearly Growth rate
1	Kathmandu	Province No. 3	**975,453**	598,848	653,152	686,437	835,688	927,400	155%	9.1%	68,139	74,317	73,218	96,194	112,618	165%	10.6%
2	Pokhara	Gandaki	**426,759**	101,285	120,494	119,889	156,607	175,963	174%	11.7%	11,859	16,117	15,473	21,117	23,475	198%	14.6%
3	Lalitpur	Province No. 3	**284,922**	139,754	155,847	163,126	205,746	230,607	165%	10.5%	21,724	23,437	23,909	32,305	34,831	160%	9.9%
4	Bharatpur	Province No. 3	**280,502**	117,060	140,194	148,383	181,903	220,976	189%	13.6%	26,821	35,352	34,817	42,899	57,112	213%	16.3%
5	Birgunj	Province No. 2	**240,922**	205,033	233,506	173,509	272,746	320,311	156%	9.3%	150,323	170,581	113,260	188,971	226,104	150%	8.5%
6	Biratnagar	Province No. 1	**214,663**	152,136	195,158	196,707	257,110	297,963	196%	14.4%	80,014	101,595	94,513	119,170	137,660	172%	11.5%
7	Janakpur	Province No. 2	**159,468**	68,017	100,897	72,967	98,654	118,933	175%	11.8%	23,766	24,123	18,701	24,876	37,663	158%	9.6%
8	Ghorahi	Province No. 5	**156,164**	38,192	73,095	66,222	94,321	107,306	281%	23.0%	15,319	46,418	2,824	61,802	68,703	448%	35.0%
9	Hetauda	Province No. 3	**152,875**	100,985	124,181	125,084	149,084	174,355	173%	11.5%	71,470	86,442	82,926	102,809	122,941	172%	11.5%
10	Dhangadhi	Sudurpashchim	**147,741**	62,914	86,052	84,019	105,940	117,958	187%	13.4%	11,217	12,818	13,829	15,983	17,354	155%	9.1%
11	Tulsipur	Province No. 5	**141,528**	12,125	15,561	15,938	16,592	19,171	158%	9.6%	2,518	2,980	2,824	3,073	4,120	164%	10.3%
12	Itahari	Province No. 1	**140,517**	83,995	96,577	90,906	110,880	124,805	149%	8.2%	51,007	58,454	55,191	66,232	72,626	142%	7.3%
13	Nepalgunj	Province No. 5	**138,951**	78,760	91,825	92,176	113,543	136,257	173%	11.6%	19,036	22,077	23,361	28,372	34,505	181%	12.6%
14	Butwal	Province No. 5	**138,741**	255,176	312,005	302,607	412,016	494,164	194%	14.1%	154,980	180,229	157,253	237,743	283,151	183%	12.8%
15	Dharan	Province No. 1	**137,705**	34,063	39,534	42,560	48,985	53,815	158%	9.6%	3,177	3,210	3,651	4,084	4,252	134%	6.0%
16	Kalaiya	Province No. 2	**123,659**	19,948	23,921	21,769	30,360	35,354	177%	12.1%	5,798	6,707	5,778	7,651	7,985	138%	6.6%
17	Jitpur Simara	Province No. 2	**117,496**	157,435	192,020	144,149	258,015	325,096	206%	15.6%	144,482	176,483	126,931	236,293	300,972	208%	15.8%

Source: NEA Finance Directorate 2017/2018

[2] Several cement companies were located in Ghorahi in recent years, and their production has been growing. Currently, Ghorahi becomes the center of Nepal's largest cement industry in the private sector. (http://www.globalcement.com/news/)



Source: JICA Study Team

Figure 3.2-1 Composition Ratio of Electricity Sales by Target Cities (Total, Industrial)

The average unit price of electricity in each target city is shown in Table 3.2-2. For the year 2018, the average unit price values for the cities are in the range of 7.0 to 11.9 (NPR/kWh), and the value of Kathmandu is the highest at 11.9 (NPR/kWh), followed by 11.6 (NPR/kWh) of Lalitpur and Biratnagar.

Table 3.2-2 Average Unit Prices of Electricity in Each Target City

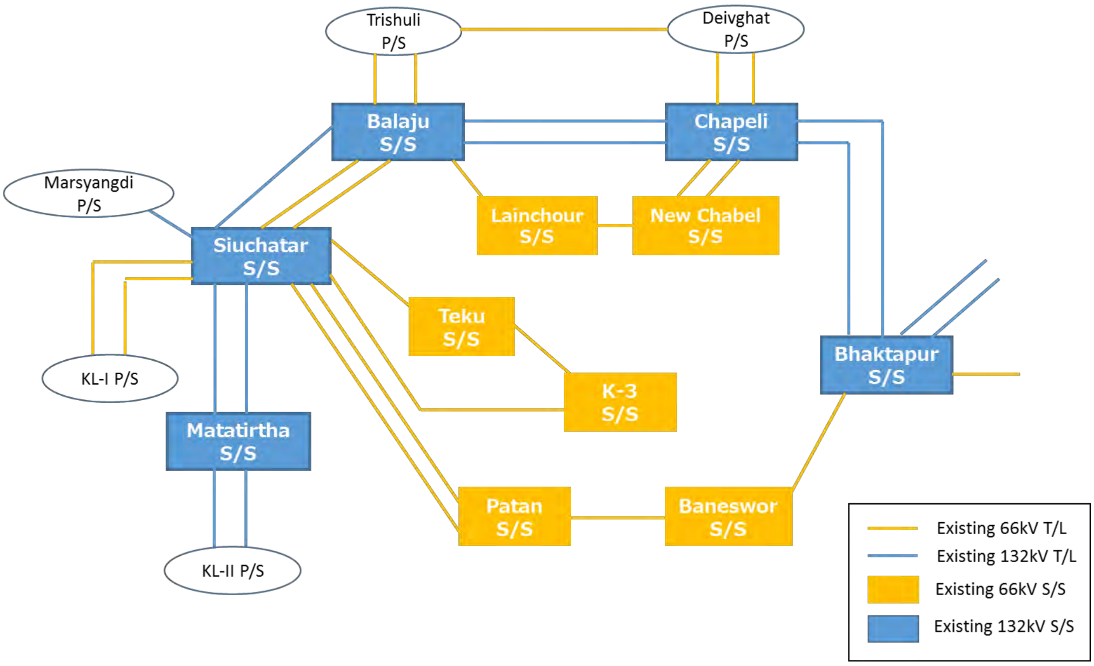
	Name of City	Province	Population (2011)	Electricity Unit Price (Total) (NPR/kWh) 2074/075 (2018)
1	Kathmandu	Province No. 3	975,453	11.9
2	Pokhara	Gandaki Pradesh	426,759	10.7
3	Lalitpur	Province No. 3	284,922	11.6
4	Bharatpur	Province No. 3	280,502	10.3
5	Birgunj	Province No. 2	240,922	10.2
6	Biratnagar	Province No. 1	214,663	11.6
7	Janakpur	Province No. 2	159,468	9.4
8	Ghorahi	Province No. 5	156,164	9.2
9	Hetauda	Province No. 3	152,875	11.5
10	Dhangadhi	Sudurpashchim Pradesh	147,741	8.4
11	Tulsipur	Province No. 5	141,528	10.0
12	Itahari	Province No. 1	140,517	9.4
13	Nepalgunj	Province No. 5	138,951	7.0
14	Butwal	Province No. 5	138,741	9.7
15	Dharan	Province No. 1	137,705	10.5
16	Kalaiya	Province No. 2	123,659	9.7
17	Jitpur Simara	Province No. 2	117,496	8.4

Source: JICA Study Team

3.3 DEVELOPMENT STATE OF TRANSMISSION AND DISTRIBUTION NETWORK IN MAJOR CITIES

(1) Kathmandu and Lalitpur

Figure 3.3-1 shows the overview of power transmission network around Kathmandu valley, where Kathmandu and Lalitpur are located. Power is supplied to Kathmandu and Lalitpur through the 132kV transmission line, running along the northern part of Kathmandu valley, and the 66kV transmission line, running towards the center of Kathmandu valley.



Source: JICA Study Team based on NEA materials

Figure 3.3-1 Overview of power transmission network around Kathmandu valley

Figure 3.3-2 shows the overview of development plan for power transmission network around Kathmandu valley. Kathmandu valley is the central area of Nepal and it has problems with increase in transmission loss and voltage drop, due to the increase in power demand with economic growth. NEA carries out the following projects in order to solve the problems.

1) Thankot－Chapagaon－Bhaktapur 132kV Transmission Line (Donor: GoN)

The scope of this project is to construct a new 132kV substation at Harsidi in Lalitpur and a new 132kV transmission line between Mathatirtha, Chapagaon, Harsidi and Bhaltapur. The projects aims to reduce voltage drop and transmission loss and improve the reliability of power supply to Kathmandu valley by constructing a ring 132kV network around Kathmandu valley. This project was commenced in 1998, but the construction of the transmission line is partly suspended due to problems related to the compensation for ROW in Lalitpur.

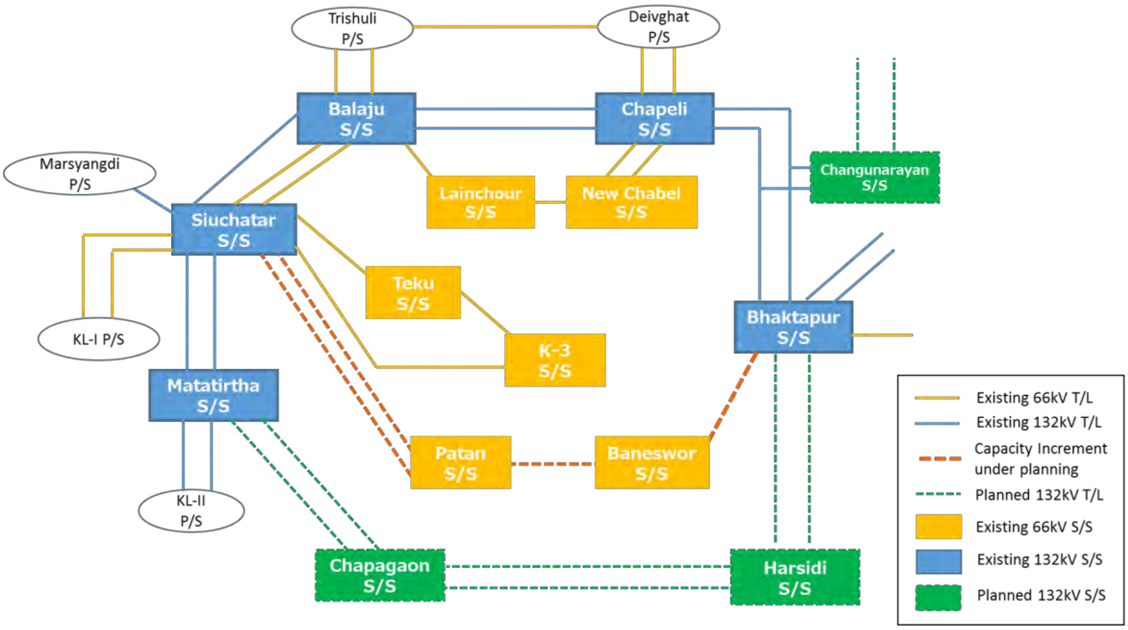
2) Bhaktapur—Baneshwor—Patan 66kV Transmission Line Up gradation Project (Donor : GoN)

The scope of this project is to replace the conductors used in the existing transmission line between Bhaktapur, Baneshwor, Patan and Suichatar with new HTLS conductors. This project aims to reinforce the existing power transmission network in Lalitpur. This project was commenced in 2017 and is planned to be completed in 2020.

On the other hand, for the reinforcement of the existing distribution network, the Power transmission and Distribution efficiency enhancement project, including the following projects are in progress with the assistance from ADB.

3) Kathmandu Valley Transmission Capacity Reinforcement Project (Donor: ADB, GoN)

The scope of this project is to construct a new 90MVA substations at Mulpani, Futung and Chapagaon to reinforce the capacity of substations in power transmission network. The project aims to improve reliability and quality of power supply in Kathmandu by reducing distribution network overload.

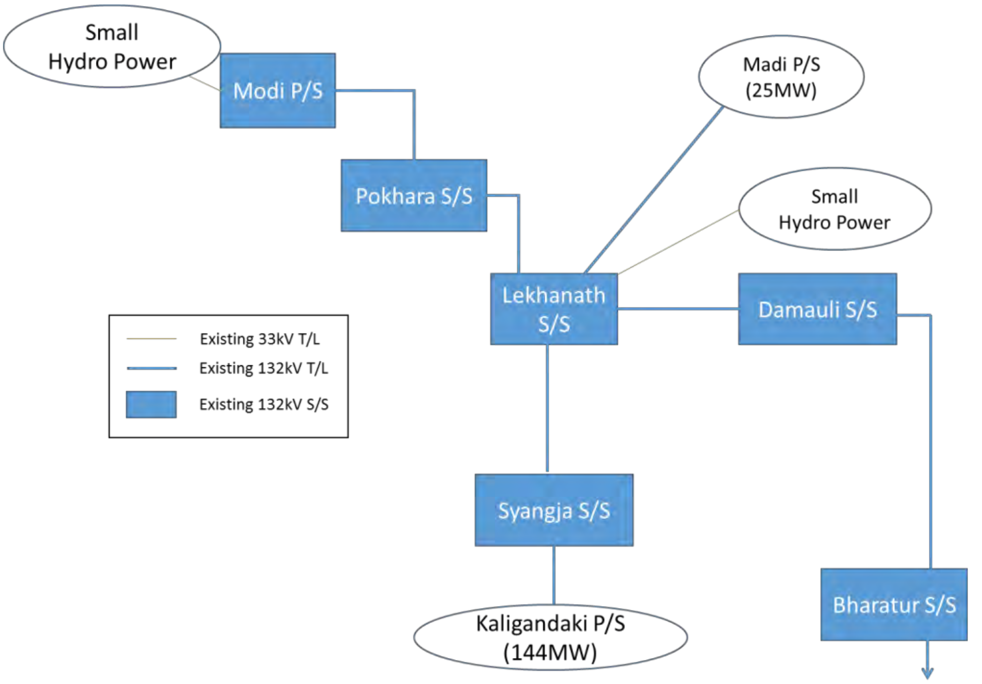


Source: JICA Study Team based on NEA materials

Figure 3.3-2 Overview of development plan for power transmission network around Kathmandu valley

(2) Pokhara

Figure 3.3-3 shows the overview of power transmission network around Pokhara. Power is supplied to Pokhara city from only the existing Pokhara substation. Pokhara substation is connected to Lekhnath substation in the east and Modi power plant in the west by 132kV single circuit transmission line. Pokhara substation receives power from Modi power plant during off-peak hours and receives power from Kaligandaki power plant via Syangia and Lekhnath substation during peak hours.



Source: JICA Study Team based on NEA materials

Figure 3.3-3 Overview of power transmission network around Pokhara

Figure 3.3-4 shows the overview of development plan for transmission network around Pokhara. Projects related to Lekhnath hub substation are planned with the objective of reinforcing transmission network around Pokhara and increasing transmission capacity to transmit the power generated by hydropower plants. Explanations about the main projects are as follows.

1) Lekhnath－Lahachowk－Modi 132kV Transmission Line (Donor: Exim Banks of India, GoN)

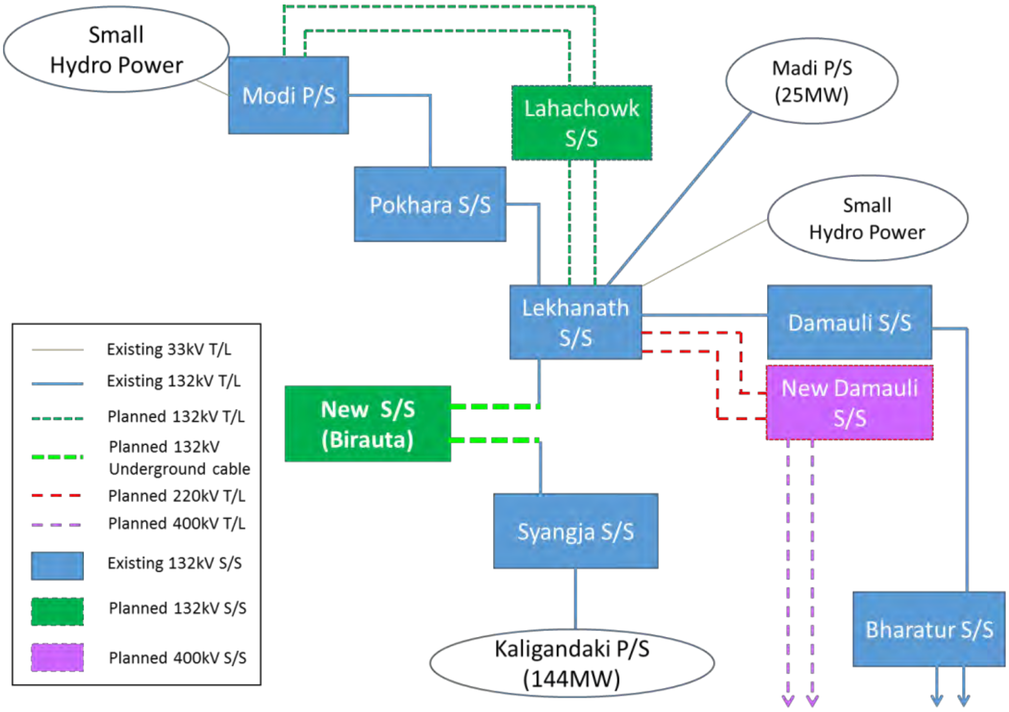
The scope of this project is to construct a new 132/33/11kV Lahachowk substation in Hemja region, located to the north of Pokhara, and a new 132kV transmission line connecting Lekhnath, Lahachowk and Modi. This project aims to increase transmission capacity to transmit the power generated by Modi power plants and IPP hydropower plants around Modi. Land acquisition for this project is already completed and the preparation works for construction are in progress.

2) Lekhnath – New Damauli 220kV Transmission Line (Donor: German Development Bank, GoN)

The scope of this project is to construct a new 220kV double circuit transmission line between Lekhnath and Damauli. This project aims to reinforce transmission network and increase evacuation capacity of power generated by hydropower plants in the western basin. The project is currently under survey and planned to be completed in 3 years.

3) Ratmate- New Damauli 400kV Transmission Line (Donor: MCC)

400kV double circuit transmission line between Ratmate and New Damauli is planned by Millennium Challenge Corporation (MCC) of the United States. The transmission line will be a part of the 400kV trunk line network.



Source: JICA Study Team based on NEA materials

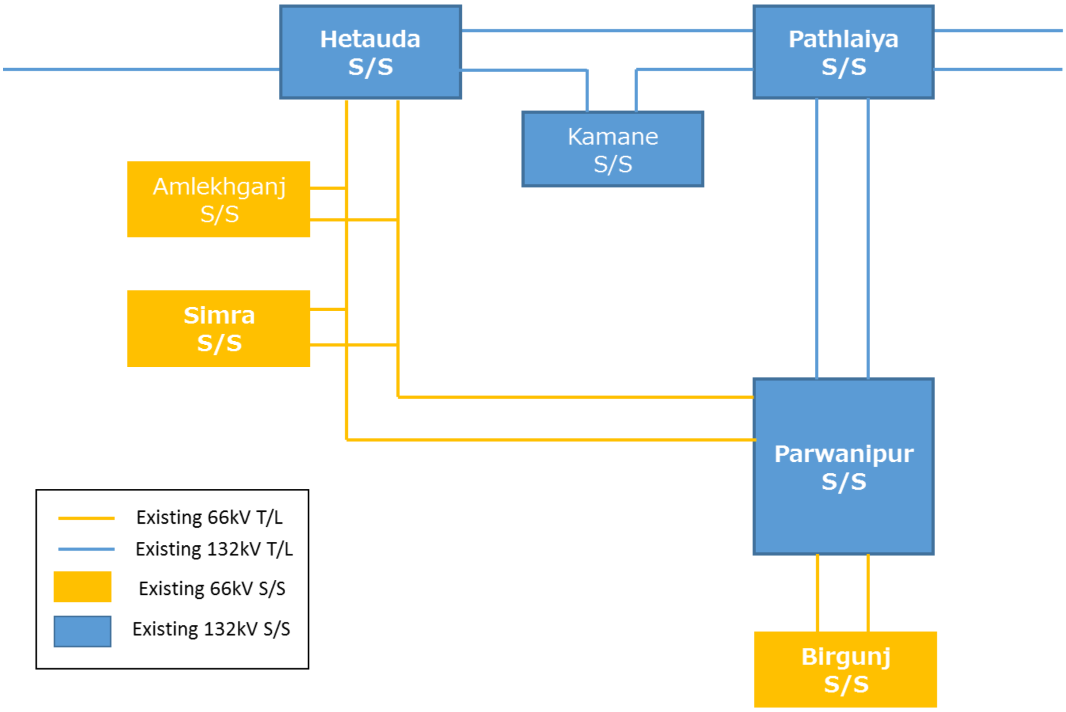
Figure 3.3-4 Overview of development plan for transmission network around Pokhara

As stated above, projects for the development of transmission network around Pokhara are in progress, but these projects focus on Lekhnath substation. No project for the development of transmission network in Pokhara city is carried out. Considering this situation, NEA plans to construct a new Birauta substation with the objective of handling the increasing power demand of Pokhara city.

(3) Birgunj and Simra

Birgunj and Simra are sub-metropolitan cities which belong to Province No.2. They are also major industrial cities, so power demand in both cities is increasing remarkably and the electricity sales in the both cities has increased by about 2 times in 5 years. Trade between Nepal and India is conducted actively in Birgunj, which is a major dry port. In Simra, the development of special economic zone is underway. Therefore, power demand in both cities is expected to increase further in the future as the industrialization goes on.

Figure 3.3-5 shows the overview of transmission network around Birgunj and Simra. Power is currently supplied to Birgunj and Simra from Parwanipur substation through 66kV transmission line.



Source: JICA Study Team based on NEA materials

Figure 3.3-5 Overview of transmission network around Birgunj and Simra

Figure 3.3-6 shows the overview of development plan for transmission network around Birgunj and Simra. NEA is carrying out the following projects in order to handle increase in power demand in Birgunj and Simra.

1) Hetauda—Birgunj 66kV Transmission Line Capacity Increment Project (Donor : GoN)

The scope of this project is to replace the conductors used in the existing transmission line between Birgunj substation and Simra substation with new HTLS conductors. This project aims to reinforce the capacity of transmission line, which supplies power to industrial areas between Birgunj and Simra. The project is planned to be completed in 2019. Preparation works and studies are currently in progress.

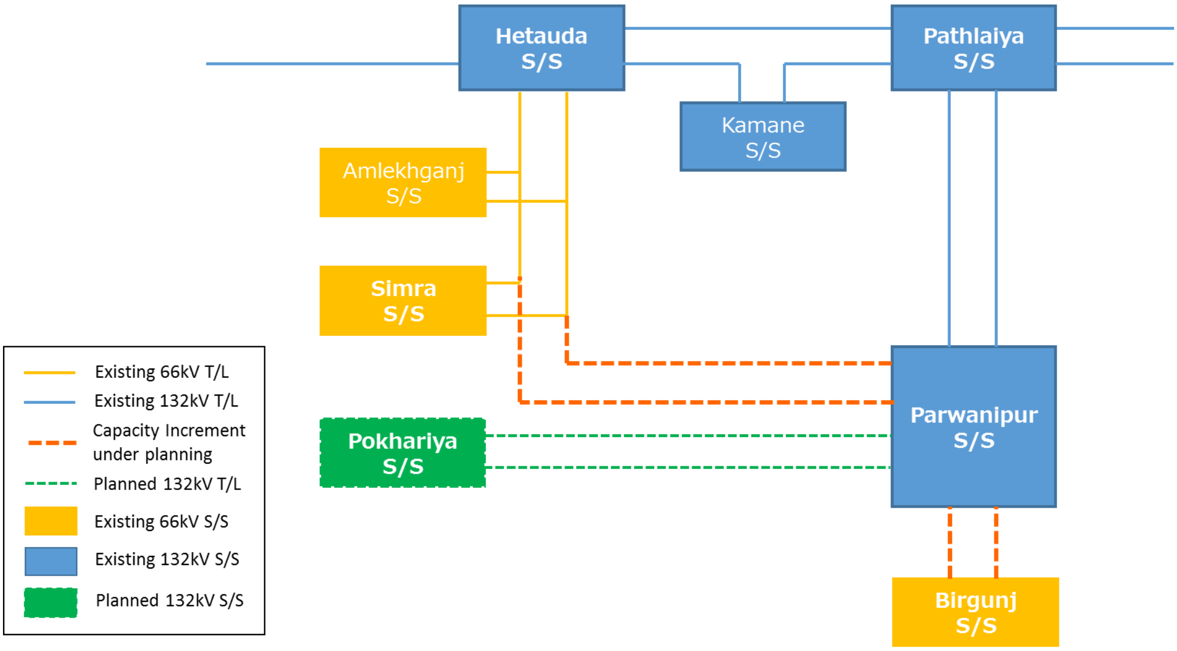
The following sub projects are proposed in the Power Transmission and Distribution System Strengthening Project, funded by ADB. These projects aim to handle the increasing power demand of Birgunj and Simra.

2) Hetauda－Parwanipur 132kV Double Circuit line upgradation (Donor : ADB, GoN)

It is assumed that this project aims to upgrade the existing 66kV transmission line between Hetauda and Parwanipur to 132kV transmission line.

3) Construction of 132kV Psrwanipur－Pokhariya Transmission Line and 132kV Substation at Pokhariya (Donor : ADB, GoN)

It is assumed that this project aims to construct a new 132kV Pokhariya substation and a new 132kV transmission line between Parwanipur and Pokhariya.



Source: JICA Study Team based on NEA materials

Figure 3.3-6 Overview of development plan for transmission network around Birgunj and Simra

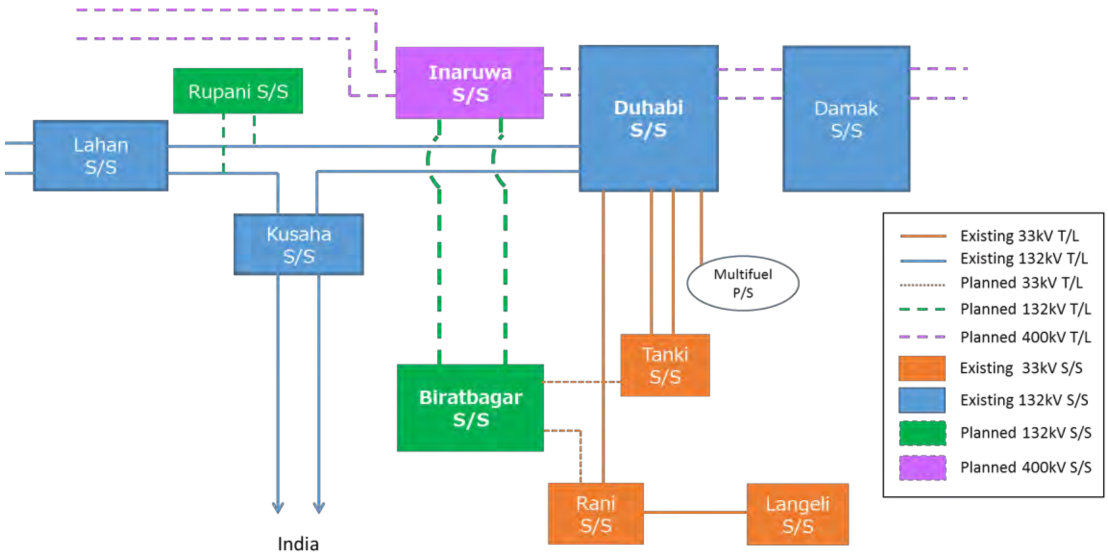
(4) Biratnagar

Biratnagar is the capital city of Province No.1 in Terai plain and the central city in the eastern part of Nepal, with the sixth largest population. Biratnagar is also a major industrial city in the eastern part of Nepal where the factories for processing jute, which are cultivated around Biratnagar are located, and other factories such as steel factory and silk reeling factory are also located.

Figure 3.3-7 shows the overview of the current situation and the development plan of power transmission network around Biratnagar. Biratnagar is not currently connected to 66kV and more transmission network, and the power is supplied to Biratnagar from Duhabi substation through 33kV distribution lines. Power demand in Biratnagar has increased by about 1.9 times in 5 years. If power demand will increase further in future, there are concerns that the capacity of 33kV distribution lines will be insufficient and the Duhabi substation will be overloaded. Therefore, NEA is carrying out the following project.

1) Kushaha (Inaruwa) - Biratnagar 132kV Transmission Line Project (Donor: GoN)

This project aims to construct a new 132/33kV substation in Biratnagar city and a new 132kV transmission line between Inaruwa substation, which is currently under construction, and Biratnagar substation. The scope of this project includes the construction of 33kV distribution lines from Biratnagar substation to Rani and Tanki distribution substation which are located around Biratnagar. The project is planned to be completed in 2021.

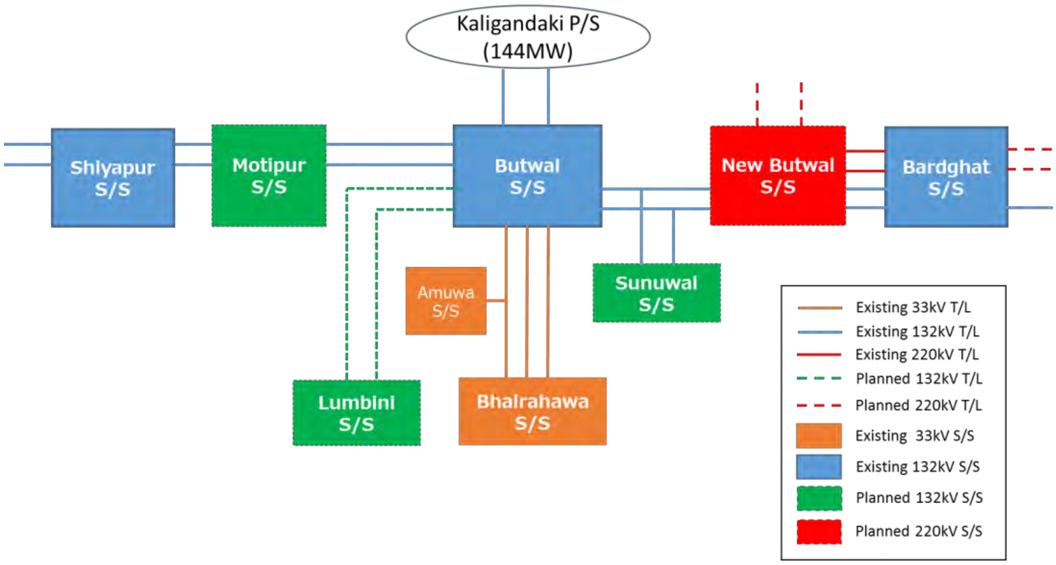


Source: JICA Study Team based on NEA materials

Figure 3.3-7 Overview of current situation and development plan of power transmission network around Biratnagar.

(5) Bhairahawa

Bhairahawa is a city of Province No.5 in Terai region. Bhairahawa is located near the border of India, so trade between Nepal and India is conducted actively in Bhairahawa. Only the special economic zone in Bhairahawa has been completed in Nepal. The economy of Bhairahawa is expected to grow due to the operation of special economic zone in future. Figure 3.3-8 shows the overview of current situation and the development plan of power transmission network around Bhairahawa. Power is currently supplied to Bhairahawa from Butwal substation through 33kV distribution network.



Source: JICA Study Team based on NEA materials

Figure 3.3-8 Overview of current situation and development plan of power transmission network around Bhairahawa

(6) Bharatpur

Figure 3.3-9 shows the overview of current situation and development plan of power transmission network around Bharatpur. Bharatpur substation is currently connected to Dumauli substation and Marsyangdi hydropower plant in the north, Hetauda substation in the east and Kawasoti substation in the west by 132kV single circuit transmission line. This 132kV single circuit transmission line is the only major transmission line connected to Bharatpur substation. However, the 220kV transmission line is planned to be connected to Bharatpur substation because the following projects are in progress.

1) Hetauda－Bharatpur 220kV Transmission Line (Donor : WB, GoN)

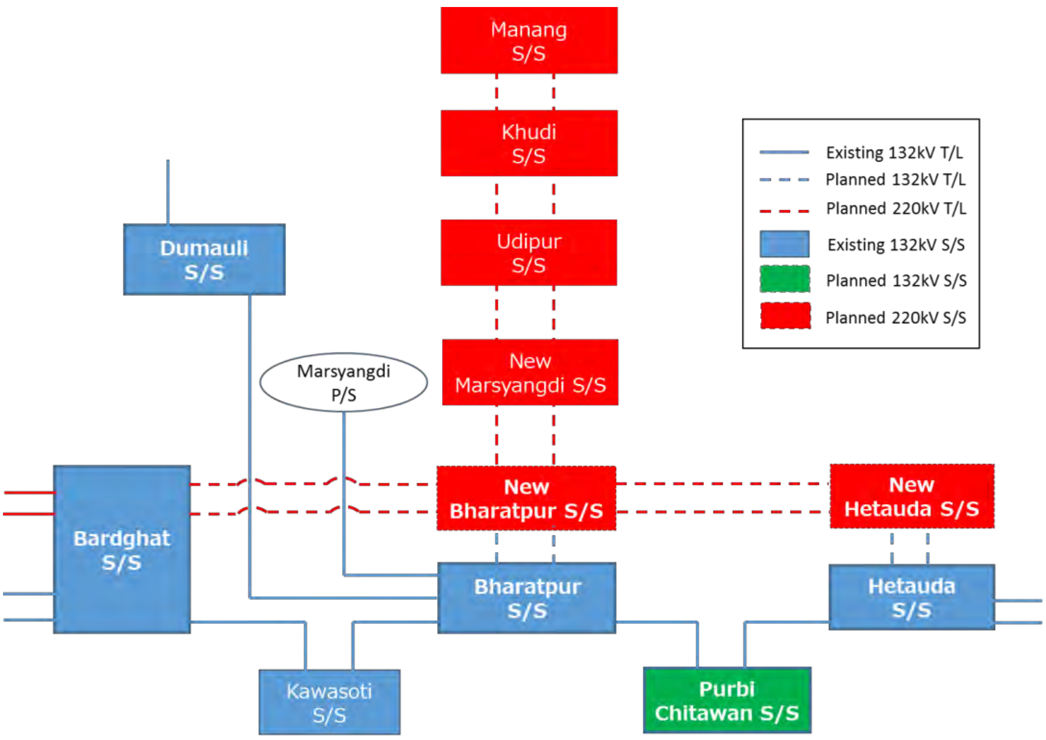
The scope of this project is to construct the New Hetauda substation, the New Bharatpur substation and a new 220kV double circuit transmission line to connect these two substations. This project aims to improve the reliability of transmission network and increase the capacity of transmission line and transmit the power generated by hydropower plants from the western part of Nepal. The project has been carried out since 2009 and is planned to be completed in 2019.

2) Bharatpur－Bardghat 220kV Transmission Line (Donor : WB, GoN)

The scope of this project is to construct a new 220kV double circuit transmission line connecting the New Bharatpur substation and the existing Bardghat substation. This project also aims to improve the reliability of transmission network and increase the capacity of transmission line and transmit the power generated by the hydropower plants from the western part of Nepal. The project has been carried out since 2009 and is planned to be completed in July 2018.

3) Marsyangdi Corridor 220kV Transmission Line (Donor: European Investment Bank)

This project aims to construct a new 220V double circuit transmission line between Manang and Bharatpur to transmit 1600MW power generated by the hydropower plants along the Marsyangdi river corridor. A new substation is planned to be constructed in Manang. In addition, new substations are planned to be constructed in Khudi and Udipur between Manang and Bharatpur. The new 220kV transmission line is planned to be connected to these substations. The length of section between Manang and Udipur is 45.57km and the length of section between Udipur and Bharatpur is 64.46km. The project is planned to be completed in 2021.



Source: JICA Study Team based on NEA materials

Figure 3.3-9 Overview of current situation and development plan of power transmission network around Bharatpur.

CHAPTER 4

SELECTION OF JICA COOPERATION PROJECT IN TRANSMISSION AND DISTRIBUTION SECTOR

CHAPTER 4 SELECTION OF JICA COOPERATION PROJECT IN TRANSMISSION AND DISTRIBUTION SECTOR

4.1 SELECTION OF PROJECT TARGET AREA

Project target areas were selected based on the results of evaluating the situation of each city from aspects of population, power demand, development situation of transmission network and the prioritized project planned by NEA.

As stated in Section 3, in Nepal, cities with population of more than 300,000 and cities with population of more than 100,000 are classified as metropolitan cities and sub-metropolitan cities respectively. Currently, 6 cities and 11 cities are specified as metropolitan cities and sub-metropolitan cities respectively. The province and population of each city are indicated in Table 3.1 1. 8 cities[1] were initially assumed to be the target candidates for project in this survey. However, it is not necessary to stick to the 8 cities and the other cities with large population should be included in the candidates from aspect of the number of beneficiaries with the development of transmission network. Based on such a thought, a total 17 cities of metropolitan and sub-metropolitan cities indicated in Table 3.1 1 were selected as target candidates for project.

Electricity sales of the 17 cities are indicated in Table 3.2 1. Electricity sales of every city increased by about 1.5 times in the last 5 years. It can be confirmed from the Table that the power demand is increasing steadily with economic growth. It is difficult to evaluate the future demand quantitatively, because NEA is still organizing the demand forecast data of each city. However, it is assumed that the power demand in metropolitan and sub-metropolitan cities will increase in future, because, the power demand in Nepal is expected to increase at an annual average rate of 7-8% as stated in "2.2.1 Current state of electric power demand and energy utilization". Therefore, it is assumed that these 17 cities have high need for the development of transmission and distribution network from aspect of power demand.

Table 4.1-1 and Table 4.1-2 show the list of development projects for transmission network in metropolitan and sub-metropolitan cities respectively. It can be confirmed from these Tables that the development projects for transmission network are carried out in many cities. The detailed development status of transmission network in 6 metropolitan cities is stated in "3.3 DEVELOPMENT STATUS OF TRANSMISSION AND DISTRIBUTION IN MAJOR CITIES". NEA and donors such as ADB are already carrying out the development of transmission and distribution network related to each city. However, no project for the development of transmission network in Pokhara city is carried out, although projects with focus on Lekhnath, a city adjacent to Pokhara city, are mainly carried out. Considering this situation, the NEA plans to construct the new Birauta substation in Pokhara city as one of its prioritized projects. Therefore, Pokhara has high need for financial cooperation and is the most suitable as the project target area among the metropolitan cities.

Development projects of transmission network are under progress in some of 10 sub-metropolitan cities but no project is carried out in Janakpur, Dhangadhi, Tulsipur, Itahari, Nepalgunj, Dharan and Kalaiya. Projects are planned in Janakpur, Tulsipur and Itahari. However, the planned projects are not yet under progress, due to problems with land acquisition. Regarding the other 4 cities, no project is planned in Dhangadhi and Kalaiya but prioritized projects are planned in Nepalgunj and Dharan by NEA. Considering such a development status

[1] Kathmandu, Pokhara, Lalitpur, Bharatpur, Birgunj, Biratnagar, Simra, Bhairahawa

of transmission network in the sub-metropolitan cities and the priority of NEA, Nepalgunj and Dharan are suitable as project target areas. Nepalgunj has a larger population and the electricity sales is 2 times more than Dharan. Therefore, Nepalgunj has a higher need for financial cooperation.

Based on the result of the above evaluation, Pokhara and Nepalgunj were selected as project target areas. The reasons for the selection can be summarized as follows.

- Pokhara

Pokhara is the second populated city, behind Kathmandu and a major tourist spot. Although power demand in Pokhara is increasing at an annual average rate of 11.7% due to its development as a tourist spot, no development project of transmission network is planned for Pokhara city in the TSDP. NEA plans to consturct Birauta substation in Pokhara city, as one of its prioritized projects, but the donor to fund the project has not yet been determined.

- Nepalgunj

Nepalgunj is one of the sub-metropolitan cities and the center of commence in the western part of Nepal. Although power demand in Pokhara is increasing at an annual average rate of 11.6%, no reinforcement project of transmission network in Nepalgunj is planned in TSDP. NEA has planned the construction of Kohalpur – Nepalgunj 132kV transmission line as one of its prioritized projects, but the donor to fund the project has not yet been determined.

Table 4.1-1 Development projects of transmission network in metropolitan cities

		Name of City	TOR	Prioritized Projects	Projects indicated in TSDP	Situation of transmission system development
Metropolitan city	1	Kathmandu	*	-	- Chapagaon to Harsidi 132kV Transmission Line - Harsiddhi to Bhaktapur 132kV Transmission Line - Bhaktapur to Baneshwor New Airport 132kV Transmission Line - Mulpani to Lapsephedi 132kV Transmission Line - Matatirtha to Chapagaon 132kV Transmission Line	- Power Transmission and Distribution Effi ciency Enhancement Project (PTDEEP) funded byADB and GoN is proceeding. - Thankot－Chapagaon－Bhaktapur 132kV Transmission Line is proceeding. - Bhaktapur－Baneshwor－Patan 66kV Transmission Line Up gradation Project is proceeding.
	2	Pokhara	*	Birauta 132/11kV Substation Project	- Lekhnath-Dumauli 220kV Transmission Line - Lekhnath-Banskot 132kV Transmission Line - Leknath 220/132 Substation	Lekhnath-Dumauli 220kV Transmission Line is expected to be completed in 2021. The land acquisition for the substation is under progress.
	3	Lalitpur	*	-	Matatirtha to Chapagaon 132kV Transmission Line	- Power Transmission and Distribution Effi ciency Enhancement Project (PTDEEP) funded byADB and GoN is proceeding. - Thankot－Chapagaon－Bhaktapur 132kV Transmission Line is proceeding. - Bhaktapur－Baneshwor－Patan 66kV Transmission Line Up gradation Project is proceeding.
	4	Bharatpur	*	-	- Butwal- Bharatpur 220kV Transmission Line - Bharatpur-Hetauda 220V Transmissio Line - Marsyangdi- Bharatpur 220kV Transmission Line - Bharatpur 220/132kV Substation	- Bharatpur-Hetauda 220V Transmissio Line is started in 2009 and scheduled to be completed by 2019. - Bharatpur-Bardghat 220kV Transmission Line project is started in 2009 and scheduled to be completed by June 2018.
	5	Birgunj	*	-	-	Hetauda-Birgunj 66 kV Transmission Line Capacity Increment Project was started in 2015/016 and expected to be completed on 2019. Objective of this project is to increase power transmission capacity to serve to the industrial corridor from Simra to Birgunj.
	6	Biratnagar	*	-	Inaruwa-Biratnagar 132kV Tranmission Line	Inaruwa-Biratnagar 132kV Tranmission Line Project is expected to be completed in 2021.The Project includes construction of double circuit 33 kV line from New Biratnagar Substation up to Rani and Tankisinwari Substations including reinforcement and upgradation of 33kV existing Rani and Tankisinwari Substations.

Source: JICA Study Team based on NEA materials

Table 4.1-2 Development projects of transmission network in sub-metropolitan cities

		Name of City	TOR	Prioritized Projects	Projects indicated in TSDP	Situation of transmission system development
Sub-metropolitan city	7	Janakpur		-	Dhalkebar-Janakpur 132kV Transmission Line	Dhalkebar-Janakpur 132kV Transmission Line Project is behaind schedule due to land acquisition problems.
	8	Ghorahi		Ghorahi-Khungri-Banfikot 132kV Transmission Line and Substation Project	Lamahi-Ghorahi 132kV Transmission Line	Lamahi-Ghorahi 132kV Transmission Line project is scheduled to be completed in 2018. The objective of this project is to provide power supply to Ghorahi Cement Industry. In order to promote cement industries, the GoN has taken policy of developing transmission line networks up to the site of cement industries. A minute of understanding was signed between Ministry of Industry (MoI) and NEA.
	9	Hetauda		-	- Dhalkebar- Hetauda 400kV Tranmission Line - Ratmate- Hetauda 400kV Transmission Line - Bharatpur- Hetauda 220kV Transmission Line - Hetauda- New Hetauda 132kV Tranmission Line - Hetauda 400/220/132kV Substation	Hetauda-Dhalkebar-Inaruwa 400kV transmission line is under construction.
	10	Dhangadhi		-	-	-
	11	Tulsipur		-	Hapure-Tulsipur 132kV Transmission Line	Hapure-Tulsipur 132kV Transmission Line Project is behaind schedule due to land acquisition problems.
	12	Itahari		-	Duhabi-Itahari-Dharan 132kV Transmission Line	Duhabi-Itahari-Dharan 132kV Transmission Line Project is behaind schedule due to land acquisition problems.
	13	Nepalgunj		Kohalpur-Nepalgunj 132kV Transmission Line and Substation Project	-	-
	14	Butwal		-	- Butwal- Gorakhpur 400kV Transmission Line - New Damauli- Butwal 400kV Transmission Line - Phulbari- Butwal 400kV Transmission Line - Andhi Khola - Butwal 220kV Transmission Line - Butwal- Bharatpur 220kV Transmission Line - Butwal-Lunmibi 132kV Transmission Line - New Butwal 400/220/132kV Substation	-New Butwal substaion is planned to be operated by December 2020. Kushma-New Butwal 220kV Transmission line is planned to be commissioned in December 2020. New Butwal -Bardaghat 220kV Transmission line will also be commissioned by the end of December 2020. - New Butwal - New Kohalpur 400 kV Transmission Line (about 150 km) is under the scope of detail study and engineering design. - Butwal-Lunmibi 132kV Transmission Line project is initiated in 2013/014 and scheduled to be completed by 2020.
	15	Dharan		Inaruwa-Dharan 132kV Transmission Line and Substation Project	Duhabi-Itahari-Dharan 132kV Transmission Line	-
	16	Kalaiya		-	-	-
	17	Jitpur Simara	*	-	-	Hetauda-Birgunj 66 kV Transmission Line Capacity Increment Project was started in 2015/016 and expected to be completed in 2019. Objective of this project is to increase power transmission capacity to serve to the industrial corridor from Simra to Birgunj.

Source: JICA Study Team based on NEA materials

4.2 STUDY ON JICA COOPERATION PROJECTS IN THE TARGET AREA

4.2.1 Pokhara

Pokhara is a major tourist spot and the second most populated city behind Kathmandu. Electricity sales in Pokhara area has been increasing at an annual rate of 11.7%. Power demand is expected to increase in the future, due to its development as a tourist spot. In addition, once the construction of the international airport is completed, power demand is expected to increase rapidly due to the increase in tourists. Power is supplied to Pokhara city from the existing Pokhara substation only. Under such a situation, there are concerns that the Pokhara substation alone cannot supply the power required to meet the increasing demands of the future. Therefore, NEA plans the construction of a new 132kV Birauta substation in Pokhara city, as one of its prioritized projects.

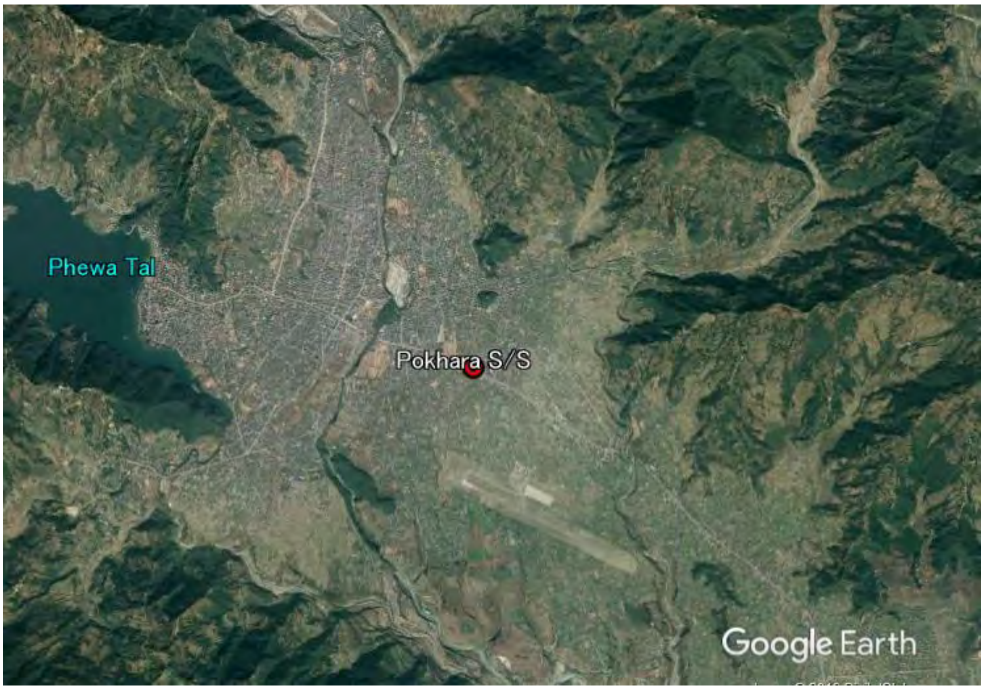
Considering this background, JICA study team selected the construction of Birauta substation, which NEA plans as a prioritized project, and the development of distribution network related to Birauta substation as the candidate for financial cooperation project. After that, JICA study team surveyed and studied the candidate project.

(1) Transmission network

In this section, the results of study on the transmission line and the substation projects related to the new construction of Birauta Substation, which was considered as a candidate for financial cooperation project of transmission network, will be explained.

1) Current situation of Pokhara Substation

The location and surroundings of the existing Pokhara substation is shown in Figure 4.2-1. Pokhara substation is located in the southeast of Pokhara city. There is a lake called Lake Fewa to the west of the substation and the lakeside is a famous tourist attraction. An international airport is under construction in the south of the substation.



Source: JICA Study Team

Figure 4.2-1 Location and surroundings of the existing Pokhara substation

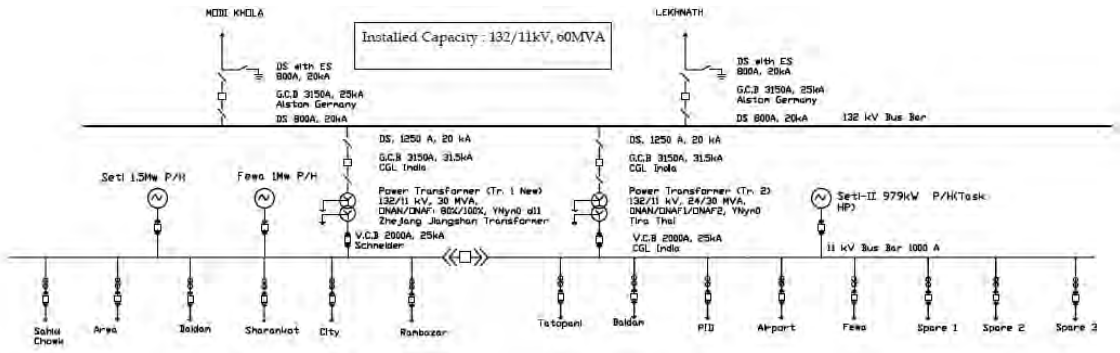
Power transmission network around Pokhara substation is shown in Figure 3.3 3. Pokhara substation is connected to Lekhnath substation in the east and Modi power station in the west by a 132kV single circuit transmission line. Pokhara substation receives power from Modi power station during off-peak hours and receives power from Kaligandaki power station via Syangja substation and Lekhnath substation during peak hours. The directions of power flow during off-peak hours and peak hours are as follows;

- During off-peak hours: Modi→Pokhara→Lekhnath

- During peak hours: Kaligandaki→Syangja→Lekhnath→Pokhara→Modi

Modi power station supplies power not only to Pokhara substation but also to the residential area around the power station. However, during peak hours, the Modi power station cannot meet the power demand of the surrounding residential area. As a result, Modi power station receives power from Pokhara substation.

Single line diagram of Pokhara substation is shown in Figure 4.2-2. Pokhara substation is connected to 132kV transmission lines and supplies power to Pokhara city by 11kV feeders. 33kV feeders are not installed. There are fourteen 11kV feeders including three hydropower station feeders. In Pokhara substation, there is monitoring system for voltages and currents of 11kV feeders. Operation staffs can monitor the condition of 11kV feeders but cannot operate the circuit breakers using this system. An example of this system is shown in Figure 4.2-3.



Source: NEA (Transmission Directorate)

Figure 4.2-2 Single line diagram of Pokhara substation

Figure 4.2-3 Monitoring system of 11kV feeders

There are two 30MVA 132/11kV transformers in Pokhara Substation. The manufacturing year of the transformers are 2007 and 2014 respectively. Although initially, there was only one transformer, the other transformer was added based on the increase in demand at Pokhara city.

In 2018, the peak load of Pokhara substation was 37.64MW. This value is lower[2] than what it was a few years ago, but it still exceeds 30MW. If one transformer fails at peak load, there is a risk that they cannot meet N-1 criteria. In addition, the amount of electric energy consumed by Pokhara is increasing at an annual rate of 7.9%. If the maximum load also increases at the same pace, the maximum load will exceed 60 MW in 5 years[3]. As shown in Figure 4.2-4, although there is space available to add one more 30MVA transformer in the substation, it is difficult to add two or more transformers. If the power demand in Pokhara city continues to increase in the future, it will be difficult to meet the N-1 criteria while securing the necessary capacity by the addition of transformers.

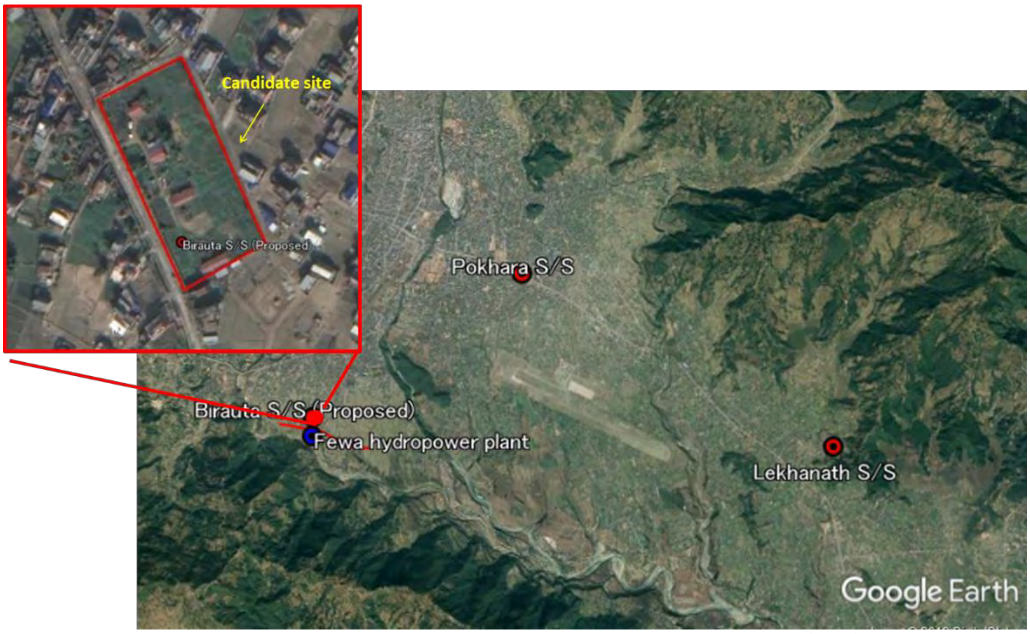
[2] Although the peak load of this substation reached about 45 MW several years ago, recent values are lower than this. This reason is assumed that load shedding is reduced by improving power quality of Nepal. Pokhara substation was frequently subjected to load shedding several years ago. Therefore, load tended to concentrate in the time when power was available. On the other hand, in recent years load shedding has not been subjected. As a result, large peaks of load in a specific time zone is being eliminated.

[3] Assuming that peak load increases at an annual rate of 11.7%, after 5 years, it becomes $37.64 \times 1.117^6 \fallingdotseq 64.45$ MW.

Figure 4.2-4 Future space for additional transformer

2) Situation of Candidate Site for Birauta substation

The candidate site of Birauta substation is owned by NEA and is located about 4 km southwest of Pokhara substation. The location and the surroundings of the candidate site for the Birauta substation is shown in Figure 4.2-5. Fewa hydropower station, owned by NEA is at the south of the candidate site, and further south from this is the existing 132 kV single circuit transmission line between Lekhnath and Syangja.



Source: JICA Study Team based on NEA materials

Figure 4.2-5 Location and surroundings of the candidate site for Birauta substation

The area of the candidate site is about 60 x 130 m^2. It is currently used as a residence for NEA staff and for temporary accommodation of the staff related to Fewa hydropower station. NEA has a plan to construct a new residential building at this site. Therefore, it is important to note that the land available for the substation is limited.

3) Current situation of 132kV transmission line

Existing 132kV transmission line between Lekhnath and Syangja is running in the south of the candidate site for Birauta substation. The candidate site is near the existing transmission line, so NEA considers connecting this existing line to Birauta substation by pi junction system.

Figure 4.2-6 shows the positional relationship between the candidate site for substation and the existing transmission line. NEA considers reconstructing the existing tower indicated by red square in the figure and installing a branch line from the tower to Birauta substation. Figure 4.2-7 shows a picture of the tower. This tower is located in an agricultural land, but NEA has already bought the agricultural land around the tower for this project.

Source: JICA Study Team based on NEA materials

Figure 4.2-6 Positional relationship between the candidate site for substation and existing transmission line

Figure 4.2-7 Picture of existing tower for junction

4) Study on transmission and substation project

The candidate site for Birauta substation is surrounded by residential area, so it is difficult to install a new tower for the 132kV transmission line around the candidate site. As shown in Figure 4.2-8, it is a practical idea to use underground cables to connect the transmission line to the substation. One of practical proposals is to replace the existing tower with a new tower to connect the overhead transmission line and underground cable, and install the underground cable along the existing road and connect the cable to Birauta substation. In this case, the length of underground cable will be about 0.4km.

The existing transmission line between Lekhnath and Syangja is important to transmit the power generated by Kaligandaki power plant. It is assumed that the period of power outage for construction will limited. Therefore, it is necessary to consider a suitable construction method for tower replacement, which will shorten power outage duration. Instead of the idea that the existing tower is reconstructed at the original position, one of the alternative ideas is that a new tower is installed at a location away from the existing tower as illustrated in Figure 4.2-9, and the transmission line will be interrupted only when the conductors are shifted from the existing tower to new one. However, in this case, the adjacent existing suspension type towers have a deviation angle, so the suspension towers have to be changed into tension type towers.

Source: JICA Study Team based on NEA materials

Figure 4.2-8 Transmission line route to Birauta substation

Source: JICA Study Team based on NEA materials

Figure 4.2-9 An example of new tower location

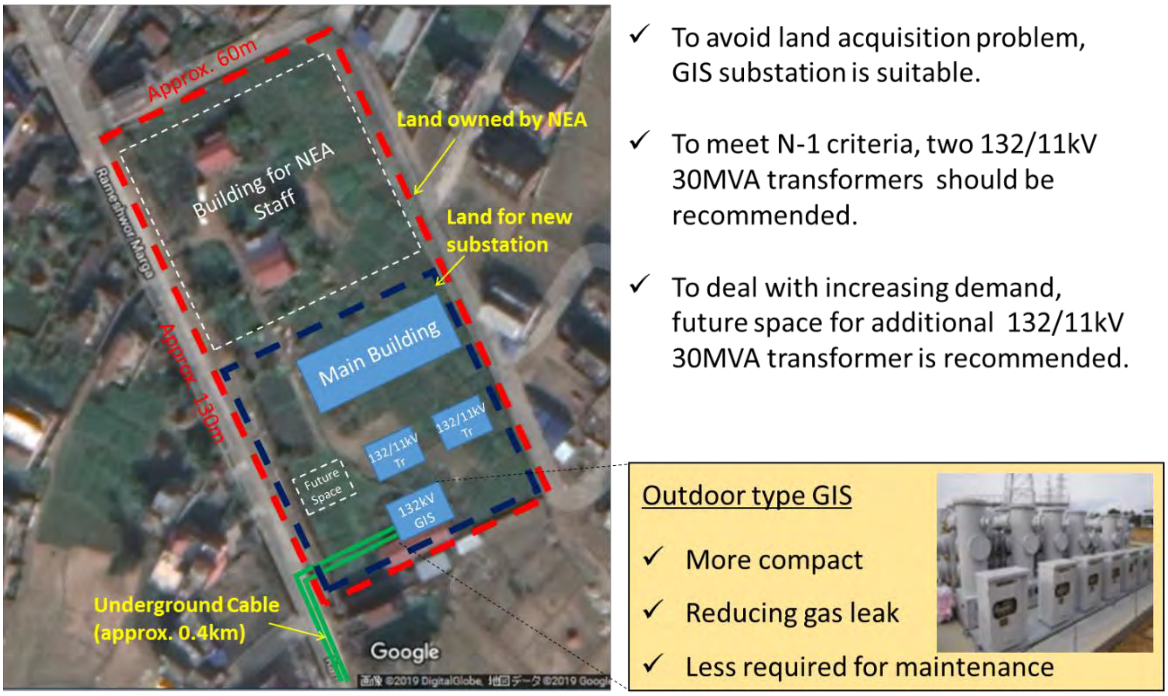
There are two options for Birauta substation site.

1. Construction of standard AIS (Air Insulated Switchgear) substation by acquiring the adjacent land and expanding the site, considering that the available land is limited due to the new residential building.

2. Construction of a space-saving GIS substation without acquiring a new site

The first plan is advantageous in terms of cost, as the standard AIS substation will be applied. . However, it is considered that land acquisition is difficult, due to the progress of urbanization in Pokhara area. On the other hand, even though the second plan will require a more detail study on the area of the building for staff residence, the number of bays and capacity of transformers, if approximately half of the candidate site can be made available for the substation, that will be sufficient to construct a standard 132kV GIS substation. Therefore, regarding the substation, the second plan is considered to be realistic.

Tentative layout of Birauta substation is shown in Figure 4.2-10. As mentioned above, GIS substation is suitable to avoid land acquisition problems. In addition, according to the NEA's plan, although the transformer capacity required for Birauta substation is one 132/11kV 30MVA, to meet N-1 criteria, two 132/11kV 30 MVA transformers are recommended. Moreover, to deal with the increasing future demand and to prepare for the future replacement, it is recommended to reserve some space for additional 132/11kV 30 MVA transformers for the future.



Source: JICA Study Team based on NEA materials

Figure 4.2-10 Tentative layout of Birauta substation

(2) Distribution network

In this section, the results of the study on the distribution project related to the new construction of Birauta Substation, which was considered as a candidate for financial cooperation project of transmission network, will be explained.

1) Current situation of distribution network in Pokhara

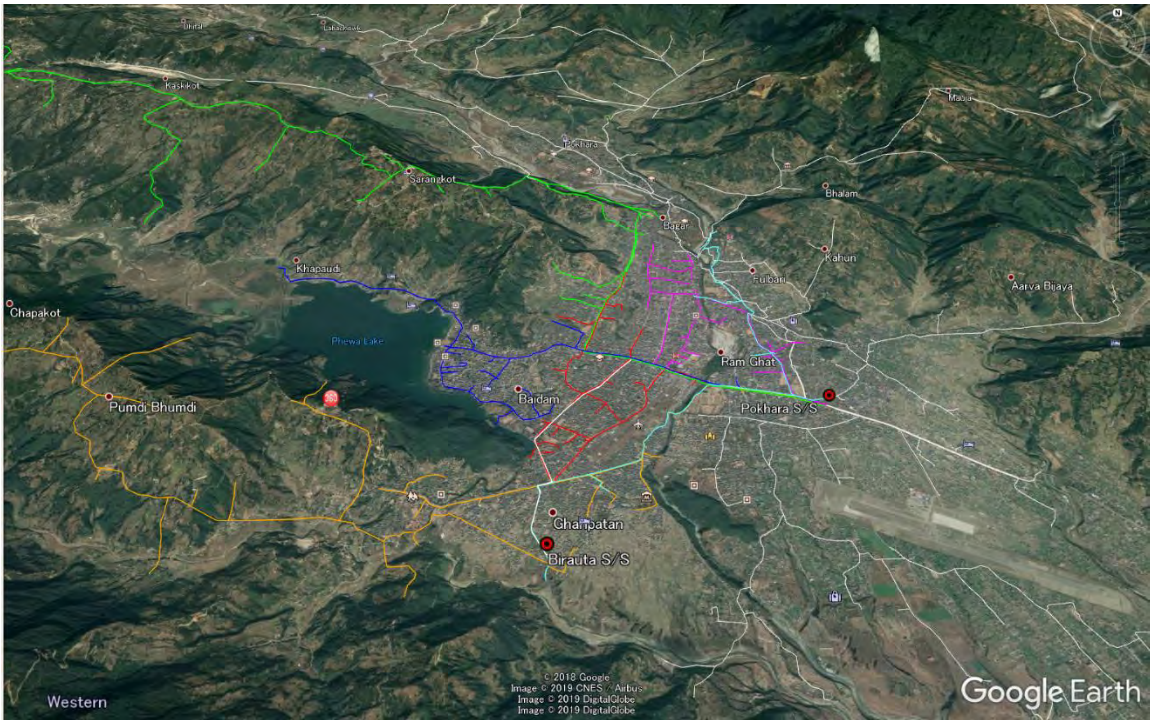
Pokhara area is supplied by 11kV distribution feeders from Pokhara Substation (132/11 kV), located in the eastern part of Pokhara City. There is no 33kV network in Pokhara city, and the Pokhara substation is the only power source. There are 11 distribution feeders and they are supplied from Pokhara Substation- seven (7) of them supply power to the city center from the west of the substation, and the remaining 4 supply around the substation. In addition, transmission lines from three small hydropower stations, located near the Pokhara area, are also connected to the Pokhara substation by 11kV lines. There are a maximum, seven 11kV distribution feeders on both sides of the main road on the west side of the substation, making it difficult to further install distribution lines to the west.

Figure 4.2-11 Congestion of distribution feeder on the west side

Figure 4.2-12 Outgoing feeders from Pokhara substation

As the new Birauta substation (132/11 kV) is planned on a land near the city center, which is owned by NEA, it is possible to supply power to the demand in the western part of Pokhara substation from this new substation.

NEA is implementing a nationwide project to enhance facility management using GIS (Geographic Information System). In the Pokhara regional office, the progress of this project is fast, and the data collection for the existing distribution facilities has already been completed. An example of a distribution feeder diagram based on GIS is shown in Figure 4.2-13.



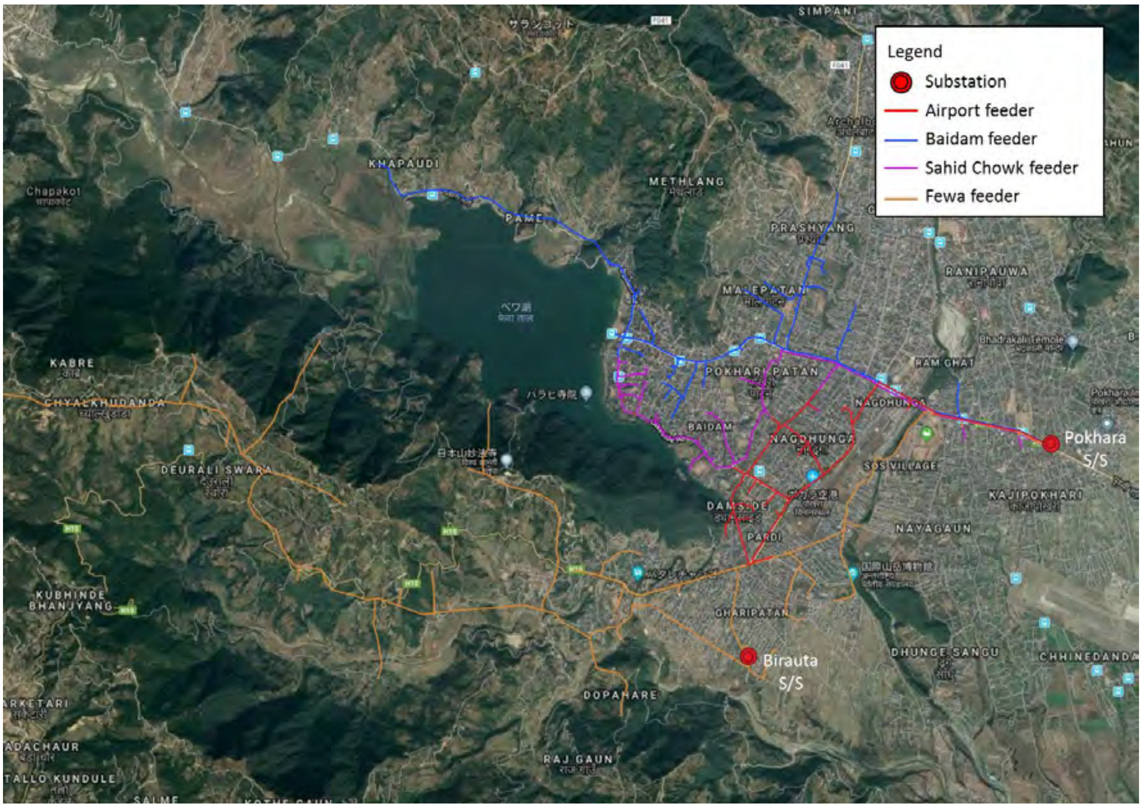
Source : NEA

Figure 4.2-13 An example of distribution feeder diagram by GIS

2) Study of distribution project

Discussion about the distribution project that will accompany the construction of new Birauta substation was conducted with the NEA's Pokhara Regional Office (PRO). As a result of the discussion, PRO requested feeder reconfiguration of four existing distribution feeders (Airport, Baidam, Sahid Chowk, Fewa) that are supplying power near the planned Birauta substation- in other words load shift from Pokhara substation to Birauta substation. Distribution feeder diagram of these four feeders is shown in Figure 4.2-14.

The basic concept of load shift is to install a new distribution line from the Birauta substation to the nearest point of each existing distribution feeder and connect it with the existing distribution line. Due to the congestion of distribution feeders, it is difficult to construct a new overhead feeder around the new Birauta substation, so the new distribution feeders will be installed with underground cables. There is no load in the section from Pokhara substation to the first load point, so it is possible to remove the section after load shifting. However, this section will be basically left as is after disconnection from the new feeders at the disconnection point, which is set on the east side of Seti Gandaki River; and this will facilitate this section to be used when the demand increases around Pokhara Substation. In addition, Time Sequential Sectionalizing switch will be installed in the distribution system after load shift, in order to improve supply reliability. It will be installed in the feeders, which are shifted to Birauta substation, and also installed at connection points with other feeders.



Source： JICA Study Team based on NEA materials.

Figure 4.2-14 Feeder diagram of requested feeders

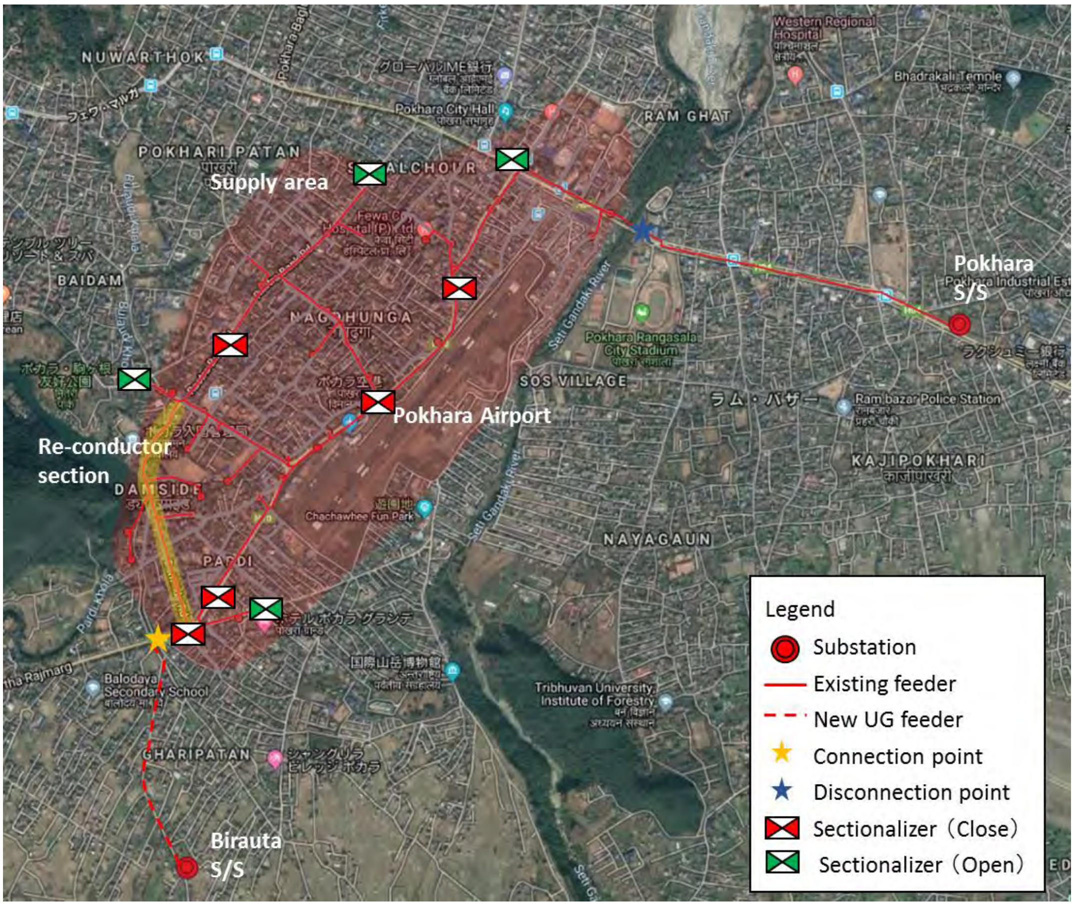
The following describes the results of study on load shift to the new Birauta substation for each distribution feeder.

a) Airport feeder

Airport feeder is installed westward along the main road (Prithvi Highway), in front of Pokhara substation. After crossing the deep valley (Seti Gandaki River), located between the substation and the city center, it supplies power to Pokhara Airport, located in the south, as well as to the surrounding domestic and commercial consumers.

Planned land of Birauta substation is located about 1.5 km to the south of the supply area of Airport feeder. So, the new underground feeder will be installed from the Birauta substation to the connection point, which is located at the southernmost end of the area, in order to shift the load to the new substation.

Since some parts of small size conductors (ACSR 30mm^2: Weasel) will become a part of the backbone section after reconfiguration, it is necessary to replace them with bigger size conductors (ACSR 100mm^2: Dog). In addition, nine sectionalizers will be installed. Five of them will be installed to the Airport feeder after the reconfiguration, and the rest will be installed at the connection point with other feeders (Baidam, Sahid Chowk, and Fewa). The line diagram after the reconfiguration of Airport feeder is shown in Figure 4.2-15.



Source： JICA Study Team based on NEA materials.

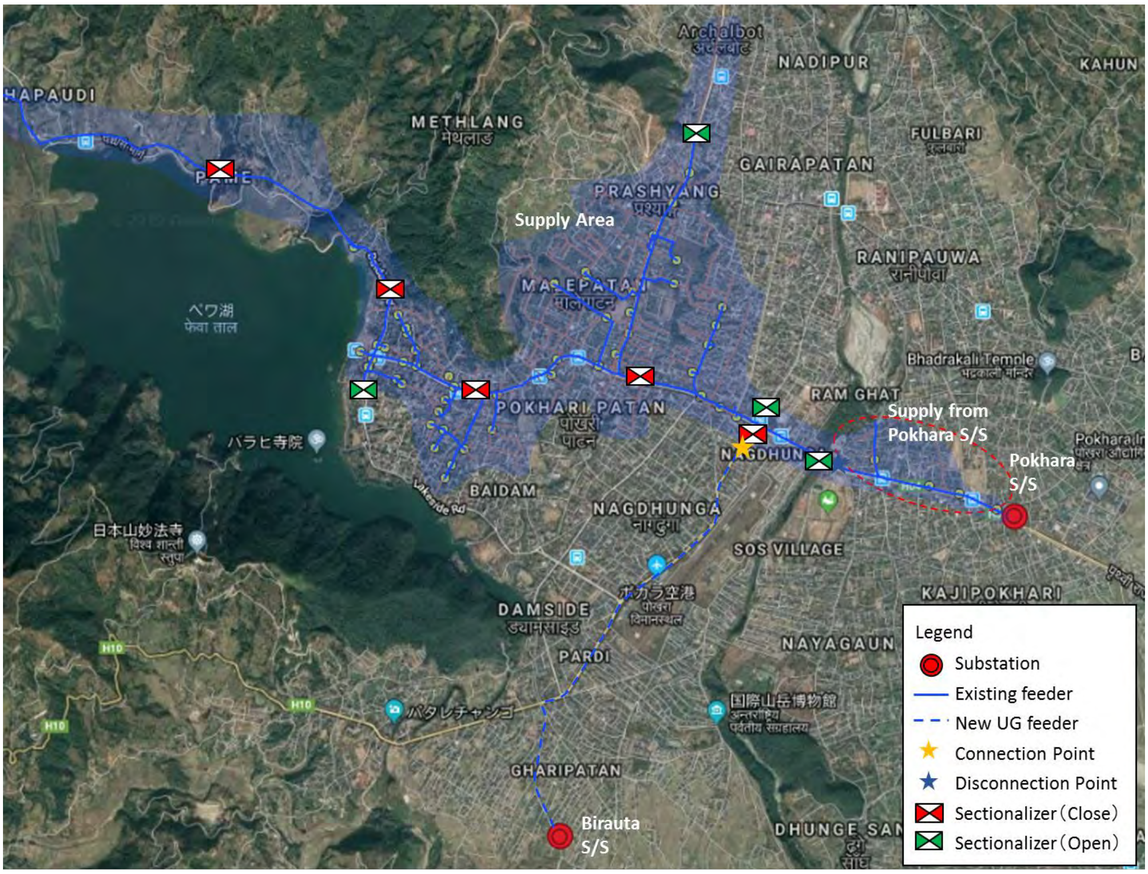
Figure 4.2-15 Line diagram of Airport feeder

b) Baidam feeder

Like the Airport feeder, the Baidam feeder is installed westward along the main road (Prithvi Highway), in front of the Pokhara substation. The feeder supplies power to the consumers along the main road (Shewa Marga), north side of Lake Phewa, as well as, to an area on the east side of the river.

The distance from Birauta substation to the nearest point of Baidam feeder is about 4 km. Load shift to Birauta substation is possible by connecting the new underground feeder to the nearest point. As for the demand on the east side of the river, it is possible to continue supplying from Pokhara Substation by using a part of the existing distribution lines, left on east side of the river.

In addition, nine sectionalizers will be installed. Five of them will be installed to the Baidam feeder after the reconfiguration, and the rest will installed at the connection point with other feeders (Sahid Chowk, City Sarangkot and remaining part of Baidam). The line diagram after the reconfiguration of Baidam feeder is shown in Figure 4.2-16.



Source： JICA Study Team based on NEA materials.

Figure 4.2-16 Line diagram of Baidam feeder

c) Sahid Chowk feeder

Like the Airport and Baidam Feeder, the Sahid Chowk feeder is installed along the main road, up to the west side of the river (Seti Gandaki River). The feeder mainly supplies power to the sightseeing and commercial consumers on the lakeside, as well as, the government area of the province. It also supplies to an area on the east side of the river. Among the four feeders requested by NEA, it can be said that the Baidam feeder is particularly an important feeder.

The distance from Birauta substation to the nearest point of the Sahid Chowk feeder is about 2.5 km. Load shift to the Birauta substation is possible by connecting the new underground feeder to the nearest point. As for the demand on the east side of the river, it is possible to continue supplying from Pokhara Substation by using a part of the existing distribution feeder, left on east side of the river.

In addition, nine sectionalizers will be installed. Six of them will be installed to the Sahid Chowk feeder after the reconfiguration, and the rest will be installed at the connection point with other feeders (Airport, Baidam and remaining part of Sahid Chowk). The line diagram after the reconfiguration of Sahid Chowk feeder is shown in Figure 4.2-17.

Source： JICA Study Team based on NEA materials.

Figure 4.2-17 Line diagram of Sahid Chowk feeder

d) Fewa feeder

Although the section of Fewa feeder, from the substation to the river, is located along the main road on the same route as the three distribution lines mentioned above, the feeder goes down to the south before the river and crosses the river at the eastside of the Pokhara airport. After crossing the river, it supplies power to domestic and commercial consumers on the east and south side of the airport, as well as, the southern and western mountain area of Phewa Lake. It also supplies to some of the demand on the east side of the river.

Since the Fewa feeder passes near the Birauta substation, it is possible to shift the load to the Birauta substation by connecting underground feeder at about 0.1 km from the Birauta substation.

As for the demand on the east side of the river, it is possible to continue supplying from Pokhara substation using the remaining parts of Baidam or the Sahid Chowk on the east side of the river. It is recommended to remove the eastern part of Fewa feeder in order to eliminate the congestion of distribution feeders.

In addition, eight sectionalizers will be installed. Seven of them will be installed to Fewa feeder after the reconfiguration, and the remaining one will be installed at the connection point with the remaining part of Baidam feeder. The line diagram after the reconfiguration of Fewa feeder is shown in Figure 4.2-18.

Source : JICA Study Team based on NEA materials.

Figure 4.2-18 Line diagram of Fewa feeder

3) Additional study on load shift to Birauta substation

The study results on the load shift of four distribution feeders (Airport, Baidam, Sahid Chowk, and Fewa) to the Birauta substation, which was requested by NEA were described in the previous section.

JICA Study Team conducted further study based on the GIS data provided by NEA. As a result, it is recommended to shift the load of additional two feeders, Fewa Incomer and Sarangkot, to Birauta substation, as it is expected to improve supply reliability and optimize the configuration.

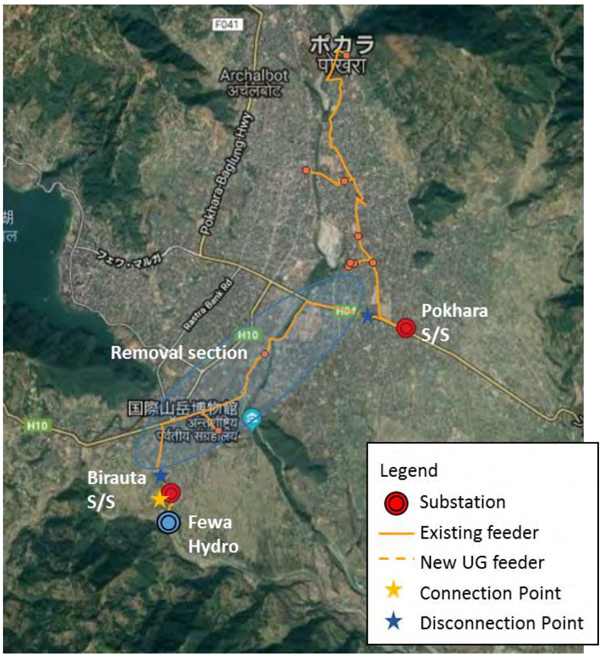
The following describes the results of the study on 2 distribution feeders.

a) Fewa Incomer（Hospital）feeder

Fewa Incomer feeder is a transmission line connected to Fewa Hydro Power Station, owned by NEA, and it is located to the south of Birauta substation. It is on the same route as the Fewa feeder. This feeder branches north at about 400 m west of Pokhara Substation, and it also supplies power to the east side of the river, which is located on northwest of the substation.

Since this feeder, like the Fewa feeder, passes near the Birauta substation, it is possible to shift the load by connecting underground feeder at about 0.1 km from the Birauta substation.

After shifting the load to the Birauta substation, it is recommended to remove the section from the north-going branch to the Birauta substation, in order to eliminate congestion on distribution lines, on the main road from the Pokhara substation to the river. The line diagram after the reconfiguration of Fewa Incomer feeder is shown in Figure 4.2-19.



Source： JICA Study Team based on NEA materials.

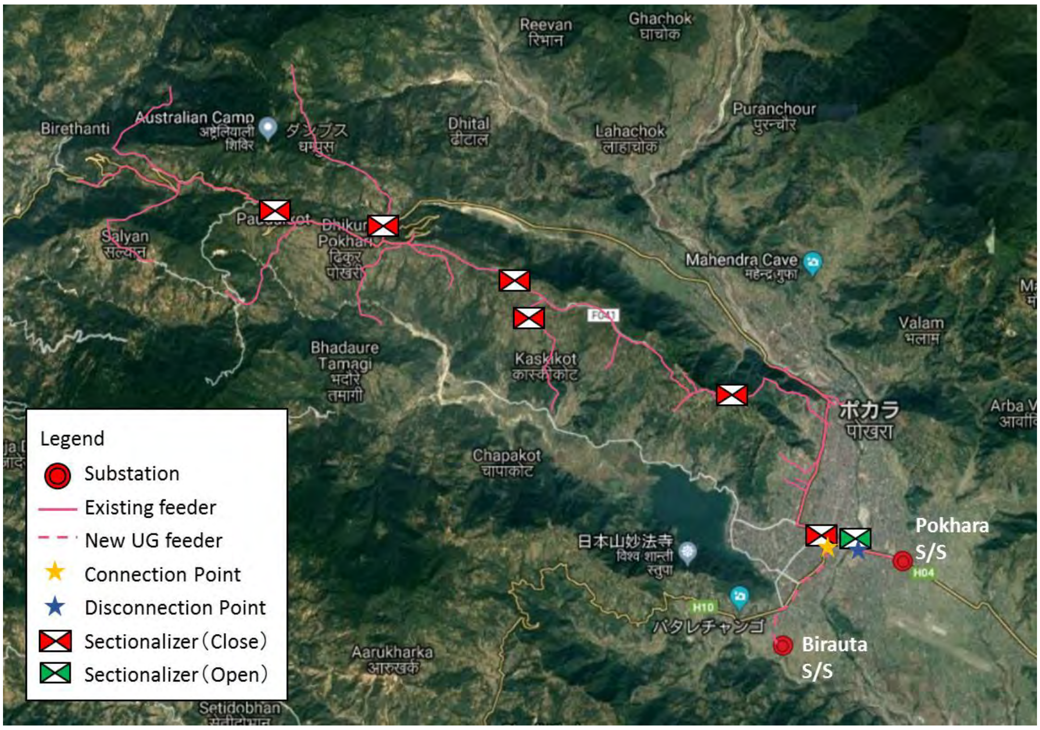
Figure 4.2-19 Line diagram of Fewa Incomer feeder

b) Sarangkot feeder

The Sarangkot feeder is a long-distance distribution feeder that passes through the same route as the Airport and Baidam feeders. It supplies power to both the center of the city and the mountain area, including Sarangkot. Since it passes through the same route as the three distribution feeder, as described above, it is possible to easily include it to the scope of the project. In addition, since it is a very long distance feeder, it can be expected to greatly improve the supply reliability by introducing a Time Sequential Sectionalizing system.

The connection point of the Sarangkot feeder is close to the connection point of Baidam. It can be load shifted by connecting new underground feeder at about 4.0 km from the Birauta substation to the point.

Six sectionalizers will be installed to the Sarangkot feeder after the reconfiguration, and one at the connection point with the remaining part of Sahid Chowk feeder, which will be left as is on east side of the river, total seven sectionalizers will be installed. The line diagram after the reconfiguration of Sarangkot feeder is shown in Figure 4.2-20.



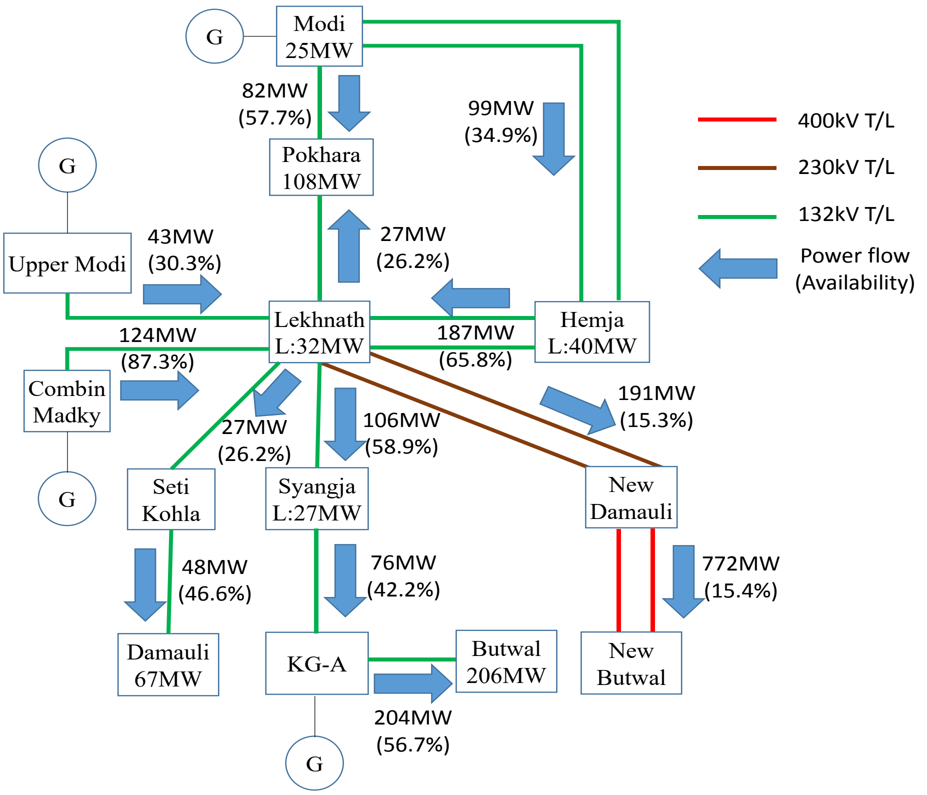
Source： JICA Study Team based on NEA materials.

Figure 4.2-20 Line diagram of Sarangkot feeder

The result of study about the load shift from Pokhara substation, along with the construction of Birauta substation was described above. This result was considered based on the present situation of distribution network. Since the distribution network is very dynamic when compared with the transmission network, it is necessary to analyze the project contents in detail along with the latest information on distribution network, at the next stage of study.

(3) Power system analysis

By using the PSS/E data received from NEA, the result of the power system analysis during the peak of 2025 rainy season was confirmed. Outline of power flow diagram around Pokhara Project, made based on PSS/E data is shown in Figure 4.2-21.



Source: JICA Study Team based on NEA materials

Figure 4.2-21 Outline of power flow diagram around Pokhara Project

The results of PSS/E data confirmation are shown below.

- Power flow calculation

  In the 132kV or more system, the power flow is within the capacity of the equipment (transmission line or transformer), so there is no problem.

- Short circuit capacity calculation

  The maximum short circuit current is 11.41kA (Lekhnath substation 132kV bus) and within the standard rated breaking current value, so there is no problem.

- Stability calculation

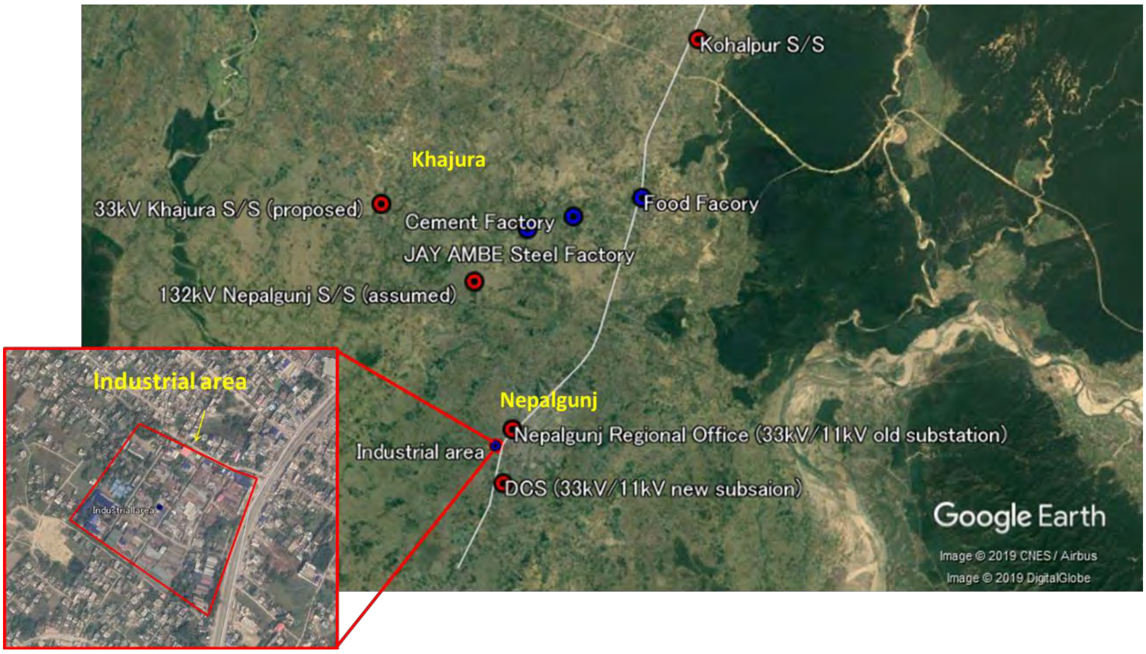
  The data required for stability calculation, such as AVR and Governor data of generators, generator constant, and so on are not managed by NEA, and it was not possible to obtain the data. So the results could not be confirmed.

  For reference, the results of power flow calculation of PSS/E, around Pokhara Project are shown in the attached document

4.2.2 Nepalgunj

Figure 4.2-22 shows the location and the surroundings of Nepalgunj. Many factories are operated in the industrial area of Nepalgunj city. In Kahjura area, located north of Nepalgunj, large factories such as steel factory, cement factory and food factory are operated and new factories are under construction. In addition, Nepalgunj is specified as a special economic zone, so industrial areas are expected to be further developed in the future. Power demand in Nepalgunj and the surrounding area is increasing with the development of industrial area. Electricity sales in Nepalgunj increases by about 173% in 5 years. Power is currently supplied to the area around Nepalgunj from Kohalpur substation through 33kV distribution lines. However, if power demand increases in future, there are concerns that the capacity of 33kV distribution line will be insufficient. Therefore, NEA plans the construction of a new 132/33kV Nepalgunj substation and a new 132kV double circuit transmission line between Kohalpur substation and Nepalgunj substation, as one of its prioritized projects.

Considering this background, JICA study team selected the construction of 132kV Nepalgunj substation and Kohalpur - Nepalgunj 132kV transmission line, which NEA plans as a prioritized project, and the development of distribution network related to the prioritized project as the candidate for financial cooperation project. After that, JICA study team surveyed and studied the candidate project.



Source: JICA Study Team based on NEA materials

Figure 4.2-22 Location and surroundings of Nepalgunj

(1) Transmission network

This section describes the results of surveys and studies on the project for constructing a new 132kV Nepalgunj substation and 132kV transmission line.

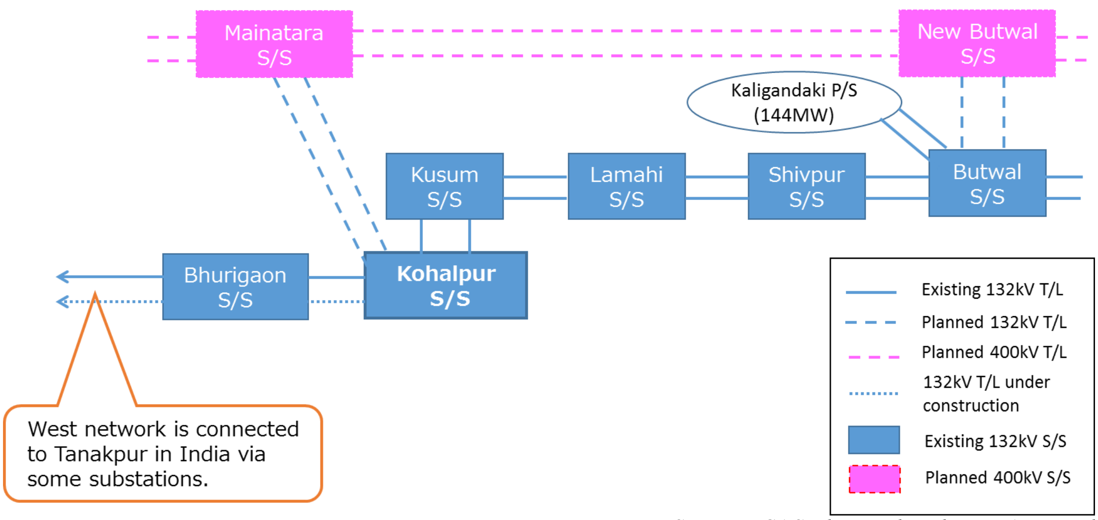
1) Current situation of Kohalpur substation

Kohalpur substation is located about 15 km northeast of Nepalgunj city, and it is connected to the 132kV transmission lines, running from east to west. Currently, Nepalgunj and the surrounding area are supplied with power from the substation by 33kV feeders.

Power transmission network around Kohalpur substation is shown in Figure 4.2-23. Kohalpur substation is connected to Kusum substation in the east and Bhurigaon substation in the west by a 132kV single circuit transmission line. The second circuit of transmission lines running toward Bhurigoaon substation is under construction. The second circuit has already been established as shown Figure 4.2-24. However, commissioning test has yet not been completed, as some houses are still present in the ROW, under the transmission line, as shown in Figure 4.2-25 and the clearance required between the transmission lines and the houses cannot be kept.

East side power system of Kohalpur substation is connected to the Kaligandaki power station, which is one of the main hydropower stations in Nepal, and the west side power system is connected to the Tanapur substation in India as shown in Figure 4.2-23. Kohalpur substation can receive power from both sides of the power system. From the east, Kohalpur substation mainly receives the power generated by Kaligandaki power station and from the west, it receives power, imported from India. On April 15, 2019, when the JICA study team visited Kohalpur substation, 132kV bus bar was being divided. At that time, one transformer received power from the east and the other transformer received power from the west.

Single line diagram of Kohalpur substation is shown in Figure 4.2-26. Kohalpur substation is connected to 132kV transmission lines, and it supplies power to the area around the load center using 33kV and 11kV feeders. There are five 33kV feeders (one of which is vacant) and six 11kV feeders (of which one is vacant). Surkhet in the north, where the state capital of the 6th province is located, and Nepalgunj in the south, are supplied by 33kV feeders.



Source: JICA Study Team based on NEA materials

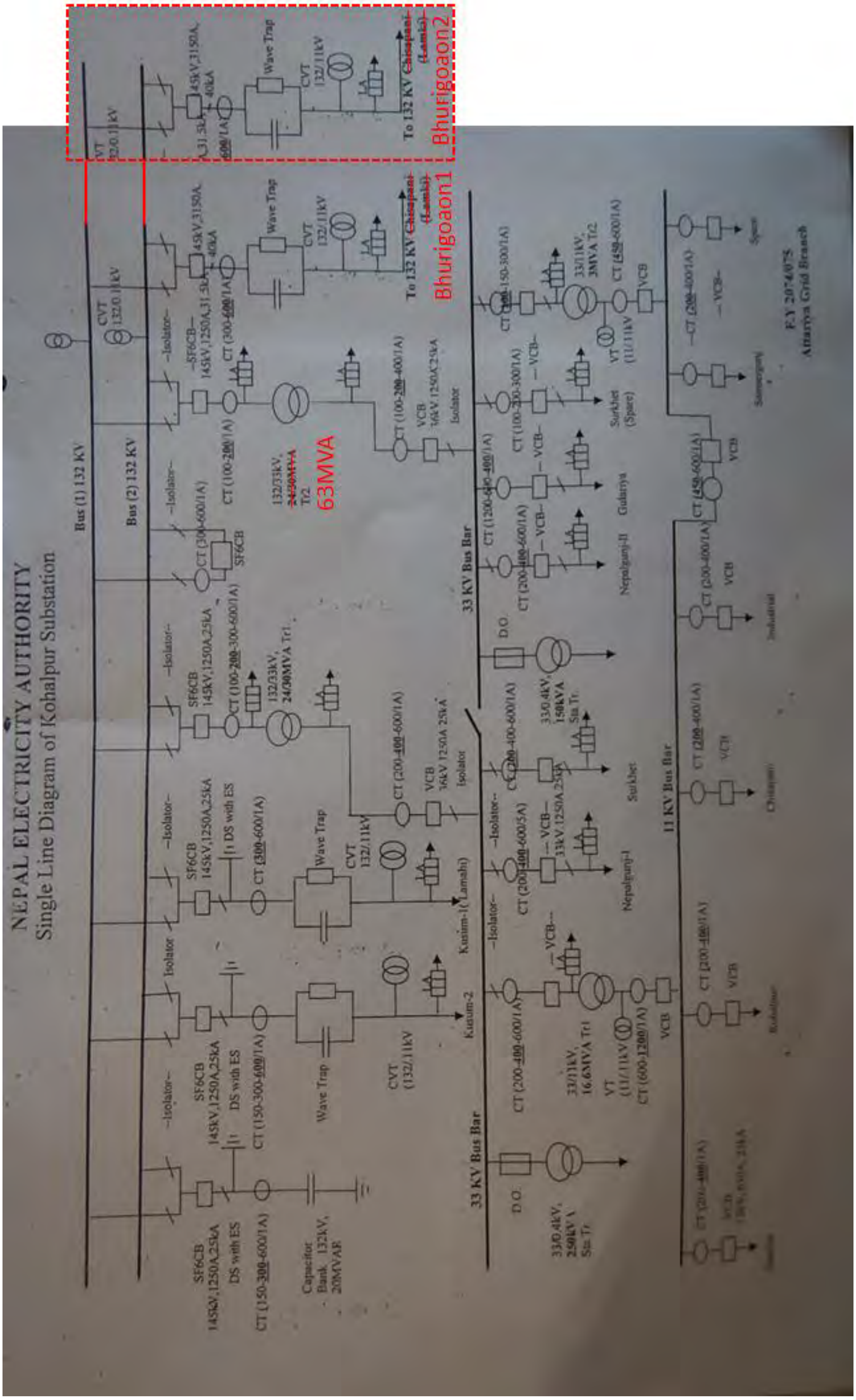
Figure 4.2-23 Overview of transmission network related to Kohalpur substation

Figure 4.2-24 Tower of the existing transmission line between Kohalpur and Bhurigaon

Figure 4.2-25 Situation under the existing transmission line between Kohalpur and Bhurigaon

There are two 132/33kV transformers in Kohalpur substation. The capacity of one transformer is 63MVA, and the other is 30MVA. One transformer was made in 2018, the other was made in 2014. Both transformers was made in China. Although two 30 MVA transformers were operated until 2018, one was replaced with 63 MVA to deal with the increase in demand. There are also two 33/11kV transformers in this substation. Their capacities are 16.6 MVA and 3 MVA, respectively.

Kohalpur Substation has introduced the SCADA system, which enables remote monitoring and control from LDC. Information such as voltage, current, circuit breaker switching status, fault message, circuit breaker switching command is shared between Kohalpur substation and LDC. It is possible to open and close the circuit breaker remotely, however, in actual operation, substation operator performs the open and close operation in response to a telephone command from LDC.



Source: JICA Study Team based on NEA materials

Figure 4.2-26 Single line diagram of Kohalpur substation

2) Study about transmission and substation project

To establish the new 132kV two-line transmission lines, connecting Kohalpur substation and Nepalgunj, it is necessary to add a new switchgear for the 132kV two-line transmission lines in Kohalpur substation. However, the place is fully occupied the existing switchgear and transformers and the place, where a new switchgear can be installed, is limited. The largest vacant space is next to the control building as shown in Figure 4.2-27, however, this space is not sufficient to install an AIS, which has a configuration similar to the existing one. Therefore, for the new switchgear, it is recommended to install a GIS that can save space. By connecting the GIS and the existing bus bar with a cable, it is considered that it is possible to install a new switchgear for the 132kV two-line transmission lines. However, as the layout of the substation yard cannot be obtained, detailed study is necessary.

Source: JICA Study Team

Figure 4.2-27 Candidate location for the new switch gears

On the other hand, the construction site of Nepalgunj substation has not been decided, but according to the information from NEA, the location near the industrial area in Khajura area is promising. Although the construction of factories in the Khajura area is progressing, much of the land is vacant, so it is thought that the land acquisition for the Nepalgunj substation will not be a problem. However the site area required for the Nepalgunj substation depends on the number and capacity of transformers, so it is necessary to carry out further study.

The Kohalpur substation is located in a residential area, and the substation is already surrounded by many houses. Figure 4.2-28 shows the situation around Kohalpur substation. It is difficult to install new towers for the 132kV transmission line in the area around the substation, where so many houses are located. Therefore, it is recommended to use underground cable in the area around the substation as shown in Figure 4.2-29. It is a practical to install underground outgoing cable from the substation along the existing road and construct a new tower to connect the overhead transmission line and underground cable at a location away from the residential area and install overhead transmission line from the tower to Nepalgunj substation. Taking into consideration the transportation of material and equipment during construction and maintenance after construction, if possible, overhead transmission line should be installed along the existing road, running from south to north.

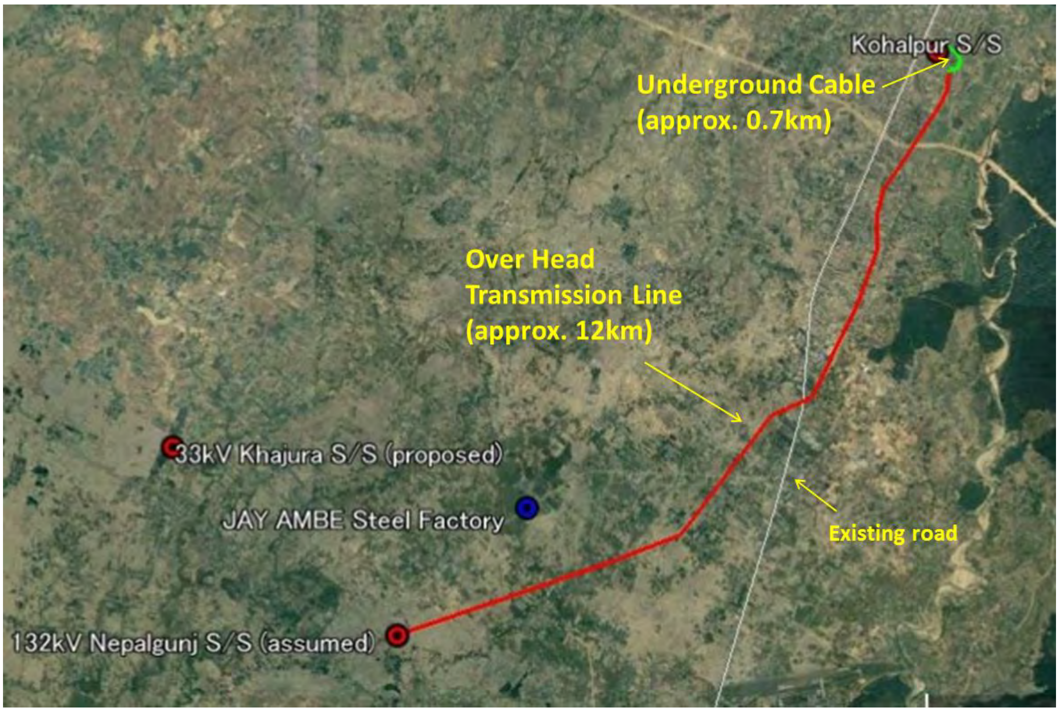
Figure 4.2-30 shows the tentative route of transmission line. The total length of the route is about 12.7km. The length of underground cable is about 0.7km and the length of overhead transmission line is about 12km. The location of Nepalgunj substation is not determined. The JICA study team selected this route assuming that the Nepalgunj substation will be installed in Khajura area, based on the information from NEA..

Source: JICA Study Team based on NEA materials

Figure 4.2-28 Situation around Kohalpur substation

Source: JICA Study Team based on NEA materials

Figure 4.2-29 Underground cable route from Kohalpur substation



Source: JICA Study Team based on NEA materials

Figure 4.2-30 Tentative route of transmission line between Kohalpur and Nepalgunj

The above is JICA study team's plan for this project. On the other hand, NEA is considering another plan as shown in Figure 4.2-31. The plan is to install a new switch station in the area west of Kohalpur substation and construct a branch line of the existing Kohalpur – Bhurigaon transmission line from the switch. In the next survey, it will be necessary to study which plan is the most suitable for the project, taking into consideration the NEA's plan.

Source: JICA Study Team based on NEA materials

Figure 4.2-31 Another plan under consideration of NEA

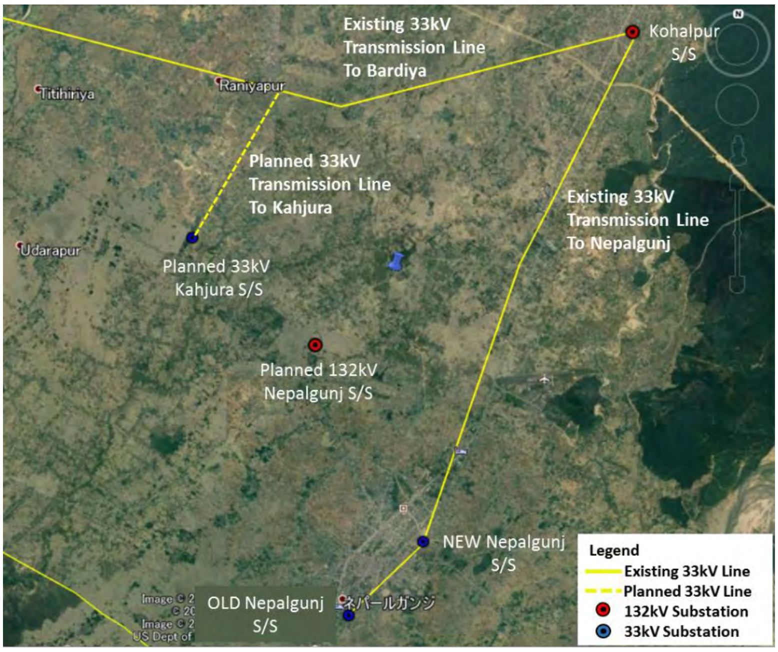
(2) Distribution network

This section describes the results of surveys and studies on distribution projects, related to the transmission project of constructing the new Nepalgunj 132kV substation and 132kV transmission line.

1) Current situation of distribution network in Nepalgunj

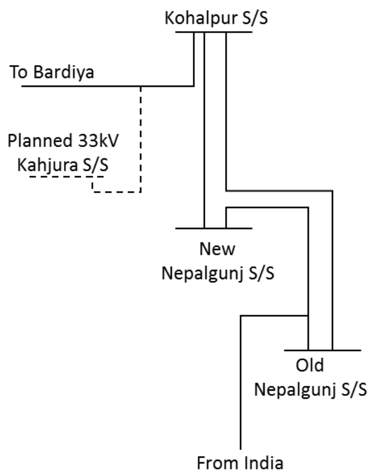
There are two distribution substations in Nepalgunj: Old Nepalgunj and New Nepalgunj substation. These substation are supplied from Kohalpur substation by 33kV sub-transmission line, and it supplies to Nepalgunj area. In addition, 33kV interconnection line with India is also connected to both substations, and power supply to both substations is carried out by system switching (Nepal-India), according to the instruction from LDC based on the supply and demand situation.

In the area, in addition to industrial parks located in the city center, many large-scale factories are in operation or under construction in the suburbs, and the demand growth is rapid. In order to cope with the increase in demand, NEA plans to construct a new distribution substation (33/11 kV) in the Kahjura area, adjacent to Nepalgunj. An overview of the 33kV system and the single line diagram of Nepalgunj area are shown in Figure 4.2-32 and Figure 4.2-33. The situation of the Nepalgunj industrial park and the large scale steel plant, which is under construction are shown in Figure 4.2-34and Figure 4.2-35.



Source: JICA Study Team

Figure 4.2-32 Overview of 33kV network in Nepalgunj



Source: JICA Study Team

Figure 4.2-33 Single line diagram of 33kV network in Nepalgunj

Figure 4.2-34 Nepalgunj Industrial Park

Figure 4.2-35 Large scale steal factory

Old Nepalgunj substation consists of two 33/11 kV 6/8 MVA transformers. The manufacturing year of both the transformers are relatively new - 2011 and 2017, and regular maintenance is being carried out and they are operating in good condition. New Nepalgunj substation is similarly constructed by two banks of 33/11 kV (6/8 MVA, 15 MVA). The

15 MVA transformer of the substation was manufactured in 2017, and was updated in 2018, but the manufacturing year of the other transformer (6/8 MVA) is unknown and it is a fairly deteriorated transformer. The power supply to the city of Nepalgunj is done by 12 circuits of 11 kV distribution feeders from the above two substations. The situation of the Old Nepalgunj substation and the New Nepalgunj substation is shown in Figure 4.2-36 and Figure 4.2-37.

Figure 4.2-36 Old Nepalgunj substation

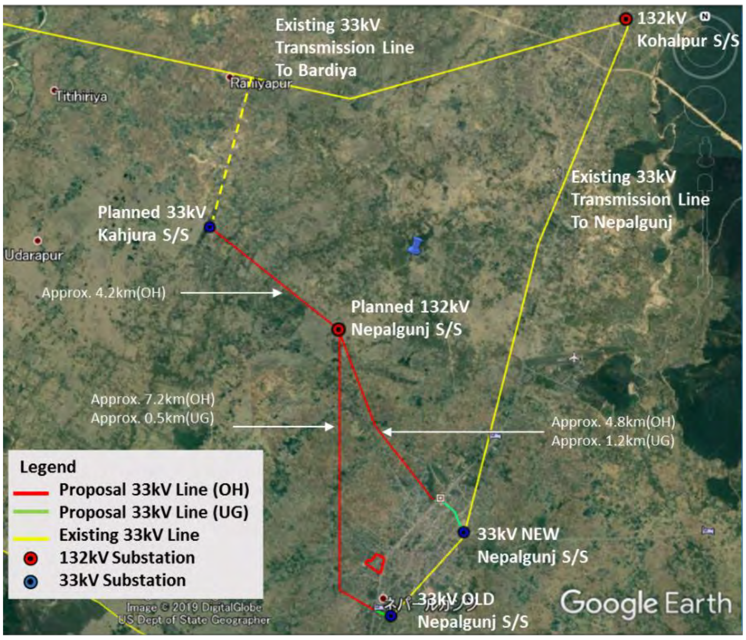
Figure 4.2-37 New Nepalgunj substation

As mentioned above, two distribution substations in Nepalgunj area are supplied by 33kV transmission line both from Kohalpur substation and 33kV interconnection line from India (Nanpara substation). How the power is received from Kohalpur and Nanpara varies depending on the daily supply and demand conditions. It is operated mainly by two patterns, sometimes the two transformers, installed at each substation are supplied from Kohalpur, and sometimes one is supplied from Kohalpur and the other is supplied from Nanpara. When JICA Study Team confirmed the operation record of the substation, power reception switching was carried out about two or three times every day, and a power cut due to switching occurred in Nepalgunj area, each time. In addition, at peak load times, rolling blackouts have sometimes been implemented to reduce the load caused by shortage of transmission capacity. Although the supply and demand situation has been greatly improved nationwide, power situation is still severe in Nepalgunj area, which is located at the end of the grid power system.

2) Study of distribution project

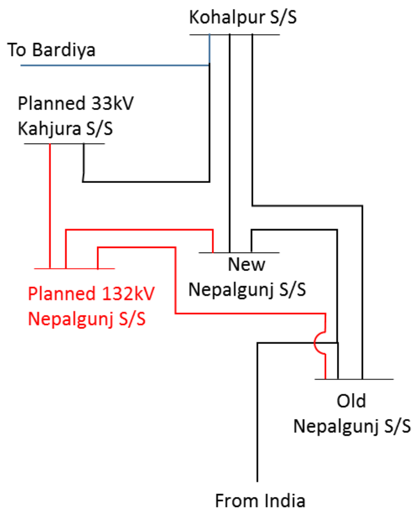
On discussing with Nepalgunj Regional Office (NRO) of NEA about the distribution project related to the transmission project involving the construction of new Nepalgunj 132 kV substation, the NRO requested to consider reinforcement of 33 kV transmission line from Kohalpur to cope with the increasing industrial demand of Nepalgunj area. In response to this request, JICA Study Team suggested to construct 33kV sub-transmission line from the planned 132kV substation to each distribution substation— Old Nepalgunj, New Nepalgunj, and the planned Kahjura substation. With this reinforcement plan, it is possible to reduce transmission loss due to the shortening of transmission distance; and it is also possible to ease loading situation of Kohalpur substation due to load shift from Kohalpur to new substation, and also to secure supply capacity to the industrial area around Nepalgunj and Bardiya area.

Although most of the new 33kV transmission line is planned to be built as overhead transmission line with steel towers, it is difficult to construct overhead facilities near the Old Nepalgunj and the New Nepalgunj substations, as they are densely populated areas of commerce and housing. So construction of underground transmission lines are planned around these area. The outline of the contents and the single line diagram of the proposed project are shown in Figure 4.2-38 and Figure 4.2-39



Source: JICA Study Team

Figure 4.2-38 Outline of the project

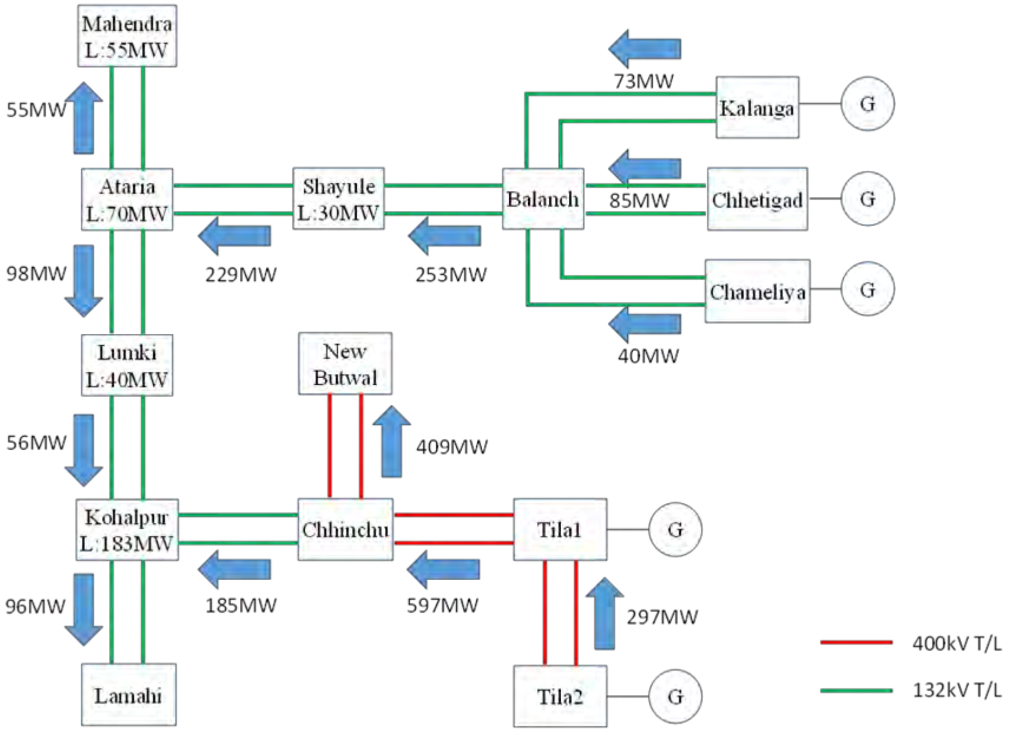


Source: JICA Study Team

Figure 4.2-39 Single line diagram of the project

(3) Power system analysis

By using the PSS/E data received from NEA, the result of power system analysis during the peak of 2025 rainy season was confirmed. Outline of power flow diagram around Nepalgunj Project made based on PSS/E data is shown in Figure 4.2-40.



Source: JICA Study Team based on NEA materials

Figure 4.2-40 Outline of power flow diagram around Nepalgunj Project

The results of PSS/E data confirmation are shown below.

- Power flow calculation

  In the 132kV or more system, the power flow is within the capacity of the equipment (transmission line or transformer), so there is no problem.

- Short circuit capacity calculation

  The maximum short circuit current is 8.64kA (Chihinchu substation 132kV bus), and it is within the standard rated breaking current value, so there is no problem.

- Stability calculation

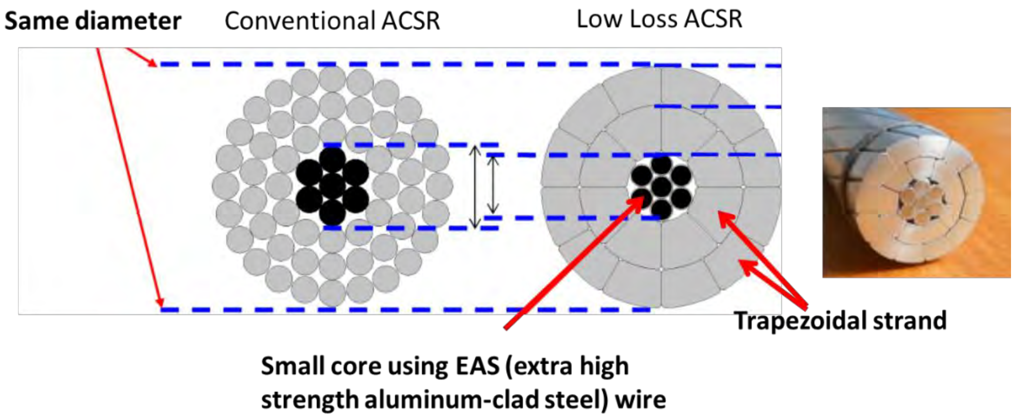
  Required data for stability calculation such as AVR and Governor data of generators, generator constant, and so on are not managed by NEA, and it was not possible to obtain the data. So the results could not be confirmed.

For reference, the results of power flow calculation of PSS/E around Pokhara Project are shown in the attached document

4.2.3 Feasibility of adopting Quality Infrastructure

(1) Low Loss Conductor

The Low Loss Conductor applies trapezoidal shaped aluminum strands to the conductive layers, while the conventional ACSR applies round aluminum strands. By the adoption of trapezoidal shaped aluminum strands, the Low Loss Conductor is able to make the gap between the aluminum strands smaller than the conventional ACSR, and the cross section area of the aluminum also increases. In addition, Low Loss Conductor adopts small core using EAS (extra high strength aluminum-clad steel) wires instead of normal galvanized steel wires, and this makes the cross section area of the aluminum larger. As the result, Low Loss Conductor can reduce electric resistance and transmission loss caused by resistance, while maintaining the same mechanical strength and total diameter for the conductor as the conventional ACSR. Figure 4.2-41 shows the cross section overview of Low Loss Conductor and Conventional ACSR.

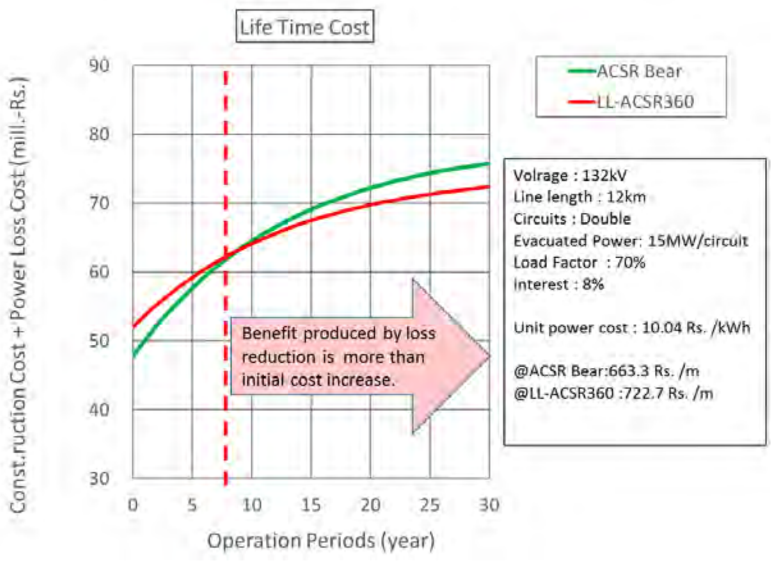


Source: JICA Study Team based on manufacturer's materials

Figure 4.2-41 Cross section of Low Loss Conductor and Conventional ACSR

Initial cost of Low Loss Conductor is more than that of Conventional ACSR, but in the long term, benefits produced by loss reduction will be more than the initial difference in cost. Therefore, Low Loss Conductor produces more benefits than the conventional ACSR in the terms of life time cost.

Figure 4.2-42 shows a rough comparison of life time cost under the assumption that the Low Loss Conductor is adopted in Kohalpur - Nepalgunj transmission line, which is the candidate for financial cooperation project. The graph in the Figure is made based on trial calculations and various assumptions. In this example, Low Loss Conductor will produce more benefit than a Conventional ACSR in 7 years after the conductors are installed.



Source: JICA Study Team

Figure 4.2-42 A rough- comparison of life time cost between Low Loss Conductor and Conventional ACSR

(2) Gas Insulated Switchgear

Gas insulated Switchgear (GIS) is installed as a substation equipment. Circuit breakers, disconnectors, bus bar, etc. are enclosed and stored in metal containers using the SF6 gas, which has a high insulation and ark-extinction performance. GIS can be achieved with about 1/50th volume and about 1/20th installation space in comparison with the conventional type air insulated switchgear. In addition, since the live parts are hermetically sealed in metal enclosures which are filled with SF6 gas, it is entirely shut off from the external environment. Therefore, high reliability and safety can be maintained over a long term. Moreover, since all the live parts are fully enclosed under the condition of no oxygen and no moisture, there is no aging decay in it. As a result, it does not require maintenance.

Installation space can be minimized by applying the outdoor type GIS. GIS of Japanese manufacturers is made for outdoor use and many have been delivered to overseas countries. Although overseas manufacturers have also started to produce the outdoor type GIS, there is still a major gap in terms of delivery record.

Source : JICA Study Team

Figure 4.2-43 Outdoor type GIS

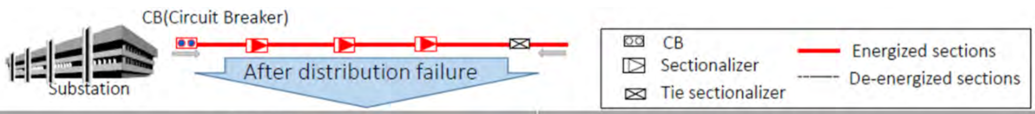
(3) Time sequential sectionalizing system (TSS)

By combining with the auto reclose function of the substation, the TSS can supply electricity to the functioning section and excluding the faulty section, which is classified by the switch at the time of power outage. One of the benefits of Quality Infrastructure is its ability to provide power supply swiftly to the functioning sections.

The sectionalizing switch of TSS mainly has functions such as "Sequential power transmission", "no-voltage release", "locking", and providing power supply to the functioning section as shown in the process of Figure 4.2-44.

First, when a power outage occurs and a circuit breaker(**CB**) of a substation trips (No. I), all pole mounted switches will be set to "no voltage release". After a certain period of time, when the substation CB is reclosed, the switches are sequentially re-closed at a certain interval time from the source side (No. II) by "Sequential power transmission". Next, when the switch is re-closed up to the faulty section, where the fault has occurred, the CB of the substation trips again and at the same time the switch is re-tripped again by "no-voltage release" (No. III)

At this time, the substation recognizes and detects the faulty section, which is judged by the time taken for the CB to trip and the time interval of "Sequential power transmission" (No. IV). Thereafter, the CB is re-closed and electricity is sequentially supplied from the substation, but the switch present before the faulty section will be not re-closed by "locking", and the power transmission in the functioning section of the source side is completed.

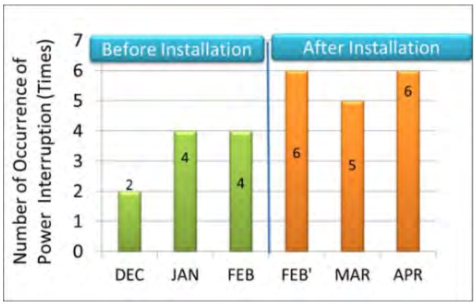


No.		Procedure	Explanation
I	CB trip (Failure occur)	Opened	➢All sectionalizers in the DL is opened.
II	CB re-close	Re-closed sequentially	➢The CB is re-closed after a certain time (1 minute). ➢Sectinalizers are re-closed sequentially at a certain interval time by monitoring feeder voltage.
III	Sectionalizer re-close	Detect Grounding	➢When the fault section is energized by the sequential re-closing …
IV	CB re-trip	Detect Fault Section	➢CB is re-tripped and all sectionalizers are re-opened. ➢The fault section is recognized and detected.
V	CB re-close	Energized	➢The sound sections on the source side are energized by performing procedure II and III.

Source: JICA Study Team

Figure 4.2-44 Procedure of Sequential power transmission

Japanese manufacturer have delivered this type of switchgears to Myanmar. As shown in Figure 4.2-45, it greatly contributes to the reduction of outage time. According to the results of the survey, currently, sectionalizing switches are not used for distribution in the Pokhara area. Moreover, since the existing distribution system in Nepal is a radial network, which is same as the general power distribution system of Japan, it was confirmed that there are no problems in the application of TSS.



Source: Manufacturers' materials

Figure 4.2-45 Comparison of Outage Time before and after the Introduction of Time Sequential Sectionalizing System in Developing Countries

4.3 EXAMINING THE POSSIBILITY OF INTRODUCING LARGE SCALE BATTERY

4.3.1 Objective of Introducing Large Scale Battery

According to the concept note issued by PMD of NEA in November 2018, the following two points are mentioned as the objectives for installing a large capacity storage battery.

① Providing reliable and uninterruptible electricity supply to the agencies, which offer basic and emergency services such as the hospitals, the major administrative offices like the Singha Durbar in Kathmandu, major security offices, offices of higher authorities like the Presidential office, the Prime Ministerial offices, and all the seven (7) provincial governmental offices.

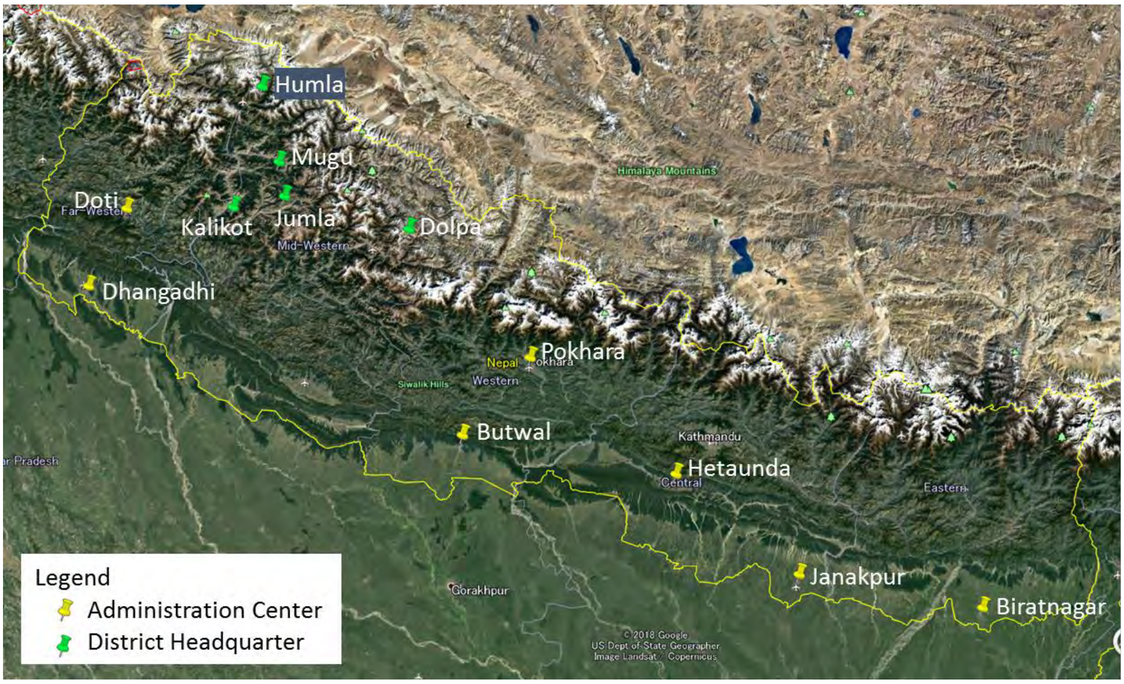
② Providing quality and reliable electricity to the district headquarters, where there is no grid connectivity and are being supplied through micro or mini hydropower plants, which are not adequate.

Furthermore, candidate offices for the installation of battery are also described in the concept note. Three administration offices in Kathmandu and seven provincial offices are listed for the objective ① and Five districts headquarters are listed for the objective ②. These candidates are listed below.

①-a 10MW ESS at Singhdurbar, Kathmandu
①-b 1MW ESS at President Residence at Maharajgunj
①-c 1MW ESS at Parliamentary Building at Baneswar
①-d 1MW each for Administration centers of 7 Provinces (Hetaunda, Biratnagar, Janakpur, Pokhra, Butwal, Doti, Dhangadhi)
② ESS system with solar power system each of capacity 1MW at Dolpa, Kalikot, Humla, Jumla and Mugu district

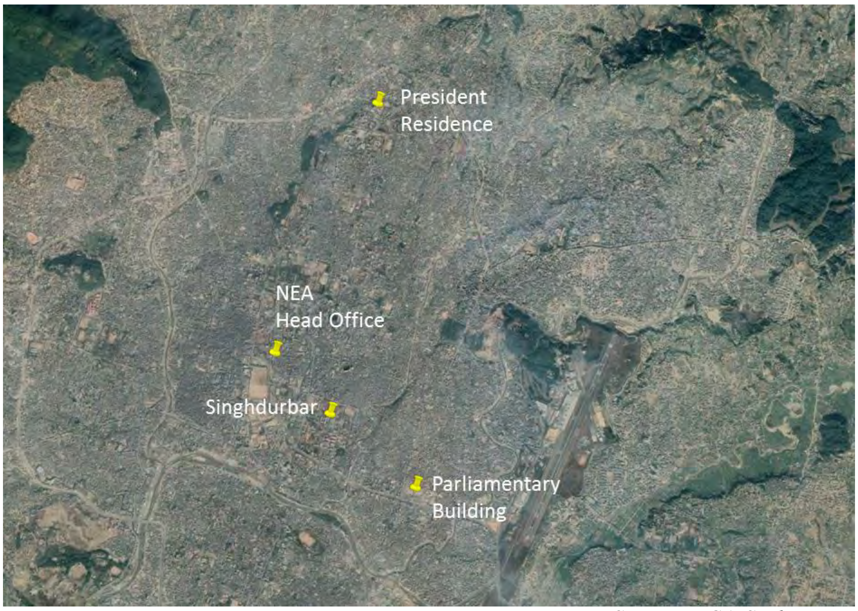
The location of the candidate sites is shown in Figure 4.3-1 and Figure 4.3-2.

On discussing the above objective and candidates with NEA, it was confirmed that the function of peak shaving that is expected to further increase the effects of battery system has been added to objective ①, because of the low load factor of Nepal power grid due to high evening peak and morning peaks. In addition, because the effects of system stabilization and peak shaving obtained by batteries will be limited in the case of off-grid system, it was decided to limit the candidates for JICA assistance to objective ①.



Source: JICA Study Team

Figure 4.3-1 Candidate site of battery (Province and District)



Source: JICA Study Team

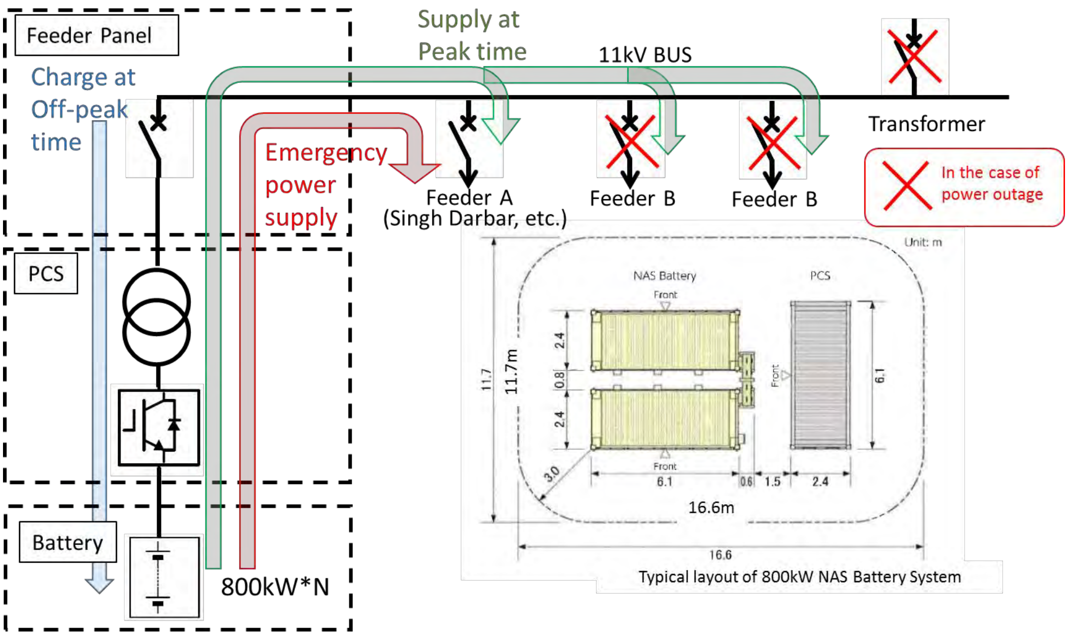
Figure 4.3-2 Candidate site of battery (Kathmandu)

4.3.2 Study on Basic System for Battery

The basic configuration of the system was established based on the objectives of installing the battery energy storage system and the candidate site. The battery system was decided to be installed at the substation compound, which supplies power to the candidate facilities, for the following reasons.

- ✓ Maximum effect of power system stabilization and peak shaving
- ✓ Easy maintenance by substation operators

The basic system configuration of the battery system is shown in Figure 4.3-3. The battery system is connected to the 11kV bus bar of substation through spare feeder panel. The battery system is charged from grid power at off-peek time, as indicated by the blue arrow. On the other hand, it supplies power to the distribution feeder at peak time through 11kV bus bar as shown by the green arrow. In addition, when a power outage occurs in the power grid, the battery system supplies only to the distribution feeder, which supplies to the candidate facilities, as shown by the red arrow. A discharge capacity of 4 hours or long is required for peak shaving, based on the charge and discharge characteristics of a typical battery and the daily load curve of Nepal, as mentioned in Section 2.2.3. It is also necessary to secure the discharge capacity for the backup power supply. So, the battery to be selected for the system should have a total discharge capacity of 6 hours.



Source: JICA Study Team

Figure 4.3-3 The basic system configuration of the battery storage system

4.3.3 Result of Field survey for the candidate site

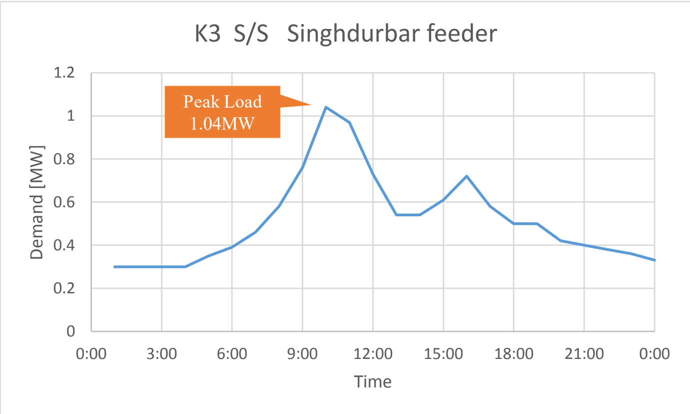
Out of the candidate sites, field survey was conducted at three administration offices in Kathmandu and the provincial administration office in Pokhara. The survey was conducted with the following in view.

- ✓ Supply situation to candidate facilities
- ✓ Capacity required for battery
- ✓ Space for installation of battery
- ✓ Feeder panel

The following describes the survey results of each site.

(1) K3 substation supplying to Singhdurbar

K3 substation is a relatively new substation built by Japanese Grant Aid in 2005. The substation is supplied by 66kV transmission line and it consist of two transformers (22.5MVA x 2). The substation is located at the northwestern end of the governmental administration office area of Singhdurbar and supplies power to the surrounding area including the government offices. The government offices, which are the target facilities for backup, are supplied by the two distribution feeders of the substation. According to the substation staff, one of the distribution feeders is connected to the old buildings that are not currently in use, so the government offices are substantially supplied by only one feeder. The load curve of the target distribution feeder is shown in Figure 4.3-4.



Source: JICA Study Team

Figure 4.3-4 Daily load curve of target feeder (Singhdurbar)

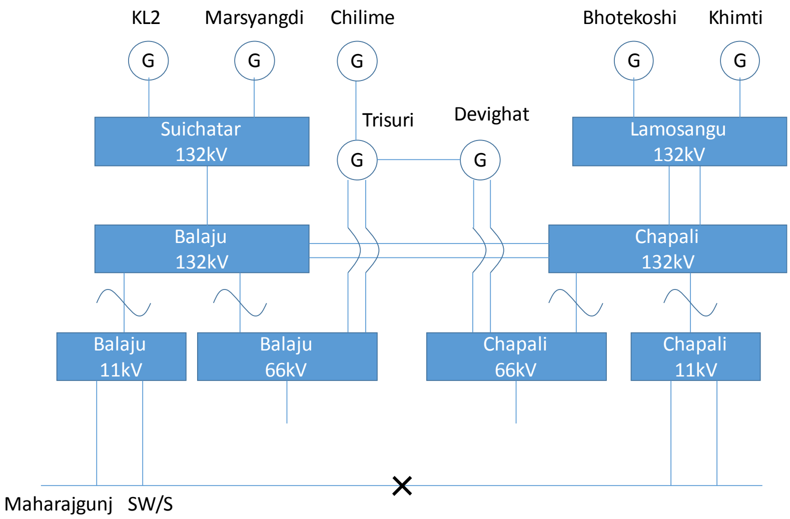
Although the peak load of the target feeder is about 1 MW based on this load curve, the annual peak load was confirmed to be about twice the value by the interviews with the substation staff. Therefore, the required capacity of the battery system is set as 2.0 MW.

There is a large open space in the Singhdurbar area, adjacent to the substation (Figure 4.3-5), and this space is sufficient to install the battery system. However, NEA has to secure this space for installation. In addition, it was confirmed that there are two spare feeder panels at the distribution feeder board, which could be used for the connection of battery system.

Figure 4.3-5 Candidate space for the battery system

(2) Maharajgunj switching station supplying to President Residence

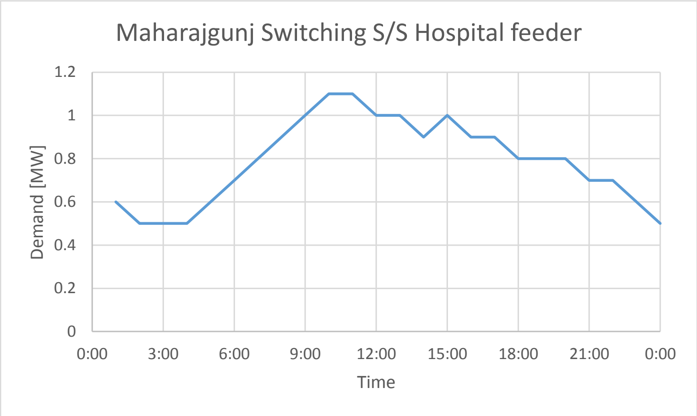
Maharajgunj SW/S was also built by Japanese grant aid in 1994. The SW/S is supplied by a total of four circuits, two 11 kV overhead transmission lines from the Balaju substation and two 11 kV underground transmission lines from the Chapali substation. Furthermore, the upper 132kV transmission line is also duplexed, so it can be said that it has high reliability compared to other SW/S. The existing power system of the Maharajgunj SW/S is shown in Figure 4.3-6.



Source: JICA Study Team

Figure 4.3-6 Existing Power System of Maharajgunj SW/S

President Residence, which is a target for backup power supply, is supplied from the SW/S with a 11kV distribution feeder. This feeder also supplies to hospitals near the President Residence. So it can be said that the backup efficiency will be relatively high, if the battery system is installed to the SW/S. Daily load curve of the target feeder is shown in Figure 4.3-7. The peak load of the target feeder is about 1.1 MW, so the required capacity of the battery will be set as 1.2 MW.



Source: JICA Study Team

Figure 4.3-7 Daily load curve of target feeder (President Residence)

There is a certain space available in the Maharajgunj SW/S, but it is necessary to arrange and clean up the materials stored on the premises, in order to install the battery system. It was also confirmed in the interview with NEA staff that the building next to the control room is currently not used and can be removed, so it can be used as a space for the battery system, after the building is removed by NEA.

Figure 4.3-8 Compound of Maharajgunj switching station

There are no spare panels in the distribution board at present, and it is also difficult to install additional feeder panels because of the narrowing of control room. It is necessary to prepare spare panels either by major remodeling work including building construction or by reconfiguration of distribution feeders, in order to connect the storage battery system.

(3) Baneswar substation supplying to Parliamentary Building

Baneswar S/S supplies to the Parliamentary Building, which is a target facility for backup supply. The S/S is an outdoor substation supplied by 66kV transmission line and it consists of two transformers (18MVA x 2). Parliamentary building is supplied from a 11kV distribution feeder. This feeder supplies power to nearby hospitals. It can be expected that the effect of the backup power supply by the battery system is high, like in the case of Maharajgunj. At the time of the survey, the load on the distribution feeder was about 200 kW, because the parliament was suspended. However, according to interviews with the substation staff, it was confirmed that the annual peak load is about 800 kW.

There is almost no vacant space in the Baneswar S/S, so installation of the battery system is difficult at the current substation compound. According to interviews with the substation staff, there is a possibility that the adjacent vacant land, which has already been purchased by NEA but not yet allocated for any purpose, can be used to install the battery system. When installing the battery system at the Baneswar S/S, it is necessary for the NEA to secure the installation space.

Figure 4.3-9 Baneswar substation compound

Figure 4.3-10 Adjacent land

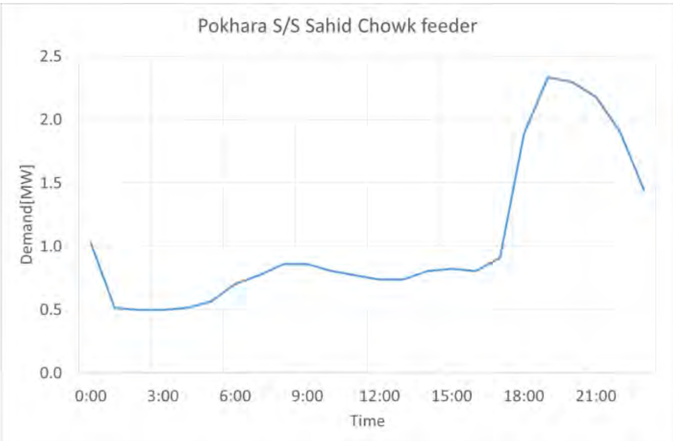
Although there are no spare panels in the feeder board at present, it is possible to install additional feeder panels to connect with the battery system, because there is a space for extension.

Figure 4.3-11 Space for additional feeder panel

(4) Pokhara substation supplying provincial offices

Pokhara S/S, located in the eastern part of Pokhara city, is supplied by 132 kV transmission line and consists of two 30MVA transformers. Administration Centers, which are target facilities for backup supply, are located in the city center and supplied with a 11kV distribution feeder. This feeder also supplies power to the north side of Lake Phewa, which is a tourist area in Pokhara, and it can be said that this feeder has high-priority in Pokhara, where tourism is a major industry.

Daily load curve of the target feeder is shown in Figure 4.3-12. The load curve has a significant peak in the evening, when compared to the three distribution feeders mentioned above; and the peak load is about 2.4 MW. It is thought that the evening peak is significantly influenced by the load of tourist area, supplied from the feeder, so the load of the Administration Center is assumed to be at most 800 kW from the daytime load. When the battery system is used as a backup power supply, it is possible to separate the tourist area from the feeder and supply only the Administration Center from the battery. However this operation is not recommended as it requires a relatively complex system operation of the distribution network. So, a battery capacity of 2.4MW is recommended.



Source: JICA Study Team

Figure 4.3-12 Daily load curve of target feeder (Pokhara)

Pokhara S/S has a relatively large space, and it seems possible to secure the installation space for the battery system. However, the vacant space at the premises is thought to be used for outgoing route of 11kV underground feeders, it is necessary to confirm the details of the cable route during detail design. There are some spare panels on the distribution board, which can be used for the battery system connection.

As mentioned above, there are no major problems with the installation of the battery system at Pokhara S/S, however the target feeder, Sahid Chowk, will be shifted from the Pokhara S/S to Birauta S/S as mentioned in Section 4.2. Therefore, it is necessary to carefully determine the timing to install the battery system at Pokhara area.

Figure 4.3-13 Candidate space for battery (Pokhara Substation)

Table 4.3 1 shows the results of the study for installation of the battery system at the four candidate sites.

Table 4.3-1 Result of the study for candidate sites

S/S SW/S	K3	Baneswar	Maharajgunj	Pokhara
Supply to	Singhdurbar	Parliament building	President Residence	Administration Center
Space for Battery	Good	With condition	With condition	With condition
Feeder Panel to be connected	Good (Spare Panel)	With condition (Possible to extend)	Difficult (No spare panel, No space for extension)	Good (Spare Panel)
Required Capacity (tentative)	2.0MW	0.8MW	1.2MW	2.4MW
Remarks	NEA has to confirm the availability of adjacent land	NEA has to secure the land.	NEA has to clean up the compound.	NEA has to confirm the cable route. Target will be shifted to new Birauta S/S

Source: JICA Study Team

APPENDICES

APPENDIX-1

SCHEDULE OF SITE SURVEY

Appendix-1：Schedule of Site Survey

- First Survey

	Date	Day	Kenichiro YAGI	Shinichi MUROYA	Shinichi KAWABE	Kazuki KONISHI	Yukihiro MIKUMO	Kouzou MATSUOKA	Kazutoshi NISHIMURA	Accommodation
			Team Leader／ Power development planning	Transmission and Substation facility planning	Distribution facility planning	Power system analysis	Economic and financial analysis / Organizational structure	Electrical Engineer 1	Electrical Engineer 2	
1	2019/4/6	Sat	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	Lv. KIX by TG623 11:45 Ar. BKK (ETD 15:35)	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	Lv. KIX by TG623 11:45 Ar. BKK (ETD 15:35)	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	Lv. KIX by TG623 11:45 Ar. BKK (ETD 15:35)		Bangkok hotel Lotus Sukhumvit
2	2019/4/7	Sun	Lv. BKK by TG319 10:15 Ar. KTM (ETD 12:25)							Hotel Himalaya
3	2019/4/8	Mon	11:00 AM Meeting with NEA (Planning, Monitoring & Information Technology Directorate（PMITD） 13:00 PM Site Visit to Baneshwor, MINBHAWAN (Substation)							same above
4	2019/4/9	Tue	09:00 Discussion with NEA (Transmission Line Directorate) 12:00 Discussion with NEA (System Control & Network, Transmission Directorate) 14:00 Meeting with NEA (Finance Directorate) 15:00 Meeting with NEA (Project Management Directorate)							same above
5	2019/4/10	Wed	10:30 Site visit (Load Dispatch Center) 11:30 Site visit (Substation at Singhdurbar area) 15:00 KICK off Meeting with NEA 20:00 Discussion with JICA Nepal				10:30 Discussion with Finance Directorate 15:00 KICK off Meeting with NEA	Same as Mr.YAGI		same above
6	2019/4/11	Thu	10:45 TV Meeting with JICA Tokyo (14:00:JST)							same above
7	2019/4/12	Fri	10：30 Site visit (Switching station at Presidential Palace area) 12:30:Meeting with NEA (Distribution Directorate)							same above
8	2019/4/13	Sat	Internal Work					Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG622 (23:59)	Lv. KIX by CX503 10:00 Ar. HKG (ETD 13:00) Lv. HKG by KA104 17:10 Ar. KTM (ETD 20:00)	same above
9	2019/4/14	Sun	Move to Nepalgunj by U4 451 PM Site Survey					Ar.KIX (ETD 07:30)	Same as Mr.YAGI	(Nepalgunj)
10	2019/4/15	Mon	Site survey at Nepalgunj						Same as Mr.YAGI	(Nepalgunj)
11	2019/4/16	Tue	Site survey at Nepalgunj							(Butwal)
12	2019/4/17	Wed	Move to Kathmandu by Car							Hotel Himalaya
13	2019/4/18	Thu	11:00 Discussion with NEA (System Planning Department) 12:00 Discussion with NEA (Distribution Directorate)				12:00 Discussion with NEA (Finance Directorate)			same above
14	2019/4/19	Fri	11:00 Discussion with NEA (Load Dispatch Center) 12:00 Discussion with NEA (Transmission Line Directorate) 13:30 Discussion with NEA (PDM)				Site visit to NEA Training Center			same above
15	2019/4/20	Sat	Move to Pokhara U4 603							(Pokhara)
16	2019/4/21	Sun	Site survey at Pokhara							(Pokhara)
17	2019/4/22	Mon	Move to Kathmandu by U4 ***						Same as Mr.YAGI	Hotel Himalaya
18	2019/4/23	Tue	10:00 Discussion with NEA (Transmission Line Directorate) 12:00 Discussion with NEA (Distribution Directorate) PM Meeting with RPGCL							same above
19	2019/4/24	Wed	AM Discussion with NEA (Transmission Line Directorate) 14:00 Meeting with JICA Expert(Mr.OZAKI)							same above
20	2019/4/25	Thu	9:00 TV Meeting with JICA Tokyo (12:15JST) AM Discussion with NEA (Load Dispatch Center) PM Discussion with NEA (Grid Operation Department)							same above
21	2019/4/26	Fri	Wrap-up meeting with NEA						Lv. KTM by KA103 21:15 Ar. HKG (ETD 04:10 4/20)	same above
22	2019/4/27	Sat	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG622 (23:59)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG622 (23:59)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)		Lv. HKG by CX594 07:55 Ar. KIX (ETD 12:55)	
23	2019/4/28	Sun	Ar.Haneda (ETD 06:55)	Ar.KIX (ETD 07:30)	Ar.Haneda (ETD 06:55)	Ar.KIX (ETD 07:30)	Ar.Haneda (ETD 06:55)			

- Second Survey

	Date	Day	Kenichiro YAGI	Shinichi MUROYA	Shinichi KAWABE	Kazuki KONISHI	Yukihiro MIKUMO	Accommodation
			Team Leader／ Power development planning	Transmission and Substation facility planning	Distribution facility planning	Power system analysis	Economic and financial analysis / Organizational structure	
1	2019/6/1	Sat	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	Lv. KIX by TG623 11:45 Ar. BKK (ETD 15:35)	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	Lv. KIX by TG623 11:45 Ar. BKK (ETD 15:35)	Lv. Haneda by TG661 00:20(4/7) Ar. BKK (ETD 05:25 on April 7)	
2	2019/6/2	Sun	Lv. BKK by TG319 10:15 Ar. KTM (ETD 12:25)					Hotel Himalaya
3	2019/6/3	Mon	Meeting with NEA					same above
4	2019/6/4	Tue	AM: Move to Pokhara PM: Site Survey					Hotel Mount Kailash Resort (Pokhara)
5	2019/6/5	Wed	Move to Kathmandu from Pokhara					Hotel Himalaya
6	2019/6/6	Thu	Meeting with NEA					same above
7	2019/6/7	Fri	Meeting with NEA					same above
8	2019/6/8	Sat	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG622 (23:59)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG622 (23:59)	Lv.KTM by TG320 (13:30) Ar. BKK (ETD 18:15) Lv.BKK TG682 (23:15)	
9	2019/6/9	Sun	Ar.Haneda (ETD 06:55)	Ar.KIX (ETD 07:30)	Ar.Haneda (ETD 06:55)	Ar.KIX (ETD 07:30)	Ar.Haneda (ETD 06:55)	

APPENDIX-2

LIST OF PARTIES

Appendix-2：List of Parties

Name	Organization	Department	Position
Mr. Kul Man Ghising Tamang	NEA		Managing Director
Mr. Jagadishwar Man Singh	NEA	Planning, Monitoing & IT Directorate	Duputy Managing Director
Mr. Braj Bhushan Chaudhary	NEA	Transmission Directorate	Duputy Managing Director
Mr. Hara Raj Neupane	NEA	Distribution Directorate	Duputy Managing Director
Mr. Manoj Silwal	NEA	Project Management Directora	Officiating Duputy Managing Director
Mr. Lekha Nath Koirala	NEA	Finance Directorate	Duputy Managing Director
Mr. Rabindra Raj Shrestha	NEA	System Planning Department	Director
Mr. Dirghayu K. Shrestha	NEA	Grid Operation Department	Director
Mr.Gagan Manandhar	NEA	System Control & Network	Director
Mr.Suresh Bdr. Bhattarai	NEA	Grid Operation Department Load Dispatch Center	Chief
Ms.Deepa Shrestha	NEA	Transmission Directorate	Deputy Manager
Mr.Jaddish Chandra Joshi	NEA	Distribution Directorate	Deputy Manager
Mr.Raju Shrestha	NEA	Distribution Directorate	Deputy Manager
Mr. Anjani Kumar MISHRA	NEA	Training Center	Deputy Manager
Mr. Rajan Raj Bista	NEA	Finace Directorate	Director
Mr. Nawa Raj Basnet	NEA	Finace Directorate	Charterd Accountant NEA
Mr. Umesh Kumalr Bhandari	NEA	Nepal India Transmission and Trade Project	Director
Ms. Jamuna Khadka	NEA	Administration Directorate (Central Personal Administration Section)	Section Chief
(Load Dispach Center)			
Mr. Surendra Prasad Agrahari	NEA	Grid Operation Department Kathmandu Grid Division	Manager/Chief
(Nepalgunj)			
Er. Sujan Paudel	NEA	Kohalpur Substation	Engineer
Er. Oman BC	NEA	Kohalpur Substation	Engineer
Er. R. D. Yodav	NEA	Nepalgunji Distribution Center	Chief
Mr. Lal Bahadur Buda	NEA	Nepalgunji Regional Office	Senior Engineer
(Pokhara)			
Mr.Suresh Bahadur Chhetri	NEA	Pokhra Regional Office	Regional Chief
Mr.Kailash Pantha	NEA	Pokhra Regional Office	Electrical Engineer
Mr.Sadam Bala	NEA	Pokhra Regional Office	Electrical Engineer
Mr. Kapili Paudel	NEA	Pokhara Electric Grid Office (Pokhara Substation兼任)	Asst. Engineer

Name	Organization	Department	Position
(RPGCL)			
Dr. Netra P. GYAWALI	RPGCL	RPGCL HQ	Chief Executive Officer
Mr. Ashish Bhandari	RPGCL	RPGCL HQ	Contract Engineer
Mr. Sujan Koirala	RPGCL	Karnali Corridor 400kV T/L Project	Sr. Transmission System Engineer, Project Manager
(Donners)			
Mr. Rabin Shrestha	World Bank		Senior Energy Specialist
Mr.Bhishma Pandit	World Bank (IFC)	Energy & Water	Operations Officer
Ms.Kamana K.C. Shah	World Bank (IFC)	Energy & Resource Efficiency Advisory	Consultant
(Japanese)			
Ms.Yumiko ASAKUMA	JICA Nepal Office		Chief Representative
Mr.Kozo NAGAMI	JICA Nepal Office		Senior Representative
Mr.Naoki NISHIMURA	JICA Nepal Office		Representative
Mr.Yukiyoshi OZAKI	NEA		JICA Export

APPENDIX-3

PSS/E

Appendix-3：PSS/E

(1) Pokhara S/S

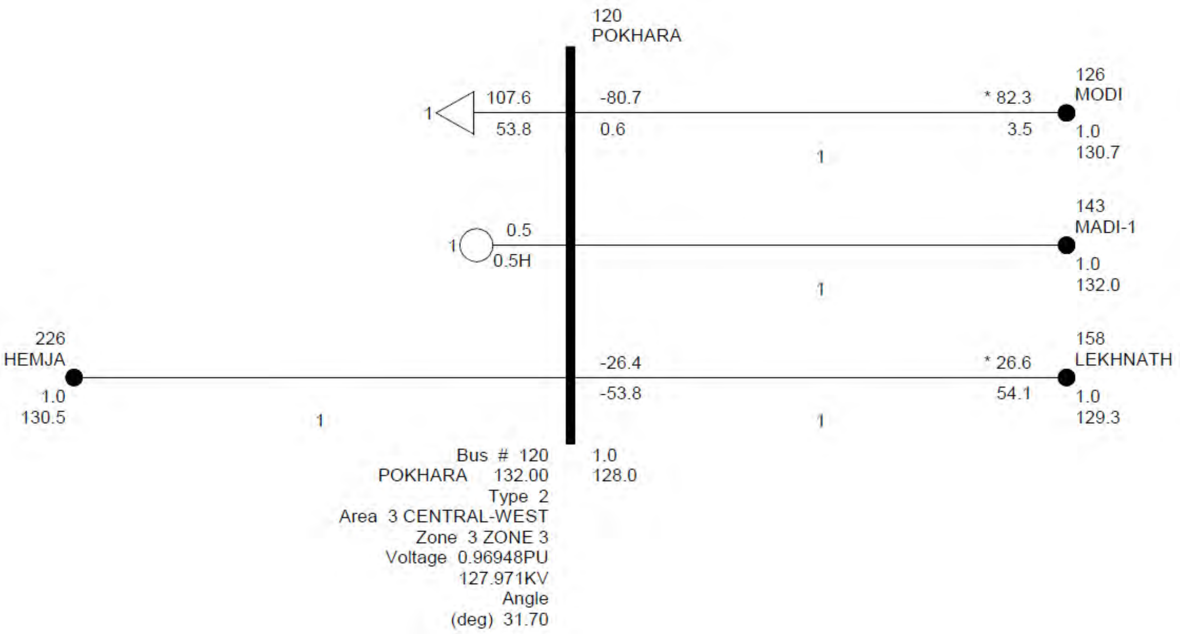


Figure 1 The result of power flow caluculation (132kV Pokhara S/S)

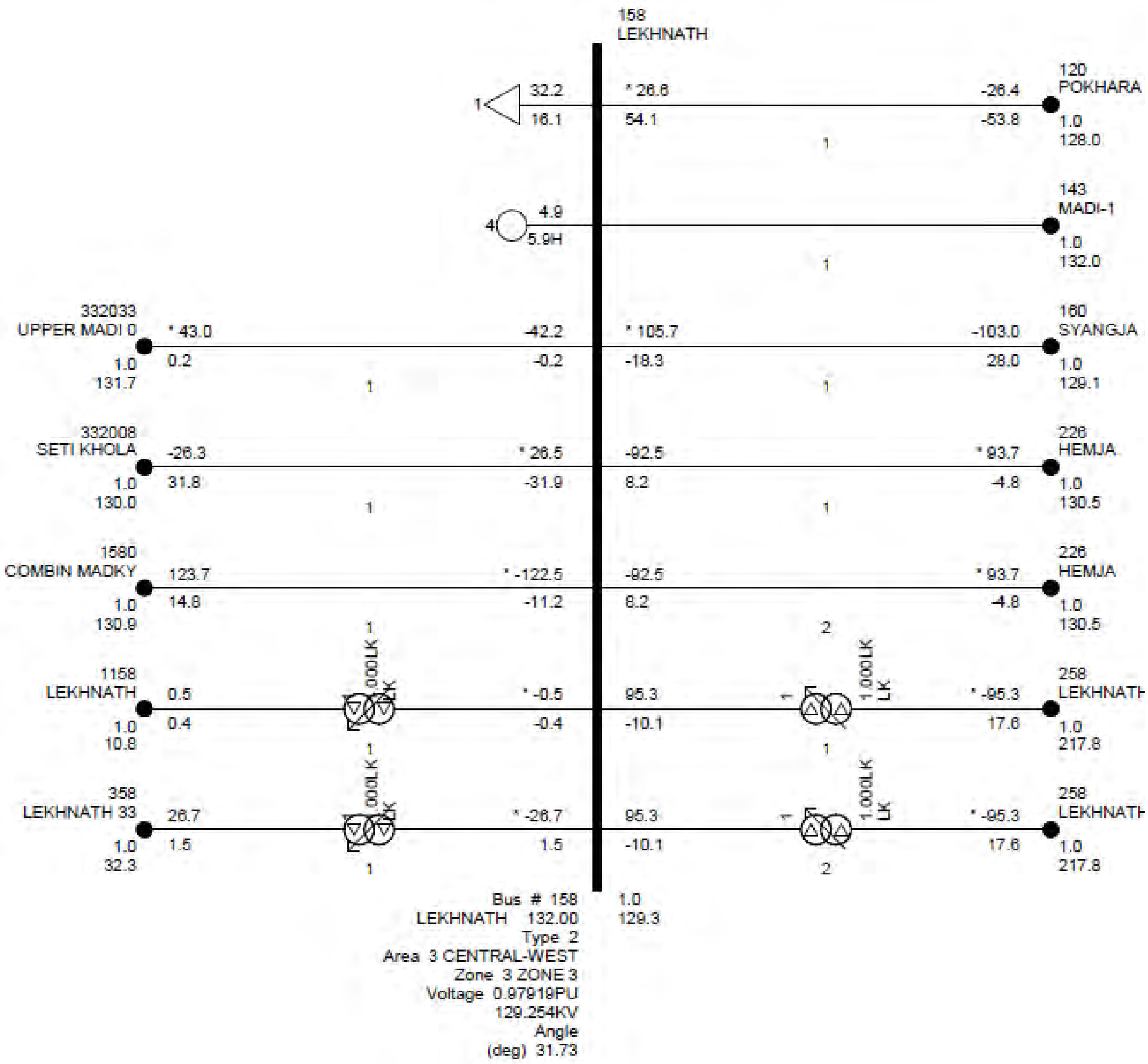


Figure 2 The result of power flow caluculation (132kV Lekhnath S/S)

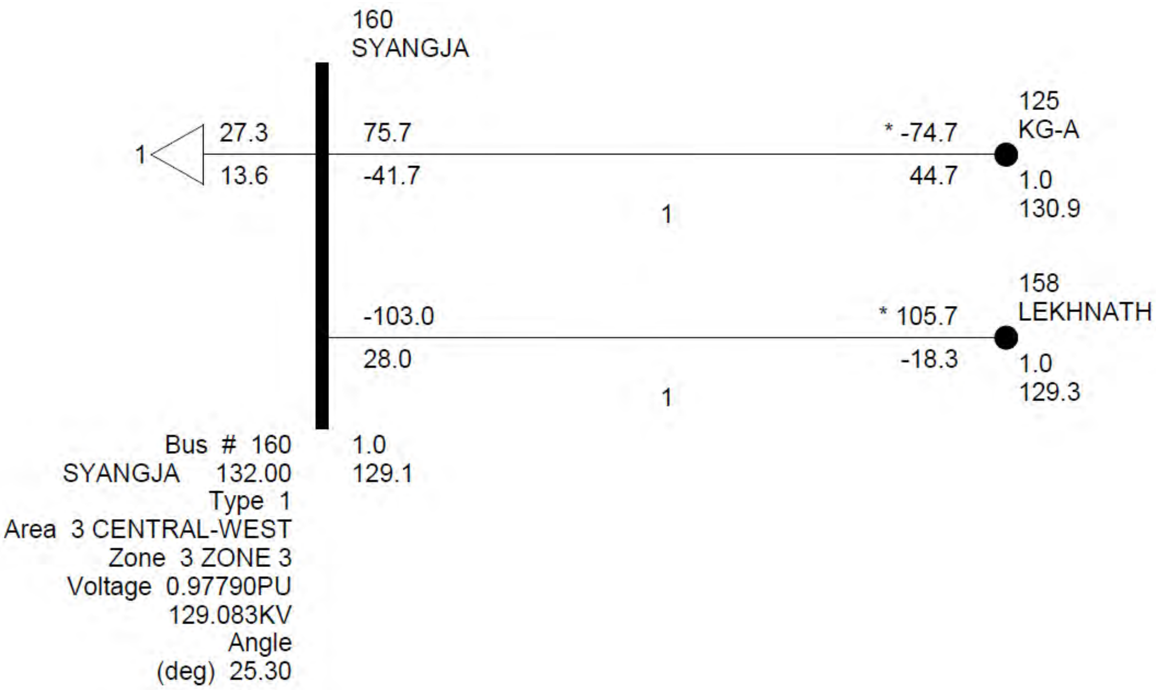


Figure 3 The result of power flow caluculation (132kV Syangja S/S)

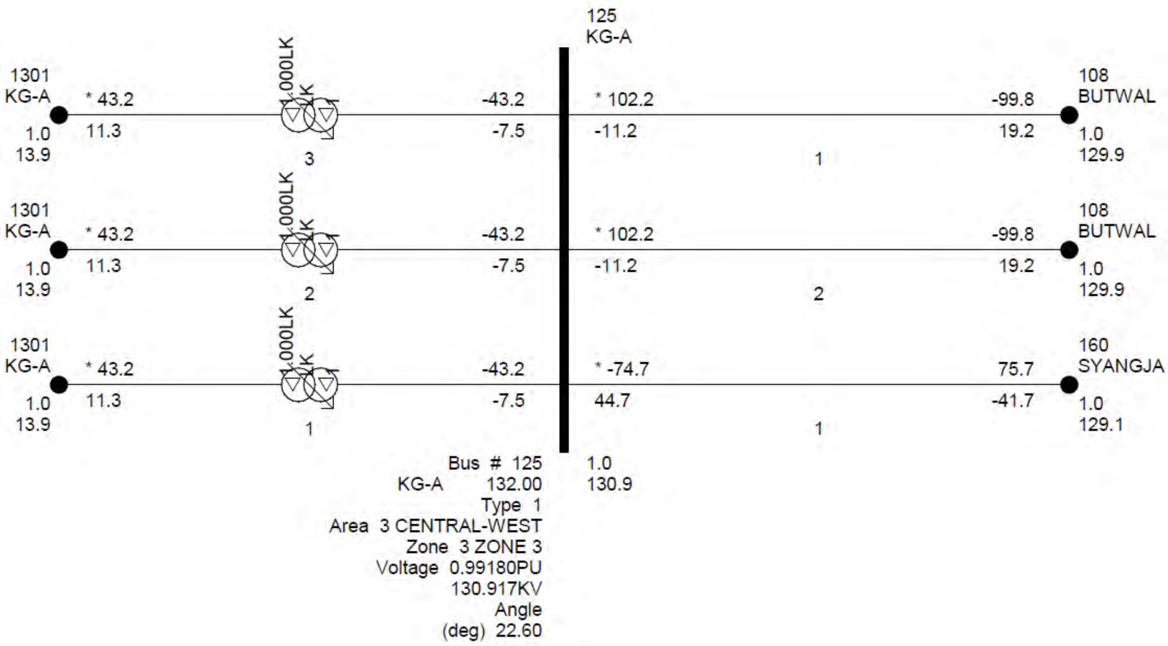


Figure 4 The result of power flow caluculation (132kV KG-A S/S)

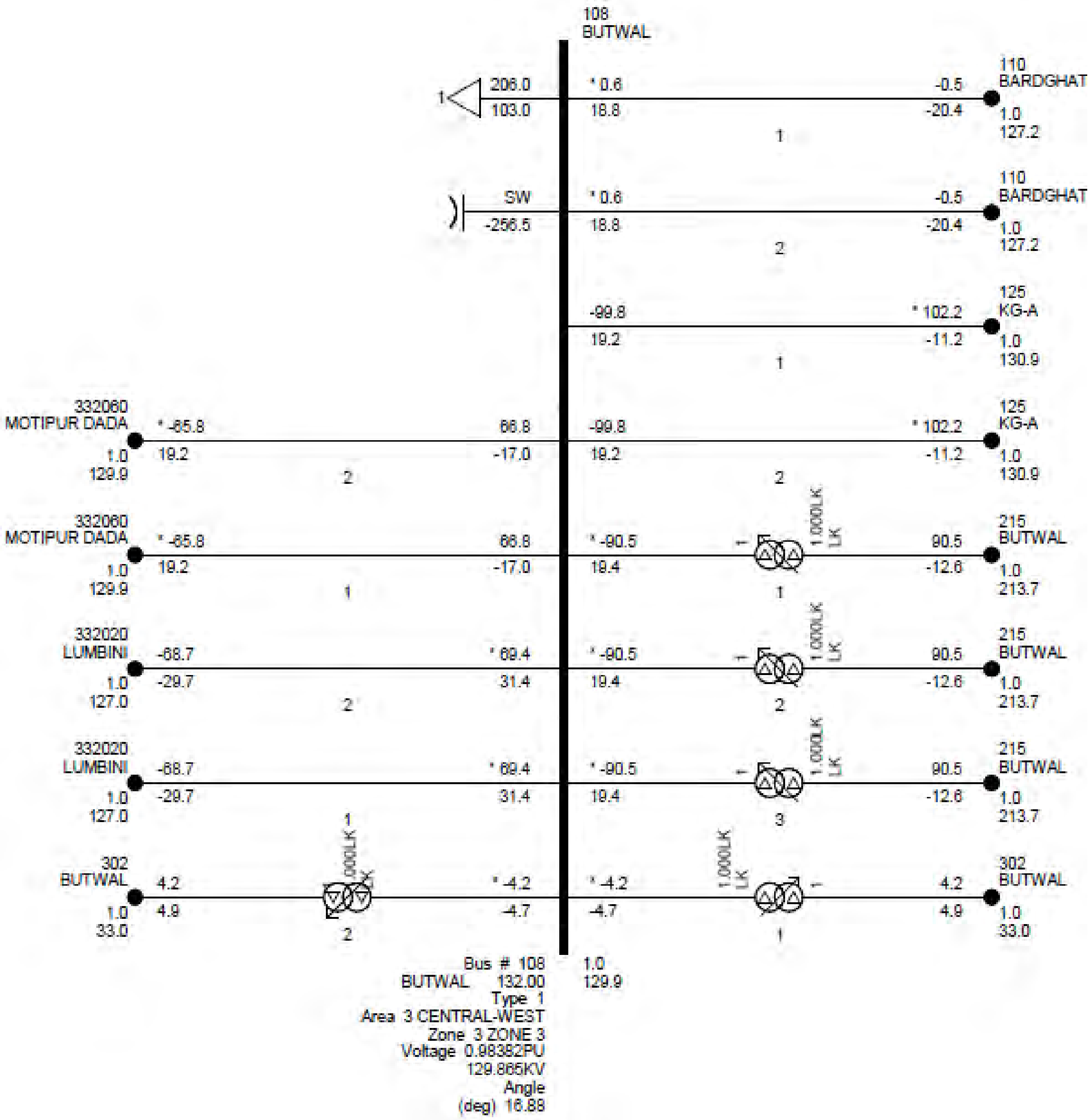


Figure 5 The result of power flow caluculation (132kV Butwal S/S)

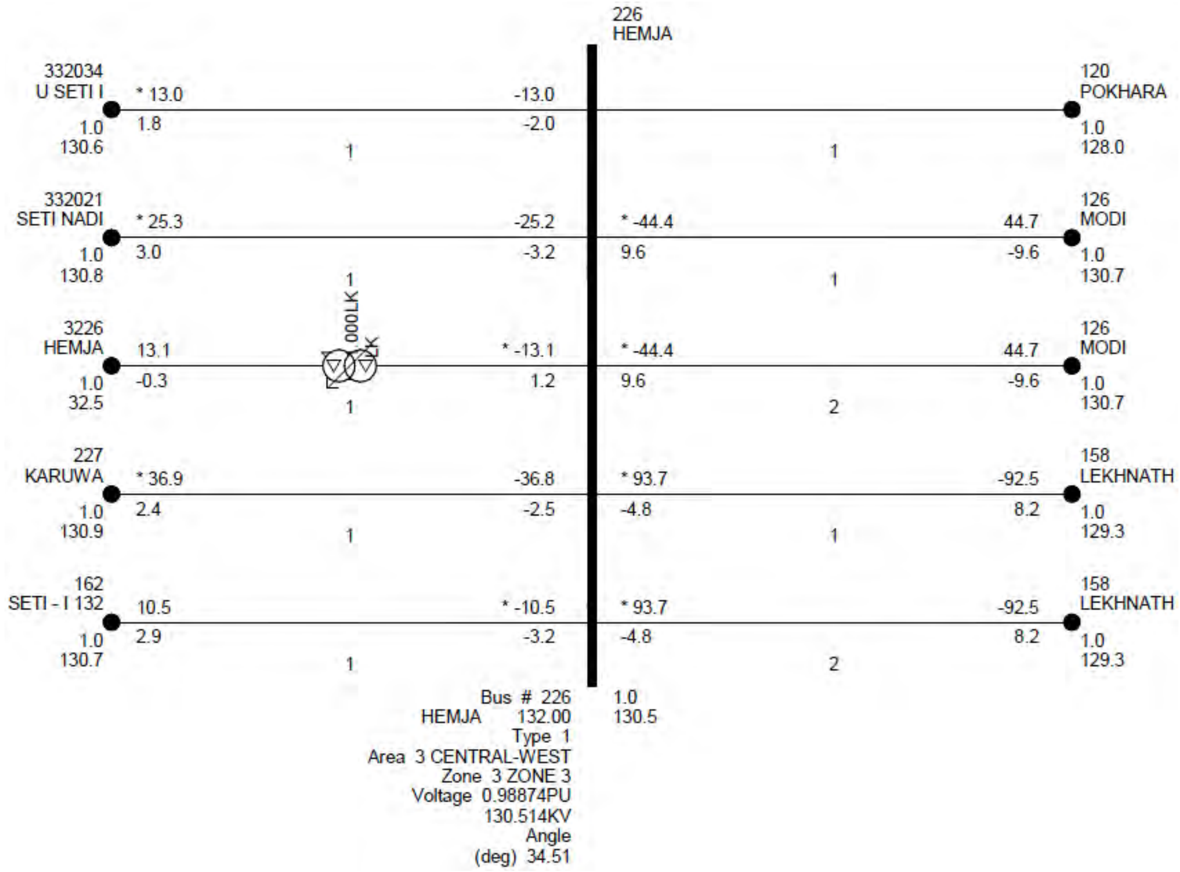


Figure 6 The result of power flow caluculation (132kV Hemja S/S)

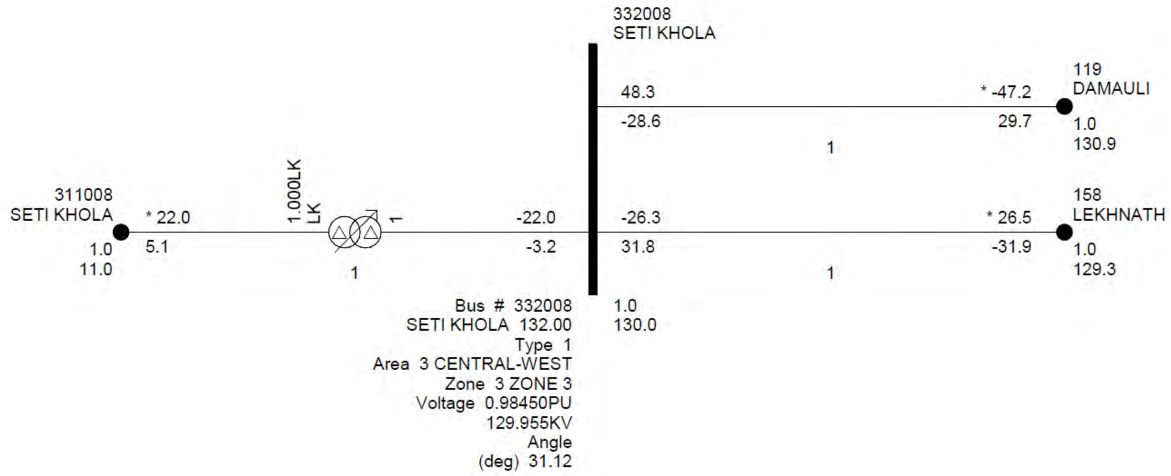


Figure 7 The result of power flow caluculation (132kV Seti Khola S/S)

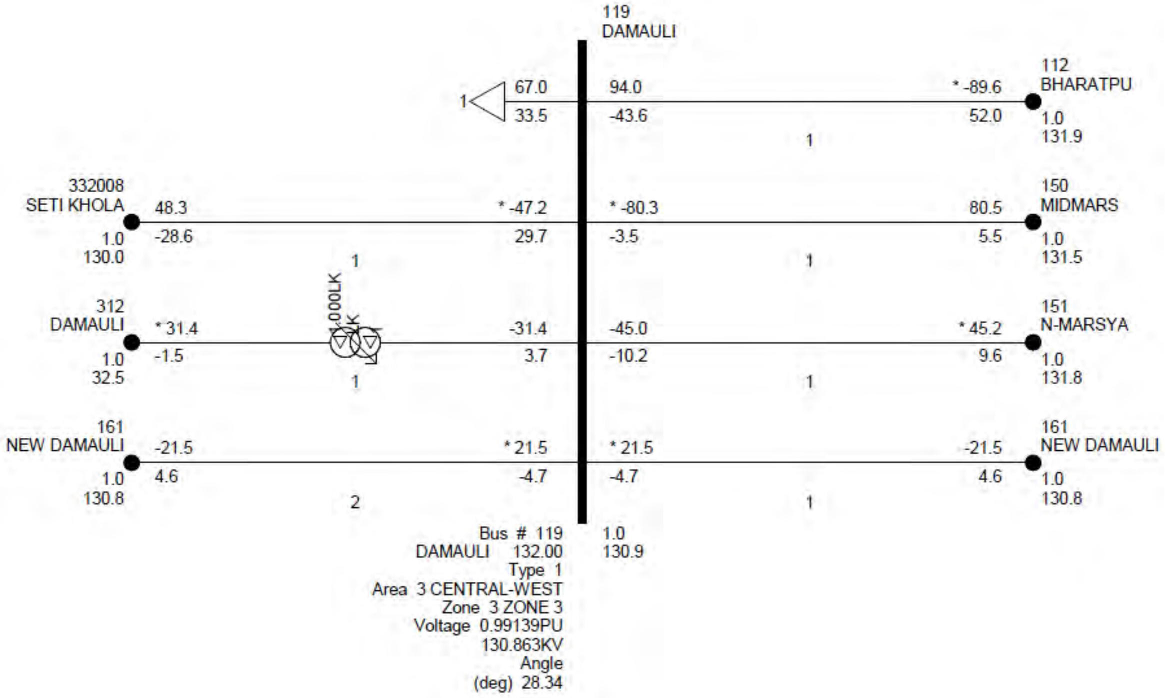


Figure 8 The result of power flow caluculation (132kV Damauli S/S)

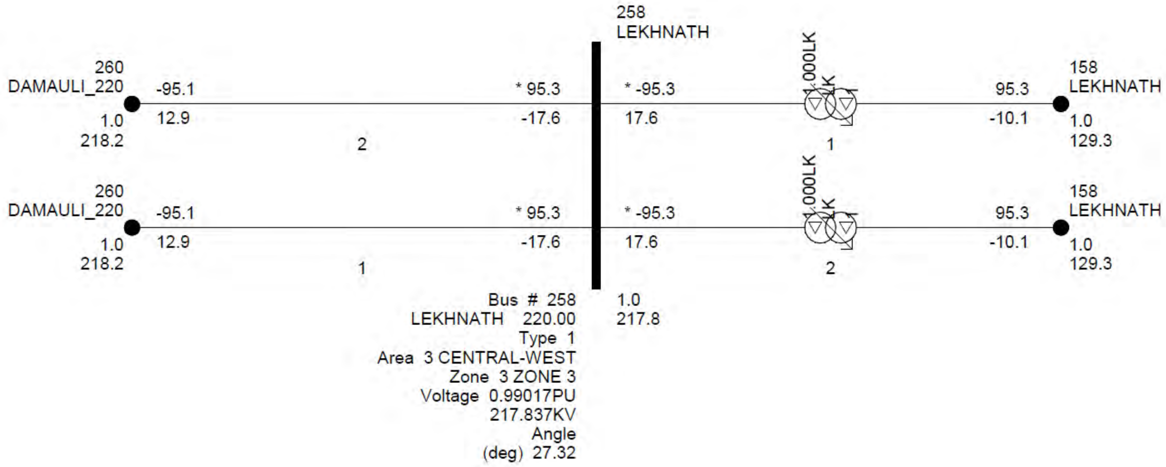


Figure 9 The result of power flow caluculation (220kV Lekhnath S/S)

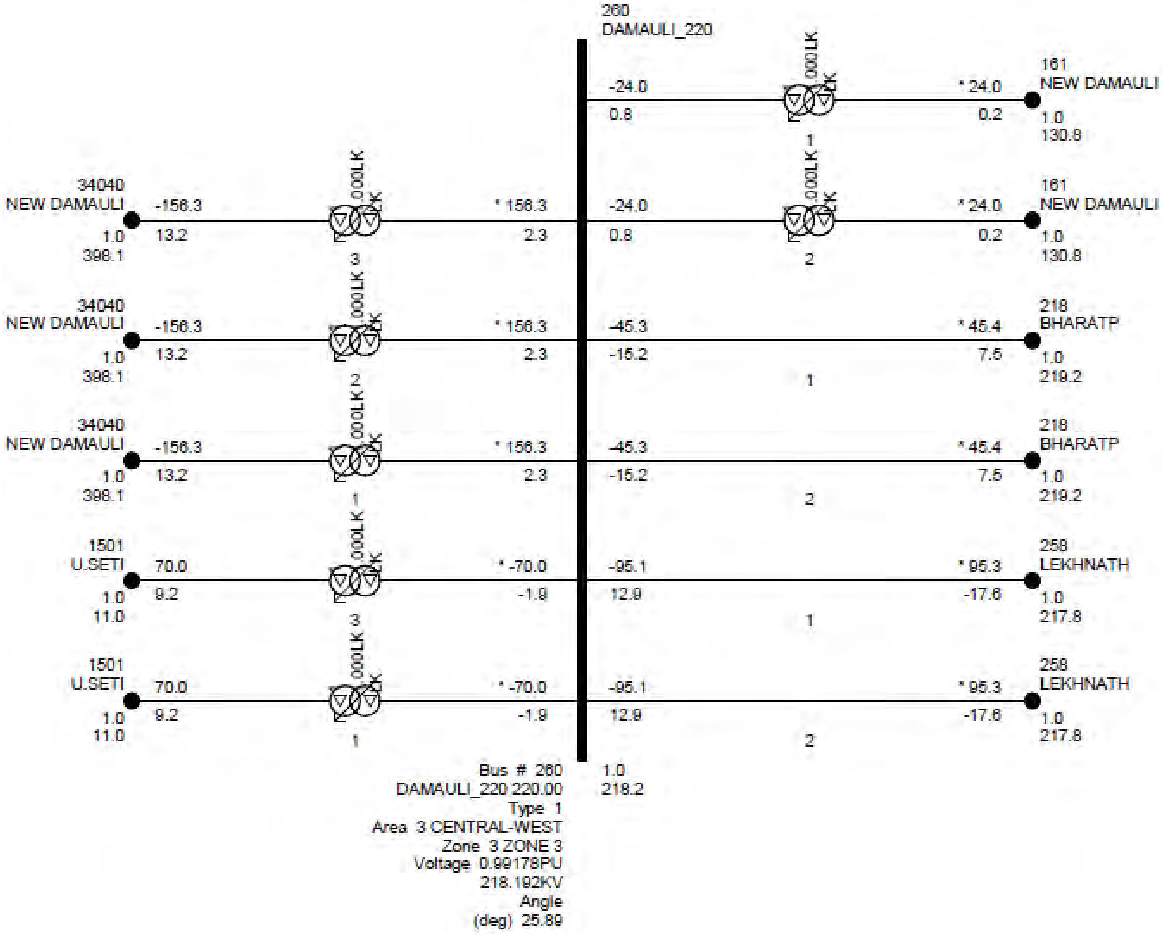


Figure 10 The result of power flow caluculation (220kV Damauli S/S)

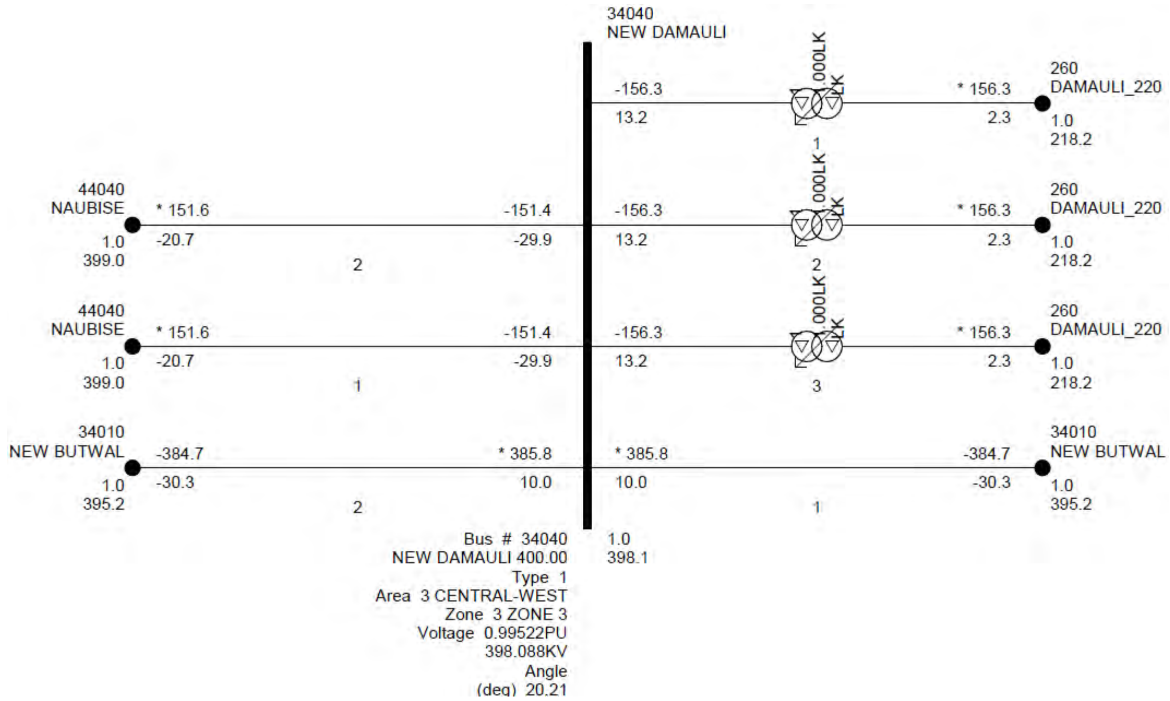


Figure 11 The result of power flow caluculation (400kV New Damauli S/S)

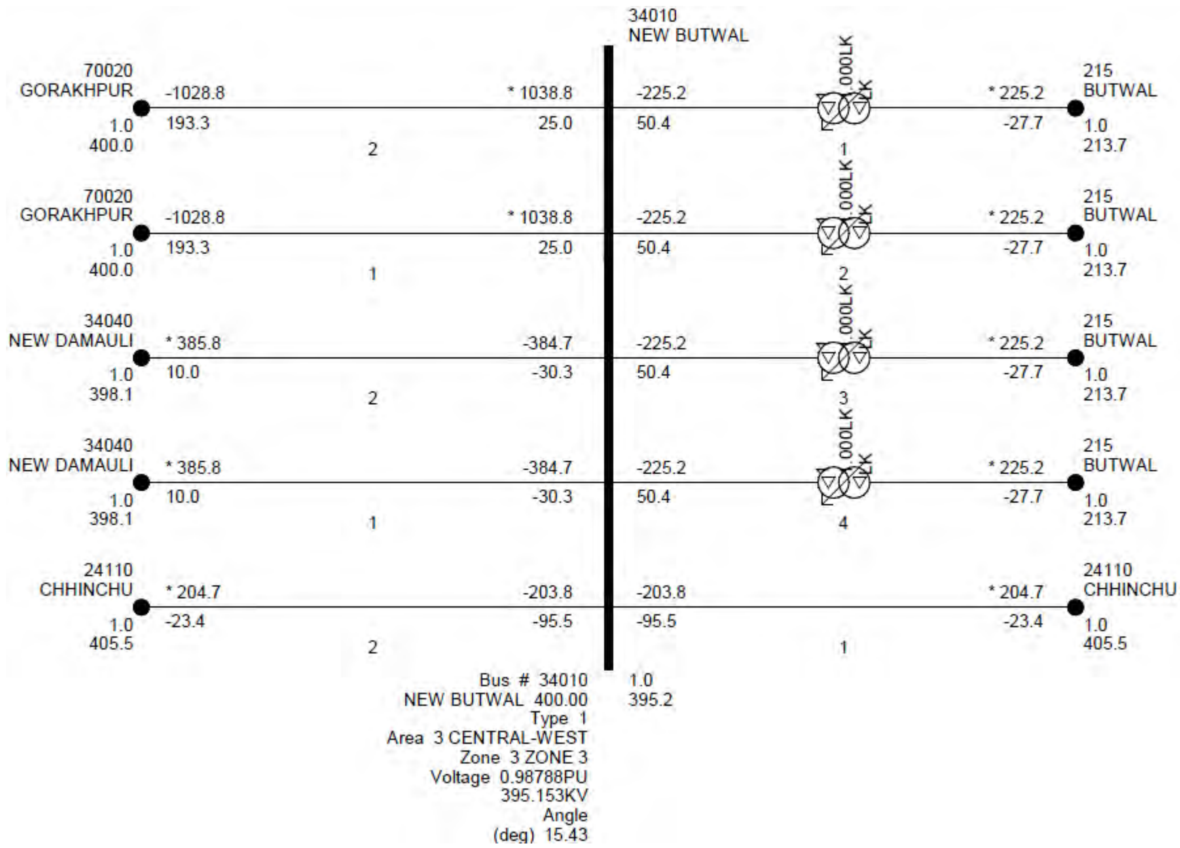


Figure 12 The result of power flow caluculation (400kV New Butwal S/S)

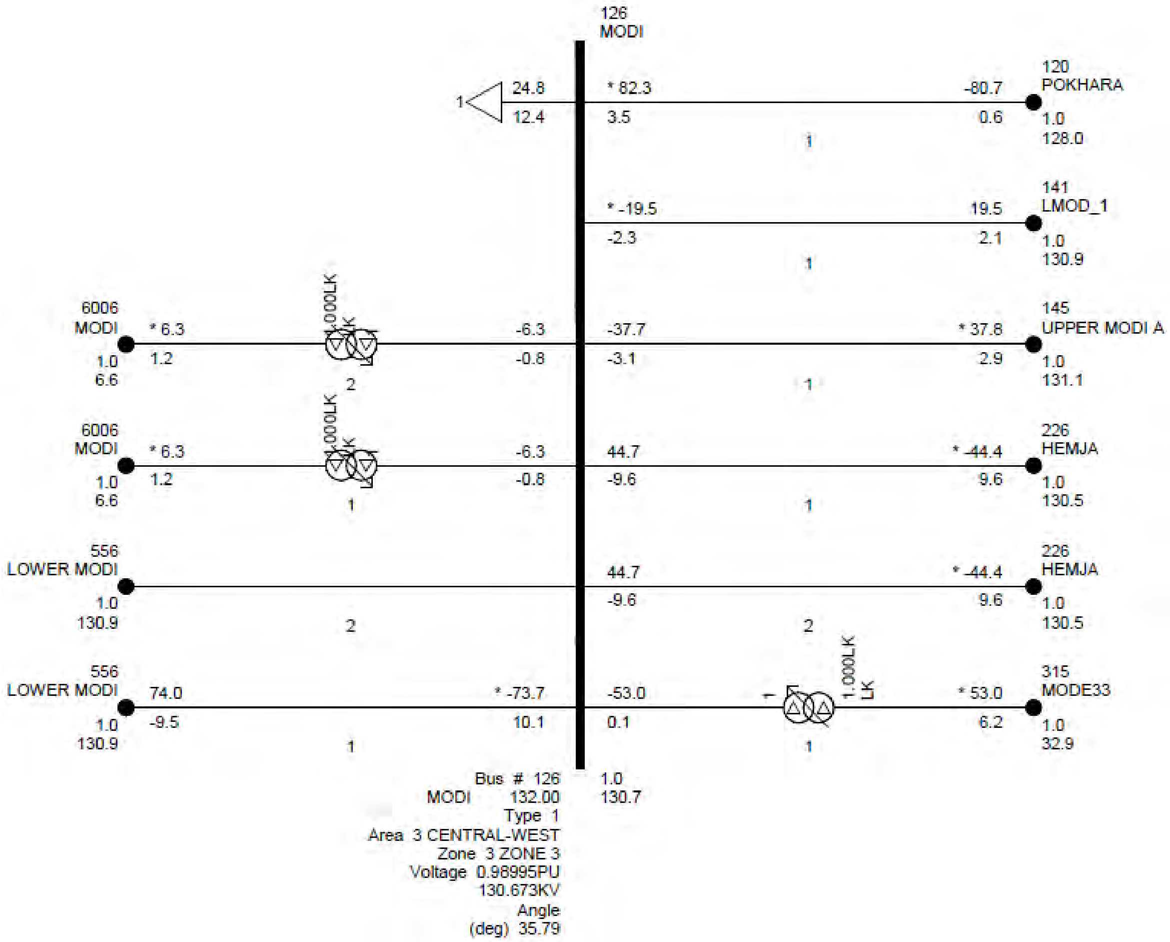


Figure 13 The result of power flow caluculation (132kV Modi S/S)

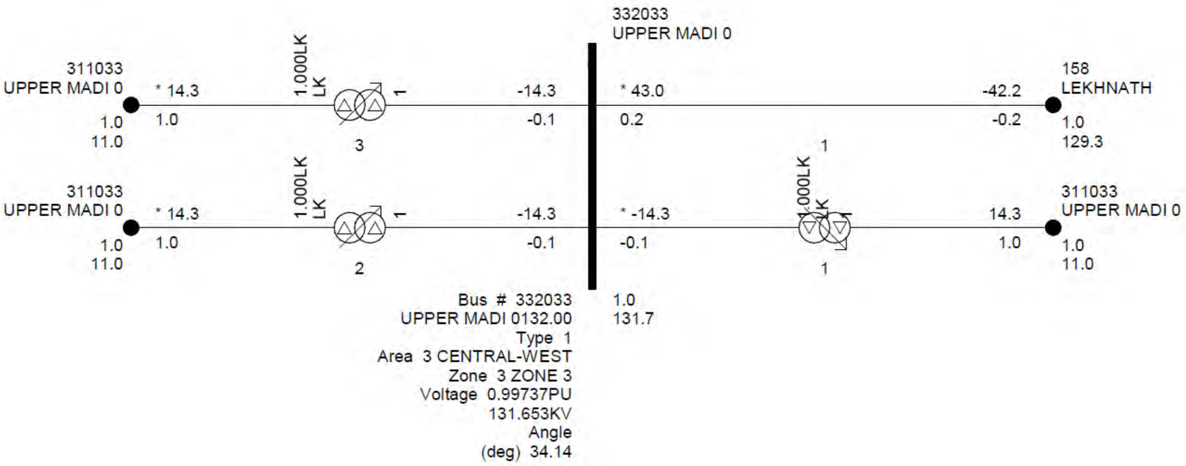


Figure 14 The result of power flow caluculation (132kV Upper Madi S/S)

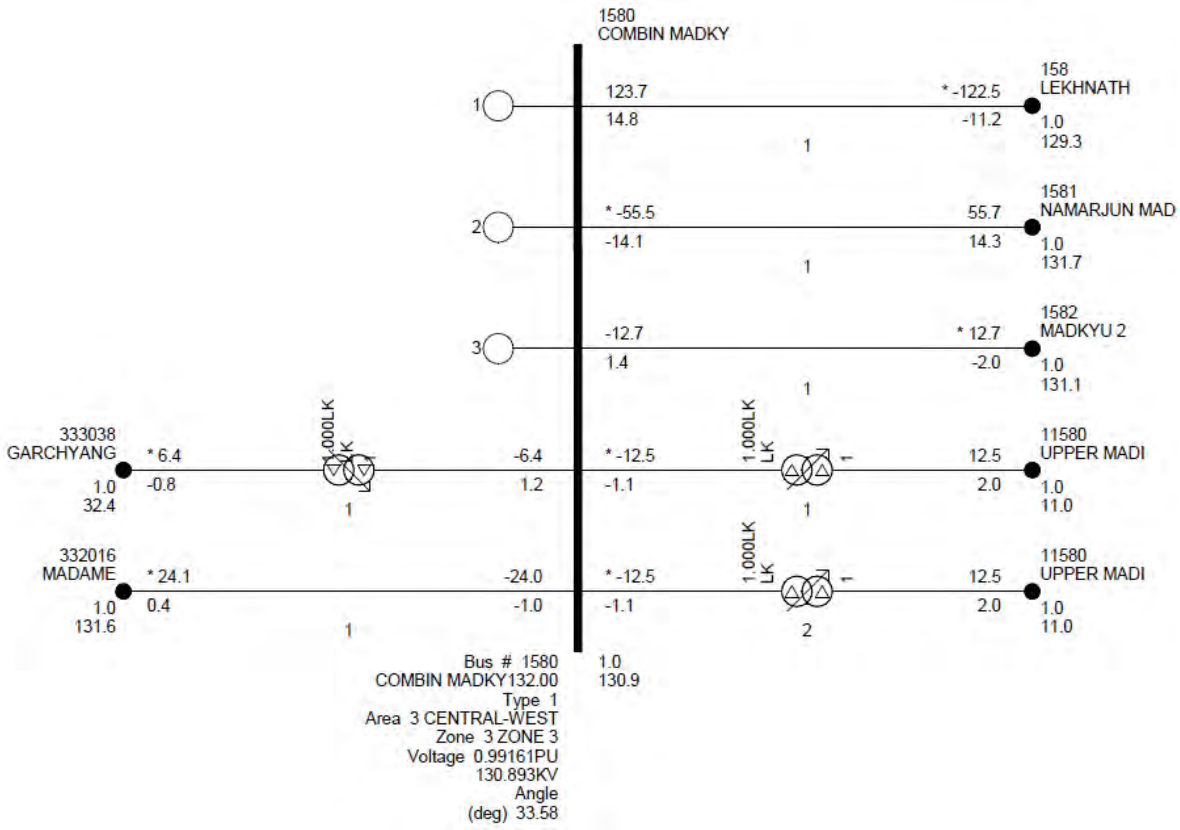


Figure 15 The result of power flow caluculation (132kV Combin Madky S/S)

(2) Nepalgunj S/S

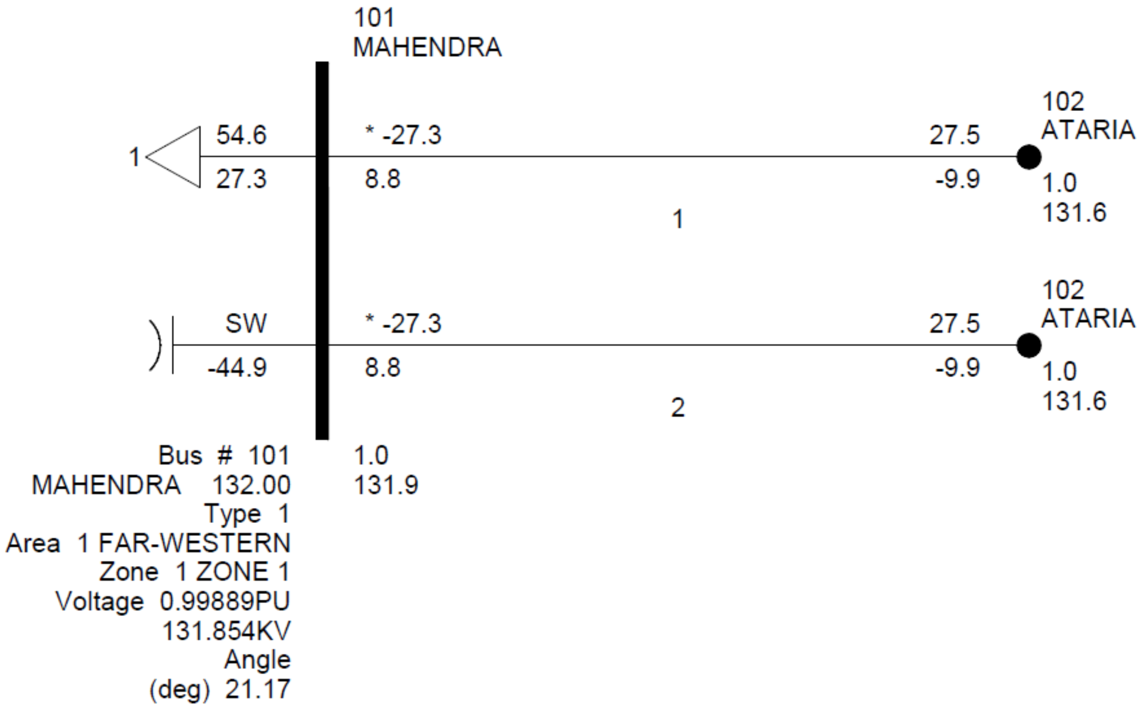


Figure 16 The result of power flow caluculation (132kV Mahendra S/S)

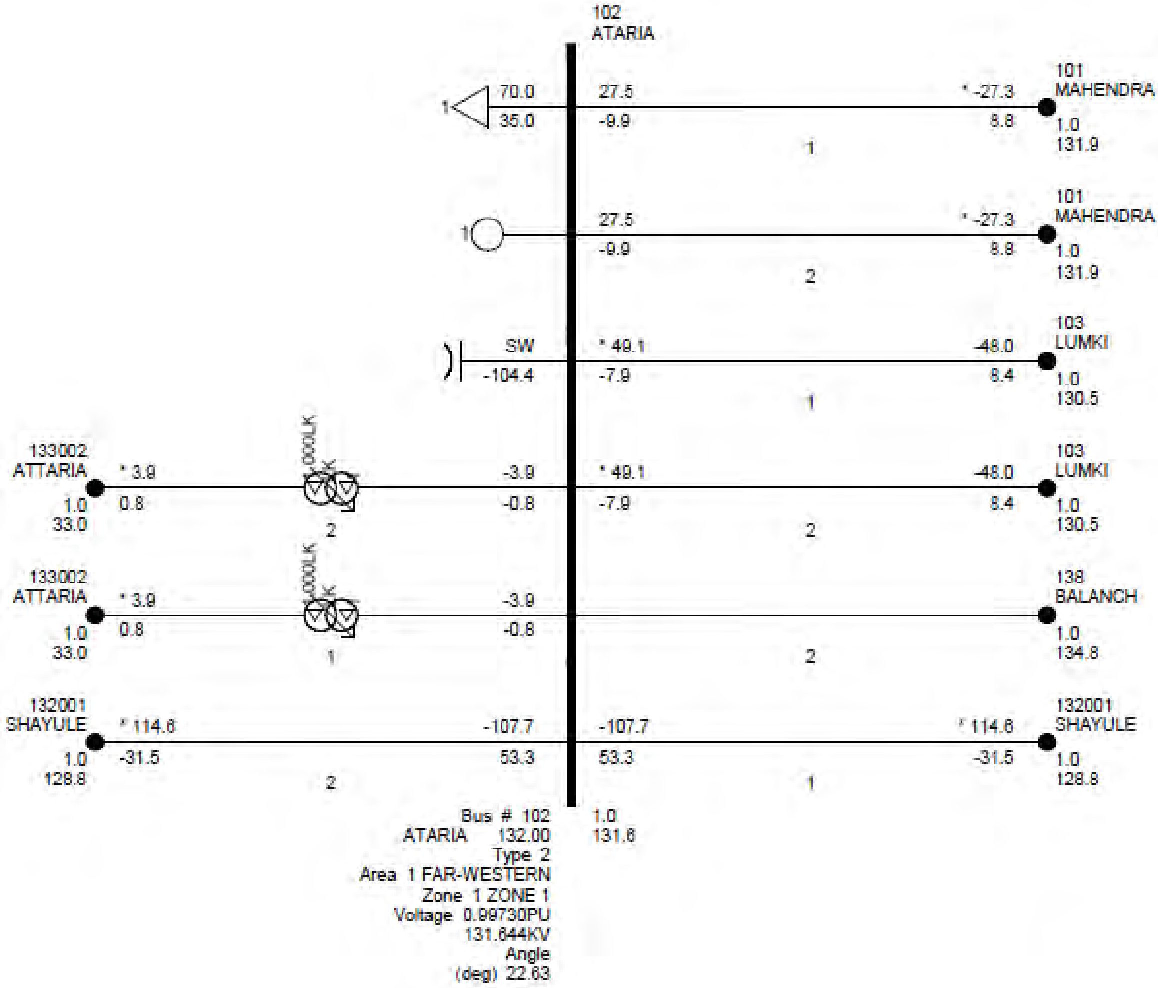


Figure 17 The result of power flow caluculation (132kV Ataria S/S)

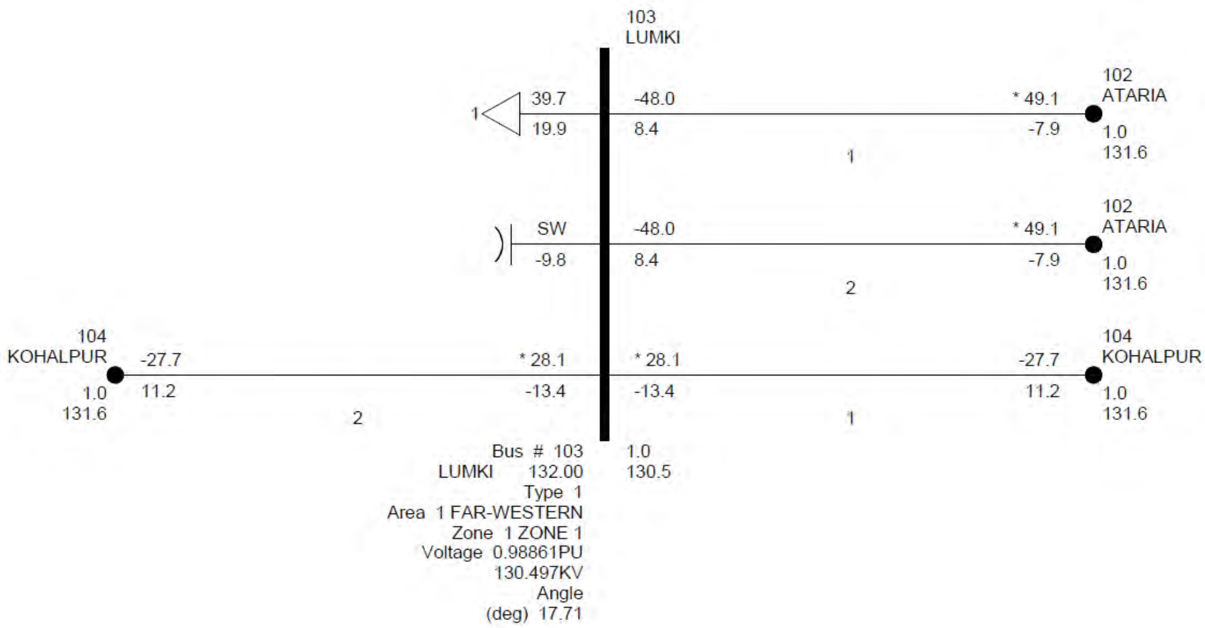


Figure 18 The result of power flow caluculation (132kV Lumki S/S)

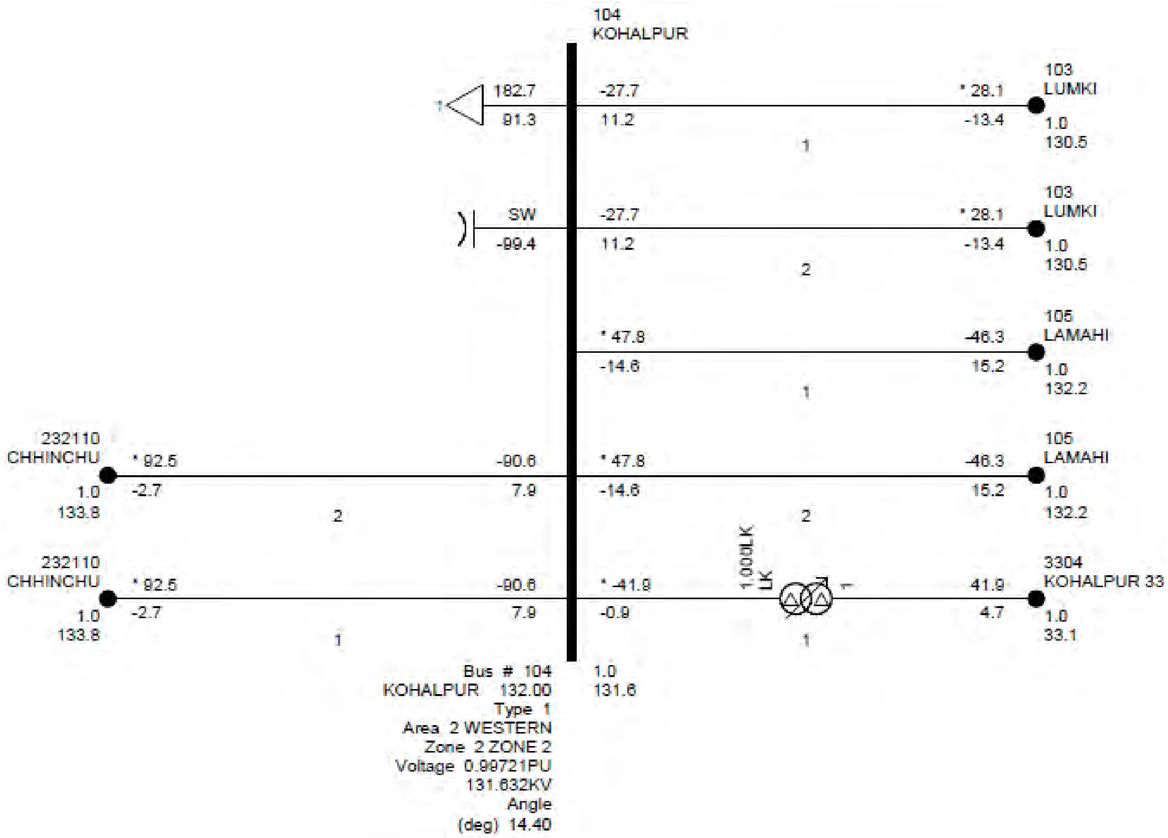


Figure 19 The result of power flow caluculation (132kV Kohalpur S/S)

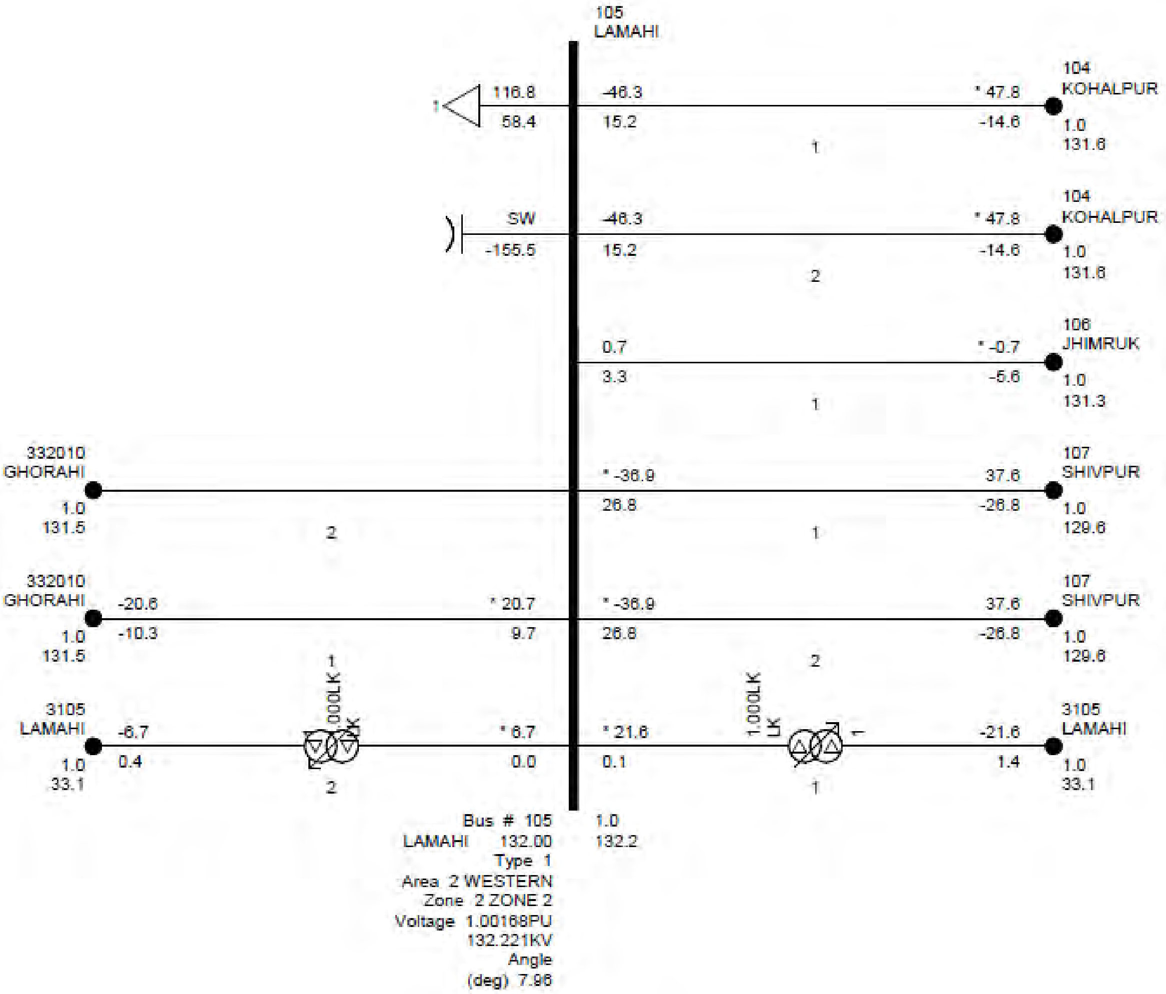


Figure 20 The result of power flow caluculation (132kV Lamahi S/S)

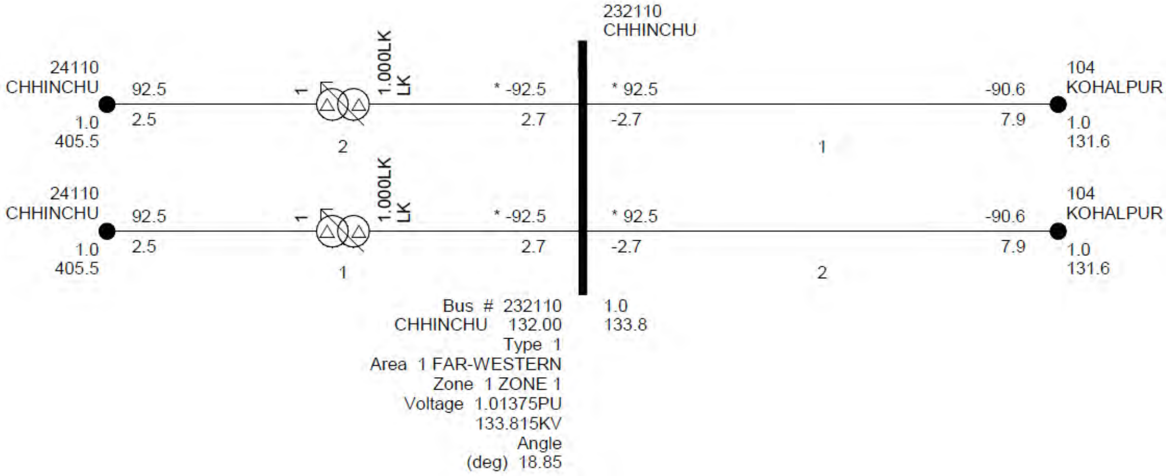


Figure 21 The result of power flow caluculation (132kV Chhinchu S/S)

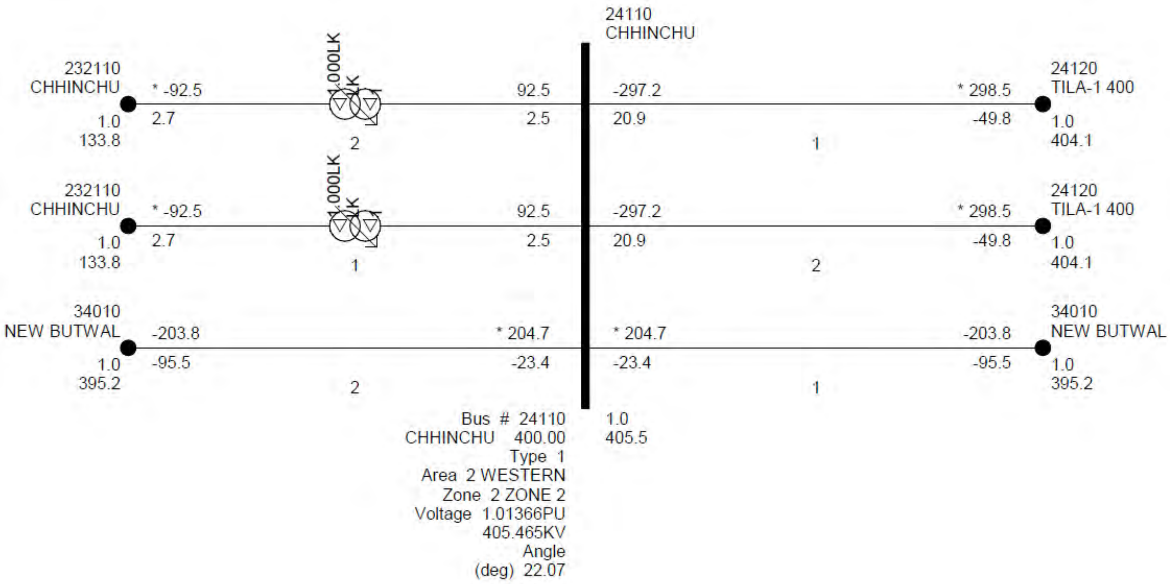


Figure 22 The result of power flow caluculation (400kV Chhinchu S/S)

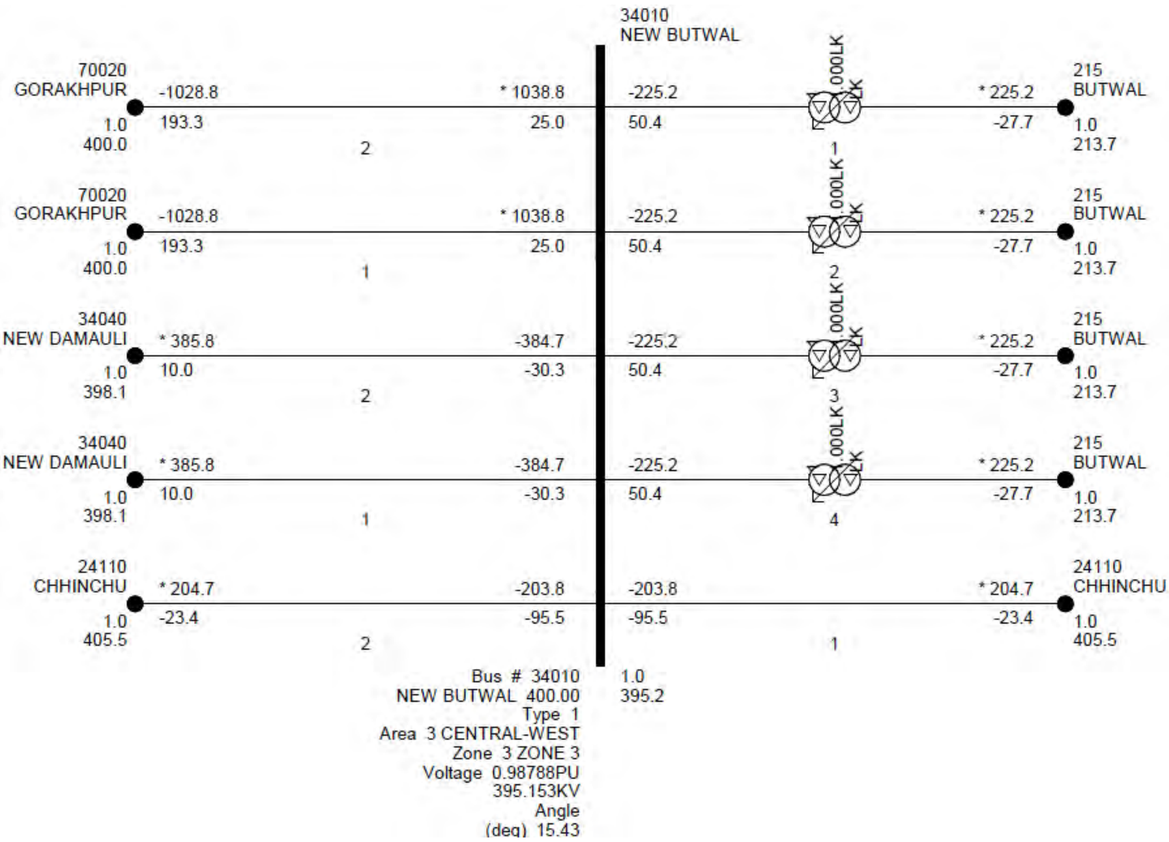


Figure 23 The result of power flow caluculation (400kV New Butwal S/S)

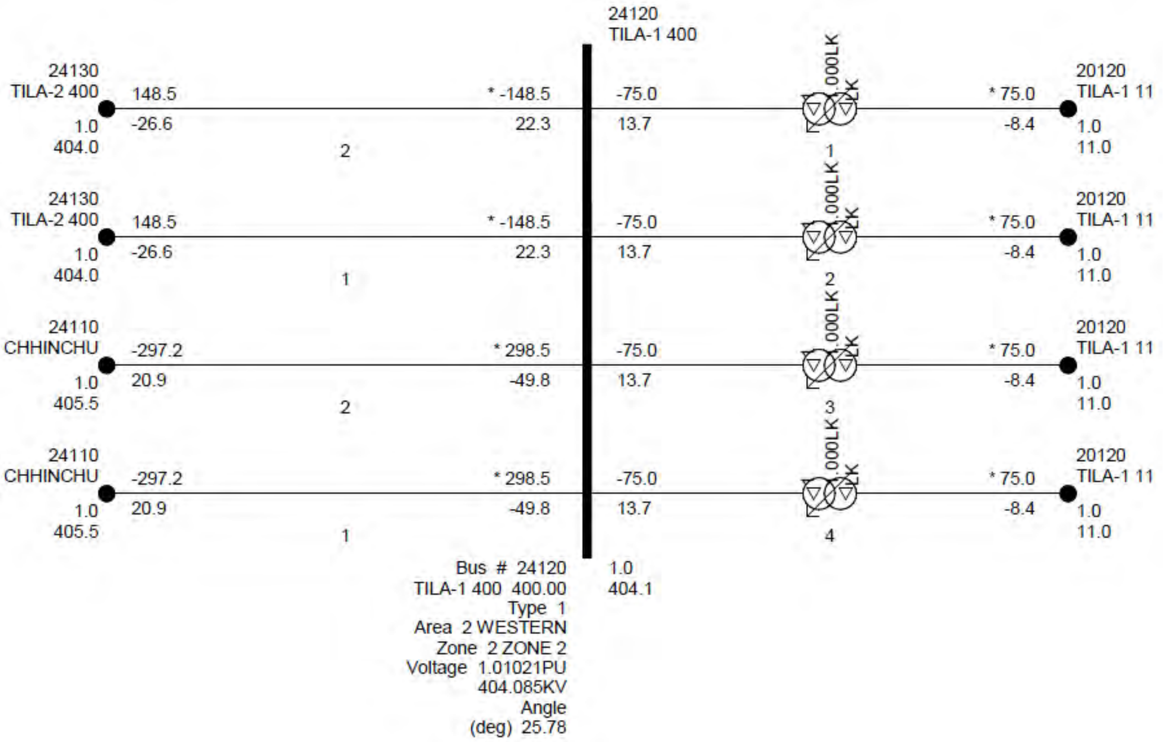


Figure 24 The result of power flow caluculation (400kV Tila 1 S/S)

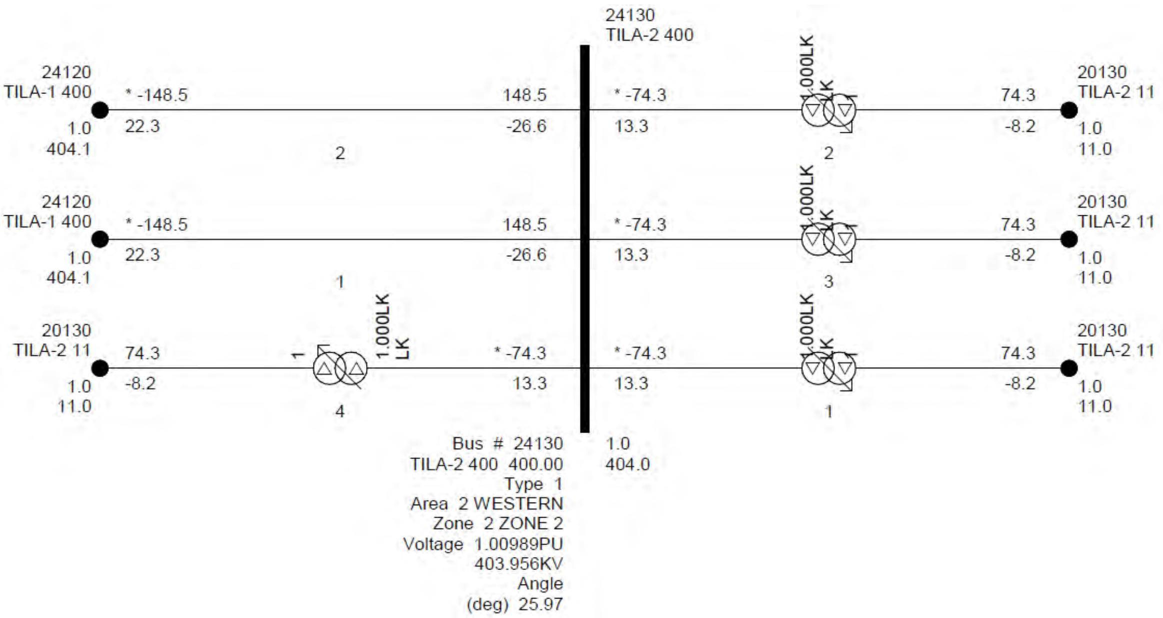


Figure 25 The result of power flow caluculation (400kV Tila-2 S/S)

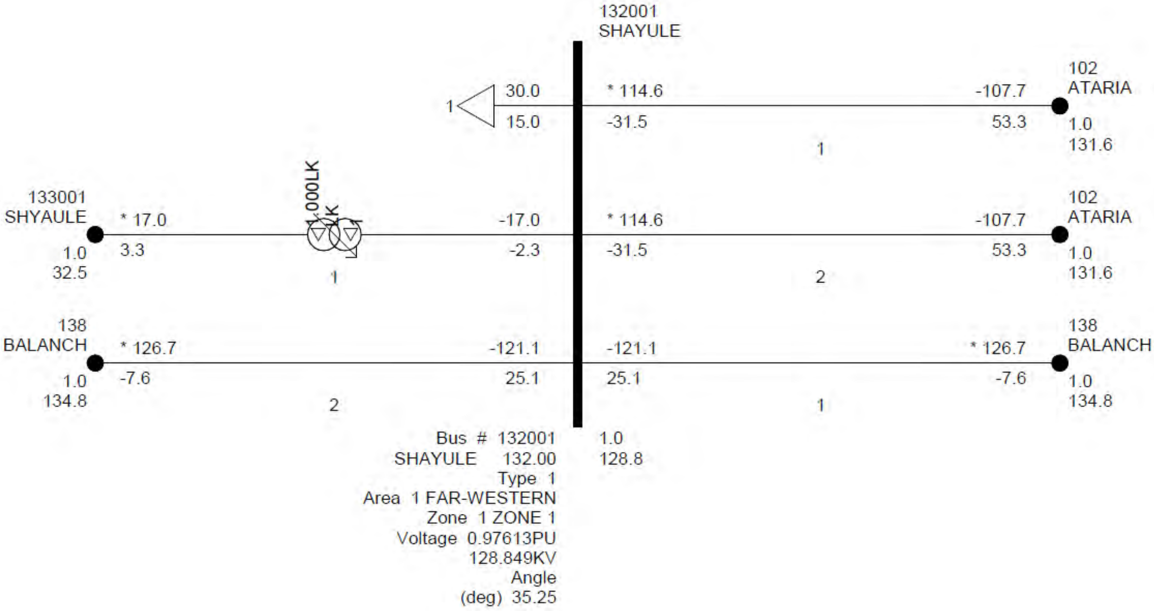


Figure 26 The result of power flow caluculation (132kV Shayule S/S)

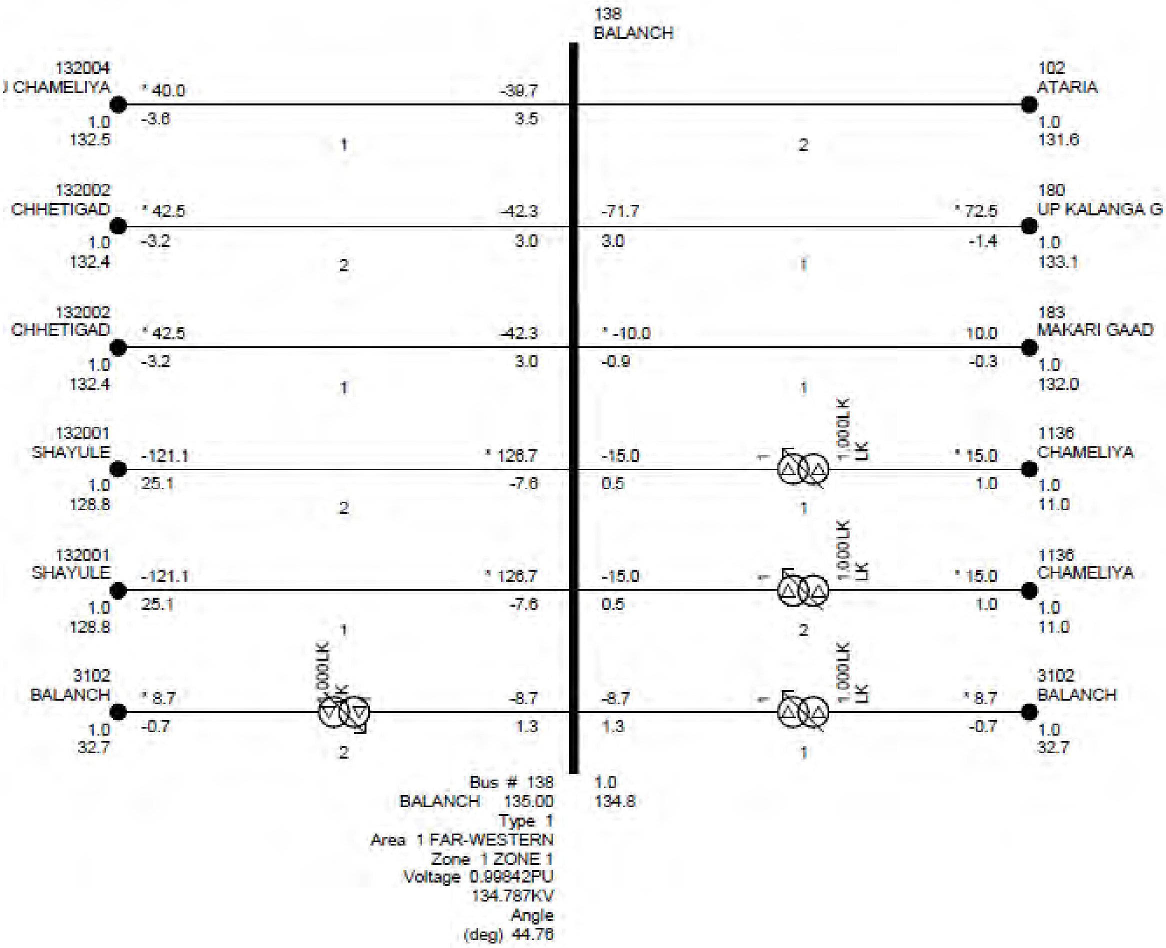


Figure 27 The result of power flow caluculation (132kV Balanch S/S)

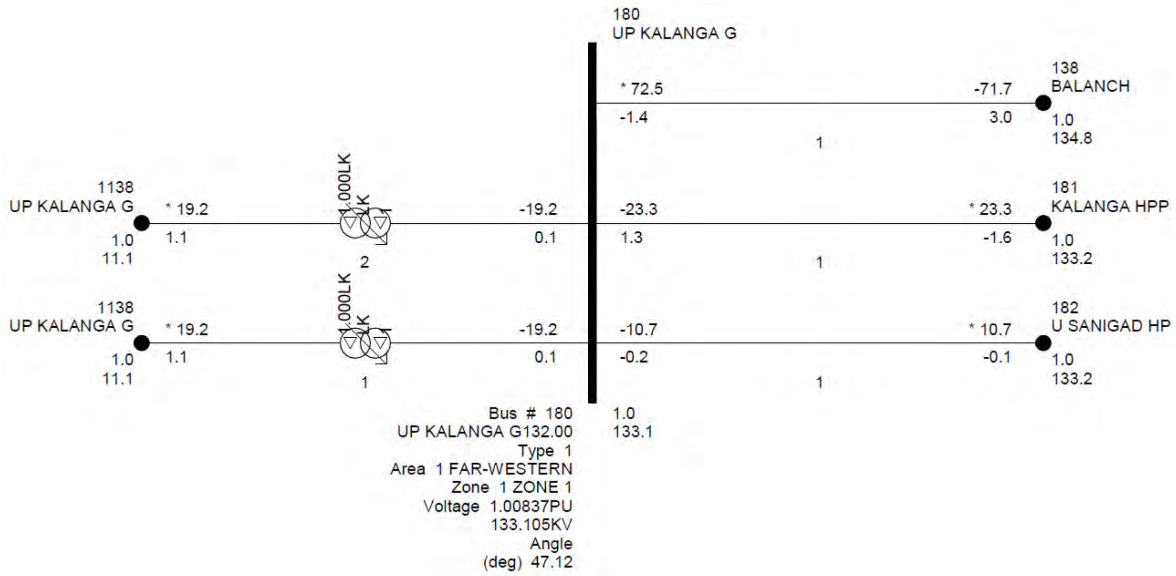


Figure 28 The result of power flow caluculation (132kV Up Kalanga G S/S)

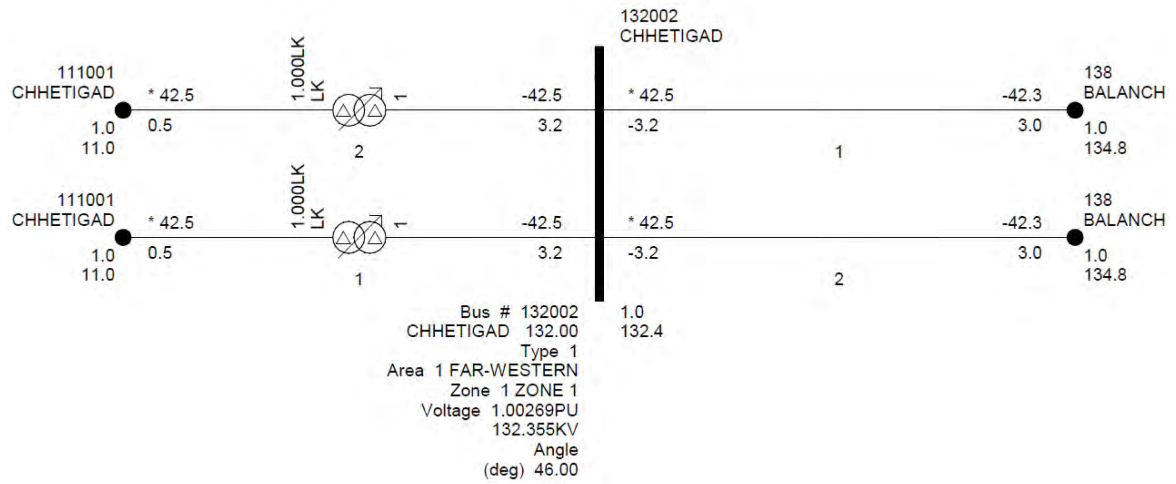


Figure 29 The result of power flow caluculation (132kV Chhetigad S/S)

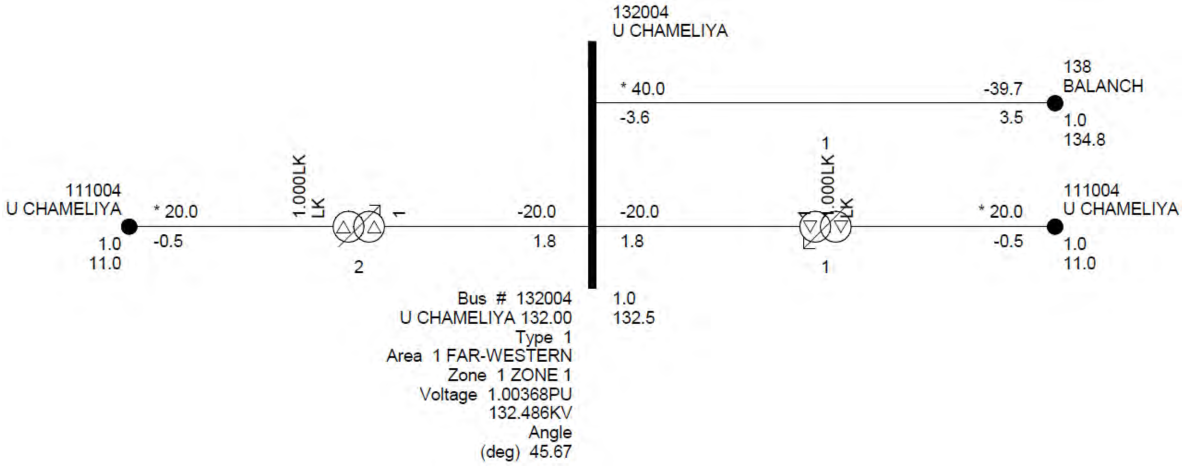


Figure 30 The result of power flow caluculation (132kV U Chameliya S/S)

APPENDIX-4

PRESENTATION MATERIAL

Data Collection Survey on Transmission and Distribution Network Development in Nepal

Second Field Survey

June 2019

Japan International Cooperation Agency

NEWJEC Inc. **The Kansai Electric Power Co., Inc.**

1.Background

As per the Study related to Power sector is described below

2015 : Transmission System Master Plan of NEA (TSMP) was prepared.

2016 : Integrated Master Plan for Evacuation of Power from Hydro Projects in Nepal (IMP) was prepared.

2018 March : Final report of Data Collection Survey on hydropower development project was prepared by JICA (NEWJEC and KANSAI).

2018 July : Transmission System Development Plan of Nepal (TSDP) was prepared by RPGCL .

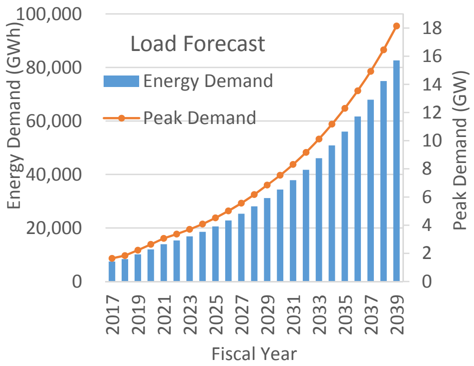
2019 February : JICA dispatched the contact mission for the transmission / distribution development in Nepal

2019 March : Data Collection Survey on the PPP Modality in Hydropower Project by JICA (NEWJEC and KANSAI) was started.

2019 April : Data Collection Survey on Transmission and Distribution Network Development by JICA (NEWJEC and KANSAI) was started.

RPGCL: Ratriya Prasaran Grid Co. Ltd.

2.Current issues of Electric Power Sector



Estimated Power Demand

Power Demand and Supply Capacity

Item			FY 2011	2012	2013	2014	2015	2016	Annual Growth Rate(%)
Installed capacity(MW)			706	719	762	787	787	856	3.9
Peak demand(MW)			946	1,027	1,095	1,201	1,292	1,385	7.9
Supply capacity shortage(MW)			240	308	333	414	505	529	17.1
Electricity requirement(GWh)			4,833	5,195	5,446	5,910	6,335	6,920	7.4
Supply (GWh)	NEA	Hydro	2,122	2,357	2,273	2,288	2,366	2,168	0.4
		Thermal	3	2	19	10	1	0.1	0
		Total NEA	2,123	2,359	2,292	2,298	2,367	2,169	0.3
	IPPs		1,039	1,074	1,176	1,070	1,269	1,173	2.5
	Imports		694	746	790	1,319	1,370	1,758	20.4
	Total		3,858	4,179	4,258	4,687	5,006	5,100	5.7
Supply shortage(GWh)			975	1,018	1,188	1,223	1,329	1,820	13.3

Source: NEPAL ENERGY SECTOR ASSESSMENT, STRATEGEY, AND ROAD

Development of power generation capacity is required for solutions of demand and supply gap. <u>At the same time, development of transmission line and distribution network also required.</u>

3.Outline of the survey (1)

Category	Contents
Purpose	Clarify the development status and plans in the power transmission and distribution sector, for the major cities of Nepal and identify the need for assistance (financial assistance and technical cooperation) concerning the development of transmission and distribution network. Also, clarify the issues concerning the improvement of power supply, which has to be achieved by 2040. The expected outcomes are described below. 1) Collection of basic information for the formation of grant/ concessional loan projects, suggestion of potential projects for financial assistance and clarification of issues 2) Suggesting the need for technical cooperation by analyzing the structure and the maintenance capability of the relevant organizations, and clarification of issues
Target areas and scope	Transmission and distribution networks of 132kV or less in major cities of Nepal (Kathmandu, Pokhara, Lalitpur, Birgunj, Biratnagar, Bhairahawa, Simla and Bharatpur)

3.Outline of the survey (2)

Category	Contents
Relevant organizatio ns	1) Ministry of Energy, Water Resources and Irrigation (MoEWRI) 2) Nepal Electric Authority (NEA) 3) Ratriya Prasaran Grid Co. Ltd. (RPGCL)
Scope of Works	1) Collection, analysis, etc. of relevant materials and information; and preparation of Inception Report 2) Collection and analysis of information from relevant local ministries, agencies and other organizations, other donors, etc. 3) Collection of information concerning candidates for loan assistance 4) Consideration of Quality infrastructure that can be utilized 5) Consideration of a plan to introduce large-capacity storage batteries 6) Proposal of candidates for loan assistance and clarification of issues 7) Suggestion of technical cooperation need

4.Work Plan

	JICA Study Team	GoN (NEA)
March 2019	• Collection and analysis of existing relevant materials, information etc. (In Japan) • Preparation of Inspection Report	
April 2019	**First Field Survey** • Explanation and discussion of Inception Report • Data collection • Site survey with NEA • Discussion with NEA	• Discussion of Inception report • Site Survey with JICA Study Team • Provide necessary information • Discussion with JICA Study Team
May 2019	• Analysis in Japan • Preparation of Draft final report **Second Field Survey** • **Explanation and discussion of Draft Final report**	Discussion of Draft Final Report
June 2019	Finalizing the Draft Report	
July 2019	Submission of Final Report	

GoN: Government of Nepal

Summary of the result of First Filed Survey

Tentative Project Proposal of Japanese Assistance

Loan Project

Transmission and distribution Line Development

1.Contents of Loan project

132kV Transmission, substations and distribution network

2. Location of Loan project

Metropolitan city (Pokhara) and Industrial area (sub- metropolitan city: Nepalgunj)
Those site was selected from the list of priorities projects (11 projects) which was received on Feb.2019 (JICA contact mission)

3. Quality infrastructure

- Low Loss Conductor (LLC) for T/L,
- Outdoor type GIS for S/S,
  Time Sequential Sectionalizing System (TSS) for D/L

Grant Project

Battery Energy Storage System (BESS)

1. General applications of BESS
   a. Energy security and reliability (Backup Power Supply)
   b. Load leveling and Peak shaving
2. Location of BESS

Candidate site will be selected from 3 sites in Kathmandu city and 7 sites of capital city of province according to the budget.

3. Capacity of BESS

4MW (800kW×5 units) x 4～6 hours : Tentative

At the wrap up meeting of First Field Survey, the Consultant explained the result of survey to NEA, NAE answered that Nepalgunj Loan Project would like to conduct by NEA budget. and the contents of Pokhara Loan Project were confirmed. However, additional component for distribution network were requested.

Loan Component of Pokhara Project

Transmission and Substation component

- ✓ Construction of 132/11 kV Birauta S/S with outdoor type GIS,
  (Land acquisition is **not necessary**)
  Final capacity of Birauta S/S is 30 MVA x 3 units , Total 90 MVA,
  JICA project will install 30 MVA x 2 units,
- ✓ Construction of 132kV underground cable from Birauta S/S to existing 132kV overhead transmission line : about 0.4km,
- ✓ Modification of existing 132kV overhead transmission line at connection point.

Distribution Network

- ✓ Installation of underground cable (6 feeders for reconfiguration) from Birauta S/S,
- ✓ Installation of Sectionalizing System (TSS) on distribution network after reconfiguration.

Connection point : Connection point between Overhead transmission line and underground cable.

Proposed Quality Infrastructure for Pokhara Project

- ✓ Transmission and Substation : Outdoor type GIS
- ✓ Distribution Network: Time Sequential Sectionalizing System (TSS)

Loan Component of Nepalgunj Project

Transmission and Substation component

- ✓ Expansion of 132kV **Kohalpul substation (S/S)**
- ✓ Construction of 132kV **Underground cable** from Kohalpul S/S to Nepalgunj（Connection Point):About 0.7km
- ✓ Construction of 132kV Overhead transmission line from Kohalpul (Connection point) to New Nepalgunj S/S : About 12km（Land acquisition is required）
- ✓ Construction of 132/33/(11) **Nepalgunj S/S**（Land acquisition is required）

Distribution Network

- ✓ Construction of 33/11kV Kahajura S/S
- ✓ Replacement of Transformer at NEW Nepalgunj S/S (Option)
- ✓ Construction of distribution line from 132kV Nepalgunj S/S to the following S/S,

NEW Nepalgunj S/S:	Overhead : about 4.1km,Underground about 1.2km
OLD Nepalgunj S/S:	Overhead : about 7.2km, Underground about 0.5km
Kahjura S/S (new):	Overhead : about 4.2km

Connection point : Connection point between Overhead transmission line and underground cable.

Proposed Quality Infrastructure for Nepalgunj Project

- ✓ Transmission and Substation : Low Loss Conductor, Outdoor type GIS (Kohalpul S/S)
- ✓ Distribution Network: Non

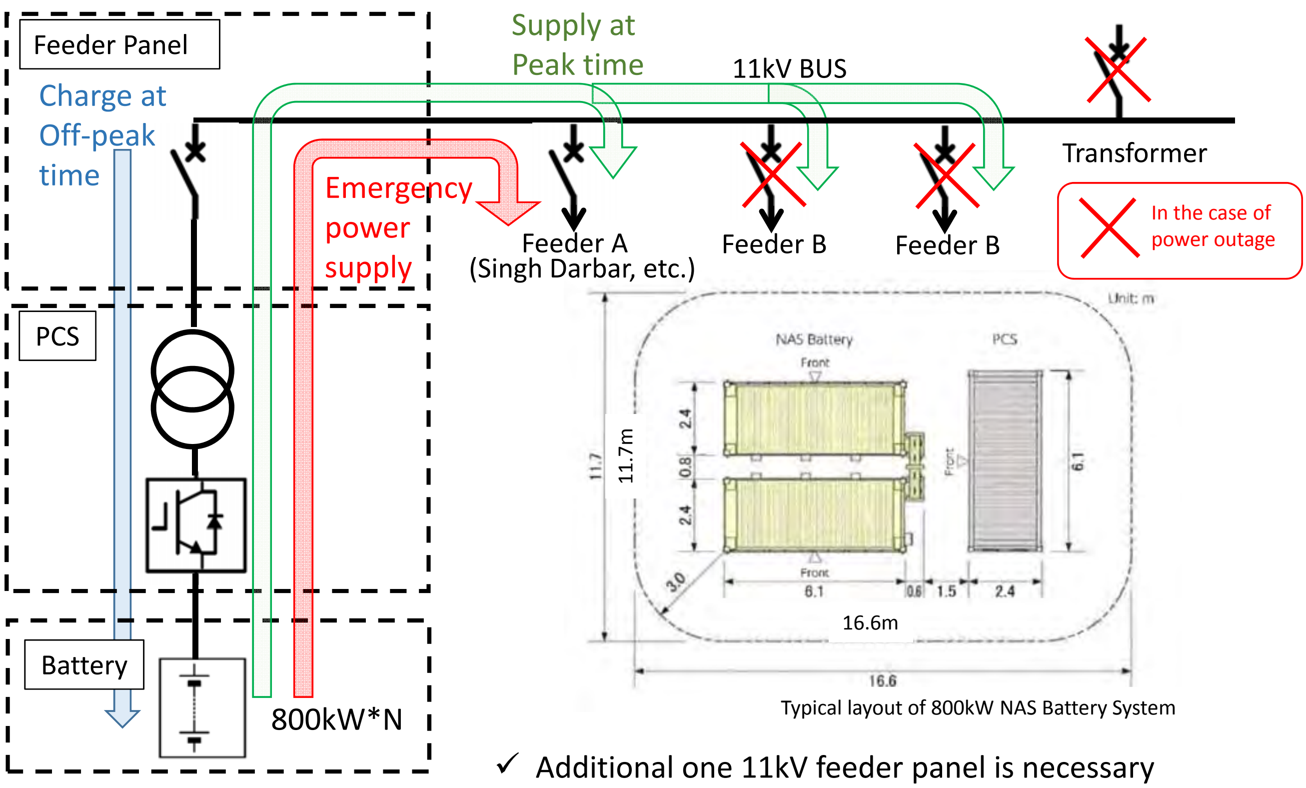
Result of Site Survey

Summary of the site survey

Service station	K3	Baneswar	Maharjgunj	Pokhara
Supply to	Singh Darbar	Parliament building	President Residence	Provincial office
Space	Good (adjacent land)	difficult	With condition	With condition
Feeder Panel to be connected	Good	With condition	Difficult	Good
Requiring Capacity (tentative)	2.0MW	0.8MW	1.2MW	2.4MW
Remarks	NEA need to secure the land space.	Necessity to secure the land	NEA need to clean up the compound.	This load will be shifted to new Birauta S/S

- ✓ From the technical view point, K3 is the first candidate for BESS among them.
- ✓ Pokhara will be second candidate after commissioning of Birauta S/S.

System Configuration of BESS (Example of NAS Battery)

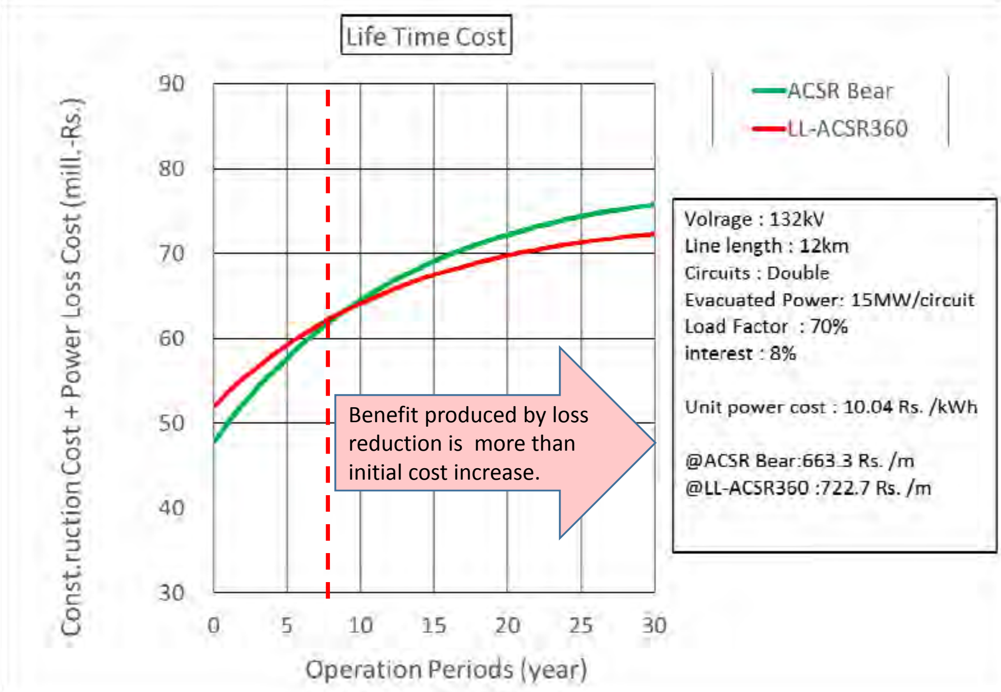


Typical layout of 800kW NAS Battery System

- ✓ Additional one 11kV feeder panel is necessary
- ✓ More than 200m2 space is necessary for 800kW BESS

Quality Inf.

Example of comparison of life time cost



The graph is made under assumption that low loss ACSR is adopted to Kohalpur-Nepalgunj Transmission Line Project. The graph is based on trial calculation. It's necessary to study life cycle cost in detail after collecting more information and data.

Quality Inf.

Layout of Birauta substation

- ✓ To avoid land acquisition problem, GIS substation is suitable.
- ✓ To meet N-1 criteria, two 132/11kV 30MVA transformers should be installed.
- ✓ To deal with increasing demand, future space for additional 132/11kV 30MVA transformer is recommended.

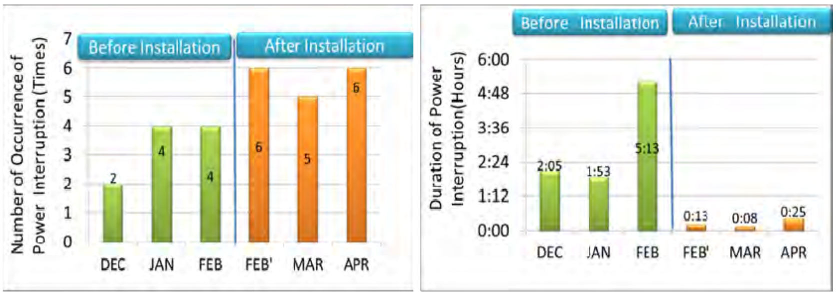
Quality Inf.

<u>Outdoor type GIS</u>

- ✓ More compact
- ✓ Reducing gas leak
- ✓ Less required for maintenance

Time sequential Sectionalizing System : TSS

- TSS system can reduce to duration and area of power outage with minimum Initial investment.
- Applicable to various distribution system.
- Compatible with centralized control system for future upgrade



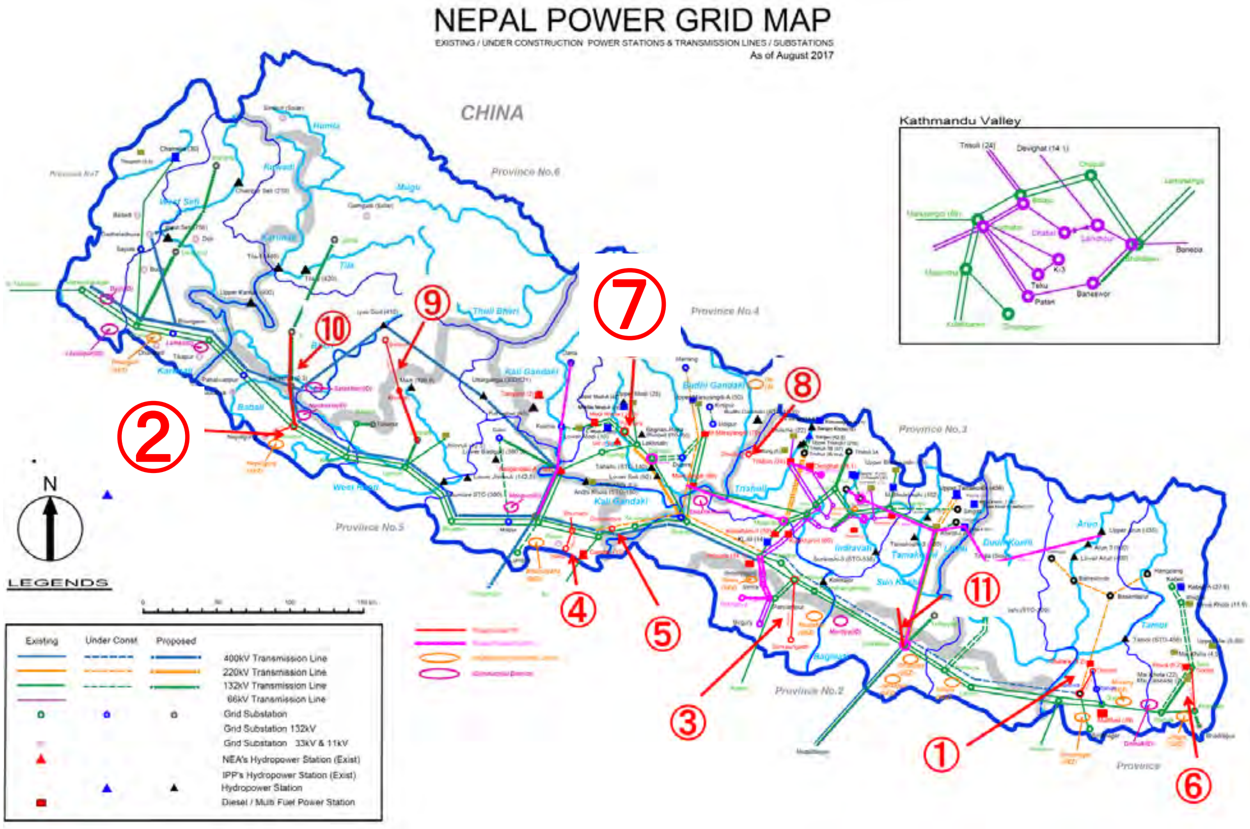
Comparison of Outage Before/After the Installation of TSS System

- ✓ **Effective to reduce outage duration**
- ✓ **Early identification of fault section**

Result of site survey

Transmission and substation

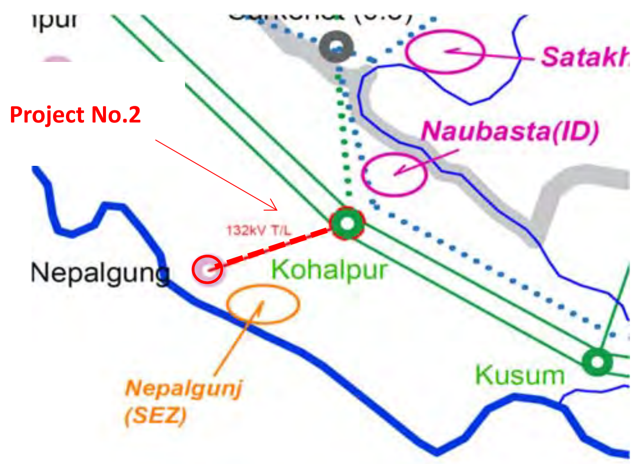
Loan Location of prioritized projects



Loan Prioritized projects No.2

Kohalpur－Nepalgunj 132kV Transmission Line and Substation Project
(132/33kV Transformer should be installed at Janaki Gaupalika)

This project aims to construct double circuits transmission line for supplying power to Nepalgunj which has industrial area including cement and steel factories.
Power is currently supplied to this area by 33kV transmission line from Kohalpur substation. The capacity of transmission line will be insufficient in the future because demand is increasing in this area. Therefore, 132kV transmission line for supplying power is needed.

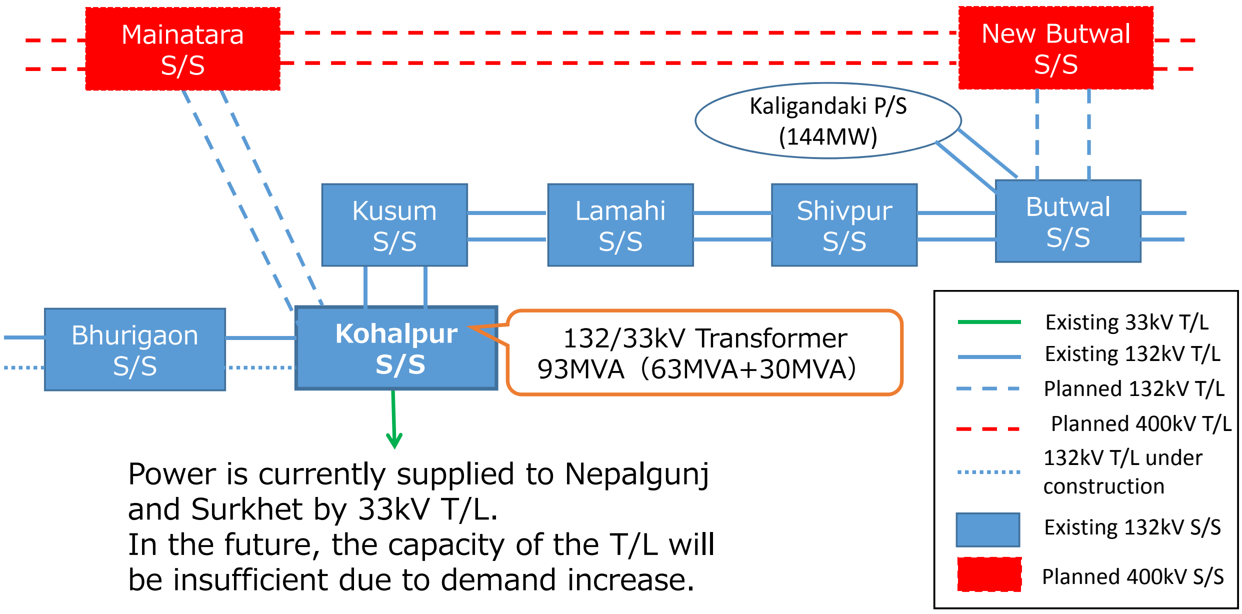


Development Plan	Planed/ unplanned
TSDP	Unplanned Project
Annual Report	Planned Project

Loan Situation of Project Site

- Nepalgunj has industrial areas and many factories are already operated. In addition, factories such as cement and steel factory are under construction in Khajura area. Power demand is increasing in these areas.
- A Steel factory is under construction in Khajura area. After this factory is completed, power demand of the factory will be large.

Loan Outline of power system related to Kohalpur subsation



- ✓ Currently 132kV Kohalpur S/S receives power from east network and west network. The east network includes Kaligandaki P/S with capacity of 144MW. The west network is connected to India.
- ✓ 400kV Mainatara S/S is under planning. In the future, power from Maintara S/S will be supplied to Kohalpur S/S.

Situation around Kohalpur Substation

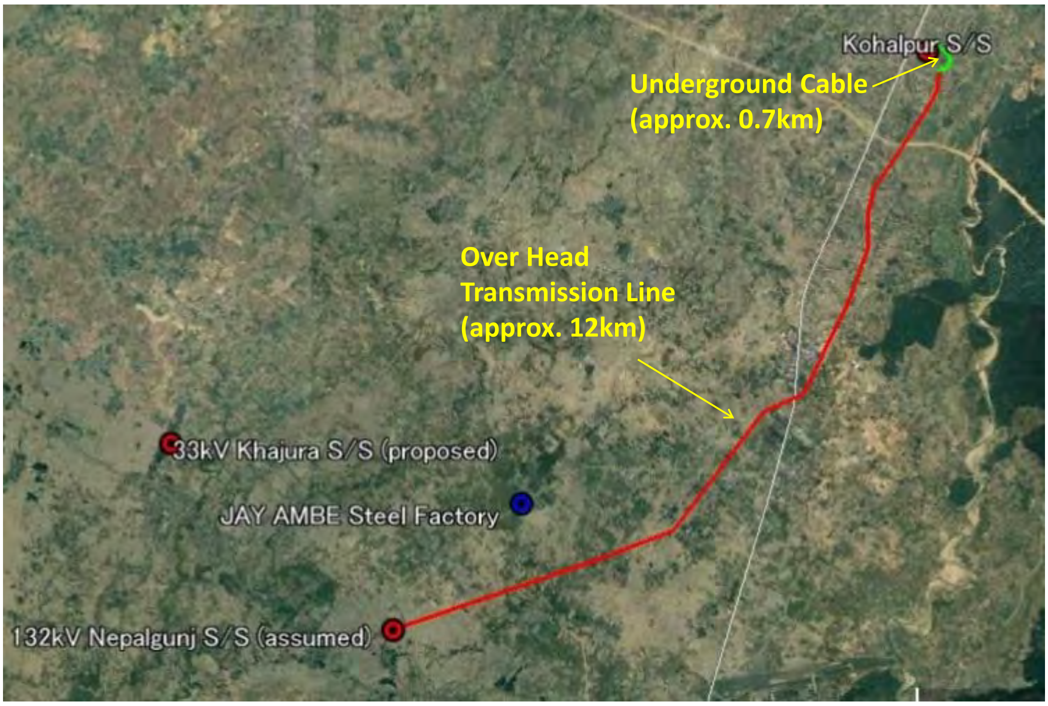
Candidate location for new 132kV switchgear

The inside of Kohalpur substation is crowded with existing transformers and switchgears.
The vacant space for new switchgear is limited, so 132kV GIS (Gas Insulated Switchgear) will be suitable.
It is necessary to consider the location in detail based on the layout drawings of substation.

Loan New 132kV transmission line route around Kohalpur substation

Residential area is around Kohalpur substation. It is difficult to install new tower for 132kV transmission line around substation. Therefore, underground cable should be adopted as alternative to over head transmission line around substation.

Loan Outline of new 132kV transmission line route

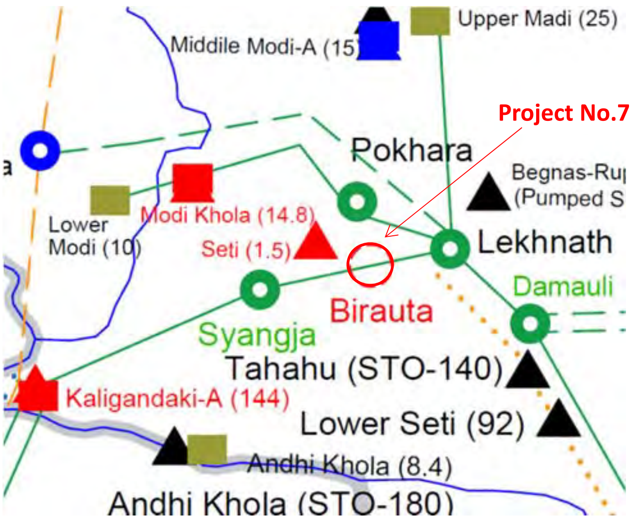


- The location of new 132kV Nepalgunj substation is under consideration. Probably, the substation will be installed near steel factory.
- The length of over head transmission is about 12km and that of underground cable is about 0.7km. The total length is about 12.7km.

Prioritized projects No.7

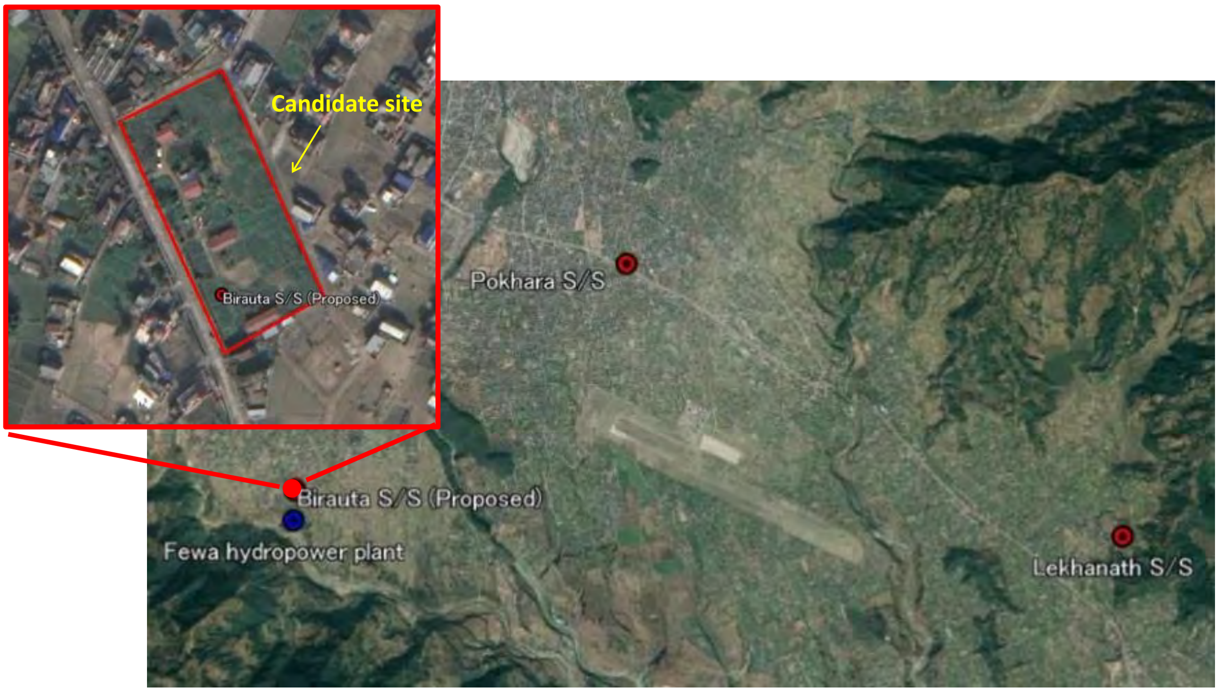
Pokhara 132/11kV Substation Project
(132/11kV Transformer should be installed at Birauta, Pokhara)

Currently existing Pokhara substation supplies power to Pokhara city where demand is increasing. Pokhara substation already has eleven 11kV feeders, so it is difficult to install more feeders.
This project aims to construct new 132/11kV substation for supplying power to Pokhara city. After new substation is completed, some 11kV feeders will be shifted from Pokhara substation to new substation.



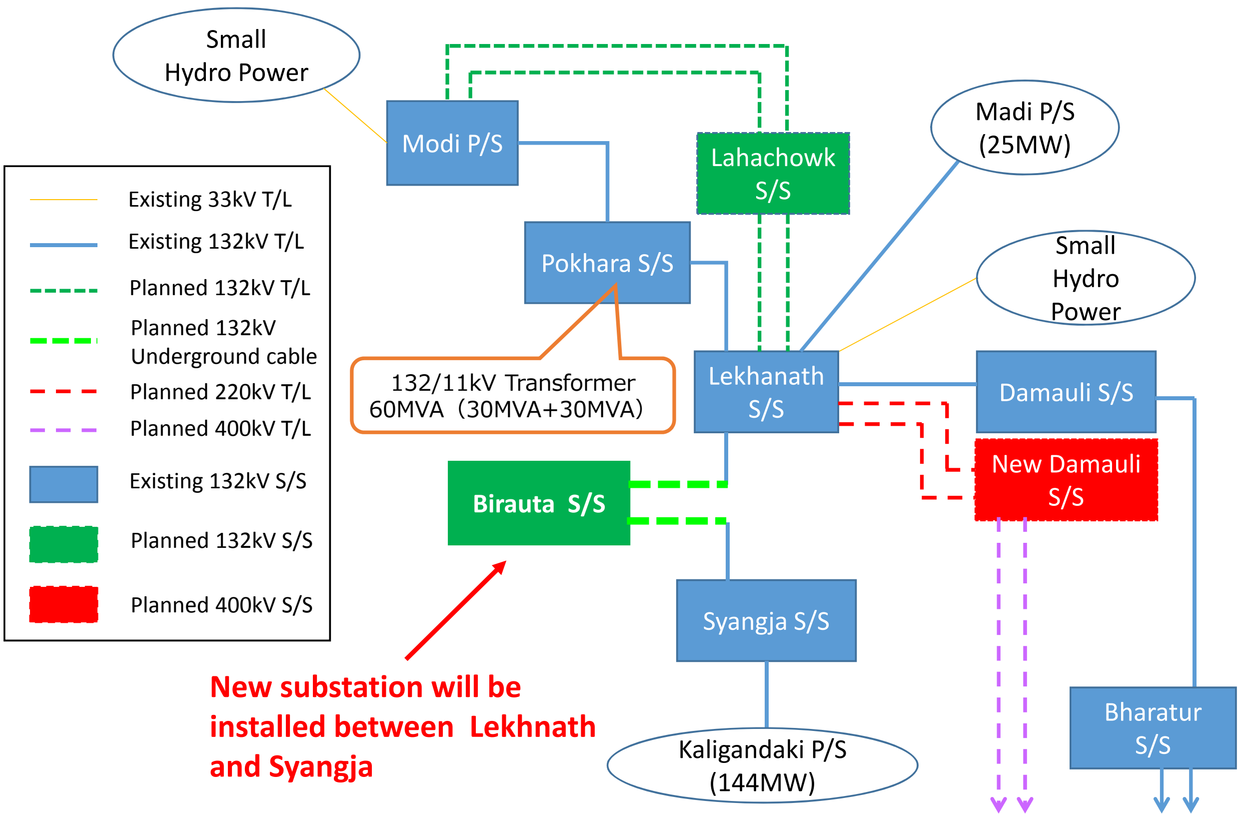
Development Plan	Planed/ unplanned
TSDP	Unplanned Project
Annual Report	Unplanned Project

Situation of Project Site



Candidate site of New Birauta Substation is located about 4km south-west of Pokhara substation. The site is owned by NEA and is currently used for NEA's staff house. Fewa hydropower plant is near the candidate site.

Loan Outline of power system related to Pokhara substation



Loan Outline of new 132kV transmission line route

Residential area is around candidate site of Birauta substation. It is difficult to install new tower around the site, so underground cable is needed as alternative to over head transmission line. The length of underground cable is about 0.4km.

Layout of Birauta subsation

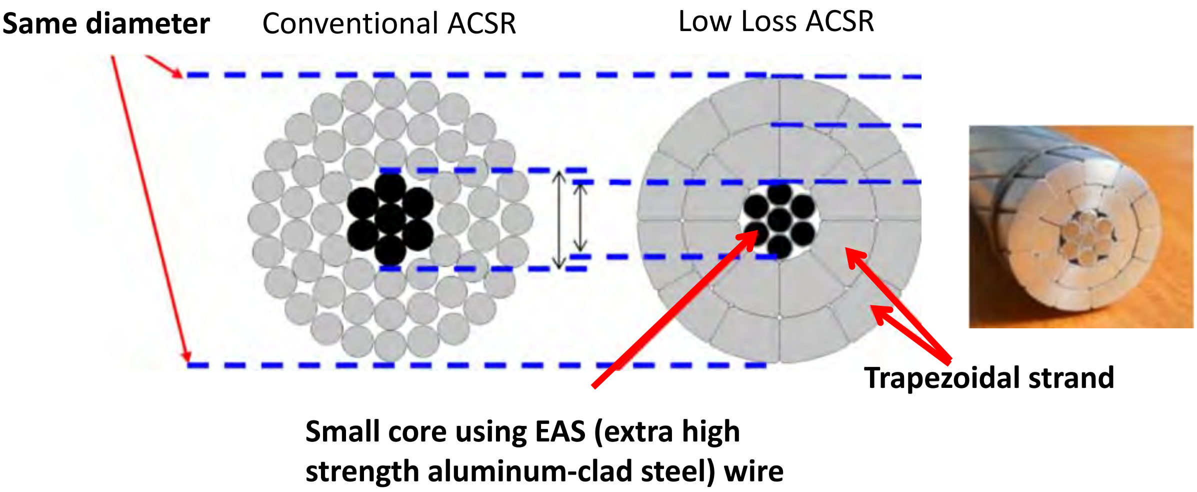
- ✓ To avoid land acquisition problem, GIS substation is suitable.
- ✓ To meet N-1 criteria, two 132/11kV 30MVA transformers should be installed.
- ✓ To deal with increasing demand, future space for additional 132/11kV 30MVA transformer is recommended.

Quality Inf.

Outdoor type GIS

- ✓ More compact
- ✓ Reducing gas leak
- ✓ Less required for maintenance

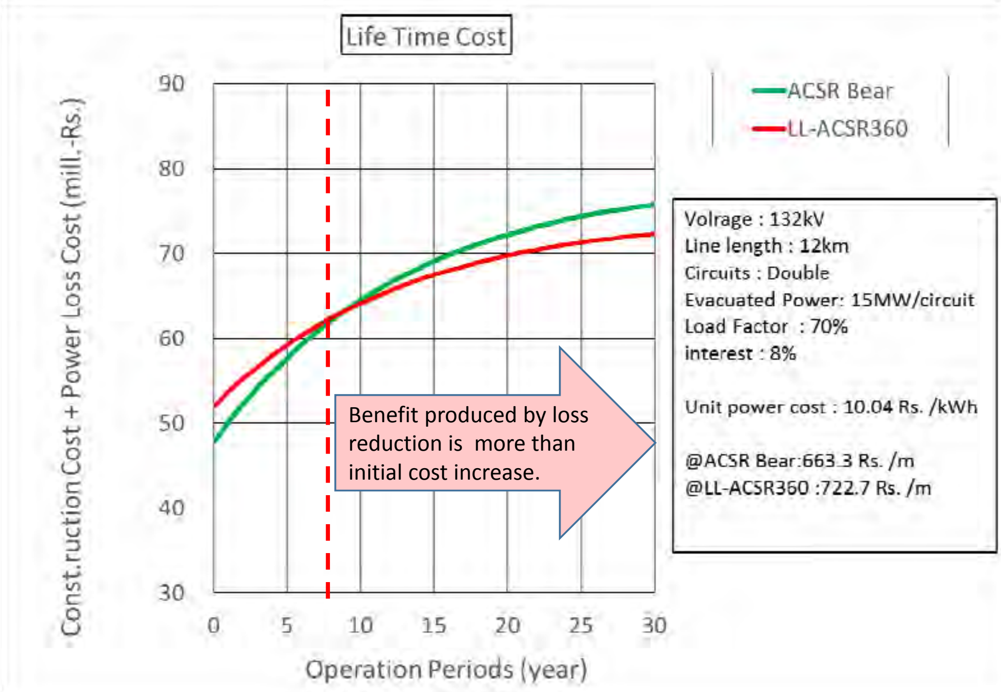
Low Loss Conductor



Low Loss ACSR adopts trapezoidal aluminum strand and EAS core wire in order to increase cross-section area of aluminum.
As shown above, Low Loss ACSR has more cross-section area of aluminum than conventional ACSR. Therefore, we can reduce electrical resistance and loss by using Low Loss ACSR.

Quality Inf.

Example of comparison of life time cost



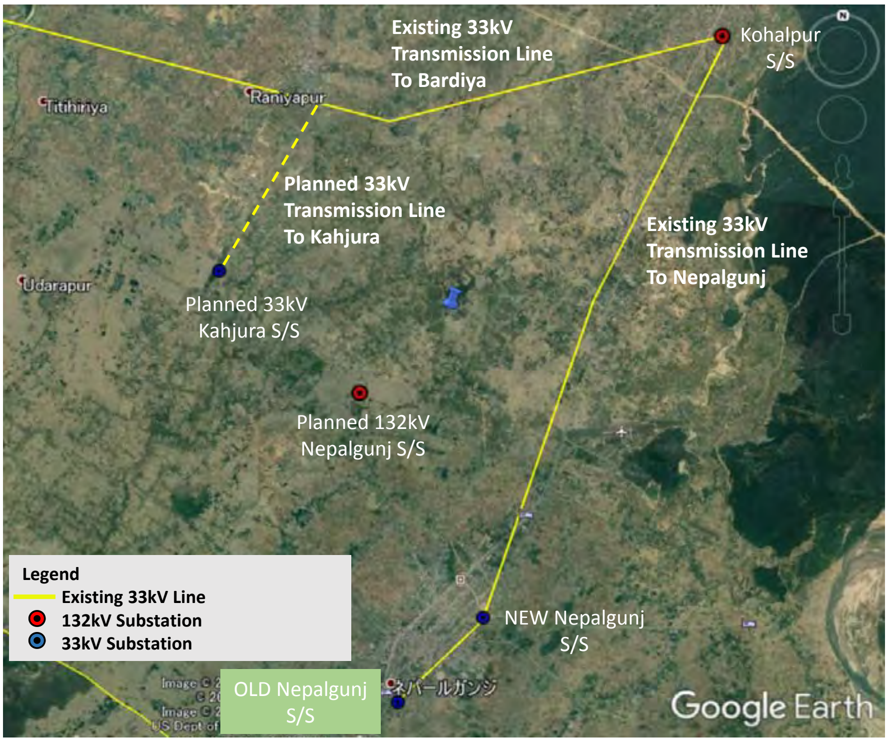
The graph is made under assumption that low loss ACSR is adopted to Kohalpur-Nepalgunj Transmission Line Project. The graph is based on trial calculation. It's necessary to study life cycle cost in detail after collecting more information and data.

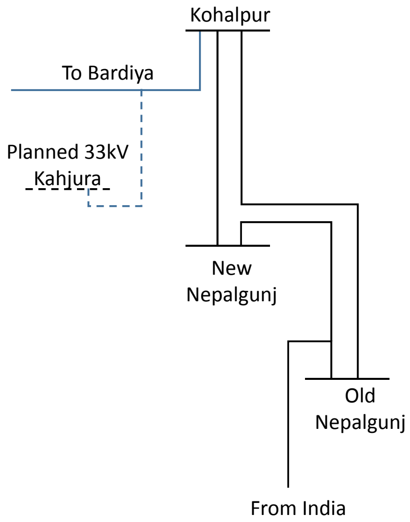
Result of site survey
Distribution network

Loan

Distribution Network - Nepalgunj

Actual situation of 33kV Distribution Network in Nepalgunj



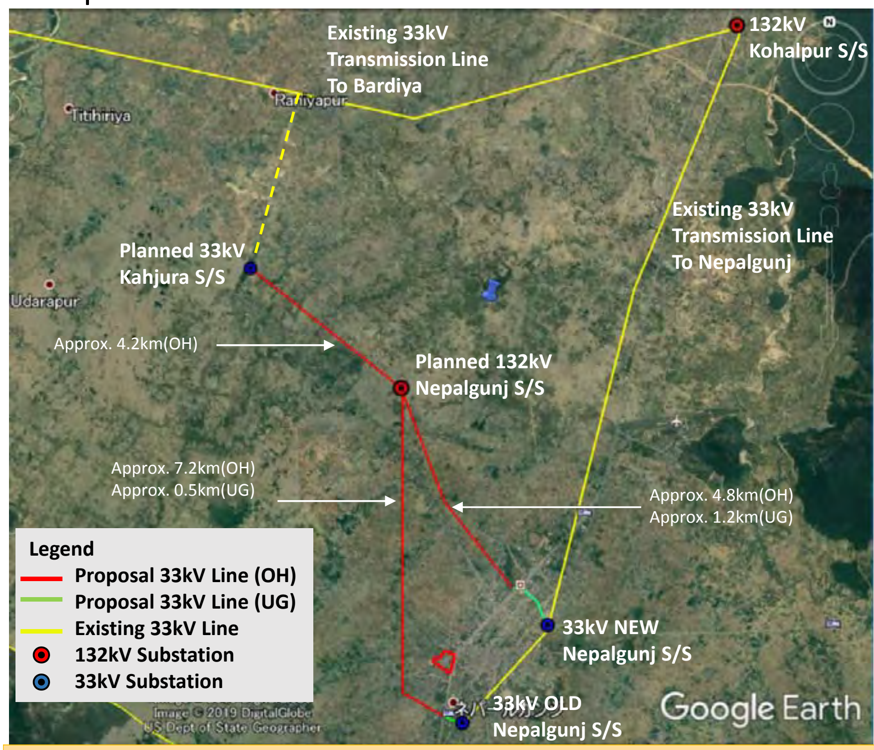


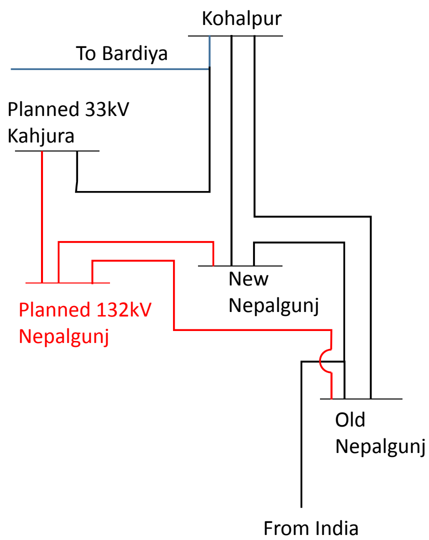
- ✓ Nepalgunj has a large industry area and demand growth is very rapid.
- ✓ There are two 33kV substation in Nepalgunj area.
- ✓ NEA is planning to construct new 33kV and 132kV substation to meet demand growth.

Loan

Distribution Network - Nepalgunj

Proposal for Reinforcement of 33kV Distribution Network in Nepalgunj

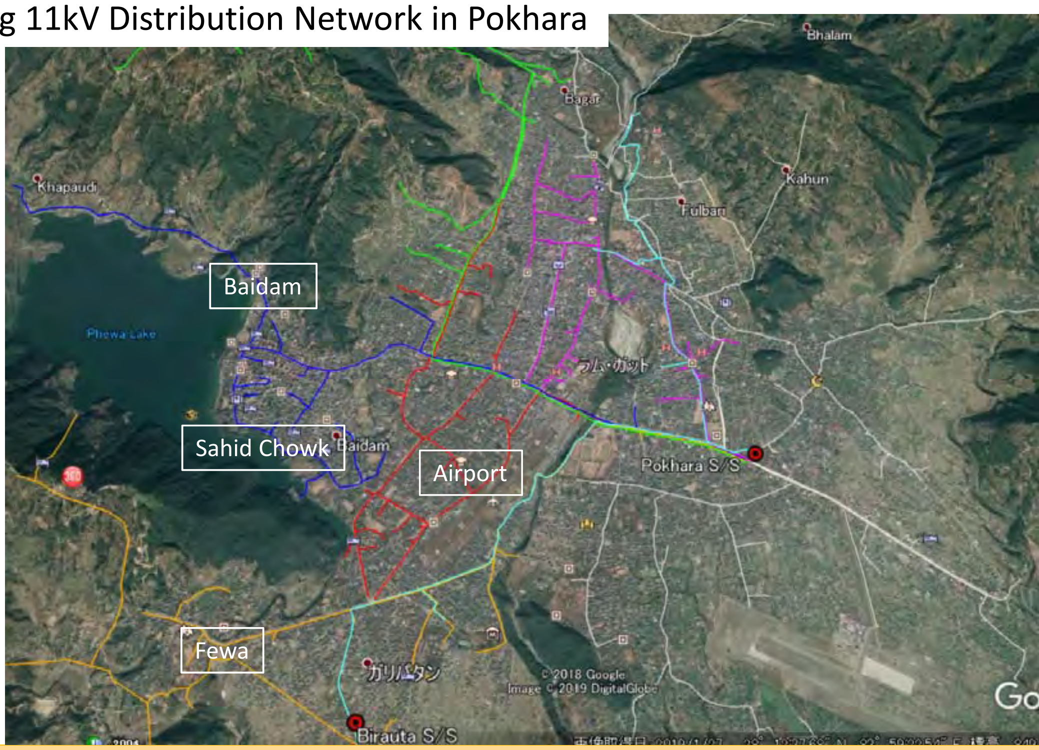




- ✓ Planned 132kV S/S will bring more supply capacity in Nepalgunj area.
- ✓ New sub-transmission lines should be constructed in order to use effectively the supply capacity.

Loan Distribution Network - Pokhara

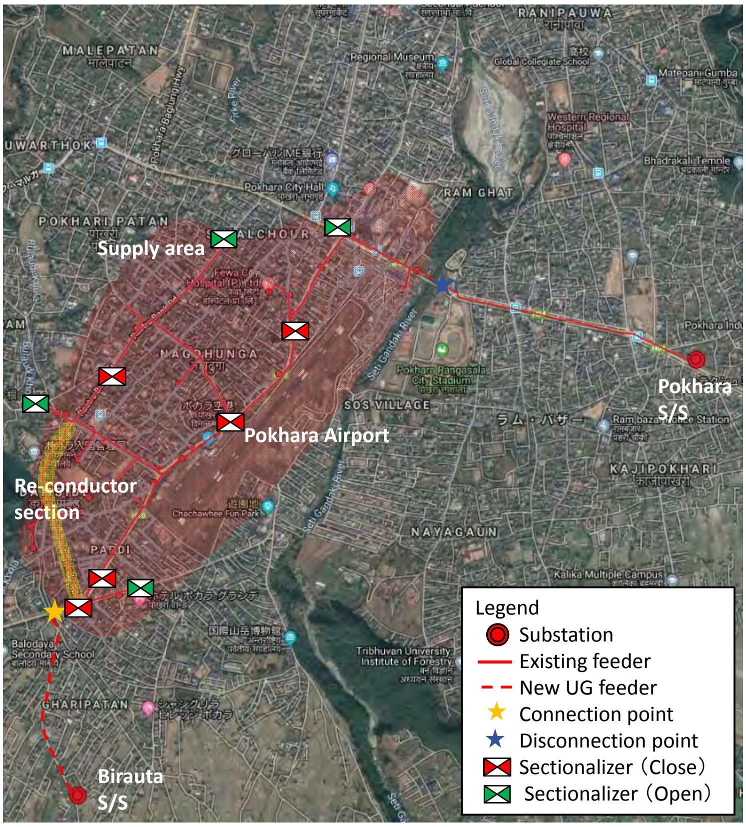
Existing 11kV Distribution Network in Pokhara



- ✓ There are 11 number of 11kV feeder in Pokhara area.
- ✓ NEA has a plan to construct new 132/11kV S/S (Birauta S/S) in Pokhara area, the planned location is near the center of city.
- ✓ After commissioning of Birauta S/S, some feeders should be shifted from Pokhara S/S.

Loan Distribution Network - Pokhara

No.1 AIRPORT Feeder (Red line)



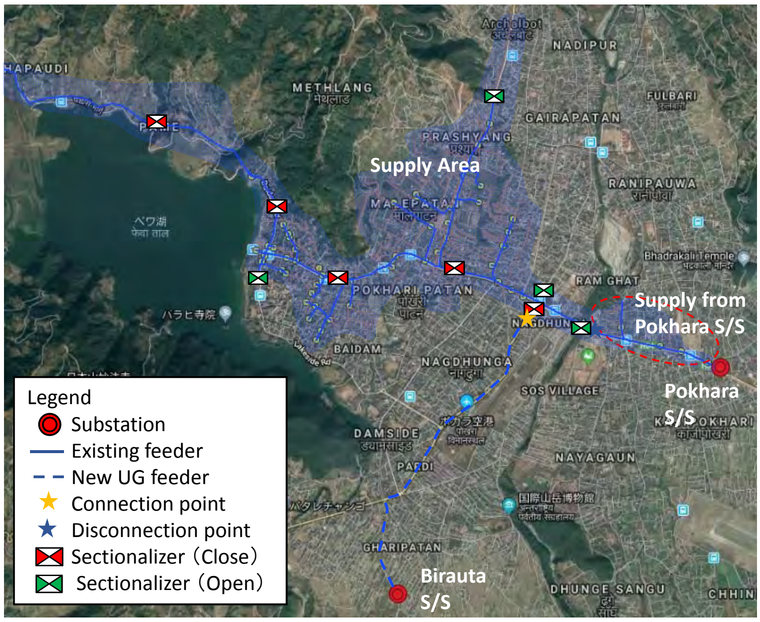
- ✓ AIRPORT feeder supplies power to the center of the city including the airport.
- ✓ This feeder should be shifted to new UG feeder from Birauta.
- ✓ In order to improve reliability, some sectionalizer should be installed to divide into some section.
- ✓ It is also better to be connected to original AIRPORT, BAIDAM, and SAHID CHOWK feeder with open sectionalizer.

Outline of proposal

- ➢ UG outgoing feeder (Approx. 1.5km) from Birauta to be connected original feeder from Pokhara.
- ➢ Re-condctoring of Small size (Weasel) section (Approx. 1.5km)
- ➢ 9 sectionalizer (5 Close and 4 Open)

Distribution Network - Pokhara

No.2 BAIDAM Feeder (Blue Line)

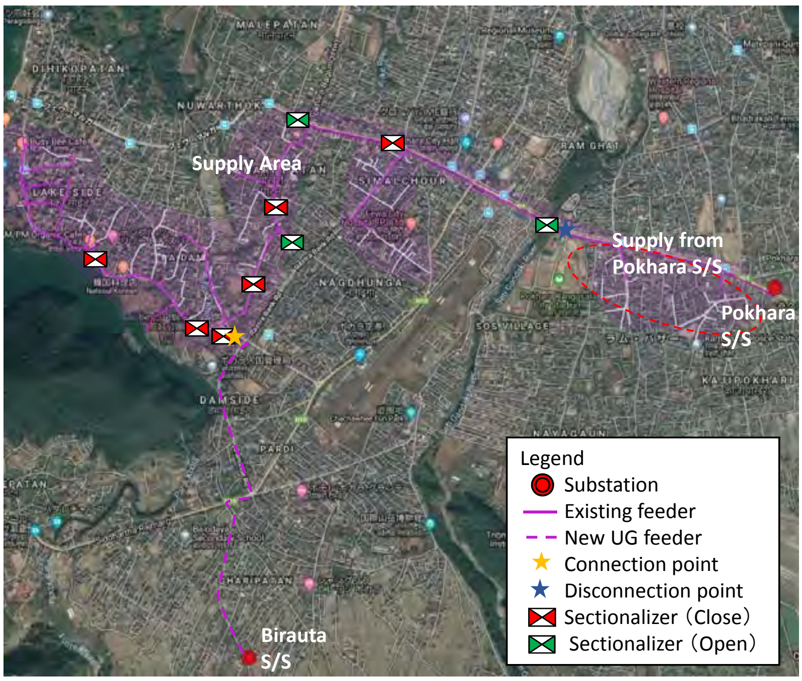


- ✓ This feeder supplies power to the center of the city and the outside of the city.
- ✓ This feeder should be shifted to new feeder from Birauta.
- ✓ In order to improve reliability, some sectionalizer should be installed to divide mountainous area and city area.
- ✓ It is also better to be connected SAHID CHOWK, CITY, SARANGKOT, and original BAIDAM from Pokhara with open sectionalizer.

Outline of proposal
- ➢ UG feeder (Approx. 4.0km) from Birauta
- ➢ 9 sectionalizer (5 Close and 4 Open)

Distribution Network - Pokhara

No.3 SAHID CHOWK Feeder (Purple Line)



- ✓ This feeder supplies power to the lakeside area including administration agency.
- ✓ This feeder should be shifted to new feeder from Birauta.
- ✓ In order to improve reliability, some sectionalizer should be installed.
- ✓ It is also better to be connected AIRPORT, BAIDAM, original SAHID CHOWK from Pokhara with open sectionalizer.

Outline of proposal
- ➢ UG feeder (Approx. 2.5km) from Birauta
- ➢ 9 sectionalizer (6 Close and 3 Open)

Distribution Network - Pokhara

No.4 FEWA Feeder

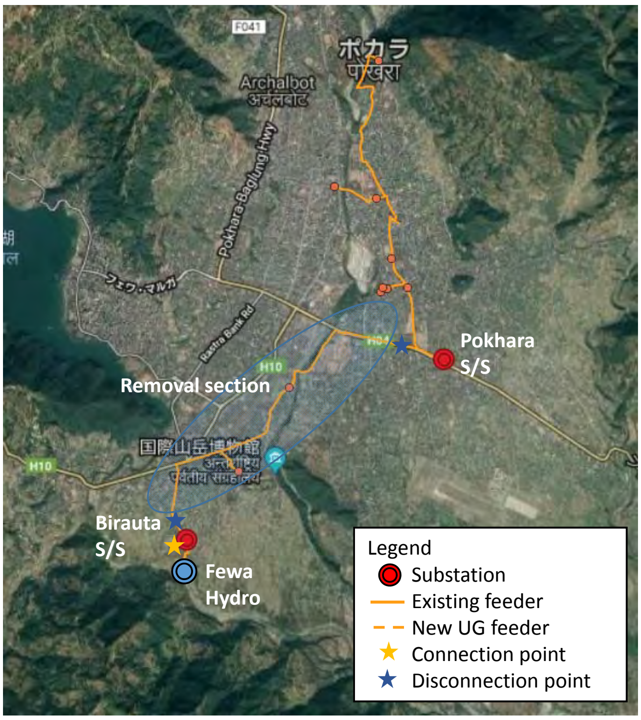
- ✓ FEWA feeder supplies power both to the city area around the airport and the mountain area.
- ✓ This feeder should be shifted to new feeder from Birauta.
- ✓ In order to improve reliability, some sectionalizer should be installed to divide mountainous area and city area. (tentative proposal is shown in above)
- ✓ It is also better to be connected to original FEWA feeder of Pokhara with open sectionalizer

Outline of proposal

- ➢ UG outgoing feeder (0.1km) from Birauta to be connected original feeder from Pokhara.
- ➢ 8 sectionalizer (7 Close and 1 Open)

Distribution Network - Pokhara

No.5 FEWA Incomer



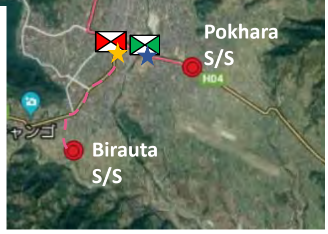
- ✓ FEWA Incomer is connected to two small Hydro generation. One is located near Birauta and the another is located in north of Pokhara.
- ✓ The west part of this feeder should be shifted to Birauta.
- ✓ If possible, the section of Pokhara to Birauta should be removed to resolve congestion of main road.

Outline of proposal

- ➢ UG outgoing feeder (0.1km) from Birauta to be connected original feeder from Pokhara.
- ➢ Remove OH feeder from Pokhara to Birauta (Approx. 6.0km)

Loan Distribution Network - Pokhara

No.6 SARANGOT Feeder (Green Line)

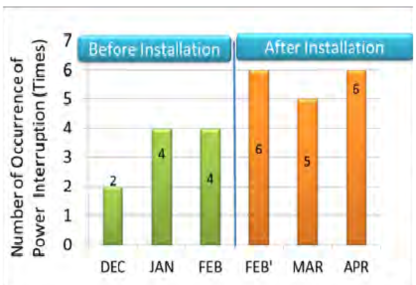


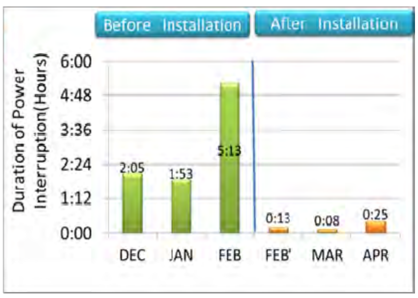
- ✓ SARANGOT feeder supplies power to the mountain area with long distance.
- ✓ Because of its long distance, it is assumed that it takes a long time to identify a fault point when a power outage occurs.
- ✓ It is better to install some sectionalizer in order to reduce outage duration.

Outline of proposal
- ➢ UG feeder (4.0km) from Birauta
- ➢ 7 sectionalizer (6 Close and 1 Open)

Quality Inf. Time sequential Sectionalizing System : TSS

- ▪ TSS system can reduce to duration and area of power outage with minimum Initial investment.
- ▪ Applicable to various distribution system.
- ▪ Compatible with centralized control system for future upgrade



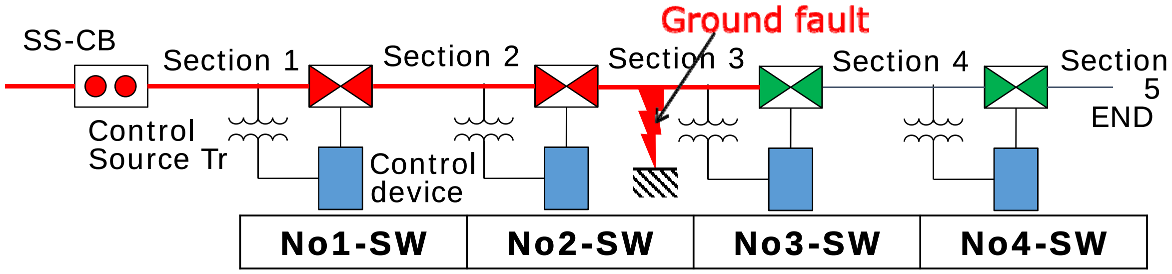


Comparison of Outage Before/After the Installation of TSS System

- ✓ Effective to reduce outage duration
- ✓ Early identification of fault section

Time sequential Sectionalizing System : TSS

Sectionalizing operation ［radial-type distribution］



Switch-Substation CB	OFF	ON
Automatic Switching Device	OFF	ON
Faulty section indicator LED Lamp	OFF	ON

Example of identification procedure

1st Ground fault occurs in section 3 and SS-CB trip (0sec)

2nd SS-CB Automatically Re-close (60sec)

3rd SW turn ON every 7 seconds after energized (No.1: 67sec, No.2: 74sec)

[The above figure shows the state of 74 seconds progress]

4th SS-CB Re-trip and No2-SW is locked (74+ sec)

It is possible to identify the fault section by the progress time from re-close.

Result of site survey

(BESS)

NEA's Objective for BESS

1. *Develop and install the BESS for major administrative offices and offices of higher authorities*. This objective is to **provide reliable and uninterruptible electricity** to the agency described below;
   a. 10 MW ESS at Singhdurbar, Kathmandu
   b. 1 MW ESS at President Residence at maharajgunj
   c. 1 MW ESS at Parliamentry Building
      (National Convention Centre), Baneswar
   d. 1 MW each for Administration centres of 7 (seven) Provinces
      (Hetaunda, Biratnagar, Janakpur, Pokhara, Butwal, Doti, Dhangadhi)

2. Develop and install the 1MW BESS *with solar power system* at Dolpa, Kalikot, *Humla*, Jumla and Mugu district. This objective is to **provide quality and reliable electricity** to the district headquarters.

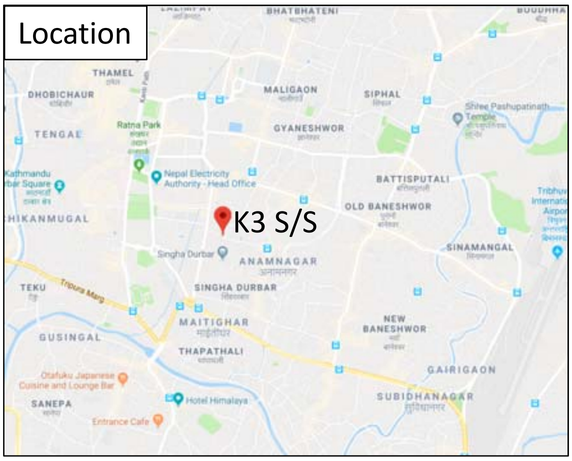
Source : BRIEF CONCEPT NOTE ON ENEARGY STORAGE SYSTEM REQUIREMENT IN NEPAL (NEA, PROJECT MANAGEMENT DIRECTORATE, November 2018

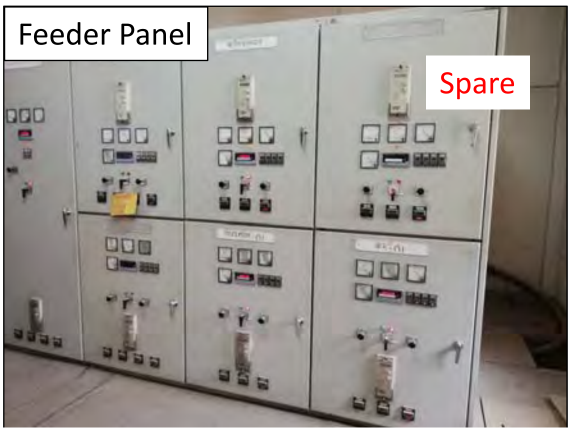
According to the above objective, field survey was conducted on the following 4 site.

- K3 S/S, supplying to Singh Durbar
- Maharajgunj S/S, supplying to the President Residence
- Baneswar S/S, supplying to the Parliamentary Building
- Pokhara S/S, supplying to Pokhara Administration center

Result of Site Survey

K3 Substation at Singhdarbar

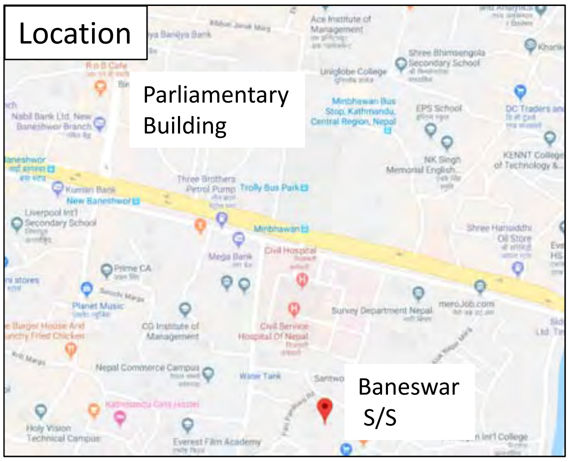


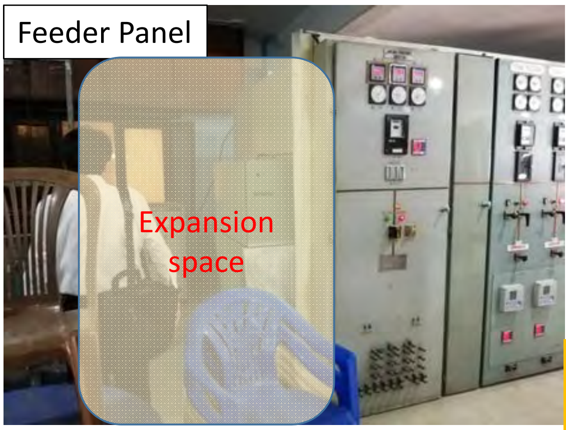


- ✓ Location
  North-West corner of Singh Darbar
- ✓ Space
  Need to secure the land adjacent to K3
- ✓ Feeder Panel
  Possible to be connected to spare panel
- ✓ Required Capacity
  Demand of Singh Darbar is up to 2MW.

There is no problem from the technical point of view.

Grant Result of Site Survey Baneswar Substation

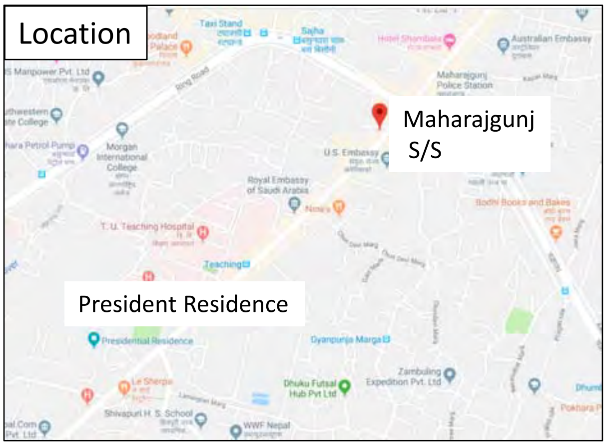




- ✓ Location
  South-East of Parliamentary Building
- ✓ Space
  Not enough space requiring for BESS
- ✓ Feeder Panel
  No spare panel, need an expansion panel
- ✓ Required Capacity
  Demand of the feeder is up to 700kW

It is difficult to install unless the land issue is resolved.

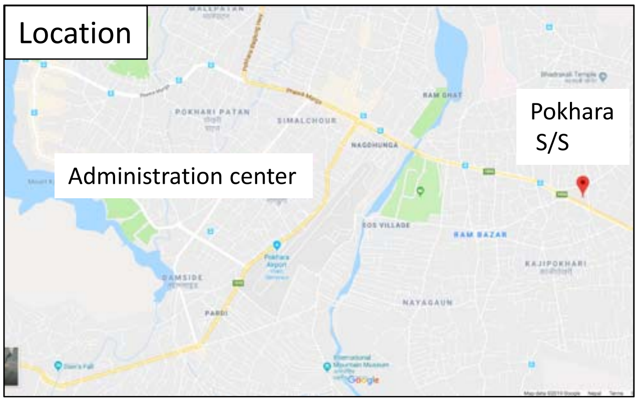
Grant Result of Site Survey Maharajgunj Switching Station

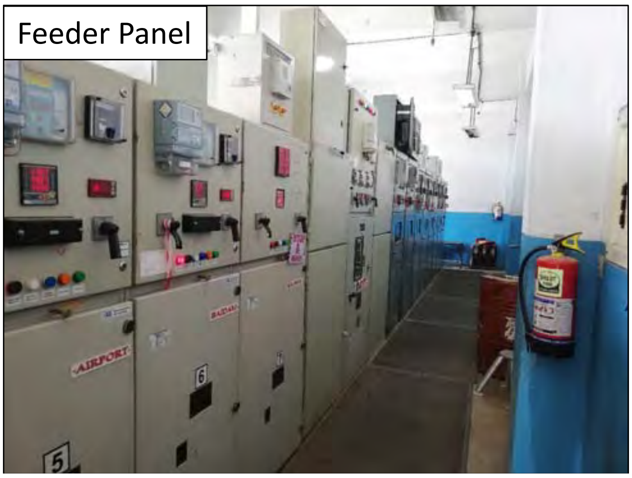


- ✓ Location
  North-East of President Residence
- ✓ Space
  Need to clean up to secure sufficient space.
- ✓ Feeder Panel
  No spare panel, Adding a panel is difficult
- ✓ Required Capacity
  Demand of the feeder is up to 1.1MW

It is difficult to install BESS unless the feeder panel will be added. It also need to confirm the necessity because this has a very reliable system.

Grant Result of Site Survey Pokhara Substation





- ✓ Location
  East side of Pokhara city
- ✓ Space
  Need to secure sufficient space (UG route).
- ✓ Feeder Panel
  Possible to be connected to spare panel
- ✓ Required Capacity
  Demand of the feeder is up to 2.4MW

From the technical point of view, there is no problem, but the target feeder is planned to be shifted to new Birauta S/S.

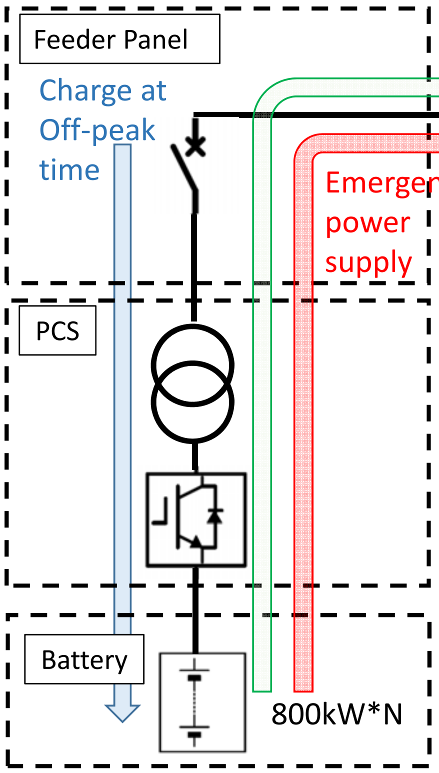
Grant Result of Site Survey Summary

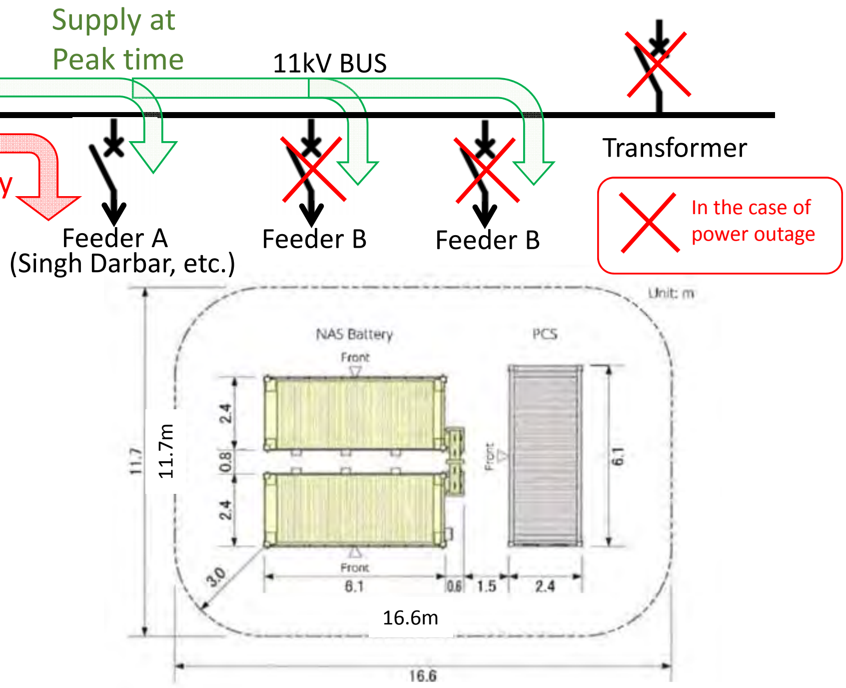
Summary of the site survey

Service station	K3	Baneswar	Maharjgunj	Pokhara
Supply to	Singh Darbar	Parliament building	President Residence	Provincial office
Space	Good (adjacent land)	difficult	With condition	With condition
Feeder Panel to be connected	Good	With condition	Difficult	Good
Requiring Capacity (tentative)	2.0MW	0.8MW	1.2MW	2.4MW
Remarks	NEA need to secure the land space.	Necessity to secure the land	NEA need to clean up the compound.	This load will be shifted to new Birauta S/S

- ✓ From the technical view point, K3 is the first candidate for BESS among them.
- ✓ Pokhara will be second candidate after commissioning of Birauta S/S.

Grant System Configuration of BEES (Example of NAS Battery)

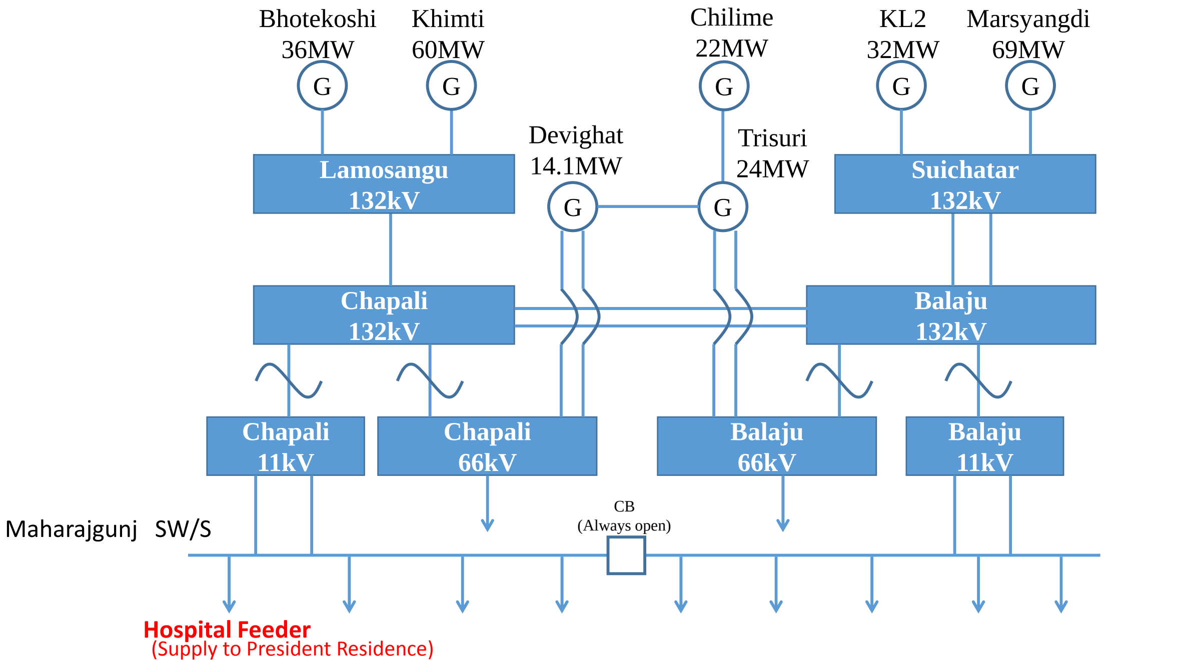




Typical layout of 800kW NAS Battery System

- ✓ Additional one 11kV feeder panel is necessary
- ✓ More than 200m2 space is necessary for 800kW BESS

Grant Necessity of BESS at Maharjgunj



- ✓ Maharajgunj SW/S is connected to Chapali S/S and Balaju S/S by 2 route and 4 lines.
- ✓ Chapali S/S and Balaju S/S are connected at 132kV each other by 2 lines.
- ✓ It is possible to supply electric power even if N-1 fault occurred.

This SW/S has a very reliable system, so it is assumed that BESS is not necessary.