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Office of the Bhutan Power System Operator

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Ministry of Energy and Natural Resources

BHUTAN POWER SYSTEM CONTINGENCY PLAN

&

OPERATING PROCEDURES

Reviewed and updated in July 2024

Revision 3

Bhutan Power System Contingency Plan & Operating Procedures

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ABBREVIATION

BHP_LS	Basochhu Hydropower Plant Lower Stage
BHP_US	Basochhu Hydropower Plant Upper Stage
CHP	Chhukha Hydropower Plant
DG	Diesel Generator
DHP	Dagachhu Hydropower Plant
IMO	Islanded Mode of Operation
KHP	Kurichhu Hydropower Plant
MHP	Mangdechhu Hydropower Plant
NHP	Nikachhu Hydropower Plant
OCC	Operation Coordination Committee
SCC	System Coordination Committee
THP	Tala Hydropower Plant

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1 INTRODUCTION

The **Bhutan Power System Contingency Plan & Operating Procedures** is a vital document that outlines the strategies and procedures for ensuring the reliability, security, and stability of the Bhutan power system network. This document provides a comprehensive overview of the measures to be taken in case of any contingency events, such as system failures, blackouts, and other unplanned disruptions in the power system. The objective of the Contingency Plan is to ensure the continuous supply of electricity to the customers while minimizing the impact of any disruptions on the system.

The Bhutan power system network is constantly evolving, and new technologies, infrastructure, and equipment are being introduced, which can impact the stability of the system. As a result, it is essential that the Contingency Plan is updated regularly to reflect these changes and ensure that the operating procedures are in line with the latest network advancements. The updates to the Contingency Plan shall be made through thorough discussions in the Operation Coordination Committee (OCC) forum, which are held periodically.

The approved Contingency Plan by the OCC forum shall be circulated to all the stakeholders for the reference by operators during real-time power system operation.

2 BLACK START AND SYNCHRONIZATION CAPABILITIES

Black Start Capability refers to the ability of a power plant or generating unit to restart itself using the diesel generator set, without relying on external power. Black start capability allows certain strategically placed power plants to get themselves up and running independently. These "islands of power" then become the foundation for gradually restoring electricity to the rest of the system. The black start capabilities are important for:

i) Critical for Restoration: During a widespread blackout, black start capability is essential for initiating the process of bringing the entire power grid back online.
ii) Self-Reliant Restart: Black start plants have their own internal power source, often a small diesel generator, which allows them to initiate critical systems and eventually bring the main generating unit online.
iii) Resilience and Reliability: Having black start capability enhances the overall resilience and reliability of the power grid by enabling a faster restoration process after major outages.

2.1 Black Start Capabilities

During the total failure of the grid, the early normalization of the station is important. Under such conditions, all generating stations must have their black start capabilities which must be maintained in healthy condition at all times. After the generator is black-started, the supply shall be extended to other power plants for synchronization.

The black start facilities available in the Bhutan power system are given in Table 2-1 .

Table 2-1 Black Start Facilities

Power plant	Installed capacity (MW)	Turbine type	Start-up facilities		Field flashing	Black start facility
			Source	Capacity (kVA)		
BHP_US	2x12	Pelton	Diesel Generator	1x130	Yes	Yes
BHP_LS	2x20	Pelton	Diesel Generator	1x150	Yes	Yes
CHP	4x84	Pelton	Diesel Generator	2x600	Yes	Yes
THP	6x170	Pelton	Diesel Generator	2x1250	Yes	Yes
KHP	4x15	Kaplan	Diesel Generator	2x500	Yes	Yes
DHP	2x63	Pelton	Diesel Generator	1x400	Yes	Yes
MHP	4x180	Pelton	Diesel Generator	2x1500	Yes	Yes
NHP	2x59	Pelton	Diesel Generator	1x650	Yes	Yes

2.2 Synchronizing facilities

Synchronizing facilities in the stations are crucial for ensuring safe and efficient flow of electricity. It involves matching three key aspects between a generator or other power source and the existing grid.

i) Frequency: Both the generator and the grid must operate at the same frequency, typically measured in Hertz (Hz). This ensures smooth power transfer and prevents equipment damage.

ii) Voltage: The voltage of the generator needs to match the voltage of the grid. Deviations can cause power surges or sags, disrupting equipment and potentially leading to blackouts.

iii) Phase Angle: This refers to the timing of the voltage wave between the generator and the grid. They need to be "in phase: for smooth power transfer.

Synchronizing facilities at stations play a important role in connecting the isolated systems to the grid. The generators shall be synchronized at the generator end only, and the available synchronizing facilities are given in Table 2-2 . Sources of power that can be extended to generating stations for synchronization are provided in Table 2-3 .

Table 2-2 Synchronization Facilities

Stations	Synchronizing Facilities
CHP	Yes
BHP_US	Yes
BHP_LS	Yes
DHP	Yes
THP	Yes
MHP	Yes
KHP	Yes
NHP	Yes

Table 2-3 Synchronization of Power Sources

Station/Plant	Voltage level (kV)		Power Source	Synchronizing facility availability
CHP	220	Chhukha Bus	Birpara – I	Yes
CHP	220	Chhukha Bus	Birpara - II	Yes
CHP	220	Chhukha Bus	Malbase	Yes
CHP	220	Chhukha Bus	Jamjee	Yes
BHP_LS	220	Basochhu Bus	Tsirang	Yes
			Semtokha	Yes
BHP_US	66	Basochhu Bus	Basochhu LS	Yes
KHP	132	Kurichhu Bus	Nangkor	Yes
KHP	132	Kurichhu Bus	Kilikhar	Yes
THP	400	Tala Bus	Binaguri I	Yes
THP	400	Tala Bus	Binaguri II	Yes
THP	400	Tala Bus	Malbase	Yes
THP	400	Tala Bus	Binaguri IV	Yes
DHP	220	DHP Bus	Tsirang	Yes
MHP	400	Mangdechhu Bus	Jigmeling I	Yes
			Jigmeling II	

			Jigmeling III	
			Jigmeling IV	
NHP	132	Mangdechhu	MHP I MHP II	Yes

3 SYSTEM IMPROVEMENT FEATURES

Within a power system, maintaining a balance between real power and reactive power is critical for efficient and reliable operation. Shunt capacitors and shunt reactors play vital roles in achieving this balance.

i) Shunt Capacitor

The Shunt capacitor acts as a source of reactive power, injecting a leading current to counteracts the lagging current inherent in inductive loads. In improves power factor, reducing energy waster and boosting overall efficiency. Additionally, it helps to maintains voltage stability, especially in long transmission lines with high capacity and reduces line losses by minimizing reactive power flow in the lines.

ii) Shunt Reactor

The Shunt reactor behaves just opposite to a shunt capacitor by absorbing reactive power. This addresses situations with excessive capacitive loads. The benefits of shunt reactors in power system includes preventing over-voltage conditions that can damage equipment, improve system stability by mitigating voltage fluctuations, and optimize power flow by managing reactive power in the grid.

3.1 Shunt Reactor in Tala Hydropower Plant (THP)

THP has a shunt reactor of 1x63 MVAR, which shall be put into service as per the system requirement.

3.2 Shunt Reactor in Kurichu Hydropower Plant

Kurichhu Hydropower Plant (KHP) has a shunt reactor of 2x5 MVAR[1], which shall be put into service as per the system requirement.

[1] Physically, there are two 5 MVAR shunt reactors at KHP. However, only one shunt reactor can be put into service since both are sharing same circuit breaker (CB).

3.3 Shunt Reactor at Jigmeling

Jigmeling has a shunt reactor of 2 x 80 MVAR, which shall be put into as per the system requirement.

3.4 Shunt Reactor at MHP

Mangdechu Hydro Power Plant (MHP) has a shunt reactor of 1x80 MVAR, which shall be put into service as per the system requirement.

3.5 2x25 MVAR Shunt Capacitor at Semtokha

The shunt capacitors on the Semtokha 66 kV bus shall be put into service as per the system requirement (if voltage goes below 5% of the normal operating voltage).

4 BUS CONFIGURATION

The bus configuration shall be kept as per the contingency document. However, depending upon the situation, the configuration can be changed with prior approval from the System Operator.

With the bus coupler remaining healthy, the bus configuration shall be kept as described below.

4.1 220 kV Semtokha substation

a. The 220 kV Jamjee - Semtokha line and one of the 50/63 MVA, 220/66 kV transformers shall be connected to Bus A.

b. The 220 kV BHP - Semtokha line and other 50/63 MVA and 40/50 MVA, 220/66 kV transformers shall be connected to Bus B.

c. The 220 kV bus coupler shall be kept closed.

d. The 66 kV bus sectionalizer shall be kept closed. The LV side 220/66 kV, 2x50/63 MVA and 40/50 MVA transformers, 66 kV Dechencholing, Dochhula, and Olakha lines shall be connected to same bus.

e. The 2x25 MVAR shunt capacitors shall be connected to 66 kV bus.

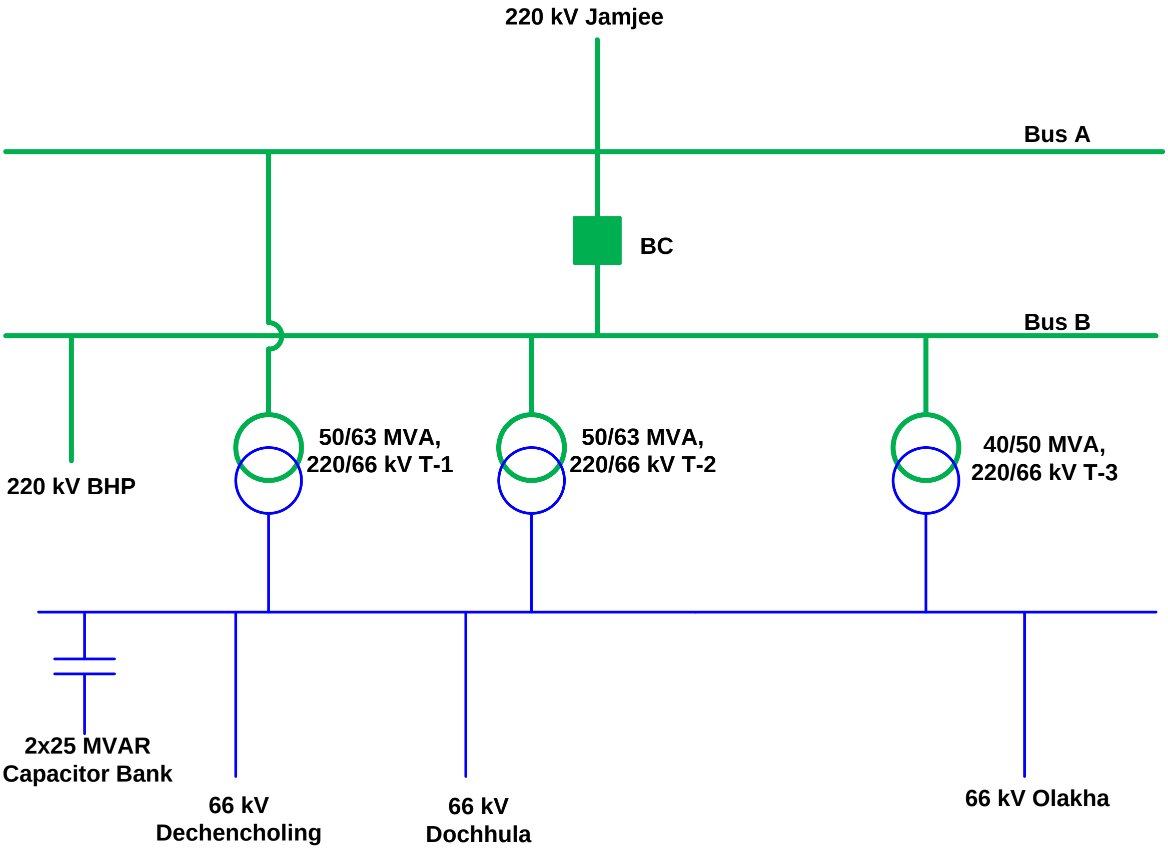

Figure 4-1 Bus Configuration of Semtokha Substation

4.2 220 kV Chhukha Switchyard

a. Two generating units and 1x20 MVA, 220/66 kV transformer along with the 220 kV CHP – Jamjee II & III, 220 kV CHP – Birpara I or II shall be connected to Bus A.

b. 220 kV CHP – Jamjee line II & III shall remain connected to Bus A, continuously[2].

c. Two other generating units and 220 kV CHP - Birpara I or II, 220 kV CHP – Jamjee I, and 220 kV CHP – Gedu lines shall be connected to Bus B. Another 1x20 MVA transformer shall be also connected to Bus B.

d. The configuration shall remain the same as above (a & b), irrespective of the season.

e. The bus coupler shall be kept closed.

[2] 220 kV CHP – Jamjee line II & III does not have provision to be connected to Bus B due to space constraint for installation of isolator at CHP end. The maintenance of Bus A will require complete shutdown of the said lines. The load shedding at Jamjee is required during the Bus A maintenance.

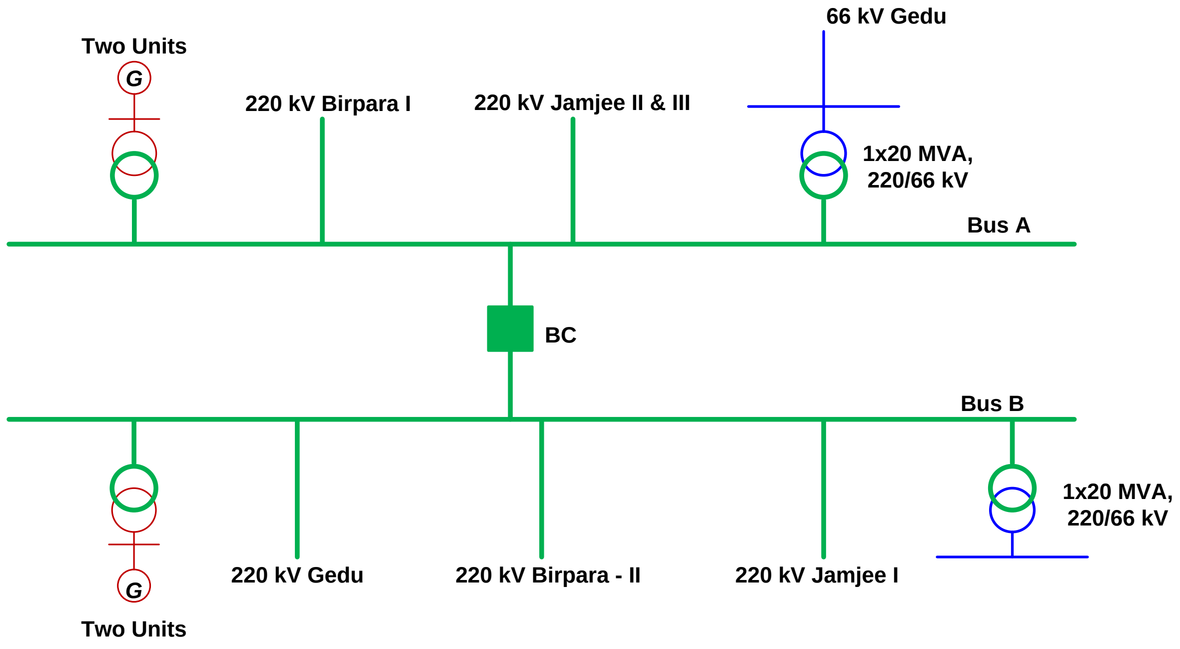

Figure 4-2 Bus Configuration of Chhukha Switchyard

4.3 400 kV THP

a. Three generating Units, 2x400 kV THP – Binaguri lines one Bus.
b. Another three generating Units along with 400 kV THP – Malbase line and one 400 kV THP – Binaguri line shall be kept in another Bus.
c. Bus coupler shall be kept closed.
d. The 63 MVAR shunt reactor shall be connected to either of the Bus as per the requirement.

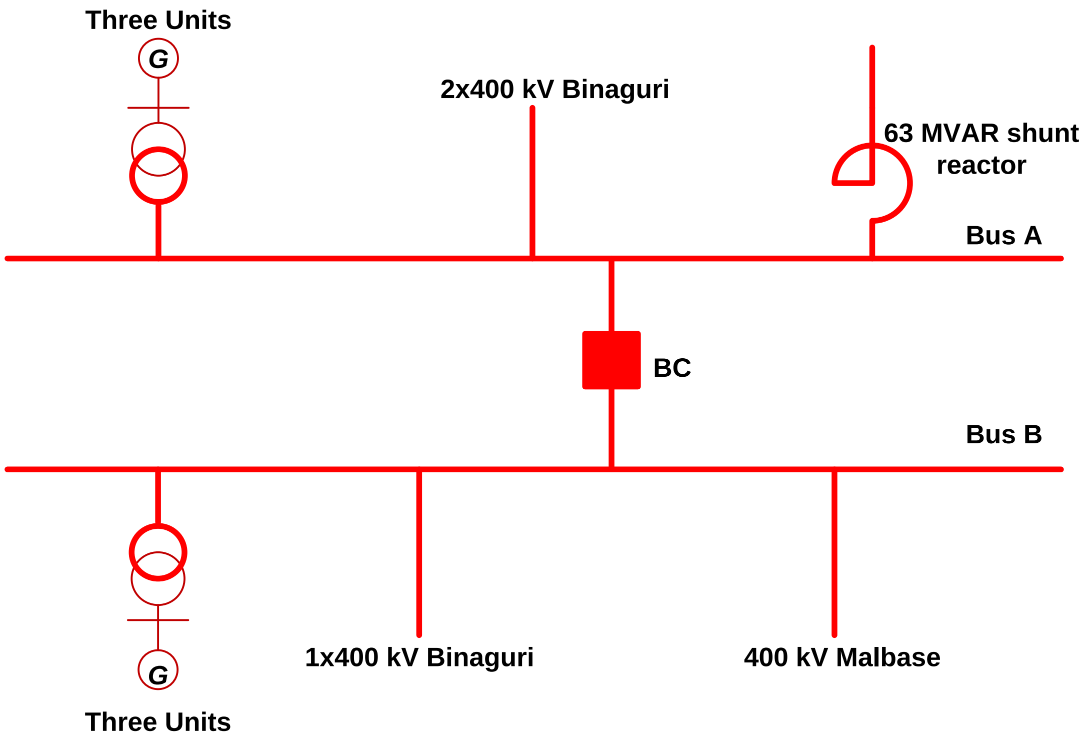

Figure 4-3 Bus Configuration of Tala

4.4 400 kV Malbase substation

a. The 400 kV Malbase - Tala line and 400kV Malbase - Siliguri line shall be connected to 400 kV Bus A.

b. 400/220 kV, 200 MVA and 300 MVA ICTs shall be connected to 400 kV Bus B.

c. The tie-breakers shall be kept closed.

d. The 220 kV Malbase - Gedu line and 220 kV Malbase - Samtse line shall be connected to 220 kV Bus A, while the 400/220 kV, 200 MVA ICT along with the Bhutan load (220 kV Malbase - Singhegaon line, 220 kV Malbase - Birpara and all 220/66 kV transformers) shall be connected to 220 kV Bus B.

e. The 220 kV bus coupler shall be kept closed.

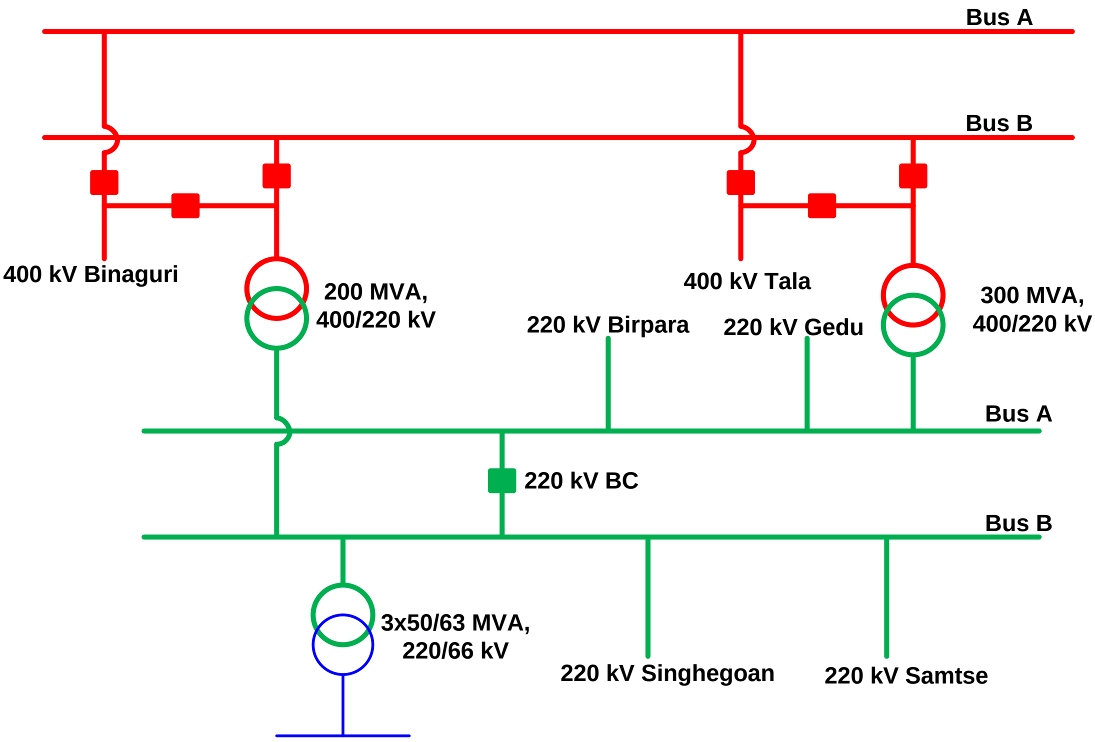

Figure 4-4 Bus Configuration of Malbase Substation

4.5 220kV BHP_LS Switchyard

a. One generating unit along with the 220 kV BHP - Semtokha line shall be connected to Bus A, while the other generating unit along with the 220 kV BHP - Tsirang line and 30 MVA, 220/66 kV ICT shall be connected to Bus B.

b. The bus coupler shall be kept closed.

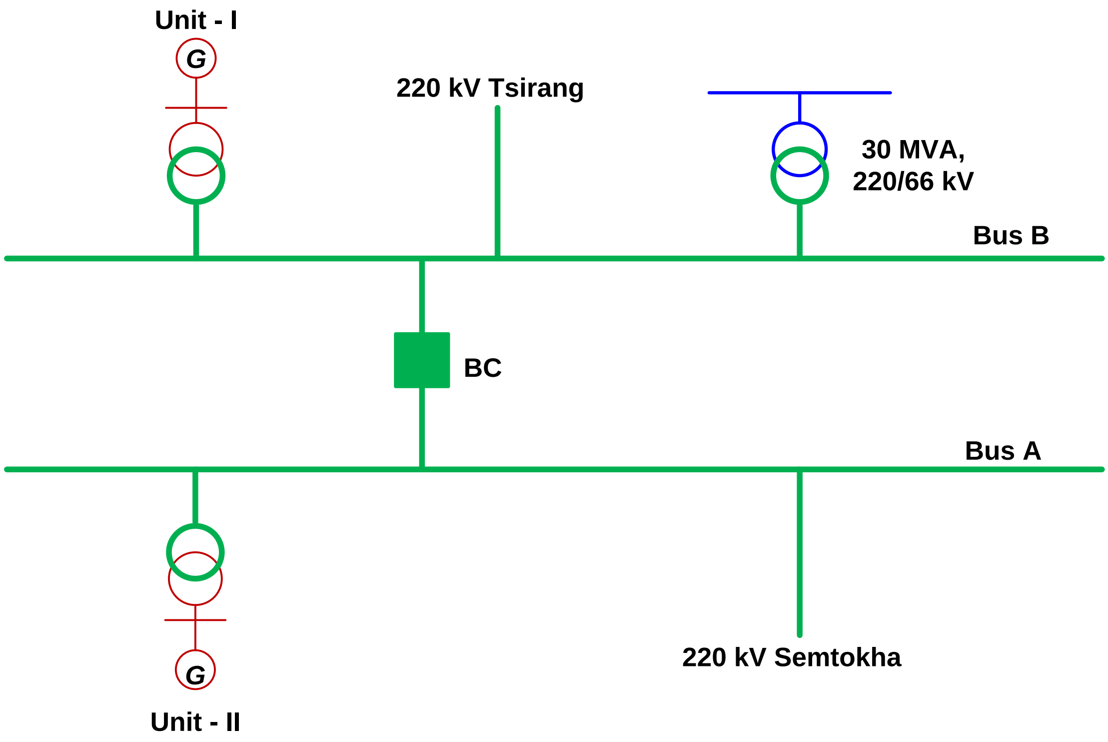

Figure 4-5 Bus Configuration of BHP_LS Switchyard

4.6 220 kV DHP

a. Since DHP has a single bus, the bus switching is not feasible.

b. In normal conditions, 220 kV DHP – Tsirang line shall be kept closed.

c. The 220 kV DHP – Dagapela line shall be put in service as per system requirement *(depending on the contingency).*

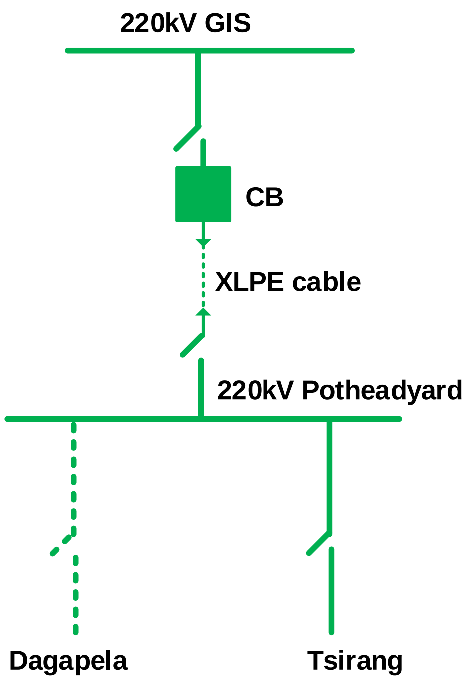

Figure 4-6 Bus Configuration of DHP

4.7 220 kV Dagapela substation

a. The 220 kV Dagapela – Jigmeling line shall be connected to Bus A.
b. The 220 kV Dagapela – DHP line shall be put in service as per system requirement.
c. The 40 MVA, 220/33 kV transformer I & II shall be kept in Bus A and B, respectively.
d. The Bus coupler shall be kept closed.

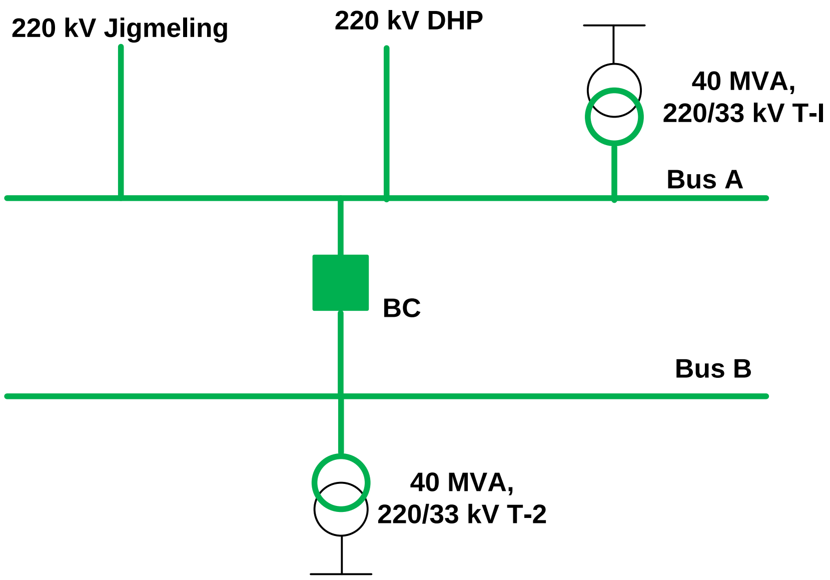

Figure 4-7 Bus Configuration of Dagapela substation

4.8 220 kV Jamjee substation

a. The 220 kV Jamjee – CHP I and 220 kV Jamjee – CHP line III shall be connected to Bus A
b. 1x80 MVA, 220/33 kV transformers shall be connected to Bus A
c. The 220 kV Jamjee – CHP line II, 220 kV Jamjee – Semtokha, and 1x80 MVA transformer shall be connected to Bus B.
d. The 30 MVA, 220/66 kV transformer II shall be connected to Bus A and 30 MVA, 220/66 kV transformer I in Bus B.
e. The 66 kV Jamjee – Pangbesa and 66 kV Jamjee – Paro shall be connected to Bus section A.
f. The 66 kV Jamjee – Jemina shall be connected to Bus section B.
g. The 66 kV bus sectionalizer shall be kept closed.

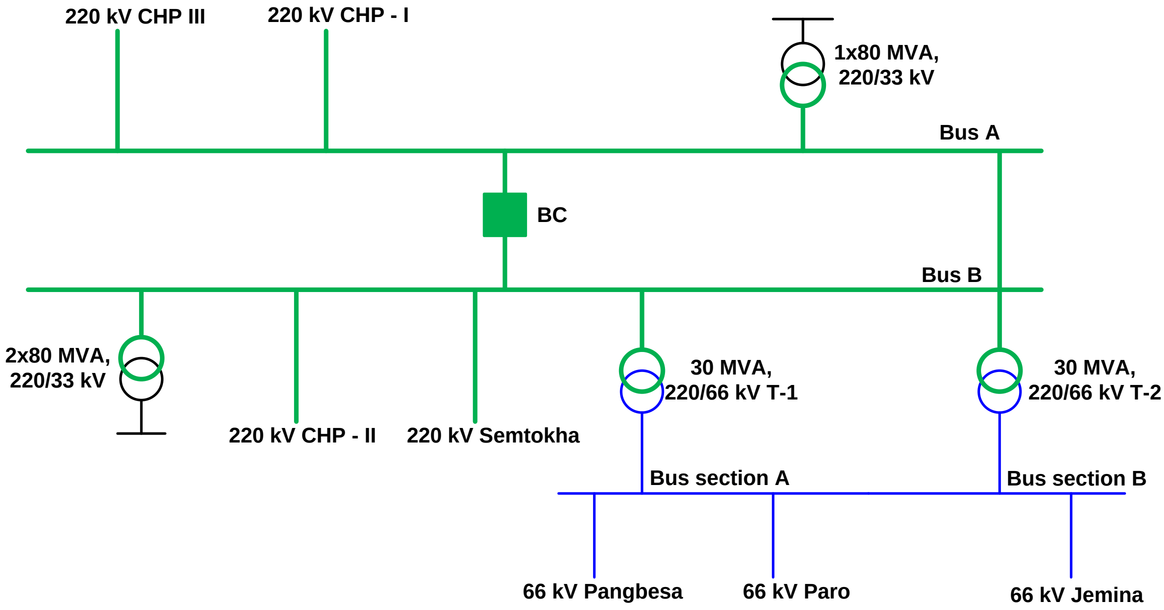

Figure 4-8 Bus Configuration of Jamjee substation

4.9 220 kV Tsirang Substation

a. The 220 kV Dagachhu -Tsirang line, 220 kV Tsirang–Jigmeling line and one of the 10 MVA, 220/33 kV transformers shall be connected to Bus A, while 220kV BHP - Tsirang line and other 10 MVA, 220/33 kV transformer shall be connected to Bus B.

b. The bus coupler shall be kept closed.

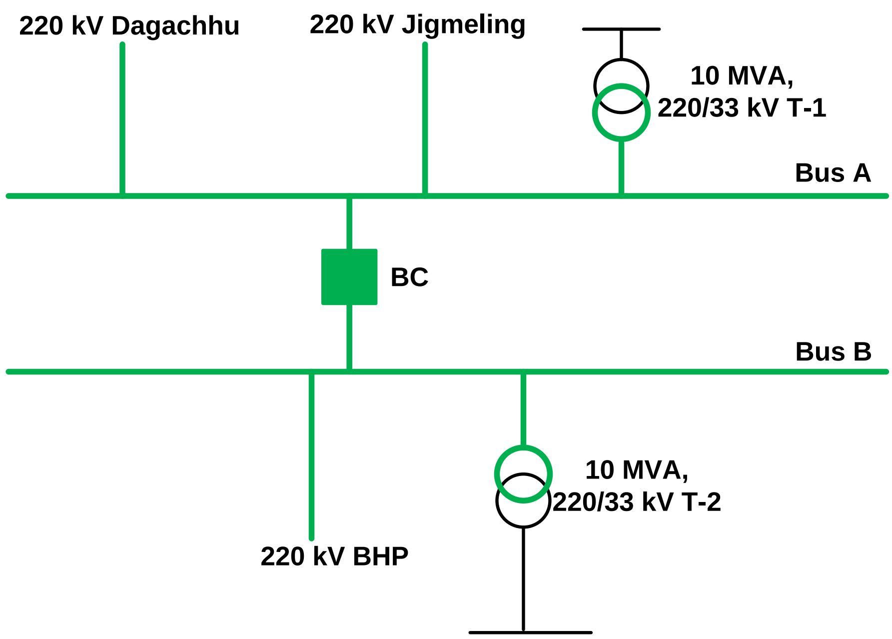

Figure 4-9 Bus Configuration of Tsirang Substation

4.10 400 kV and 132 kV MHP

a. Two generators shall be kept in Bus A along with 400 kV MHP – Jigmeling line I & III.

b. Another two generators shall be kept in Bus B along with 400kV MHP – Jigmeling line II & IV.

c. The 400 kV bus coupler shall be kept closed.

d. 400/132 kV ICT shall be kept in either Bus of 400 kV side and LV side of ICT shall be connected to 132 kV Bus A.

e. The MHP – Yurmo lines shall be kept in 132 kV Bus B.

f. The 80 MVAR shunt reactor shall be connected to either of the 400 kV Bus as per the requirement.

g. 132kV MHP-Nikachhu I will be in Bus A and 132kV MHP-Nikachhu II will be in Bus B.

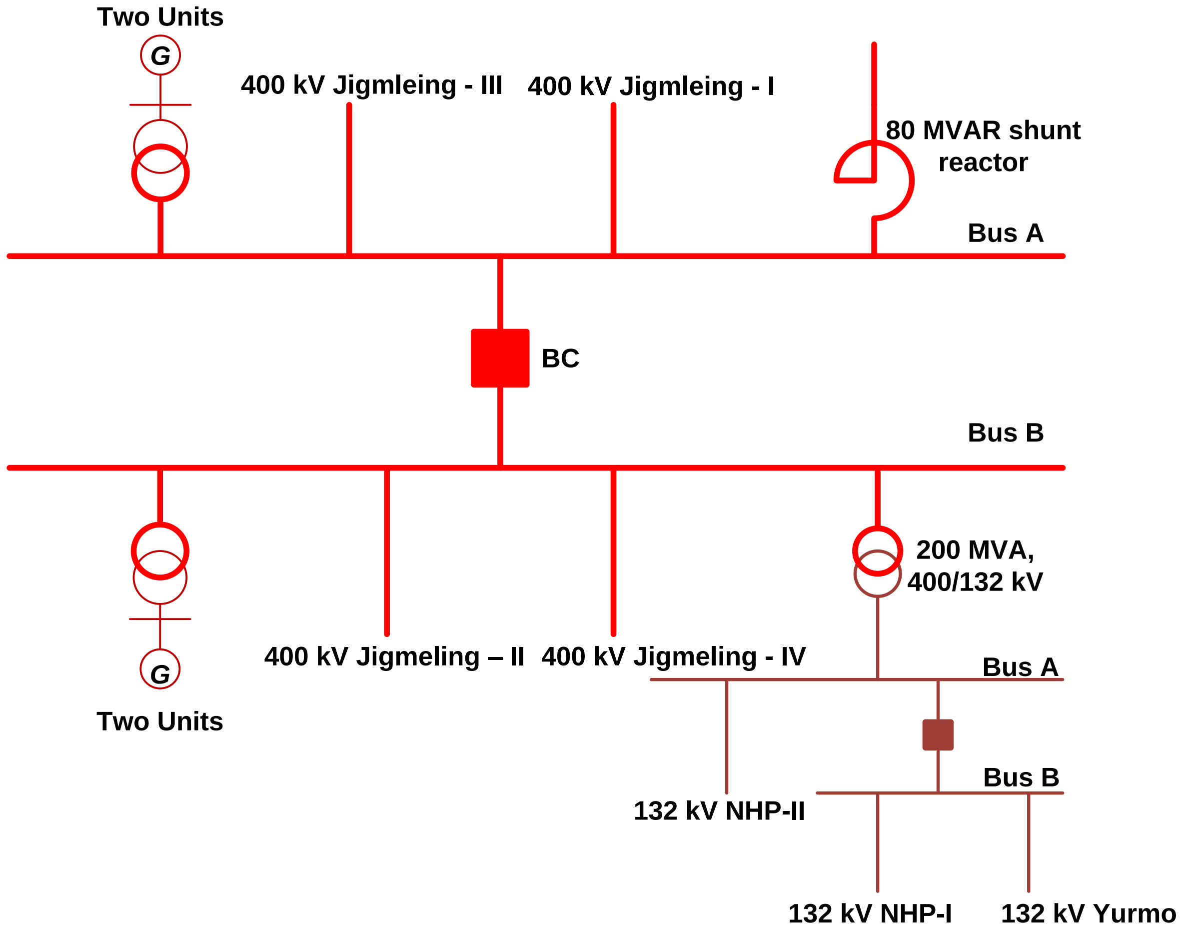

Figure 4-10 Bus Configuration of MHP

4.11 132 kV KHP

a. Two generating units and 132 kV KHP – Kilikhar line shall be kept in Bus A.

b. Two generating units and 132 kV KHP – Nangkor line shall be kept in Bus B.
c. The 5 MVAR shunt reactor[3] shall be put into any of the Bus as per the system requirement.
d. The Bus coupler shall be kept closed.

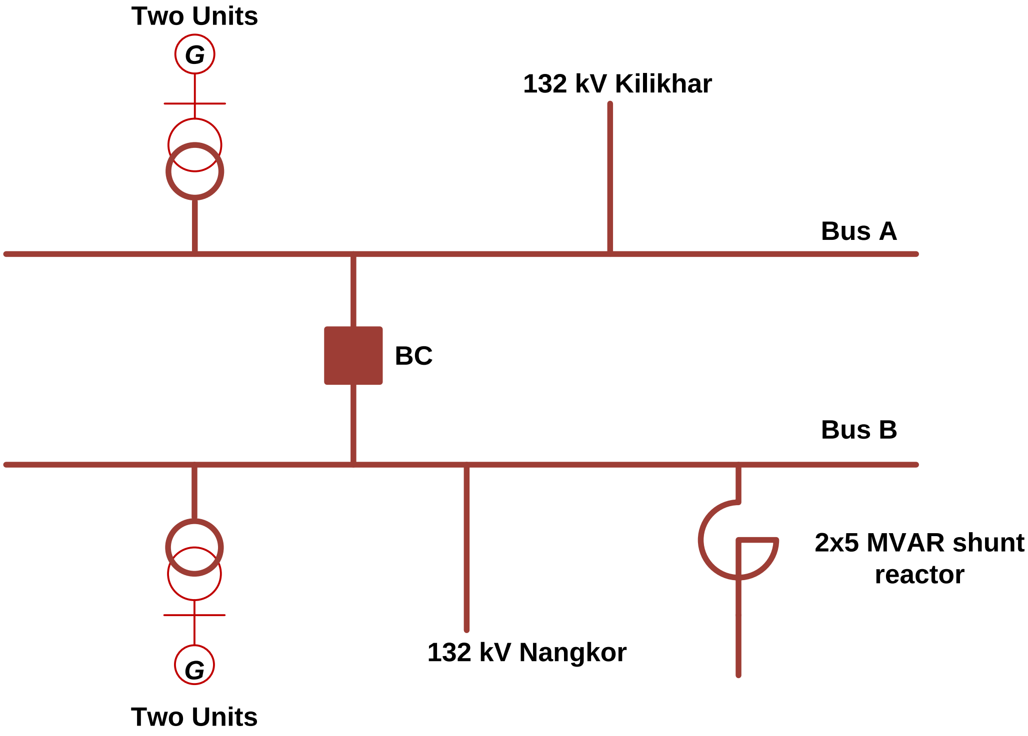

Figure 4-11 Bus Configuration of KHP

4.12 400/220 kV Jigmeling Substation

a. All tie breakers shall be kept closed when respective lines are in service, and it shall be kept open when only one line is in service.

b. The 400/220 kV LV side, 220 kV Jigmeling - Tsirang line along with 63/80 MVA, 220/132 kV ICT - II shall be connected to Bus A.

c. The 220 kV Jigmeling – Dagapela line and 63/80 MVA, 220/132 kV ICT – I shall be connected to Bus B.

d. The 220 kV bus coupler shall be kept Closed.

e. The 132 kV Bus scheme is main with transfer scheme. The 132 kV Tintibi and Gelephu lines shall be kept in same bus.

[3] Physically, there are 2x5 MVAR shunt reactors. However, only one shunt reactor can be put in service as both reactors shares one circuit breaker (CB).

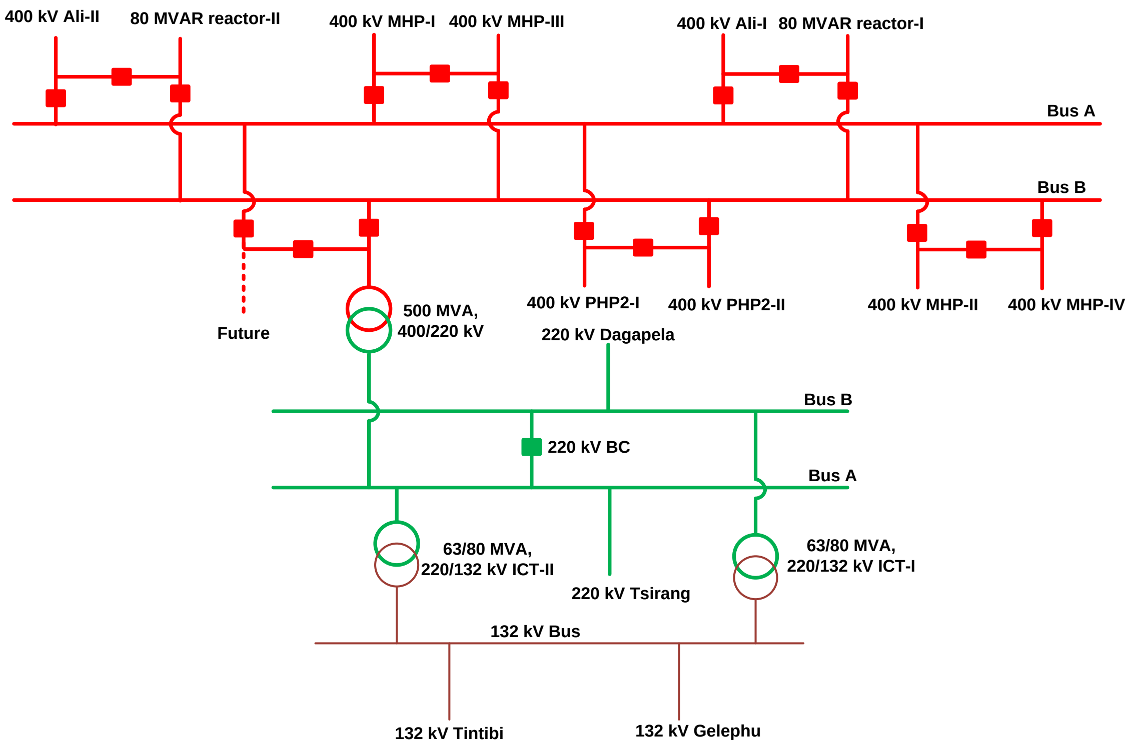

Figure 4-12 Bus Configuration of 400kV Jigmeling Substation

4.13 132 kV Nikachhu

f. One generating unit and one of the 132 kV MHP line shall be kept in Bus A.

g. Similarly, another generating unit and 132 kV MHP line shall be kept in Bus B.

h. The 132 kV bus coupler shall be kept closed.

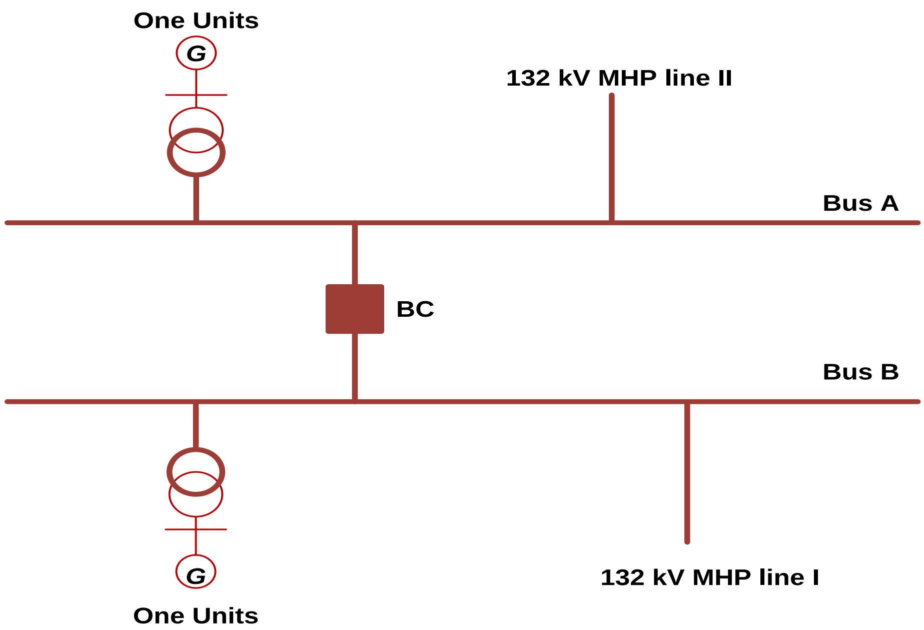

Figure 4-13 Bus Configuration of Nikachhu Hydropower Plant

5 SYSTEM UNDER NORMAL CONDITION

Under normal condition, the system for the western grid will be kept as follows irrespective of the seasons:

a. Both the 66 kV Jamjee – Jemina – Changedaphu - Olakha - Semtokha line, 220 kV CHP – Jamjee lines, and 220 kV Jamjee - Semtokha shall be in service to form a ring.

b. Both the 66 kV BHP_LS – Gewathang – Lobeysa – Dochhula - Semtokha line and 220 kV BHP_LS - Semtokha line shall be in service to form a ring.

c. The 66 kV CHP – Gedu – Phuentsholing - Gomtu - Samtse and 220 kV Samtse – Malbase – Gedu - CHP shall be kept in ring.

d. The 132 kV KHP – Kilikhar – Corlung – Kanglung - Phuntshothang line and 132 kV KHP – Nangkor – Deothang – Motanga - Phuntshothang line shall be kept in ring.

e. The eastern and western grid shall be kept connected via 220 kV Tsirang - Jigmeling line.

f. During the peak seasons, all the international lines shall be kept in service. However, during the lean seasons, some international lines shall be kept OPEN/CLOSE as per system requirement.

6 CONTINGENCIES AND OPERATING PROCEDURES FOR PEAK GENERATION

The contingencies during the peak generation were identified through simulation in PSSE software. The N-1 and N-2 contingencies scenarios were derived, and the restoration procedures are framed to be used by operators during real-time operation.

6.1 Failure of 66 kV Olakha – Semtokha line

During the failure/tripping of 66 kV Olakha – Semtokha line, 66 kV Jamjee – Jemina, and 2x30 MVA 220/66 kV transformers at Jamjee will overload and trip. This will result in supply interruption and blackouts at Jemina, Changedaphu, Olakha, Paro, Pangbisa, and Haa susbtations.

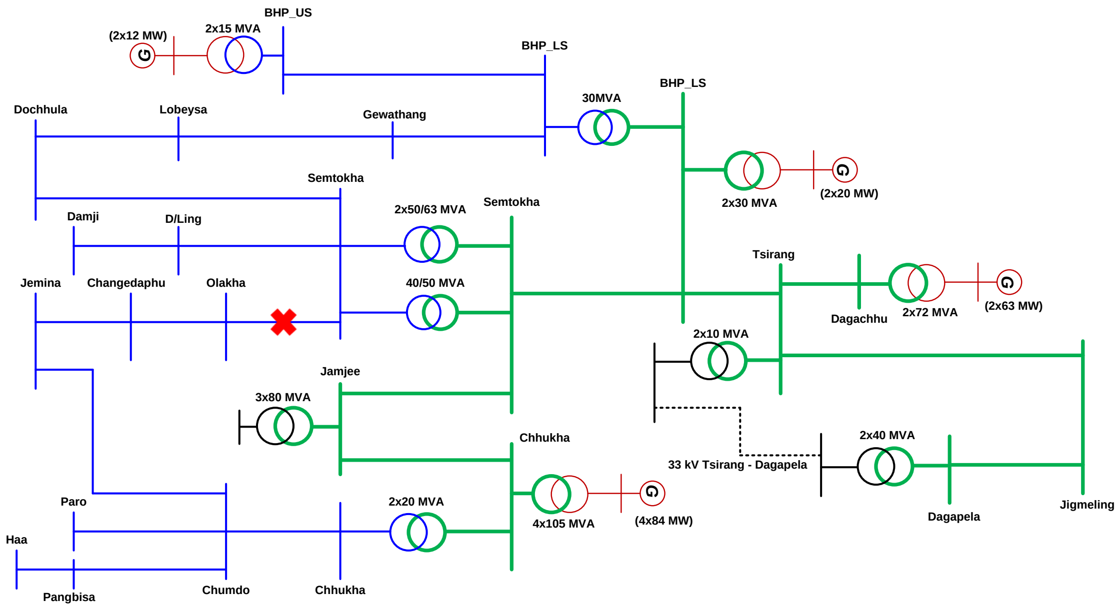

Figure 6-1 Failure of 66 kV Semtokha – Olakha line during peak generation

6.1.1 Normal Restoration Process:

a. Manually open 66 kV Olakha – Changedaphu line at Olakha end[4].
b. Close 2x30 MVA transformers at Jamjee substation.
c. Close 66 kV Olakha – Semtokha line.
d. Close 66 kV Olakha – Changedaphu line.
e. Close 66 kV Jamjee – Jemina line.

6.1.2 Restoration Process during Permanent Fault:

a. Some of the domestic load must be reduced to the carrying capacity of Jamjee transformers until the line is restored.

[4] This is to avoid the overloading of 220/66 kV transformers at Semtokha substation.

b. Follow the process in (6.1.1) d to e.

6.2 Failure of 66 kV Semtokha – Dochhula line

The failure/tripping of 66 kV Semtokha – Dochhula line will result in overloading 220/66 kV 30 MVA ICT at BHP and 66 kV BHP – Gewathang – Lobeysa – Dochhula. And BHP upper stage generators (Units) will also trip.

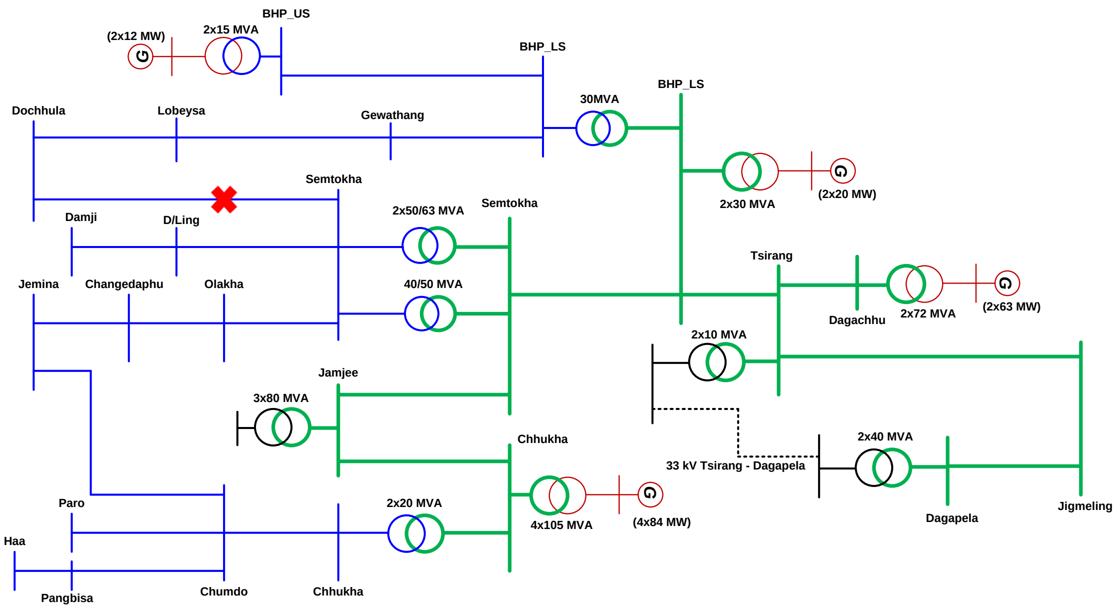

Figure 6-2 Failure of 66 kV Semtokha – Dochhula line during peak generation

6.2.1 Normal Restoration Process:

a. Close 66 kV Semtokha – Dochhula line followed by 66 kV Dochhula – Lobeysa – Gewathang – BHP lines.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Synchronize the BHP upper stage units.

6.2.2 Restoration Process during Permanent Fault:

a. Open the 66 kV Dochhula – Lobeysa line.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Close 66 kV BHP – Gewathang – Lobeysa line.
d. Synchronize the BHP upper stage units.
e. Close 66 kV Lobeysa - Dochhula line and maintain load to the capacity of 66 kV BHP – Gewathang line.

6.3 Failure of any of the 220/66 kV transformer at Semtokha substation

The failure/tripping of the any of the 220/66 kV transformer at Semtokha substation, the remaining two transformers and the 66 kV BHP – Gewathang line will get overloaded. However, the remaining transformers will not trip until it reaches the overloading setting.

Therefore, System Operator shall instruct to reduce the Dochhula load and maintain to the loading capacity of the other transformers and the 66 kV BHP – Gewathang line.

6.4 Failure of 66 kV Lobeysa – Gewathang – BHP line

The failure of any section of the 66 kV Lobeysa – Gewathang – BHP line, there will be overloading of 66 kV Semtokha – Dochhula line.

System Operator shall instruct to reduce the Dochhula load and maintain the loading capacity of 66 kV Semtokha – Dochhula line.

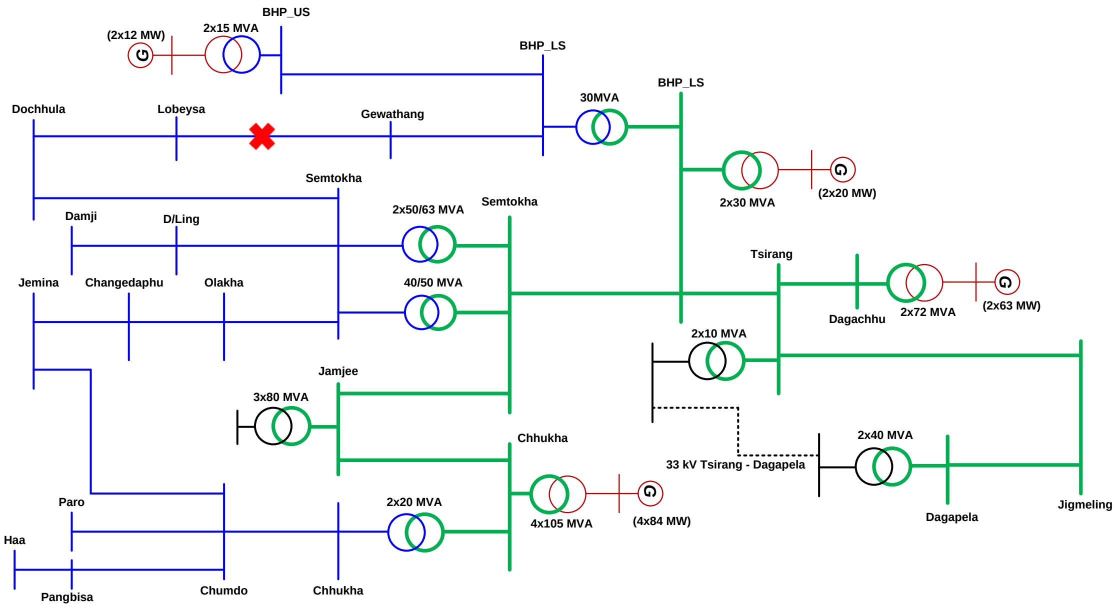

Figure 6-3 Failure of 66 kV Lobeysa – Gewathang or 66 kV Gewathang - BHP line during peak generation

6.5 Failure of 220 kV Semtokha – BHP line

The failure/tripping of 220 kV Semtokha – BHP line will result in overloading of 220/66 kV 30 MVA ICT and 66 kV BHP – Gewathang – Lobeysa line, and trip. However, to avoid the overloading and cascading tripping, inter-tripping of 30 MVA ICT during failure of 220 kV Semtokha – BHP line was implemented. The BHP lower stage and BHP upper stage generation will flow via 220 kV BHP – Tsirang line and via 66 kV BHP – Gewathang line, respectively.

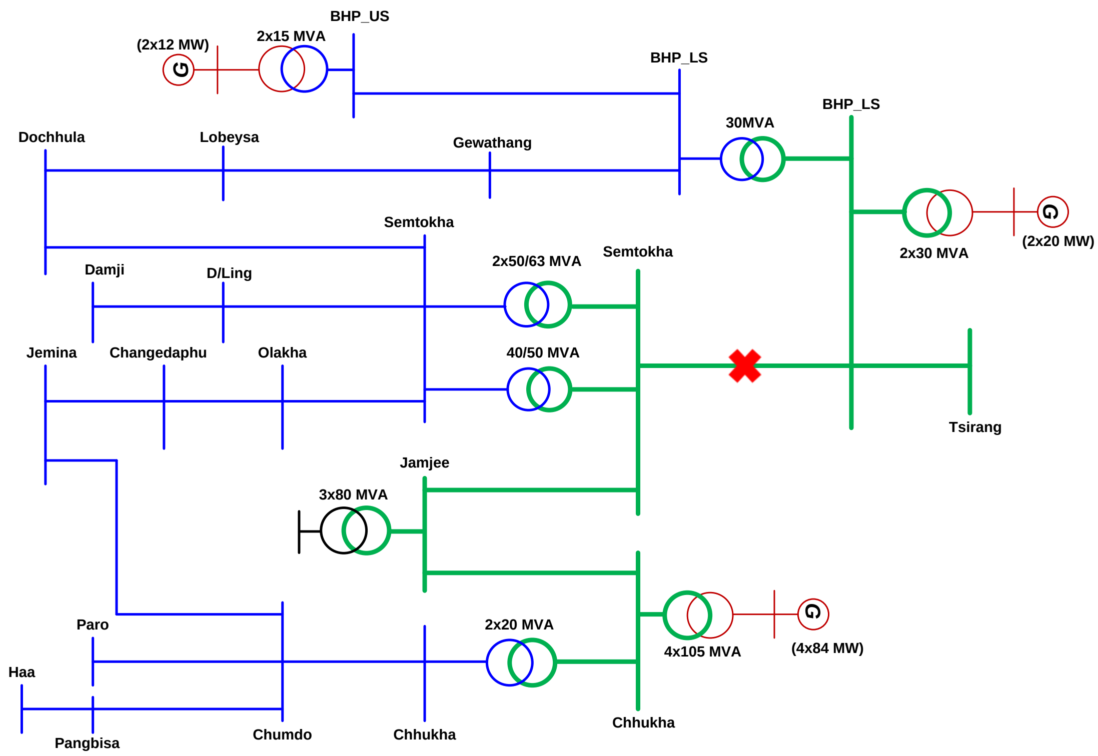

Figure 6-4 Failure of 220 kV Semtokha – BHP line during peak generation

6.5.1 Normal Restoration Process:

a. Close 220 kV Semtokha – BHP line.
b. Close 220/66 kV 30 MVAT ICT.

6.5.2 Restoration Process during Permanent Fault:

a. 220/66 kV 30 MVA ICT shall be kept open until the 220 kV Semtokha – BHP line is rectified.
b. Close 220 kV Semtokha – BHP line after rectification.
c. Close 220/66 kV 30 MVAT ICT.

6.6 Failure of 220 kV Jigmeling – Dagapela line

During the failure of 220 kV Jigmeling – Dagapela line, the load connected to Dagapela substation will be affected. The following procedures shall be followed.

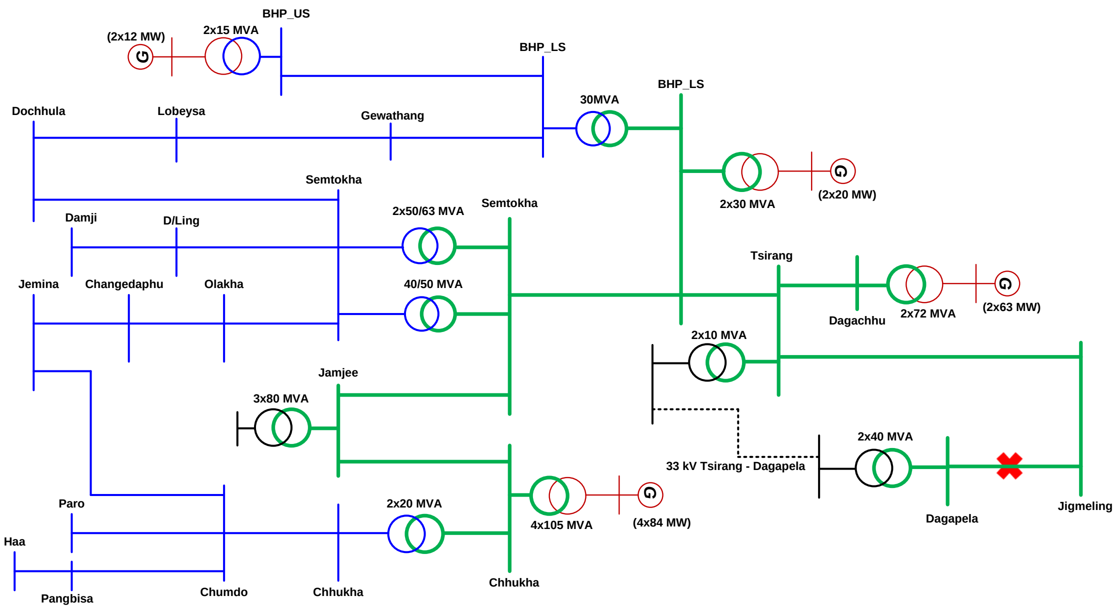

Figure 6-5 Failure of 220 kV Jigmeling – Dagapela line during peak generation

6.6.1 DHP Generation > load connected at Dagapela

a. Dagachhu units shall be shut down to switch over from 220 kV DHP – Tsirang to 220 kV DHP – Dagapela line.
b. Open 220 kV Jigmeling – Dagapela line at Jigmeling end.
c. Close 220 kV DHP – Dagapela line at Dagapela end followed by DHP.
d. Close 33 kV Tsirang – Dagapela line and synchronize DHP units.
e. Dagapela load will be fed from DHP end.
f. DHP generation must maintained according to Dagapela load and line loading capacity of 33 kV Tsirang – Dagapela line.

6.6.2 DHP Generation < connected load of Dagapela

a. Dagachhu units shall be shut down in order to switch over from 220 kV DHP – Tsirang to 220 kV DHP – Dagapela line.
b. Open 220 kV Jigmeling – Dagapela line at both ends.
c. Close 33 kV Tsirang – Dagapela line.
d. Close 220 kV DHP – Dagapela line at Dagapela end followed by DHP and synchronize DHP units.
e. Dagapela load must maintained according to available DHP generation and carrying capacity of 33 kV Tsirang – Dagapela line.

6.7 Overloading of 132 kV MHP – Yurmo line

During summer season, there is overloading of 132 kV MHP – Yurmo line. To avoid cascading tripping from the overloading of the said line, the 132 kV Yurmo – Tintibi line shall be kept open, continuously.

6.8 Failure of 220 kV Gedu – CHP and 220 kV Semtokha – BHP line

During the tripping/failure of 220 kV Gedu – CHP and 220 kV Semtokha – BHP lines, there will be overloading of 66 kV BHP – Gewathang – Lobeysa line and 220/66 kV 30 MVA ICT at BHP. The ICT will trip on inter-tripping scheme, avoiding the overloading of the 66 kV line from BHP till Lobeysa.

6.9 Failure of 220 kV Malbase – Singhigoan and 220 kV Malbase – Samtse lines

During the failure/tripping of these two lines, there will be overloading of 66 kV Malbase – P/ling – Gomtu – Samtse line, causing blackout in Singhigoan, Gomtu, and Samtse substations.

6.9.1 Normal Restoration Process

a. Close 220 kV Malbase – Singhigoan line.
b. Close 220 kV Malbase – Samtse line.

6.9.2 Restoration Process during Permanent Fault:

In case of permanent fault in 220 kV Malbase – Singhigoan and 220 kV Malbase – Samtse line, the load feeding from the Singhigoan shall be disconnected.

a. Disconnect the outgoing 66 kV lines from Singhigoan until lines are rectified.
b. Follow restoration process in (6.9.1) a to b.

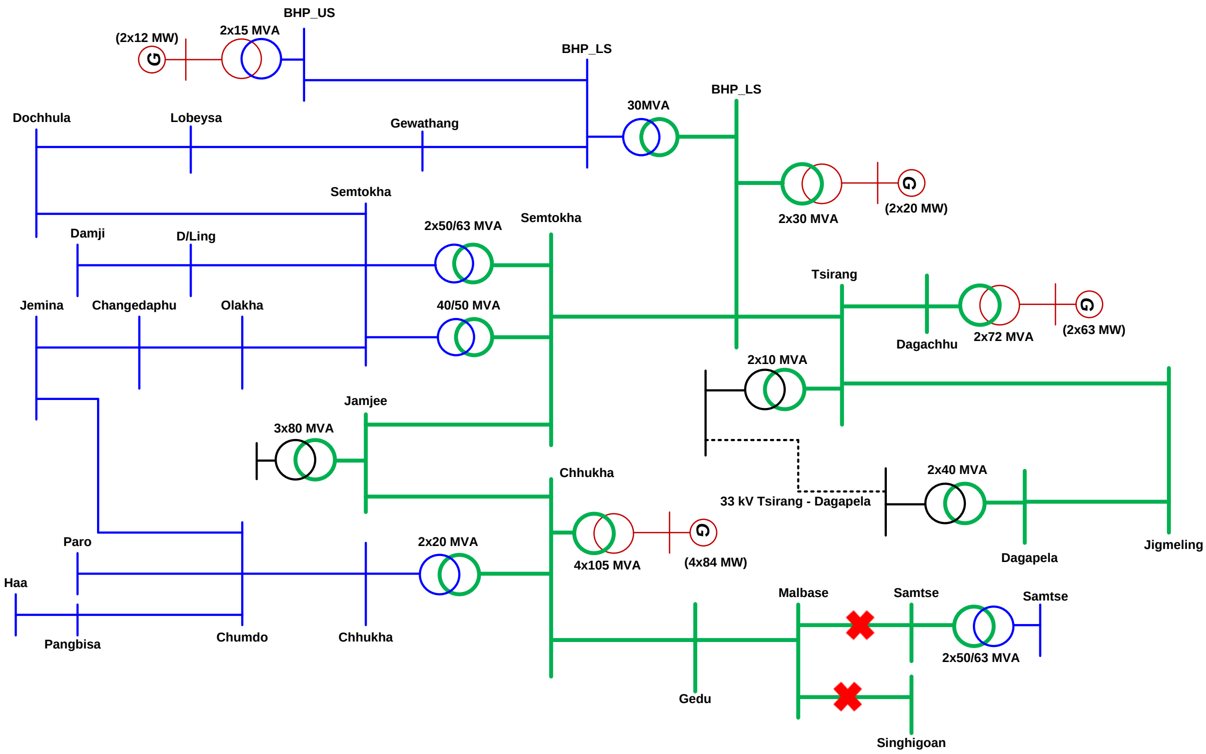

Figure 6-6 Failure of 220 kV Malbase – Singhigoan and 220 kV Malbase – Samtse lines during peak generation

6.10 Failure of 220 kV Semtokha – BHP and 220 kV BHP – Tsirang

During the failure/tripping of 220 kV Semtokha – BHP and 220 kV BHP – Tsirang line, the 220/66 kV 30 MVA ICT at BHP will trip on inter-tripping scheme. The BHP lower stage generating units will get isolated and trip.

6.10.1 Normal Restoration Process

a. Close 220 kV BHP – Tsirang line.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Close 220 kV Semtokha – BHP line.

6.10.2 Restoration Process during Permanent Fault:

a. Disable the inter-tripping scheme of 30 MVA ICT and close.
b. Synchronize BHP generators.
c. Maintain the BHP lower stage generation to 28 MW until the lines are restored. Considering 0.95 power factor, 30 MVA ICT can cater 28 MW.

After rectification

d. Close 220 kV BHP – Semtokha line.
e. Close 220 kV BHP – Tsirang line.

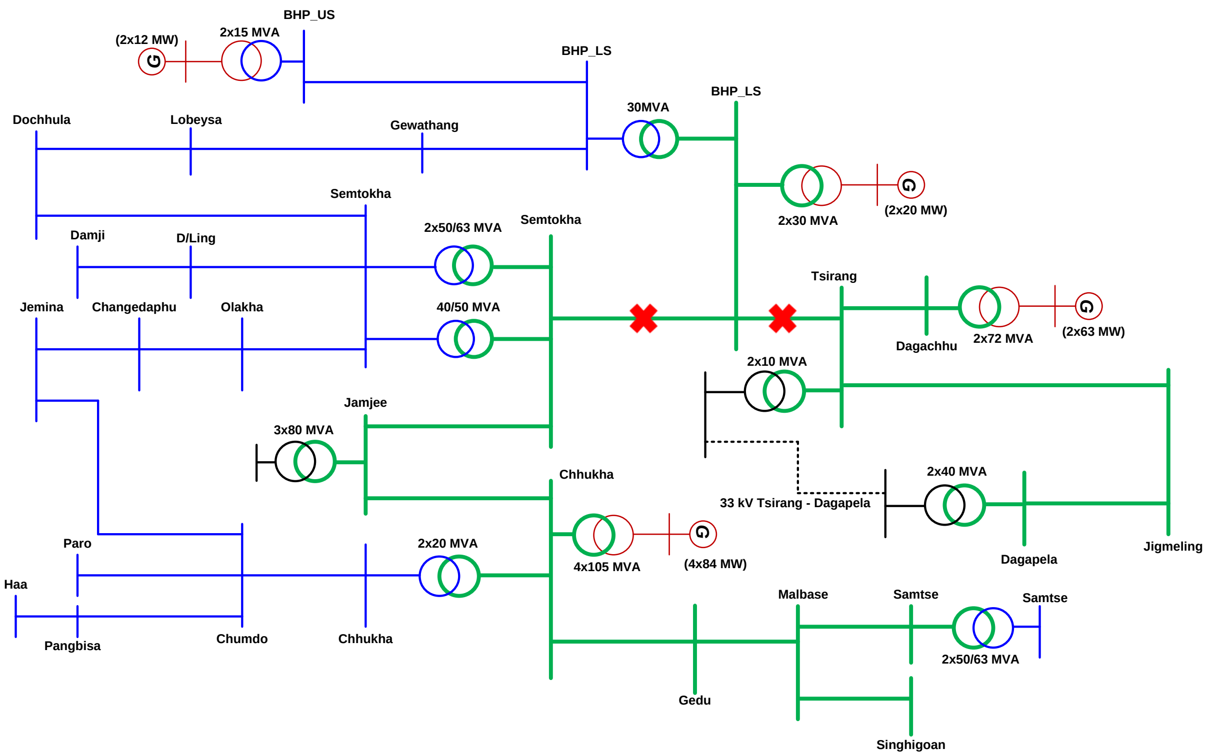

Figure 6-7 Failure of 220 kV Semtokha – BHP and 220 kV BHP – Tsirang lines during peak generation

6.11 Failure of 220 kV Semtokha – BHP and 220 kV Tsirang - Jigmeling

During the failure/tripping of 220 kV Semtokha – BHP and 220 kV Tsirang – Jigmeling lines, 220/66 kV 30 MVA ICT at BHP will trip on inter-tripping scheme. The BHP lower stage and DHP generating units tripped, resulting in supply interruption in Tsirang.

6.11.1 Normal Restoration Process

a. Close 220 kV Tsirang – Jigmeling line. The power supply in Tsirang will be restored.
b. Synchronize DHP generators.
c. Synchronize BHP lower stage generators. The generation of BHP lower stage will flow via 220 kV BHP – Tsirang line.
d. Close 220 kV Semtokha – BHP line.
e. Close 220/66 kV 30 MVA ICT.

6.11.2 Restoration Process during Permanent Fault:

a. Disable the inter-tripping scheme of 30 MVA ICT and close.
b. Synchronize BHP generators.
c. Maintain the BHP lower stage and upper stage generation equivalent to carrying capacity of 66 kV BHP – Gewathang – Lobeysa line and load of Tsirang.
d. 220 kV DHP – Tsirang line shall open and switch over to 220 kV DHP – Dagapela line.
e. After all lines are restored, increase the BHP generations.

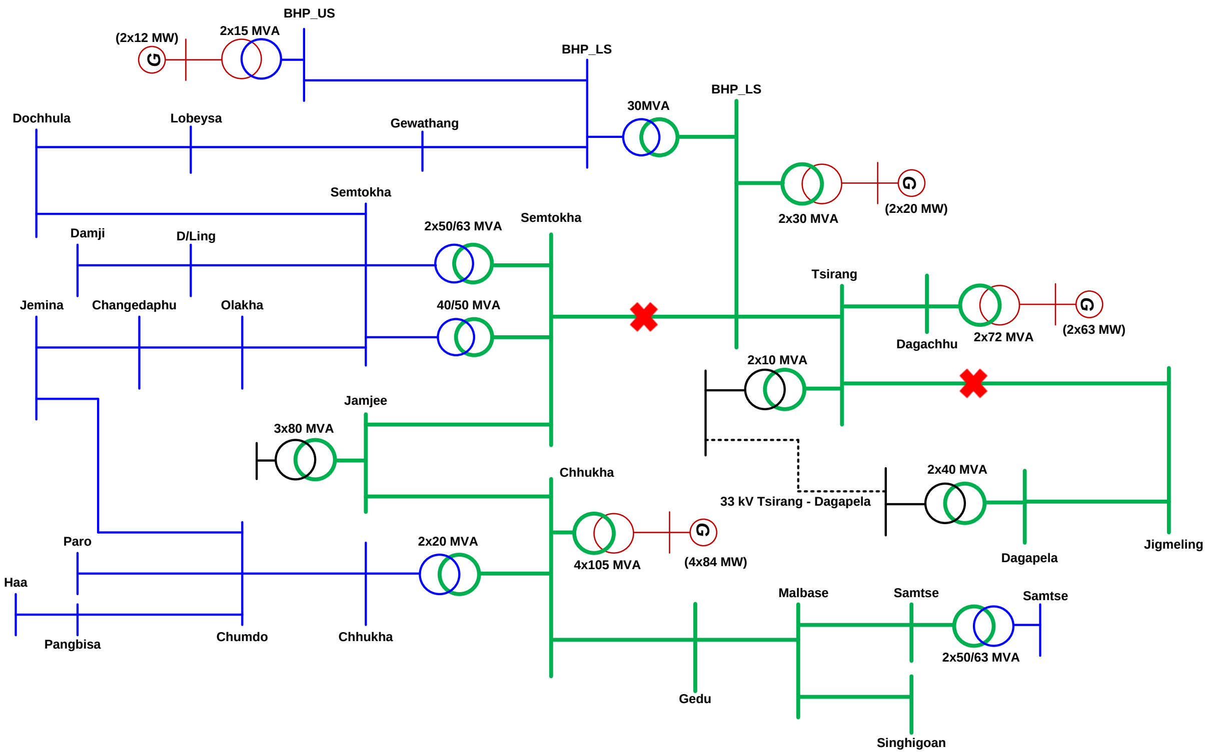

Figure 6-8 Failure of 220 kV Semtokha – BHP and 220 kV Tsirang - Jigmeling lines during peak generation

6.12 Failure of 220 kV CHP – Jamjee line II & III

The failure/tripping of 220 kV D/C line from CHP – Jamjee will result in overloading of the 220 kV CHP – Jamjee line I.

The System Operator shall instruct to open the 220 kV Semtokha – Jamjee line. If overloading persists, the load shedding shall be carried out at Jamjee.

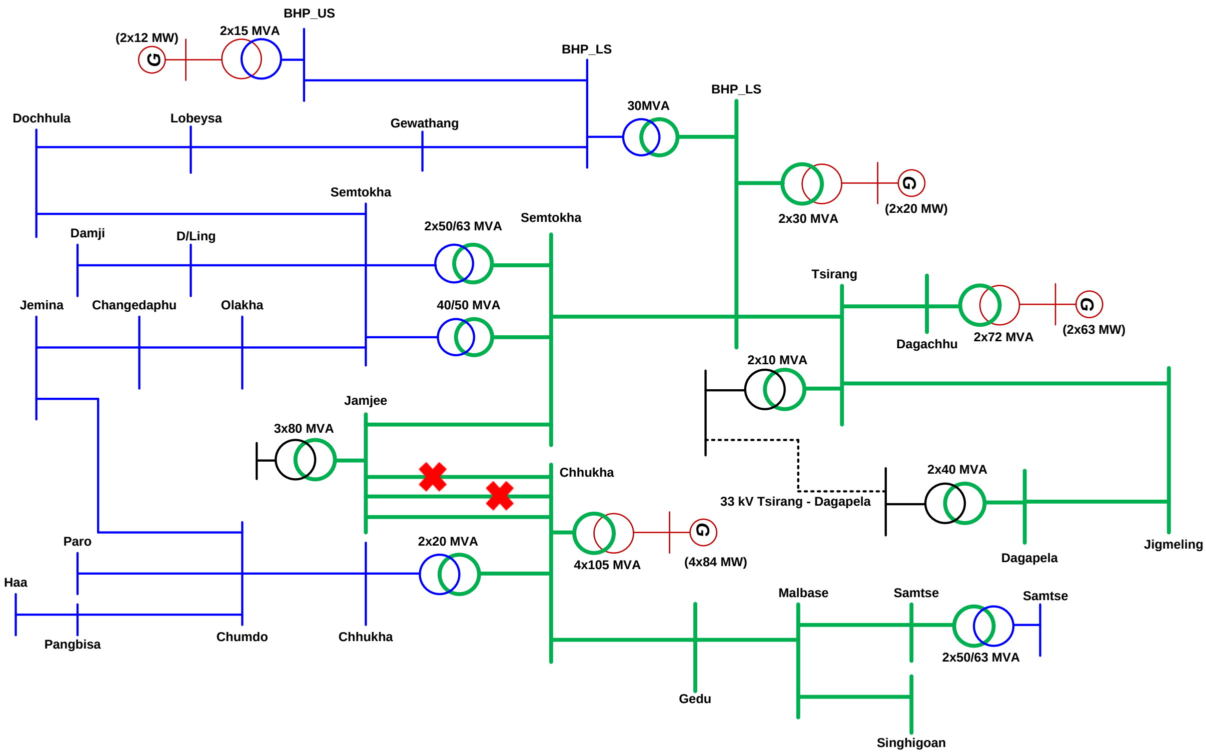

Figure 6-9 Failure of 220 kV CHP – Jamjee line II & III during peak generation

7 CONTINGENCIES AND OPERATING PROCEDURES FOR LEAN GENERATION

During the lean hydro generation, the power deficit is being imported from India. The power flow direction in lean generation is completely opposite from peak generation which necessitates the separate contingency plan and operating procedures. Various contingencies were derived from the contingency simulation using PSSE software and accordingly, the best restoration procedures were framed.

7.1 Failure of 66 kV Olakha – Semtokha line

During the failure of 66 kV Olakha – Semtokha line, 66 kV Jamjee – Jemina, and 2x30 MVA 220/66 kV transformers at Jamjee will overload and trip. This will result in supply interruption and blackouts at Jemina, Changedaphu, Olakha, Paro, Pangbisa, and Haa susbtations.

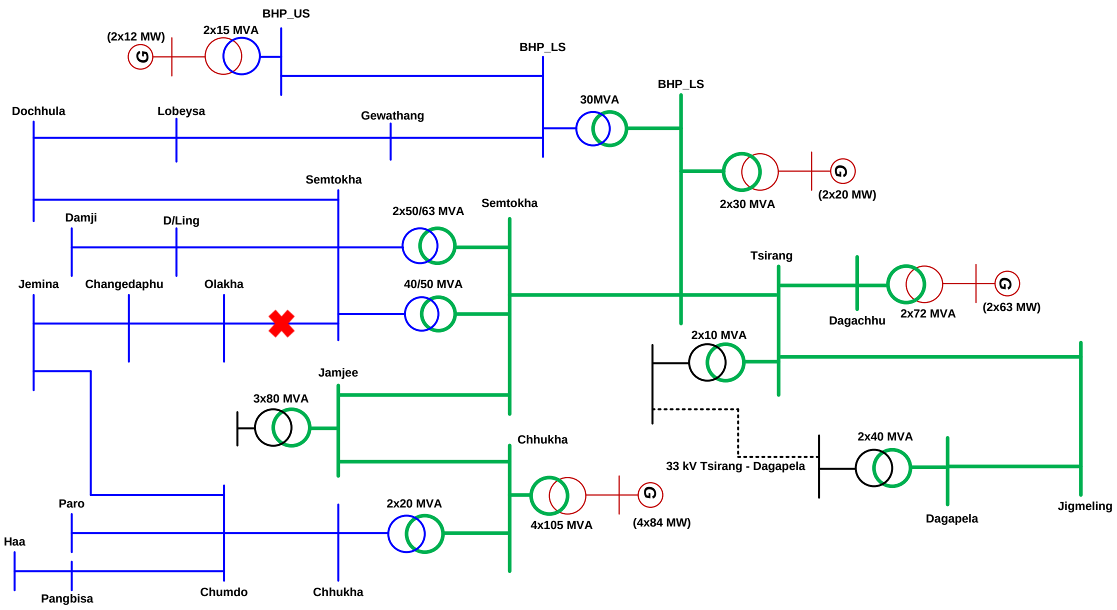

Figure 7-1 Failure of 66 kV Semtokha – Olakha line during lean generation

7.1.1 Normal Restoration Process:

a. Manually open 66 kV Olakha – Changedaphu line at Olakha end[6].
b. Close 2x30 MVA transformers at Jamjee substation.
c. Close 66 kV Olakha – Semtokha line.
d. Close 66 kV Olakha – Changedaphu line.
e. Close 66 kV Jamjee – Jemina line.

7.1.2 Restoration Process during Permanent Fault:

a. Some of the domestic load must be reduced to the capacity of Jamjee transformers (58 MW)

7.2 Failure of 66 kV Semtokha – Dochhula line

The failure of 66 kV Semtokha – Dochhula line will result in overloading 220/66 kV 30 MVA ICT at BHP and 66 kV BHP – Gewathang – Lobeysa – Dochhula. And BHP upper stage generators (Units) will also trip.

[6] This is to avoid the overloading of 220/66 kV transformers at Semtokha substation.

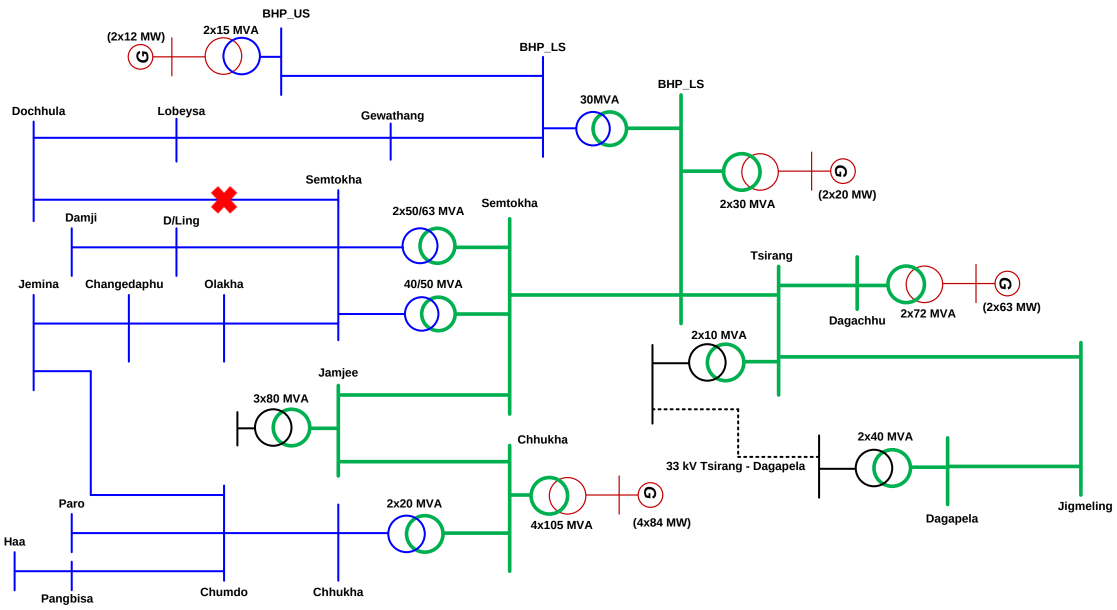

Figure 7-2 Failure of 66 kV Semtokha – Dochhula line during lean generation

7.2.1 Normal Restoration Process:

a. Close 66 kV Semtokha – Dochhula line followed by 66 kV Dochhula – Lobeysa – Gewathang – BHP lines.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Synchronize the BHP upper stage units.

7.2.2 Restoration Process during Permanent Fault:

a. Open the 66 kV Dochhula – Lobeysa line.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Close 66 kV BHP – Gewathang – Lobeysa line.
d. Synchronize the BHP upper stage units.
e. Close 66 kV Lobeysa - Dochhula line and maintain load to the capacity of 66 kV BHP – Gewathang line.

7.3 Failure of 66 kV Lobeysa – Gewathang – BHP line

Failure of any section of 66 kV Lobeysa – Gewathang – BHP line, there will be overloading of 66 kV Semtokha – Dochhula line.

System Operator shall instruct to reduce the Dochhula load and maintain the loading capacity of 66 kV Semtokha – Dochhula line.

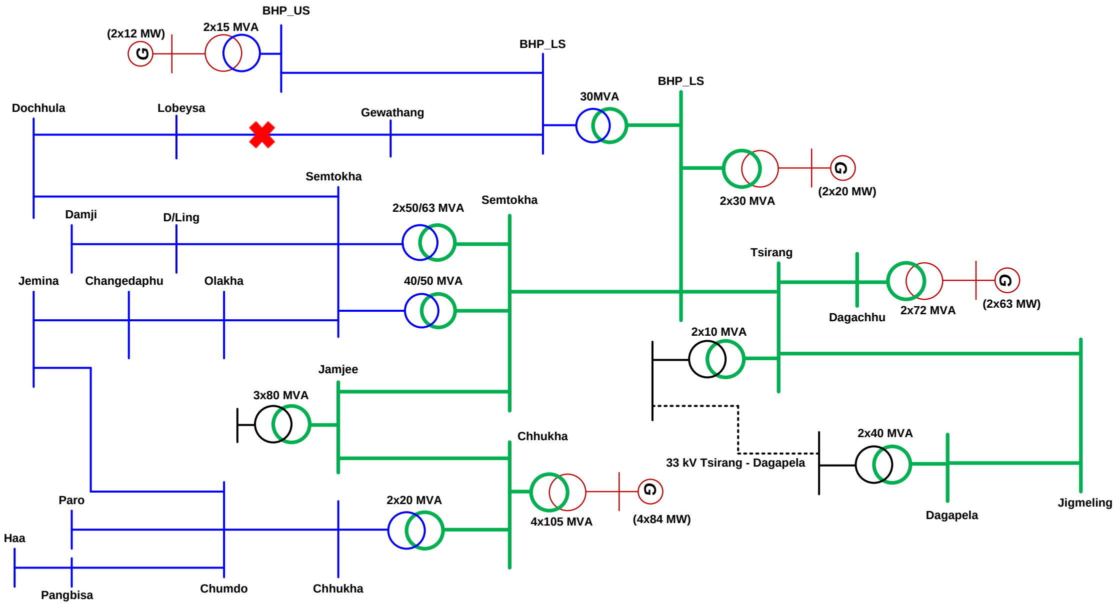

Figure 7-3 Failure of 66 kV Lobeysa – Gewathang or 66 kV Gewathang - BHP line during lean generation

7.4 Failure of 400/220 kV 300 MVA ICT at Malbase substation

Failure of 400/220 kV 300 MVA ICT at Malbase substation will result in overloading of 400/220 kV 200 MVA ICT. System Operator shall instruct to reduce the load at 220 kV Gedu substation and maintain the loading of 200 MVA ICT at 180 MW considering the 0.9 power factor (pf).

7.4.1 Normal Restoration Process:

a. Close the 300 MVA ICT.

7.4.2 Operating Procedures during Permanent Fault:

a. Load shedding at 220 kV Gedu substation.
b. Maintain the power flow in 200 MVA ICT at Malbase to 180 MW.

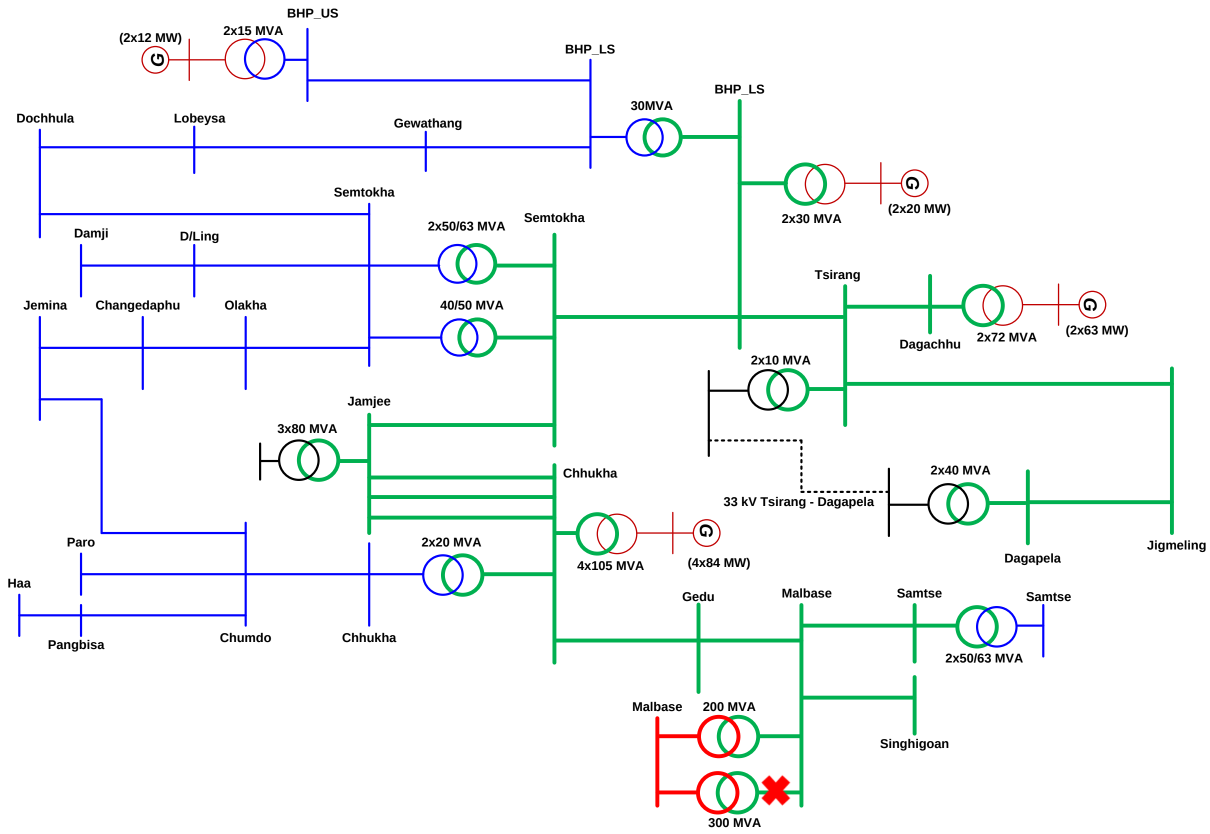

Figure 7-4 Failure of 400/220 kV 300 MVA ICT at Malbase during lean generation

7.5 Failure of 220 kV Semtokha – BHP line

During the failure/tripping of 220 kV Semtokha – BHP line, 30 MVA ICT will trip on inter-tripping scheme. The 220 kV Malbase – Gedu line will be overloaded. System Operator shall immediately instruct to open the 220 kV Gedu – CHP line at Gedu end to avoid overloading of the 220 kV Malbase – Gedu line.

7.5.1 Normal Restoration Process:

a. Close 220 kV Semtokha – BHP line.
b. Close 30 MVA ICT at BHP.
c. Restore 220 kV CHP – Gedu line.

7.5.2 Restoration Process during Permanent Fault:

a. 220 kV Gedu – CHP line and 30 MVA ICT at BHP shall be kept open until 220 kV Semtokha – BHP line is rectified.
b. Follow normal restoration process in (7.5.1) after the 220 kV Semtokha – BHP line is rectified.

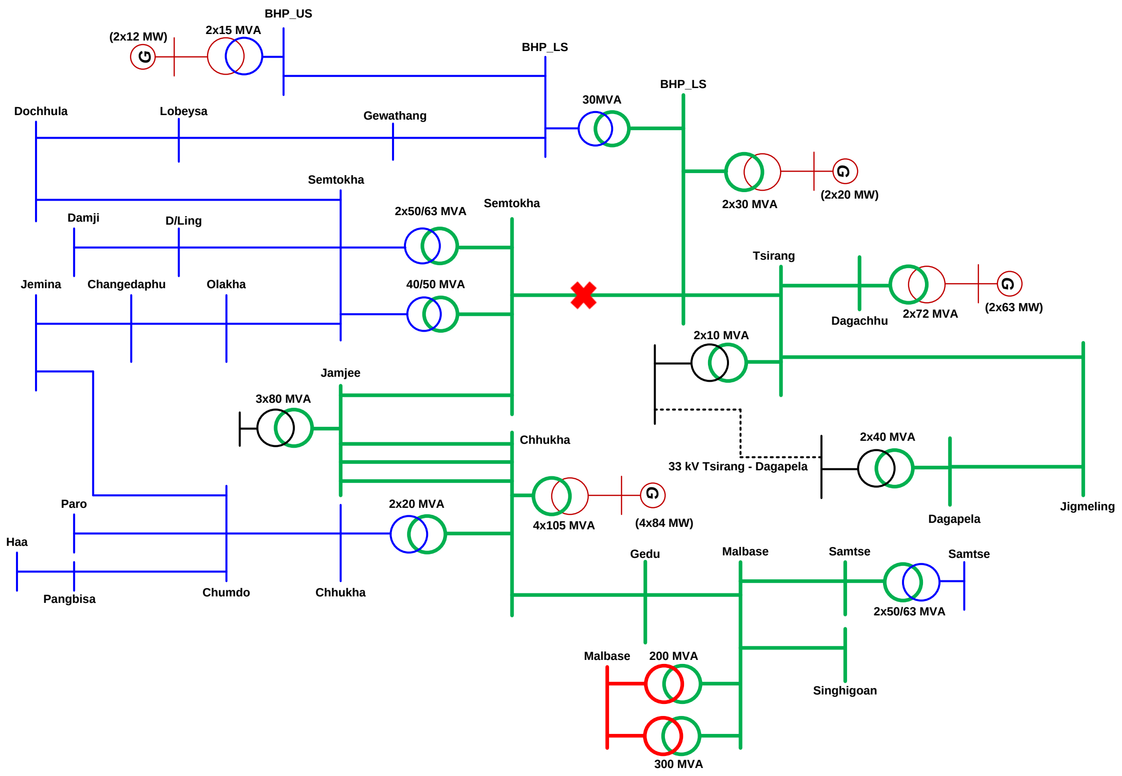

Figure 7-5 Failure of 220 kV Semtokha – BHP line during lean generation

7.6 Failure of any of the 220 kV BHP – Tsirang – Jigmeling line

The tripping of any of the line section from 220 kV BHP – Tsirang – Jigmeling, there will be overloading of 220 kV Malbase – Gedu line. System Operator shall immediately instruct to open the 220 kV Gedu – CHP line at Gedu end to avoid overloading of the 220 kV Malbase – Gedu line.

7.6.1 Normal Restoration Process:

a. Close any of the tripped line in 220 kV BHP – Tsirang – Jigmeling section.
b. Close 220 kV Gedu – CHP line.

7.6.2 Restoration Process during Permanent Fault:

a. 220 kV Gedu – CHP line shall be kept open until tripped line is rectified.
b. Close the tripped line in 220 kV BHP – Tsirang – Jigmeling section after rectification.
c. Close 220 kV Gedu – CHP line.

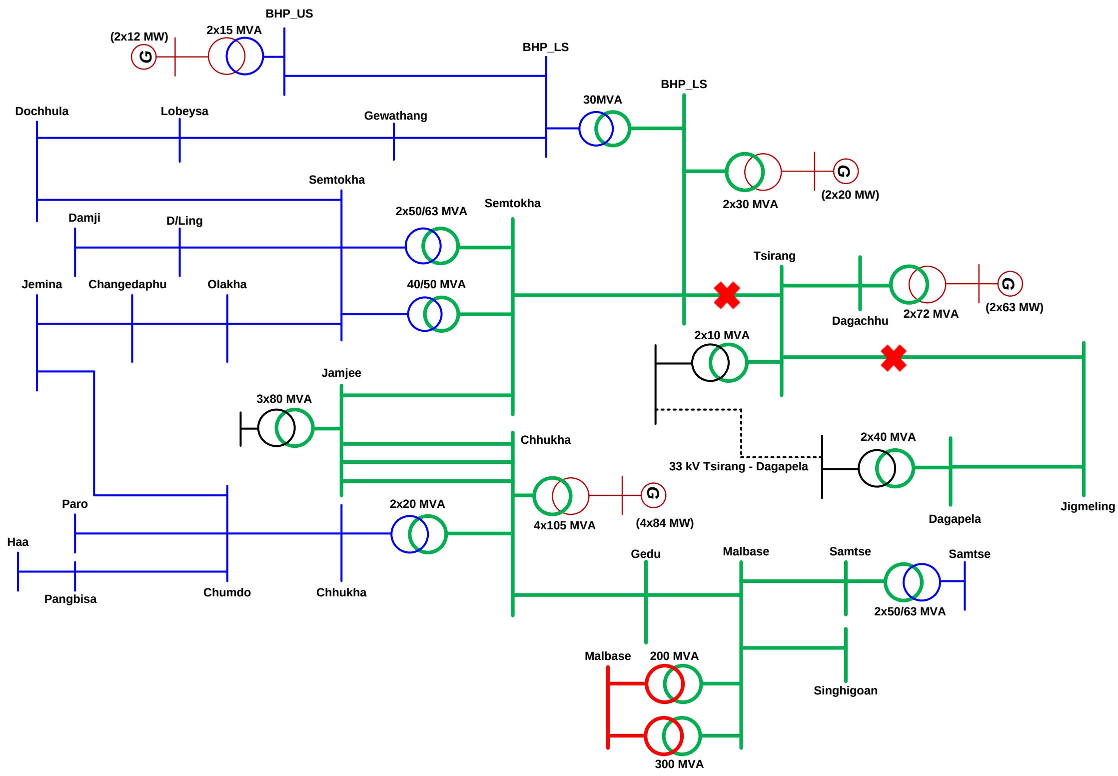

Figure 7-6 Failure of 220 kV BHP – Tsirang - Jigmeling lines during lean generation

7.7 Failure of 400/220 kV 500 MVA ICT at Jigmeling substation

During the failure of 400/220 kV 500 MVA ICT at Jigmeling substation, there will be overloading of 220 kV Malbase – Gedu line and 132 kV MHP – Yurmo line. The System Operator shall immediately instruct to open the 220 kV Gedu – CHP line at Gedu end to avoid the overloading of 220 kV Malbase – Gedu. Also, the 132 kV Yurmo – Tintibi line will be open.

7.7.1 Normal Restoration Process:

a. Close 400/220 kV 500 MVA ICT at Jigmeling.
b. Close 220 kV Gedu – CHP line.
c. Close 132 kV Yurmo – Tintibi line.

7.7.2 Operating Procedures during Permanent Fault:

a. 220 kV Gedu – CHP line and 132 kV Yurmo – Tintibi line shall be kept open until the restoration of 500 MVA ICT.
b. Follow procedure in (7.7.1) after the restoration of 500 MVA ICT.

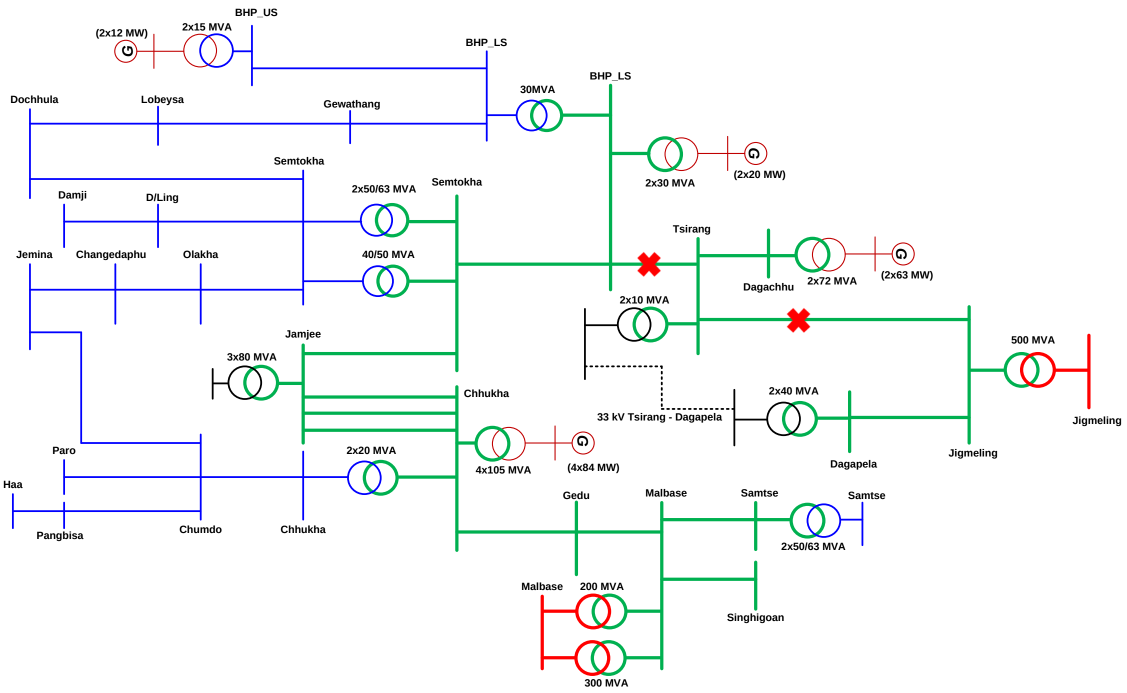

Figure 7-7 Failure of 400/220 kV 500 MVA ICT at Jigmeling during lean generation

7.8 Failure of any of the 220 kV CHP – Birpara lines

During the failure of any of the 220 kV CHP – Birpara line, there will be overloading of the 220 kV Malbase – Gedu line. The System Operator shall immediately instruct to open the 220 kV Gedu – CHP line at Gedu end.

7.8.1 Normal Restoration Process:

a. Close the tripped 220 kV CHP – Birpara line.
b. Close 220 kV Gedu – CHP line.

7.8.2 Operating Procedures during Permanent Fault:

a. 220 kV Gedu – CHP line shall be kept open until the tripped line is rectified.
b. Follow (7.8.1) after restoration of the tripped line.

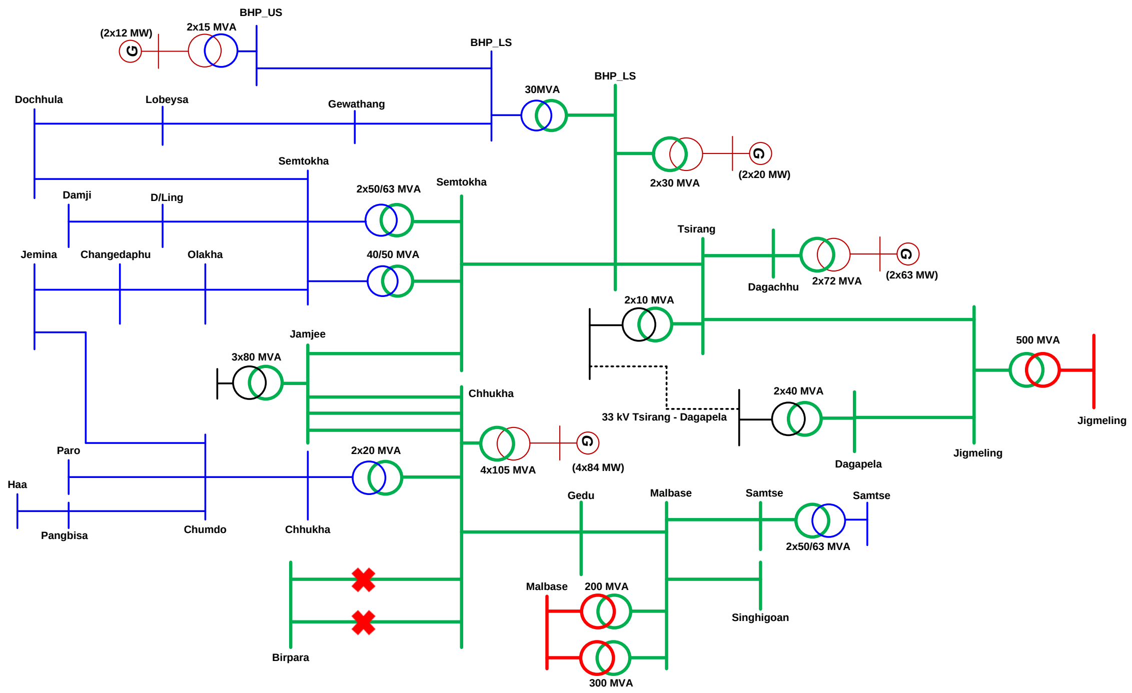

Figure 7-8 Failure of 220 kV CHP – Birpara line I & II during lean generation

7.9 Failure of any of the 220 kV CHP – Jamjee with 220 kV Semtokha – BHP line

During this N-2 contingency, there will be overloading of 220 kV Malbase – Gedu line and 220/66 kV 30 MVA ICT at BHP. The 30 MVA ICT will automatically trip on inter-tripping scheme.

The System Operator shall immediately instruct to open the 220 kV Gedu – CHP line at Gedu end.

7.9.1 Normal Restoration Process:

a. Close 220 kV Semtokha – BHP line.
b. Close 220/66 kV 30 MVA ICT at BHP.
c. Close 220 kV Gedu – CHP line.
d. Close 220 kV CHP – Jamjee (tripped line).

7.9.2 Operation procedures for Permanent Fault (shutdown together):

a. 220 kV Gedu – CHP line shall be kept open until the line is restored from the maintenance of tripping.
b. Follow (7.9.1) after the completion of maintenance or restored from the tripping.

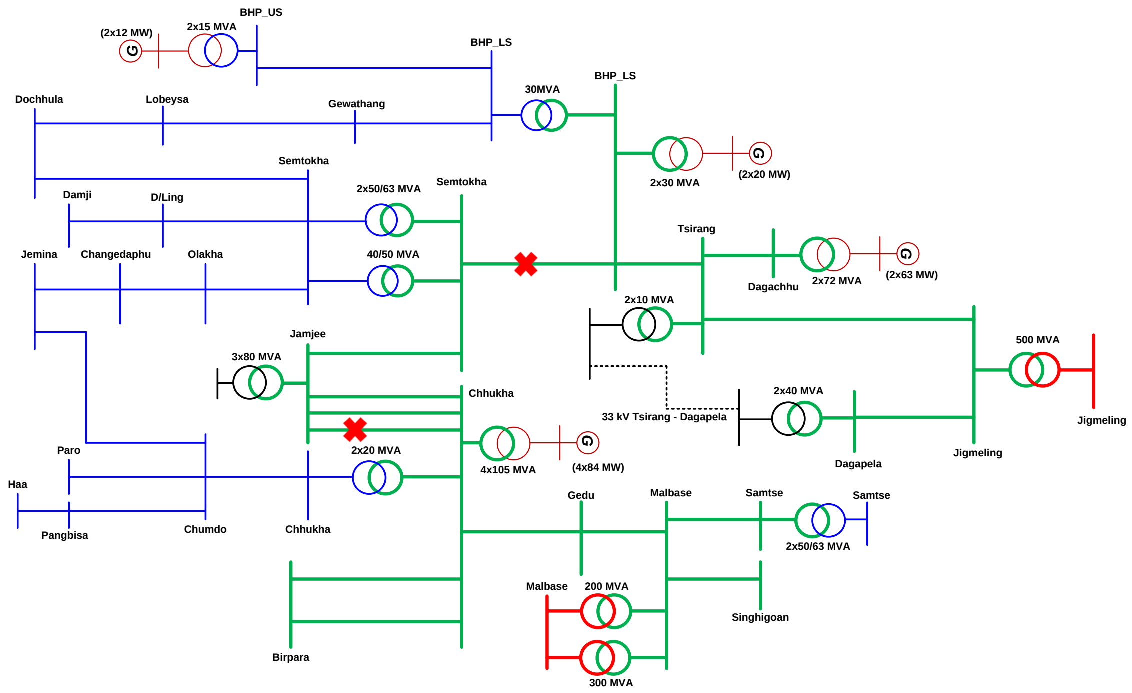

Figure 7-9 Failure of any of the 220 kV CHP – Jamjee and 220 kV BHP – Semtokha lines during lean generation

7.10 Failure of 220 kV Malbase – Singhigoan and 220 kV Malbase – Samtse lines

During the failure of these two lines, there will be overloading of 66 kV Malbase – P/ling – Gomtu – Samtse line, causing blackout in Singhigoan, Gomtu, and Samtse substations.

7.10.1 Normal Restoration Process

a. Close 220 kV Malbase – Singhigoan line.
b. Close 220 kV Malbase – Samtse line.

7.10.2 Operation procedures for Permant Fault

In case of permanent fault in 220 kV Malbase – Singhigoan and 220 kV Malbase – Samtse line, the load feeding from the Singhigoan shall be disconnected.

a. Disconnect the outgoing 66 kV lines from Singhigoan until lines are rectified.
b. Follow restoration process in (6.9.1) a to b.

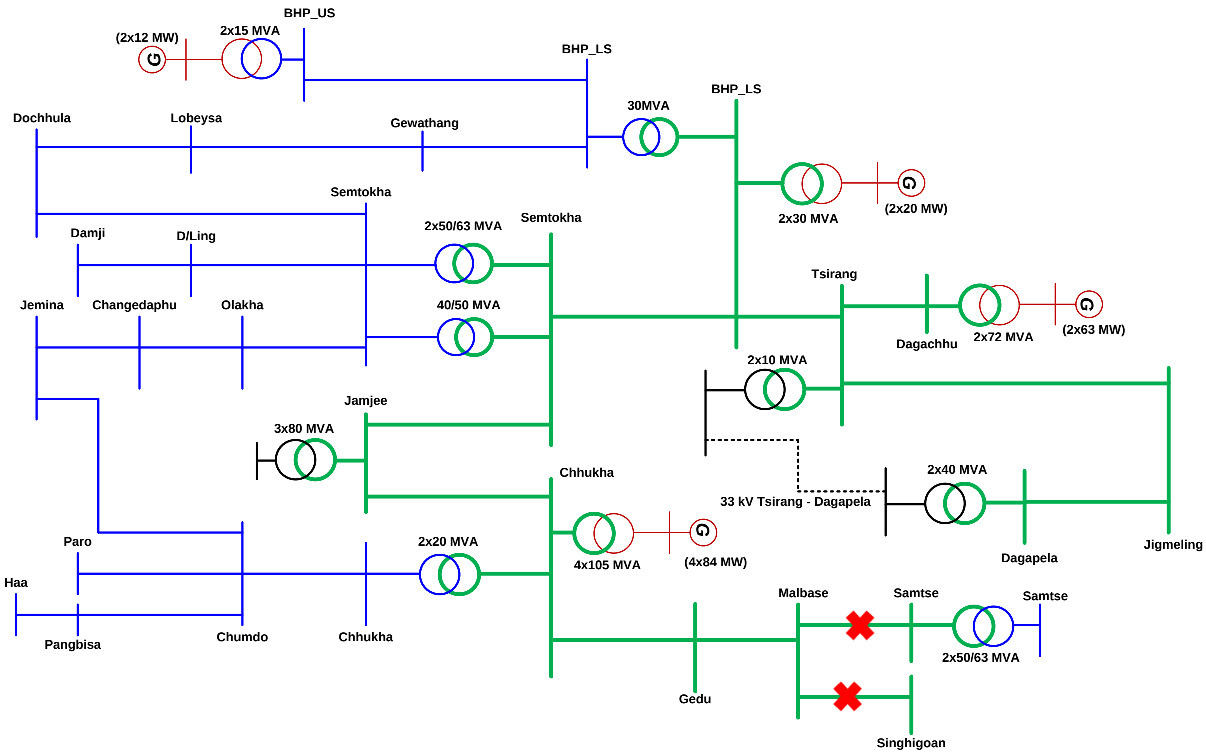

Figure 7-10 Failure of 220 kV Malbase – Samtse and 220 kV Malbase – Singhigoan lines during lean generation

7.11 Failure of 220 kV Semtokha – BHP and 220 kV Semtokha – Jamjee lines

During the tripping/failure of 220 kV Semtokha – BHP and 220 kV Semtokha – Jamjee lines, there will be widespread blackout affecting the Thimphu, Paro, Haa, Punakha, Gasa, and Wangdue regions. Also, BHP both upper and lower stage generating units will be trip.

7.11.1 Normal Restoration Process:

a. Close 220 kV Semtokha – Jamjee line.
b. Close 220 kV Semtokha – BHP line.
c. Close 220/66 kV 30 MVA ICT at BHP.
d. Close 66 kV BHP upper and lower stage line and synchronize the BHP upper stage units.

7.11.2 Operation procedures for Permanent Fault:

If 220 kV Semtokha – Jamjee line cannot be restored due to permanent fault;

a. Close 220 kV Semtokha – BHP line. The power supply in the affected regions will be restored.
b. Close 220/66 kV 30 MVA ICT at BHP.

If 220 kV Semtokha – BHP line cannot be restored due to permanent fault;

a. Close 220 kV Semtokha – Jamjee line. The power supply in the affected regions will be restored.
b. Disable inter-tripping scheme of 220/66 kV 30 MVA ICT at BHP and close.
c. Maintain the loading of 30 MVA ICT to 28 MW. If ICT is overloading, keep it open until 220 kV Semtokha – BHP line is restored.

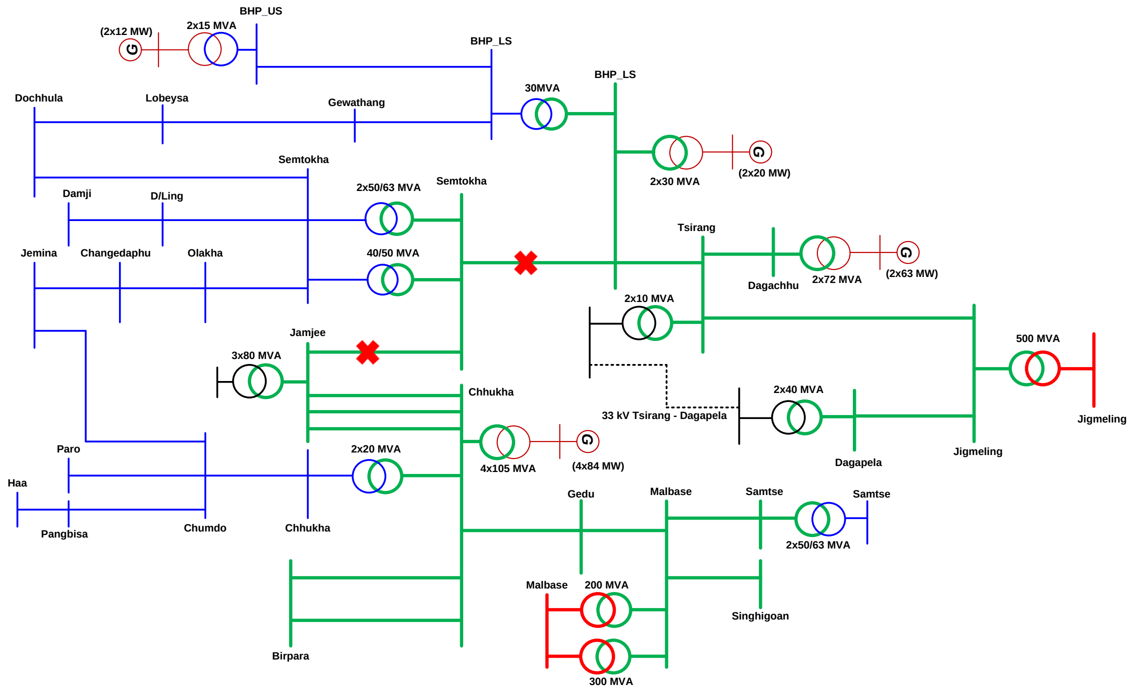

Figure 7-11 Failure of 220 kV Semtokha – BHP and 220 kV Semtokha – Jamjee lines during lean generation

7.12 Failure of 220 kV Semtokha – Jamjee and 220 kV Tsirang – Jigmeling lines

During the tripping/failure of 220 kV Semtokha – Jamjee and 220 kV Tsirang – Jigmeling lines, there will be widespread blackout affecting the Thimphu, Paro, Haa, Punakha, Gasa, Wangdue, and Tsirang regions. Also, BHP both upper and lower stage and DHP generating units will either trip or sustain in IMO.

7.12.1 Normal Restoration Process:

a. Close 220 kV Semtokha -Jamjee line, thereby restoring the power supply to affected areas.
b. Synchronize BHP upper and lower stage.
c. Synchronize DHP units.
d. Close 220 kV Tsirang – Jigmeling line.

7.12.2 Operation procedures for Permanent Fault:

If 220 kV Tsirang – Jigmeling line cannot be restored due to permanent fault;

a. Close 220 kV Semtokha – Jamjee line. The power supply will be restored in the affected regions.
b. Synchronize BHP upper and lower stage.
c. Synchronize DHP units.

If 220 kV Semtokha – Jamjee line cannot be restored sue to permanent fault;

a. Close 220 kV Semtokha – Jamjee line. The power supply will be restored in the affected regions.
b. Synchronize BHP upper and lower stage.
c. Synchronize DHP units.

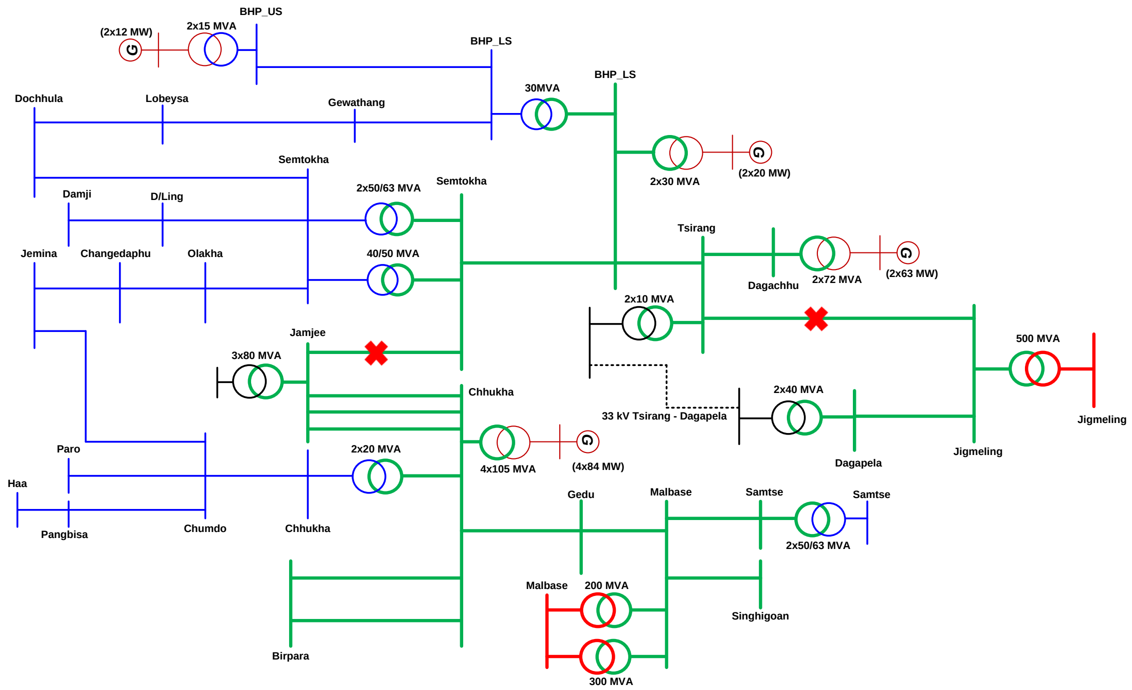

Figure 7-12 Failure of 220 kV Semtokha – Jamjee and 220 kV Tsirang – Jigmeling lines during lean generation

7.13 Failure of 220 kV BHP - Semtokha and 220 kV Tsirang - Jigmeling Lines (N-2)

Failure of 220 kV BHP – Semtokha and 220 kV Tsirang – Jigmeling lines will lead to IMO or blackout of DHP and BHP lower stage. The 220/66 kV, 30 MVA ICT at BHP will trip on inter-tripping scheme. Power generation from BHP upper stage will flow via 66 kV BHP – Gewathang-Lobeysa line.

System Operator shall follow the following cases for restoration:

7.13.1 DHP sustained in IMO

a. If DHP generators sustain in IMO feeding Tsirang load, close 220 kV Jigmeling – Tsirang line. Here, DHP will have to momentarily undergo blackout.
b. Close the 220kV Tsirang-DHP line and sync at DHP end.
c. Close 220 kV BHP – Semtokha line at BHP end.
d. Synchronize BHP lower stage.
e. Close 220/66 kV, 30 MVA ICT to synchronize BHP upper stage.

7.13.2 DHP not sustained in IMO

a. Close 220 kV BHP – Semtokha and 220 kV Tsirang – Jigmeling lines.
b. Restore the DHP and BHP lower stage Units.
c. Close 220/66 kV, 30 MVA ICT to synchronize BHP upper stage.

7.13.3 If 220 kV Tsirang – Jigmeling and BHP – Semtokha line could not be restored

a. 220/66 kV, 30 MVA ICT to be remain opened to avoid overloading of 66 kV lines.
b. DHP to change the isolator position to synchronize DHP Units.
c. Extend supply from Dagapela to DHP.
d. DHP power to flow via 220 kV DHP – Dagapela – Jigmeling line.
e. Disable the inter-tripping scheme of 220/66 kV, 30 MVA ICT at BHP and close.
f. Generation shall be such that 66 kV BHP – Gewathang – Lobeysa is not overloaded and Tsirang load to be fed from BHP.
g. BHP generation must maintain as (as per the load):
   BHP_LS = 20 MW.
   BHP_US = 14 MW (7 MW from each Units).
h. Enable inter-tripping scheme.

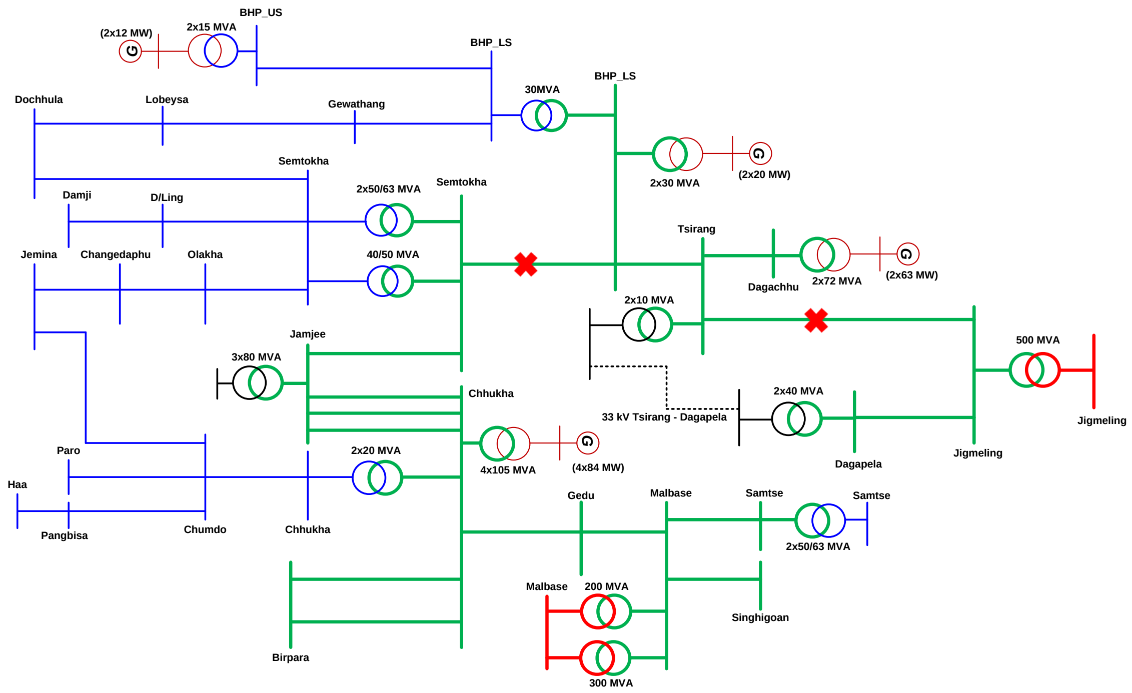

Figure 7-13 Failure of 220 kV BHP - Semtokha and 220 kV Tsirang – Jigmeling lines during lean generation

8 CONCLUSION

In conclusion, the Bhutan Power System Contingency Plan & Operating Procedures – 2024 serves as a vital guide for ensuring the reliability and stability of Bhutan's electrical grid. This document outlines a comprehensive framework for anticipating, mitigating, and recovering from potential disruptions within the system. By adhering to the outlined procedures and maintaining a state of preparedness, Bhutan can effectively navigate power system contingencies and minimize the impact on consumers. For continuous improvement, it is recommended to:

i) Regularly review and update the contingency plan to reflect changes in the power system infrastructure.
ii) Conduct periodic training exercises to ensure personnel are proficient in emergency response procedures.
iii) Foster open communication and collaboration among all stakeholders involves in power system operations.

The successful implementation of this plan and procedures will safeguard the integrity of Bhutan's power system and contribute to the nation's economic growth and development.