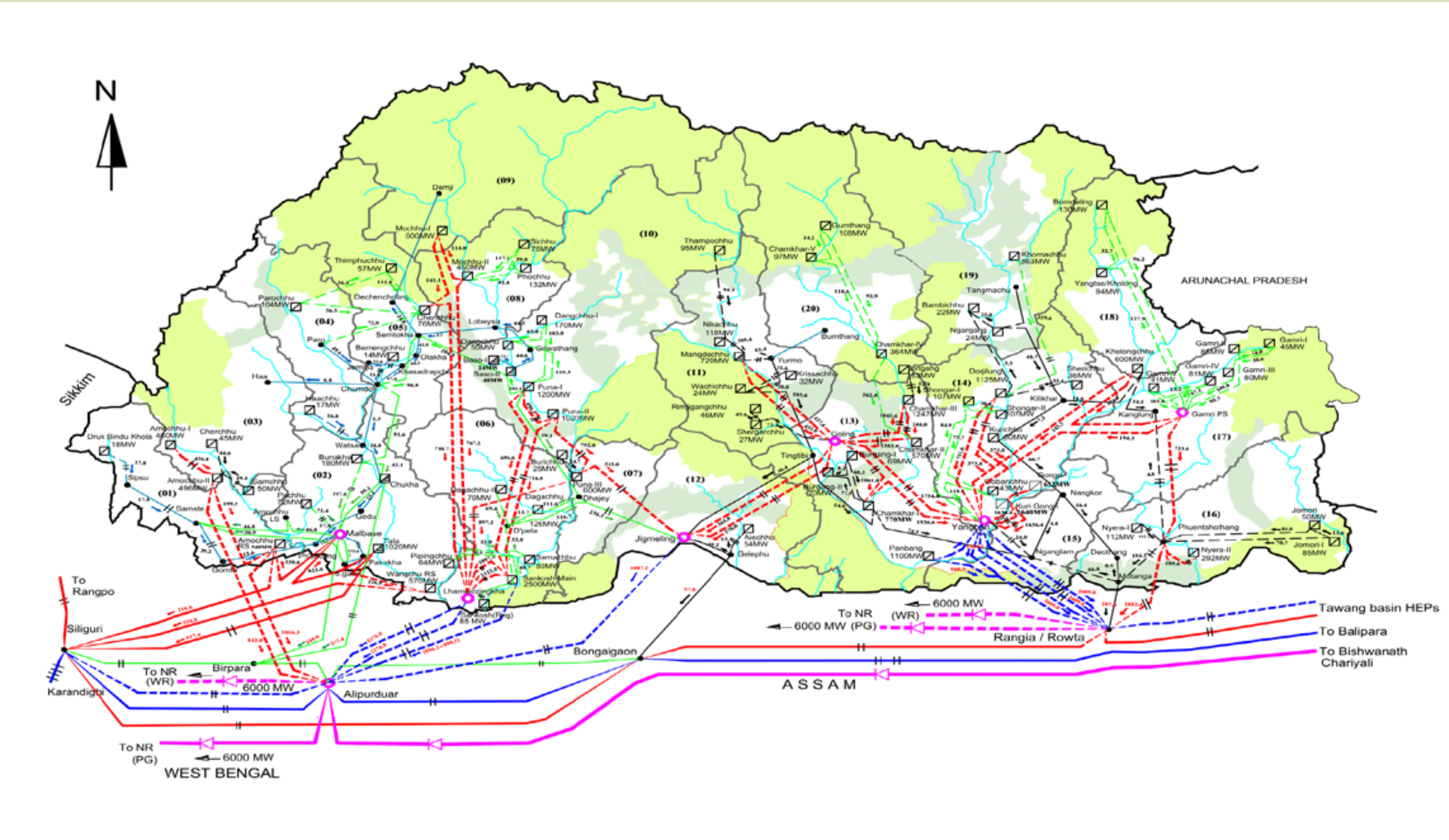
National Transmission Grid Master Plan (NTGMP) of Bhutan-2018



Department of Hydropower & Power Systems

Ministry of Economic Affairs

Royal Government of Bhutan

Thimphu

June 2018

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DEPARTMENT OF HYDROPOWER & POWER SYSTEMS
MINISTRY OF ECONOMIC AFFAIRS
BHUTAN

FOREWORD

The National Transmission Grid Master Plan (NTGMP 2012) was formulated in 2012 with the assistance of Central Electricity Authority (CEA) of India to support the accelerated hydropower development strategy of the Royal Government. Among others, the primary focus was to harmonize the evacuation of power from the 10,000MW initiative program.

During the 11th plan period, Royal Government has completed Detailed Project Reports of two hydropower projects; Pre-feasibility Reports of nine hydropower projects; and Reconnaissance Studies of seven hydropower projects. These new developments and availability of data on cost of construction in mountainous terrain from hydropower projects under construction have necessitated the updation of the NTGMP 2012. There was also the need to confirm transmission availability and reliability to cater to the significant growth in national peak load (CAGR of 4.85%) and electrification coverage of almost 100%.

This updation was also a capacity building exercise and was done in-house to utilize the expertise acquired in Transmission Planning, System Analysis, Load Forecasting et al built within the Department over the past few years with support of various agencies such as CEA, NORAD, SARI/EI, SAARC, World Bank, ADB, etc.

The NTGMP 2018 takes into account the system requirements based on five-year timeframes from 2020 till 2035, to provide flexibility in planning based on the prioritization of implementation of proposed projects. To ensure a comprehensive and holistic plan, all the potential projects have been considered in the time frame beyond 2040.

The NTGMP 2018 shall be the regulation for development of Associated Transmission Systems for smooth evacuation of power from earmarked projects to the load centers and beyond. We hope that this revised Master Plan will be useful to all the stakeholders.

Tashi Delek!

(Sonam P Wangdi)

Director General

Acknowledgement

The Updation of National Transmission Grid Master Plan (NTGMP)-2012 has been carried out in-house to develop the capacity of the Department with the financial support from the Royal Government of Bhutan. The achievement of this task would not have been possible without outstanding contributions and participation from relevant sectors such as Bhutan Power Corporation Ltd, Druk Green Power Corporation Ltd, Department of Forest and Park Services, National Environment Commission Secretariat and National Land Commission Secretariat, amongst others

We are grateful to Mr. Sonam P. Wangdi, Director General, Department of Hydropower and Power Systems (DHPS), Mr. Karma P. Dorji, Chief Engineer-DHPS, Mr. Karma Tshewang, Chief Engineer-DHPS and all the officials of DHPS for their valuable guidance, suggestions and feedbacks rendered during the preparation of this report.

Our special appreciation goes to Mr. Karma Namgyel, Offtg. Chief Engineer, TPSD for his continuous leadership guidance and involvement with the Project Team Members during the entire period of the preparation of this report. Furthermore, we would like to thank Mr. Pradeep Jindal and Mr. S.K. Ray Mohapatra, Chief Engineers, and their officials in Central Electricity Authority (CEA) and Mr. Ashok Pal, General Manager and Mr. Anupam Kumar, Engineer of POWERGRID, India for their assistance in providing the Indian power system data and necessary technical assistance rendered during the system analysis.

(Project Team)

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Abbreviations

AAAC	All Aluminium Alloy Conductor
ACCC	Aluminum Conductor Composite Core
ACSR	Aluminium Conductor Steel Reinforced
ATS	Associated Transmission System
BHP-I	Basochhu Hydropower Plant (Upper Stage)-I
BHP-II	Basochhu Hydropower Plant (Lower Stage)-II
BPC	Bhutan Power Corporation Limited
Ckt	Circuit
CEA	Central Electricity Authority
CHEP-I	Chamkharchhu Hydro Electric Project -I
CHP	Chukha Hydropower Plant
D/C	Double Circuit
DGPC	Druk Green Power Corporation Limited
DHPS	Department of Hydropower & Power Systems
DHP	Dagachhu Hydropower Plant
DoI	Department of Industry
DoE	Department of Energy
DPR	Detailed Project Report
EJG	Empowered Joint Group
Fd	Feeder
FYP	Five Year Plan
GIS	Gas Insulated Substation
GoI	Government of the Republic of India
HEP	Hydro Electric Project
HP	Hydropower Plant
HTLS	High Temperature Low Sag Conductor
HVDC	High Voltage Direct Current
ICT	Inter Connecting Transformer
KHP	Kurichhu Hydropower Plant
KHEP	Kholongchhu Hydro Electric Project
LILO	Loop-In-Loop-Out
MHEP	Mangdechhu Hydroelectric Project

MoEA	Ministry of Economic Affairs
MU	Million Unit
MVA	Mega Volts Ampere
MVAr	Mega Volt Ampere Reactive
MW	Mega Watts
NTGMP	National Transmission Grid Master Plan
NR	Northern Region
PHEP-I	Punatsangchhu Hydro Electric Project-I
PHEP-II	Punatsangchhu Hydro Electric Project-II
PH	Power House
P.F.	Power Factor
PFS	Pre-Feasibility Study
PS	Pooling Station
PSSE	Power System Simulator for Engineer
RGoB	Royal Government of Bhutan
RoW	Right of Way
S/C	Single Circuit
S/C on D/C	Single Circuit on Double Circuit Tower
SLBPH	Sankosh Left Bank Power House
SIL	Surge Impedance Loading
SRBPH	Sankosh Right Bank Power House
S/S	Sub-Station
THP	Tala Hydropower Plant
WR	Western Region

Chapter-1

Background

An Umbrella Agreement was signed between Royal Government of Bhutan (RGoB) and Government of Republic of India (GoI) in March 2009 for the development of 10,000MW hydropower projects by 2020, thus calling for the need to outline power evacuation plan for the 10,000MW initiative projects as well as other future potential projects and also to integrate the same with the power evacuation system being developed adjacently in India. Therefore, the National Transmission Grid Master Plan (NTGMP) was prepared jointly by the erstwhile Department of Energy (DoE) now called Department of Hydropower & Power Systems (DHPS), Ministry of Economic Affairs, RGoB and the Central Electricity Authority (CEA), Ministry of Power, GoI between 2010-2012 at a cost of Nu. 18million under the GoI's PTA financing in the 10^{th} FYP. The NTGMP-2012 provides a comprehensive, integrated and holistic road map for the construction of common power evacuation networks and pooling substations (both new and upgradation of existing infrastructures) including system strengthening.

The NTGMP report was presented and approved in the 9^{th} Empowered Joint Group (EJG) meeting and it was decided that all the hydroelectric projects under the 10,000MW initiative to adopt and implement their Associated Transmission Systems (ATSs) as per the NTGMP-2012. However, concerns were expressed from the GoI that the costs of ATSs were loaded to the GoI assisted projects as the ATSs proposed in the NTGMP-2012 appeared to be designed for future projects as well. Accordingly, in August 2014, relevant agencies from both the governments reviewed and finalized the cost apportionment of the ATSs to the beneficiary projects considering the appropriate usage of the system by the respective projects.

Further, after the finalization of NTGMP-2012, the DHPS has undertaken detailed project reports (DPR), pre-feasibility and reconnaissance studies of several hydropower projects based on which there were changes in the capacity and power evacuation arrangement of some of the projects. Moreover, there is delay in construction of some of the projects under 10,000 MW initiatives by 2020 and those projects which are under construction are now faced with geological problems, thereby pushing the completion deadline beyond 2020. Therefore, it has become important to provide the realistic hydropower developmental timeframe.

In addition, there is a need to revisit the transmission systems arrangment for some of the projects to further optimize the right of ways (RoW) to minimize impact of transmission lines on the national parks and biological corridors to the extent possible. Further, the location of HEPs, river profiles and Park and Corridors require the updation based on the latest available information.

In view of the above reasons, DHPS has initiated the updation of NTGMP-2012 in FY 2016-17 in-house as part of capacity building exercices of the Department. Subsequently, the RGoB has approved Nu. 1.00 million in the FY 2017-18.

Chapter-2

Introduction

Bhutan has one of the largest repositories of hydropower in Asia with a theoretical potential of 30GW, out of which 23.8GW is said to be techno-economically feasible for development. Currently, Bhutan has total installed generating capacity of 1,606MW (excluding embedded generations, solar and wind) comprising of Tala (1,020MW), Chukha (336MW), Kurichhu (60MW), Basochhu-U/S (24MW) & L/S (40MW) and Dagachhu (126MW) HPs.

Hydropower project are still the highest revenue earner and hence lots of priorities have been placed for its development. Currently, works for the five projects, viz., 1,200MW Punatsangchhu-I, 1,020MW Punatsangchhu-II, 720MW Mangdechhu, 118MW Nikachhu and 600MW Kholongchhu are at different stages of implementation, all of which are scheduled for completion between 2020 and 2025. When all these projects are commissioned, the country's hydro capacity will be 5,264MW with additional firm power of 589MW. Meanwhile, the Department is also carrying out detail investigations studies of many other projects for implementation in the future.

Exploration of hydropower potential is important to secure and supply domestic demand which has been steadily growing owing to increased developmental activities, 100% rural electrification coverage ratio and for meeting the demand of the existing HV industries (about 75% of the total domestic demand). The peak domestic demand was recorded 375.23MW on 24^{th} February 2018, which is more than available firm power capacity (320MW). In order to meet the peak deficit during the lean months, power has to be imported from India.

The existing transmission voltage level in the country is 400kV, 220kV, 132kV and 66kV. The entire 220kV and 400kV transmission system networks are in the western part, and it was largely developed as Associated Transmission Systems for Chukha and Tala HPs. Major quantum of electricity generated from these power plants are exported to India after meeting domestic demand. In the eastern part of Bhutan, Kurichhu (60MW) HP and its 132kV evacuation system caters to the local consumer and industrial load and the surplus power is transmitted to India through 132kV lines.

The updated NTGMP considered the realistic hydropower development timeframe as 2020, 2025, 2030, 2035, 2040 and beyond 2040. By 2025, all the under construction hydropower projects are expected to get commissioned. The timeframe in beyond 2040 is indicative of how the transmission systems would appear if all the techno-economically viable projects (greater than 10 MW) with total capacity of 23,833 MW are developed.

Bhutan's transmission network is integrated with Indian Grid and therefore, planning has to be carried out concurrently. In order to capture their future transmission plan and also to discuss the cross border transmission links and landing points in India, project team members visited CEA and POWERGRID. Since, the Indian Transmission Planning is carried out after every five years; they have the power system planning till 2021. Therefore, the future transmission plan of Bhutan is integrated to the power system data of India till 2021 and system analysis were carried out by rescaling the generation and load data of Indian systems.

The team members also discussed with the top level management of BPC to solicit their views and suggestions on the transmission planning. BPC expressed that the option of HTLS and quad moose line in Bhutan should be discarded considering the topography of our country. As such, the HDVC lines and HTLS conductors are not considered for the power evacuation arrangement. However, the quad moose lines are adopted in the cross border transmission links to evacuate bulk power to India. In addition, based on the concerned shared by BPC, the establishment cost of Goling switching station is loaded to Kholongchhu HEP.

Chapter-3

System Data

3.1. Existing Power System Data

The following list of information/data are compiled in order to create base case input file for carrying out load flow studies using PSSE software (ver. 33):

- Existing HPs & Under construction HEPs — Annexure-I
- DPR/PFR completed and DPR under preparation HEPs — Annexure-II
- All other potential HEPs — Annexure-III
- Existing transmission lines (66kV and above) — Annexure-IV
- Under construction and proposed transmission lines — Annexure-V
- Existing substations (66kV and above) — Annexure-VI
- Planned/under construction/proposed substations — Annexure-VII

To be able to develop the transmission projects in phase manner, the NTGMP is updated in following different time frame:

1. Transmission grid plan by 2020
2. Transmission grid plan by 2025
3. Transmission grid plan by 2030
4. Transmission grid plan by 2035
5. Transmission grid plan by 2040.
6. Transmission grid plan beyond 2040.

3.2. HEPs beyond 2040 Time frame

Under this scenario, all the techno-economically viable projects are considered, whereby the country will have total installed capacity of 23,833MW from 73 hydropower potential sites identified at different basins. The list of projects considered in beyond2040 time frame is given in Annexure-VIII.

3.3. HEPs by 2040 Timeframe

In the 2040 timeframe, five HEPs (Gongri, Khomachhu, Panbang, Chamkharchhu II & IV) are envisaged to be added. Except for Gongri which is at reconnaissance stage, other four are PFR completed projects. Their details are given in Annexure-VIII.

3.4. HEPs by 2035 Time frame

In the 2035 scenario, four HEPs (Bunakha, Wangchhu, Chamkharchhu-I and Kurigongri) are expected to get added. The DPR of Kurigongri is under preparation while the DPR for remaining projects are completed, which will be implemented in Joint Venture mode. Their details are given in Annexure-VIII.

3.5. HEPs by 2030 Time frame

In the 2030 time frame, three HEPs (Sankosh, Dorjilung, Nyera Amari I&II(integrated) are considered. While the DPR of Nyera Amari I & II (integrated) is under preparation, the DPR for other two projects are completed. Their details are given in Annexure-VIII.

3.6. HEPs by 2025 Time frame

In the 2025 time frame, two HEPs which are under construction (Punatsangchhu-I and Kholongchhu) are considered. Their details are given in Annexure-VIII.

3.7. HEPs by 2020 Time frame

In the 2020 time frame, three HEPs (Punatsangchhu-II, Mangdechhu and Nikachhu) are considered. They are under advanced stage of construction and it is expected to commission within 2020. Their details are given in Annexure-VIII.

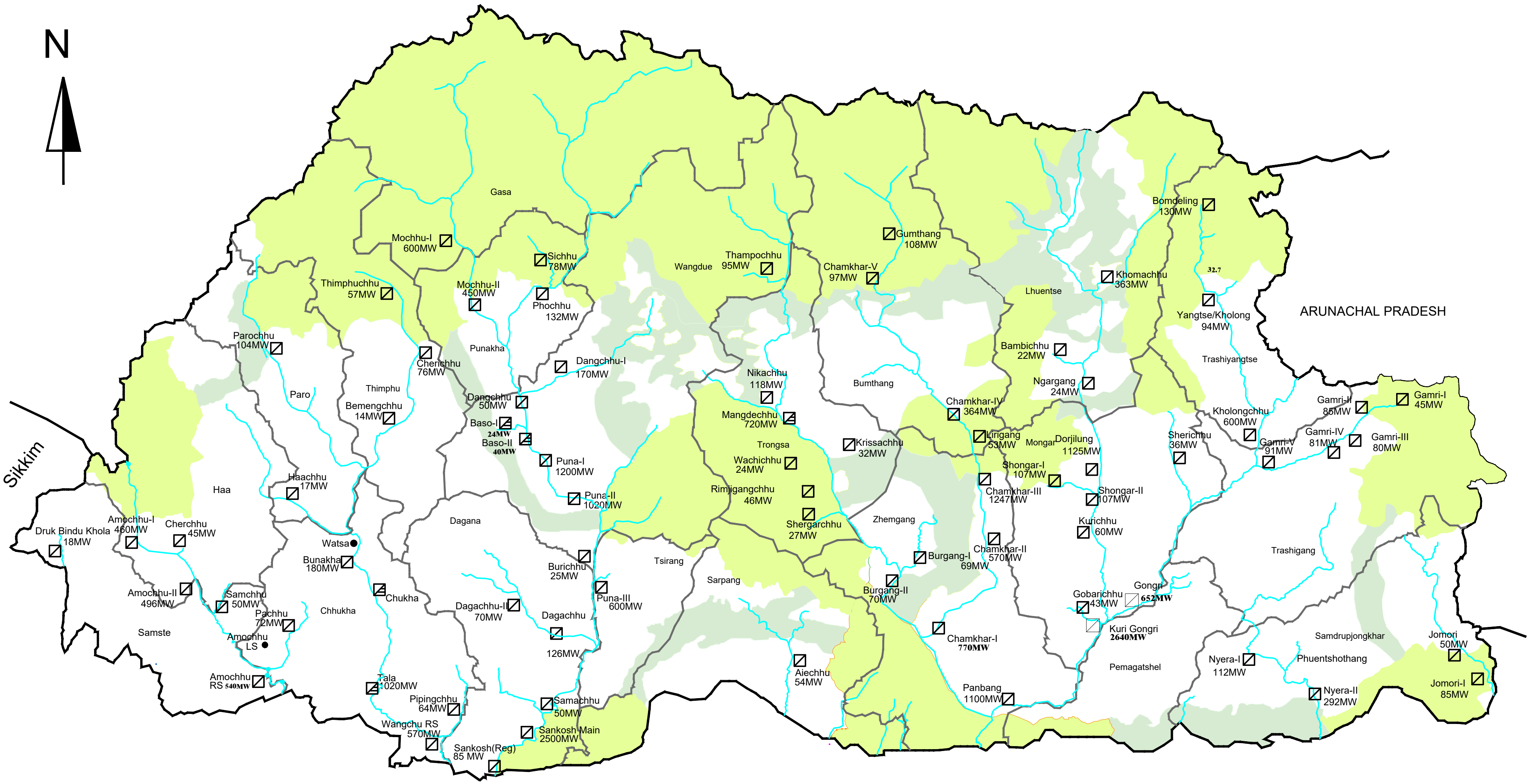
3.8. Topological map of Hydro projects

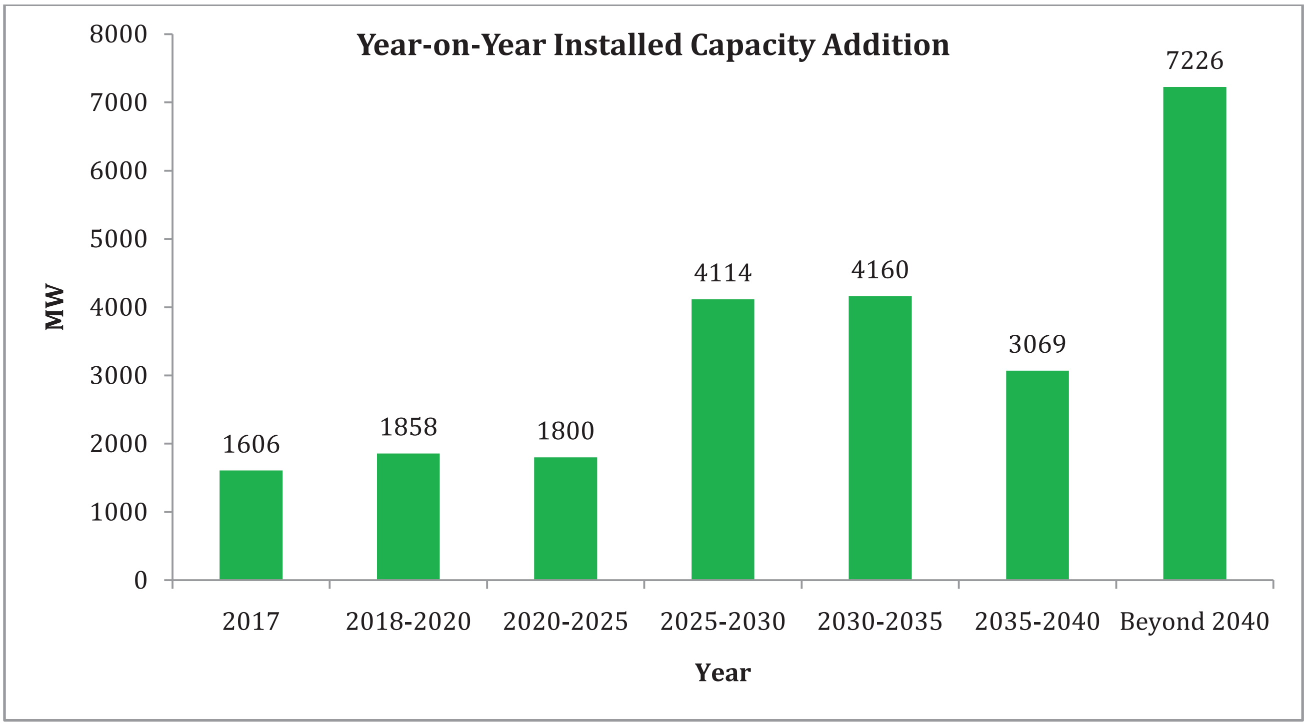
The map showing locations of existing HPs and potential HEPs being envisaged beyond 2040 time frame is given in Fig. 1.

3.9. Installed Generation Capacity

The year-wise capacity addition from potential hydropower projects in Bhutan is shown below:

Fig. 1: Tentative Location of HEPs Beyond 2040

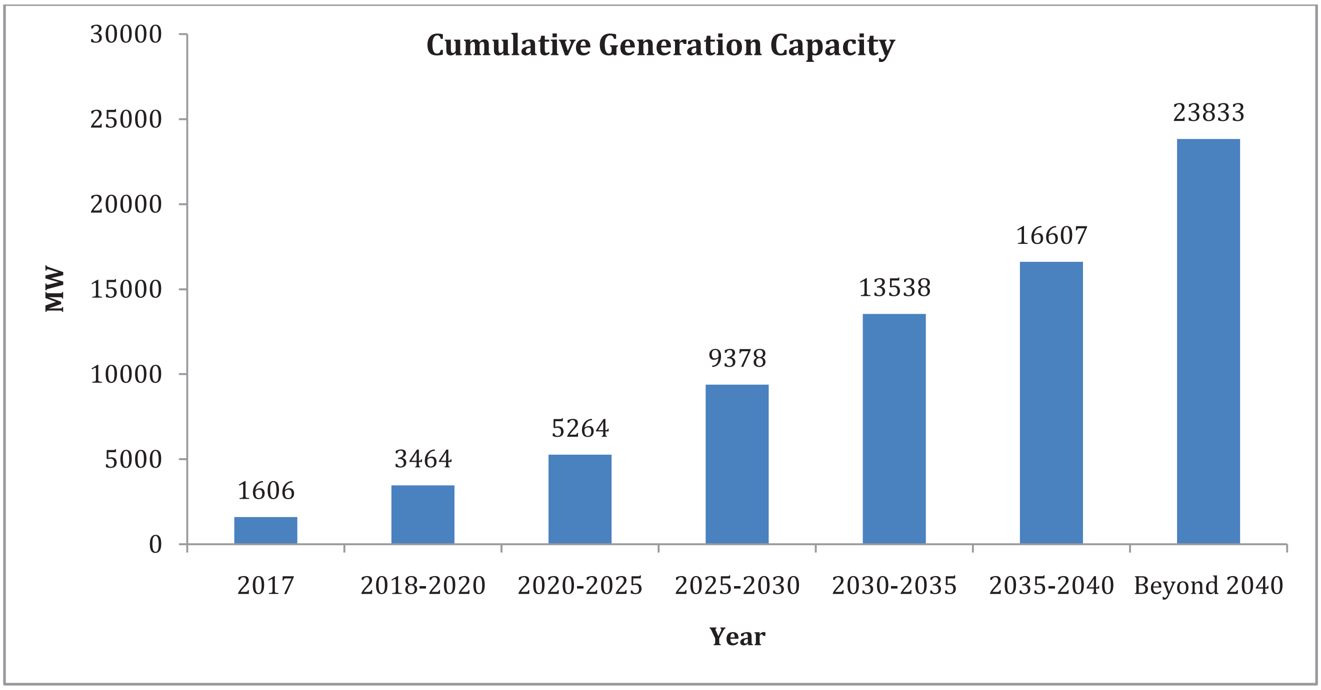




Graph 1: Year-on-Year installed capacity addition

3.10. The cumulative installed generating capacity:

The graph given below shows the cumulative generating capacity from 2018 to beyond 2040.



Graph 2: Cumulative generation capacity from 2018 to beyond 2040

3.11. Generation Dispatches.

The generation dispatch at hydro stations in Bhutan are worked out to carry out various system studies for different scenarios (See Annexure-IX). [1]0.5% auxiliary consumption is considered to work out the peak generation dispatches.

3.12. Electricity Demand forecast (2018-2040).

Accurate models for power demand forecast is essential for operation and planning purposes. Load forecasting helps planning agency and utility to make important decisions on purchasing and generating electric power and infrastructure development. Load forecasting is extremely vital for electric energy generation, transmission, distribution, system operator and markets.

The Department of Industries (DoI) under the Ministry of Economic Affairs has planned to develop four (4) industrial estates viz. Jigmeling Industrial Estate, Motanga Industrial Estate, Dhamdum Industrial Estate and Bondeyma Industrial Estate by 2020 timeframe. The total power demand from these four Industrial Estates will be 444 MW. Accordingly, the power requirement to the industrial parks was estimated in a phase manner in consultation with DoI and BPC.

The following methodologies were adopted to forecast the substations peak load:

- The energy consumption data of 23 major substations were compiled from 2008 to 2017. The growth rate was computed and accordingly energy forecast till 2040 was carried out.
- While doing the load flow analysis in PSSE software, the load data in 23 major substations were required. Hence, demand forecast (in MW) till 2040 was carried out substation wise.
- The peak loads of all major substations were compiled from 2008 to 2017 and average load factor was determined.
- Using the average load factor and energy forecast data, the peak load was determined till 2040

Assumptions:

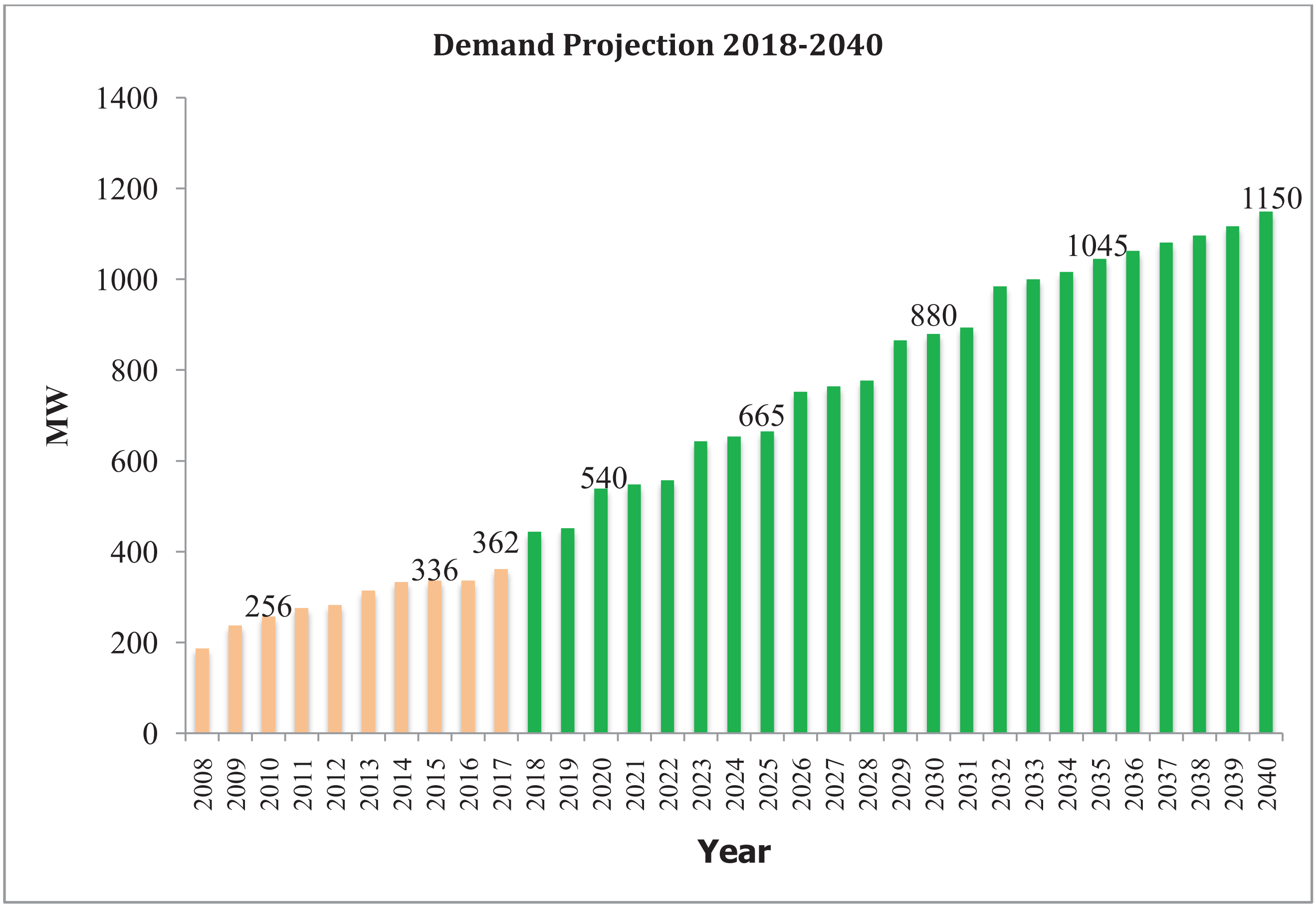
- The energy forecast was based on the historical growth rate of the 23 major substations.
- The energy consumption growth rate was computed considering the smooth growth only. If the growth rate is erratic, the data corresponding to a particular year was discarded.
- The upcoming industrial estates are assumed to be coming online only after 2020. The demand factor for the up-coming industrial estate was assumed to be 90.32%. The initial load

[1]As per Manual on Transmission Planning Criteria, CEA.

of four industrial estates is 88MW and balance loads are equally divided within given developmental period. The loads are added every after tariff cycle.

- The existing Motanga Industrial load is included in the Deothang substation load to segregate the future power demand of upcoming Motanga Industrial estate.
- 0.9 lagging power factor was used while calculating the MVAr.
- Construction power requirement for hydro project is considered to be embedded to MV industries.

[2]The annual energy generation for 2016 was decreased by 88.74MU compared to 2015 with 7,731.21MU. Similarly, the energy consumption has also been decreased compared to the previous year. The decreased in energy consumption was primarily due to decrease in HV industrial consumption, which reduced from 1,526.16MU in 2015 to 1,437.44MU in 2016. The total energy demand of Bhutan is expected to be 6,404.46MU with a peak demand of 1,150MW by 2040. As per the demand forecast, the average annual load growth was found out to be 4.4%.



Graph 3: Electricity Demand Forecast 2018-2040

[2]Power Data Book-2016, Bhutan Power Corporation Limited.

Table 1: Substation wise electricity demand forecast.

Name of Substation	2020		2025		2030		2035		2040	
	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr	MW	MVAr
Semtokha	22	10	25	12	30	14	35	17	41	20
Olakha	31	15	40	19	52	25	66	32	85	41
Dechencholing	15	7	17	8	19	9	22	10	24	12
Jemina	13	6	15	7	17	8	19	9	22	11
Lobesa	19	9	23	11	27	13	33	16	39	19
Haa	3	2	4	2	5	2	6	3	7	3
Paro	9	4	11	6	15	7	19	9	24	12
Gedu	5	3	6	3	6	3	7	3	7	3
Gomtu	17	8	19	9	21	10	24	12	27	13
Singhigaon	65	32	67	33	69	34	71	35	73	36
Phuentsholing	10	5	11	5	13	6	15	7	18	9
Watsa	3	2	3	2	3	2	3	2	3	2
Darjay/Tsirang	8	4	10	5	13	6	16	8	21	10
Kilikhar	7	3	9	4	11	5	14	7	17	8
Kanglung	12	6	16	8	22	11	29	14	39	19
Nangkor	3	2	3	2	4	2	4	2	4	2
Nganglam	33	16	33	16	33	16	33	16	33	16
Tingtibi	2	1	2	1	2	1	2	1	3	1
Gelephu	14	7	20	10	28	14	39	19	54	26
Deothang	29	14	34	16	40	19	47	23	56	27
Malbase	130	63	133	64	135	66	138	67	141	68
Yurmo	9	4	8	4	9	4	9	5	10	5
Jigmeling (200MW in 15 yrs)	45	22	79	38	147	71	181	87	181	87
Motanga (164 MW in 15 yrs)	27	13	57	28	118	57	148	72	148	72
Samtse (70 MW in 20 yrs)	5	2	15	7	36	17	56	27	63	31
Bondeyma (10 MW in 20 yrs)	3	1	4	2	6	3	8	4	9	4
Total	**540**		**665**		**880**		**1045**		**1150**	

Chapter-4

Existing Transmission System Scenario in Bhutan

The transmission networks in Bhutan comprised of eastern and western grids, which were previously operated separately prior to the commissioning of 2x63/80MVA, 220/132kV Jigmeling substation. With the establishment of the east-west interconnection, it has enhanced the energy security in the country.

The existing transmission network in western grid consists of 66kV, 220kV and 400kV voltage levels. The 220kV lines are used for evacuation of power from Chukha, Basochhu-II (Rurichhu) and Dagachhu HPs. Three 220kV feeders from CHP connect to Birpara S/S in India (one S/C LILOed at Malbase S/S). The power from Dagachhu is evacuated by 220kV D/C from Dagachhu-Jigmeling with LILO of one circuit at 220kV Dagapela S/S and another circuit at Tsirang S/S.

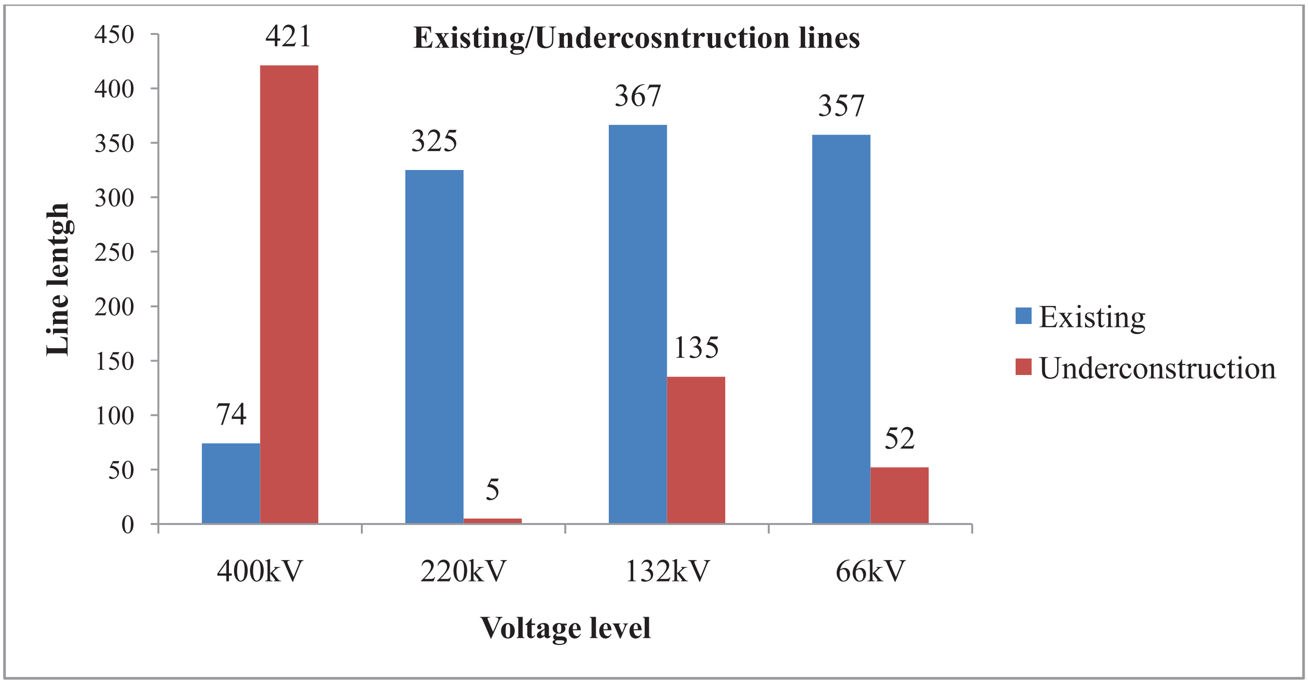
The 400kV system is used for evacuation of power from Tala HP. There are four 400kV Twin Moose conductors as feeder I, II, III & IV on two D/C tower connecting to Siliguri S/S (India). Feeder no. III is LILOed at 400/220/66kV Malbase S/S. From the 220kV D/C lines from Malbase to Singhigaon, one circuit is LILOed at Samtse S/S to meet the future industrial loads at Dhamdum(Samtse). The underlying 66kV wide spread network is well interconnected to 220kV system in the western Bhutan and is supplying electricity to the load centers. Eastern Bhutan currently has only 132kV system connecting different substations from KHP. However, with the upcoming HEPs in the east, 400kV system will be added to the grid.

All the surplus power after meeting domestic demand is exported to India from following cross border links:

1. 400kV, 2xD/C Twin Moose line, Tala-Siliguri with LILO of one circuit at Malbase S/S;
2. 220kV, 1xD/C line, Chukha- Birpara
3. 220kV, 1xS/C line, Chukha- Malbase-Birpara
4. 132 kV, 1xS/C line, Motanga-Rangia
5. 132kV, 1xS/C line, Gelephu-Salakati .

The detail of existing and under construction transmission systems are given in Annex-IV and Annex-V respectively.

Total transmission line length of different voltages for existing and under construction in Bhutan is shown in graph 4.



Graph 4: Existing & under construction Transmission lines in Bhutan

Chapter-5

System Planning Guidelines

5.1. Planning Approach

During the preparation of NTGMP 2012, following key factors were considered:

- Meeting the requirements of adequacy, security and reliability;
- Amenable to development in stages;
- Overall cost optimization of transmission system;
- Optimum utilization of Right-of-Ways;
- Ease of operation & maintenance;
- Identification of Pooling Stations for aggregation of generation;
- Identification of sub-stations for catering to the demand of load centers in Bhutan;
- Identification of cross border transmission links and their landing points in India;
- Minimum environmental impact.

All above aspects are given due consideration while updating NTGMP, however, identification of cross border transmission links and their landing points in India were discussed with relevant GoI agencies to capture their future development plan of transmission system and development of national grid including interconnection links and pooling substations.

With the above objectives, the following norms are followed to carry out the transmission planning exercise:

- Planning for development of integrated transmission grid;
- (n-1) contingency including tower outage in hilly terrain;
- Power transmission at 400kV, 220kV, 132kV and 66kV AC voltage
- 0.5% auxiliary consumption at hydropower stations.

5.2. System Studies methodology & Software

Load flow studies have been carried out to plan and determine the system requirement of transmission network for all the scenarios using PSSE software. The base case input files are prepared to carry out load flow studies for all the scenarios. The details are provided in the chapter 6.

5.3. Transmission line loading capacity

[3]The transmission line loading limits are governed by many factors such as voltage regulation, stability and current carrying capacity (thermal capacity limit). The Surge Impedance Loading (SIL) gives a general idea of the loading capability of the line with respect to stability. It is usual to load the short line above SIL and long lines lower than SIL.

The planning of future transmission lines are based on maximum conductor temperature of 85^0Cand ambient temperature of 40^0C. Among the ACSR conductors, Quad and Moose conductors are considered in 400kV, Zebra in 220kV, Panther in 132kV and Wolf/Dog in 66kV transmission lines.

The approximate thermal loading capacity is based on the standard values of ampacity adopted in NTGMP-2012. Since Bhutan has lines falling in the range of 'short (<80km)/medium length lines (80>200km)', the line loading is taken as per the thermal loading. The approximate values of capacity (thermal loading capacity) of above conductors at ambient temperature 40^0C are given in Appendix-1.

[3]Statement of Reasons for rates, charges and Terms & Conditions for usage of Intervening Transmission Facilities, Sept 2010, Central Electricity Regulatory Commission, New Delhi

Chapter-6

Base case Simulation results & analysis

A strong base case is crucial in order to have accuracy in terms of future transmission planning as load flow studies will be carried on the base case that has been prepared. Further, it also checks for the precision of data that are used. In view of the importance of base case file, 6 simulations were carried out i.e. 3 different data sets from summer months and 3 different data sets from winter months using PSSE software.

After running the base case simulations for 6 data sets, Table 2 shows the comparison of errors for all 6 data sets:

Table 2: Comparison of Base case data sets.

Sl. No.	**Dates**	**Average % Error**	
		Above 66kV feeders considered	**66kV feeders excluded**
1	23-Dec-15	63.00%	51.01%
2	15-Jan-16	33.00%	45.27%
3	5-Feb-16	52.00%	71.80%
4	5-Jun-16	58.00%	40.24%
5	3-Jul-16	11.70%	7.39%
6	15-Aug-16	11.00%	6.32%

When comparing the actual recorded power flow in every branches and generations with the simulation results, it was found that the best base case was on 15 August, 2016 with minimum error of 11%. Hence, the load flow analysis for all scenarios was carried out on the base case data corresponding to 15 August 2016.

The most challenging factor while creating base case data was accuracy and reliability. In order to validate the PSSE simulation results, actual recorded data were gathered from BPSO. During the simulation, it was found that there were some errors in the recorded data received from BPSO and accordingly corrections had been done. Data accuracy and reliability is the most important input to carry out PSSE simulation and results are dependent on the input data.

The 11% error corresponding to 15 August 2016 has resulted mainly due to the 66kV lines as our transmission network is largely dominated by 66kV lines and also it may be due to the load being directly pegged to 66kV bus. If the load data is not accurate then it contributes to more percentage error. It is noticeable from the computations that there is not much difference in the power flow in terms of MW; however when it is converted in terms of percentage, the error is huge. Therefore, error is calculated both inclusive of 66kV lines and excluding 66kV lines, in both cases, the error is found to be less with data set of 15 August 2016.

Chapter-7

Transmission Grid Plan by 2020

The transmission grid by 2020 includes 1,020MW Punatsangchhu-II, 720MW Mangdechhu and 118MW Nikachhu HEPs which are under advanced stage of construction and are expected to commission within 2020. The total generation capacity from these three projects will add 1,858MW to the existing 1,606MW. Transmission grid plan for 2020 scenario showing power flow in full hydro dispatch is given in Figs. 2A & 2B

7.1.1. Punatsangchhu-II HEP (1,020MW)

1,020MW PHEP-II (15km downstream of PHEP-I) is located in Wangduephodrang Dzongkhag. The contract for the supply and construction of 400kV D/C line form PHEP-II to Jigmeling pooling station has been awarded to M/s KEC International Ltd and is in the advanced stage of completion. The ATS of PHEP-II is as follows:

- 400kV step up voltage
- LILO of 400kV, 1xD/C line of PHEP-I to Lhamoizingkha(Bhutan border) at PHEP-II
- 400kV, 1xD/C Twin Moose line, PHEP-II to Jigmeling
- 1x80MVAr, 420kV bus reactor at PHEP-II
- 400/220kV, 4x167MVA ICT at Jigmeling GIS including bays (Cost shared by CHEP-I, KHEP & PHEP-II)

7.1.2. Mangdechhu HEP (720MW)

The MHEP is located under Trongsa Dzongkhag in the central Bhutan. The construction of two numbers of 400kV D/C transmission line with twin ACSR Moose conductor from MHEP pothead yard to Jigmeling pooling substation via Goling has been awarded to M/s Kalpataru Power Transmission Ltd., India and are expected to complete before commissioning of MHEP.

The design, supply, construction, testing and commissioning of 400kV indoor GIS substation in Jigmeling is carried out by M/s Hyosung Corporation, South Korea and KEC International, India and the same work has been completed and inaugurated in December 2017.

The ATS of MHEP is as follows:

- 400kV step up voltage
- 400kV, 2xS/C Twin Moose on D/C tower line, MHEP - Goling switching station.
- 400/132kV, 4x67MVA ICT at Mangdechhu switchyard
- 400kV, 1xD/C Twin Moose line, Goling - Jigmeling

- 132kV, 1xD/C tower lines, MHEP - Yurmo (Cost shared between MHEP and Nikachhu HEP).
- 1x80MVAr, 420kV bus reactor at MHEP
- Establishment of 400/220kV Jigmeling GIS substation
- 1x80MVAr, 420kV reactor at Jigmeling including bays
- 400kV, 1xD/C Quad Moose line (Bhutan portion only), Jigmeling - Alipurduar (Cost shared between MHEP (50% of the cost) and CHEP-I/KHEP).

7.1.3. Nikachhu HEP (118MW)

Nikachhu HEP is located upstream of MHEP in Trongsa Dzongkhag. The construction of 18.60km 132kV transmission line is being taken up by BPC and the BPC has awarded the erection works of transmission line to CDCL in July 2017.

The ATS of Nikachhu HEP is as follows:

- 132kV step up voltage
- Stringing of 2nd circuit line of 400kV, 2xS/C on D/C tower lines of MHEP-Goling
- 132kV, 1xD/C, Nikachhu-MHEP
- 132kV, 1xD/C, MHEP-Yurmo (balance 50% cost apportioned from MHEP)

7.2. Results of Power Flow analysis for 2020 scenario

Simulation results showing power flow in various cross borders transmission links are given below:

Table 3: PSSE simulation results for 2020 scenario.

Sl/No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri (Fd. IV)	214.1	1.01	1.01
2	401	Tala	444072	Siliguri (Fd. I&II)	219*2	1.01	1.01
3	402	Malbase	444072	Siliguri(Fd.III)	206.7	1.01	1.01
4	406	L/Zingkha	444073	Alipur (2 ckts)	453.6*2	0.99	0.99
5	403	Jigmeling	444073	Alipur (2 ckts)	420.1*2	0.99	0.99
6	201	Chukha	442025	Birpara (2 ckts)	90.8*2	0.99	0.99
7	202	Malbase	442025	Birpara	62.5	1.01	0.99
8	107	Motanga	211150	Rangia1	6.4	0.95	0.99

9	108	Gelephu	211550	Salakati1	18.5	0.98	0.99
10	205	Tsirang	206	Jigmeling	69.3	0.99	0.99

Table 4: Summary of total power generation, load and export.

Sl.No	Total Generation	Total Load	Total Export
1	3,464 MW	556.80 MW	2,875.20 MW

7.2.1. System voltage, Line and Transformer loading

With load power factor presumed to be 0.9 at grid-substations, it was observed that most of the 66kV buses in western grid enters into [4]**Alert State,** where the voltage at connection points are outside the normal limit but within the limits of 0.9 times and 1.1 times of the nominal values. However, the bus voltage in 400kV, 220kV and 132kV were within the [5]**Normal State**, where the voltage at all connection points is within the limits of 0.95 times and 1.05 times of the nominal values. With regard to lines and transformers loadings, it was observed to be within the permissible limit.

[4] As per Grid Code Regulation-2008 of Bhutan
[5] As per Grid Code Regulation-2008 of Bhutan

Fig. 2A: Base Case with Full hydro dispatch in 2020 Scenario

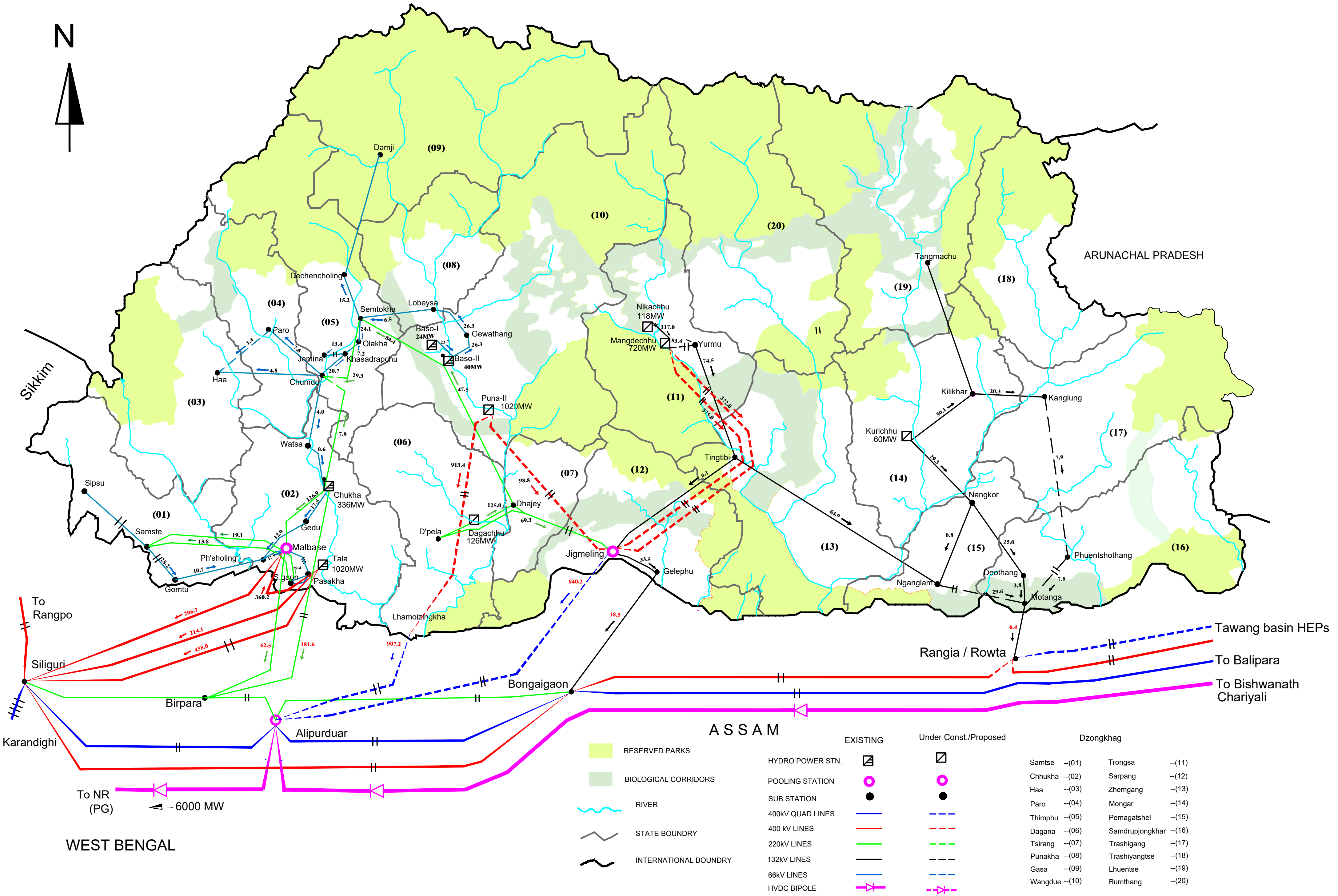
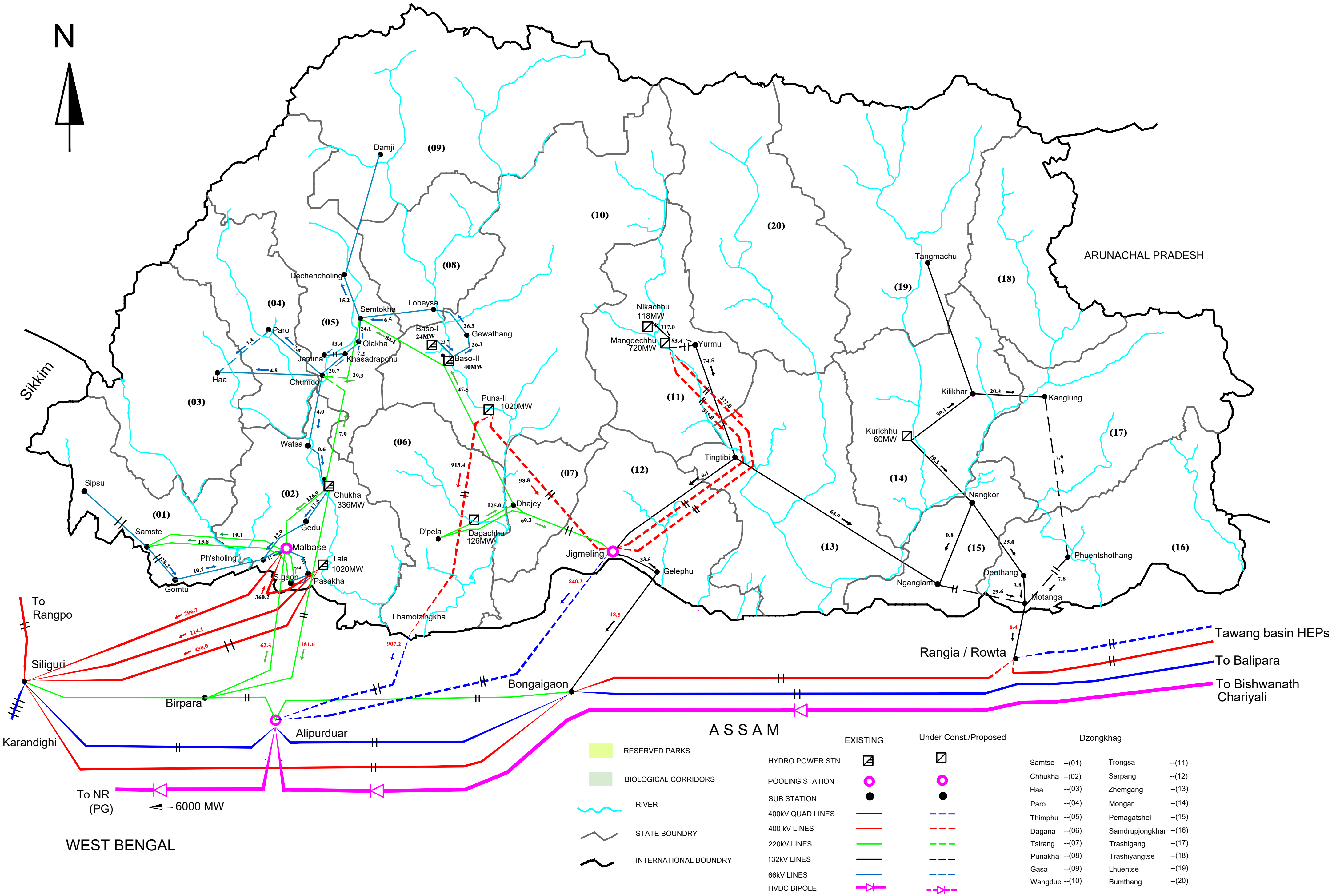


Fig. 2B: Base Case with Full hydro dispatch in 2020 Scenario



Chapter-8

Transmission Grid Plan by 2025

Under 2025 scenario, following HEPs which are under construction stage are considered based on their expected commissioning year:

1. 1,200MW Punatsangchhu-I HEP
2. 600MW Kholongchhu HEP

The total capacity addition from the above HEPs will be 1,800MW. The ATS of KHEP is as per the decision of the two governments meeting held in August, 2014 while the ATS of PHEP-I is as per the actual construction. Transmission grid plan for 2025 scenario showing power flow in full hydro dispatch is given in Figs. 3A & 3B

8.1.1. Punatsangchhu-I HEP (1,200MW)

PHEP-I is located in the upstream of PHEP-II in Wangdephodrang Dzongkhag. The contract for the supply and construction of two numbers of 400kV D/C transmission line from PHEP-I to Lhamoizingkha (Bhutan border) has been awarded to consortium of M/s Jyoti Structure Ltd., India and M/s Gammon India Ltd. for package A and package B respectively.

The ATS of PHEP-I is as follows:

- 400kV, 2xD/C Twin Moose line, PHEP-I to Lhamoizingkha (Bhutan border) (one D/C routing via PHEP-II)
- 400/220kV, 4x105MVA ICT at PHEP-I
- LILO of 220kV S/C line of Basochhu-II to Tsirang line at PHEP-I
- 1x80MVAr 420kV Bus reactor at PHEP-I

8.1.2. Kholongchhu HEP (600MW)

KHEP is the first of the four JV projects to start after signing of IG Agreement for JV projects on April 22, 2014. It is located in Trashiyangtse Dzongkhag. For the supply of construction power to the project site, 132kV Kanglung-Kilikhar line is to be LILOed at the KHEP and the construction works for the same was awarded to M/s Shayama Power India Limited in July 2016.

The ATS of KHEP is as follows:

- 400kV step-up voltage
- 400kV, 2xS/C Twin Moose on D/C tower lines, KHEP - Yangbari.
- 400/132/33kV, 4x67MVA ICT at KHEP

- 400kV, 1xD/C Twin Moose line, Yangbari - Goling (2nd line)
- LILO of 132kV S/C line of Kanglung - Kilikhar at KHEP
- 1x80MVAr 420kV bus reactor at KHEP
- 400kV, 1xD/C Twin Moose line, Goling - Jigmeling (2nd line, Cost to be shared between KHEP and CHEP-I)
- 400kV, 1xD/C Quad Moose line, Jigmeling - Alipurduar (50% of the cost to be shared between KHEP and CHEP-I).
- 400/220kV, 4x167MVA ICT at Jigmeling GIS including bays(Cost to be shared between KHEP, CHEP-I and PHEP-II)
- 400kV Goling GIS switching station establishment cost (Since KHEP is anticipated to come ahead of CHEP-I, this scope is proposed under KHEP ATS, which was initially under the scope of CHEP-I)

The tentative cost estimate for the ATS is given in Annexure: XIII.

8.2. Results of Power Flow analysis for 2025 Scenario

Simulation results showing power flow in various cross borders transmission links are given below:

Table 5: PSSE simulation results for 2025 scenario

Sl.No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri(Fd. I&II)	229*2	1.01	1.01
2	401	Tala	444072	Siliguri (Fd. IV)	223.8	1.01	1.01
3	402	Malbase	444072	Siliguri(Fd.III)	225	1.01	1.01
4	407	Jigmeling	444073	Alipur (2 ckts)	642.4*2	0.98	0.98
5	409	L/Zingkha	444073	Alipur (2 ckts)	967.5*2	0.98	0.98
6	201	Chukha	442025	Birpara (2 ckts)	105.8*2	0.99	0.99
7	202	Malbase	442025	Birpara	50.8	0.99	0.99
8	205	Tsirang	206	Jigmeling	51.6	0.99	0.98
9	107	Motanga	211150	Rangia1	83.4	0.97	0.965
10	108	Gelephu	211550	Salakati1	39.9	0.98	0.98

Table 6: Summary of total power generation, load and export.

Sl/No	Total Generation	Total Load	Total Export
1	5,264 MW	687 MW	4,512 MW

8.2.1. System voltage, line and Transformer loading.

With load power factor presumed to be 0.9 at grid-substations, low bus voltages were observed at various 66kV substations during peak load condition. However, the bus voltage in 400kV, 220kV and 132kV were within the normal state. All the transmission lines above 66kV in Bhutan and cross border transmission links are found to be within the permissible loading limit. The system strengthening requirement in the 2025 scenario is given in chapter 11.

Fig. 3A: Base Case with Full hydro dispatch in 2025 Scenario

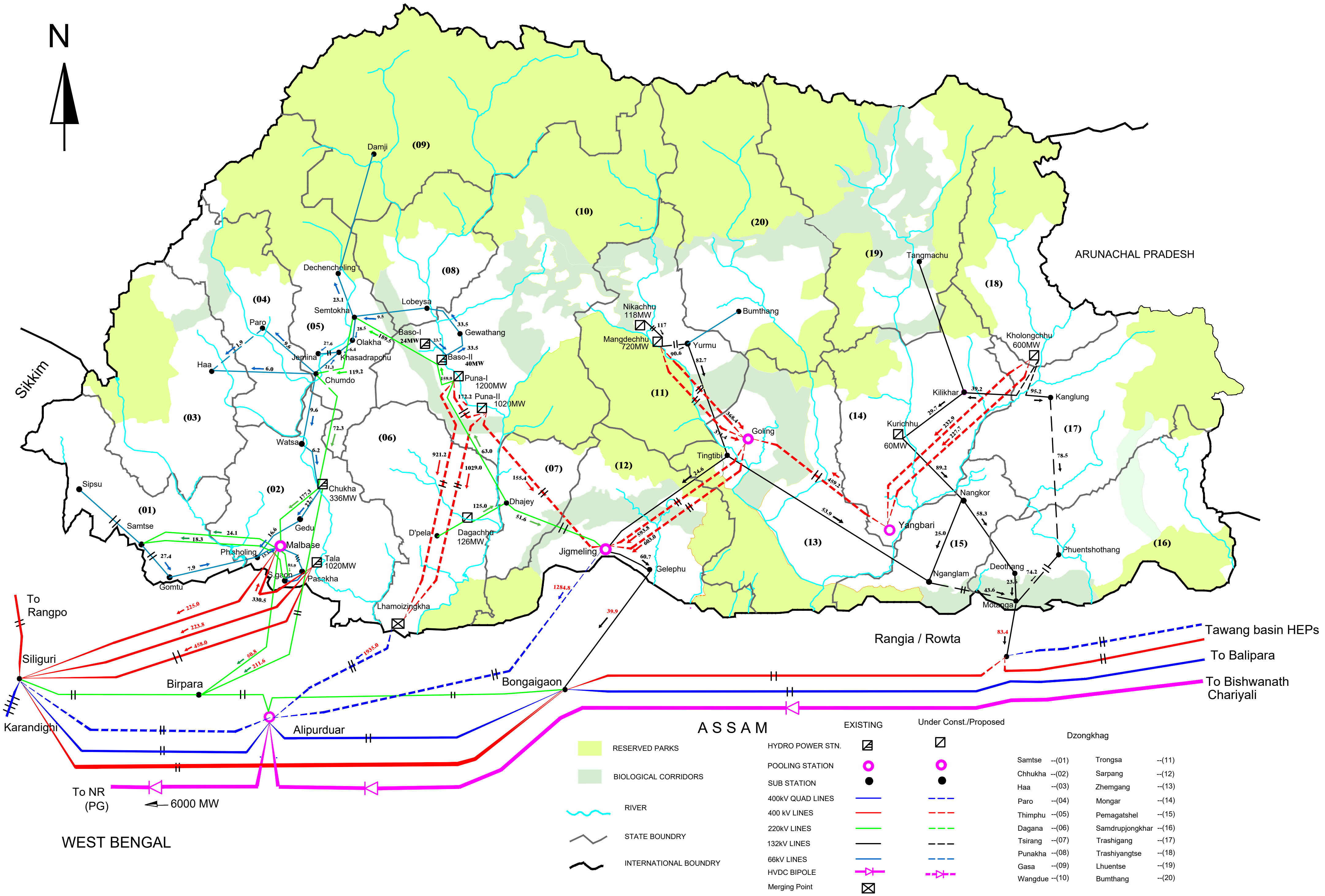
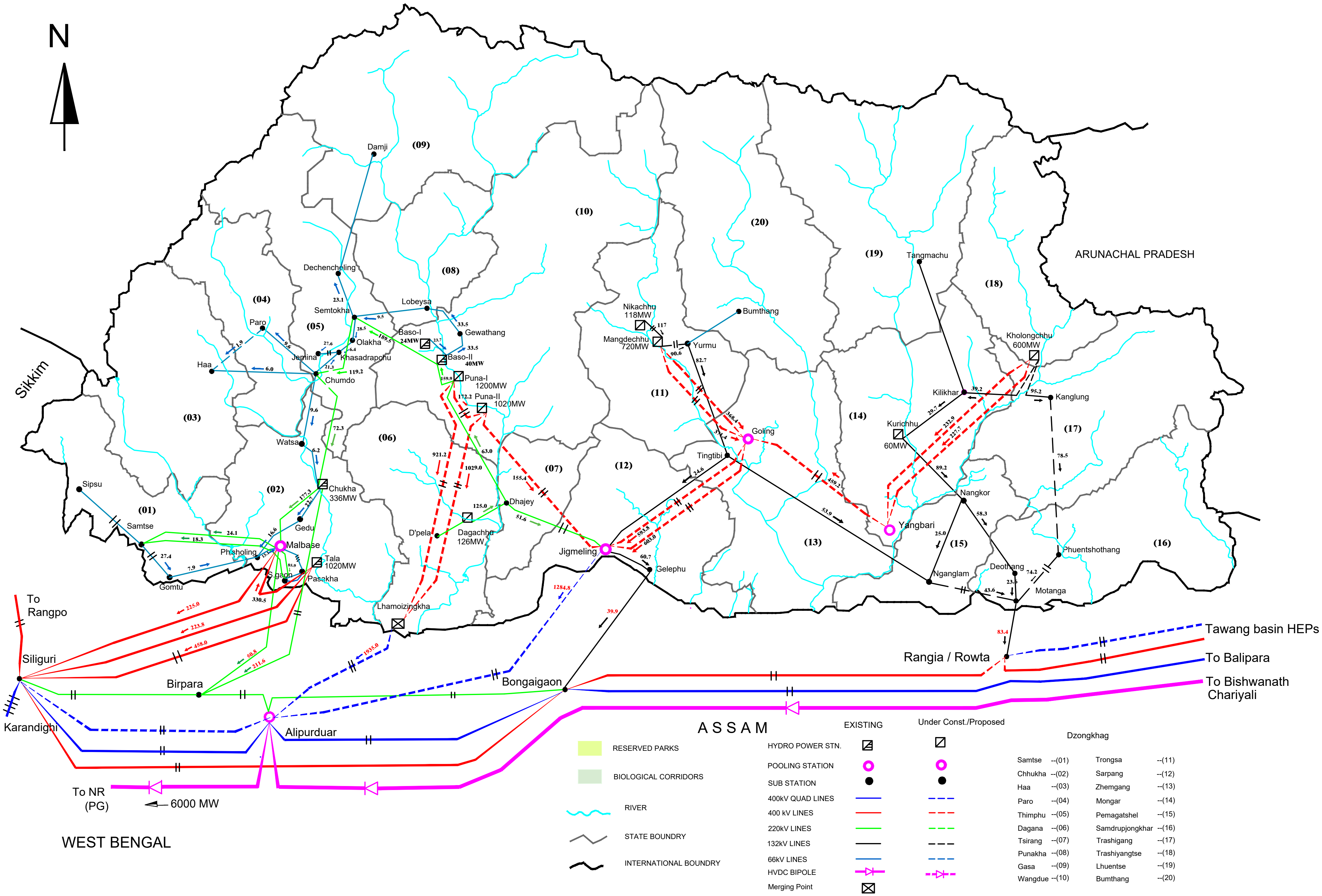


Fig. 3B: Base Case with Full hydro dispatch in 2025 Scenario



Chapter -9

Transmission Grid Plan by 2030.

In the 2030 scenario, the following HEPs which are DPR completed projects are considered:

1. 1,125MW Dorjilung HEP
2. 2,585MW Sankosh HEP
3. 404 MW Nyera Amari I & II (integrated) HEP

Their ATSs are firmed up based on NTGMP-2012 and as per the final DPR. The total capacity addition from these HEPs will be 4,114 MW. Transmission grid plan for 2030 scenario showing power flow in full hydro dispatch is given in Figs. 4A & 4B

9.1.1. Sankosh HEP (2,585MW)

Sankosh HEP is located in the southern part of Bhutan and is about 14km away from the Bhutan-India border. It comprises of main dam power house with 2,500MW and a regulating dam with 85MW installed capacity. The power from the SLBPH and SRBPH is proposed to be generated at 15.75kV voltage level and stepped up to 400kV through 4 no. 15.75/400kV, 382MVA three phase transformers each. For the supply of construction power to the project, 220kV S/C will be extended from Dagapela substation.

The ATS of Sankosh HEP is as follows:

- 400kV step-up voltage
- Looping-in of 400kV D/C Twin Moose PHEP-II –Lhamoizingkha (Bhutan border) line at SLBPH with 400kV D/C Twin Moose Conductor (point of LILO is about 15km from Bhutan border
- Looping-out of 400kV D/C PHEP-II – Lhamoizingkha line with 400kV S/C (Quad Moose) line from SLBPH-(this looping out S/C line would be about 0.02km length, after which it would become a part of 400kV D/C Quad line for about 5km and then merged with PHEP-II Lhamozingkha 400kV Twin Moose line)
- Looping-in of 400kV D/C Twin Moose PHEP-I –Lhamoizingkha (Bhutan Border) line at SRBPH with 400kV D/C Twin Moose Conductor (point of LILO is about 15km from Bhutan border)
- Looping-out of 400kV D/C PHEP-I – Lhamoizingkha line with 400kV S/C (Quad Moose) line from SRBPH- (this looping out S/C line would be about 0.02km length, after which it

would become a part of 400kV D/C Quad line for about 5km and then merged with PHEP-I Lhamozingkha 400kV Twin Moose line)

- Two 400kV S/C Quad lines, one each from SLBPH and SRBPH (which is about 0.02km in length) would merge to form 400kV D/C Quad Moose line up to Alipurduar
- 2x80MVAr, 420kV bus reactor one each at SLBPH & SRBPH
- 2x104MVA, 400/220kV ICT, one each at SLBPH & SRBPH
- Provision of one (1) no. 220kV line bay each at SLBPH &SRBPH
- Space provision for 1 no. 220kV bay each at SLBPH & SRBPH(for drawal of power by Bhutan)
- Regulating Dam PH –SLBPH 220kV S/C with Zebra conductor
- Regulating Dam PH- RBPH 220kV S/C with Zebra conductor

The tentative cost estimate for the ATS is given in Annexure: XIII.

9.1.2. Dorjilung HEP (1,125MW)

Dorjilung HEP is located in the eastern Bhutan, upstream of the existing 60MW Kurichhu HP. The power generated will be stepped up to 400kV and evacuated through 2xD/C 400kV lines. While one 400kV D/C line will be a dedicated line from Dorjilung to Yangbari, 2nd D/C line will be strung on the two empty arms of 400kV KHEP to Yangbari transmission lines.

The ATS of Dorjilung HEP as per DPR is as follows:

- 400kV step-up voltage
- 400kV, 2xD/C Twin Moose line, Dorjilung – Yangbari line (2nd D/C line will be drawn towards the 400kV S/C KHEP lines and will be hooked on the vacant arm of the D/C tower at suitable spot).
- 400kV, 1xD/C Quad Moose line, Yangbari – Rangia/Rowta (Bhutan portion).

The tentative cost estimate for the ATS is given in Annexure: XIII.

9.1.3. Nyera Amari-I & II (integrated) HEP (404MW)

Nyera Amari-I & II (integrated) HEP is located in the East/South of Bhutan. The power generated from Nyera Amari-I & II will be pooled at Phunshothang Pooling station at 132kV and 400kV voltage level respectively.

The ATS of Nyera Amari-I & II (integrated) HEP is as follows:

- 400kV step-up voltage

- 132kV, 2xD/C line, Nyera Amari-I – Phuntshothang substation.
- 400kV, 2xD/C Twin Moose line, Nyera Amari-II – Phuntshothang substation.
- 400kV, 1xD/C Twin Moose line, Phuntshothang – Rangia/Rowta (Bhutan portion).

The tentative cost estimate for the ATS is given in Annexure: XIII.

9.2. Result of Power Flow analysis for 2030 Scenario.

Simulation results showing power flow in various cross borders transmission links are given below:

Table 7: PSSE simulation results for 2030 scenario

Sl/No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri (Fd. I&II)	240.9*2	0.99	0.98
2	401	Tala	444072	Siliguri(Fd.IV)	235.4	0.99	0.98
3	402	Malbase	444072	Silliguri	247.1	0.99	0.98
4	407	Jigmeling	444073	Alipur (2 ckts)	657.8*2	0.98	0.96
5	409	L/Zingkha	444073	Alipur (2 ckts)	1160*2	0.97	0.96
6	410	Yangbari	214151	Rangia(2ckts)	682.7*2	0.99	1.00
7	414	P/thang	214151	Rangia(2ckts)	110*2	1.00	1.00
8	418	Sankosh LB	444073	Alipur	923.5	0.98	0.96
9	419	Sankosh RB	444073	Alipur	915.4	0.98	0.96
10	201	Chukha	442025	Birpara (2 ckts)	109.4*2	0.98	0.98
11	202	Malbase	442025	Birpara	18.4	0.97	0.98
12	107	Motanga	211150	Rangia1	93.2	0.96	0.99
13	108	Gelephu	211550	Salakati1	29.5	0.97	0.97

Table 8: Summary of total power generation, load and export.

Sl/No	Total Generation	Total Load	Total Export
1	9,378 MW	927 MW	8,383 MW

It was observed that there isn't any transmission line constraint for delivery of power to India as the loadings of all the cross border transmission lines, as well as voltage deviation are found to be within the permissible limit.

Fig. 4A: Base case with full hydro dispatch in 2030 scenario

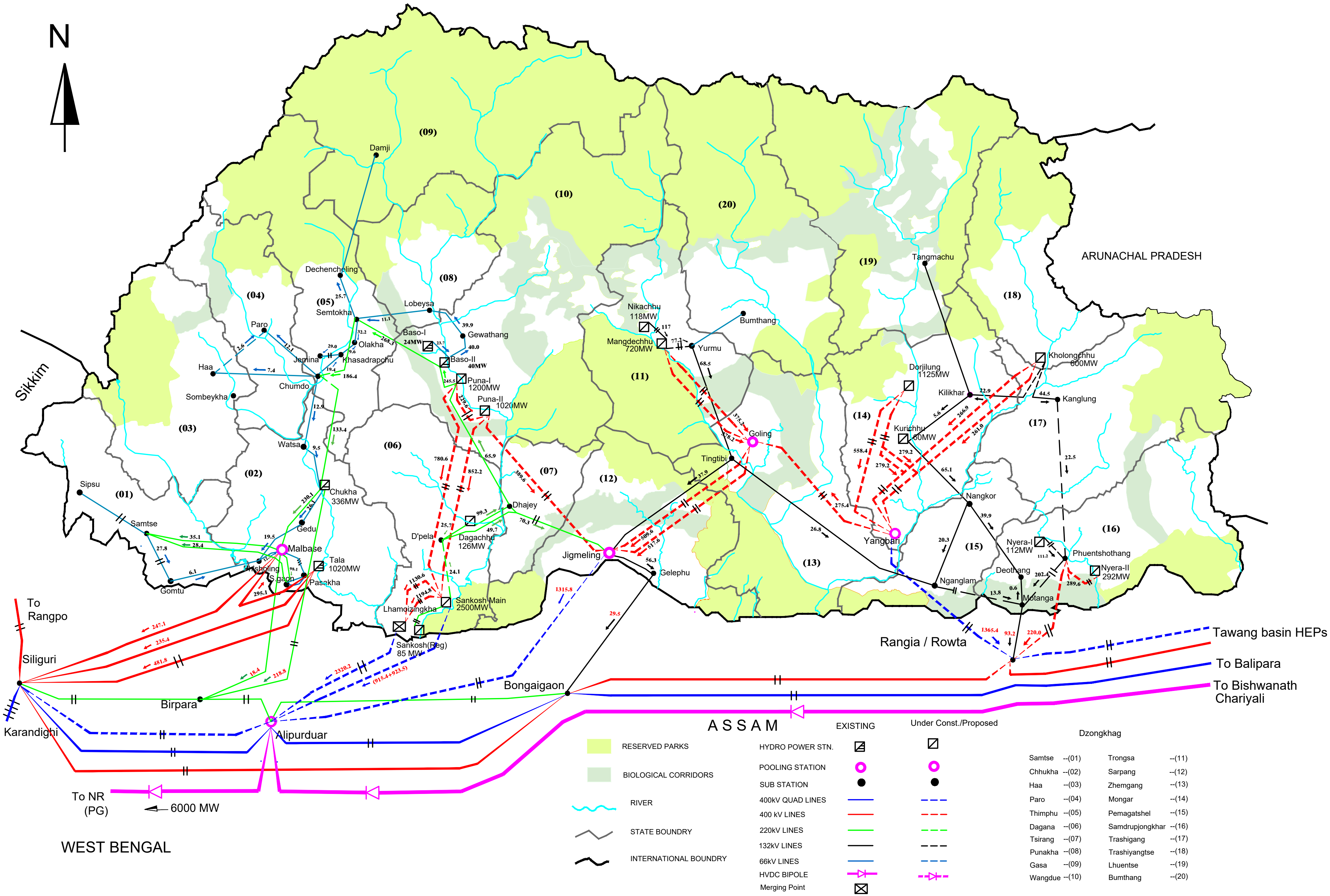
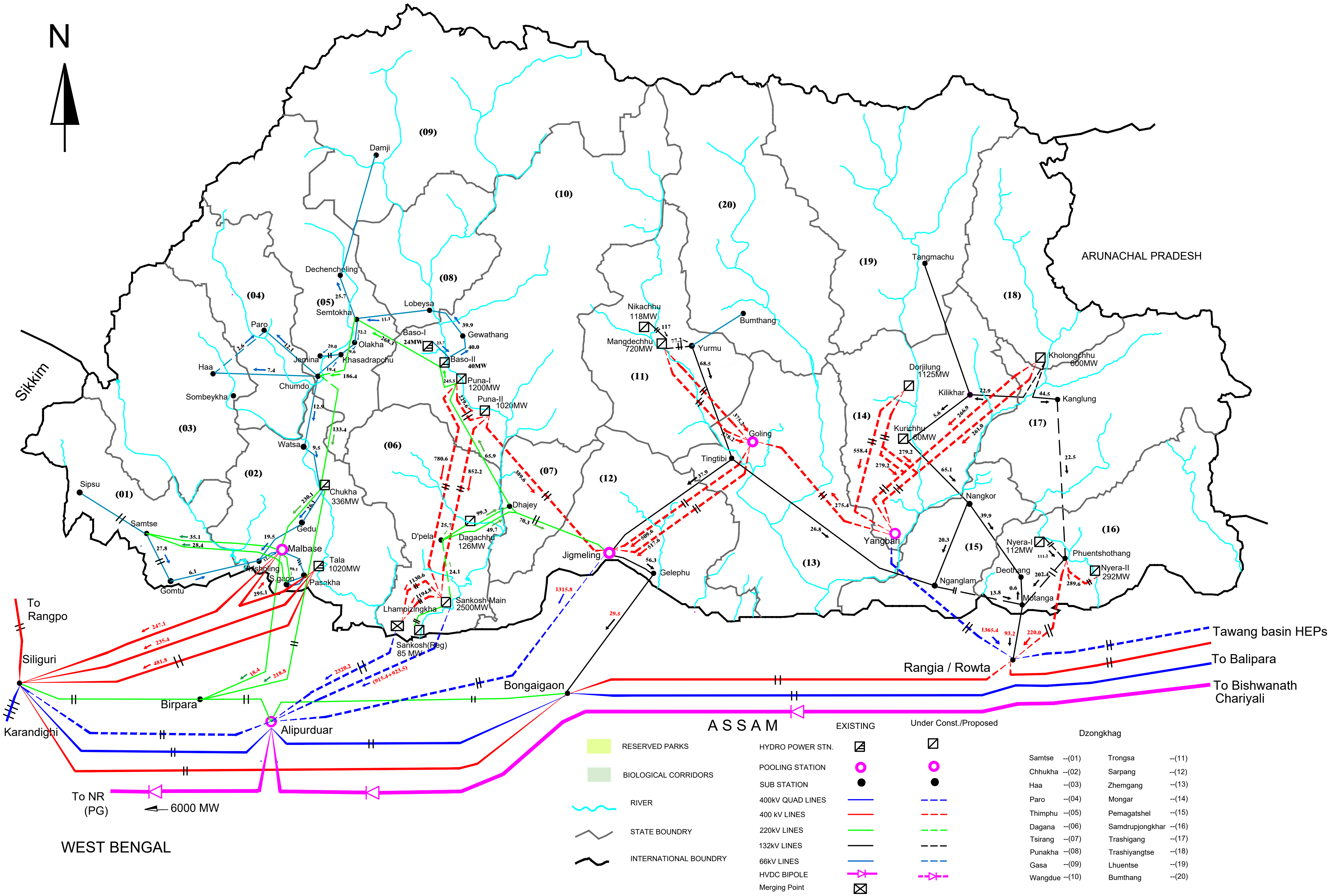


Fig. 4B: Base case with full hydro dispatch in 2030 scenario



Chapter -10

Transmission Grid Plan by 2035.

In the 2035 scenario, the following HEPs are considered based on their expected commissioning year:

1. 2,640 MW Kuri-Gongri HEP
2. 180MW Bunakha RS HEP
3. 770MW Chamkharchhu-I HEP
4. 570 MW Wangchhu HEP

Their ATSs are firmed up based on NTGMP-2012 and as per the final DPR. The total capacity addition from these HEPs will be 4,160 MW. Transmission grid plan for 2035 scenario showing power flow in full hydro dispatch is given in Figs. 5A & 5B

10.1.1. Kuri - Gongri HEP (2,640MW)

Kuri-Gongri HEP is one of the largest HEP located in Eastern Bhutan. The DPR is currently being prepared by WAPCOS. As per the latest information, the generation capacity of Kuri-Gongri HEP is expected to be 2,640MW. NTGMP-2012 has prepared ATS for Kuri-Gongri HEP envisaging its installed capacity to be 1,800/3,400MW.

ATS of Kuri-Gongri HEP is as follows:

- 400kV step-up voltage
- 400kV, 2xD/C Twin Moose line, Kuri Gongri HEP - Yangbari PS
- 400kV, 1xD/C Quad Moose line, Yangbari PS - Rangia/Rowta (Bhutan Portion)
- 400/132/33kV 4x67MVA Yangbari PS
- 2x80MVAr, 420kV bus reactor at Yangbari
- 132kV, 1x D/C line, Yangbari – Nganglam.

The tentative cost estimate for the ATS is given in Annexure: XIII.

10.1.2. Bunakha RS (180MW)

Bunakha HEP is also one of the four projects which will be developed under JV mode with GoI. The HEP is proposed to be located about 30km from the existing Chukha HP.

ATS of Bunakha RS is as follows:

- 220kV step-up voltage
- 220kV, 2xS/C lines, Bunakha - Malbase
- LILO of 220kV Chukha-Simtokha line at Bunakha
- Additional 400/220kV, 4x67MVA ICT at Malbase.

The tentative cost estimate for the ATS is given in Annexure: XIII.

10.1.3. Chamkharchhu-I HEP (770MW)

CHEP-I is located in Zhemgang Dzongkhag. The ATS of CHEP-I is as follows:

- 400kV step-up voltage
- 400kV, 1xD/C line (1st) out of 2xD/C Twin Moose line, Yangbari - Goling
- LILO of 400kV Twin Moose line, Yangbari-Goling at CHEP-I
- 400/132/33kV, 4x67MVA ICT at CHEP-I
- 2x80MVAr, 420kV bus reactor in Goling switching station
- 1x80MVAr, 420kV bus reactor at Jigmeling including bays
- 400kV, 1xD/C Twin Moose line, Goling – Jigmeling (2nd line, Cost to be shared by CHEP-I and KHEP)
- LILO of 132kV Nganglam-Tintibi S/C line at CHEP-I
- 400/220kV, 4x167MVA ICT at Jigmeling GIS including bays (Cost shared by CHEP-I, KHEP & PHEP-II).
- 400kV, 1xD/C Quad Moose line, Jigmeling to Alipurduar (50% of the cost to be shared between KHEP and CHEP-I)

  **Establishment cost for Goling switching station is loaded to Kholongchhu HEP since it is coming ahead of CHEP-I.*

The tentative cost estimate for the ATS is given in Annexure: XIII.

10.1.4. Wangchhu HEP (570MW)

The Wangchhu HEP will be developed as JV project between RGoB and GoI. It is located downstream of Tala HP. The ATS of Wangchu HEP is as follows:

- 400kV step-up voltage
- LILO of one ckt of 400kV Tala-Khogla/Pugli-Siliguri lines (except the line being LILOed at Amochhu) at Wangchhu HEP
- 1x63MVAr 420kV bus reactor at Wangchhu HEP

The tentative cost estimate for the ATS is given in Annexure: XIII.

10.2. Result of Power Flow analysis for 2035 Scenario.

Simulation results showing power flow in various cross borders transmission links are given below:

Table 9: PSSE simulation results for 2035 scenario

Sl/No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri (Fd. I&II)	351.1*2	0.99	0.99
2	412	Wangchu	444072	Siliguri	376.9	0.99	0.99
3	402	Malbase	444072	Silliguri	356.5	0.99	0.98
4	407	Jigmeling	444073	Alipur (2 ckts)	453.8*2	0.98	0.98
5	409	L/Zingkha	444073	Alipur (2 ckts)	1047*2	0.98	0.96
6	410	Yangbari	214151	Rangia(4ckts)	1367.5*4	0.99	1.00
7	414	P/thang	214151	Rangia(2ckts)	142.2*2	0.99	1.00
8	418	Sankosh LB	444073	Alipur	829.9	0.99	0.98
9	419	Sankosh RB	444073	Alipur	827.2	0.9	0.98
10	201	Chukha	442025	Birpara (2 ckts)	117*2	0.99	0.99
11	202	Malbase	442025	Birpara	132.4	0.99	0.99
12	107	Motanga	211150	Rangia1	85	0.96	0.99
13	108	Gelephu	211550	Salakati1	29.3	0.97	0.97

Table 10: Summary of total power generation, load and export.

Sl/No	Total Generation	Total Load	Total Export
1	13,538 MW	1,113 MW	12,329 MW

In 2035 scenario also, it was observed that there isn't any transmission line constraint for delivery of power to India as the loadings of all the cross border transmission lines as well as voltage deviation are within the permissible limit.

Fig. 5A: Base case with full hydro dispatch in 2035 scenario

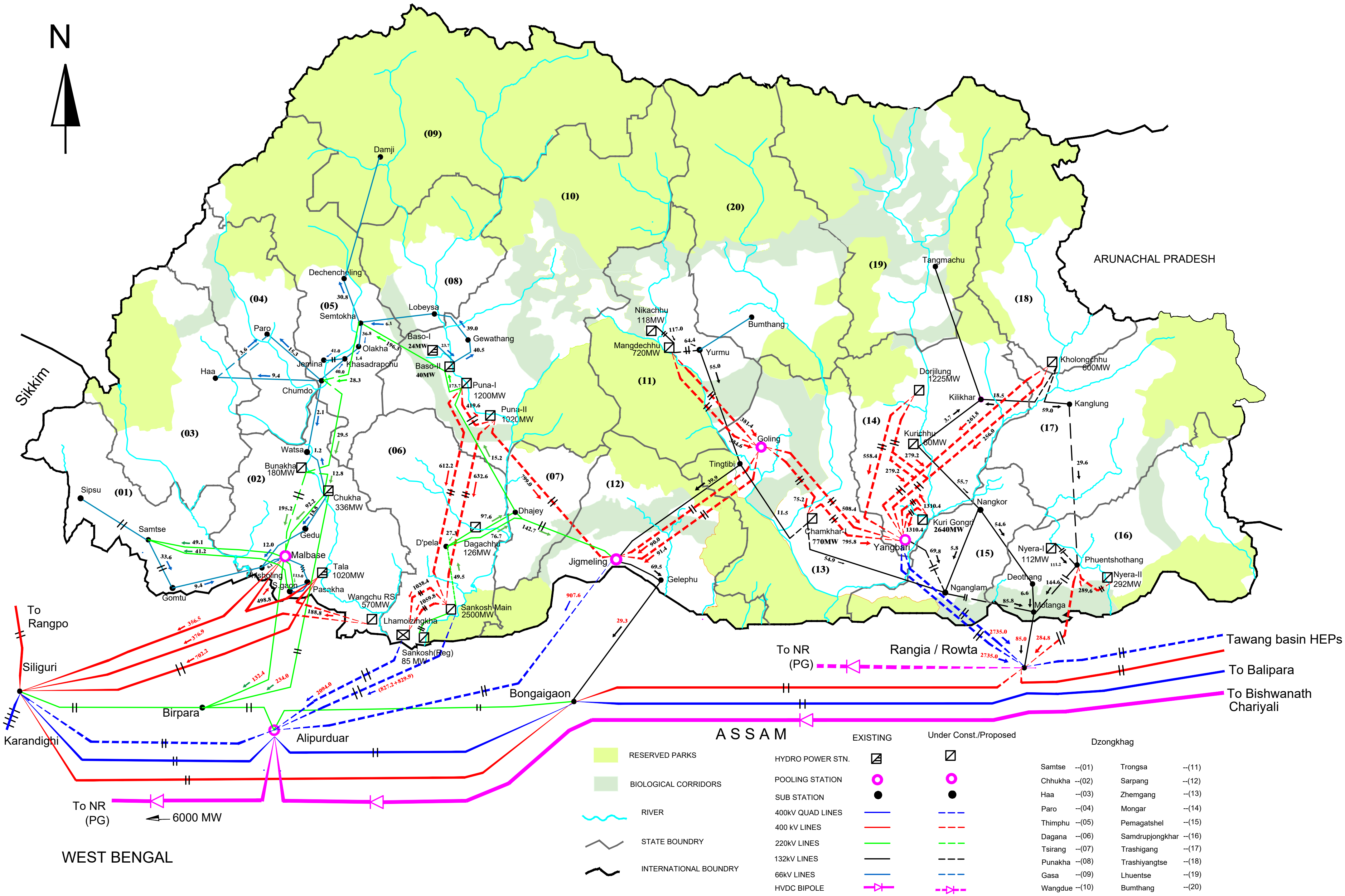
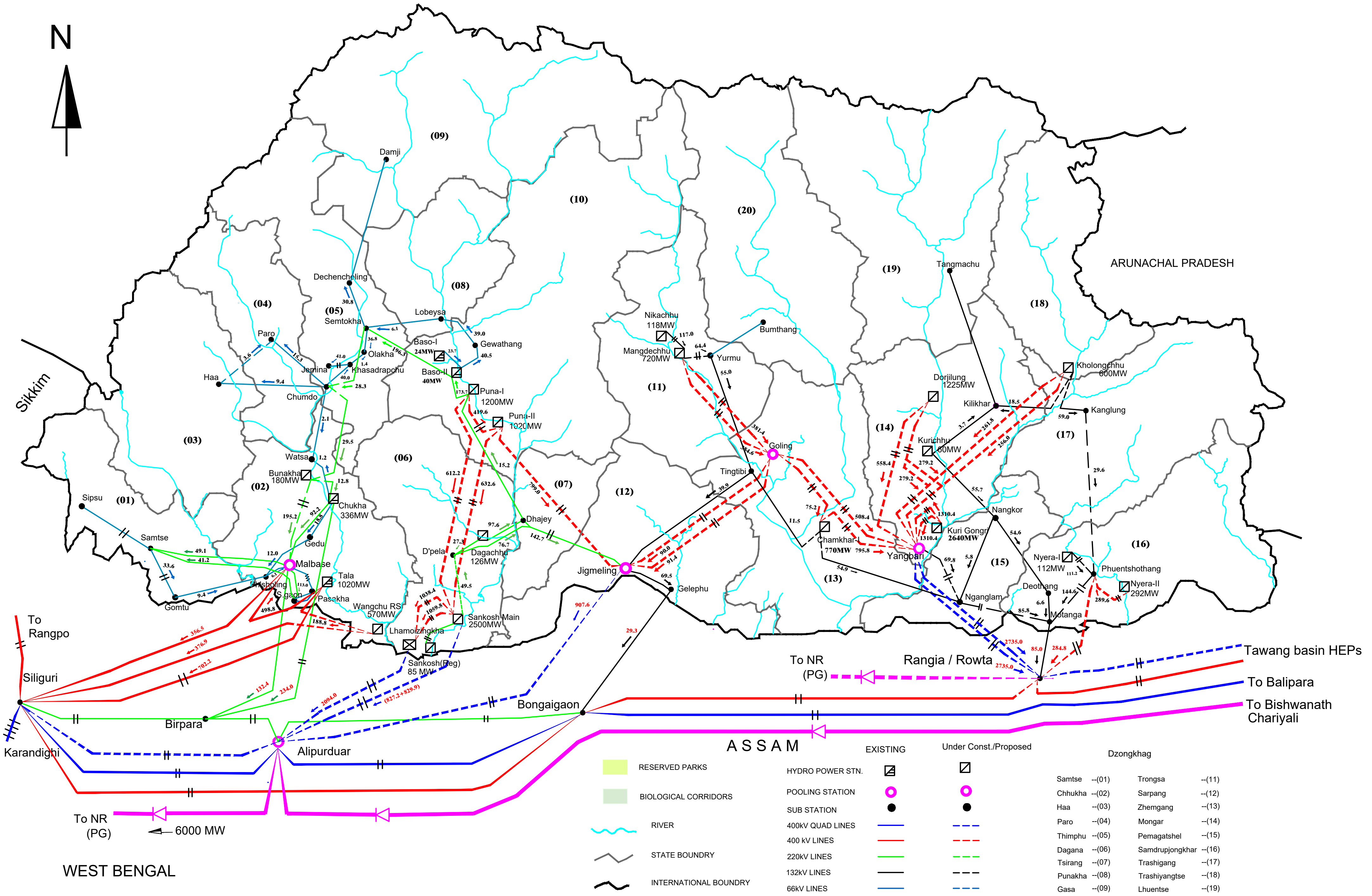


Fig. 5B: Base case with full hydro dispatch in 2035 scenario



Chapter -11

Transmission Grid Plan by 2040.

In the 2040 scenario, the following HEPs are considered based on their expected commissioning year:

1. 1,100 MW Panbang HEP
2. 363 MW Khomachhu HEP
3. 590 MW Chamkharchhu-II HEP
4. 364 MW Chamkharchhu-IV HEP
5. 652 MW Gongri HEP

While the study of Gongri HEP is in the reconnaissance stage, the pre-feasibility study for others four projects are completed. The total capacity addition contributed from these HEPs will be 3,069 MW. Transmission grid plan for 2040 scenario showing power flow in full hydro dispatch is given in Figs. 6A & 6B. Their ATSs are firmed up based on their PFS and recconnaissance reports.

11.1.1. Panbang HEP (1,100 MW)

Panbang HEP is located in the Zhemgang Dzongkhag. The pre-feasibility study of Panbang HEP was carried out by M/s. Mott MacDonald. As per the report, the power is proposed to be pooled at Rangia/Rowta via 400kV D/C Quad Moose line. However, in order to supply the royalty power and also to improve the reliability of the transmission lines, the ATS is proposed as follows:

- 400kV step up voltage
- 400kV, 1xD/C Quad Moose line, Panbang - Rangia/Rowta with one circuit LILOed at Yangbari Pooling station.

11.1.2. Khomachhu HEP (363 MW)

Khomachhu HEP is located in Lhuntse Dzongkhag. The Pre-feasibility study was carried out by NORPLAN. The ATS of Khomachhu HEP is proposed as follows:

- 220kV step up voltage
- 220kV, 1xD/C line, Khomachhu - Dorjilung HEP.
- 400/220kV, 500MVA ICT at Dorjilung HEP.

11.1.3. Chamkharchhu-IV HEP (364 MW)

Chamkharchhu IV HEP is located under Bumthang Dzongkhag. The pre feasibility study of Chamkharchhu IV HEP was carried out by M/s Lahmeyer India. As per the PFR report, the power is recommended to be pooled at MHEP. However, due to lack of space in MHEP pothead yard, the ATS is proposed as follows:

- 220kV step up voltage.

- 220kV, 1xD/C line, Chamkharchhu IV - Chamkharchhu-II.
- 400/220 kV, 500MVA ICT at Chamkharchu-II.

11.1.4. Chamkharchhu-II HEP (590 MW)

Chamkharchhu-II HEP is located in Zhemgang Dzonkhag, downstream of Chamkharchhu-IV HEP. The pre-feasibility study was carried out by M/s. Lahmeyer India. As per the PFR report, the power from this HEP was proposed to be pooled at Yangbari pooling station. However, as per the system studies, the Yangbari Pooling station was getting congested and the line length is also more. As such, the ATS is proposed as follows:

- 400kV step up voltage.
- 400kV, 1xD/C Twin Moose line, Chamkharchhu II - Goling.

11.1.5. Gongri HEP (652 MW)

Gongri HEP is located in upstream of Kurigongri HEP, whose potential was not identified in Power System Master Plan. The reconnaissance study of this HEP was carried out by DHPS. The ATS of Gongri HEP is proposed as follows:

- 400 kV step up voltage.
- 400kV, 1x D/C Twin Moose line, Gongri - Kuri Gongri HEP.

11.2. Result of Power Flow analysis for 2040 Scenario.

Simulation results showing power flow in various cross borders transmission links are given below:Table 11:PSSE simulation results for 2040 scenario

Sl/No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri (Fd. I&II)	367.2*2	0.99	0.98
2	412	Wangchhu	444072	Siliguri	391.6	0.99	0.98
3	402	Malbase	444072	Silliguri	386.4	0.99	0.98
4	407	Jigmeling	444073	Alipur (2 ckts)	761.9*2	0.98	0.96
5	409	L/Zingkha	444073	Alipur (2 ckts)	1212.9*2	0.97	0.96
6	422	Panbang	214151	Rangia	955.8	1.00	1.00
7	410	Yangbari	214151	Rangia(5ckts)	1234.5*5	0.99	1.00
8	414	P/thang	214151	Rangia(2ckts)	128.1*2	0.99	1.00
9	418	Sankosh LB	444073	Alipur	967	0.97	0.96

10	419	Sankosh RB	444073	Alipur	956.8	0.97	0.98
11	201	Chukha	442025	Birpara (2 ckts)	111.2*2	0.98	0.97
12	202	Malbase	442025	Birpara	107.4	0.97	0.97
13	107	Motanga	211150	Rangia1	103.2	0.96	0.99
14	108	Gelephu	211550	Salakati1	31.7	0.97	0.97

Table 12: Summary of total power generation, load and export.

Sl/No	Total Generation	Total Load	Total Export
1	16,607 MW	1,211.00MW	15,235 MW

It was observed that there isn't any transmission line constraint for delivery of power to India as the loadings of all the cross border transmission lines as well as voltage deviation are within the permissible limit.

Fig.6A: Base case with Full Hydro Dispatch in 2040 scenario

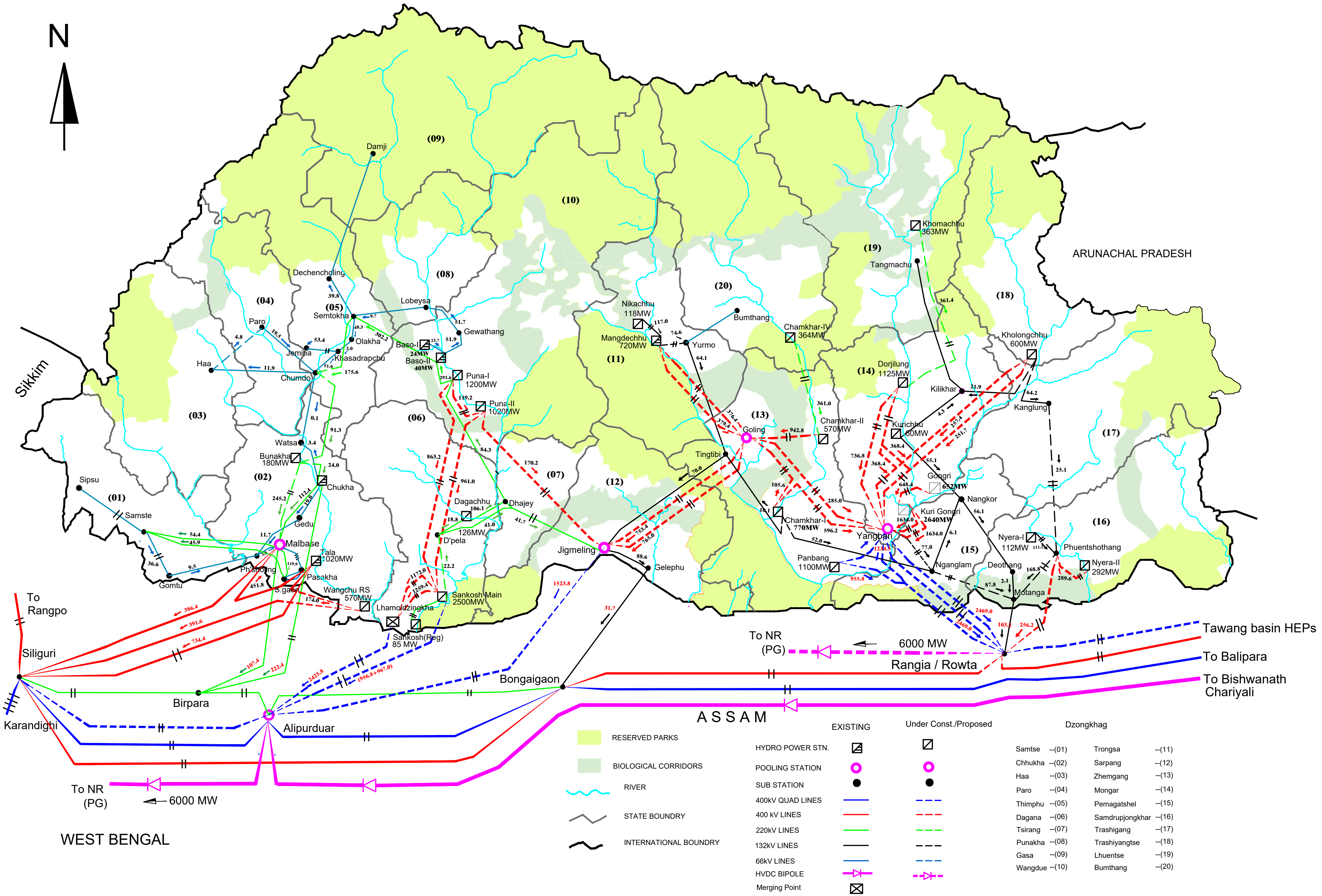
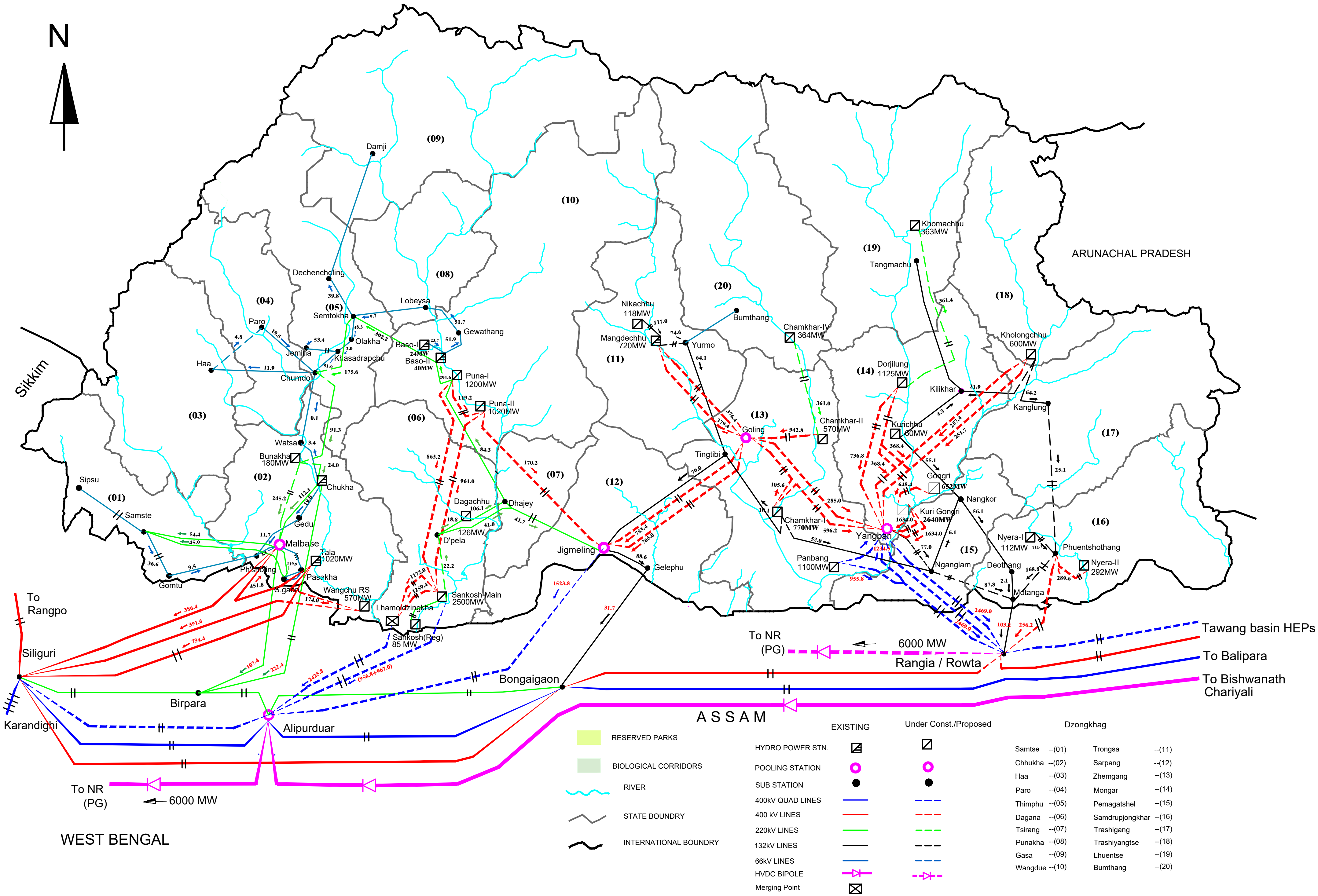


Fig.6B: Base case with Full Hydro Dispatch in 2040 scenario



Chapter -12

Transmission Grid Plan beyond 2040.

Under the beyond 2040 time frame, all the techno-economically viable projects are considered whereby the country would have total capacity of 23,833MW from 73 hydropower potential sites identified at different river basins. Transmission grid plan for beyond 2040 scenario showing power flow in full hydro dispatch is given in Figs. 7A & 7B. Their ATS detail is given in Annexure-X.

12.1. Result of Power Flow analysis.

It was observed from the system study that the major quantum of power from the hydropower projects will be pooled to Lhamozingkha and Yangbari Pooling stations and then evacuated to Alipurduar and Rangia substations respectively. As per NTGMP-2012, ±800kV, 6000MW HVDC were proposed from these respective substations. However, since HVDC is not feasible in Bhutan, additional 400 kV quad moose lines are proposed as follows:

- 400kV, 1xD/C Quad Moose line from Yangbari to Rangia/Rowta
- 400kV, 1xD/C Quad Moose line from Lhamozingkha to Alipurduar.

With this arrangement, it was observed that most of the major transmission lines including cross border export lines are loaded within the thermal loading limits and bus voltages were also found to be within the limits.Simulation results showing power flow in various cross borders transmission links are given below:

Table 13: PSSE simulation results for beyond 2040 scenario

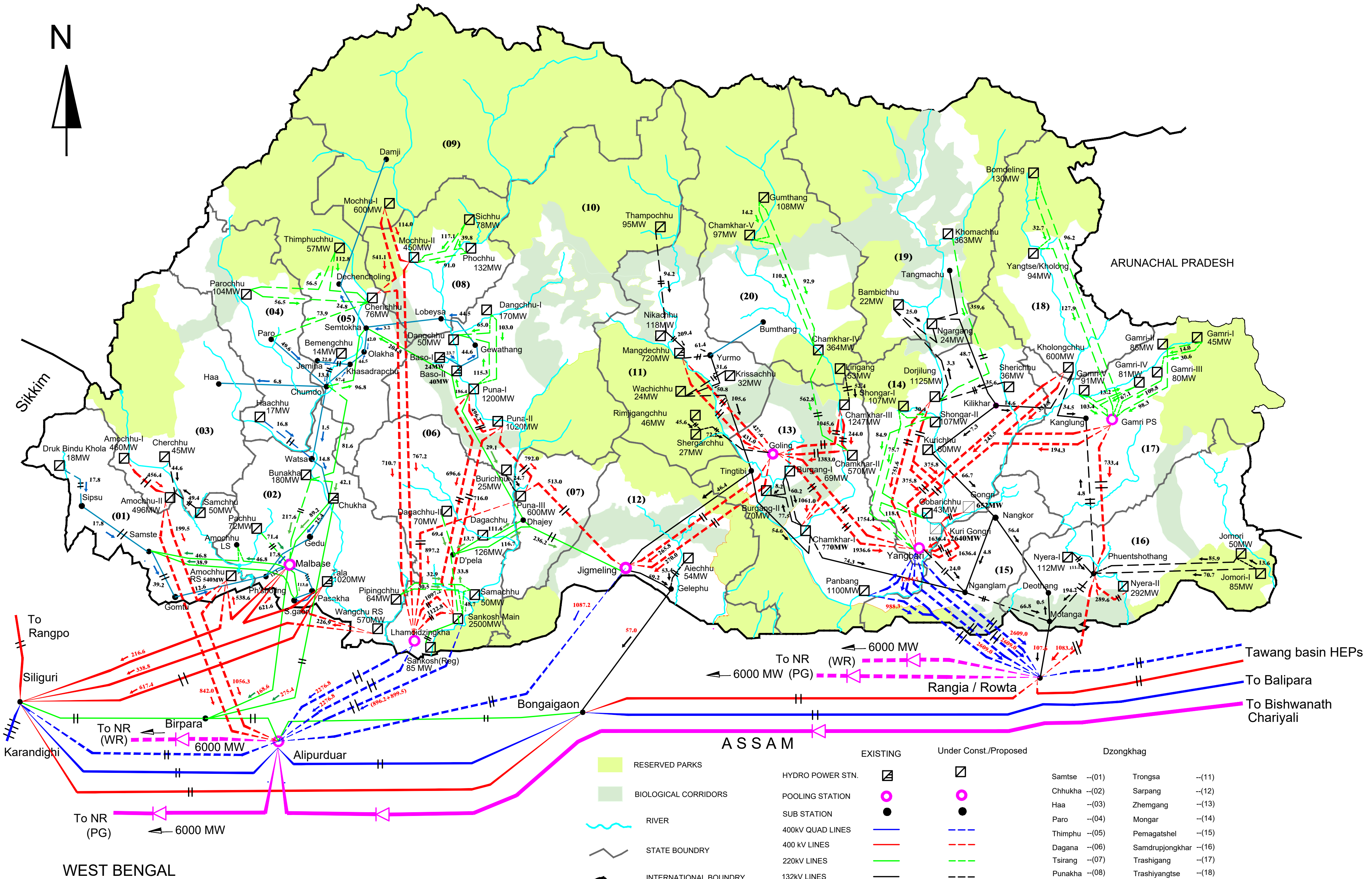
Sl.No	From		To		Power Flow (MW)	Bus Voltage(PU)	
	Bus No.	Bus Name	Bus No.	Bus Name		From	To
1	401	Tala	444072	Siliguri (Fd. I&II)	308.7*2	0.99	1.00
2	417	Amochu RS	444072	Siliguri(Fd.III)	216.6	0.99	1.00
3	417	Amochu RS	444073	Alipurduar	1056.3	0.99	0.98
4	424	Amochu-II	444073	Alipurduar	842	0.99	0.98
5	407	Jigmeling	444073	Alipur (2 ckts)	543.6*2	0.99	0.98
6	409	L/Zingkha	444073	Alipur (4 ckts)	1138.4*4	0.98	0.98

7	410	Yangbari	214151	Rangia(7ckts)	1304.5*7	0.99	1.00
8	422	Panbang	214151	Rangia	988.3	0.99	1.00
9	412	Wangchhu	444072	Siliguri (Fd. IV)	338.8	0.99	1.00
10	414	Phuntshothang	214151	Rangia(2ckts)	541.7*2	0.99	1.00
11	418	Sankosh LB	444073	Alipur	899.5	0.98	0.98
12	419	Sankosh RB	444073	Alipur	896.2	0.98	0.98
13	201	Chukha	442025	Birpara (2 ckts)	137.7*2	0.99	0.99
14	202	Malbase	442025	Birpara	168.6	0.99	0.99
15	107	Motanga	211150	Rangia1	107.6	0.95	0.99
16	108	Gelephu	211550	Salakati1	57	0.96	0.97

Table 14: Summary of total power generation, load and export.

Sl/No	Total Generation	Total Load	Total Export
1	23,833 MW	1,265 MW	22,319 MW

Fig.7A: Base case with Full Hydro Dispatch beyond 2040 Scenario

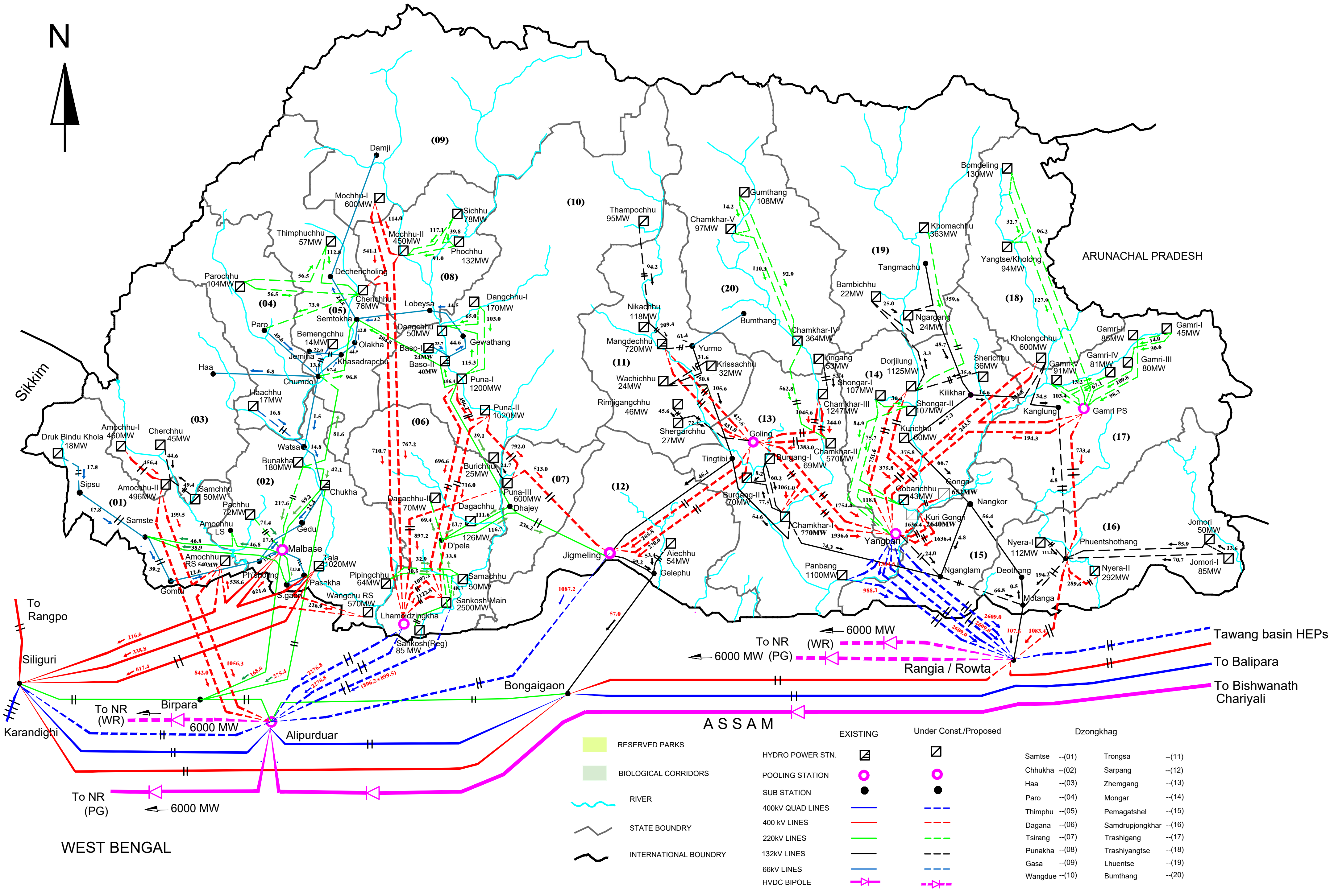


	EXISTING	Under Const./Proposed
HYDRO POWER STN.		
POOLING STATION		
SUB STATION		
400kV QUAD LINES		
400 kV LINES		
220kV LINES		
132kV LINES		
66kV LINES		
HVDC BIPOLE		

Dzongkhag

Samtse	--(01)	Trongsa	--(11)
Chhukha	--(02)	Sarpang	--(12)
Haa	--(03)	Zhemgang	--(13)
Paro	--(04)	Mongar	--(14)
Thimphu	--(05)	Pemagatshel	--(15)
Dagana	--(06)	Samdrupjongkhar	--(16)
Tsirang	--(07)	Trashigang	--(17)
Punakha	--(08)	Trashiyangtse	--(18)
Gasa	--(09)	Lhuentse	--(19)
Wangdue	--(10)	Bumthang	--(20)

Fig.7B: Base case with Full Hydro Dispatch beyond 2040 Scenario



Chapter-13

System Strengthening in Bhutan

System studies were carried out to identify the system strengthening requirements in Bhutan for the lines 66kV and above till 2025. It is assumed that the domestic loads are supplied directly from 66kV busbars and therefore, the system strengthening requirement of distribution lines 33kV and below were excluded. Further, the upgradation and replacement of old conductors, transmission lines, transformers, etc are also excluded in this study.

13.1.1. System Strengthening in Western Bhutan.

To meet the anticipated load growth in Bhutan, it was observed from the load flow studies that creation of 220/66kV substation by LILO of the existing 220kV Chukha-Simtokha S/C line at Chumdo switching station, would cater to the load growth around Paro, Jemina and Haa areas, which are currently fed through 66kV lines, and thus it improves voltage stability and reliability of power supply.

Similarly, the load of Paro substation supplying power to the Bhutan International Airport and Royal Law College at Pangbesa are considered to be of higher priority. Presently, power of Paro Dzongkhag is met with 66kV transmission line from Chumdu switching station. The line is radial and in the event of failure of the transmission line, the power supply gets interrupted. In order to improve the reliability of Paro as well as Haa Dzongkhag, it is recommended to construct 66kV transmission line from Paro to Haa to make the ring system along with a bay extension at Haa substation.

Thus, in addition to the evacuation systems envisaged for HEPs in the western Bhutan (Bunakha, Wangchhu and Sankoshh HEPs), the following network expansion/augmentation in 220kV and 66kV systems are proposed:

220kV System

- LILO of 220kV Chukha-Simtokha S/C line at 220kV Chumdo substation
- Upgradation off 66kV Chumdo S/S to 220kV level with 2x50/63 MVA, 220/66kV transformers.

66kV System

- Paro-Haa S/C line

Based on load forecast as shown in Table 1, the forecasted load at Jemina substation in 2025 is 15 MW, while the existing transformer is of 1x10MVA, 66/33 kV. In order to meet the growing load demand and for the reliability purpose, one additional 10 MVA transformer may be proposed depending on the actual load condition.

Similarly, the forecasted load at Lobesa s/s in 2025 is 23 MW, while the existing transformers are of 1x5MVA, 66/33kV and 2x5MVA 66/11kV. Thus, the upgradation of one of these transformers to 15 or 20 MVA may be proposed based on the actual load condition during that year.

13.1.2. System Strengthening in Southern Bhutan

Based on the load flow analysis, it is seen that all the lines of 66kV and above are within permissible limits. However, the load in Gomtu S/S in 2025 is forecasted as 19 MW, while the existing transformer is 2x5 MVA, 66/11kV. In order to meet the future load, the existing transformers may be upgraded to 2x15 MVA.

13.1.3. System Strengthening in Eastern Bhutan

In order to meet the load growth in the eastern Bhutan, LILO of existing 132kV Nganglam-Tingtibi line at Yangbari PS has been considered as part of ATS of Chamkharchhu-I. Further, the construction of 132kV Yangbari-Nganglam D/C line is envisaged under ATS of Kuri-Gongri HEP.

Currently, 132kV S/C on D/C tower line from Kanglung to Phuntshothang, 132kV D/C line from Phuntshothang-Motanga and 132kV S/C on D/C tower line from Motanga to Nganglam lines are under construction, thus forming the 132-ring system i.e. Nganglam-Nangkor-Deothang-Motanga-Nganglam. Further, with the LILO of Kanglung to Killikhar 132kV S/C line at Kholongchu HEP, another 132kV ring systems will be formed. Thus, these rings will make strong 132kV grid for supply of power to load center in eastern Bhutan under any credible contingency and does not require any grid enhancement.

As per the load forecast, the load in Kanglung substation is 16 MW in 2025, while the existing transformer ratings are 132/33kV, 2x5 MVA. In order to meet the growing demand, one of the existing transformer may be upgraded to 15 MVA.

Similarly, with the upcoming of Bondeyma Industrial estate, the future demand of Killikhar substation is expected to increase. Currently, there are 1x5 MVA and 1x10 MVA transformers. To meet the future load, 5 MVA transformers may also be upgraded to 10 MVA.

13.1.4. Reactive Power Compensation.

With load power factor presumed to be 0.9 at grid-substations, low bus voltages are observed at various 66kV substations during peak load condition. From the system studies, 180MVAr is the total quantum of compensation required. The following switchable capacitive shunt compensations were required to maintain the system voltage within the limit:

Table 15: Reactive power compensation requirement.

Sl/No	Name of the substation	Voltage level (kV)	Capacitive Compensation (MVAr)
1	Semtokha	66	20
2	Olakha	66	10
3	Dechencholing	66	15
4	Lobeysa	66	5
5	Pasakha	66	50
6	Singhigaon	66	30
7	Gelephu	66	5
8	Motanga	132	25
9	Nganglam	132	20

Chapter-14

Indian Grid Reinforcements for export of Bhutan surplus.

The total current installed hydro generating capacity in Bhutan is 1,606MW. Capacity addition is expected to grow drastically in the future as indicated in different timeframes in earlier chapters.The power demand and supply forecast till 2040, shows there will be surplus power available for export to India. Accordingly, grid reinforcements in India may be requested to be planned in phased manner to match with the commissioning schedule of various upcoming HEPs of Bhutan.The proposed grid reinforcement plans are as per NTGMP-2012, however, developmental period has been prioritized based on the HEPs that are expected to come in the future.

14.1. Indian Grid Strengthening for import of Bhutan surplus power by 2020 and 2025.

In 2020 scenario, Punatsangchhu-II, Mangdechhu, Nikachhu HEPs with total capacity of 1,858MW are expected to come online. Similarly, in 2025 scenario, Punatsangchu-I and Kholongchu HEPs are expected to get added.

Therefore, for the transfer of power from Bhutan to NR/WR, following transmission systems, as recommended in NTGMP-2012, are constructed and some lines are under construction stage:

1. 2x315MVA, 400/220kV AC & HVDC sub-station with ±800kV, 3000MW converter module at Alipurduar.
2. Extension of ±800kV HVDC station with 3000MW inverter module at Agra.
3. LILO of ±800kV of Bishwanath Chariali - Agra HVDC line at Alipurduar for parallel operation of the HVDC station at Alipurduar
4. LILO of 400kV D/C Bongaigaon - Siliguri line at Alipurduar
5. LILO of 220kV D/C Birpara-Salakati at Alipurduar.
6. 400kV D/C Quad Moose from Jigmeling-Alipurduar (Indian portion).
7. 400kV D/C Quad Moose from Lhamozingkha-Alipurduar.

14.2. Indian Grid Strengthening for import of Bhutan surplus power by 2030.

In 2030 scenario, Sankosh, Nyera Amari I & II (Integrated) and Dorjilung HEPs with total capacity of 4,114MW are envisaged to get added by 2030.

Therefore, for the transfer of Bhutan Power to India, following transmission links and ATS (as necessary) are required in addition to those proposed in 2025 scenario:

1. 400kV D/C Quad Moose from Sankosh-Alipurduar(Indian portion)
2. 400kV D/C Quad Moose from Yangbari- Rangia/Rowta(Indian portion)

3. 400kV D/C Twin Moose line from Phuntshothang-Rangia (Indian portion).

14.3. Indian Grid Strengthening for import of Bhutan surplus power by 2035.

In 2035 scenario, the HEPs such as Bunakha, Wangchhu, Kuri Gongri and Chamkharchhu-I HEPs are considered. The total capacity addition by 2035 will be 4,160MW. Therefore, to export the surplus power from Bhutan to NR/WR India, the following transmission links and ATS (as necessary)are required to be developed in addition to 2030 scenario:

- 400kV D/C Quad Moose line from Yangbari- Rangia/Rowta(Indian portion)
- ±800kV, Rangia/Rowta – NR/WR HVDC bipole line with converter capacity 6,000MW each at Rangia/Rowta and NR/WR.

14.4. Indian Grid Strengthening for import of Bhutan surplus power by 2040.

By 2040 scenario, Khomachhu, Chamkharchhu II & IV, Panbang and Gongri HEPs with capacity addition of 3,069 MW are expected to get added. Therefore, to evacuate the power, the following new transmission link and ATS (as necessary) is required:

- 400kV D/C Quad Moose line from Panbang-Rangia/Rowta(Indian portion).

14.5. Indian Grid Strengthening for import of Bhutan surplus power beyond 2040.

Under beyond 2040 scenario, all the techno-economically viable projects are considered. To evacuate Power from Bhutan, following new transmission lines and ATS (as necessary) are envisaged to be developed in India:

1. 400kV D/C Amochhu-II -HEP to Alipurduar (Indian portion)
2. 400kV D/C Quad Moose line from Yangbari-Rangia/Rowta(Indian portion)
3. ±800kV, Rangia/Rowta – NR/WR HVDC bipole line with converter capacity 6,000MW each at Rangia/Rowta and NR/WR.
4. 400kV D/C Quad Moose line from Lhamozingkha-Alipurduar (Indian portion)
5. ±800kV, Alipurduar – NR/WR HVDC bipole line with converter capacity 6,000MW each at Rangia/Rowta and NR/WR.

Chapter-15

Contingency Analysis Results for 2035

15.1 Load Flow Case Studies

The details of the load flow study results and contingency analysis are given at the following Exhibits.

1. Exhibit I: Outage of 400kV D/C line from Punatsangchhu-I to Lhamozingkha
2. Exhibit II: Outage of 400kV D/C line from Punatsangchhu-II to Lhamozingkha
3. Exhibit III: Outage of 400kV S/C line from Wangchhu to Silliguri
4. Exhibit IV: Outage of one pole of ±800kV,6000MW Alipurduar to Agra
5. Exhibit V: Outage of 220kV S/C line from Bunakha to Malbase
6. Exhibit VI: Outage of 400kV S/C line from Sankosh Leftbank Powerhouse to Alipurduar
7. Exhibit VII: Outage of 400kV S/C line from Sankosh Rightbank Powerhouse to Alipurduar
8. Exhibit VIII: Outage of one ckt of 400kV D/C line from Lhamozingkha to Alipurduar
9. Exhibit IX: Outage of 400kV D/C line from Yangbari to Goling
10. Exhibit X: Outage of 400kV D/C line from Goling to Jigmeling
11. Exhibit XI: Outage of one ckt of 400kV D/C line from Jigmeling to Alipurduar
12. Exhibit XII: Outage of one D/C of 400kV 2xD/C line from Yangbari to Rangia
13. Exhibit XIII: Outage of one pole ±800k, 3000MW Rangia-NR
14. Exhibit XIV: Case study with mimimum hydro dispatch for 2035 scenario.
15. Exhibit XV: Case study with maximum hydro dispatch in 2035 scenario

15.2. Sensitivity Studies on NTGMP for 2035 Scenario.

The following case studies have been additionally carried out to meet the adequacy & reliability of the proposed NTGMP plan for 2035 scenario.

15.3. Minimum hydro generation with maximum load.

A case study was carried out considering maximum load and minimum hydro dispatch (winter scenario) for 2035 scenario and corresponding power flows in the network is given in Exhibit-XIV. It was observed that the grid is stable in Bhutan.

15.4. Case Study with 10% higher generation dispatches during high hydro season.

The rainfall pattern in Bhutan is unpredictable with maximum discharge in the river in summer and minimum in winter season. The machines are designed with 10% overloading capacity to utilize the maximum discharge available in monsoon season. Thus, system study has been carried out considering the 10% additional dispatch at hydro stations during high monsoon season. It was observed from the results of the studies that the Bhutan grid would have no other transmission constraints to cater to the internal load demand within Bhutan by 2035 and also to export surplus power to India. The power flow is given in Exhibit-XV

15.5. Fault Analysis.

The three-phase fault is computed for 2040 grid configuration with all hydro machines in operation to enable designing of various electrical equipment and protection systems. Accordingly, from the study results, fault level at various 400kV, 220kV, 132kV and 66kV buses in Bhutan were found within the permissible limits (less than 63kA) in 2040 scenario. The fault levels for 2040 scenario are provided in Annexure XI.The PSSE input parameters for the 2040 scenario is given in Annexure XII.

Chapter-16

Cost Estimate

Investment requirement for implementation of the updated NTGMP in Bhutan by 2035 has been tentatively worked out considering the cost reference received from CEA and tentative final completion cost of MHEP ATS, wherever information were missing, certain percentage escalation has been worked out to reach at a realistic figure. For almost all the lines, the escalation percentage has been referenced to tentative final completion cost of MHEP ATS. The PL is taken on the basis of 1st Qtr. 2018. For couple of projects whose DPR has been completed, the cost of ATS has been maintained as per the DPR only. ATS for Punatsangchhu-I, Punatsangchhu-II, Mangdechhu and Nikachhu HEPs being in implementation stage is not considered in the cost estimates. In case of transmission lines crossing the Bhutan border, cost of Bhutan portion has been considered in the cost estimates. The tentative investments needed for development of ATS for 8 HEPs by 2035 is Nu./Rs. 52,116.9 million (Nu./Rs. 5,211.69 crores).

Table 16: Estimated investment required for developing updated NTGMP by 2035

Sl/ No	System head	Rs. (Crore)
1	ATS for HEPs	5,211.69
Total*		**5,211.69**

*excluding the Cost of ATS for PHEP-I & II, MHEP& Nikachhu

The detailed break-up of estimated costs for project specific evacuation system in Bhutan corresponding to 2035 is given at Annex-XIII. Since, Kholongchhu HEP is envisaged to come before Chamkharchhu-I HEP as per the revised timelines, the switching station at Goling is included under the Kholongchhu ATS.

Conclusion

- The updation of NTGMP is carried out in every five year timeframe viz. 2020, 2025, 2030, 2035, 2040 and beyond 2040, considering the realistic hydropower developmental timeframe. By 2025, all the under construction hydropower projects are expected to get commissioned. The timeframe in beyond 2040 is just the indication of how the transmission scenario would look like if all the techno-economically viable projects (greater than 10 MW) with total capacity of 23,833 MW are considered.
- Bilateral discussion with CEA and POWERGRID were carried out to discuss on the cross border transmission links and landing point in India. The discussions with top level management of BPC were also carried out to solicit their views on the proposed transmission plan.
- The PSSE base case file has been formulated to ensure that the data used for system analysis are accurate. Accordingly, the system analyses for different scenario are carried out in the given base case file.
- Substation wise load forecasting was carried out till 2040 using the historical data. It is seen that the average annual load growth is 4.4 %.
- The thermal rating is considered to determine the loading capacity of the transmission lines. The maximum conductor temperature is considered at 85^0C for future transmission lines and 75^0C for existing transmission lines at ambient temperature of 40^0C.
- System requirements have been evolved considering (n-1) contingency.
- System strengthening and reactive power compensation requirements is computed for the transmission lines 66kV and above till 2025 scenario.
- During high hydro season, adequacy of the proposed transmission lines has been tested with 10% additional dispatch at HEPs over normal peak load dispatch.
- Three phase to ground fault levels at 400kV, 220kV, 132kV and 66kV buses corresponding to 2040 are also computed.
- Based on the recommendation of stakeholder, the option of using HTLS and HVDC conductors are discarded. However, it may be explored in next update of the NTGMP.

Appendix 1

Approximate Ampacity(A) of ACSR Overhead Conductors.

Sl/ No	Conductor Name, nominal area(mm^2, OD(mm) & configuration	Ampacity at 40^0C ambient temperature		Thermal Loading (MW)		SIL(MW)
		75^0C	85^0C	75^0C	85^0C	
1	400kV Moose A=520mm^2 (Al), D=31.77mm 54/3.53mm Al, 7/3.53mm St.	700A	850A	873	1,060	515(Twin)
				1,746	2,120	614(Quad)
2	220kV Zebra A=420mm^2 (Al), D=28.62mm 54/3.18mm Al, 7/3.18mm St.	620A	750A	212	257	132(S/C)
3	132kV Panther A=200mm^2 (Al), D=21mm 30/3 mm Al, 7/3 mm St.	415A	490A	86	101	50(S/C)
4	66kV Dog A=150mm^2 (Al), D=18.13mm 30/2.59 mm Al, 7/2.59 mm St.	345A	410 A	35	42	10(S/C)

Air Density (kg/m3) = 1.0588kg/m3

Abs. viscosity in air(kg/m hr)=0.072027 kg/m hr

Wind Velocity (m/hr)=2000m/hr

Solar Radiation=1045w/m2

Thermal emissivity Const =0.45

Appendix2

Transmission Line Technology

Transmission line technology has emerged over time with invention of HVDC to superconducting transmission lines. Bhutan currently has ACSR conductors for transmitting High Voltage power.

New transmission technologies are required to explore in order to have maximum power transfer with minimum losses also optimizing physical structures (towers) to minimize the social and environmental impacts. However, owing to the hilly landscape of Bhutan, preferred new technologies must suit with the terrain of Bhutan. Right of Way (RoW) has become critically important and technologies such as multi-circuit towers and HVDC have greatly reduced RoW.

Table 1: Right of Way rewuirement.

Sl/No	Voltage level (kV)	Right of Way(metres)
1	400	52
2	220	35
3	132	27
4	66	18

14.1. High Temperature, Low-Sag (HTLS) conductors[6]

HTLS conductors are comparatively new technology which can become a possible measure to increase transmission capability. To improve the current capacity and to reduce thermal sag HTLS conductors are used. HTLS conductors could become economically feasible in tedious environment conditions such as higher span crossings in mountainous terrains, rivers, marshy lands etc. Due to its superior tensile strength and damping performances, the conductors can provide more reliable service compared to conventional conductors.

Merits:

- *Higher Current Carrying Capacity*:HTLS conductors can be operated at elevated temperatures around 150°C-250°C. Therefore the amount of current rating of these conductors is high compared to the conventional conductors such as Aluminum Conductor

[6] The information on HTLS section is extracted from a thesis report by Hewa Buhege Dayan Yasaranga ‘Techno Economic Analysis on the use of HTLS conductors for Sri Lanka’s Transmission system’

Composite Core (ACCC), Aluminum Conductor Composite Reinforced (ACCR) and Aluminum Conductor Steel Reinforced (ACSR) conductors.

- *ROW saving*:Since HTLS conductors can be used to transfer bulk power from one station to other, it has the potential to reduce number of transmission lines being constructed where they can eliminate the requirement of multiple lines by a single tower line.
- *Thermal Uprating of Existing Lines*:One of the main advantages of HTLS conductors is to use them as a medium for thermal uprating of existing transmission lines. The best option is to use a suitable HTLS conductor with similar mechanical properties where the existing towers can still be used without violating tower safety requirements as well as minimum ground clearances.*Long Span Crossing*:HTLS conductors can be used for longer spans crossings.

Demerits:

- *Low Service Experience*:ACSR conductors have more than hundred years of service experience and those conductors are being used all over the world. However HTLS conductors came to the world of transmission line construction at a later stage where no utility has that much service experience regarding the use of HTLS conductors. All other HTLS conductors such as ACSS, ZTACIR, ACCC have limited experience regarding the service life.
- *Special Stringing Requirements and Spares*:One of the main disadvantages of some of the HTLS conductors is the requirement of specialized stringing methods. They require special mid span joints unlike in the case of ACSR. They must be handled very carefully during stringing and cannot be subjected to rough and rigid handling. The dependency of the performance of the line on stringing had made utilities of selecting HTLS conductors less probable.
- *High Price of HTLS*:Unit cost of HTLS conductors are considerably higher compared to the cost of ACSR and AAAC. Still in case of a new line construction, use of HTLS will cost additional amount other than the saving of ROW. However in situations where existing line uprating, HTLS has the ability to cut down the cost of new transmission line only by restring conductors.

14.2. Aluminum Conductor Composite Core (ACCC)[7]

ACCC is the latest type stranded conductor usually used in the overhead power transmission lines; it has double the capacity of ACSR at same conditions.

ACCC is a concentrically stranded conductor composed of one or more layers of hard-drawn 1350H19 aluminum wire stranded with a high strength carbon and glass fiber core. The core maybe single wire or stranded depending on the size.

Merits:

- Light weight and high strength carbon
- Designed to perform efficiently at temperatures significantly higher than conventional ACSR conductors
- ACCC conductor installations use conventional installation methods, tools, and mostly conventional hardware
- ACCC conductor can reduce CO^2 emissions by thousands of tons over the 40 year life of a line and reduce tower height and cost at the same time

Demerits:

- Requires adherence to special stringing methods which requires trained staffs to carryout special stringing works as the performance of the line is heavily dependent on stringing
- Requires special hardware tools such as compression dead ends and splices to match with their superior behavior.

14.3. ACSR (Aluminium Conductor Steel Reinforced)

ACSR is a type of high-capacity, high-strength stranded conductor and used worldwide. The outer strands are high-purity aluminium, chosen for its excellent conductivity, low weight and low cost.

Merits:

- ACSR is conventional conductor, used and successfully operating since many years in the power sector industry. Stringing and installation methods are well known to majority of the power sector.
- Various Government Utilities have standardized the design of their transmission line towers for various voltage class range starting from 66kV up to 765 kV using ACSR conductor as a base conductor.

[7] Information on ACCC, ACSR, AAAC are compiled from scribd.com

Demerits:

- Thermal sag is considered one the major disadvantages when it comes to ACSR. With the increase in temperature, the expansion of the conductor gets increased as a result of the increase in current.
- Construction of ACSR conductor is bi-metallic, combination of Steel and EC Graded Aluminium. Thus there are changes of galvanic reaction between the two different materials.
- ACSR Conductor likely to catch corrosion

14.4. AAAC (All Aluminium Conductor)

Merits:

- AAAC conductor can be used in coastal areas as it offers property of corrosion resistance due to presence of Magnesium (Mg).
- Homogeneous thus no galvanic reaction occurs between steel and EC Grade Aluminium as in the case of ACSR conductor.
- Current carrying capacity of AAAC conductor is 15-20% higher than that of conventional ACSR conductor.
- Weight of AAAC conductor having same mechanical properties as that of ACSR is less (2MT/km for ACSR and 1.6 MT/km (approx.) for AAAC, thus vertical loading due to conductor on the transmission line tower reduces. However, the transverse load purely depends upon the wind acting on the total cross sectional area of the conductor.

Demerits:

- AAAC conductor maximum continuous operating temperature is restricted to 90^{0}C thus current can be boosted to 15-20% only.
- Vertical sag at its maximum operating temperature is higher than that of conventional ACSR conductor at its maximum continuous operating temperature. Thus, Design/Ruling span for new transmission line has to be reduced or tower extension has to be provided.
- For re-conductoring scenario, Refurbishment on the existing tower structures has to be carried out for proposing AAAC conductor.

14.5. HVDC Transmission Technology[8]

High voltage is used for electric power transmission to reduce the energy lost in the resistance of the wires. Power loss can also be reduced by reducing resistance, for example by increasing the diameter of the conductor, but larger conductors are heavier and more expensive.

Merits:

- *Asynchronous connection*: Being independent of frequency, HVDC can interconnect two regions, operating at different frequencies
- *Economical*: Although HVDC terminal equipments are costlier compared to the conventional AC terminal equipments, but beyond 600km HVDC is cheaper than equivalent AC system, mainly owing to less no. of conductors, towers along with accessories & intermittent substations
- *Environment friendly*: Due to reduced corridor i.e. only 46m exactly half right of way requirement, for same quantum of power to be transmitted over AC
- *Regulated Power flow*: Power flow through HVDC link can be precisely controlled/regulated, to ordered value under both steady state as well as dynamic conditions, independent of the conditions in AC system
- *System stability*: During dynamic conditions e.g. during swings caused by faults, HVDC provides stability to the transmission system by modulating power flow in HVDC link, assisting the grid in damping disturbance.
- *Bulk power transmission*: Since a DC transmission lines neither generate nor absorb any reactive power, it helps to increase the capability of the link to transmit large quantities of power over long distances in an efficient and economical manner. Due to the absence of reactive power, the losses on DC line are also low compared to an equivalent AC line.
- *Effective use of conductor*: Due to absence of frequency factor on DC link, the skin effect does not play any part and thus complete cross-section of the conductor can be effectively used and more power can be transmitted on same size of the conductor.
- *The DC transmission lines do not contribute to short circuit levels at the terminals*: The feature becomes important if two large networks are being connected where short circuit level are in the vicinity of maximum values specified for the network.

[8] Information on HVDC is extracted from a presentation made by PowerGrid to Bhutanese delegates during visit to HVDC Bhiwadi terminal in September 2010.

Demerits:

- *Less Reliability*: HVDC is less reliable and has lower availability than AC systems, mainly due to the extra conversion equipment
- *Availability*: Single pole systems have availability of 98.5%, with about a third of the downtime unscheduled due to faults. Fault redundant bipole systems provide high availability of the full capacity is about 97-98%.
- In the context to AC systems, realizing multi-terminal systems is complex, as in expanding existing schemes to multi-terminal systems. Controlling power flow in a multi-terminal DC system requires good communication between all the terminals.
- *High voltage DC circuit breakers*: are difficult to build because some mechanism must be inbuilt in the circuit breaker to force current to zero, otherwise arching and contact wear & tear would be too great to allow reliable switching.
- *Spare parts*: Operating a HVDC scheme requires many spare parts to be kept, often exclusively for one system as HVDC systems are less standardized than AC systems and technology changes faster.

14.6. Economic Choice of Transmission Voltage[9]

From the above advantages and limitations of high voltage transmission, we can say that with increase in transmission voltage the cost of conductor material can be reduced and the efficiency can be increased. But the cost of transformers, insulators, switchgear etc. is increased at the same time. Thus, for overall economy, there is an *optimum transmission voltage*. The limit to use of higher transmission voltage is reached when the saving in cost of conductor material is offset by the increased cost of transformers, switchgear, insulators etc. The economical transmission voltage is one for which the sum of cost of conductor material, transformers, switchgear, insulators and other equipment is minimum.

An economical transmission voltage for a 3 phase AC system can be computed by formula below:

$$V = 5.5\sqrt{0.62L + \frac{3xP}{100}}$$

Where, V = line voltage in kV.

P = maximum power per phase (in kW) to be delivered over single circuit.

[9] Compiled from various open sources

L = distance of transmission line in km.

Economical transmission voltage depends on the power to be transmitted and the length of transmission. If the power to be transmitted is large, cost per kW of terminal equipment reduces. This results in increased economic transmission voltage. If the distance of transmission is increased, saving in the cost of conductor material can be significantly increased by increasing the transmission voltage.

Existing Hydropower Plants

Annexure I

Sl. No	Name	Location	Installed Capacity (No. x MW)	Generation Transformer		Firm Power (MW)
				Voltage Ratio (kV)	MVA Rating (No. x MVA)	
1	Chukha Hydropower Plant	Chukha	336 (4x84)	11/220	420 12x35	79.7
2	Tala Hydropower Plant	Chukha	1020 (6x170)	13.8/400	1260 (18x70)	190.7
3	Basochhu-I Hydropower Plant	Wangdue	24 (2x12)	11/66	30 (2x15)	15.6
4	Basochhu-II Hydropower Plant	Wangdue	40 (2x20)	11/220	60 (2x30)	
5	Kurichhu Hydropower Plant	Monger	60 (4x15)	11/132	20 (4x20)	18.6
6	Dagachhu Hydropower Plant	Dagana	126 (2x63)	11/220	24 (6x24)	15.8
Total			**1606**			**320**

Projects under Construction

Sl. No.	Name of Project	Location	Installed Capacity (MW)	Firm Power (MW)	Expected COD
1	Punatsangchhu-II HEP	Wangdiphodrang	1020	164	2019
2	Punatsangchhu-I HEP	Wangdiphodrang	1200	199	2021
3	Nikachhu HEP (Tangsebji)	Trongsa	118	22.55	2019
4	Mangdechhu HEP	Trongsa	720	90	2018
5	Kholongchhu HEP	Trashiyangtse	600	113.8	2023
Total			**3658**	**589.35**	

Projects under DPR & PFR stage

Annexure II

Sl. No	Name of Project	Installed Capacity (MW)	Firm Power (MW)	Study Stage
1	Amochu RS	540	67.5	DPR completed
2	Bunakha RS	180	31.71	-do-
3	Chamkharchhu-I	770	137	-do-
4	Dorjilung	1125	168	-do-
5	Sankosh RS	2585	427.44	-do-
6	Wangchhu	570	94.96	-do-
7	Kuri-Gongri	2640	331.1	DPR under preparation
8	Nyera-Amari I & II Integrated	404	102	DPR under preparation
9	Druk Bindu	18	2.5	-do-
10	Chamkharchhu-II	590	95.18	PFR completed
11	Chamkharchhu-IV	364	58.68	-do-
12	Dagachhu-II	70	12	-do-
13	Dangchhu	170	27.53	-do-
14	Gamri-I	45	11	-do-
15	Gamri-II	85	20	-do-
16	Jomori-I	85	23	-do-
17	Khomachhu	363	41.99	-do-
18	Panbang HEP	1100	165.6	-do-

Projects under Recon & Desktop study Annexure III

Sl. No.	Name of Project	Installed Capacity (MW)	Study Stage
1	Bemengchhu	14	Recon.
2	Gamrichhu-5	91	-do-
3	Mochhu - 1	660	-do-
4	Mochhu - 2	450	-do-
5	Pachhu	72	Recon (DHPS-2016)
6	Parochhu	114	Recon
7	Pipingchhu	64	Recon (DHPS-2016)
8	Punatsangchhu-III	600	Recon
9	Shongarchu-1	107	-do-
10	Shongarchu-2	55	-do-
11	Yangtse/Kholong	96	Recon by DHPS, 2016
12	Amochu-1	460	Recon by DHPS, 2017
13	Amochu-2	496	Recon by DHPS, 2017
14	Samchu	50	Recon by DHPS, 2017
15	Gongri	652	Recon by DHPS, 2018
16	Bambichhu	22	RS (DRE)
17	Haachhu	17	-do-
18	Ngargangchhu	24	-do-
19	Cherchhu/Burichhu	25	-do-
20	Aiechhu	54	-do-
21	Bomdeling/Kholong	130	Desktop
22	Burgangchu-1	69	-do-
23	Burgangchu-2	70	-do-
24	Chamkharchhu-3	1247	Desktop by LII

25	Chamkharchhu-5	97	Desktop
26	Cherchu (Churchhu/Chechhu)	45	-do-
27	Cherichhu	76	-do-
28	Dangchhu (below confluence)	50	Desktop by LII
29	Gamri-4/Yamkhari	81	-do-
30	Gamrichu-3	80	-do-
31	Ghijam/Lirigang/Gayzamchu	53	-do-
32	Gobarichu	43	-do-
33	Gumthang	108	-do-
34	Krissa	32	-do-
35	Phochhu	132	-do-
36	Rimjigangchhu	46	-do-
37	Shergarchhu	27	-do-
38	Sherichu	36	-do-
39	Sichhu	78	-do-
40	Thampochhu	95	-do-
41	Thimphuchhu	57	-do-
42	Wachi	24	-do-
43	Samachhu	16	-do-
44	Jomori	50	-do-

Existing Transmission Lines

Annexure IV

Sl. No	Name of Line	No. of Circuits	Route Length (km)	Remarks
A	**400kV Lines (ACSR Twin Moose)**			
1	Tala - Khogla (Feeder No. I & II)	Double	24.615	
2	Tala-Malbase-Pugli (Feeder No.III & IV)	Double	49.528	
Total			**74.143**	
B	**220kV Lines (ACSR Zebra)**			
1	Chukha-Semtokha	Single	54.010	
2	Semtokha-Rurichhu	-do-	44.900	
3	Rurichhu-Tsirang	-do-	46.600	
4	Chukha-Gedu-India border	Double	35.780	
5	Chukha-Gedu-Malbase	Single	29.841	
6	Malbase-India border(Birpara)	-do-	4.075	
7	Malbase-Singhigaon -Fdr-2	-do-	2.607	
8	Malbase-Samtse-Singhigaon	-do-	41.642	
9	Dagachhu-Tsirang	Double	20.202	
10	Tsirang-Jigmeling	-do-	30.565	
11	Jigmeling-Pelrithang(Lodrai)	-do-	10.420	Presently Charged at 132kV
12	Tshendengang-Dagapela(LILO)		4.396	
Total			**325.038**	
C	**132kV Lines (ACSR Panther)**			
1	Kurichhu - Kilikhar	Single	10.060	
2	Kilikhar - Kanglung	-do-	29.705	
3	Kilikhar - Tangmachhu(Lhuentse)	-do-	42.800	Presently charged at 33kV
4	Kurichhu - Nangkor	-do-	31.080	
5	Nangkor - Deothang	-do-	23.300	
6	Nangkor - Nganglam	-do-	33.793	

7	Nganglam-Tingtibi	-do-	83.330	
8	Gelephu-Pelrithang (Lodrai)	-do-	10.784	
9	Pelrithang (Lodrai) - Tingtibi	-do-	34.956	
10	Gelephu - India Border	-do-	0.100	
11	Deothang- Motanga	-do-	10.500	
12	Motanga-India (Border)	-do-	1.500	
13	Tintibi-Yurmoo	-do-	32.628	Presently charged at 33kV
14	Motanga-Phuntshothang	Double	22.000	
Total			**366.54**	
D	**66kV Lines (ACSR Dog)**			
1	Chhukha -Chumdo	Single	36.980	
2	Khasadrapchu - Olakha	-do-	11.740	1km under ground at IT Park
3	Chumdo - Paro	-do-	24.010	
4	Chumdo - Haa	-do-	33.400	
5	Chumdo-Khasadrabchu	-do-	4.780	
6	Watcha Tie Line	-do-	0.500	
7	Semtokha - Olakha	-do-	1.700	
8	Khasadrapchu - Jemina	Double	5.960	
9	Semtokha - Lobeysa	Single	24.430	
10	Lobeysa -Rurichhu	-do-	20.300	
11	Rurichhu-Hebisa	-do-	3.080	
12	Semtokha - Dechencholing	-do-	11.450	
13	Chhukha-Gedu	-do-	20.400	
14	Gedu-Phuentsholing	-do-	16.700	
15	Phuentsholing - Gomtu	-do-	26.900	
16	Malbase-Phuentsholing	-do-	8.986	
17	Malbase-Pasakha	3 Circuits	3.405	
18	Yurmo-Bumthang	Single	34.856	Charged at 33kV
19	Yurmo-Trongsa	Single	20.940	Charged at 33kV

20	Samtse-Sibso	Double	26.958	ACSR WOLF
21	Samtse-Gomtu	Double	14.851	ACSR WOLF
22	Pasakha Industrial area	Single	5.018	Under ground cable
	Total		**357.344**	

Existing Transmission systems associated with Chukha, Kurichhu, Tala HPPs are as follows:

1. Chukha HPP(336MW)
   - 220kV,1xD/C, Chukha(Bhutan)-Birpara(West Bengal)
   - 220kV,1xD/C, Chukha(Bhutan)-Birpara(West Bengal)
2. Kurichhu HPP(60MW)
   - 132kV,1xS/C, Kurichhu(Bhutan)-Gelephu(Bhutan)-Salakati(Assam)
   - 132kV,1xS/C, Kurichhu(Bhutan)-Motanga(Bhutan)-Rangia(Assam)
3. Tala HPP(1020MW)
   - 400kV, 2xD/C, Tala(Bhutan)-Silliguri(West Bengal) with one of a D/C line LILOed at Malbase S/S in Bhutan

Under Construction Transmission Lines Annexure V

Sl. No	Name of Line	No. of Circuits	Route Length (km)	Remarks
A	**400kV Lines (ACSR Twin Moose)**			
1	Punatshangchhu(I)-Lhamoizingkha (Indian Border)	Double	92.867	Under construction
2	Punatshangchhu(I) via PHPA II-Lhamoizingkha	-do-	93.502	-do-
3	Punatsangchhu II-Jigmeling	-do-	65.000	-do-
4	Mangdechhu via Going-Jigmeling	-do-	85.126	-do-
5	Mangdechhu via Going-Jigmeling	-do-	84.683	-do-
Total			**421.178**	
B	220kV Lines (ACSR Zebra)			
1	LILO of Rurichu-Tsirang at Puna I	Single	5.000	Under construction
Total			**5.000**	
C	132kV Lines (Panther)			
1	Motanga-Nganglam	Double	34.730	-do-
2	Kanglung-Phutshothang	Single	58.000	-do-
3	Merung-Corlung (LILO of Kanglung to Killikhar line)	Double	19.000	Under construction.
4	Mangechhu -Nikachhu	-do-	18.600	Under Construction
5	Mangdechhu-Yurmo	-do-	5.000	Under Construction
Total			135.330	
D	66kV Lines			
1	Dechenling-Gasa	Single	42.000	Under construction.
2	Jemina - Thimphu	Single	10.000	Under construction.
	Total		**52.000**	

Existing Substations (66kV & above) Annexure VI

Sl. No.	Substation	Voltage ratio (kV)	No. of Trfs & Capacity (No.xMVA)	% Impedance	Total Capacity (MVA)
1	Dechencholing	66/33	2 x 10	8.12	20
		33/11	2 x 2.5	6.02	
2	Olakha	66/33	2 x 20	8.48	40
3	Semtokha	220/66	2 x 50/63	12.36	126
		66/11	2 x 10	10	
4	Paro Olathang	66/11	1 x 10	9.61	10
5	Chumdo Switching Station	66			
6	Watsa	66/33	1 x 8	8.29	8
7	Gedu	66/33	1 x 6.3/8	8.35	8
		66/33/11	1 x 5	7.66, 17.29, 8.18	5
		66/11	2 x 4/5	7.2	10
8	Malbase	400/220/33	1 x 120/160/200	11.99	200
		220/66	3 x 50/63	12.50	
		66/11	2 x 20	9.39	
9	Singhigaon	220/66	1 x 40/50	11.99	50
			1 x 21/28/35	13.29	35
		66/11	1 x 3	6.82	
			1 x 10	6.8056	
10	Phuentsholing	66/33	2 x 10	8.96	20
		66/11	1 x 3	7.11	15.5
			1 x 10/ 12.5	8.3	
11	Dhamdum Samtse	220/66	2x50/63	12.32	126
		66/33	2x5	7.47	
		132/66	2x12.5/ 25	9.83	

12	Gelephu	66/11	1x10	9.414	50
		66/33/11	2x5(2.5/2.5)	6.99, 10.232, 3.328	
13	Jigmeling	400/220	3x167		500
		220/132	2x63/80	12.53	160
		132/33	1x15	9.32	
14	Darjey Tsirang	220/66	2x10	8.49	20
		66/33	2x5	7.17	
15	Gomtu	66/33	1x5	7.32	5
		66/11	2x5	6.97	10
16	Jemina	66/33	1x10		10
		33/11	1x5		
17	Haa	66/11	2x5		10
18	Lobeysa	66/33	1x5		5
		66/11	2x5		10
19	Tingtibi	132/33	2x3		6
		33/11	2x1.5		
20	Yurmoo	132/33	2x15		30
21	Dewathang	132/33	2x5		10
		33/11	2x2.5		
22	Nangkor	132/33	2x5		10
		33/11	2x2.5		
23	Kilikhar	132/33	1x5, 1x10		10
		33/11	2x2.5		
24	Kanglung	132/33	2x5		10
		33/11	2x2.5		
25	Nganglam	132/33	2x3		6
		33/11	2x1.5		

Under Construction Substations (66kV & above) Annexure VII

Sl. No.	Substation	Voltage ratio (kV)	No. of Trfs & Capacity (No.xMVA)	Total Capacity (MVA)
1	Mangdechhu	400/132	4x67	200
2	Punatsangchhu-I	400/220	4x105	315
3	Dagapela	220/33	2 x 10	20
4	Kholongchhu	132/33	2 x 10	20
5	Pangbesa	66/33	2 x 10	20
6	Phuntshothang	132/33	2 x 10	20

Proposed Construction Substations(66kV & above)

Sl. No.	Substation	Voltage ratio (kV)	No. of Trfs & Capacity (No.xMVA)	Total Capacity (MVA)
1	Chumdo	220/66	2x50/63	126
2	Damji	66/33	2x5	10
3	Changidaphu	66/33	2 x 20	40

List of Projects in different timeframe Annexure VIII

Sl. No.	Name	IC (MW)	Status
Existing HEPs			
1	Basochhu-I HPP	24	Under operation
2	Basochhu-II HPP	40	-do-
3	Chukha HPP	336	-do-
4	Dagachhu HPP	126	-do-
5	Kurichhu HPP	60	-do-
6	Tala HPP	1020	-do-
Total		**1606**	
2020 Time frame			
7	Mangdechhu HEP	720	Under cons. Estimated COD 2018
8	Punatsangchhu-II HEP	1020	Under cons. Estimated COD 2019
9	Nikachhu HEP	118	Under cons. Estimated COD 2019
Total		**1858**	
2025 Time frame			
10	Punatsangchhu-I HEP	1200	Under cons. Estimated COD 2021
11	Kholongchhu HEP	600	Under cons. Estimated COD 2022
Total		**1800**	
2030 Time Frame			
12	Dorjilung HEP	1125	DPR completed
13	Sankosh HEP	2585	-do-
14	Nyera-Amari I & II HEP	404	DPR under preparation
Total		**4114**	
2035 Time Frame			
15	Wangchhu HEP	570	DPR completed
16	Bunakha reservoir	180	-do-
17	Chamkharchhu-I HEP	770	-do-
18	Kuri-Gongri HEP	2640	DPR under preparation
Total		**4160**	

2040 Time frame			
19	Chamkharchhu-II	590	PFR completed
20	Chamkharchhu-IV	364	-do-
21	Khomachhu	363	-do-
22	Pambang	1100	-do-
23	Gongri	652	Recon(DHPS- 2018)
Total		**3069**	
2040 and beyond timeframe			
24	Amochhu reservoir	540	DPR completed
25	Druk Bindu	18	DPR under preparation
26	Dagachhu-II	70	PFR completed
27	Dangchhu	170	-do-
28	Gamri-I	45	-do-
29	Gamri-II	85	-do-
30	Jomori-I	85	-do-
31	Bemengchhu	14	Recon.
32	Gamrichhu-5	91	-do-
33	Mochhu - 1	660	-do-
34	Mochhu - 2	450	-do-
35	Pachhu	72	Recon (DHPS-2016)
36	Parochhu	114	Recon
37	Pipingchhu	64	Recon (DHPS-2016)
38	Punatsangchhu-III	600	Recon
39	Shongarchu-1	107	-do-
40	Shongarchu-2	55	-do-
41	Yangtse/Kholong	96	Recon by DHPS, 2016
42	Amochu-1	460	Undergoing RS (DHPS)
43	Amochu-2	496	Undergoing RS (DHPS)
44	Samchu	50	Undergoing RS (DHPS)
45	Bambichhu/Wambichhu	22	RS (DRE)
46	Haachhu	17	-do-

47	Ngargangchhu/Yunarichu	24	-do-
48	Cherchhu/Burichhu	25	-do-
49	Aiechhu	54	Desktop
50	Bomdeling/Kholong	130	Desktop
51	Burgangchu-1	69	-do-
52	Burgangchu-2	70	-do-
53	Chamkharchhu-3	1247	Desktop by LII
54	Chamkharchhu-5	97	Desktop
55	Cherchu (Churchhu/Chechhu)	45	-do-
56	Cherichhu	76	-do-
57	Dangchhu (below confluence)	50	Desktop by LII
58	Gamri-4/Yamkhari	81	-do-
59	Gamrichu-3	80	-do-
60	Ghijam/Lirigang/Gayzam chhu	53	-do-
61	Gobarichu	43	-do-
62	Gumthang	108	-do-
63	Krissa	32	-do-
64	Phochhu	132	-do-
65	Rimjigangchhu	46	-do-
66	Shergarchhu	27	-do-
67	Sherichu	36	-do-
68	Sichhu	78	-do-
69	Thampochhu	95	-do-
70	Thimphuchhu	57	-do-
71	Wachi	24	-do-
72	Samachhu	16	-do-
73	Jomori	50	-do-
Total		**7226**	

Generation Dispatches during 2035 & beyond 2040 Annexure IX

Sl. No.	Name of the Generating Station	Installed Capacity	I.C. by 2035	I.C. by beyond 2040	Peak Gen. 2035	Off peak Gen. 2035	Peak Gen. beyond 2040
Wangchhu Basin							
1	Bemengchhu	14		14			15
2	Bunakha RS	180	180	180	197	32	197
3	Cherichhu	76		76			83
4	Chukha	336	336	336	368	80	368
5	Haachhu	17		17			19
6	Parochhu	114		114			125
7	Pipingchhu	64		64			70
8	Tala	1020	1020	1020	1117	191	1117
9	Thimphuchhu	57		57			62
10	Wangchhu	570	570	570	624	95	624
Total		**2448**	**2106**	**2448**	**2306**	**397**	**2681**
Amochhu Basin							
11	Amochhu RS	540		540			591
12	Amochhu-1	460		460			504
13	Amochhu-2	496		496			543
14	Cherchhu	45		45			49
15	Pachhu	72		72			79
16	Samchhu	50		50			55
Total		**1663**	**0**	**1663**	**0**	**0**	**1821**
Punatsangchhu Basin							
17	Basochhu-I	24	24	24	26	16	26
18	Basochhu-II	40	40	40	44		44
19	Cherchhu/Burichhu	25		25			27
20	Dagachhu	126	126	126	125	16	125
21	Dagachhu-II	70		70			77
22	Dangchhu-I	170		170			186

23	Dangchu	50		50			55
24	Mochhu-1	660		660			723
25	Mochhu-2	450		450			493
26	Phochhu	132		132			145
27	Punatsangchhu-I	1200	1200	1200	1314	199	1314
28	Punatsangchhu-II	1020	1020	1020	1117	164	1117
29	Punatsangchhu-III	600		600			657
30	Samachhu	16		16			18
31	Sankosh RS	2585	2585	2585	2831	427	2831
32	Sichhu	78		78			85
Total		**7246**	**4995**	**7246**	**5457**	**822**	**7922**
Mangdechhu Basin							
33	Burgangchhu-1	69		69			76
34	Burgangchhu-2	70		70			77
35	Chamkharchhu-I	770	770	770	843	137	843
36	Chamkharchhu-II	590		590			646
37	Chamkharchhu-III	1247		1247			1365
38	Chamkharchhu-IV	364		364			399
39	Chamkharchhu-V	97		97			106
40	Ghijam/Lirigang	53		53			58
41	Gumthang	108		108			118
42	Krissa	32		32			35
43	Mangdechhu	720	720	720	788	90	788
44	Nikachhu	118	118	118	129	35	129
45	Shergarchhu	27		27			30
46	Rimijigangchhu	46		46			50
47	Thampochhu	95		95			104
48	Wachi	24		24			26
Total		**4430**	**1608**	**4430**	**1761**	**262**	**4851**
Drangmechhu Basin							
49	Bambichhu	22		22			24

50	Bomdeling/Kholong	130		130			142
51	Dorjilung	1125	1125	1125	1232	168	1232
52	Gamri-3	80		80			88
53	Gamri-4/Yamkhari	81		81			89
54	Gamri-5	91		91			100
55	Gamri-I	45		45			49
56	Gamri-II	85		85			93
57	Gobarichhu	43		43			47
58	Kholongchhu	600	600	600	657	114	657
59	Khomachhu	363		363			397
60	Kurichhu	60	60	60	66	19	66
61	Kuri-Gongri	2640	2640	2640	2891	331	2891
62	Panbang	1100		1100			1205
63	Ngargangchhu	24		24			26
64	Serichhu	36		36			39
65	Shongarchhu-1	107		107			117
66	Shongarchhu-2	55		55			60
67	Yangtse/Kholong	96		96			105
68	Gongri	652		652			714
Total		**7435**	**4425**	**7435**	**4845**	**632**	**8141**
Other Basins							
69	Aiechhu	54		54			59
70	Druk Bindu	18		18			20
71	Jomori-I	85		85			93
72	Jomori	50		50			
73	Nyera Amari-I & II	404	404	404	442	102	442
Total		**611**	**404**	**611**	**442**	**102**	**614**
Grand Total		**23833**	**13538**	**23833**	**14812**	**2215**	**26030**

Tranmission systems beyond 2040 Annexure X

Sl/ No	Name of the Generating Stations	Route Length(30% increase)
Beyond 2040		
WANGCHHU BASIN		
1	Bemengchhu -14MW	
	66 kV,1x D/C, Bemengchhu - Chumdo	10
2	Cherichhu-76MW	
	i. LILO of one ckt. of 400 kV 1xD/C Mochhu I-Sankosh at Cherichhu	5
	ii. 220 kV,1xS/C, Cherichhu-Paro	15
	iii. 400/220 kV ,4x67 MVA at Cherichhu	
3	Hachhu -17 MW	
	66 kV, 1xD/C, Hachhu - Watsa	10
4	Parochhu -104 MW	
	220 kV, 1xD/C, Parochhu-Cherichhu	45
5	Pipingchhu -64 MW	
	220 kV, 1xD/C, Pipingchhu - Sankosh Left Bank PH	30
6	Thimphuchhu - 57 MW	
	LILO of one ckt. of 220 kV D/C Parochhu-Cherichhu at Thimphuchhu	5
AMOCHHU BASIN		
7	Amochu RS-540	
	LILO of 400kV S/C Tala-Silliguri line at Amochhu RS	
8	Amochhu-1 -460MW	
	400 kV, 1xD/C, Amochhu I - Amochhu II	15
9	Amochhu-II -496MW	
	i.400 kV, 1xD/C Amochhu II- Alipurduar with one ckt LILO at Amochhu RS	40
	ii. 400/220kV, 4x50 MVA Transformer at Amochhu II	
10	Cherchu -45 MW	
	220 kV, 1xD/C, Cherchu- Amochhu II	20
11	Pachhu -72 MW	

	220 kV, 1xD/C, Pachhu-Malbase	15
12	Samchu -50 MW	
	220 kV, 1xD/C, Samchu -Amochhu II	10
PUNASANGCHHU BASIN		
13	Punatsangchhu III -600 MW	
	i.400kV, 1xD/C, Punatsangchhu III - Lhamozingkha	55
	ii. LILO of 400kV D/C Punatsangchhu II-Jigmeling at Punatsangchhu III	10
	iii. 400/132 kV ,1x30 MVA ICT	
14	Cherchhu/Burichhu -25 MW	
	132kV, 1xS/C, Cherchhu - Punatsangchhu III	5
15	Dangchhu 1 – 170 MW	
	220kV, 1xD/C, Dangchhu I- Punatsangchhu I	65
16	Dangchhu-50 MW	
	LILO of one circuit of 220kV D/C Dangchu-I to Punatsangchu -I at Dangchhu.	5
17	Dagachhu 2 – 70 MW	
	220kV, 1xS/C, Dagahhu 2 - Dagapela	15
18	Mochhu I -600MW	
	400kV, 1xD/C, Mochhu I - Lhamozingkha	175
19	Mochhu II -450 MW	
	LILO of one ckt. of 400kV D/C Mochhu I - Lhamozingkha at Mochhu II	3
20	Phochhu -132MW	
	220kV, 1x D/C, Phochhu - Mochhu II	30
21	Samachu -16 MW	
	LILO of one ckt of 220kV D/C Pipingchhu I - Lhamoizingkha	5
22	Sichhu -78 MW	
	LILO of one ckt.of 220kV D/C Phochhu - Mochhu II	10
MANGDECHHU BASIN		
23	Burgangchhu I-69 MW	
	132kV, 1xD/C, Burgangchhu I - Chamkharchu I	20

24	Burgangchhu II -70 MW	
	LILO of one ckt of 132kV D/C Burgangchhu I - Chamkharchu I at Burgangchu II.	5
25	Chamkharchu V (97 MW)	
	LILO of one ckt of 220 kV D/C Gumthang-Chamkharchu IV at Chamkahrchhu V	10
26	Chamkharchu III -1247 MW	
	i. 400kV, 1xD/C, Chamkharchu III - Goling	55
	ii.400kV, 1xD/C, Chamkharchu III – Chamkharchu II	10
	iii.400/132 kV, 1x67 MVA ICT	
27	Ghijam/Lirigang -53 MW	
	132kV 1xD/C Ghijam- Chamkharchu III	10
28	Gumthang - 108MW	
	220 kV, 1xD/C, Gumthang - Chamkharchu IV	55
29	Krissa -32MW	
	132kV, 1xD/C, Krissa - Wachi line	10
30	Shergarchhu-27 MW	
	132kV, 1xD/C, Shergarchhu - Goling	15
31	Rimjigangchhu -46 MW	
	132kV, 1xD/C, Rimjigangchhu - Shergarchhu	5
32	Thampochhu -95 MW	
	132 kV, 1xD/C, Thampochhu-Nikachhu	45
33	Wachi -24 MW	
	LILO of 132kV S/C Tingtibi-Yurmoat Wachi	5
	DRANGMECHHU BASIN	
34	Gamrichu 1(45 MW)	
	i.220 kV, 1xS/C, Gamrichhu I- Gamrichhu III	15
	ii.220 kV, 1x S/C, Gamrichhu I- Gamrichhu II	10
35	Gamrichu II (85 MW)	
	220 kV, 1xS/C, Gamrichhu II- Gamri PS	20

36	Gamrichu III (80 MW)	
	220 kV, 1xS/C line, Gamrichhu III- Gamri PS	15
37	Gamri IV /Yamkhari (81 MW)	
	LILO of 220kV S/C Gamrichhu V- Gamri PS 220 kV at Gamri-IV	5
38	Gamrichu V (91 MW)	
	i. 220 kV, 1x D/C, Gamrichhu V- Gamri PS	15
	ii. LILO of one ckt of 400 kV D/C Kholongchu-Yangbari line at Gamri PS	5
	iii.400kV, 1x D/C, Gamri PS to Phuntshothang	30
	iv. 400/220 kV, 2x 315 MVA Transformer at Gamri PS	
39-40	Ngargangchhu (24 MW)&Bambichhu (22 MW) &	
	i.132 kV 1xS/C Ngargangchhu-Dorjilung	5
	ii.LILO of 132kV Tagmachu-Killikhar line at Ngargangchhu	5
	iii.LILO of 132kV S/C Ngargangchhu-Dorjilung at Bambichhu.	
41	Shongarchhu-I (107 MW)	
	220 kV, 1x D/C line, Shongarchhu-I-Yangbari	45
42	Shongarchhu-II (55 MW)	
	LILO of 1 ckt of 220kV D/C Shongarchhu-I-Yangbari	5
43	Gobarichhu (43 MW)	
	LILO of 1 ckt of 220kV D/C Shongarchhu 1-Yangbari at Gobarichhu	5
44	Bomdeling (130MW)	
	220kV, 1x D/C, Bomdeling - Gamri PS	75
OTHER BASINS		
45	Aiechhu -54 MW	
	132kV, 1x D/C, Aiechhu - Gelephu	10
46	Sherichu -36 MW	
	132 kV, 1x D/C Sherichu - Dorjilung	15
47	Yangtse/ kholong -94 MW	
	LILO of one ckt of 220kV D/C Bombdeling- Gamri PS at Kholong	5
48	Druk Bindu-18 MW	
	66kV, 1x D/C, Druk Bindu-Sipso	15

Short Circuit Result Result for 2040 Scenario at Various Buses in Bhutan

Annexure XI

BUS NO. BUS NAME VOLTAGE THREE PHASE FAULT VALUE

/I+/AN(I+) FACTOR

101	[KURICHHU	132.00]	AMP	7743.0	-74.57	1.10
102	[KILIKHAR	132.00]	AMP	7374.3	-74.01	1.10
103	[KANGLUNG	132.00]	AMP	9505.2	-79.53	1.10
104	[NANGKOR	132.00]	AMP	9748.8	-71.94	1.10
105	[NGANGLAM	132.00]	AMP	15020.0	-74.49	1.10
106	[DEOTHANG	132.00]	AMP	11269.8	-71.94	1.10
107	[MOTANGA	132.00]	AMP	17990.0	-74.68	1.10
108	[GELEPHU	132.00]	AMP	6301.2	-75.72	1.10
109	[TINGTIBI	132.00]	AMP	11011.6	-73.55	1.10
110	[YURMO	132.00]	AMP	11595.2	-81.41	1.10
111	[JIGMELING	132.00]	AMP	9481.2	-80.37	1.10
112	[MANGDECHU	132.00]	AMP	12359.4	-83.47	1.10
113	[NIKACHHU	132.00]	AMP	9159.3	-80.26	1.10
114	[CORLUNG	132.00]	AMP	11711.0	-81.73	1.10
115	[PTHANG	132.00]	AMP	22793.1	-81.74	1.10
116	[NYERA-I	132.00]	AMP	18629.8	-79.47	1.10
117	[CHMKHR-I	132.00]	AMP	21645.0	-82.15	1.10
118	[YANGBARI	132.00]	AMP	13238.3	-80.50	1.10
201	[CHHUKHA	220.00]	AMP	19591.3	-84.36	1.10
202	[MALBASE	220.00]	AMP	20675.9	-84.68	1.10
203	[SEMTOKHA	220.00]	AMP	10306.3	-81.93	1.10
204	[BASO-LS	220.00]	AMP	13419.1	-84.34	1.10
205	[TSIRANG	220.00]	AMP	14062.5	-83.87	1.10
206	[JIGMELING	220.00]	AMP	17246.5	-85.82	1.10
207	[DAGACHU	220.00]	AMP	13167.4	-84.28	1.10
208	[SINGHIGAON	220.00]	AMP	17981.0	-84.07	1.10
209	[SAMTSE	220.00]	AMP	9418.6	-82.00	1.10
210	[PUNA I	220.00]	AMP	14636.4	-85.00	1.10
211	[BUNAKHA	220.00]	AMP	18553.7	-84.06	1.10
212	[SANKOSH RB	220.00]	AMP	10323.3	-84.96	1.10
213	[SANKOSH LB	220.00]	AMP	7574.4	-84.78	1.10
214	[AMOCHU LS	220.00]	AMP	16166.2	-83.66	1.10
215	[S.REGULATING	220.00]	AMP	8911.9	-84.91	1.10
216	[DAGAPELA	220.00]	AMP	13153.6	-84.31	1.10
217	[CHUMDO	220.00]	AMP	11694.5	-82.15	1.10
219	[KHOMACHU	220.00]	AMP	5230.8	-87.54	1.10
220	[DORJILUNG	220.00]	AMP	6864.3	-89.69	1.10
221	[CH-IV	220.00]	AMP	8628.1	-86.69	1.10
222	[CH-II	220.00]	AMP	12360.0	-89.37	1.10
401	[TALA	400.00]	AMP	24625.1	-86.85	1.10
402	[MALBASE	400.00]	AMP	19458.3	-86.13	1.10
403	[KHOLONGCHU	400.00]	AMP	20954.8	-85.89	1.10
404	[MANGDECHU	400.00]	AMP	33087.4	-86.34	1.10
405	[PUNA I	400.00]	AMP	37724.3	-86.95	1.10
406	[PUNA II	400.00]	AMP	40522.6	-87.00	1.10
407	[JIGMELING	400.00]	AMP	41960.6	-86.56	1.10
408	[GOLING	400.00]	AMP	46869.2	-86.79	1.10
409	[LHAMOZING	400.00]	AMP	41149.9	-87.10	1.10

410	[YANGBARI	400.00]	AMP	62849.0	-87.57	1.10
411	[DORJILUNG	400.00]	AMP	40880.8	-86.83	1.10
412	[WANGCHU	400.00]	AMP	20030.9	-86.54	1.10
413	[NYERA-II	400.00]	AMP	20441.8	-85.50	1.10
414	[PTHANG	400.00]	AMP	21565.0	-85.50	1.10
415	[KURIGONGRI	400.00]	AMP	46028.3	-87.33	1.10
416	[CHMKHR-I	400.00]	AMP	42274.9	-86.55	1.10
418	[SANKOSH LB	400.00]	AMP	39382.6	-87.01	1.10
419	[SANKOSH RB	400.00]	AMP	38669.1	-87.01	1.10
420	[GONGRI	400.00]	AMP	26079.4	-86.35	1.10
421	[CH-II	400.00]	AMP	36426.0	-86.42	1.10
422	[PANBANG	400.00]	AMP	36443.7	-87.36	1.10
601	[CHHUKHA	66.000]	AMP	7707.3	-78.87	1.10
602	[WATSA-TAP	66.000]	AMP	6540.3	-73.78	1.10
603	[WATSA	66.000]	AMP	6334.8	-73.58	1.10
604	[CHUMDO	66.000]	AMP	12313.2	-82.12	1.10
605	[PARO	66.000]	AMP	4170.0	-72.23	1.10
606	[HAA	66.000]	AMP	3859.4	-71.86	1.10
607	[GEDU	66.000]	AMP	5919.6	-72.63	1.10
608	[JEMINA	66.000]	AMP	8314.7	-76.54	1.10
609	[OLAKHA	66.000]	AMP	10987.4	-80.33	1.10
610	[SEMTOKHA	66.000]	AMP	11884.7	-82.25	1.10
611	[D-CHOLING	66.000]	AMP	5752.9	-75.18	1.10
612	[LOBEYSA	66.000]	AMP	5010.6	-74.31	1.10
613	[GAYWATHANG	66.000]	AMP	5546.8	-81.44	1.10
614	[BASO-LS	66.000]	AMP	5715.4	-82.55	1.10
615	[BASO-US	66.000]	AMP	5170.4	-81.48	1.10
616	[TSIRANG	66.000]	AMP	3058.8	-86.25	1.10
617	[P-LING	66.000]	AMP	9293.5	-75.67	1.10
618	[MALBASE	66.000]	AMP	14110.7	-84.90	1.10
619	[GOMTU	66.000]	AMP	7191.5	-76.88	1.10
620	[SAMTSE	66.000]	AMP	9488.7	-83.57	1.10
621	[SINGHIGAON	66.000]	AMP	5946.9	-87.46	1.10
622	[GELEPHU	66.000]	AMP	3984.5	-83.80	1.10
623	[KHASADRAPC	66.000]	AMP	10322.8	-78.39	1.10
624	[SIBSO	66.000]	AMP	4208.3	-74.44	1.10

PSSE Input parameters for 2040 Scenario. Annexure XII

a. Bus Data.

Bus No.	Bus Name	Base kV	Area No	Code	Angle (deg)	Vmax (pu)	Vmin (pu)
1	kurichu	11	6	2	74.88	1.1	0.9
2	chhukha	11	6	2	61.05	1.1	0.9
3	baso-us	11	6	2	66.11	1.1	0.9
4	tala	13.8	6	2	63	1.1	0.9
5	baso-ls	11	6	2	70.57	1.1	0.9
6	dagachu	11	6	2	73.46	1.1	0.9
7	puna i	13.8	6	2	78.99	1.1	0.9
8	puna ii	13.8	6	2	77.73	1.1	0.9
9	mangdechu	13.8	6	2	80.28	1.1	0.9
10	nikachu	11	6	2	82.8	1.1	0.9
11	kholongchu	13.8	6	2	80.35	1.1	0.9
12	nyera-i	11	6	2	73.5	1.1	0.9
13	nyera-ii	13.8	6	2	74.09	1.1	0.9
14	sankosh lb	15.5	6	2	74.42	1.1	0.9
15	sankosh rb	15.5	6	2	74.3	1.1	0.9
16	s.regulating	11	6	2	76.26	1.1	0.9
17	wangchu	13.8	6	2	63.24	1.1	0.9
18	dorjilung	13.8	6	2	79.37	1.1	0.9
20	kurigongri	13.8	6	2	82.18	1.1	0.9
21	bunakha	11	6	2	62.27	1.1	0.9
22	chmkhr-i	13.8	6	2	79.64	1.1	0.9
26	gongri	13.8	6	2	82.78	1.1	0.9
27	khomachu	11	6	2	96.87	1.1	0.9
28	ch-iv	11	6	2	86.7	1.1	0.9
29	ch-ii	13.8	6	2	79.67	1.1	0.9
30	panbang	13.8	6	2	89.88	1.1	0.9
101	kurichhu	132	6	1	69.51	1.1	0.9
102	kilikhar	132	6	1	69.48	1.1	0.9
103	kanglung	132	6	1	69.66	1.1	0.9
104	nangkor	132	6	1	67.13	1.1	0.9
105	nganglam	132	6	1	67.32	1.1	0.9
106	deothang	132	6	1	65.3	1.1	0.9
107	motanga	132	6	1	65.14	1.1	0.9
108	gelephu	132	6	1	64.51	1.1	0.9
109	tingtibi	132	6	1	71.6	1.1	0.9
110	yurmo	132	6	1	74.59	1.1	0.9
111	jigmeling	132	6	1	67.15	1.1	0.9
112	mangdechu	132	6	1	74.85	1.1	0.9
113	nikachhu	132	6	1	76.23	1.1	0.9
114	corlung	132	6	1	70.38	1.1	0.9
115	pthang	132	6	1	67.35	1.1	0.9
116	nyera-i	132	6	1	67.71	1.1	0.9
117	chmkhr-i	132	6	1	71.82	1.1	0.9
118	yangbari	132	6	1	68.73	1.1	0.9
201	chhukha	220	6	1	55.49	1.1	0.9
202	malbase	220	6	1	53.87	1.1	0.9

203	semtokha	220	6	1	58.6	1.1	0.9
204	baso-ls	220	6	1	65.54	1.1	0.9
205	tsirang	220	6	1	68.07	1.1	0.9
206	jigmeling	220	6	1	68.12	1.1	0.9
207	dagachu	220	6	1	69.1	1.1	0.9
208	singhigaon	220	6	1	53.72	1.1	0.9
209	samtse	220	6	1	52.81	1.1	0.9
210	puna i	220	6	1	66.27	1.1	0.9
211	bunakha	220	6	1	55.73	1.1	0.9
212	sankosh rb	220	6	1	69.35	1.1	0.9
213	sankosh lb	220	6	1	69.46	1.1	0.9
214	amochu ls	220	6	1	53.74	1.1	0.9
215	s.regulating	220	6	1	69.68	1.1	0.9
216	dagapela	220	6	1	69.06	1.1	0.9
217	chumdo	220	6	1	56.95	1.1	0.9
219	khomachu	220	6	1	87.09	1.1	0.9
220	dorjilung	220	6	1	82.93	1.1	0.9
221	ch-iv	220	6	1	80.19	1.1	0.9
222	ch-ii	220	6	1	77.53	1.1	0.9
401	tala	400	6	1	56.26	1.1	0.9
402	malbase	400	6	1	55.03	1.1	0.9
403	kholongchu	400	6	1	73.51	1.1	0.9
404	mangdechu	400	6	1	73.35	1.1	0.9
405	puna i	400	6	1	71.24	1.1	0.9
406	puna ii	400	6	1	71.15	1.1	0.9
407	jigmeling	400	6	1	70.52	1.1	0.9
408	goling	400	6	1	72.53	1.1	0.9
409	lhamozing	400	6	1	65.77	1.1	0.9
410	yangbari	400	6	1	71.53	1.1	0.9
411	dorjilung	400	6	1	73.1	1.1	0.9
412	wangchu	400	6	1	56.62	1.1	0.9
413	nyera-ii	400	6	1	67.92	1.1	0.9
414	pthang	400	6	1	67.84	1.1	0.9
415	kurigongri	400	6	1	75.18	1.1	0.9
416	chmkhr-i	400	6	1	72.72	1.1	0.9
418	sankosh lb	400	6	1	67.24	1.1	0.9
419	sankosh rb	400	6	1	67.13	1.1	0.9
420	gongri	400	6	1	76.23	1.1	0.9
421	ch-ii	400	6	1	73.11	1.1	0.9
422	panbang	400	6	1	71.8	1.1	0.9
601	chhukha	66	6	1	51.48	1.1	0.9
602	watsa-tap	66	6	1	51.42	1.1	0.9
603	watsa	66	6	1	51.41	1.1	0.9
604	chumdo	66	6	1	51.63	1.1	0.9
605	paro	66	6	1	49.33	1.1	0.9
606	haa	66	6	1	49.7	1.1	0.9
607	gedu	66	6	1	49.31	1.1	0.9
608	jemina	66	6	1	49.43	1.1	0.9
609	olakha	66	6	1	50.37	1.1	0.9
610	semtokha	66	6	1	50.86	1.1	0.9
611	d-choling	66	6	1	48.17	1.1	0.9
612	lobeysa	66	6	1	52.96	1.1	0.9

613	gaywathang	66	6	1	59.29	1.1	0.9
614	baso-ls	66	6	1	59.7	1.1	0.9
615	baso-us	66	6	1	60.06	1.1	0.9
616	tsirang	66	6	1	62.58	1.1	0.9
617	p-ling	66	6	1	48.05	1.1	0.9
618	malbase	66	6	1	47.69	1.1	0.9
619	gomtu	66	6	1	49.35	1.1	0.9
620	samtse	66	6	1	50.59	1.1	0.9
621	singhigaon	66	6	1	45.95	1.1	0.9
622	gelephu	66	6	1	57.21	1.1	0.9
623	khasadrapchu	66	6	1	50.3	1.1	0.9
624	sibso	66	6	1	50.24	1.1	0.9

B. Generators data.

Bus No	Bus Name	Area Num	Code	PGen (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
1	kurichu 11.000	6	2	60	17.2	50	-43.3
2	chhukha 11.000	6	2	336	87.6	280	-242.6
3	baso-us 11.000	6	2	24	9.2	24	-12
4	tala 13.800	6	2	1020	165.6	906.7	-680
5	baso-ls 11.000	6	2	40	15.5	32.5	-27.5
6	dagachu 11.000	6	2	126	39.3	112	-84
7	puna i 13.800	6	2	1200	233.2	633.6	-316.8
8	puna ii 13.800	6	2	1020	212.1	538.6	-269.3
9	mangdechu 13.800	6	2	720	107.8	380.2	-190.1
10	nikachu 11.000	6	2	118	6.6	62.3	-31.2
11	kholongchu 13.800	6	2	600	63.8	316.8	-158.4
12	nyera-i 11.000	6	2	112	17.4	66	-33
13	nyera-ii 13.800	6	2	291.9	10	167.3	-83.6
14	sankosh lb 15.500	6	2	1250	331.8	660	-330
15	sankosh rb 15.500	6	2	1250	322.7	660	-330
16	s.regulating11.000	6	2	84.9	19.4	44.8	-22.4
17	wangchu 13.800	6	2	570	91.3	301	-150.5
18	dorjilung 13.800	6	2	1125	98	594	-297
20	kurigongri 13.800	6	2	2640	210.7	1393.9	-697
21	bunakha 11.000	6	2	180	52.1	95	-47.5
22	chmkhr-i 13.800	6	2	770	87.9	406.6	-203.3
26	gongri 13.800	6	2	652	39.7	344.3	-172.1
27	khomachu 11.000	6	2	363	63.3	191.7	-95.8
28	ch-iv 11.000	6	2	364	43	192.2	-96.1
29	ch-ii 13.800	6	2	590	88.8	311.5	-155.8
30	panbang 13.800	6	2	1100	201.5	580.8	-290.4

C. Load data

Bus Number	Bus Name	Code	Area Num	Pload (MW)	Qload (Mvar)
1	kurichu 11.000	2	6	0.3	0
2	chhukha 11.000	2	6	2	0
3	baso-us 11.000	2	6	.12	0

4	tala 13.800	2	6	5	0
5	baso-ls 11.000	2	6	.2	0
6	dagachu 11.000	2	6	1	0
7	puna i 13.800	2	6	6	0
8	puna ii 13.800	2	6	5	0
9	mangdechu 13.800	2	6	4	0
10	nikachu 11.000	2	6	1	0
11	kholongchu 13.800	2	6	3	0
12	nyera-i 11.000	2	6	1	0
13	nyera-ii 13.800	2	6	1	0
14	sankosh lb 15.500	2	6	6	0
15	sankosh rb 15.500	2	6	6	0
16	s.regulating11.000	2	6	0	0
17	wangchu 13.800	2	6	3	0
18	dorjilung 13.800	2	6	6	0
20	kurigongri 13.800	2	6	13	0
21	bunakha 11.000	2	6	1	0
22	chmkhr-i 13.800	2	6	4	0
26	gongri 13.800	2	6	2	0
27	khomachu 11.000	2	6	2	0
28	ch-iv 11.000	2	6	2	0
29	ch-ii 13.800	2	6	3	0
102	kilikhar 132.00	1	6	26	12
103	kanglung 132.00	1	6	39	19
104	nangkor 132.00	1	6	4	2
105	nganglam 132.00	1	6	33	16
106	deothang 132.00	1	6	56	27
107	motanga 132.00	1	6	148	72
109	tingtibi 132.00	1	6	3	1
110	yurmo 132.00	1	6	10	5
206	jigmeling 220.00	1	6	181	88
209	samtse 220.00	1	6	63	31
313	chubachu 33.000	1	6	10	5
603	watsa 66.000	1	6	3	2
605	paro 66.000	1	6	24	12
606	haa 66.000	1	6	7	3
607	gedu 66.000	1	6	7	3
608	jemina 66.000	1	6	22	11
609	olakha 66.000	1	6	85	41
609	olakha 66.000	1	6	10	5
610	semtokha 66.000	1	6	41	20
611	d-choling 66.000	1	6	24	12
612	lobeysa 66.000	1	6	40	19
616	tsirang 66.000	1	6	21	10
617	p-ling 66.000	1	6	18	9
618	malbase 66.000	1	6	141	68
619	gomtu 66.000	1	6	27	13
621	singhigaon 66.000	1	6	73	36
622	gelephu 66.000	1	6	54	26

D. Shunt Data.

Bus Number	Bus Name	Area Num	Code	B-Shunt (Mvar)
101	kurichhu 132.00	6	1	-5
101	kurichhu 132.00	6	1	-5
401	tala 400.00	6	1	-63
403	kholongchu 400.00	6	1	-80
404	mangdechu 400.00	6	1	-80
405	puna i 400.00	6	1	-80
406	puna ii 400.00	6	1	-80
407	jigmeling 400.00	6	1	-80
407	jigmeling 400.00	6	1	-80
408	goling 400.00	6	1	-80
408	goling 400.00	6	1	-80
410	yangbari 400.00	6	1	-80
410	yangbari 400.00	6	1	-80
412	wangchu 400.00	6	1	-63
418	sankosh lb 400.00	6	1	-80
419	sankosh rb 400.00	6	1	-80

E. Transmission lines data.

From Bus Name	To Bus Name	Line R (pu)	Line X (pu)	Charging B (pu)	Rate A	Rate B	(km)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)
kurichhu	kilikhar	0.009	0.022	0.005	50	95	10	0.023	0.094	0.004
kurichhu	nangkor	0.029	0.069	0.016	50	95	31	0.072	0.289	0.011
kilikhar	corlung	0.032	0.077	0.018	50	95	35	0.012	0.047	0.002
kanglung	corlung	0.003	0.019	0.032	50	95	23	0.010	0.063	0.020
kanglung	pthang	0.054	0.129	0.030	50	112	58	0.135	0.540	0.020
kanglung	pthang	0.054	0.129	0.030	50	112	58	0.135	0.540	0.020
nangkor	nganglam	0.032	0.075	0.017	50	95	34	0.079	0.315	0.012
nangkor	deothang	0.022	0.052	0.012	50	95	23	0.054	0.217	0.008
nganglam	motanga	0.032	0.077	0.018	50	112	35	0.081	0.323	0.012
nganglam	motanga	0.032	0.077	0.018	50	112	35	0.081	0.323	0.012
nganglam	chmkhr-i	0.059	0.140	0.032	50	95	63	0.147	0.590	0.022
nganglam	yangbari	0.028	0.067	0.015	50	112	30	0.070	0.279	0.011
nganglam	yangbari	0.028	0.067	0.015	50	112	30	0.070	0.279	0.011
deothang	motanga	0.010	0.023	0.005	50	95	11	0.024	0.098	0.004
motanga	pthang	0.021	0.049	0.011	50	112	22	0.051	0.205	0.008
motanga	pthang	0.021	0.049	0.011	50	112	22	0.051	0.205	0.008
motanga	rangia1	0.043	0.102	0.023	50	95	46	0.107	0.427	0.016
gelephu	jigmeling	0.020	0.047	0.011	50	95	21	0.049	0.197	0.007
gelephu	salakati1	0.047	0.111	0.026	50	95	50	0.116	0.466	0.018
tingtibi	yurmo	0.030	0.072	0.017	50	95	33	0.076	0.304	0.012
tingtibi	jigmeling	0.043	0.101	0.023	50	95	46	0.106	0.426	0.016
tingtibi	chmkhr-i	0.028	0.067	0.015	50	95	30	0.070	0.279	0.011
yurmo	mangdechu	0.005	0.011	0.003	50	112	5	0.012	0.047	0.002
yurmo	mangdechu	0.005	0.011	0.003	50	112	5	0.012	0.047	0.002
mangdechu	nikachhu	0.017	0.040	0.009	50	112	10	0.042	0.168	0.006
mangdechu	nikachhu	0.017	0.040	0.009	50	112	10	0.042	0.168	0.006
pthang	nyera-i	0.005	0.011	0.003	50	112	5	0.012	0.047	0.002
pthang	nyera-i	0.005	0.011	0.003	50	112	5	0.012	0.047	0.002
chhukha	malbase	0.004	0.025	0.042	132	236	30	0.013	0.082	0.026

chhukha	bunakha	0.002	0.012	0.021	132	236	15	0.006	0.041	0.013
chhukha	birpara-pg	0.010	0.058	0.099	132	236	70	0.030	0.194	0.062
chhukha	birpara-pg	0.010	0.058	0.099	132	236	70	0.030	0.194	0.062
malbase	singhigaon	0.000	0.002	0.004	132	236	3	0.001	0.007	0.002
malbase	bunakha	0.004	0.025	0.042	132	236	30	0.013	0.083	0.027
malbase	bunakha	0.004	0.025	0.042	132	236	30	0.013	0.083	0.027
malbase	amochu ls	0.001	0.004	0.007	132	236	5	0.002	0.014	0.004
malbase	birpara-pg	0.006	0.034	0.058	132	236	41	0.017	0.112	0.036
semtokha	baso-ls	0.006	0.037	0.063	132	236	45	0.019	0.124	0.040
semtokha	chumdo	0.002	0.014	0.024	132	236	17	0.007	0.047	0.015
baso-ls	puna i	0.001	0.004	0.007	132	236	5	0.002	0.014	0.004
tsirang	jigmeling	0.004	0.025	0.043	132	236	31	0.013	0.084	0.027
tsirang	dagachu	0.003	0.017	0.029	132	236	20	0.009	0.056	0.018
tsirang	puna i	0.006	0.034	0.059	132	236	42	0.018	0.115	0.037
jigmeling	dagapela	0.007	0.041	0.071	132	236	50	0.021	0.138	0.044
dagachu	dagapela	0.001	0.004	0.007	132	236	5	0.002	0.014	0.004
singhigaon	samtse	0.006	0.033	0.057	132	236	41	0.017	0.112	0.036
samtse	amochu ls	0.005	0.029	0.049	132	236	35	0.015	0.097	0.031
bunakha	chumdo	0.003	0.018	0.031	132	236	22	0.009	0.061	0.020
sankosh rb	s.regulating	0.002	0.011	0.018	132	286	13	0.006	0.036	0.012
sankosh rb	dagapela	0.004	0.023	0.040	132	286	28	0.012	0.077	0.025
sankosh lb	s.regulating	0.002	0.012	0.021	132	286	13	0.006	0.036	0.012
khomachu	dorjilung	0.007	0.039	0.066	132	286	47	0.020	0.130	0.042
khomachu	dorjilung	0.007	0.039	0.066	132	286	47	0.020	0.130	0.042
ch-iv	ch-ii	0.004	0.025	0.043	132	286	30	0.013	0.084	0.027
ch-iv	ch-ii	0.004	0.025	0.043	132	286	30	0.013	0.084	0.027
tala	malbase	0.000	0.005	0.145	515	970	24	0.004	0.016	0.088
tala	wangchu	0.000	0.003	0.108	515	970	18	0.003	0.012	0.066
tala	siliguri-pg	0.003	0.031	0.830	515	970	150	0.025	0.100	0.549
tala	siliguri-pg	0.003	0.031	0.830	515	970	150	0.025	0.100	0.549
malbase	siliguri-pg	0.002	0.024	0.753	515	970	125	0.021	0.084	0.459
kholongchu	yangbari	0.001	0.013	0.420	515	1178	70	0.011	0.046	0.251
kholongchu	yangbari	0.001	0.013	0.411	515	1178	68	0.011	0.046	0.251
mangdechu	goling	0.001	0.007	0.227	515	1178	38	0.006	0.025	0.138
mangdechu	goling	0.001	0.007	0.227	515	1178	38	0.006	0.025	0.138
mangdechu	goling	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
mangdechu	goling	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
puna i	puna ii	0.000	0.003	0.078	515	1178	13	0.002	0.009	0.048
puna i	puna ii	0.000	0.003	0.078	515	1178	13	0.002	0.009	0.048
puna i	sankosh rb	0.001	0.016	0.499	515	1178	83	0.014	0.056	0.304
puna i	sankosh rb	0.001	0.016	0.499	515	1178	83	0.014	0.056	0.304
puna ii	jigmeling	0.001	0.013	0.391	515	1178	65	0.011	0.044	0.238
puna ii	jigmeling	0.001	0.013	0.391	515	1178	65	0.011	0.044	0.238
puna ii	sankosh lb	0.001	0.014	0.424	515	1178	71	0.012	0.047	0.259
puna ii	sankosh lb	0.001	0.014	0.424	515	1178	71	0.012	0.047	0.259
jigmeling	goling	0.001	0.009	0.285	515	1178	47	0.008	0.032	0.174
jigmeling	goling	0.001	0.009	0.281	515	1178	47	0.008	0.032	0.174
jigmeling	goling	0.001	0.009	0.285	515	1178	47	0.008	0.031	0.171
jigmeling	goling	0.001	0.009	0.281	515	1178	47	0.008	0.031	0.171
jigmeling	alipurdu	0.002	0.026	1.220	614	2356	167	0.026	0.104	0.705
jigmeling	alipurdu	0.002	0.026	1.220	614	2356	167	0.026	0.104	0.705
goling	yangbari	0.001	0.012	0.361	515	1178	60	0.010	0.040	0.220

goling	yangbari	0.001	0.012	0.361	515	1178	60	0.010	0.040	0.220
goling	chmkhr-i	0.001	0.007	0.211	515	1178	35	0.006	0.024	0.128
goling	chmkhr-i	0.001	0.007	0.211	515	1178	35	0.006	0.024	0.128
goling	ch-ii	0.000	0.002	0.056	515	1178	10	0.002	0.007	0.037
goling	ch-ii	0.000	0.002	0.056	515	1178	10	0.002	0.007	0.037
lhamozing	sankosh lb	0.000	0.004	0.120	547	2356	20	0.003	0.013	0.073
lhamozing	sankosh lb	0.000	0.004	0.120	547	1178	20	0.003	0.013	0.073
lhamozing	sankosh rb	0.000	0.004	0.120	547	1178	20	0.003	0.013	0.073
lhamozing	sankosh rb	0.000	0.004	0.120	547	1178	20	0.003	0.013	0.073
lhamozing	alipurdu	0.001	0.010	0.469	614	2356	64	0.010	0.040	0.270
lhamozing	alipurdu	0.001	0.010	0.469	614	2356	64	0.010	0.040	0.270
yangbari	dorjilung	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
yangbari	dorjilung	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
yangbari	dorjilung	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
yangbari	dorjilung	0.001	0.007	0.229	515	1178	38	0.006	0.026	0.139
yangbari	kurigongri	0.001	0.008	0.241	515	1178	40	0.007	0.027	0.147
yangbari	kurigongri	0.001	0.008	0.241	515	1178	40	0.007	0.027	0.147
yangbari	kurigongri	0.001	0.008	0.241	515	1178	40	0.007	0.027	0.147
yangbari	kurigongri	0.001	0.008	0.241	515	1178	40	0.007	0.027	0.147
yangbari	chmkhr-i	0.001	0.007	0.211	515	1178	35	0.006	0.024	0.128
yangbari	chmkhr-i	0.001	0.007	0.211	515	1178	35	0.006	0.024	0.128
yangbari	panbang	0.000	0.003	0.147	614	2356	20	0.003	0.013	0.084
yangbari	rangia	0.000	0.006	0.293	614	2356	40	0.006	0.025	0.169
yangbari	rangia	0.000	0.006	0.293	614	2356	40	0.006	0.025	0.169
yangbari	rangia	0.000	0.006	0.293	614	2356	40	0.006	0.025	0.169
yangbari	rangia	0.000	0.006	0.293	614	2356	40	0.006	0.025	0.169
yangbari	rangia	0.000	0.006	0.293	614	2356	40	0.006	0.025	0.169
wangchu	siliguri-pg	0.003	0.031	0.957	515	970	159	0.027	0.107	0.583
nyera-ii	pthang	0.000	0.001	0.030	515	1178	5	0.001	0.003	0.018
nyera-ii	pthang	0.000	0.001	0.030	515	1178	5	0.001	0.003	0.018
pthang	rangia	0.001	0.012	0.361	515	1178	60	0.010	0.040	0.220
pthang	rangia	0.001	0.012	0.361	515	1178	60	0.010	0.040	0.220
kurigongri	gongri	0.001	0.006	0.150	515	1178	27	0.005	0.018	0.099
kurigongri	gongri	0.001	0.006	0.150	515	1178	27	0.005	0.018	0.099
sankosh lb	alipurdu	0.001	0.015	0.476	614	2356	79	0.013	0.053	0.290
sankosh rb	alipurdu	0.001	0.015	0.476	614	2356	79	0.013	0.053	0.290
panbang	rangia	0.001	0.009	0.403	614	2356	55	0.009	0.034	0.232
chhukha	watsa-tap	0.082	0.194	0.003	10	31	22	0.204	0.815	0.002
chhukha	gedu	0.076	0.181	0.003	10	31	20	0.190	0.760	0.002
watsa-tap	watsa	0.002	0.004	0.000	10	31	1	0.005	0.019	0.000
watsa-tap	chumdo	0.056	0.134	0.002	10	31	15	0.141	0.562	0.001
chumdo	paro	0.089	0.213	0.003	10	31	24	0.224	0.894	0.002
chumdo	haa	0.124	0.296	0.004	10	31	33	0.311	1.240	0.003
chumdo	khasadrapchu	0.018	0.042	0.001	10	31	5	0.045	0.178	0.000
paro	haa	0.056	0.133	0.002	10	31	15	0.140	0.559	0.001
gedu	p-ling	0.062	0.148	0.002	10	31	17	0.156	0.622	0.001
jemina	khasadrapchu	0.022	0.053	0.001	10	31	6	0.056	0.222	0.001
jemina	khasadrapchu	0.022	0.053	0.001	10	31	6	0.056	0.222	0.001
olakha	semtokha	0.006	0.015	0.000	10	31	2	0.016	0.063	0.000
olakha	khasadrapchu	0.044	0.104	0.002	10	31	12	0.109	0.437	0.001
semtokha	d-choling	0.043	0.101	0.001	10	31	11	0.107	0.426	0.001
semtokha	lobeysa	0.091	0.217	0.003	10	31	24	0.227	0.910	0.002

lobeysa	gaywathang	0.081	0.193	0.003	10	31	22	0.203	0.812	0.002
gaywathang	baso-ls	0.006	0.013	0.000	10	31	2	0.014	0.056	0.000
baso-ls	baso-us	0.012	0.027	0.000	10	31	3	0.029	0.115	0.000
p-ling	malbase	0.034	0.080	0.001	10	31	9	0.084	0.335	0.001
p-ling	gomtu	0.100	0.238	0.003	10	31	27	0.250	1.000	0.002
gomtu	samtse	0.055	0.132	0.002	10	31	15	0.138	0.553	0.001
gomtu	samtse	0.055	0.132	0.002	10	31	15	0.138	0.553	0.001
samtse	sibso	0.100	0.239	0.003	10	31	27	0.251	1.000	0.002
samtse	sibso	0.100	0.239	0.239	10	31	27	0.251	1.000	0.002

F. Transformers Details.

From Bus Name	To Bus Name	Specified R (pu)	Specified X (pu)	Rate A	Rate B	Vector
kurichu 11.000	kurichhu 132.00	0.0281	0.6184	20	20	Dyn1
kurichu 11.000	kurichhu 132.00	0.0281	0.6184	20	20	Dyn1
kurichu 11.000	kurichhu 132.00	0.0281	0.6184	20	20	Dyn1
kurichu 11.000	kurichhu 132.00	0.0281	0.6184	20	20	Dyn1
chhukha 11.000	chhukha 220.00	0.0031	0.1142	105	105	Dyn1
chhukha 11.000	chhukha 220.00	0.0031	0.1142	105	105	Dyn1
chhukha 11.000	chhukha 220.00	0.0031	0.1142	105	105	Dyn1
chhukha 11.000	chhukha 220.00	0.0031	0.1142	105	105	Dyn1
baso-us 11.000	baso-us 66.000	0.0481	0.8653	15	15	Dyn1
baso-us 11.000	baso-us 66.000	0.0481	0.8653	15	15	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
tala 13.800	tala 400.00	0.0015	0.0686	210	210	Dyn1
baso-ls 11.000	baso-ls 220.00	0.0173	0.433	30	30	Dyn1
baso-ls 11.000	baso-ls 220.00	0.0173	0.433	30	30	Dyn1
dagachu 11.000	dagachu 220.00	0.005	0.12	72	72	Dyn1
dagachu 11.000	dagachu 220.00	0.005	0.12	72	72	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna i 13.800	puna i 400.00	0.0014	0.0667	225	225	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
puna ii 13.800	puna ii 400.00	0.0015	0.0667	210	210	Dyn1
mangdechu 13.800	mangdechu 400.00	0.0013	0.0667	225	225	Dyn1
mangdechu 13.800	mangdechu 400.00	0.0013	0.0667	225	225	Dyn1
mangdechu 13.800	mangdechu 400.00	0.0013	0.0667	225	225	Dyn1
mangdechu 13.800	mangdechu 400.00	0.0013	0.0667	225	225	Dyn1
nikachu 11.000	nikachhu 132.00	0.0059	0.1944	72	72	Dyn1
nikachu 11.000	nikachhu 132.00	0.0059	0.1944	72	72	Dyn1

kholongchu 13.800	kholongchu 400.00	0.0018	0.0793	189	189	Dyn1
kholongchu 13.800	kholongchu 400.00	0.0018	0.0793	189	189	Dyn1
kholongchu 13.800	kholongchu 400.00	0.0018	0.0793	189	189	Dyn1
kholongchu 13.800	kholongchu 400.00	0.0018	0.0793	189	189	Dyn1
nyera-i 11.000	nyera-i 132.00	0.0051	0.1794	78	78	Dyn1
nyera-i 11.000	nyera-i 132.00	0.0051	0.1794	78	78	Dyn1
nyera-ii 13.800	nyera-ii 400.00	0.0028	0.1111	135	135	Dyn1
nyera-ii 13.800	nyera-ii 400.00	0.0028	0.1111	135	135	Dyn1
nyera-ii 13.800	nyera-ii 400.00	0.0028	0.1111	135	135	Dyn1
sankosh lb 15.500	sankosh lb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh lb 15.500	sankosh lb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh lb 15.500	sankosh lb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh lb 15.500	sankosh lb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh rb 15.500	sankosh rb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh rb 15.500	sankosh rb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh rb 15.500	sankosh rb 400.00	0.0008	0.0393	382	382	Dyn1
sankosh rb 15.500	sankosh rb 400.00	0.0008	0.0393	382	382	Dyn1
s.regulating11.000	s.regulating220.00	0.0032	0.3996	35	35	Dyn1
s.regulating11.000	s.regulating220.00	0.0032	0.3996	35	35	Dyn1
s.regulating11.000	s.regulating220.00	0.0032	0.3996	35	35	Dyn1
wangchu 13.800	wangchu 400.00	0.0018	0.0804	174	174	Dyn1
wangchu 13.800	wangchu 400.00	0.0018	0.0804	174	174	Dyn1
wangchu 13.800	wangchu 400.00	0.0018	0.0804	174	174	Dyn1
wangchu 13.800	wangchu 400.00	0.0018	0.0804	174	174	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
dorjilung 13.800	dorjilung 400.00	0.0012	0.0583	240	240	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
kurigongri 13.800	kurigongri 400.00	0.0007	0.037	405	405	Dyn1
bunakha 11.000	bunakha 220.00	0.0053	0.1866	75	75	Dyn1
bunakha 11.000	bunakha 220.00	0.0053	0.1866	75	75	Dyn1
bunakha 11.000	bunakha 220.00	0.0053	0.1866	75	75	Dyn1
chmkhr-i 13.800	chmkhr-i 400.00	0.0013	0.0625	240	240	Dyn1
chmkhr-i 13.800	chmkhr-i 400.00	0.0013	0.0625	240	240	Dyn1
chmkhr-i 13.800	chmkhr-i 400.00	0.0013	0.0625	240	240	Dyn1
chmkhr-i 13.800	chmkhr-i 400.00	0.0013	0.0625	240	240	Dyn1
gongri 13.800	gongri 400.00	0.002	0.07	200	200	Dyn1
gongri 13.800	gongri 400.00	0.002	0.07	200	200	Dyn1
gongri 13.800	gongri 400.00	0.002	0.07	200	200	Dyn1
gongri 13.800	gongri 400.00	0.002	0.07	200	200	Dyn1
khomachu 11.000	khomachu 220.00	0.0001	0.139	150	150	Dyn1
khomachu 11.000	khomachu 220.00	0.0001	0.139	150	150	Dyn1
khomachu 11.000	khomachu 220.00	0.0001	0.139	150	150	Dyn1

ch-iv	11.000	ch-iv	220.00	0.0033	0.1244	112	112	Dyn1
ch-iv	11.000	ch-iv	220.00	0.0033	0.1244	112	112	Dyn1
ch-iv	11.000	ch-iv	220.00	0.0033	0.1244	112	112	Dyn1
ch-iv	11.000	ch-iv	220.00	0.0033	0.1244	112	112	Dyn1
ch-ii	13.800	ch-ii	400.00	0.0018	0.0771	182	182	Dyn1
ch-ii	13.800	ch-ii	400.00	0.0018	0.0771	182	182	Dyn1
ch-ii	13.800	ch-ii	400.00	0.0018	0.0771	182	182	Dyn1
ch-ii	13.800	ch-ii	400.00	0.0018	0.0771	182	182	Dyn1
panbang	13.800	panbang	400.00	0.0001	0.14	270	270	Dyn1
panbang	13.800	panbang	400.00	0.0001	0.14	270	270	Dyn1
panbang	13.800	panbang	400.00	0.0001	0.14	270	270	Dyn1
panbang	13.800	panbang	400.00	0.0001	0.14	270	270	Dyn1
panbang	13.800	panbang	400.00	0.0001	0.14	270	270	Dyn1
gelephu	132.00	gelephu	66.000	0.0171	0.3928	25	25	YNd1
gelephu	132.00	gelephu	66.000	0.0171	0.3928	25	25	YNa0
jigmeling	132.00	jigmeling	220.00	0.0049	0.1565	80	80	YNa0
jigmeling	132.00	jigmeling	220.00	0.0049	0.1565	80	80	YNa0
mangdechu	132.00	mangdechu	400.00	0.0058	0.1865	67	67	YNa0
mangdechu	132.00	mangdechu	400.00	0.0058	0.1865	67	67	YNa0
mangdechu	132.00	mangdechu	400.00	0.0058	0.1865	67	67	YNa0
corlung	132.00	kholongchu	400.00	0.0058	0.1865	67	67	YNa0
corlung	132.00	kholongchu	400.00	0.0058	0.1865	67	67	YNa0
corlung	132.00	kholongchu	400.00	0.0058	0.1865	67	67	YNa0
pthang	132.00	pthang	400.00	0.0058	0.0838	67	67	YNa0
pthang	132.00	pthang	400.00	0.0058	0.0838	67	67	YNa0
pthang	132.00	pthang	400.00	0.0058	0.0838	67	67	YNa0
chmkhr-i	132.00	chmkhr-i	400.00	0.0058	0.07485	67	67	YNa0
chmkhr-i	132.00	chmkhr-i	400.00	0.0058	0.07485	67	67	YNa0
chmkhr-i	132.00	chmkhr-i	400.00	0.0058	0.07485	67	67	YNa0
yangbari	132.00	yangbari	400.00	0.0058	0.186567	67	67	YNa0
yangbari	132.00	yangbari	400.00	0.0058	0.186567	67	67	YNa0
yangbari	132.00	yangbari	400.00	0.0058	0.186567	67	67	YNa0
chhukha	220.00	chhukha	66.000	0.0267	0.5864	20	20	YNy0
chhukha	220.00	chhukha	66.000	0.0267	0.5864	20	20	YNy0
malbase	220.00	malbase	400.00	0.0013	0.0599	200	200	YNd11
malbase	220.00	malbase	400.00	0.0058	0.186567	67	67	YNa0
malbase	220.00	malbase	400.00	0.0058	0.186567	67	67	YNyn0
malbase	220.00	malbase	400.00	0.0058	0.186567	67	67	YNyn0
malbase	220.00	malbase	66.000	0.0066	0.1983	63	63	YNyn0
malbase	220.00	malbase	66.000	0.0066	0.1983	63	63	YNyn0
malbase	220.00	malbase	66.000	0.0083	0.2499	50	63	YNyn0
semtokha	220.00	semtokha	66.000	0.0061	0.1961	50	63	YNyn0
semtokha	220.00	semtokha	66.000	0.0061	0.1961	50	63	YNyn0
baso-ls	220.00	baso-ls	66.000	0.0133	0.3331	30	30	YNyn0
tsirang	220.00	tsirang	66.000	0.053	0.8473	10	10	YNyn0
tsirang	220.00	tsirang	66.000	0.053	0.8473	10	10	YNyn0
jigmeling	220.00	jigmeling	400.00	0.0017	0.0748	167	167	YNyn0
jigmeling	220.00	jigmeling	400.00	0.0017	0.0748	167	167	YNyn0
jigmeling	220.00	jigmeling	400.00	0.0017	0.0748	167	167	YNyn0
singhigaon	220.00	singhigaon	66.000	0.01	0.2996	50	50	YNyn0
singhigaon	220.00	singhigaon	66.000	0.0165	0.3794	35	35	YNyn0
samtse	220.00	samtse	66.000	0.0061	0.1951	50	63	YNyn0

samtse	220.00	samtse	66.000	0.0061	0.1951	50	63	YNyn0
puna i	220.00	puna i	400.00	0.0032	0.119	105	105	YNa0
puna i	220.00	puna i	400.00	0.0032	0.119	105	105	YNa0
puna i	220.00	puna i	400.00	0.0032	0.119	105	105	YNa0
sankosh rb	220.00	sankosh rb	400.00	0.0032	0.119	104	104	YNa0
sankosh lb	220.00	sankosh lb	400.00	0.0032	0.119	104	104	YNa0
chumdo	220.00	chumdo	66.000	0.0062	0.1983	63	63	YNa0
chumdo	220.00	chumdo	66.000	0.0062	0.1983	63	63	YNa0
dorjilung	220.00	dorjilung	400.00	0.001	0.139	150	150	YNa0
dorjilung	220.00	dorjilung	400.00	0.001	0.139	150	150	YNa0
dorjilung	220.00	dorjilung	400.00	0.001	0.139	150	150	YNa0
ch-ii	220.00	ch-ii	400.00	0.001	0.0625	200	200	YNa0
ch-ii	220.00	ch-ii	400.00	0.001	0.0625	200	200	YNa0
ch-ii	220.00	ch-ii	400.00	0.001	0.0625	200	200	YNa0

Tentative Cost Estimate for updated NTGMP for 2035 Scenario

Annexure XIII

Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
1	**Sankosh HEP - (2500+85) MW**							
i	Loop-in of the 400 kV PHPA II - Lhamoizingkha (Bhutan border) line at SLBPH	400	Twin Moose D/C	5	4.90			75.66
ii	As per DPR - Loop-out of 400 kV PHPA-II - Lhamoizingkha line with 400 kV S/C Quad Moose line from SLBPH (S/C Quad line would be about 0.02 km length and after which it would become a part of 400 kV D/C Quad line for about 5 km and then merge with PHPA-II - Lhamoizingkha 400 kV D/C Twin Moose line)	400	Quad Moose S/C	5.02	5.95			43.19
iii	Loop-in of the 400 kV PHPA I - Lhamoizingkha (Bhutan border) line at SRBPH	400	Twin moose D/C	5	4.90			75.66
iv	Loop-out of 400 kV PHPA-I - Lhamoizingkha line with 400 kV S/C Quad Moose line from SRBPH (S/C Quad line would be about 0.02 km length and after which it would become a part of 400 kV D/C Quad line for about 5 km and then merge with PHPA-I - Lhamoizingkha 400 kV D/C Twin Moose line)	400	Quad Moose S/C	5.02	5.95			43.19
v	Two 400 kV S/C Quad Moose lines, one each from SLBPH & SRBPH (which is about 0.02km in length) would merge to form 400 kV D/C Quad Moose line upto Alipurduar.	400	Quad Moose S/C (upto Bhutan Border)	15.04	5.95			116.20
vi	2x80 MVAr 420 kV Bus reactor one each at SLBPH & SRBPH (with 2 nos. 400 kV reactor bays)	420	80 MVAr	2	5.04			36.72
vii	2x104 MVA, 400/220 kV ICT, one each at SLBPH & SRBPH (with 2 nos. 400 kV GIS Bay + 2 nos. 220 kV GIS bay)	400/220	200	2	7.32			56.88
viii	220 kV Regulating Dam - SLBPH (with with one no. 220 kV GIS bay each at Regulating Dam & SLBPH)	220	Zebra S/C	13	1.49			34.97
ix	220 kV Regulating Dam - SRBPH (with with one no. 220 kV GIS bay each at Regulating Dam & SLBPH)	220	Zebra S/C	13	1.49			34.97
	Total for Sankosh							**517.45**

Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
2	**Chamkharchhu-I HEP - 770 MW**							
i	*400kV Yangbari - Goling 1xD/C line out of 2xD/C line (with 2 nos. of 400kV GIS line bays each at Yangbari & Goling)*	400	Twin Moose 1xD/C	60	4.90	242.4	*242.4*	347.41
ii	*LILO of 400kV Yangbari-Goling D/C line at Chamkharchhu-I HEP (with 4 nos. of 400kV GIS line bays at Chamkharchhu-I)*	400	Twin Moose D/C	5	4.90	60.9	*60.9*	77.791
iii	*2x80MVAr Bus Reactor in Goling Switching station (with 2 nos. 400kV GIS Reactor bays)*	420	80 MVAr	2	5.04	30.6	*30.6*	36.72
iv	*1x80MVAr Reactor at Jigmeling (with 1 no. 400kV GIS Reactor bay)*	420	80 MVAr	1	5.04	15.3	*15.3*	20.34
v	*400/132/33kV, 4x67MVA ICT at Chamkharchhu-I HEP (with 1 no. 400kV GIS bay + 1 no. 132kV AIS bay)*	400/132 /33	200 MVA	1	7.8	19.6	*19.6*	23.52
vi	*400kV Goling - Jigmeling 2xD/C line (2nd) (with 2 nos. 400kV GIS line bays each at Goling and Jigmeling)*	400	2xD/C	45	4.90	114.40	*118.65*	163.58
vii	*LILO of 132kV Nganglam-Tintibi S/C line at Chamkharchhu-I HEP (with 2 nos. of 132kV AIS line bays at Chamkharchhu-I)*	132	Panther S/C	5	2.18	13.75	*9.75*	15.7
viii	*400/220 kV, 4x167MVA Jigmeling GIS substation including ICT bays (with 1 no. 400kV GIS bay + 1 no. 220kV GIS bay)*	400/220	500MVA	1	15.24	0	*10.1*	12.12
ix	*400kV Jigmeling-Alipurduar D/C line (Bhutan portion only) (with 2 nos. of 400kV GIS line bays at Jigmeling)*	400	Quad Moose D/C	2	6.55	0	*6.63*	13.21
x	*2 nos. of 400kV GIS line bays at Goling for 400kV Goling-Jigmeling lines (1st D/C line)*	400				0	*11.1*	13.32

Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
xi	*2 nos. of 400kV GIS line bays at Goling for Mangdechhu HEP-Goling switching station 2xS/C on D/C tower lines*	400				0	*11.1*	13.32
xii	*2 nos. 400kV GIS line bays at Goling for Stringing of 2nd ckt in each line of 400kV Mangdechhu-Goling 2xS/C on D/C*	400				0	*11.1*	13.32
	Total for Chamkharchhu-I					**496.95**	***547.23***	**750.36**
3	**Kholongchhu HEP - 600 MW**							
i	*400 kV Kholongchhu HEP - Yangbari 2xS/C on D/C tower lines (with 2 nos. 400kV GIS bays each at Kholongchhu & Yangbari)*	400	Twin Moose 2xS/C	85	4.90	520.4	*474.5*	886.66
ii	*400/132/33kV, 4x67MVA ICT at Kholongchhu (with 1 no. 400kV GIS + 1 no. 132kV AIS bay)*	400/132	200 MVA	1	7.8	19.6	*19.6*	23.52
iii	*400kV Yangbari - Goling 1xD/C (2nd) line (one additional 400kV D/C line in between Yangbari and Goling LILOed at Chamkharchhu-I HEP to be built with Chamkharchhu-I HEP) (with 2 nos. 400kV GIS line bays each at Yangbari & Goling)*	400	Twin Moose 1xD/C	60	4.90	242.4	*242.4*	347.41
iv	*LILO of 132kV S/C Kanglung-Kilikhar line at Kholongchhu HEP (with 2 nos. 132kV AIS bays)*	132	Panther S/C	5	2.18	9.75	*9.75*	15.7
v	*1x80MVAr 420kV Bus Reactor at Kholongchhu (with 1 no. 400kV GIS Reactor bay)*	400	80 MVAr	1	5.04	15.3	*15.3*	18.36
vi	*400kV Goling - Jigmeling 1xD/C line (2nd)*	400	Twin Moose 1xD/C	45	4.90		*74.25*	110.30
vii	*400kV Jigmeling-Alipurduar D/C line (Bhutan portion only) (with 2 nos. of 400kV GIS line bays at Jigmeling)*	400	Quad Moose D/C	2	6.55		*6.63*	13.21
viii	*2 nos. of 400kV GIS line bays at Goling for 400kV Goling-Jigmeling lines (1st line)*	400					*11.1*	13.32

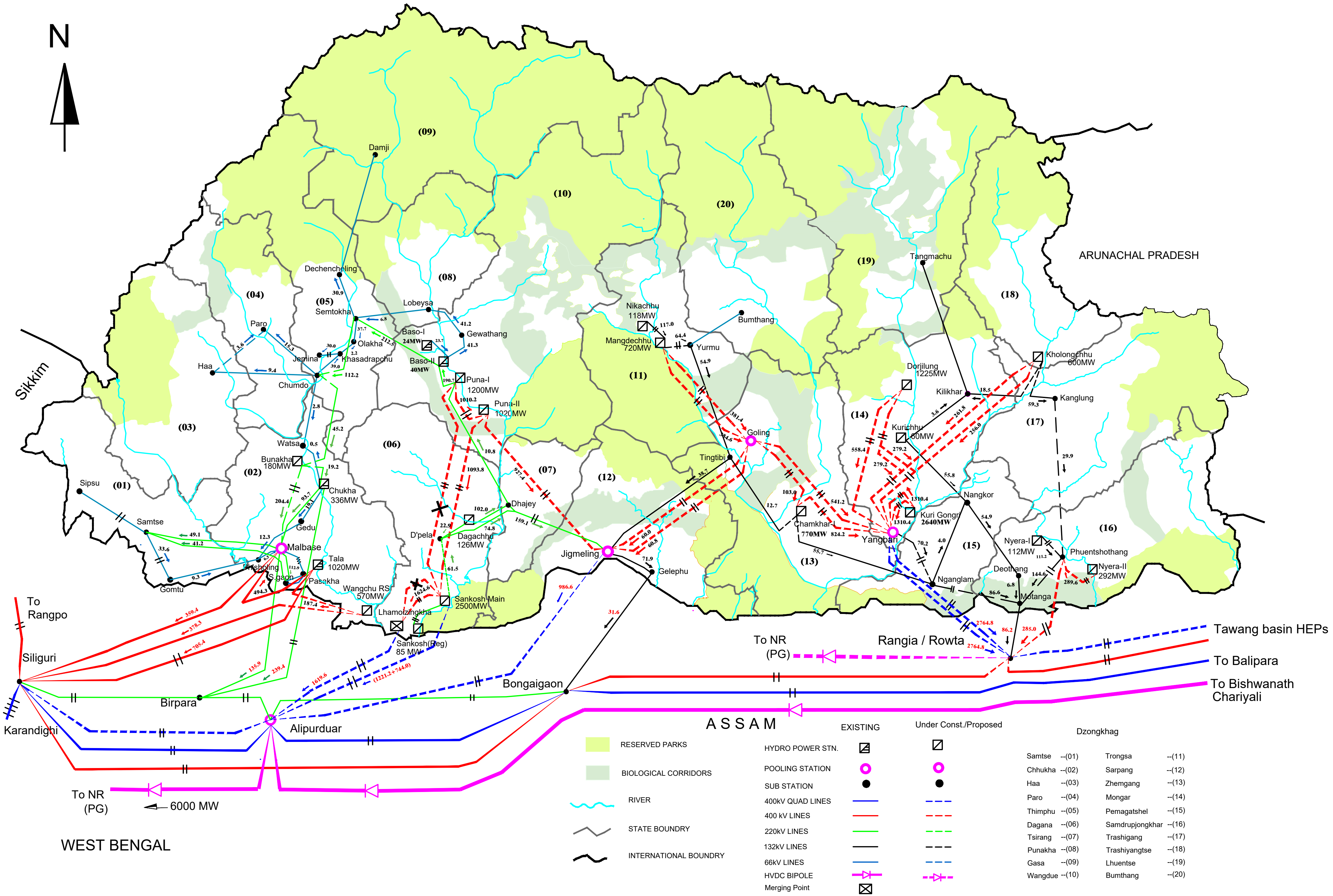
Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
ix	*2 nos. of 400kV GIS line bays at Goling for Mangdechhu HEP-Goling switching station 2xS/C on D/C tower lines*	400					*11.1*	13.32
x	*2 nos. 400kV GIS line bays at Goling for Stringing of 2nd ckt in each line of 400kV Mangdechhu-Goling 2xS/C on D/C*	400					*11.1*	13.32
xi	*400/220 kV, 4x167MVA Jigmeling GIS substation including ICT bays (with 1 no. 400kV GIS bay + 1 no. 220kV GIS bay)*	400/220	500MVA	1	15.24	0	*10.1*	12.12
xii	*400kV Goling GIS switching station (Establishment Cost etc.)*	400				90	*90*	108
	Total for Kholongchhu					**897.45**	***975.825***	**1575.25**
4	**Bunakha HEP - 180 MW**							
i	*220 kV Bunakha-Malbase 2xS/C lines (with 2 nos. 220 kV AIS bays each at Bunakha & Malbase)*	220	2xS/C	30	1.49	74	*74*	123
ii	*Additional 400/220kV, 4x67 MVA ICT at Malbase (with 1no. 220KV AIS bay + 1no. 400 KV AIS bay)*	400/200	200 MVA	1	7.32	15.5	*15.5*	18.12
	Cost apportioned to Bunakha						**89.5**	141.12
iii	*LILO of 220 kV Semtokha - Chhukha line (with 2nos. 220 kV AIS bays)*	220	S/C Zebra	5	1.49	14.5	*0*	15.85
	Cost approtioned to BPC/RGoB						*14.5*	
	Total for Bunakha					**104.00**	***104.00***	**156.97**
5	**Wangchhu HEP - 570 MW**							
i	*LILO of one ckt of 400kV Tala-Khogla-Siliguri D/C line at Wangchhu HEP (with 2 nos. of 400 kV line bays at Wangchhu)*	400	Twin Moose	5	4.90	38.7	*38.7*	51.15
ii	*1x63 MVAr Reactor at Wangchhu (with 400 kV GIS line bays at Wangchhu)*	420	63 MVAr	1	5.04	15.1	*15.1*	18.36
	Total for Wangchhu					**53.80**	***0.00***	**69.51**

Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
6	**Kuri Gongri HEP - 2640 MW**							
i	*400 kV Kuri-Gongri HEP - Yangbari 2xD/C lines (with 4 nos. 400 kV GIS line bays each at Kuri-Gongri & Yangbari)*	400	Twin Moose 2xD/C	40	4.90	352.8	*0*	498.74
ii	*400/132/33 kV, 4x67 MVA Yangbari pooling station (with 1 no. 400 kV GIS bay + 1 no. 132 kV AIS bay + Establishment cost)*	400/132/33	200	1	7.8	119.6	*0*	131.52
iii	*400 kV Yangbari - Rangia/Rowta (Assam) 2xD/C lines upta Bhuan border (with 4 nos. 400 kV GIS line bays at Yangbari)*	400	Quad Moose 2xD/C	40	6.55	264.4	*0*	577.68
iv	*132 kV Yangbari - Nganglam D/C line (2 nos. 132 kV GIS line bays each at Yangbari & Nganglam)*	132	Panther D/C	30	2.53	42.5	*0*	205.35
v	*2x80 MVAr Reactor at Yangbari (with 2 nos. 400 kV GIS Reactor bays)*	420	80 MVAr	2	5.04	30.6	*0*	36.72
	Total for Kuri Gongri					**809.90**	***0.00***	**1450.01**
7	**Nyera Amari I & II Integrated HEP**							
	Nyera Amari I							
i	*132 kV AIS Bay*	132					6	
ii	*Construction of 132 kV D/C line from Nyera Amari - I Switchyard to Phuntshothang PS including design & engineering etc.*	132	Panther D/C	19.5	1.18		23.01	
iii	*Civil works*		LS	1	4		3	
iv	*Contingency (10% of Sl.2)*						2.301	
	For Nyera Amari - I						34.311	
	Nyera Amari II							
i	*400 kV AIS Bay*	400					33	
ii	*Construction of 400 kV D/C line from Nyera Amari - II Switchyard to Phuntshothang PS and till Bhutan - India border including design & engineering etc.*	400	Twin Moose D/C	13.95	3.062		42.7149	
iii	*400/132 kV, 4 x 67 MVA ICT*	400/132	200	1	6.5		6.5	
iv	*Civil works*		LS	1	10		4.5	
v	*Contingency (10% of Sl.2)*						4.27149	
	For Nyera Amari - II						90.99	
	Total for Nyera Amari I & II Integrated						**125.30**	

Sl. No.	Associated Transmission Systems	Voltage (kV)	Ckt/MVA/ MVAr	Route Length (Km/ No.)	Unit rate (INR Cr. per km) Line, ICT, Reactor	Total Cost as per NTGMP (Rs. In Cr.) PL-2012	Total Cost as decided on 8.8.14 (Rs. In Cr.)	Total Revised cost (Nu. In Cr.) PL-1st Qtr 2018
8	**Dorjilung/Kuri-I HEP - 1125 MW**							
i	*1x400 kV D/C transmission line from Kuri-I to Yangbari*	400	Twin Moose D/C	38			125.4	
ii	*Stringing of 2nd ckt on 2x400 kV D/C lines from Kuri-I to Yangbari*	400	Twin Moose	38			*41.8*	
iii	*1x400 kV D/C transmission line from Yangbari to Bhutan - India border towards Rangia*	400	Twin Moose	37			101.75	
iv	*Walk on survey*						*0.23*	
v	Environmental Impact Assessment						*0.45*	
vi	Environmental Management Program (EMP) 1% of 1+2+3+4+5						*2.70*	
	Sub-total						**272.32**	
vii	Deposit work charges of BPC (10% of sub-total						*27.23*	
	Total						**299.55**	
	Substation							
viii	ICT substation at Yangbari						*243*	
ix	Deposit work charges of BPC (10% of viii)						*24.3*	
	Total						**267.3**	
	Grand Total						**566.85**	
	Total ATS cost for 2035 Scenario							**5211.69**

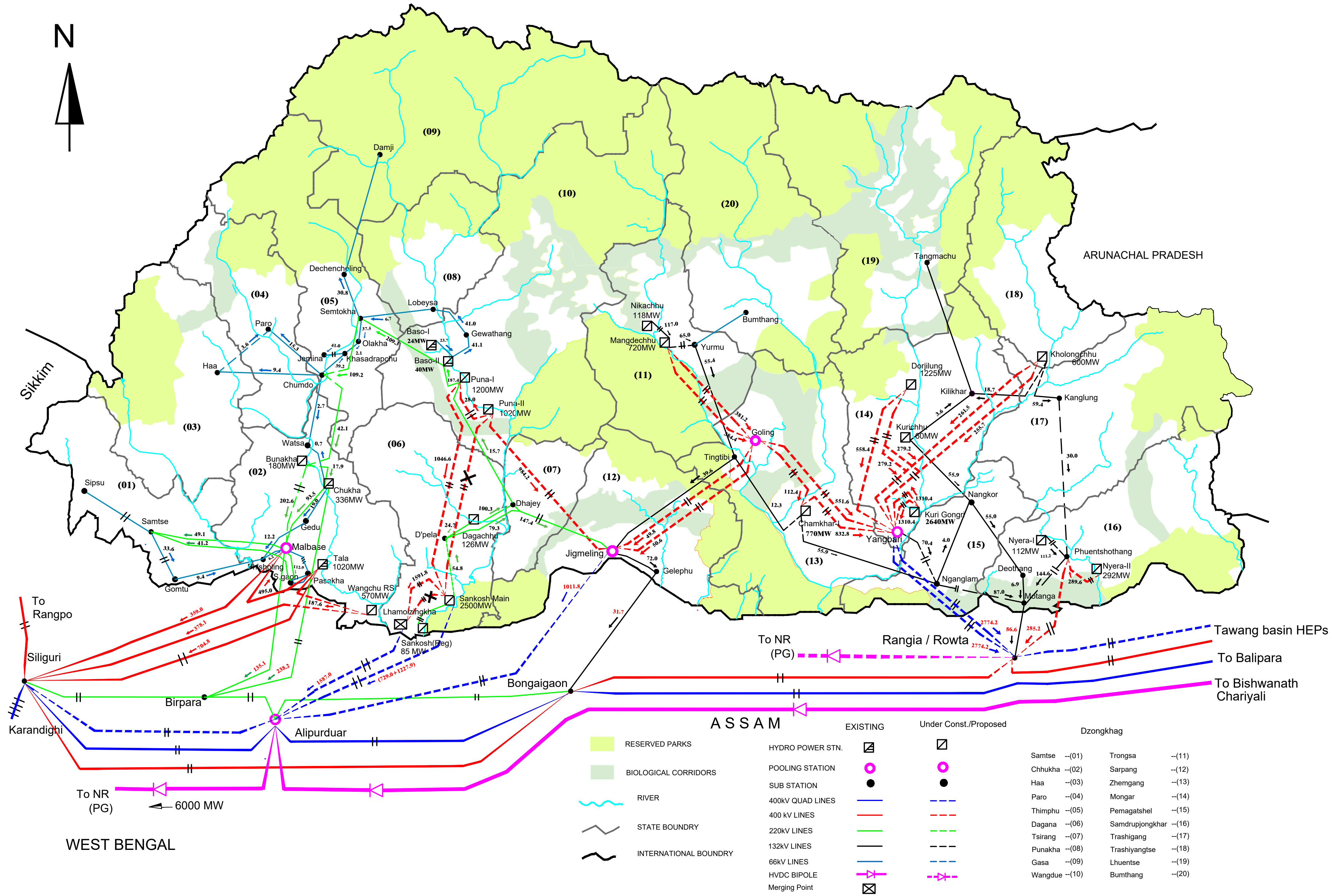
Outage of 400kV D/C Line from Puna I to Lhamozingkha - 2035 scenario

Exhibit - I



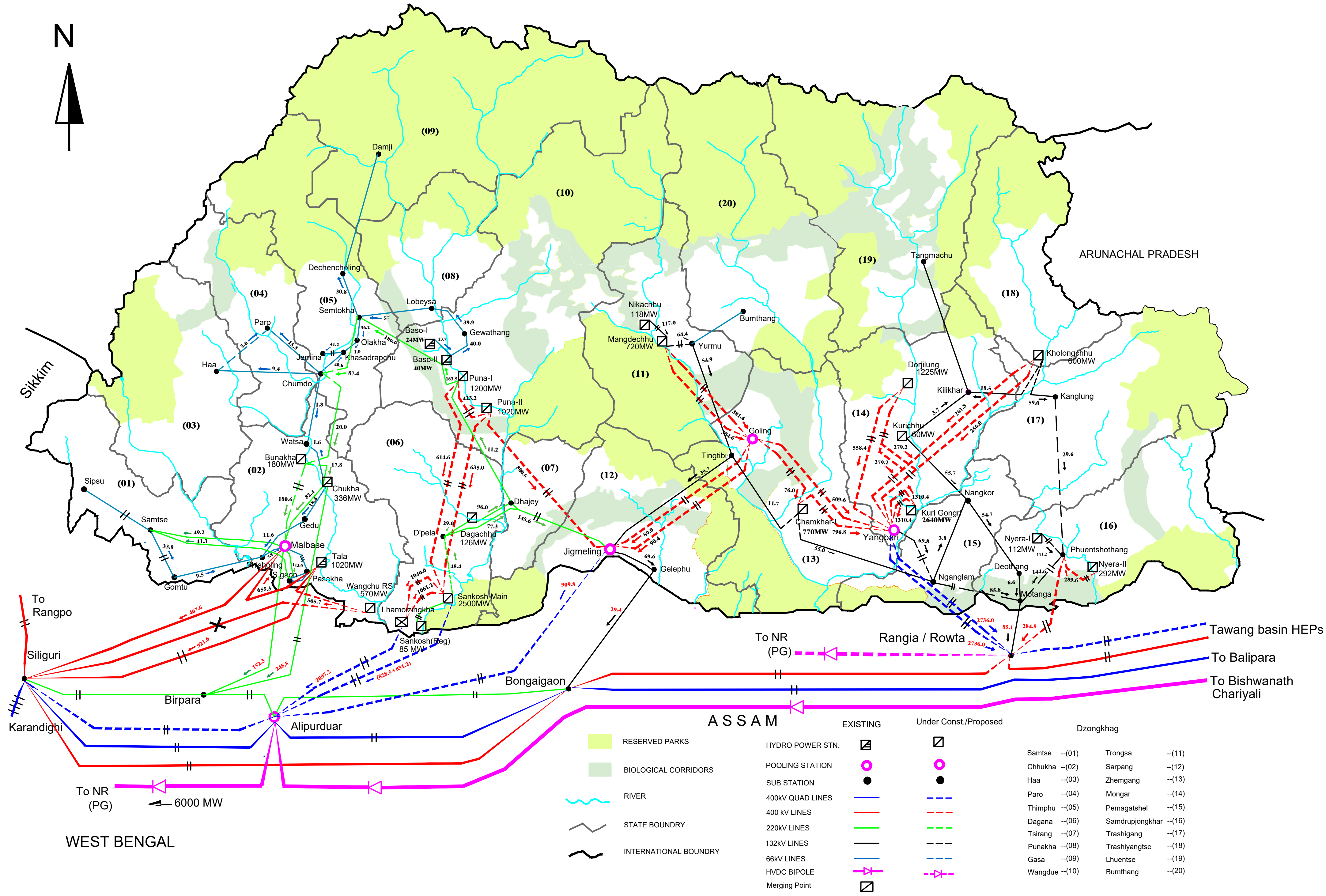
Outage of 400kV D/C Line from Puna II to Lhamozingkha - 2035 scenario

Exhibit -II



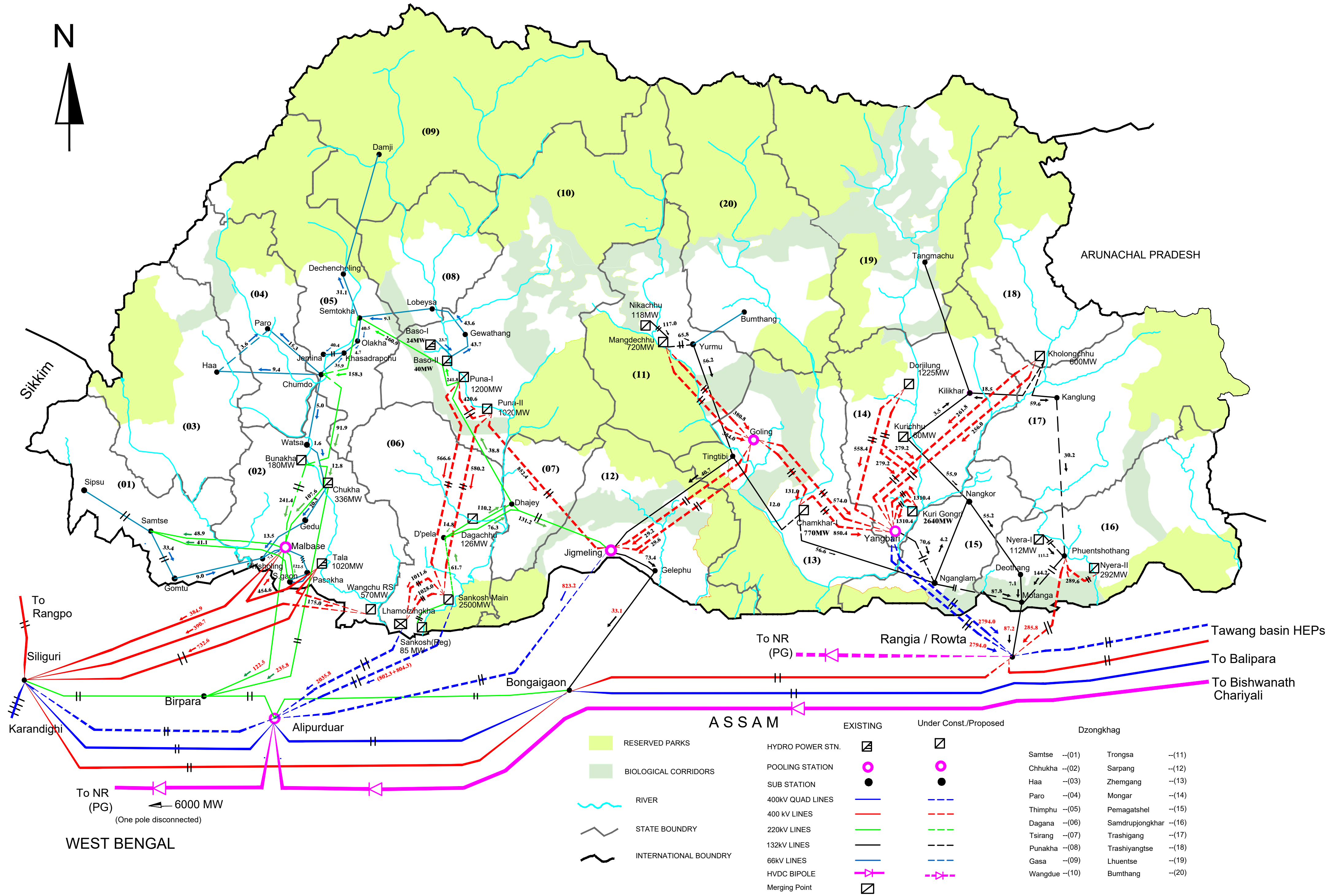
Outage of 400kV S/C Line from Wangchu to Siliguri - 2035 scenario

Exhibit -III



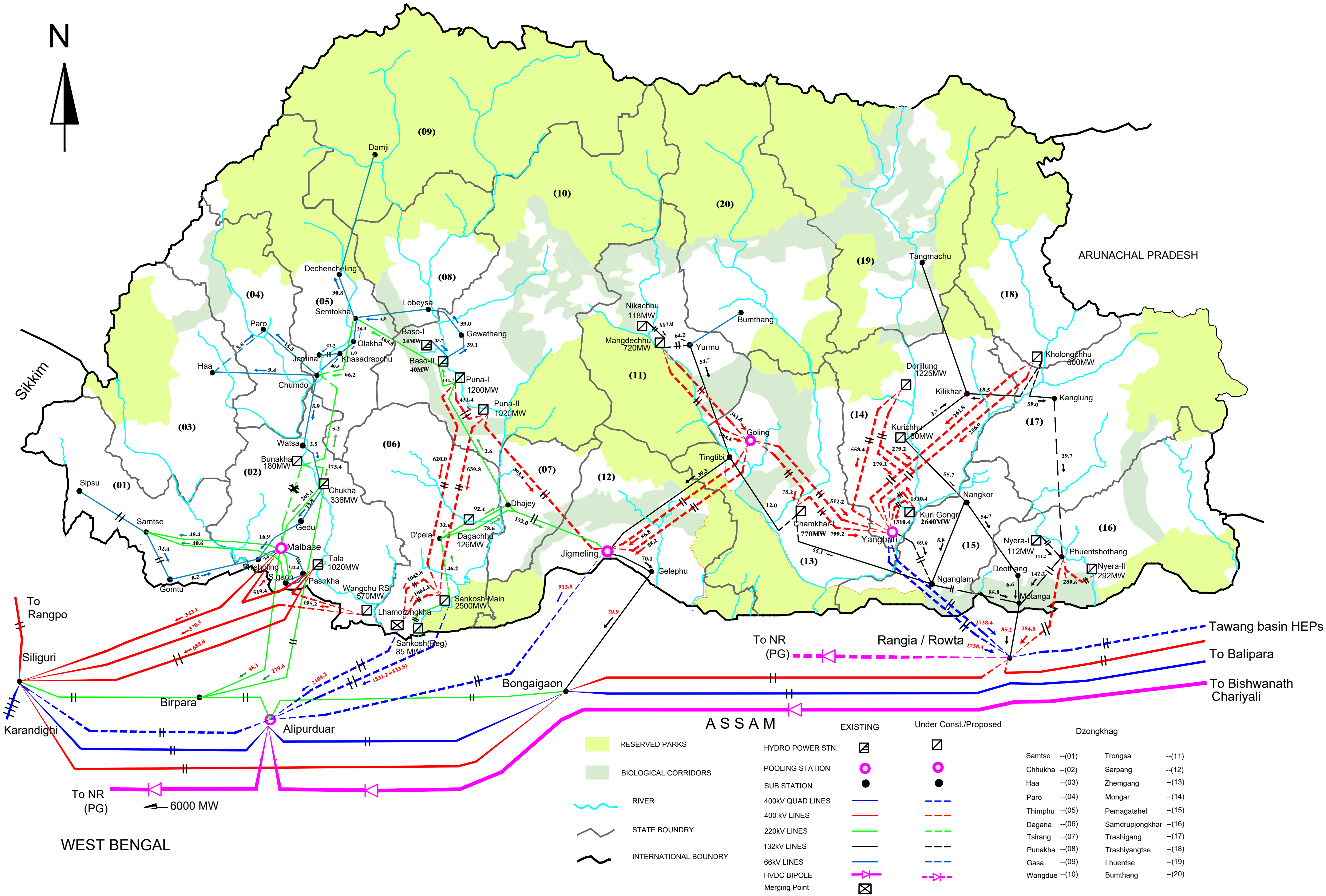
Outage of one pole of 800kV HVDC Line from Alipurduar to AGRA- 2035 scenario

Exhibit - IV



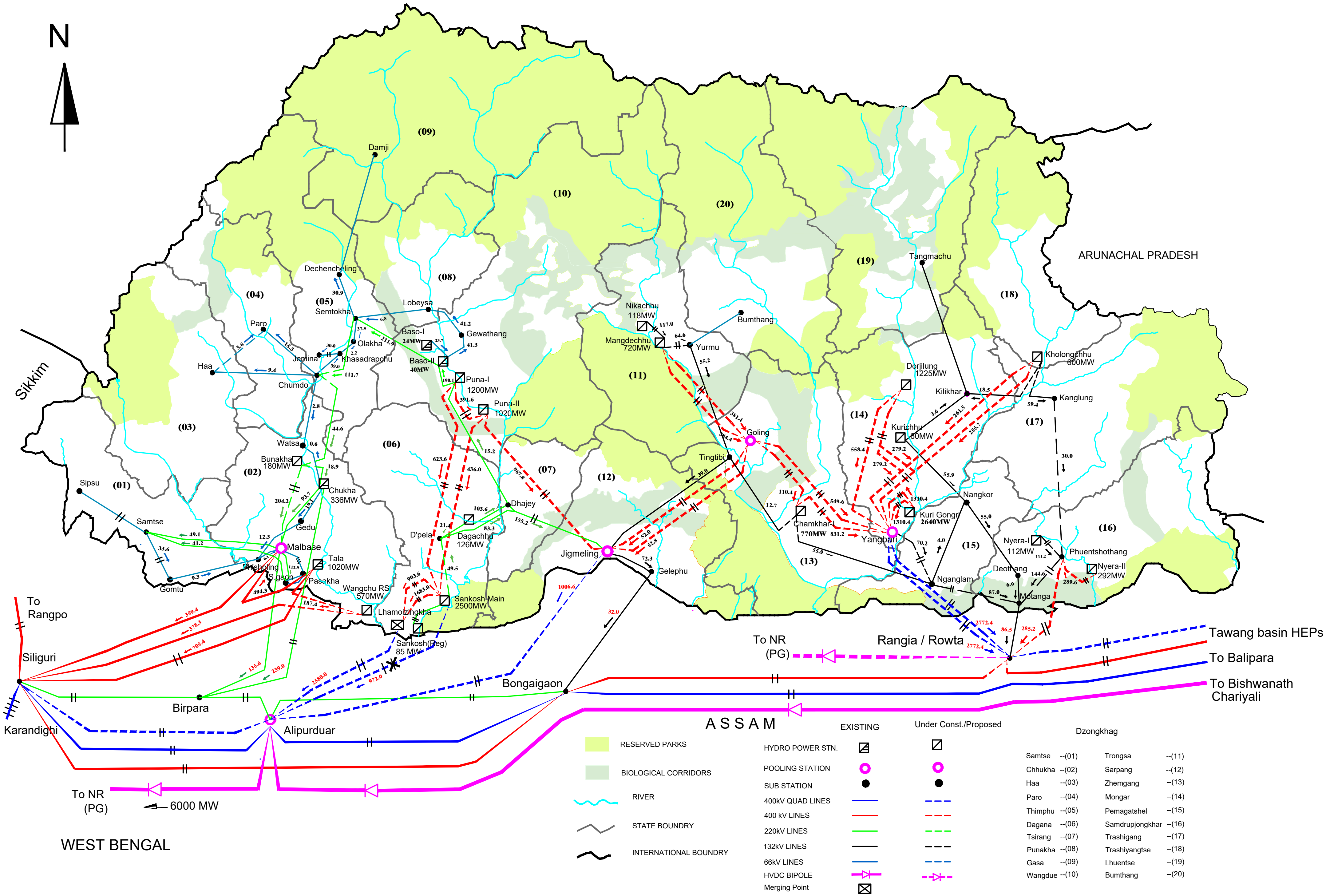
Outage of 200kV S/C Line from Bunakha to Malbase - 2035 scenario

Exhibit - V



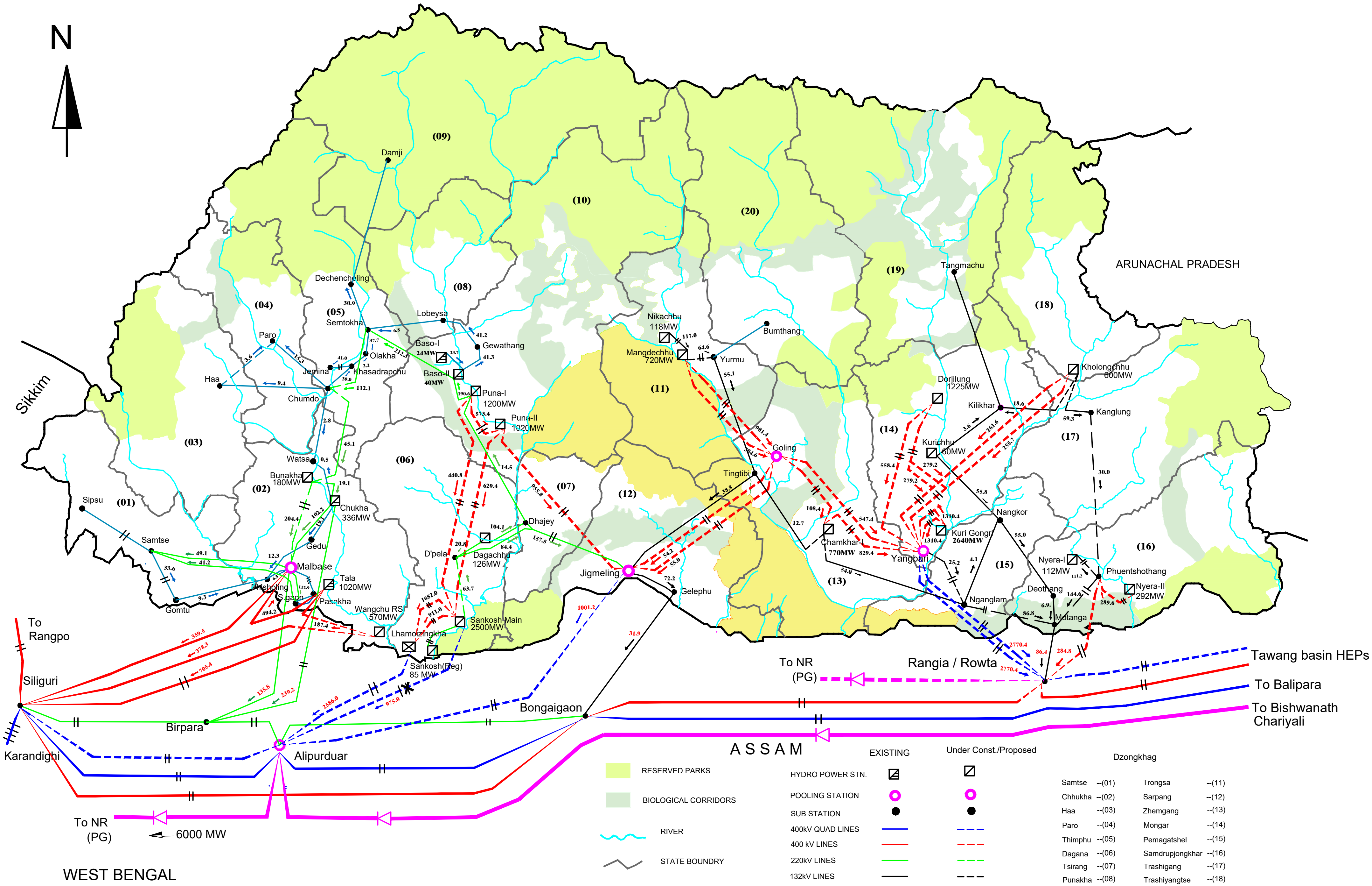
Outage of 400kV S/C Line from Sankosh LB to Alipuduar - 2035 scenario

Exhibit -VI



Outage of 400kV S/C Line from Sankosh RB to Alipurduar - 2035 scenario

Exhibit -VII



	EXISTING	Under Const./Proposed
HYDRO POWER STN.		
POOLING STATION		
SUB STATION		
400kV QUAD LINES		
400 kV LINES		
220kV LINES		
132kV LINES		
66kV LINES		
HVDC BIPOLE		
Merging Point		

RESERVED PARKS

BIOLOGICAL CORRIDORS

RIVER

STATE BOUNDRY

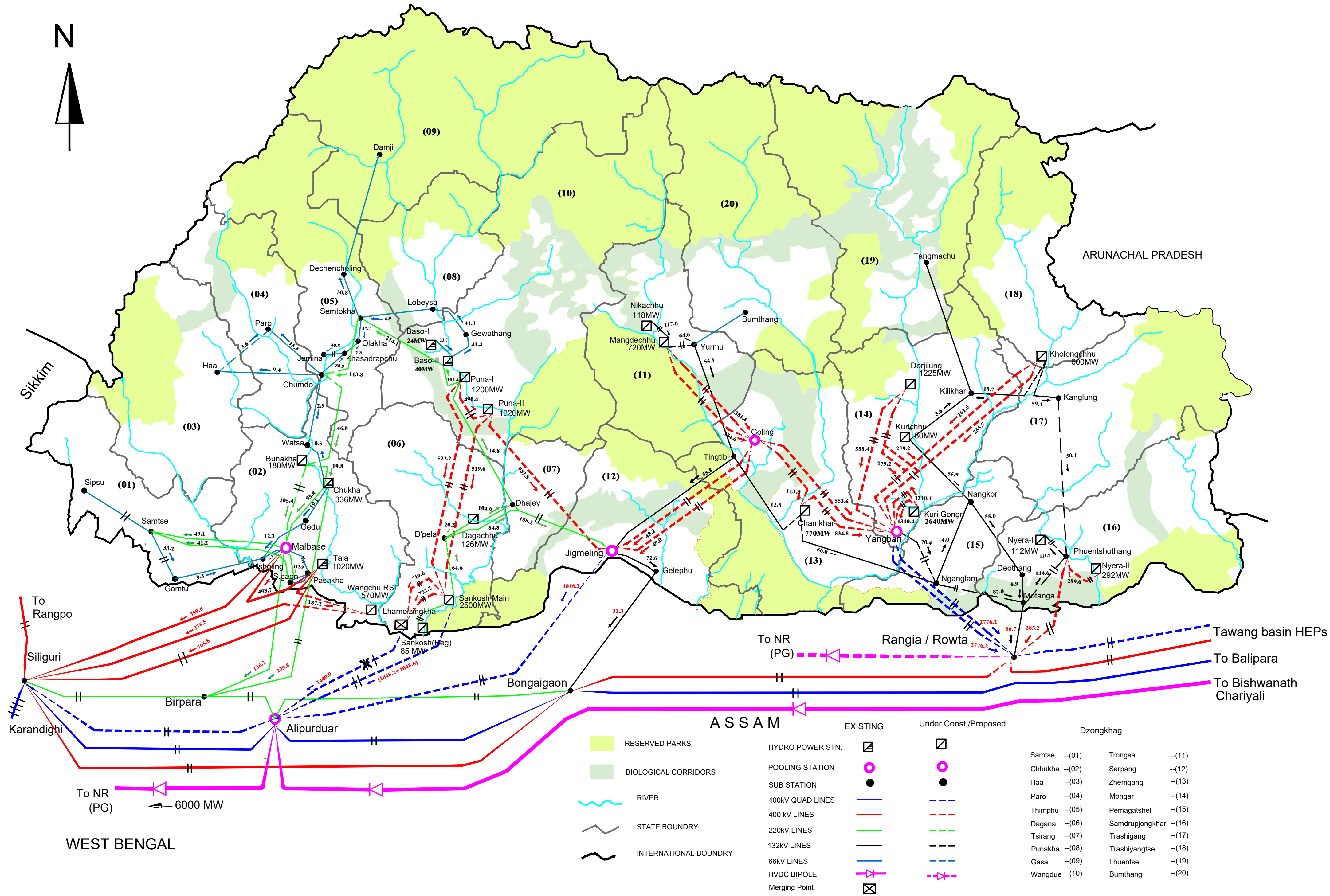
INTERNATIONAL BOUNDRY

Dzongkhag

Samtse	--(01)	Trongsa	--(11)
Chhukha	--(02)	Sarpang	--(12)
Haa	--(03)	Zhemgang	--(13)
Paro	--(04)	Mongar	--(14)
Thimphu	--(05)	Pemagatshel	--(15)
Dagana	--(06)	Samdrupjongkhar	--(16)
Tsirang	--(07)	Trashigang	--(17)
Punakha	--(08)	Trashiyangtse	--(18)
Gasa	--(09)	Lhuentse	--(19)
Wangdue	--(10)	Bumthang	--(20)

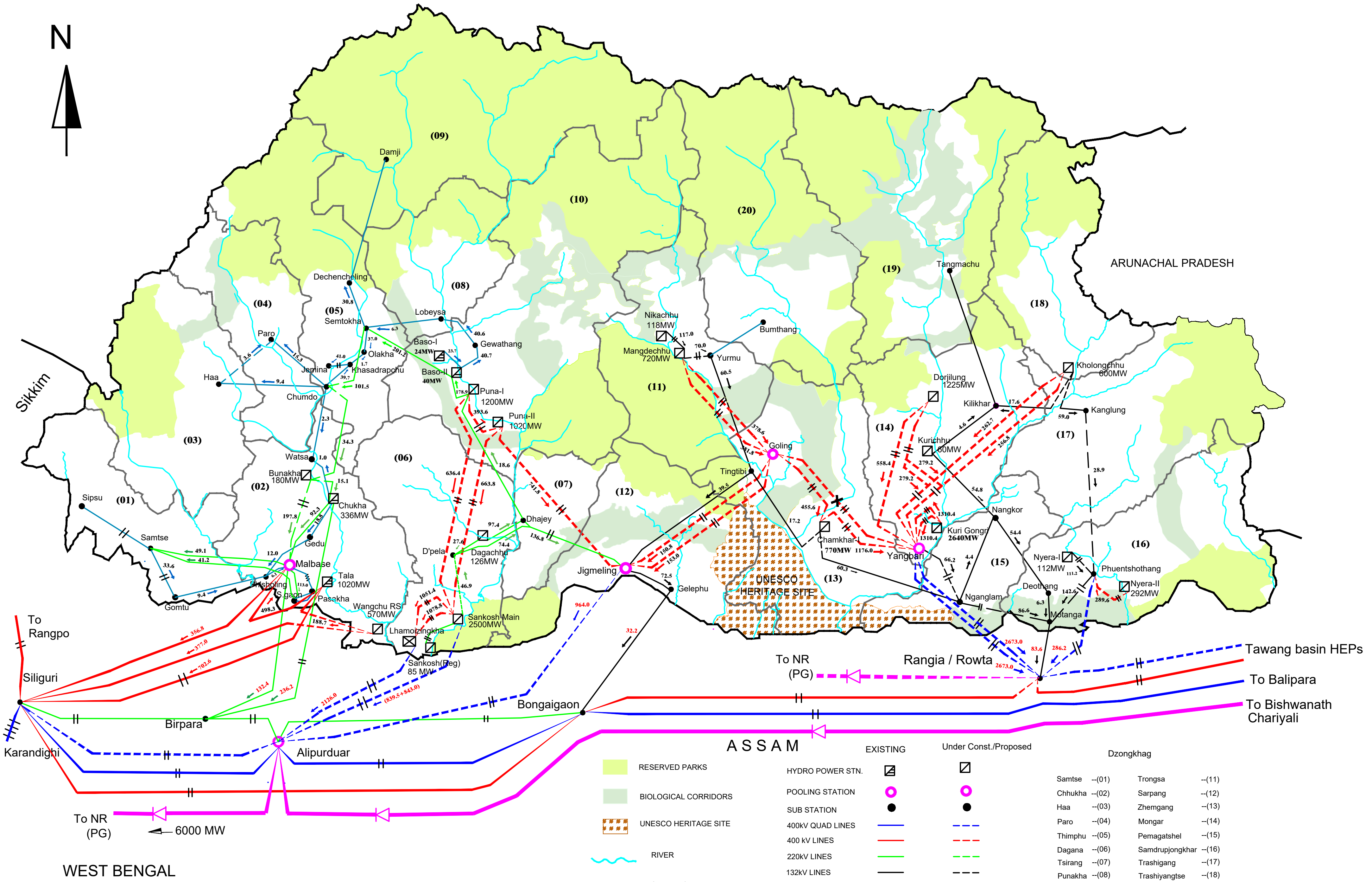
Outage of one circuit of 400kV D/C Quad Line from Lhamoizingkha to Alipurduar - 2035 scenario

Exhibit - VIII



Outage of 400kV D/C Line from Goling to Yangbari - 2035 scenario

Exhibit - IX



	EXISTING	Under Const./Proposed
HYDRO POWER STN.		
POOLING STATION		
SUB STATION		
400kV QUAD LINES		
400 kV LINES		
220kV LINES		
132kV LINES		
66kV LINES		
HVDC BIPOLE		
Merging Point		

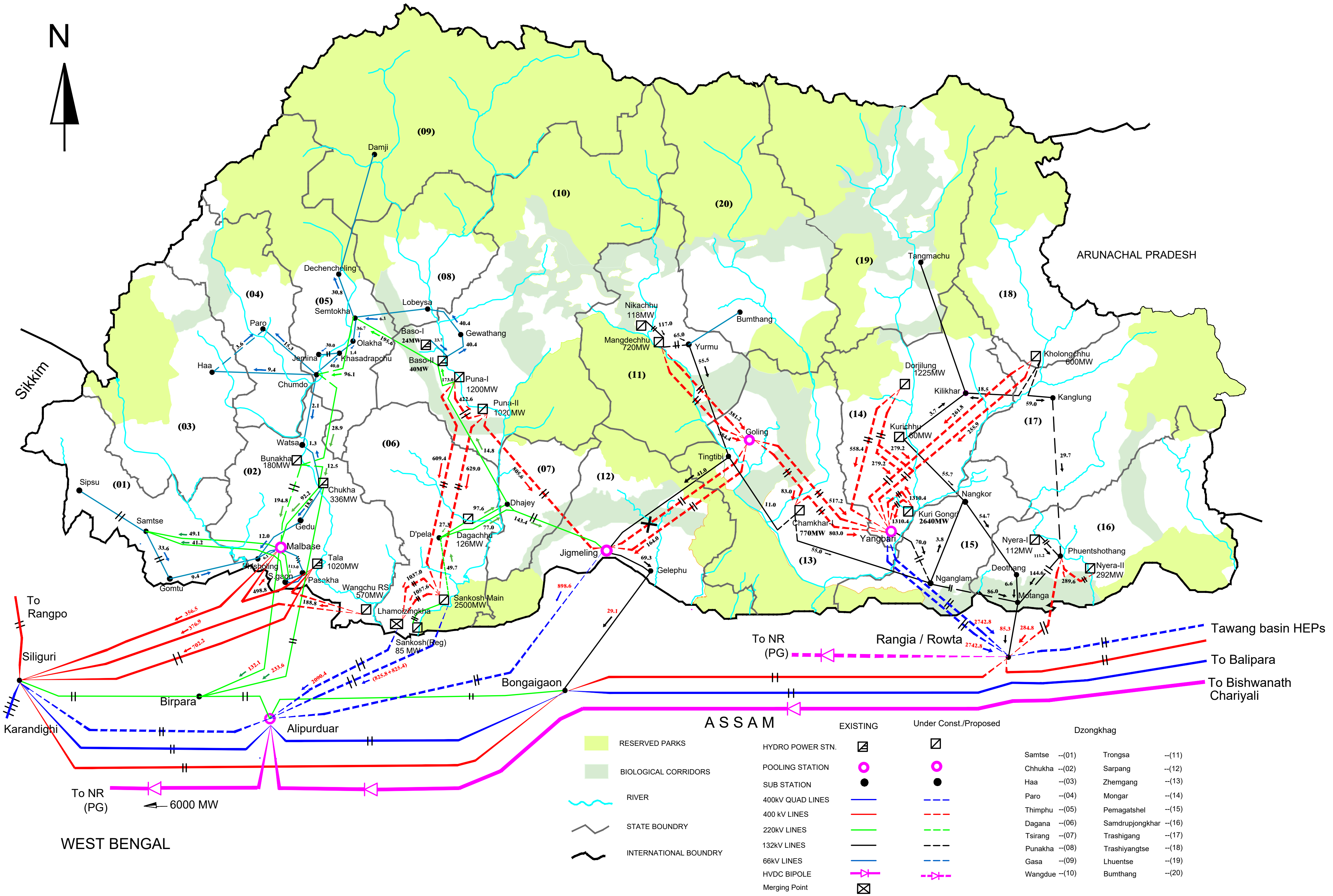
RESERVED PARKS
BIOLOGICAL CORRIDORS
UNESCO HERITAGE SITE
RIVER
STATE BOUNDRY
INTERNATIONAL BOUNDRY

Dzongkhag

Samtse	--(01)	Trongsa	--(11)
Chhukha	--(02)	Sarpang	--(12)
Haa	--(03)	Zhemgang	--(13)
Paro	--(04)	Mongar	--(14)
Thimphu	--(05)	Pemagatshel	--(15)
Dagana	--(06)	Samdrupjongkhar	--(16)
Tsirang	--(07)	Trashigang	--(17)
Punakha	--(08)	Trashiyangtse	--(18)
Gasa	--(09)	Lhuentse	--(19)
Wangdue	--(10)	Bumthang	--(20)

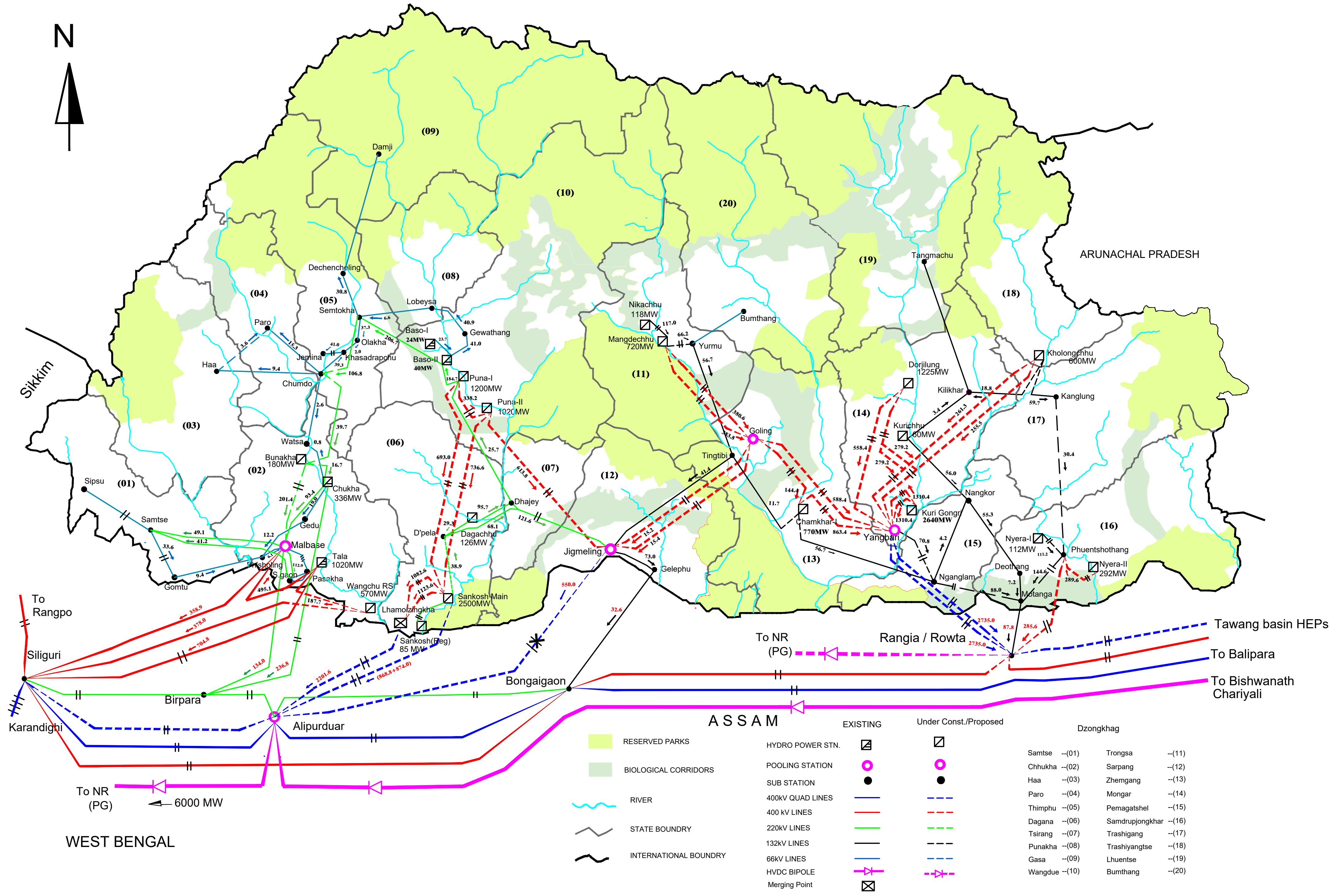
Outage of 400kV D/C line from Goling to Jigmeling - 2035 scenario

Exhibit - X



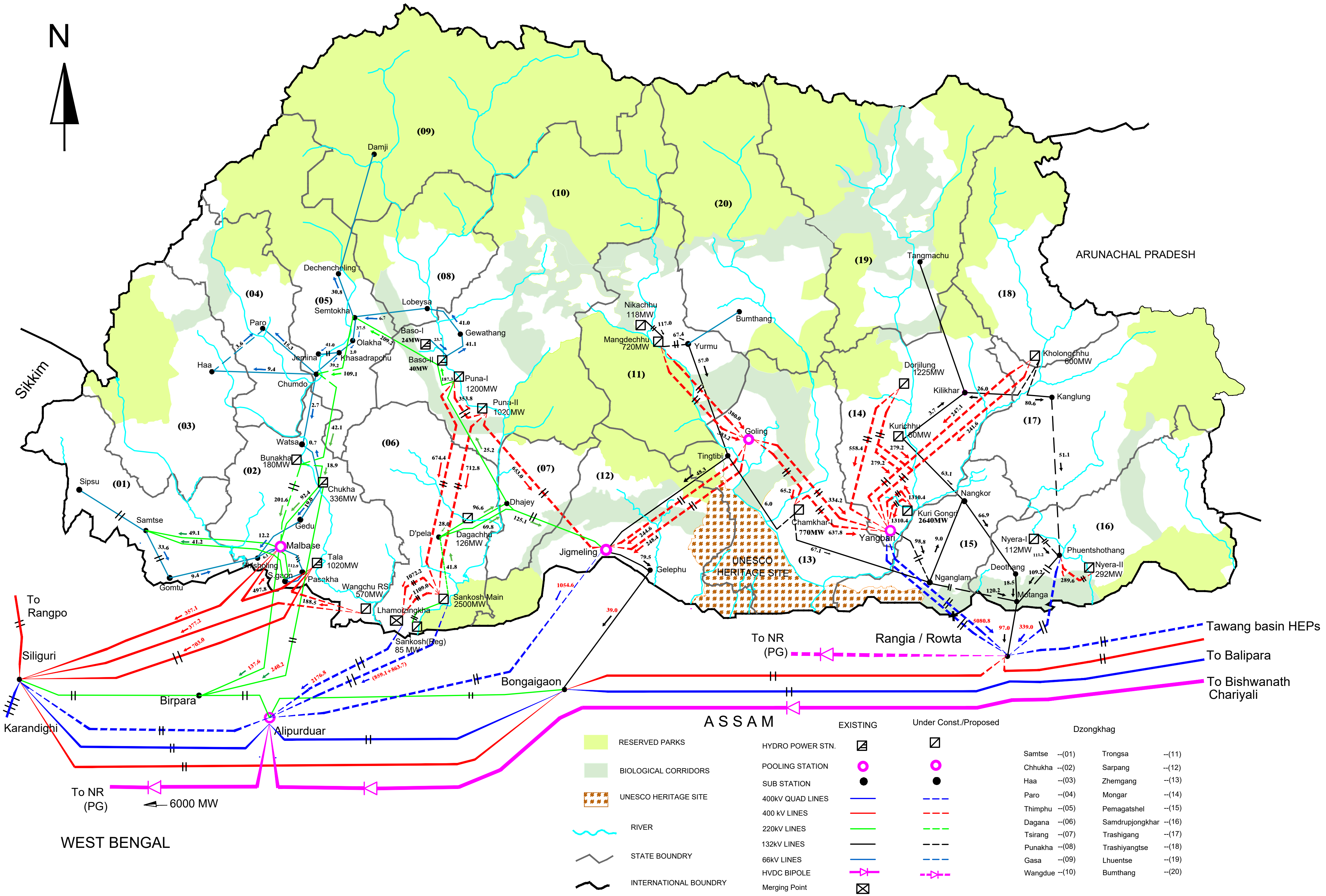
Outage of one circuit of 400kV D/C Line from Jimgeling to Alipurduar - 2035 scenario

Exhibit - XI



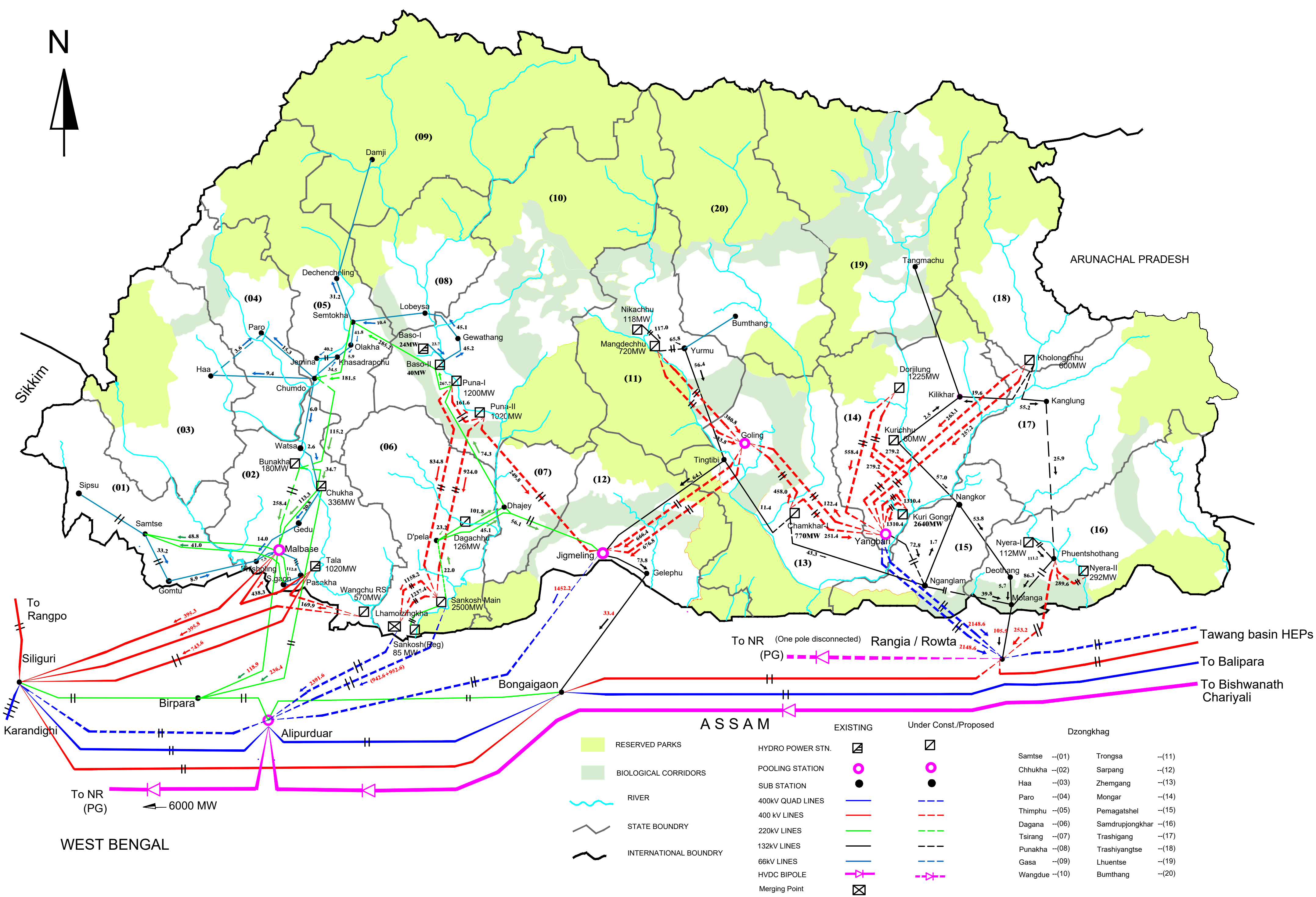
Outage of one 400kV D/C Line from Yangbari to Rangia - 2035 scenario

Exhibit -XII



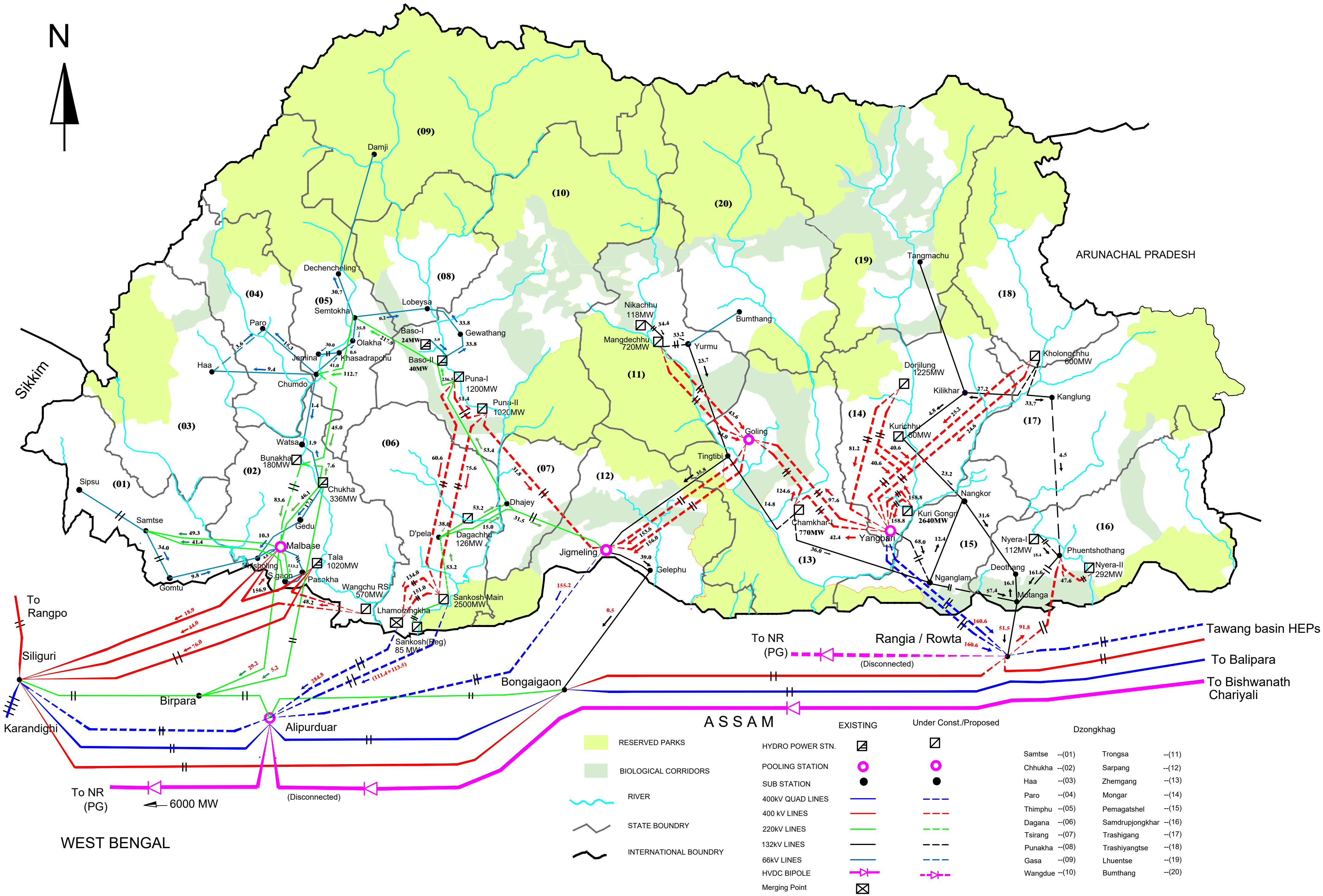
Outage of one pole of 800kV HVDC Line from Rangia to NR- 2035 scenario

Exhibit -XIII



Minimum Hydro Dispatch - 2035 scenario

Exhibit - XIV



Maximum Hydro Dispatch- 2035 scenario

Exhibit - XV