OPERATIONALIZATION OF GRID CODE REGULATION, 2008

BHUTAN POWER SYSTEM OPERATOR,
BHUTAN POWER CORPORATION LTD.
THIMPHU: BHUTAN

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DEVELOPED BY:

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Abbreviation

BPSO	Bhutan Power System Operator
RTU	Remote Terminal Unit
DPH	Diesel Power House
SCADA	Supervisory Control and Data Acquisition
NLDC	National Load Dispatch Centre
AMP	Annual Maintenance Plan
ICT	Inter-Connecting Transformer
OLTC	On-Load Tap Changer
RSC	Resource scheduling commitment
DCSD	Distribution and Customer Service Department
ESD	Electricity Service Division
LT	Low Tension
WCA	Work Clearance Authorization

1 SAFETY PRINCIPLES APPLICABLE TO EQUIPMENT MAINTENANCE

This is in compliance to Grid Code Regulation Clause No. 6.13.4.1 and 6.13.4.2 regarding the safety co-ordination, where the System Operator should establish procedures for establishing and maintaining the necessary isolation and earthing when work or test are carried out.

1.1 Purpose

The purpose of this chapter is to describe the process for:

a) Authorizing and controlling the configuration of equipment or system to allow for maintenance and return to service.
b) Providing protection for personnel performing maintenance work.

1.2 Responsibilities

1.2.1 System Operator

The System Operator has responsibility for reviewing the shutdown requests submitted by the field operators for maintenance and to initiate the approval of shutdown. The approval/rejection of the proposal shall be accorded through written communication.

1.2.2 Field Operators

Upon receiving the approval from System Operator, switching off clearance/switching code should be sought from System Operator before taking any shutdown. The field operators have responsibilities of switching off equipment to be maintained, isolation of that equipment, completing the maintenance work and returning the equipment to service.

1.3 Description and Intent of the System Operator

1.3.1 System Monitoring

System Operator receives real time data in its central control room from the number of Remote Terminal Units (RTU) installed at various generating stations and sub-stations. These data are necessary for monitoring safe and reliable operation of Bhutan power system.

1.3.2 Device Switching and Isolation Capability

The System Operator's control room has remote circuit switching capabilities to open and close circuit breakers on the transmission system and generating stations as follows:

a) Down to 33kV and 11kV voltage levels at all terminals and substations fed by transmission lines at 66kV and above.
b) No switching capabilities at terminals and substations fed by 33kV distribution lines, except the following in Thimphu area;

i. 33/11kV Chubachu
ii. 33/11kV Motithang
iii. 33/11kV RICB
iv. 33/11kV DPH
v. 33/11kV Thimphu Mini Hydel
vi. 33/11kV Gidakom (Khasadrapchu)

1.3.3 Operational Switching

The System Operator may carry out or instruct the field operators to carry out operational switching from time to time as may be necessary for operation of the Bhutan power system to achieve steady state, which includes voltage control and switching of overloaded transmission lines.

1.3.4 Switching of Devices to Achieve De-energization and Isolation

The authorization for switching of devices to achieve de-energization and isolation for maintenance and the coordination of the work shall be carried out under the guidelines established by the System Operator.

1.3.5 Operation of Isolators

Motor operated isolators cannot be operated from the System Operator's control room. It has to be operated by local control units at respective stations. However, System Operator will receive real time status of all isolators at its control room.

1.4 System Operator Control Room and RTU Site Interactive Logic

1.4.1 Remote/System Operator control room and Local/RTU Site Logic

Each circuit breaker under the control of a RTU has a Local (L) /Remote (R) selector switch in the Trip Coil circuit. Local means the site of the RTU and Remote means the System Operator control room. This L/R switch is in series with a contact which is closed by the digital output (DO) unit of the RTU on command from System Operator control room, as shown in the diagram below.

a) When the L/R switch is in the Local position (Open), this opens the series circuit to System Operator control room. In such case, any signal from the System Operator control room to the RTU to trip the circuit breaker will be ignored. Hence, control of circuit breaker should be from the Local, or RTU site.

When the L/R switch is in the Remote position (Closed), this completes the series circuit to System Operator control room. Hence, the control of the circuit breaker is from System Operator's control room.

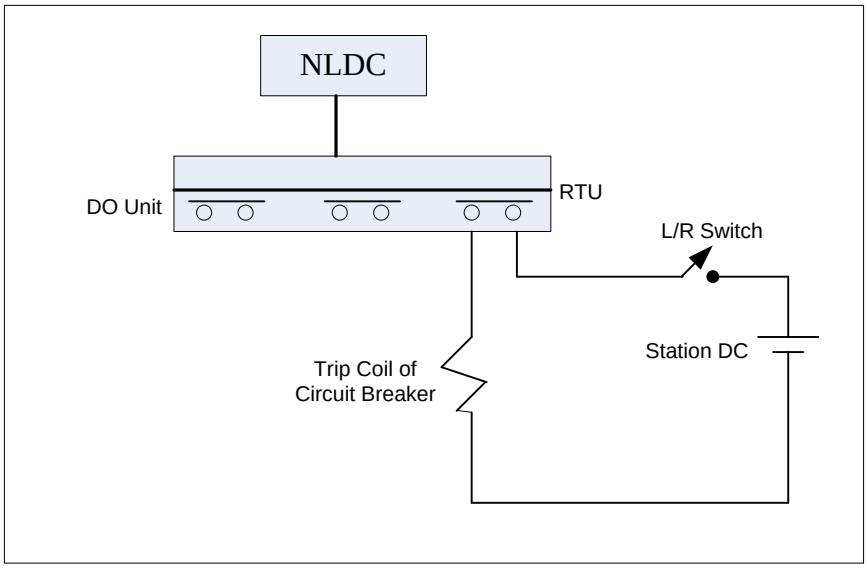


Figure 1: Remote and Local Logic Operation

1.4.2 Circuit Breaker Logic

The remote selection switch of RTU logic at the System Operator's control room is only a one-path for energization of the Trip Coil of the circuit breaker. In order to be prepared to authorize and monitor maintenance and testing, it is necessary to understand all paths for energization of the trip coil in order to trip the circuit breaker.

Circuit Breaker operation logic

a) With the 'Test-Operate' switch in the TEST position, pressing the Test Push Button (PB) will immediately trip the circuit breaker (with no conditions).
b) With the 'Test-Operate' switch in the OPERATE position, we now reach a second switch called the Local-Remote switch. This is a second, lower level of Local and Remote (the RTU/Local and the NLDC/Remote being the first level).
c) With the Local-Remote switch in the LOCAL position, an Operator at the site of the circuit breaker has a push button or like mechanism to trip the circuit breaker.
d) With the Local Remote switch in the REMOTE position, an Operator in the terminal Control Building now has three options as described in the next three items.
e) The Operator can press a Push Button (or turn a handle) on the switchgear panel to trip the circuit

breaker.

f) The Operator can use the site SCADA to trip the circuit breaker.

g) The Operator can select L on the L/R switch, and prevent the NLDC from taking any control action.

h) The 52a contact is in series with all the trip circuit. The auxiliary contact of the circuit breaker (52) is normally closed when the circuit breaker is closed. This means that a Trip signal can only be sent when circuit breaker is in closed condition. It is not logical to send a Trip signal to the breaker when open condition as the operator seeing no response may continue to press the trip push button and burn out the trip coil.

i) The 52 CC b contact is in series with all the trip paths. It is a contact associated with the Close Coil and is open when the Close Coil is energized. This means that the Trip Coil and the Close Coil cannot be energized at the same time. This prevents rapid open-close cycling of the circuit breaker.

j) Our diagram shows only System Operator, or Field Operator, initiated tripping of the circuit breaker. There could be upward of 6-8protective relay-activated contacts in parallel with all the other parallel paths, and all relays (over current, over voltage, under voltage, phase imbalance, etc) can trip the circuit breaker. This is called a protective trip, as opposed to an operator-initiated trip.

Summary:

a) When the L/R switch is set at LOCAL, circuit breaker control is under the exclusive control of the Field Operator.

b) When the L/R switch is set at REMOTE, circuit breaker control can be carried out by either the System Operator or the Field Operator.

c) The Field Operator at the site of the RTU controls the L/R switch. Therefore that Field Operator, either on her/his own initiative or at the direction of the System Operator, establishes who the control authority will be.

1.4.3 Establishing Guaranteed Safety

The following procedure will be followed for ensuring safety during all operations:

a) The switching code for operation of circuit breaker shall be availed only after ensuring the readiness of work at site. The switching code shall be valid for one hour and if the switching needs to be delayed the new switching code shall be obtained.

b) Upon receiving the switching code from the System Operator (as per the Bhutan Electricity Authority safety codes), the field operator shall isolate the equipment on which maintenance is to be carried out.

c) The System Operator shall observe the network status changes at its control room.

d) After the isolation of equipment for maintenance, the field operator shall physically verify the

same.

e) The field operator shall ground the device or component on which maintenance is to be carried out using an appropriate grounding device.
f) The field operator shall place a cautionary sign like "Equipment Under Shutdown" on the control panels/equipment, wherever necessary.
g) After ensuring the complete isolation of the equipment, the field operators shall issue work permit to the concern maintenance personnel.
h) The System Operator shall contact the field operator to list the network status changes that have been made and to confirm the status on the network model at its central control room.
i) In System Operator's control room, status of permanently configured Ground Switches will appear in the network model. However, temporary grounding devices, such as those used for grounding rackable circuit breakers, etc. will not appear in the network model.

1.4.4 Returning Equipment to Service

The field operator shall inform the System Operator that the maintenance is complete and that the maintained device or component is ready to be returned to service by the following procedures:

a) The field operator shall ensure that all work permit covering the equipment have been returned and cancelled.
b) The field operator shall intimate the system operator that the equipment is ready for returning to service. Any changes which have been made and how it will affect the operation after putting it to service shall also be intimated to the System Operator and wait for charging clearance (switching code). The Field Operator shall normalize the equipment (open the earth switch including the temporary grounding, close the isolator). ***Note:*** *system operator shall ensure that both the ends of the connected lines are clear for charging and issue the charging code.*
c) Close the circuit breaker in coordination with other end of the connected line, and inform the System Operator.

1.5 Maintenance of Cross-Border Transmission Lines

The maintenance of transmission lines connecting to Indian substation shall be guided by the following procedures:

1.5.1 If the site is to be maintained in Bhutan

a) The System Operator will initiate the authorization approval process.
b) The System Operator will complete a Work Authorization Form covering the intent, duration and target completion date for the maintenance activity.
c) The System Operator will inform the appropriate field operators in Bhutan that an authorization form has been initiated on-line.
d) The System Operator will continue to communicate and coordinate with the appropriate concern authorities in India.

e) After confirming the consent of Indian authorities, the System Operator will release the on-line authorization form (shutdown form).
f) Upon on-line release of the authorization form, the field operators at site will switch the L/R switch to Local and will proceed to open the circuit breakers and the isolators.
g) The System Operator will observe at control room the circuit breaker and isolator operation being carried out in Bhutan.
h) The System Operator will be able to see and confirm with ERLDC, India over voice communication.
i) Upon confirming that the circuit breaker and isolators at both ends are opened, the System Operator will authorize the field operators to apply the ground switches to all three phases.
j) The appropriate body in India will inform the System Operator when the grounding of the transmission line in India has been carried out.
k) Upon confirmation from India and from the Bhutan field operators, that grounding of the line has been carried out, the System Operator will authorize the field operators to proceed with the approved maintenance work.
l) When the maintenance work is completed in Bhutan, the System Operator will inform the appropriate body in India.
m) The System Operator will request the Bhutan field operators and the appropriate body in India, to open the grounding switches on all three phases.
n) Upon confirmation from both parties that the grounding switches have been removed, the System Operator will request the Bhutan field operator and the appropriate body in India, to close the isolators.
o) The System Operator will request the appropriate body in India to close the transmission line circuit breaker putting the line back into service at the Indian end.
p) The System Operator will issue the charging code to the field operators to close the circuit breaker.

1.5.2 If the site is to be maintained in India

a) The System Operator will initiate the authorization approval process, which will cover only the isolation and grounding of the transmission line at the Bhutan end.
b) The System Operator will complete a Work Authorization Form covering the intent, duration and target completion date for the maintenance activity (as information for the field operators).
c) The System Operator will inform the appropriate field operators in Bhutan that an authorization form has been initiated on-line.
d) The System Operator will continue to communicate and coordinate with the appropriate concerned authorities in India.
e) After all the required similar steps have been taken in both countries, the System Operator will release the on-line authorization form.
f) Upon on-line release of the authorization form, the field operators at site will switch the L/R switch to Local and will proceed to open the circuit breakers and the isolators.
g) The System Operator will observe at control room the circuit breaker and isolator operation being

carried out in Bhutan.

h) The System Operator will be able to see grid and confirm with ERLDC, India over voice communication.

i) Upon confirmation from India and from the Bhutan field operators, that isolation of the line has been carried out, the System Operator will authorize the field operators to apply the ground switches to all three phases.

j) The System Operator will inform the concern authorities in India when grounding of the transmission line has been completed in Bhutan.

k) Upon confirmation from India, and from the Bhutan field operators, that grounding of the line has been carried out, the System Operator will authorize the field operators to proceed with the approved maintenance work.

l) When the maintenance work is completed in India, the System Operator will be informed by the appropriate body in India.

m) The System Operator will request the Bhutan field operators to open the grounding switches on all three phases.

n) Upon confirmation from India that the grounding switches have been opened, the System Operator will request the Bhutan field operators close the isolators.

o) The System Operator will issue the charging code to the field operators to close the circuit breaker.

2 SYSTEM RESTORATION AND BLACKSTART CAPABILITIES

This is in compliance to Grid Code Regulation, 2008 Clause No. 6.6 and 6.12 regarding power system security aspects and recovery procedures respectively.

2.1 Purpose

The purpose of this document is to:

a) Identify system components with black start capability
b) Identify different scenarios from which system restoration will have to take place
c) Provide operating procedures by which system restoration will be accomplished

2.2 System Restoration

System restoration under different scenarios are covered in "Bhutan Power System Contingency Plan, 2017" issued by BPSO. All stake holders are to follow the operating norms detailed in contingency plan.

2.3 Black Start Capabilities

During the total failure of Indian grid/blackout condition, the early normalization of station is important. Under such condition, all generating stations must have its black start capabilities which must be maintained in healthy condition at all times.

At present only BHP and DHPC have the capability to extend its supply to other stations for start-up in case of grid failure. The other generators have limitations in its governing system in extending the local load. However, for speedy restoration all generating stations must use their own black start facilities to start-up its units so that it is ready for synchronization based on the grid conditions.

Normally, station black starting is achieved by diesel generator set. In case, failure of supply extension from DG sets, the generating stations must use its station DC supply for field flashing. After building up the generator voltage, the station LT system must be normalized in usual manner and proceed for synchronization and loading as per the grid condition.

The table below shows the black start facilities available at generating stations.

Table 1: Black Start Facilities

Plant Name & Location	Plant Installed Capacity (MW)	Type of Turbine	Start-Up Facilities		Field Flashing	Black Start Facility
			Source	Capacity (kVA)		
BHP (Upper Stage)	2x12	Pelton	Diesel Generator	1x130	Yes	Yes
BHP (Lower Stage)	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	1x500 & 1x320	Yes	Yes
DHP	2x63	Pelton	Diesel Generator	1x400	Yes	Yes

2.4 Synchronizing Facilities

Synchronizing facilities at stations play a vital role in connecting the isolated systems to grid. A list of major stations which have synchronizing facilities is as discussed in Table: 2.4-1.

Table 2: Synchronizing Facilities

Station/Plant	Voltage Level (kV)	Point 1	Point 2	Circuit Breaker	Synchronizing Facility Availability
CHP	220	CHP Bus	Birpara - I	E_F1	Yes
CHP	220	CHP Bus	Birpara - II	E_F2	Yes
CHP	220	CHP Bus	Malbase	E_F3	Yes
CHP	220	CHP Bus	Semtokha	E_F4	Yes
BHP (Lower Stage)	11	BHP Bus	Semtokha/Lobeysa	E_F1	Yes
BHP (Upper Stage)	66	BHP Bus	Semtokha/Lobeysa	C_F1	Yes
KHP	132	KHP Bus	Nangkor	D_F1	Yes
KHP	132	KHP Bus	Kilikhar	D_F2	
THP	400	THP Bus	Binaguri-I	F_F1	Yes
THP	400	THP Bus	Binaguri-II	F_F3	Yes
THP	400	THP Bus	Malbase-III	F_F4	Yes

3 REACTIVE POWER AND VOLTAGE CONTROL

3.1 Grid Code Clause:

Clause 7.6.1:
Reactive power compensation should ideally be provided locally, by generating reactive power as close to the reactive power compensation as possible. The utilities are therefore, expected to provide local reactive power compensation/generation such that they do not draw reactive power from the Transmission System, particularly under low-voltage conditions.

Clause 7.6.2:
Notwithstanding the above, the System Operator may issue instructions to the generators to generate or absorb reactive power as per their capability curves in order to control the voltage level. The System Operator may also instruct switching in/out of lines/transformers in order to control the voltage level. The security and reliability criteria need to critically examine while issuing such switching instructions.

Clause 7.6.3:
In general, the Distribution Licensees shall endeavour to minimize the reactive power drawal at an interchange point when the voltage at that point is below 95% of rated, and shall not return reactive power when the voltage is above 105%. ICT taps at the respective drawal points may be changed to control the reactive power interchange as per a Distributions Licensee's request but only at reasonable intervals. The System Operator shall periodically review the reactive power drawal/injection at the distribution points and may suggest programmes for installation of Reactors/Capacitors.

Clause 7.6.4:
Switching in/out of all bus and line reactors, and shunt capacitors throughout the Transmission System shall be carried out as per instructions of the System Operator. Tap changing of all ICTs up to 66/33kV shall also be done as per the System Operator's instructions only.

3.2 Purpose

The purpose of this document is to identify:

a) Identify voltage control devices on the Bhutan power network, including ratings, ranges, and capability.
b) Identify normal, emergency and restorative scenarios which are likely to occur on the power system.
c) Identify control strategies for use of switchable and continuously variable reactive power sources, as well as direct voltage control sources (tap changing transformers), for control of voltage on the transmission system.

3.3 Transmission Elements Affecting Reactive Power Balance at Bus

Table 3: Transmission element affecting reactive power balance

Sources of Reactive Power	VAR Neutral Devices	Sinks of Reactive Power
Shunt capacitors		Shunt inductors/reactors
Filter banks		
Underground cables (per km almost five times that of similar voltage transmission line)		
Lightly loaded transmission lines	Transmission lines loaded at Surge Impedance Loading (SIL) – a statistically random event on a power system	Heavily loaded transmission lines
Synchronous generators (over excited)		Synchronous generators (under excited)
Synchronous condensers (over excited)		Synchronous condensers (under excited)
Static VAR compensators (SVC)		Static VAR compensators (SVC)
		Transformer
		Induction motor loads, especially those operating at less than rated load
		Induction heating
		Inductive arc furnaces
	An all-residential load on a substation (almost at 1.0 power factor)	
		High Voltage Direct Current system (HVDC)
		Induction generators (wind farms)

3.4 Bhutan Transmission System

The Bhutan transmission system consists of 400kV, 220kV and 132kV transmission line. There is also a 66kV transmission system connected mostly in ring with 220kV transmission system, which serves as reliability during the outage of 220kV lines and to feed the distribution system in western region at present.

The 220kV and 66kV transmission system are connected together at a series of points by inter connecting Transformer (ICTs). These ICTs form a series of loops or meshes in the transmission system. All of the ICTs are tap-changing under load transformers, and as a result have the ability to cause MVARs to be wheeled as required within the various loops in the system.

The entire Bhutan Power System Network diagram is enclosed as **Annexure-1** for reference by stake holders.

The network diagram shall be reviewed and updated from time to time with expansion of network.

3.5 Transformers in Bhutan Power System

3.5.1 Listing of Tap Changing Transformers

The transformers on the Bhutan power system have been divided into two groups. These are:

a) Transformers in transmission loops (ICTs),
b) Transformers in radial configurations.

As control devices, it is necessary to know their ratings, whether or not they can tap change under load, the tap range, and the winding of the transformer on which tap changing takes place.

Table 4: List of Tap Changing Transformers

Sr. No.	From kV	To kV	Rating (MVA)	Tap Changing	Tap Range	Tap On Side	Tap Position	Remarks
1	400_MAL	220_MAL	200	OLTC	1 to 17	HV-Side	9	Malbase
2	220_MAL	66_MAL	50/63	OLTC	1 to 17	HV-Side	9	Malbase
3	220_MAL	66_MAL	50/63	OLTC	1 to 17	HV-Side	9	Malbase
4	220_MAL	66_MAL	50/63	OLTC	1 to 17	HV-Side	9	Malbase
5	66_MAL	11_MAL	20	OLTC	1 to 17	HV-Side	9	Malbase
6	66_MAL	11_MAL	20	OLTC	1 to 17	HV-Side	9	Malbase
7	66_GED	33_GED	8	OLTC	1 to 13	HV-Side	5	Gedu
8	66_GED	33_GED	5	OLTC	1 to 17	HV Side	9	
9	66_GED	11_GED	5	OLTC	1 to 17	HV-Side	5	Gedu
10	66_GED	11_GED	5	OLTC	1 to 17	HV-Side	5	Gedu
11	66_PLG	33_PLG	10	OLTC	1 to 17	HV-Side	5	Phuentsholing
12	66_PLG	11_PLG	10/12.5	OLTC	1 to 17	HV-Side	6	Phuentsholing

13	66_PLG	11_PLG	10	OLTC	1 to 7	HV-Side	6	Phuentsholing
14	66_PLG	11_PLG	3	OLTC	1 to 7	HV-Side	6	Phuentsholing
15	66_GOM	33_GOM	5	OLTC	1 to 17	HV-Side	5	Gomtu
16	66_GOM	11_GOM	5	OLTC	1 to 17	HV-Side	9	Gomtu
17	66_GOM	11_GOM	5	OLTC	1 to 17	HV-Side	9	Gomtu
18	220_SGO	66_SGO	50/63	OLTC	1 to 17	HV-Side	9	Singhigaon
19	220_SGO	66_SGO	35	OLTC	1 to 17	HV-Side	9	Singhigaon
21	220_SAM	66_SAM	2x50	OLTC	1 to 17	HV-Side	9	Samtse
22	66_SAM	33_SAM	5	OLTC	1 to 17	HV-Side	9	Samtse
23	66_SGO	11_SGO	10	OLTC	1 to 17	HV-Side	9	Singhigaon
24	66_SGO	11_SGO	5	OLTC	1 to 17	HV-Side		Singhigaon
25	66_WAT	33_WAT	5	OLTC	1 to 13	HV-Side	5	Watsa
26	66_LSA	33_LSA	5	OLTC	1 to 13	HV-Side	4	Lobeysa
27	66_LSA	33_LSA	5	OLTC	1 to 13	HV-Side	4	Lobeysa
28	66_LSA	11_LSA	5	OLTC	1 to 17	HV-Side	8	Lobeysa
29	66_LSA	11_LSA	5	OLTC	1 to 17	HV-Side	8	Lobeysa
30	66_JEM	33_JEM	10	OLTC	1 to 17	HV-Side	5	Jemina
31	33_JEM	11_JEM	5	OLTC	1 to 17	HV-Side	5	Jemina
32	66_DEN	33_DEN	10	OLTC	1 to 17	HV-Side	5	Dechencholing
33	66_DEN	33_DEN	10	OLTC	1 to 17	HV-Side	5	Dechencholing

34	33_DEN	11_DEN	2.5	Off load	1 to 5	HV-Side	3	Dechencholing
35	33_DEN	11_DEN	2.5	Off load	1 to 5	HV-Side	3	Dechencholing
36	66_HAA	11_HAA	5	OLTC	1 to 17	LV-Side	6	Haa
37	66_HAA	11_HAA	5	OLTC	1 to 17	HV-Side	6	Haa
38								
39	66_PRO	33_PRO	2x20	OLTC	1 to 17	HV-Side	9b	Paro
40	220_SEM	66_SEM	50/63	OLTC	1 to 17	HV side	9b	Semtokha
41	220_SEM	66_SEM	50/63	OLTC	1 to 17	HV side	9b	Semtokha
42	66_SEM	11_SEM	10	OLTC	1 to 17	HV side	9	Semtokha
43	66_SEM	11_SEM	10	OLTC	1 to 17	HV side	9	Semtokha
44	132_KAN	33_KAN	5	OLTC	1 to 17	HV side	2	Kanglung
45	132_KAN	33_KAN	5	OLTC	1 to 17	HV side	2	Kanglung
46	33_KAN	11_KAN	2.5	OLTC	1 to 5	HV side	2	Kanglung
47	33_KAN	11_KAN	2.5	OLTC	1 to 5	HV side	2	Kanglung
48	132_KIL	33_KIL	5	OLTC	1 to 17	LV side	1	Kilikhar
49	132_KIL	33_KIL	5	OLTC	1 to 17	LV side	1	Kilikhar
50	33_KIL	11_KIL	2.5	OLTC	1 to 5	LV side	2	Kilikhar
51	33_KIL	11_KIL	2.5	OLTC	1 to 5	LV side	2	Kilikhar
52	33_TAN	11_TAN	1.5	OLTC	1 to 5	LV side		Tangmachu
53	33_TAN	11_TAN	1.5	OLTC	1 to 5	LV side		Tangmachu

54	132_GEL	66_GEL	25	OLTC	1 to 17	HV side	9	Gelephu
55	132_GEL	66_GEL	2x25	OLTC	1 to 17	HV side	12	Gelephu
56	66_GEL	11_GEL	10	OLTC	1 to 17	HV side	5	Gelephu
57	66_GEL	11_GEL	5	OLTC	1 to 17	HV side	4	Gelephu
58	132_NGA	33_NGA	3	OLTC	1 to 17	HV side	2	Nganglam
59	132_NGA	33_NGA	3	OLTC	1 to 17	HV side	1	Nganglam
60	33_NGA	11_NGA	1.5	OLTC	1 to 5	HV side	4	Nganglam
61	33_NGA	11_NGA	1.5	OLTC	1 to 5	HV side	1	Nganglam
62	132_TIN	33_TIN	3	OLTC	1 to 17	HV side	5	Tintibi
63	132_TIN	33_TIN	3	OLTC	1 to 17	HV side	5	Tintibi
64	33_TIN	11_TIN	1.5	OLTC	1 to 5	HV side	3	Tintibi
65	33_TIN	11_TIN	1.5	OLTC	1 to 5	HV side	3	Tintibi
66	132_YUR	33_YUR	2x15	OLTC	1 to 17	HV side	9	Yurmo
67	220_TSI	66_TSI	2x10	OLTC	1 to 17	HV side	9	Tsirang
68	66_TSI	33_TSI	2x5	OLTC	1 to 17	HV side	9	Tsirang
69	132_DEO	33_DEO	5	OLTC	1 to 17	HV side	2	Deothang
70	132_DEO	33_DEO	5	OLTC	1 to 17	HV side	2	Deothang
71	33_DEO	11_DEO	2.5	OLTC	1 to 5	HV side	2	Deothang
72	33_DEO	11_DEO	2.5	OLTC	1 to 5	HV side	2	Deothang
73	132_NKO	33_NKO	5	OLTC	1 to 17	HV side	5	Nangkhor

74	132_NKO	33_NKO	5	OLTC	1 to 17	HV side	2	Nangkhor
75	33_NKO	11_NKO	2.5	OLTC	1 to 5	HV side	2	Nangkhor
76	33_NKO	11_NKO	2.5	OLTC	1 to 5	HV side	2	Nangkhor
77	400_JIG	220_JIG	4x167	OLTC				Jigmeling
78	220_JIG	132_JIG	2x63/80	OLTC	1 to 17	HV side	9b	Jigmeling
79	132_JIG	33_JIG	15	OLTC	1 to 17	HV side	9b	Jigmeling

3.5.2 Tap Changing Equation

As indicated in the table above, all tap changing transformers taps are on the high voltage side.
The tap changing equation is:

$$V_{220}/V_{66} = N_{220}/N_{66}$$

$$V_{66} = V_{220} . N_{66}/N_{220}$$

a) To increase V_{66}, the number of turns on the 220 winding must be decreased.
b) To decrease V_{66}, the number of turns on the 220 winding must be increased.

NOTE: *Transformer tap position shall be changed depending on the requirement of system voltage*

3.6 Switched Inductors and Capacitors

Table 5: List of Shunt reactor and Inductor

Device	Bus Location	Rating	Switching	Remarks
Inductor/Reactor	400kV Tala Bus	1x63MVAR	0 to 100%	In Service
Shunt Reactor	132kV KHP Bus	2x5MVAR		In Service
Shunt Reactor	400kV MHP Bus	1x80MVAR		Not in Service
Shunt Reactor	400kV Jigmeling	2x80MVAR		Not in Service

3.7 MVAR Production by High Voltage Transmission Lines

3.7.1 MVAR net production by high voltage lines

The MVARs produced in the naturally-occurring capacitance of a transmission line are calculated as : $\frac{V^2}{Xc}$ (where V is system voltage and X_c is the line capacitive reactance). Normally the voltage variations on the high voltage transmission lines are not large. Consequently, it is reasonable to calculate the MVARs

produced at nominal voltage and to use this value as representative.

The MVARs consumed in the naturally-occurring inductance of a transmission line are calculated as I^2X_L (where I is the line current and X_L is natural inductive reactance). Therefore the MVAR consumption is load dependent. The Bhutan power system essentially has two representative patterns. One is high summer flows with high generation and relatively low summer load. The other is low winter flows with low generation and high winter load. Load flow results are available for each of these respective patterns. These load flow results have been used to calculate "representative values" for MVAR consumption.

These scenarios are simulated in PSS/E software and the results are tabulated as below and simulated network diagrams are enclosed as **Annexure-2.**

Table 6: MVAR net production by high voltage lines

Bus		Charging MVAR	Length (Km)	MVAR Consumed/Produced			
From	To			Peak Generation		Firm Generation	
				Sending end	Receiving end	Sending end	Receiving end
400kV Lines							
THP	BINAGURI-I		146	38.3	22.8	4.4	82.8
THP	BINAGURI-II		146	38.3	22.8	Line kept out of service	
THP	BINAGURI-IV		149.5	39.9	25.1	7.9	83
THP	MALBASE		24.01	9.5	4.6	47.5	58.4
MALBASE	BINAGURI		125	37.2	22.6	8.1	74.1
MHP	JIGMELING-I		84.345	63.1	22.3	30	21.2
MHP	JIGMELING-II		84.345	63.1	22.3	Line kept out of service	
MHP	JIGMELING-III		84.745	62.8	23.1	30	21
MHP	JIGMELING-IV		84.745	62.8	23.1	Line kept out of service	
220kV Lines							
CHP	BIRPARA-I		70.21	3.2	1.4	6.6	15.8
CHP	BIRPARA-II		70.21	3.2	1.1	Line kept out of service	
CHP	MALBASE		29.84	41.5	42.5	49	52.2
MALBASE	BIRPARA		40.77	33.4	30.5	20.3	51.1
MALBASE	SINGHIGOAN		1.21	29.8	30	30.7	30.8
MALBASE	SAMTSE		40.15	7.5	2.3	7.2	2.1
SINGHIGOAN	SAMTSE		41.1	9.5	4.1	9.2	3.9
CHP	SEMTOKHA		54.01	10.4	17.1	7.4	4.3
SEMTOKHA	BHP		44.9	21.3	15.7	41.4	35.9
BHP	TSIRANG		46.6	2.2	8.7	21.8	15.7
TSIRANG	JIGMELING		30.56	2.4	1.7	0.6	1.9
132kV Lines							
JIMELING	GELEPHU		15.4	3.6	4.2	0.1	0.6
JIMELING	TINTIBI		45.74	9.3	10.6	3.4	4.7
TINTIBI	YURMO		32.63	4.5	6	4.6	6
TINTIBI	NANGLAM		83.33	15.8	16.1	9.9	10.2
NANGLAM	NANGKOR		34.07	23.5	23.2	17.6	17.2
NANGKOR	DEOTHANG		23.31	21.6	24.3	20.6	20.4
DEOTHANG	MOTANGA		10.5	26.6	27.7	22.7	22.5
MOTANGA	RANGIA		46.4	42.8	46.4	37.6	37.1
NANGKOR	KHP		31	2.7	3	2.3	3.8
KHP	KILIKHAR		10.06	4.6	5.1	4.8	5.2
KILIKHAR	KANGLUNG		29.6	2.1	4	2.3	4

3.8 Generator Capability Curves

The capability curve of the generator defines the boundary within which the machine shall be operated safely. It gives the basic information regarding the limiting zones of operations so that limiters can be set suitably for safe operation of units. Usually capability charts are represented in PU system. To obtain the actual values, the PU figures from the curves should be multiplied by the base MVA of the machines.
The permissible region of operation in the chart is determined by the following conditions:

a) The MVA loading should not exceed the generator rating (over load if any).
b) The MW loading should not exceed the rating of prime mover (over load if any).

The useful information the operators can obtain from the capability curve are as below.

a) Reactive Power (MVAR) is positive for lagging power factor (over excitation region) and negative for leading power factor (under excitation region). The point '0' is defined as the ideal condition.

b) In the over excited region the operating range of generator is limited by rotor heating range. Increase in excitation produces more MVAR & MW leading to rotor heating. The field current limiter is suitably set to give indication to operators. The operators must accordingly reduce the excitation voltage to bring the operating point in safer zone.

c) In the under excited region, the operating zone is limited by stator current limit. This condition usually occurs during the lightly loaded condition of lines whereby receiving end voltage becomes higher than the sending end voltage and MVAR flows towards the generator. The load angle limiter is suitably set to indicate the operators. Under this condition, operators must adjust the excitation voltage of machines operating in parallel so that MVAR absorption is equally shared. The operator may also switch off one of the lines to reduce the system voltage.

d) It is undesirable to operate the machine up to theoretical limits.

Capability curve of all the generators are enclosed as **Annexure-3.**

3.9 Voltage Control Resource Analysis

3.9.1 Generators

Generators are the first priority for control of the system voltage. They are important because the AVR set points are continuously variable. The influence in system voltage in 220kV and 400kV transmission system is very strong due to long and mostly lightly loaded lines. An attempt to raise the AVR set point at generating station will have minimal impact on the system voltage. Moreover it is not recommended to keep the generator voltage on higher side continuously, therefore, the generator voltage shall be set at nominal value.

3.9.2 Switched Inductor

The 63MVAR reactor at Tala can only be switched at 0 or 100%, that is all or nothing. Its sole purpose is to absorb some of MVARs produced by the four 400kV lines terminating at the bus. Without the shunt reactor, it is likely that the Tala generators would have to move so far into the under excited region that they would not stay with the P-Q Generator capability curves.
Another way of saying this is that the generators would move so far into the under excited region that they would run up against the Under Exciter Limiters and voltage control at the Tala bus would be lost.

The capacitive MVAR is always produced proportional to the voltage in the 400kV transmission line even with the presence of the nominal voltage in the lines. To contain the system voltage to nominal value, the 63MVAR shunt reactor is recommended to keep switched ON. The 63MVAR reactor is a local device, with no implication on broader transmission system.

Tap Changing Transformers in Radial Configuration

The features of transformers with tap changing facility can be summarized as follows:

a) They have well defined local effect.
b) The control is precise within the tap changing increment.
c) They have no impact, or interaction, at all on other transmission system voltage control devices.

NOTE: *However the OLTC is preferred for fast and effective voltage control, Offload tap changing shall be avoided unless it is required in extreme condition.*

3.9.3 Tap Changing Transformers in Transmission Loops

These should be considered individually.

a) 220/66kV Rurichhu ICT, 30MVA.

One end of this ICT (220kV) is connected directly to Basochhu lower bus which is controlled by its digital AVR. The other end (66kV) is connected through a very short 1.3 Km transmission line to the upper bus which is controlled by its digital AVR. Any action by this ICT would simply be countered by the AVRs of the generating stations, and it should not be tapped under the normal transmission configuration.

b) 220/66kV Semtokha ICT, 2x50/63 MVA

The Semtokha 220kV bus provides a point for tap changing of this ICT to broadly control the voltage on the 66kV transmission line which is supplying power to a large segment of the Bhutan domestic load (Olakha-Jemina-Chumdo to Haa and Paro, Dechencholing and Lobeysa)

c) 220/66kV Chhukha ICT, 2x20MVA

The Chhukha 220kV bus is held by the AVRs on the Chukha generating units. It provides a point for tap changing of this ICT to control the voltage on 66kV transmission line which is feeding more of the Bhutan domestic load (Watsa, Gedu and Phuentsholing).

d) 400/220kV Malbase, 200MVA and 220/66kVSinghigaon ICTs, 50MVA & 35MVA

There is very short (1.7 Km), 220kV transmission line connecting the 220kV Malbase and Singhigaon buses. Electrically they are at the same point.

This effectively puts the two ICTs in a "series configuration", which is highly unusual. The impedance of the Malbase ICT is 11.78% which will cause some voltage drop on the 220kV bus as the transformer is loaded up.

The 220/66kV Singhigaon ICT could be used to control the voltage of industrial loads at Pasakha. The 400/220kV ICT at Malbase is provided for interconnecting the two voltage systems and therefore, there is

no provision to exercise the voltage control.

e) 220/66kV Malbase ICT, 3x50/63MVA

The Malbase 66kV bus is only (3.5+1.5) Km away from the Singhigaon 66kV bus. This effectively creates a "parallel combination" of the 220/66kV Malbase ICT and the 220/66kV Singhigaon ICT.

When parallel tap-changing ICT gets out of step during tap changing one by one, the result will create large circulating MVARs between the two.

It would appear that either by themselves should not be used to control the voltage at of industrial loads at Pasakha. In combination, the tap changing operation would have to be coordinated.

3.10 Voltage Control Strategy in the Normal Configuration

3.10.1 Transmission System voltage

Voltage control through use of the generators AVRs should be continuously put in place within the set limit. If the voltage levels are beyond the permissible limit, then, Voltage control on the transmission system shall be carried out by tap changing through selected ICTs as required in that region/area as follows.

a) 220/66kV Semtokha ICTs
b) 220/66kV Chukha ICTs
c) Coordination tap changing of the 220/66kV Malbase ICT and the 220/66kV Singhigaon ICTs

4 INTERCHANGE SCHEDULING

This is in compliance to Grid Code Regulation, 2008 Clause No. 7.5 regarding scheduling and dispatch procedures.

4.1 Purpose

The intention of this chapter is to explain the following:

a. Involvement of various stakeholders in fulfilling the requirements of section 7 of Grid Code Regulation, 2008
b. Various process and procedures involved in scheduling and dispatch.

4.2 Generation Scheduling

Individual generating plants shall declare a day ahead ex-bus available generation based on unit availability and the anticipated inflow in 96 blocks as given in **Annexure-4.**

System Operator shall run the scheduling application software, Resource Scheduling Commitment (RSC) in SCADA system to study and assess the schedule for its optimum utilization of the available inflow for generation. The necessary changes in the schedule if required will be made by the system operator keeping in mind the grid security and stability.

Generating stations are expected to generate power according to the daily schedule advised to them. In the event of any unforeseen situation at the generating stations necessitating deviation from the schedules, the same should be informed to the system operator immediately. The system operator after examining the grid conditions shall interact with the relevant stakeholders and reschedule the dispatch for compliance by the concerned agencies.

4.3 Load Forecast

Distribution and Customer Service Department (DCSD) shall submit the day ahead demand of 19 ESDs in 96 blocks as per **Annexure-5.**

The System Operator shall study the generation and demand forecast for meeting the internal consumption.

4.4 Declaration of the expected export power

The expected export power shall be arrived after subtracting the national demand from the available ex-bus power declared. The System Operator shall intimate NLDC and ERLDC, India of the expected export power in prescribed time and procedure. The expected export power shall be submitted in the format as per **Annexure-6.**

4.5 Scheduling and Dispatch Procedure

As per the Grid Code Regulations 2008, Section 7, Clause 7.5, the concerned agencies shall adopt the following procedures.

1. At 0930Hrs, all generating stations shall declare their day ahead ex-bus power availability to the System Operator in 96 blocks.
2. At 0930Hrs, Distribution licensees shall declared their day ahead demand forecast to the System

Operator in 96 blocks.

3. The System Operator shall determine the total domestic consumption and total power available for export based on the available ex-bus power and demand forecast. The System Operator shall check for system healthiness within Bhutan and accordingly advise for revision of demand and generation forecast.
4. At 1130Hrs, the System Operator shall intimate total export power to ERLDC.
5. At 1330Hrs, the System Operator shall obtain backing/shutting down requirements if any due to line constraints in the region from ERLDC. Reconfirmation for any changes shall be obtained from ERLDC by 1730Hrs.
6. At 1800Hrs, System Operator shall issue the final hourly generation schedule to individual generating stations.
7. At 1800Hrs, System Operator shall issue the Net Drawal Schedule for Distribution Licensees.
8. In case any unscheduled outages of units/lines, the concerned agencies shall intimate the information to System Operator on real time basis. System Operator shall accordingly initiate the rescheduling and further intimate to ERLDC.

5 COMMUNICATION

This is in compliance to Grid Code Regulation, 2008 Clause 3.8 regarding the Communication.

5.1 Representatives for Communication between System Operator and Users

Station in-charge/shift in-charge shall be responsible for all communications between the System Operator and the respective end users/field operators.

5.2 Mode of Communication

a) The System Operator may use any mode of communication for issuing instructions. However, any communication considered to be of importance by one of the parties shall subsequently be confirmed in writing within 24 hours.

b) The System Operator shall provide in writing for instructions having commercial implications for Licensees and users unless the instruction have an emergency character. All parties shall accept recording by whatever means of communications as evidences of communications.

c) Any data or notices to be submitted to System Operator shall be authenticated by responsible official and confirm within 24 hours by electronic message or in writing.

6 OUTAGE PLANNING

This is in compliance to Grid Code Regulation, 2008 Clause no. 6.11 regarding outage planning which has to be carried out annually and periodically.

6.1 Purpose

The purpose of this chapter is to

a) Explain the procedure in submitting and approving the maintenance plan as per the Grid Code Regulations, 2008.
b) State the various classifications of maintenance.
c) Outage procedures.

6.2 Maintenance

There are three classifications of maintenance as follows:

6.2.1 Planned maintenance

The planned maintenance are the activities which are proposed in advance by the individual agency in the Annual Maintenance Plan (AMP), and approved in principle by the System Operator in line with the Grid Code Clause No. 6.11.

The final shutdown request for the planned maintenance of equipment shall be submitted to system operator 14 days prior to actual shutdown. Any changes in the maintenance plan shall also be informed to system operator.

6.2.2 Emergency maintenance (break down)

The emergency maintenance are required to be taken by the agency/field operators immediately as a result of the failure/breakdown of equipment or components which otherwise will have catastrophic effect.

Note: Depending upon the severity of the situation, the field operators shall prioritize the operation to isolate the necessary equipment for safeguard of equipment in danger. The information describing status of the equipment shall be provided to system operator.

6.2.3 Ad hoc maintenance (preventive)

The ad-hoc maintenance are the ones which are requested by the agencies to the System Operator (not envisaged during the AMP meeting) as felt necessary based on the condition of the equipment so that preventive maintenance of the system can be done.

The final shutdown request for the ad-hoc maintenance of equipment shall be submitted to system operator three days before the actual shutdown.

Note: *However, depending upon the condition of the equipment, the immediate shutdown shall be considered*.

6.3 Authorizing and Monitoring Maintenance Activities

Prior to authorizing maintenance activities, there are five reference Appendices with which the System Operator should be familiar. These are:

a) Appendix- A: Approved Protective Devices
b) Appendix- B: Tagging Equipment

c) Appendix- C: Maintenance Jobs Not Requiring Approval.
d) Appendix- D: Definitions

6.3.1 Authorizing Maintenance

The following procedures shall be followed:

a) Generating and transmission licenses shall provide the System Operator the schedule of planned maintenance activities for next operational year by 1st of December of the current year.
b) The proposed maintenance plans shall contain identification of each generating unit/line/inter-connecting transformers (ICTs), the preferred date for each outage and its duration, the earliest start date and latest completion date. The format for the submission of planned maintenance is given in **Annexure - 8.**
c) The System Operator shall carry out necessary system studies and, if necessary, the maintenance plans of the respective agencies shall be rescheduled. The finalized maintenance plan will be communicated to the respective agencies latest by 31st of December prior to the beginning of the Operational year.

The approval form and approved annual maintenance plan shall be available in BPSO web site.

Note*: System operator shall ensure the coordination amongst the agencies (generation and transmission licenses including Indian counterparts) and provide an integrated maintenance schedule to avoid repeated shutdown of transmission lines.*

d) Field Operators shall seek the shutdown approval in the prescribed format given in **Annexure - 7**. Shutdown Request form is available at BPSO website www.bpso.bpc.bt
e) The System Operator shall follow the approval process as laid down in the flow chart given in **Annexure - 9** for all the maintenance activities.
f) The outage plan shall be reviewed by the System Operator on quarterly and monthly basis in coordination with the concerned agencies and adjustments may be made as per requirements.
g) In case of emergency in the system (loss of generation, breakdown of an element, transmission system disturbance, system isolation or any disturbance which has adverse effect on the grid, the System Operator may conduct study again before clearance of the plan outage).
h) The concerned agency shall obtain the final approval from the System Operator by submitting a shutdown request in the format given in **Annexure-7** prior to availing an outage.

7 PERIODIC REPORTS

This is in compliance to Grid Code Regulation, 2008 Clause No. 6.14 regarding the periodic reports which needs to be developed and submitted to the concerned or relevant agencies.

7.1 Purpose

The purpose of this chapter is to

a) Describe the various reports prepared by the relevant agencies
b) The importance and the significance of the reports

7.2 Quarterly and Annual Reports

A report covering the performance of the Transmission System shall be prepared and submitted by the System Operator for every quarter and year. The report should be submitted to the relevant agencies, Bhutan Electricity Authority and the Ministry.

A quarterly report shall be issued by the System Operator to all Licensees, Authority and the Ministry, and shall cover the performance of the Transmission System for the previous quarter. The report shall contain the following but not limited to:

a) Performance of Generating Stations;
b) Peak demand, energy availability and requirement for the country;
c) Export and import of electricity to/ from neighboring countries;
d) Frequency profile: Maximum and minimum frequency recorded and the frequency duration in different frequency bands;
e) Voltage profile of selected substations;
f) Major generation and transmission outages;
g) Transmission constraints; and Instances of persistent or significant non-compliance with the Grid Code Regulation.

8 ANNEXURES

8.1 Annexure 1: Bhutan Power System Network Diagram

8.2 Annexure 2: Simulated Network Diagram (Peak Generation)

8.3 Annexure 3: Simulated Network Diagram (Firm Generation)

8.4 Annexure 4: Generator Capability Curve of All Generator

a. Capability curve of Chhukha Generator

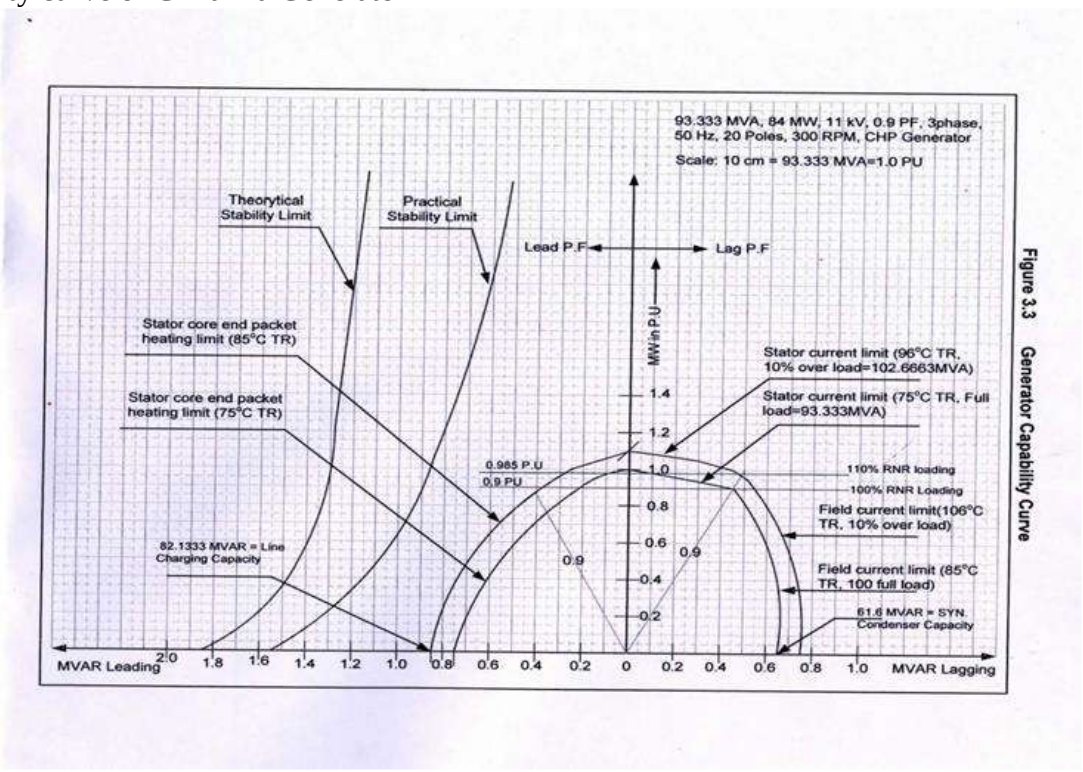
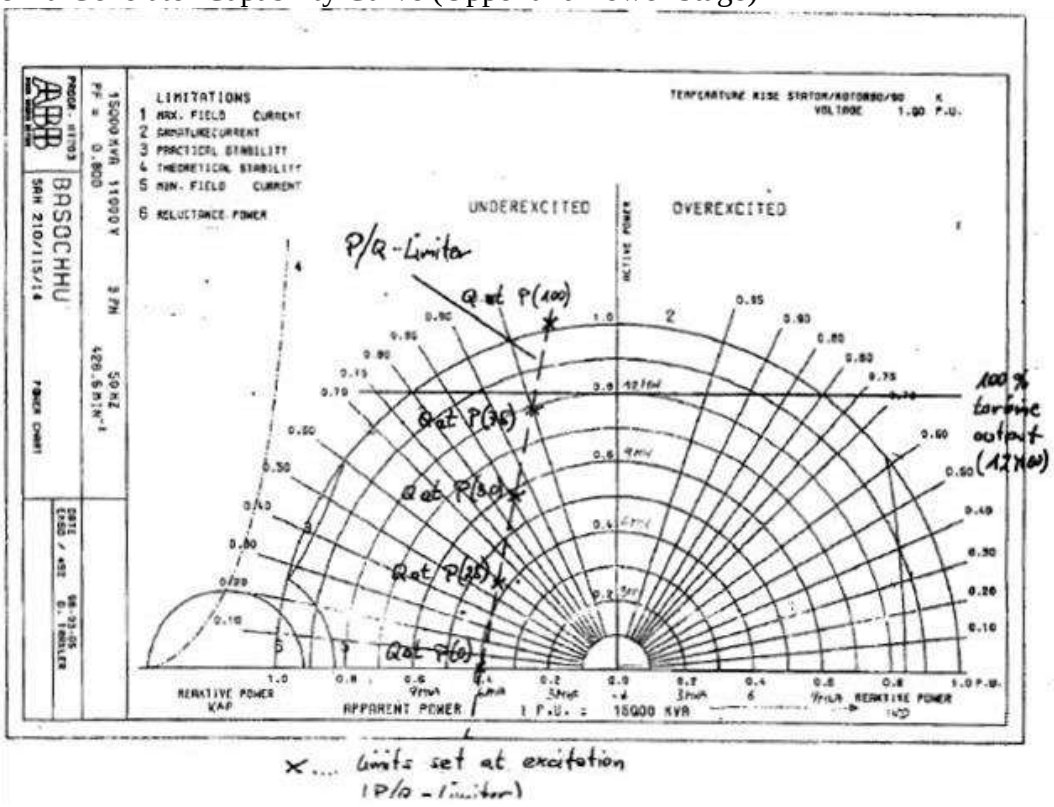
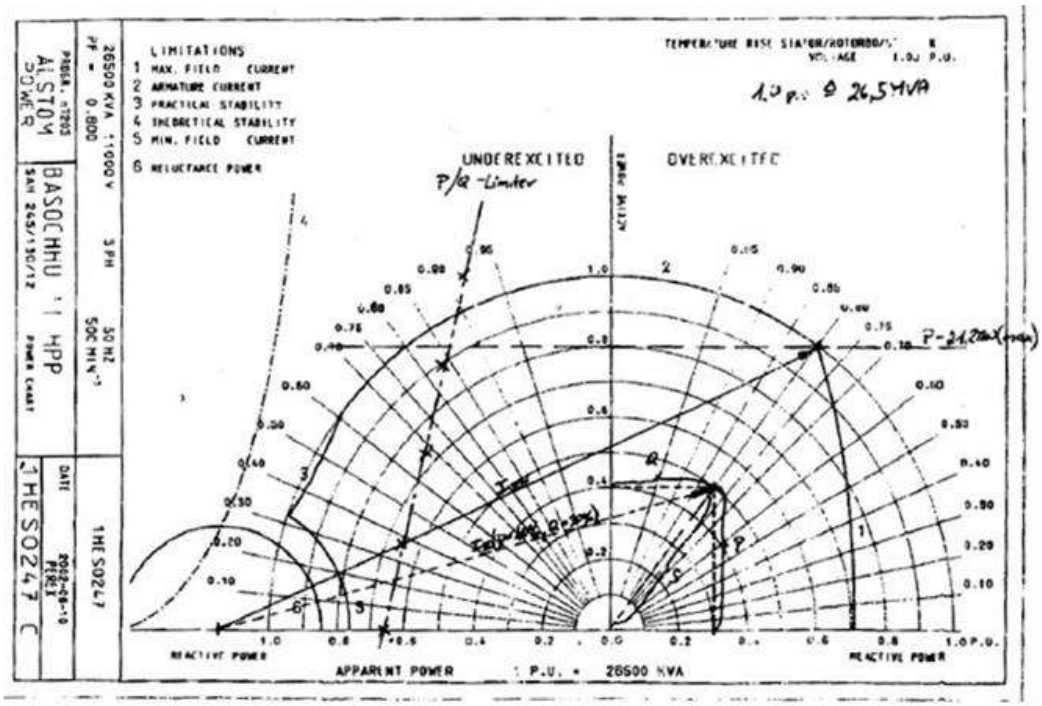


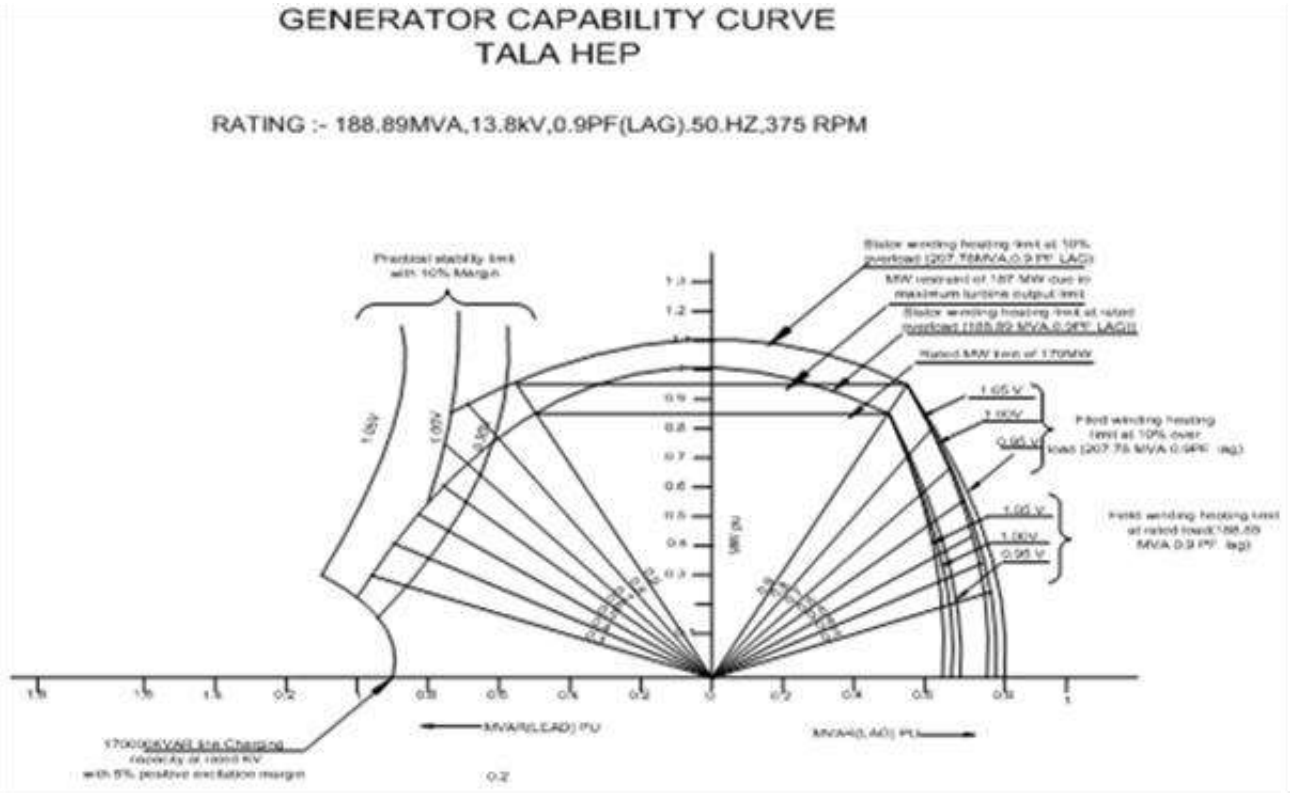
Figure 3.3 Generator Capability Curve

b. Basochhu Generator Capability Curve (Upper and Lower Stage)

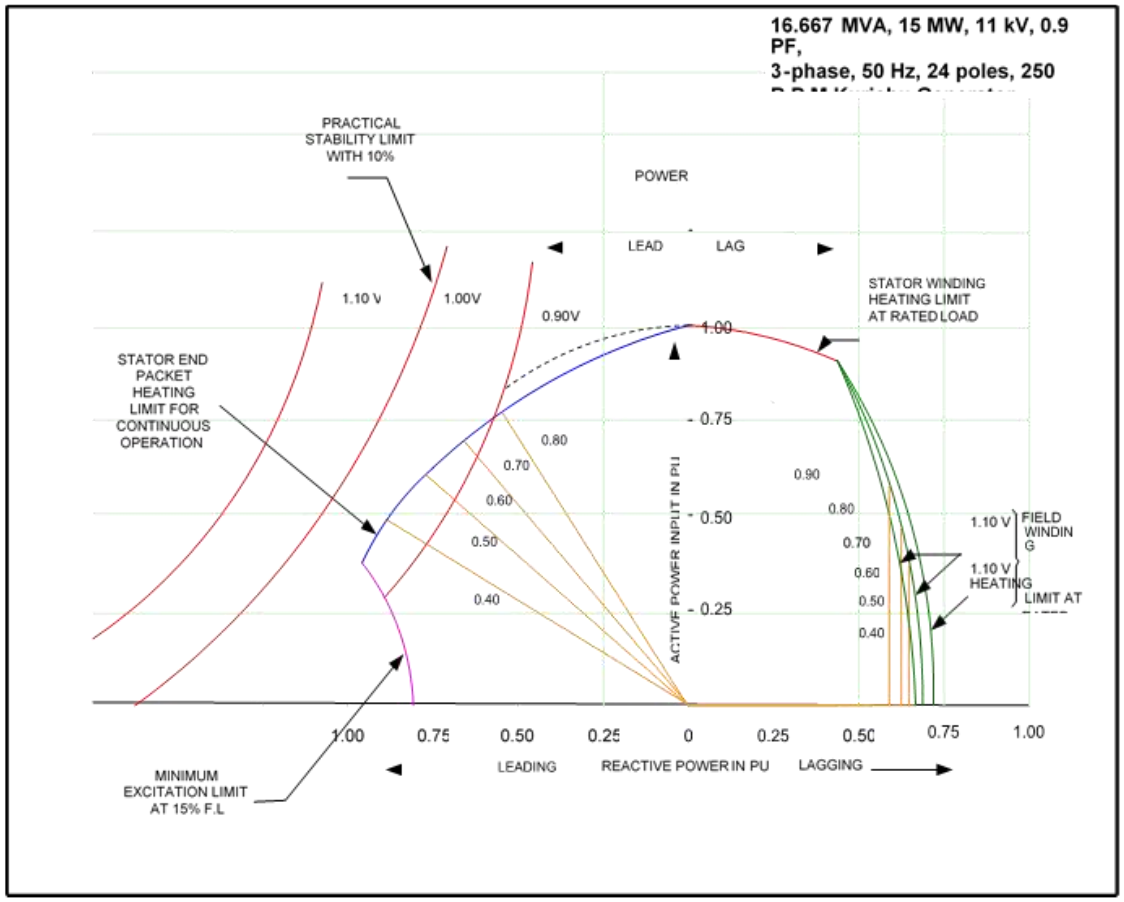




c. Tala Generator Capability Curve



d. Kurichhu Generator Capability Curve



8.5 Annexure 5: Day Ahead Generation Declaration Form

GENERATION AVAILABILITY DECLARATION

(To be sent to the System Operator by the Generators in accordance with Grid Code Regulation, 2008)

Message No.:	Enter message number	**Date:**	mm/dd/yyyy format
Name of Plant:	Choose Power Plant	**Time:**	hh:mm format

Expected Ex-Power Plant Availability Declaration for Date:	**mm/dd/yyyy format**
Expected Maximum Ex-Power Plant Power (MW):	
Expected Ex-Power Plant Energy (MWh):	
Anticipated Line Constrains/Outages/Other constrains, if any:	

Hours	Expected Ex-Power Plant Power (MW)	Anticipated In-flow (m^3/s)	Remarks	Hours	Expected Ex-Power Plant Power (MW)	Anticipated In-flow (m^3/s)	Remarks
0:00 - 0:15				12:00 - 12:15			
0:15 - 0:30				12:15 - 12:30			
0:30 - 0:45				12:30 - 12:45			
0:45 - 1:00				12:45 - 13:00			
1:00 - 1:15				13:00 - 13:15			
1:15 - 1:30				13:15 - 13:30			
1:30 - 1:45				13:30 - 13:45			
1:45 - 2:00				13:45 - 14:00			
2:00 - 2:15				14:00 - 14:15			
2:15 - 2:30				14:15 - 14:30			
2:30 - 2:45				14:30 - 14:45			
2:45 - 3:00				14:45 - 14:00			
3:00 - 3:15				15:00 - 15:15			
3:15 - 3:30				15:15 - 15:30			
3:30 - 3:45				15:30 - 15:45			
3:45 - 4:00				15:45 - 16:00			
4:00 - 4:15				16:00 - 16:15			
4:15 - 4:30				16:15 - 16:30			
4:30 - 4:45				16:30 - 16:45			
4:45 - 5:00				16:45 - 17:00			
5:00 - 5:15				17:00 - 17:15			
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6:45 - 7:00				18:45 - 19:00			
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7:45 - 8:00				19:45 - 20:00			
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8:30 - 8:45				20:30 - 20:45			
8:45 - 9:00				20:45 - 21:00			
9:00 - 9:15				21:00 - 21:15			
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9:30 - 9:45				21:30 - 21:45			
9:45 - 10:00				21:45 - 22:00			
10:00 - 10:15				22:00 - 22:15			
10:15 - 10:30				22:15 - 22:30			
10:30 - 10:45				22:30 - 22:45			
10:45 - 11:00				22:45 - 23:00			
11:00 - 11:15				23:00 - 23:15			
11:15 - 11:30				23:15 - 23:30			
11:30 - 11:45				23:30 - 23:45			
11:45 - 12:00				23:45 - 0:00			

Signature: Your name if you want to send electronically

Name: Your Name
Designation: Your Designation

8.6 Annexure 6: Day Ahead Demand Forecast Form

LOAD DEMAND DECLARATION

(To be sent to System Operator by the Distribution Licensees as per Grid Code Regulation, 2008)

Message No.:	Enter message number	**Date:**	mm/dd/yyy format
Department:	Distribution and Customer Service Department, BPC	**Time:**	hh:mm format

Forecasted Load Demand Declaration for Date: mm/dd/yyy format

Anticipated Line Outages/Other constrains, if any:

Electricity Service Division	0:00 - 0:15	0:15 - 0:30	0:30 - 0:45	0:45 - 1:00	1:00 - 1:15	1:15 - 1:30	1:30 - 1:45	1:45 - 2:00	2:00 - 2:15	2:15 - 2:30	2:30 - 2:45	2:45 - 3:00	3:00 - 3:15	3:15 - 3:30	3:30 - 3:45	3:45 - 4:00	4:00 - 4:15	4:15 - 4:30	4:30 - 4:45	4:45 - 5:00	5:00 - 5:15	5:15 - 5:30	5:30 - 5:45	5:45 - 6:00	6:00 - 6:15	6:15 - 6:30	6:30 - 6:45	6:45 - 6:00	7:00 - 7:15	7:15 - 7:30	7:30 - 7:45	7:45 - 8:00	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00	9:00 - 9:15	9:15 - 9:30	9:30 - 9:45	9:45 - 10:00	10:00 - 10:15	10:15 - 10:30	10:30 - 10:45	10:45 - 11:00	11:00 - 11:15	11:15 - 11:30	11:30 - 11:45	11:45 - 12:00
Bumthang																																																
Dagana																																																
Gelephu																																															
Haa																																															
Lhuentse																																															
Mongar																																															
Paro																																															
Pemagatshel																																															
Phuentsholing																																															
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Wangue Phodrang																																															
Zhemgang																																															
Total (MW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Electricity Service Division	0:00 - 0:15	0:15 - 0:30	0:30 - 0:45	0:45 - 1:00	1:00 - 1:15	1:15 - 1:30	1:30 - 1:45	1:45 - 2:00	2:00 - 2:15	2:15 - 2:30	2:30 - 2:45	2:45 - 3:00	3:00 - 3:15	3:15 - 3:30	3:30 - 3:45	3:45 - 4:00	4:00 - 4:15	4:15 - 4:30	4:30 - 4:45	4:45 - 5:00	5:00 - 5:15	5:15 - 5:30	5:30 - 5:45	5:45 - 6:00	6:00 - 6:15	6:15 - 6:30	6:30 - 6:45	6:45 - 6:00	7:00 - 7:15	7:15 - 7:30	7:30 - 7:45	7:45 - 8:00	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00	9:00 - 9:15	9:15 - 9:30	9:30 - 9:45	9:45 - 10:00	10:00 - 10:15	10:15 - 10:30	10:30 - 10:45	10:45 - 11:00	11:00 - 11:15	11:15 - 11:30	11:30 - 11:45	11:45 - 12:00
Bumthang																																																
Dagana																																																
Gelephu																																															
Haa																																															
Lhuentse																																															
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Trongsa																																															
Tsirang																																															
Wangue Phodrang																																															
Zhemgang																																															
Total (MW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Signature: Your name if you want to send electronically

Name: Your Name

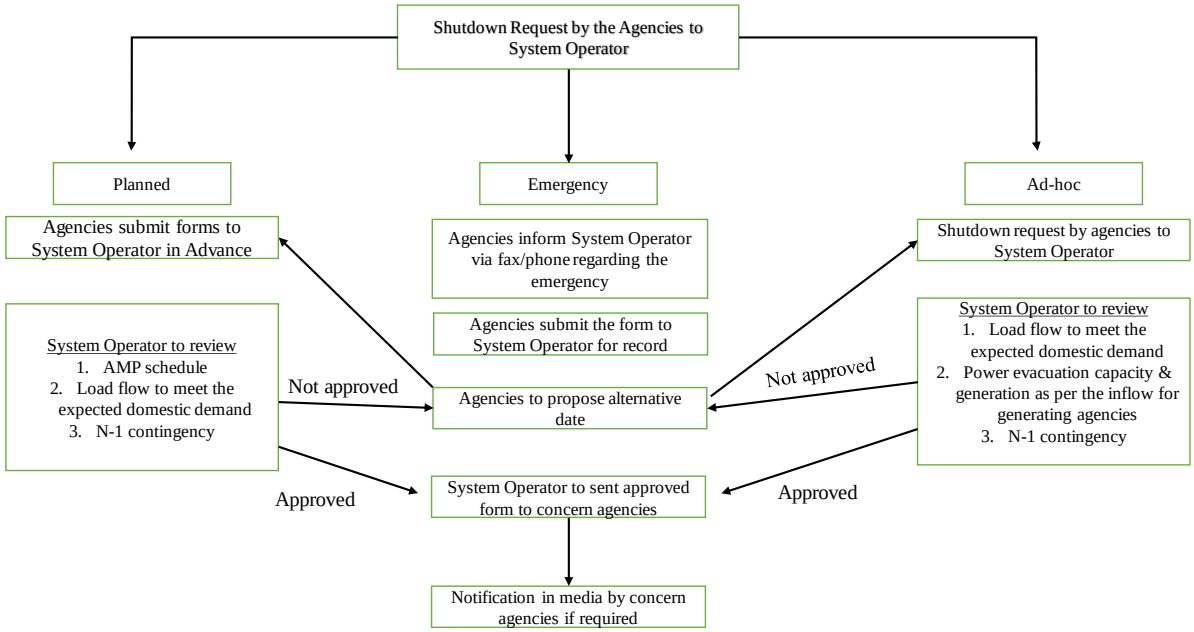
Designation: Your Designation

8.7 Annexure 7: Shutdown Request Form

8.8 Annexure 8: Annual Maintenance Plan Form

Sl. No	Name of Element/Feeder	From Data/Time	To Date/Time	Programs	Remarks

8.9 Annexure 9: Flow Chart for Availing Shutdown by Stake Holders



9 APPENDIXES

9.1 APPENDIX A: APPROVED PROTECTION DEVICES

This appendix describes the approved protection devices and how these devices must be operated to provide acceptable isolation and de-energization points for protection under a Guaranteed Work Clearance Authorization.

General Guidelines for Electrical and Mechanical

The following are the general electrical and mechanical guidelines.

Electrical Guidelines

Open Contacts

Whenever possible, electrical isolating devices should meet the requirement that all phases of the circuit be confirmed 'open' by visual inspection of the contacts or conductors.
If this confirmation cannot be performed due to physical design of the device, perform the required checks to verify the contacts open using an approved Electrical procedure and record it on Work Clearance Document tagging list.
If this confirmation cannot be performed due to previous isolation requirements denying access to contacts (example: MCC breaker door lock closed), refer the Work Clearance Document that performed the check.
A potential check is not required for switchgear breakers (33kV or below) as protection is provided by ensuring physical separation of the breaker from the bus or disconnected leads from such breakers.

Grounding

No work must proceed on any apparatus with a voltage of 300V or above, unless all conductors have been properly grounded. Certain apparatus, such as insulated cables, generator windings, and motors may be exempted from these rules if it is not reasonably possible to apply proper grounds.

Potential Checks

Before manually applying temporary grounds or before starting work on any electrical apparatus, perform a potential check of all conductor phases to confirm isolation or de- energization. Although this check is primarily the responsibility of the Work Clearance Holder, personnel working under the Work Clearance Application must not take for granted that this check has been performed

Split Phase Circuits (common neutral)

Complete isolation of one phase in a two phase, common neutral circuit (that is, 347 V lighting system) can only be provided by isolation of the power supply to all phases of the circuits.
When it is decided to take out of service only the circuit on which work is to be done, follow an approved

Procedure and provide Limited Protection by isolating only the power supply of the circuit on which work is to be done. In this condition low voltages and currents will probably be present in the common neutral. However, if the common neutral is broken, voltage and available fault current from the common neutral to ground will be the full value of the energized phase of the circuit.

Locking Devices

With the exception of specified devices (fuses, temporary grounds, cable or bus bar removal), all electrical protection devices must be locked in position to provide guaranteed protection. A device that cannot be locked is considered a Limited Protection device.

Mechanical Guidelines

Depressurizing or Draining

Systems or equipment must be drained and vented or depressurized to ensure that all sources of energy or hazardous substances have been adequately removed. If this cannot be confirmed, define a special procedure or enter appropriate statements of caution on the Work Clearance Application.

Use caution when ensuring adequate isolation through the ability to depressurize or drain. A false indication may occur if:

a) The drain or vent point is plugged a device (*example:* check valve, control valve) located between the isolation and drain or vent points was in a closed state (eventual opening can occur).

Locking Devices

All isolation devices are to be secured in the protecting position using approved securing devices if practical (example: ice plugs and check valves without external swing arms are isolation points that cannot be physically secured). Air operated valves that fail in the protected state can be considered isolated if there is no built in manual operator and the air supply is isolated disconnected and tagged.

Approved securing devices are:

a) locks with numbered keys
b) chains with a breaking strength greater than 22 kgs
c) Tie wraps with a breaking strength greater than 22 kgs and other Operations stocked safety lock out devices.

Double Isolation

When dealing with high pressure, high temperature, or toxic or corrosive substances, consider providing double isolation (if available) whereby two valves in series are closed to provide isolation.

Electrical Guaranteed protection devices

Guaranteed protection devices provide a protection guarantee because:

a) The physical characteristic of the device enables the device position to be verified and ensures this protecting position will not change (*example:* metal clad rackable switchgear).
b) Verification is through visual observation (*example:* electrical contacts open).
c) Verification is through or an approved indirect method (*example:* potential check of electrical circuit).

Electrical guidelines by devices

Cables or bus bars

Sections of cables or bus bars may be removed to provide guaranteed protection (without the need for locking). Connection points on the protected side must be tagged to identify them as isolating points. When leads are disconnected, open the associated breaker and attach a lamacoid to the door stating that the leads are disconnected. Remove the lamacoids when the leads are reconnected. When performing maintenance on the MCC during a maintenance outage and the tag is removed from the load leads, remove the lamacoids and reconnect the leads as part of the return to service. The lamacoid does not provide protection and will be recorded as a comment in the tagging or untangling list.

In the case of bus links, isolation can be provided if approved links are removed, the complete separation of the bus observed, and the cover installed, locked or secured in place, and tagged.

Use caution to ensure possible live components are remote from the work location. Where this is not practical, enter adequate cautionary notes on the associated Work Clearance Application.

Disconnected cables must have their bare leads taped.

Operated switches

Electrically operated or remote mechanically operated switches must be locked in the guaranteed state or a portion of the mechanism must be removed to prevent accidental operation. In the case of 345kV disconnect switches, block electrical operation by setting the selector handle to Manual and locking it. Block mechanical operation by chain locking the hand wheel.

Lockable circuit breakers

Lockable circuit breakers can be used as guaranteed protection devices as long as the device is tagged and one of the following conditions exist:

b) contacts on all phases can be (and are) visually inspected for confirmation of the open state
c) All phases have their contacts verified open using an approved Electrical procedure. This check must be performed at the appropriate part of the circuit, by a qualified person.

Fuses

Fuses can be used as guaranteed protection devices, without the need for locking, as long as the device or open circuit is tagged and the circuit can be confirmed in the open state by visual inspection. Removal or installation of PT fuses must be performed under a Work Clearance Application. The fuse(s) must be removed from the circuit and, if applicable, removed from the fuse holder (example: 120V ac, Class 2), and the protected side of the circuit tagged.

Removing the fuse from the holder is not necessary if the fuses can be locked in the retracted position (example: 11kV and 13.8kV PT fuses).

Caution: The associated bus must be isolated before opening or closing the PT compartment door. If unsure of the circuitry design such that the protected side is not obvious, the operator must obtain qualified assistance in making this determination.

Temporary grounds

Temporary grounds (cables) are considered guaranteed protection devices without the need for locking in place. These grounds must be properly applied by trained and qualified personnel. If installed as part of the protection Work Clearance Document, the grounds must be tagged with red **Do Not Operate** tags.

Tags must be attached at the point where the ground disconnected to the protected circuit or bus and also at the point where the ground is connected to the station grounding network.

Note: Installation or removal of the grounds on the generator lighting arrestors or IPB must be performed under a Work Clearance Application.

Grounding devices

A grounding device is available for installing in a 13.8kV breaker cell if necessary. The primary use of this device is to ground the electrical apparatus on which work is performed. Installation of this device must be performed by an approved individual who has received training in its use. It must be locked in place.

Note: *Installation or removal of the grounding device in any cell that supplies power to the bus must be performed under* a Work Clearance Application.

The grounding device must be racked into the connected position, and have the racking lever tagged, all three phases connected to the station ground, and each phase tagged and the racking lever locked to be considered a protection point.

If the grounding device is used to provide protection to disconnect or reconnect a load and is removed after the device is disconnected, the disconnected leads must be tagged in addition to the supply device.

Metal clad circuit breakers

Draw-out types of metal clad circuit breakers provide satisfactory guaranteed protection (without visual inspection of the contacts) when they are disconnected from the bus and either the shutters are locked closed(example: 4.16-13.8 kV switchgear) or the breaker is locked in the disconnected position (example: 600V switchgear).

Electrical de-energization devices

De-energization of electrical equipment (when necessary) is provided by the application of grounds. These

grounds may be temporary ground cables, integral grounding switches, or installed grounding devices.

Electrical guaranteed protection devices by voltage level

Voltage Level	Guaranteed Protection Device	Requirements for Approval
26 – 345 kV	Isolator/disconnect switch Cables and bus bars 26 kV PT fuses	isually verified that all phases are physically open, and the mechanism is locked in open state, and if electrically operated then locked in Manual Mode and tagged isually verified that all sections are physically removed and connection points on the protected side are identified as isolation points by tagging. Work Clearance Authorization is required to remove these fuses
11kV – 33 kV	Circuit breaker (switchgear) Cables and bus bars Grounding Device Isolator/disconnect switch 11-33 kV PT fuses	Racked out to test or disconnect position. Shutters confirmed closed and locked and tagged. As above (for 26-345 kV cables and bus bars). Racked to the connect position in accordance with Approved procedures (by persons approved to operate the device) to ground the equipment to be isolated or de-energized, and locked in place and
600 volt	Circuit breaker (switchgear) and bus bars Circuit reaker (MCC) Isolator/disconnect switch	Racked clear of bus to test or disconnect position, locked in that position and tagged. As above (for 26-345 kV cables and bus bars) Selected to OFF and contacts confirmed open, either visually or by an approved Electrical Measurement procedure. Door closed, and breaker locked open and
110 – 220 volt	ircuit breaker	Selected to OFF and all contacts open, either

48-250 volt	Fuses: 250 v dc, 120V AC, Fuses: 48V dc, Isolator/disconnect switch	visually or by an approved Electrical Measurement procedure. Circuit breaker locked in the open position and tagged. Fuse and holder retracted, fuses removed from holder. Tags installed on protected side.

9.2 APPENDIX B: TAGGING EQUIPMENT

Tagging hierarchy

Level 1:
Level 1 tags establish work protection. These are the red 'Do Not Operate' tags. Normally equipment with a red 'Do Not Operate' tag is not permitted to operate.
There may be exceptions to this rule. For example, after maintaining an electric motor it may be necessary to carry out a Bump Test, or Direction of Rotation Test. Operation of any device covered by these tags must be performed in accordance with procedures established to control these tags (examples: suspension for test, Work Permit Modification).

Level 1 tag includes:

- Red Work Clearance 'Do Not Operate' tags

Other types of tags include Temporarily Energized tags that provide information about energized equipment and should not be removed without approval.

Level 2:
Level 2 tags provide information about a particular device. These are normally lined white tags on which information can be written. (Example: while working on an SF6 circuit breaker, it is necessary to remove the SF6 supply to the circuit breaker. As an isolation point, it could be covered by a red 'Do Not Operate' tag. Alternatively a white Information Tag could be placed adjacent to the red 'Do Not Operate' tag on the electrical supply to the circuit breaker.

9.3 APPENDIX C: MAINTENANCE JOBS NOT REQUIRING APPROVAL

JOBS NOT REQUIRING WORK CLEARANCE AUTHORIZATION (WCA)

Activity	Exception or Condition	Comments

Transporting material within the plant	Control Room Operator (CRO) to be notified before transporting bulk hazardous chemicals (for example, a drum)	
Unloading equipment at site	Work Clearance required if using Boom Trucks under power lines.	
Maintenance of on-site Security Equipment	Maintenance must not impact ability to establish audio or video contact between Plant Security and the Room Operator.	Maintainer to coordinate with Plant Security and the CRO.
Normal painting process for equipment and floors		Maintainer to observe restrictions and coordinate with Plant Supervisor as required.
Repair or replace site fluorescent and incandescent bulbs.	Work Clearance required for areas under surveillance by Security Cameras. Reduced lighting cause safety concerns for maintenance or operations activities.	Maintainer performing responsible to ensure exception is not compromised.
Battery banks, non-intrusive tests	The following activities are allowed: voltage checks internal resistance checks specific gravity checks.	Maintainer responsible for staying within the scope of the work. CRO to be informed before starting, and when work is completed.

	Removing rectifiers or battery chargers from service is intrusive and requires Work Clearance	

Non-intrusive clip-on in-rush and running current measurements on transformers and other loads.	Co-ordination with CRO to place load in-service if required. Exception: Work Clearance required if un-insulated and exposed cables or bus bars are present and within 18 inches of the work.	Maintainer responsible to co-ordinate with CRO.
Routine vibration readings	Not applicable	
Thermo-vision checks	Work Clearance is required for opening of electrical or mechanical equipment.	
Equipment rebuild in other than shop areas	Work Clearance is required if welding, grinding, burning or soldering is involved,	Maintainer responsible for obtaining Work Clearance if welding, burning or soldering is required, and for following station procedures for such activities.
Routine oil sampling	Verbal approval from the CRO required before starting.	
Monthly crane or hoist inspections.	The intent is that no isolations are required for inspections.	Maintainer performing maintenance responsible for ensuring isolations are required
Excavation activities.	Consult all facility diagrams to avoid buried cables.	
Maintenance in parking lot and other outside grounds.		

Staging	Staging within 20 feet of crane bus bars requires Work Clearance.	Maintainer responsible for obtaining Work Clearance for work in this area.

Standard repairs on water fountains, washroom sinks, toilets, and urinals.	No burning, welding or soldering required.	Maintainer to obtain Work Clearance if burning, welding or soldering required

9.4 APPENDIX D: DEFINITIONS

These definitions apply to both the System Operator and the Field Operators. There are four pivotal terms.

a) **Work Clearance Authorization (WCA**) - which is the actual authorization to carry out maintenance work.
b) **Guaranteed Protection** - which is the physical assurance that a worker authorized to carry out the work, maintenance, or testing will be protected from all electrical hazards and electrical injury while carrying out the assigned duties.
c) **Isolated** - refers to a state whereby equipment is physically disconnected or separated from sources of dynamic energy by means of approved isolating devices. Isolated does not infer de-energized. (Example: a capacitor bank may be completely isolated from any electrical supplies. However it might still retain some residual charge or energy until both ends of the capacitor are connected to ground, so it is not yet de-energized)
d) **De-energized** - refers to an isolated state of the system that is also:
    1) in the electrical sense: at the potential of the earth or ground
    2) in the mechanical sense: at rest, at atmospheric pressure; free from stored or potential mechanical energy (*example:* spring loaded, or compressed air in an Air Blast circuit breaker); free from chemical, poisonous, suffocating, or explosive substances.

The supporting terms associated with these pivotal terms are described in the following list.

Configuration management
Configuration management is the integrated set of processes, programs and procedures required to ensure that the physical plant is in accordance with the paper plant. That is, it is the process which assures that there will be no surprise configurations encountered in the course of planning and carrying out maintenance.

Confirmation
A confirmation is a record of the time spent and work performed by individuals while performing work related to an Order.

De-energizing device
A de-energizing device is one that ensures that the de-energized state (mechanical or electrical) is achieved and maintained.

Emergency

An emergency is an abnormal event that necessitates prompt actions in order to mitigate adverse consequences. Emergencies include situations for which prompt action is warranted to respond to a perceived hazard or threat.

Ground

A ground is a metallic plate or rod buried or driven into the earth, or an extended conducting body connected to such a plate or rod, or to a buried metallic system. Temporary grounds must be copper wire and installed with clamp-on or clip-on connectors. Grounding devices satisfy these requirements.

Guaranteed Protection

A Guaranteed Protection Work Clearance Authorization provides protection from hazards by guaranteeing both of the following:

a) The equipment on which work is authorized is isolated and, where possible, de- energized (in the case of bus work, grounds will be applied) or instructions are provided for safely de-energizing the equipment.
b) The devices used are approved as guaranteed protection devices and the protecting position will not change while the Guaranteed Protection Work Clearance Authorization is in effect (unless the Work Clearance Authorization is suspended for testing or modifications in accordance with this document).

Isolating device

An isolating device is an approved device that provides a positive physical separation between equipment on which work is authorized and any source or potential source of energy.

Job Safety Analysis

The Job Safety Analysis is a formal plan that complements the protection provided by the Work Clearance Authorization by setting limits (example: on Oxygen requirements) or providing detailed procedures. It is used to provide more guidance on conventional hazards when the hazard is not covered by an approved issued procedure.

Limited protection device

A limited protection device is one that provides work protection, but cannot be positively guaranteed to remain in the same state or the position cannot be clearly identified.

Limited Protection Work Clearance Application

A Limited Protection Work Clearance Application provides a degree of protection that is limited because of one or more of the following:

a) Isolation from all hazards, sources, or potential sources, of energy cannot be guaranteed for the equipment on which work is authorized.

b) One or more of the devices used to isolate or de-energize the equipment is a limited protection device.
c) One or more of the devices used for isolation or de-energization has a Condition Abnormal tag attached.

No Protection WCA

A No Protection WCA is a Work Clearance Authorization that is used when there is no hazard from which the holder needs protection. They are used to keep the Control Room Operator and Shift Supervisor aware of activities that may affect plant operations (examples: computer software changes, painting in normal access areas).

Operations activities

Operations activities are activities related to testing, changing, and monitoring the status of station structures, systems, or components (SSCs).

Plant status control

Plant status control refers to control of the configuration of systems to ensure the plant is operable, safe, and kept within the established operating boundaries.

Protection Guarantee

Protection Guarantee is a protection boundary established using only protection guarantee devices positioned and secured in accordance with the lists given in Appendix B: Approved Protection Devices, and all energy sources have been isolated and, where possible, de- energized.

Protection Points

Protection points are the points used to provide work protection and includes both isolation and de-energization points.

Safe Deviation

Safe deviation is an approved departure from the normally prescribed process, ensuring safety of personnel and plant equipment are not compromised. Approval is required for a safe deviation.

Safety Work Plan or Hazard Plan

The Safety Work Plan, Hazard Plan or Job Safety Analysis is a formal plan that complements the protection provided by the Work Clearance Authorization by setting limits (example: no work at elevations without Fall Protection Equipment) or providing detailed procedures.

Self Protection Work Clearance Authorization

A Self Protection Work Clearance Application provides no guarantee of protection or reduction of the hazards or risk associated with the work authorized. Protection will be provided by the Work Clearance Holder through safe work practices and the use of green self-protection tags.

A Self Protection Work Clearance Application can be used when:

a) the system must remain energized due to the nature of the maintenance (*examples:* troubleshooting 48 VDC logic circuits, obtaining vibration readings on operating equipment)
b) it is not practical to provide protection due to the nature of the maintenance (*examples:* removing a stab type breaker drawer from an energized MCC for breaker maintenance or adjusting the packing on a valve)
c) it is not practical to provide a protection guarantee due to the nature of the maintenance (*examples:* adjusting stop limits on cranes where the maintainer must alternate between the isolated state to perform adjustments and the energized state to assess the adjustments)
d) calibrating instrumentation

Verification

Verification is the act of reviewing, inspecting, testing, checking, or otherwise determining and documenting whether items, processes, services, or documents conform to specified requirements.

Work authorization

Work authorization is authorization to perform work on, or gain access to, structures, systems, or components (SSCs).

Work Clearance Authorization

A formal approval to do the work becomes the Work Authorization. The Work Clearance Authorization may contain instructions or restrictions for the Work Clearance Holder.

Work Clearance Document

A Work Clearance Document is the actual paper copy of a Work Clearance Authorization, which provides additional details and controls for the work, specifically:

a) Applying and removing Work Clearance protection, including: a list of the equipment to be operated, the desired state for the equipment, the sequence of operations, tag type for devices
b) Aligning plant equipment to prevent process disturbances during maintenance and returning to the desired configuration after maintenance
c) Performing authorized testing
d) Returning maintained equipment or systems to service, including: a list of the equipment to be operated, the desired state for the equipment, the sequence of operation.
e) Modifying protection points
f) Changing from red 'Do Not Operate' tags to 'Conditions Abnormal' tags.
g) A record of the preparation, checking, modification, and testing performed.

Work Clearance Package

The Work Clearance Package is a compilation of documents including the following:

a) Work Clearance Authorization

b) Work Clearance Document

c) Work Clearance Document Check Forms

d) Any attachments (*examples:* tagging and un-tagging lists, flow sheets, appropriate system diagrams, Safety Work Plan).

The package provides authorization and procedures for performing and monitoring maintenance.

Committee members

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