BLACK START AND RESTORATION PROCEDURE FOR

ASSAM STATE GRID

Prepared in Compliance to

Clause 34.1 of CERC (Indian Electricity Grid Code) Regulations, 2023 and

Clause 12.4 of AERC (Electricity Grid Code) Regulations, 2024.

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PREFACE

This document Operating Procedure for Assam state grid has been prepared in compliance to Clause 34.1 of CERC (Indian Electricity Grid Code) Regulations, 2023 and Clause 12.4 of AERC (Electricity Grid Code) Regulations, 2024 and is subject to change as per procedures laid down by competent authority from time to time.

The intent of this document is to serve as a guide for the necessary formalities and procedures to be followed while running the power system during black out condition. The procedure incorporated in this document is to be followed by the stakeholders for bringing normalcy to the state grid after a state of partial or full blackout. It is subject to change as per procedures laid down by competent authority from time to time. If any modification is required for removing difficulties, the same shall be done with prior approval of the Commission.

Words and expressions used in these procedures and not defined herein but defined in various regulations of AERC/CERC/CEA orders and procedures of CERC, judgments of ATE, rules and policies of MOP and Electricity Act, 2003 shall have the meaning assigned to them under these regulations, orders, procedures, rules, policies & the act.

Disclaimer: All efforts have been made to make this book error free and up to date. However, in view of the fast-changing network conditions, it is possible that some of the changes could have not been incorporated as per actual. Any typographical error which may have crept up inadvertently may please be ignored.

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CHAPTER 1: INTRODUCTION

1.1 The State Grid presently comprises of a Discom Utility i.e Assam Power Distribution Company Ltd. (APDCL), a state generator Assam Power Generation Corporation Ltd. (APGCL), Independent Power Producers (IPP), Captive Power Producers (CPP), Open Access consumers, Bulk Consumers etc. at various voltage levels.

The Assam transmission system is the largest in the North Eastern Region and accounts for more than 60% of the total energy requirement of the NER. It has interconnections with neighbouring states of Meghalaya, Tripura, Nagaland, Manipur and Arunachal Pradesh and is also connected with the rest of the national grid by various Inter State Transmission lines (ISTS) at 132kV, 220 kV and 400 kV levels. There is also a connectivity with Bhutan at 132kV level from Rangia Grid substation.

As on date of publishing this document, the Assam Grid comprises of around Eighty-Two (82) EHV grid substations of AEGCL, seven (08) Generating stations of APGCL and twelve (12) Independent Power Producers.

1.2 GRID DISTURBANCE AND BLACKOUT STATE

As per CEA (Grid Standards) Regulations, 2010, "Grid disturbance" means tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, resulting in total failure of supply at a sub-station or loss of integrity of the grid, at the level of transmission system at 220 kV and above (132 kV and above in the case of North-Eastern Region).

As per IEGC 2023, power system can be categorized under normal, alert, emergency, extreme emergency and restorative state depending on the type of contingencies and value of operational parameters of the power system by RLDC, NLDC or SLDC, as the case may be. "Blackout state" means a condition at a specific time where a part or all the operations of the power system have got suspended.

1.3 CLASSIFICATION OF GRID DISTURBANCE

The classification of grid disturbances in increasing order of severity as per CEA Grid Standards is given below:

i. Category: GD-1: When less than ten percent of the antecedent generation or load in a regional grid is lost;

ii. Category: GD-2: When ten percent to less than twenty percent of the antecedent generation or load in a regional grid is lost.

iii. Category: GD-3: When twenty percent to less than thirty percent of the antecedent generation or load in a regional grid is lost

iv. Category: GD-4: When thirty percent to less than forty percent of the antecedent generation or load in a regional grid is lost

v. Category: GD-5: When forty percent or more of the antecedent generation or load in a regional grid is lost.

vi. Category: Near Miss: Near miss event means an incident of multiple failures that had the potential to cause a grid disturbance, power failure or partial collapse but did not result in a grid disturbance. Such incidents proactively analyzed and reported to have a better control on grid on any eventuality.

CHAPTER 2: SYSTEM RESTORATION APPROACH

2.1 GENERAL GUIDELINES

1. This document should be available in the Control Room of State Load Despatch Centre & readily accessible to all system operators.
2. List of Priority wise loads in each GSS shall be prepared in consultation with DISCOM and loads to be restored on priority shall be readily available to system operator at SLDC.
3. SLDC will co-ordinate entire restoration process through the grid substations/ generators etc.
4. During restoration process, SLDC is authorized to operate the Grid with reduced security standard for voltage and frequency in order to achieve fastest possible recovery.
5. All communication channels required for voice communication during the restoration process must be operational.
6. Healthiness of communication system and ancillaries at Power Stations and Sub-Stations should be checked at least once in every week to ensure availability of communication system during the periods of crisis
7. List of phone numbers (VOIP, Landline, Mobile) of Control Rooms of Power Stations and Grid Sub-Stations shall be available at SLDC.
8. System Operators are expected to be thoroughly conversant with

   (a) Reactive Capability of Generators.

   (b) Voltage Control through the following means:

   - Charging the shorter line first
   - Switching off Capacitor Bank
   - Taking Bus Reactors into service
   - Charging Transformers and taking Bus Reactors into service
   - Converting Line Reactors into Bus Reactors wherever feasible.
   - Operating Generators at minimum Voltage levels
   - Changing Transformer Taps
   - Energisation of fewer High Voltage Lines.

   (c) Network configuration and

9. Synchronization facility wherever available should be checked periodically and should be kept in working condition. Periodic report of non-functioning of Synchronoscope is to be sent to SLDC.

10. All equipment such as Disturbance Recorders and Event Loggers shall be kept in healthy condition, so that under no condition such important data is lost. Periodic report of non-functioning of Disturbance Recorder/Sequential Event Recorder to be sent to SLDC by the entity.

11. OLTC of Transformers shall be tested periodically. Periodic report of non-functioning of OLTC of Transformer to be sent to SLDC by the entity.

2.2 INITIAL COURSE OF ACTION

1. Assess

   (a) extent of black out,

   (b) whether any sub-system/island is alive or not,

2. Appraise the severity of disturbance to all concerned utilities.
3. Open all circuit breakers at Power Station / Sub-Stations that have blacked out, to establish well defined starting point of restoration.
4. Note down the relay indications and request field officials to reset them, if operated.
5. Enquire whether any equipment or any element has suffered damage or developed a technical snag.
6. Chalk out the optimum path for restoration after checking the grid elements that were under outage before disturbance.

2.3 IMPORTANT CONSIDERATIONS DURING RESTORATION

1. Generating Stations which have black start facilities have to start up immediately
2. Availability of Generation Capacity in each island / sub system to be ensured
3. Availability of transmission lines in the interconnection between islands / sub systems to be ensured.
4. Lower voltage (e.g. 132 kV) and short lines should be preferred while forming island/sub-system.
5. Load to be added in small steps with smaller and radial loads. Restoration of essential/critical loads should be prioritized.
6. For developing island / sub system, special care should be taken to closely co-ordinate the load pick-ups with the ramp rate of generation and to be ensured that the frequency of the island is maintained within sustainable limit (around 50 Hz).
7. If required, Governor and AVR of the units of the island are to be kept in manual mode.
8. UFRs are to be kept deactivated as frequency excursions at this stage may be wider than normal condition. SPS are also to be kept deactivated.
9. A reasonable active to reactive power ratio is to be maintained so that the machine can be operated normally.
10. Auxiliary power to be readily available so that machine can be operated normally.
11. Total auxiliary power drawn by the sub-system to be kept within 3% of the capacity of the source.
12. Before synchronization between two islands there should be proper co-ordination for frequency adjustment.
13. Risky synchronization shall be avoided as Small Island may not be able to survive the jerk
14. While releasing loads, it is to be ascertained whether machines can supply the power
15. Tap position of Transformer, Bus Voltage and Frequency at Power Stations and Sub-Stations should be closely monitored to ensure that over fluxing does not occur.

16. SLDC Shift personnel should promptly formulate the strategy to be adopted in co-ordination with NERLDC for quick restoration of the Grid.
17. The work of restoration in the SLDC Control Room should be shared & coordinated among the shift personnel for smooth & quick restoration. Crisis Management Group to be formed, consisting of expert personnel & called for early restoration of the system.
18. SLDC Shift personnel should preferably be retained till restoration is over, before handing over the charge to the next shift

2.4 SPECIAL CONSIDERATION IN EXTENDING/AVAILING START UP POWER

1. Power Plant Operators should be able to differentiate between the followings:
   a. Full auxiliary power needed to start all machines.
   b. Minimum auxiliary power needed to start a minimum number of machines.

2. For availing start up power, the following considerations should be kept in mind:
   a. Nearness to the source
   b. 132 kV lines vis-à-vis 220 kV/ 400 kV lines.
   c. Shorter route having a number of intermediate sub-stations vis-a-vis longer route having very few/ no intermediate sub-stations.

3. For extending start up power from one sub-system to another sub-system or from one utility to another utility, the following clear-cut authority should be given to SLDC:
   a. Line through which start up power is to be extended.
   b. Quantum of such start up power.
   c. Normal time period admissible.

4. SLDC is empowered to resort to load shedding or bring up additional generation wherever possible, to extend start up power to neighbouring sub- systems/utilities during the period of crisis.

2.5 SOME DON'TS:

1. Do not panic.
2. Do not load any Generator, ICT and line beyond 80% of its capacity.
3. Do not hastily connect loads and ensure that the island / sub-system frequency be within sustainable range.
4. Once power extended to a Power Station/Utility, it should not be withdrawn except in case of extreme emergency and without intimation to NERLDC, wherever applicable.
5. No disputes should be raised during the restoration period
6. Till the restoration procedure is over, SLDC should not be disturbed in undesirable manner while discharging their duties and they should not be expected to function as Management Information System.

CHAPTER 3: ESSENTIAL INFORMATION FOR BLACK START AND RESTORATION

3.1 GENERATING PLANT DETAILS

The List of Generating Stations of Assam with /without black start facilities are as follows:

Name of power station	Installed Capacity (MW)	Type	Source of black start	Startup capacity (kVA)	Black Start Facility	Auxiliary Power (MW)
NTPS	41	GAS	DG SET	2X750	NO	1.13
NRPP	98.4	GAS	DG SET	1x850	NO	2.5
LTPS	97.2	GAS	DG SET	1x400	NO	0.8
LRPP	69.755	GAS	DG SET	1x250	NO	0.8
KLHEP	100	HYDRO	DG SET	1x500	NO	0.134
LKHEP	120	HYDRO	DG SET			

The list of Generators belonging to Independent Power Producers:

Sl No.	Name of Power Station	Type	Installed Capacity (MW)
1	HAYEN HYDEL PRIVATE LIMITED, CHAMPAVATI	Hydro	4.05
2	SURYATAAP SOLAR, GHORAMARI	SOLAR	4.05
3	AZURE SOLAR, ROWTA	SOLAR	25
4	AZURE SOLAR, BOKO	SOLAR	25
5	AZURE SOLAR, NAGAON	SOLAR	15
6	AZURE SOLAR, PAILAPOOL	SOLAR	25
7	MAHESHWARI MINING SOLAR, SAMAGURI	SOLAR	10
8	PATANJALI AYURVED SOLAR	SOLAR	4
9	O2 SOLAR POWER, AMGURI	SOLAR	70
10	CALCOM SOLAR	SOLAR	24
11	CALCOM WHRS	WASTE HEAT	8
		TOTAL	215.05

Survival/Auxiliary power is required to avoid damages of some equipment as well as functioning of some essential facilities, in case of supply failure. Immediate arrangement of power is very essential for the following: Battery Charging, Emergency Lighting, Compressors for Breaker operation, Lubricating Oil Pumps, Communication & Telemetry System, Turbine Emergency Oil Pump etc.

3.2 RAILWAY TRACTION DETAILS

A number of Railway traction points are connected to the State Grid. The details of the same is attached as ANNEXURE 1.

3.3 SYSTEM PROTECTION SCHEME (SPS)

A number of System Protection Schemes are operative in the state of Assam details of which is available as a separate document. The document is attached as ANNEXURE 2.

3.4 ISLANDING SCHEME

The Upper Assam Islanding Scheme is currently operative in the State. Details of the scheme is appended as ANNEXURE 3.

3.5 BUS AND LINE REACTORS IN ASSAM SYSTEM

LOCATION	TYPE OF REACTOR	CAPACITY (MVAr)
400 kV Bus Reactor at MIRZA	BUS REACTOR	63
400 KV MIRZA-SILCHAR (PG)	LINE REACTOR	63
220KV Bus Reactor 1 AT MARIANI	BUS REACTOR	12.5
220KV Bus Reactor 2 AT MARIANI	BUS REACTOR	12.5
TOTAL REACTOR CAPACITY		151

3.6 CAPACITOR BANK DETAILS IN ASSAM SYSTEM

Sl No	NAME OF LOCATION	Operating Voltage (in kV)	Quantity	Capacity (in VAR)	Total Capacity (in MVAR)	REMARKS
1	BAGHJAP	33	2	5	10	NOT IN SERVICE, PARTS NOT AVAILABLE
2	BARNAGAR	33	2	5	10	ONE IN SERVICE, PARTS NOT AVAILABLE
3	DEPOTA	33	2	5	10	NONE IN SERVICE. CIRCUIT BREAKER ISSUE, ISOLATOR IN OTHER
4	DIBRUGARH	33	1	10	10	IN SERVICE
5	DIPHU	33	2	5	10	ONE IN SERVICE, DAMAGED CAPACITOR CELL UNIT
6	DULLABCHERA	33	1	5	5	NOT IN SERVICE
7	GAURIPUR	33	1	10	10	IN SERVICE
8	GOSAIGAON	33	1	5	5	IN SERVICE
9	GOHPUR	33	2	6.3	12.6	NONE IN SERVICE, BREAKER ISSUE
10	JORHAT	33	2	10	20	IN SERVICE
11	KAHELIPARA	33	3	5	15	ONE IN SERVICE, CIRCUIT BREAKER ISSUE IN OTHER
12	MARGHERITA	33	2	5	10	ONE IN SERVICE, FAULTY CT
13	N. LAKHIMPUR	33	1	5	5	IN SERVICE
14	NALBARI	33	2	5	10	ONE IN SERVICE, CIRCUIT BREAKER ISSUE IN OTHER
15	NAZIRA	33	2	5	10	ONLY ONE IN SERVICE
16	RANGIA	33	2	10	20	ONE IN SERVICE, CIRCUIT BREAKER ISSUE IN OTHER
17	ROWTA	33	1	15	15	NOT IN SERVICE, RELAY ISSUE
18	RUPAI	33	2	5	10	ONE IN SERVICE, CT ISSUE IN OTHER
19	SANKARDEV NAGAR	33	2	5	10	NOT IN SERVICE, BREAKER ISSUE IN OTHER, CT ISSUE IN OTHER
20	SARUSAJAI	33	2	10	20	ONE IN SERVICE, CIRCUIT BREAKER ISSUE IN OTHER
21	SISUGRAM	33	2	10	20	ONE IN SERVICE, CAPACITOR ISSUE IN OTHER
22	SRIKONA	33	2	13.26	26.52	BOTH IN SERVICE

3.7. GRID SUBSTATION WISE PRIORITY LOADS.

Grid Substation-wise priority list of feeders is an important information which must be available to the system operator. This list will give a comprehensive analysis of the 33kV loads which are to be restored one after another. The list is appended as ANNEXURE 4.

3.8 CAPTIVE PLANT DETAILS.

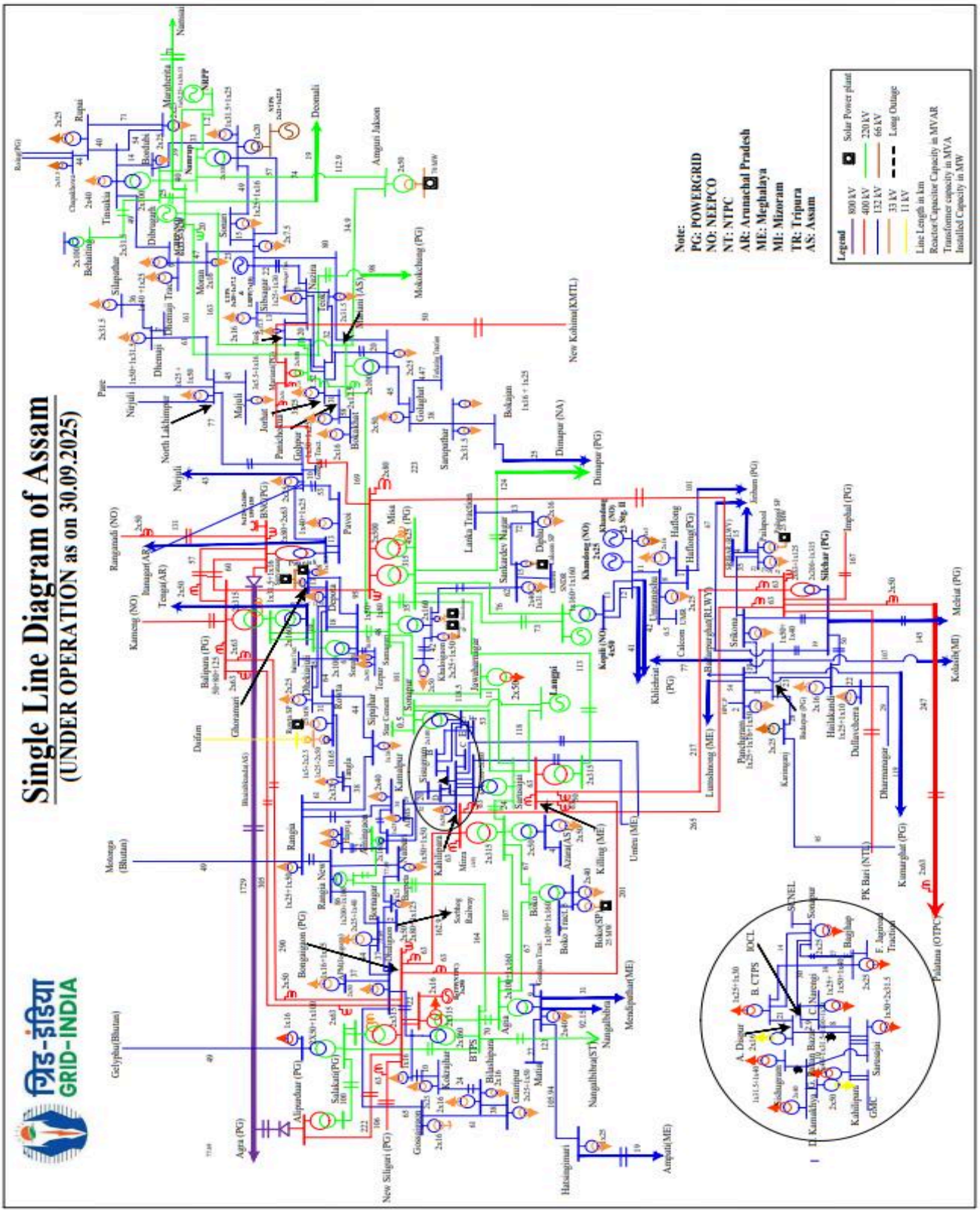
The list of grid connected captive plants is stated below:

Sl No	CPP Name	Installed Capacity (MW)
1	Dalmia NE ltd. Lanka	29
2	Dalmia NE ltd. Umrangshu	28.8
3	Patanjali Ayurved	4
4	BCPL	68.43
5	IOCL BGR	71.195
6	IOCL Digboi	45.5
7	IOCL Guwahati	28
8	NRL	78
9	OIL Duliajaan	81.38
10	ONGC Nazira	62.16

3.9 CONTACT DETAILS OF CONTROL ROOM OF ALL GRID SUBSTATIONS / POWER PLANTS.

The contact details of control rooms of substations and generating plants is attached as **ANNEXURE 5.**

3.10 SINGLE LINE DIAGRAM OF ASSAM SYSTEM



CHAPTER 4: PROTOCOLS DURING SYSTEM RESTORATION

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1. Following major protocols are essentially required for quick restoration of power supply after a blackout:
2. The start-up procedure for generating units should be available in control room and shift duty personnel/ working-level personnel should be familiar with the procedure, and they should start the machines (other than technical and safety issues of the machine) as per the direction given by SLDC
3. Shift duty personnel should remain present till the restoration process is completed before handing over charge to the next shift.
4. Survival / Auxiliary / Start-up power should be provided on a priority basis to the collapsed system and power should be utilized for other purposes only after meeting these power requirements.
5. Priority should be accorded in restoration as under:
    i. The main priorities are to restore power supply to the generating stations and load dispatch centers, formation of self-sustaining islands around the generating stations.
    ii. Extending power for synchronizing islanded nuclear power stations or survival/start-up power to nuclear power plants.
    iii. Extending start-up power to thermal power plants.
    iv. Extending start-up power to non-self-starting hydro power plants.
    v. Restoration of traction power supply.
    vi. Building up subsystems and synchronizing with each other.
    vii. Restoration of supply to other essential loads such as mines, Hospitals etc.
    viii. Restoration of supply to all other customers.
    ix. Restoration of supply to communication system nodes and repeater stations.
    x. Formation of self-sustaining islands around the generating station as per laid down procedure:
6. Area Load Dispatch concept should be adopted during start-up to avoid jamming of the communication system.
7. A list of contact numbers of all the Grid sub-stations and Power Plants should be available at SLDC as communication is the essential requirement and time is essence during the restoration process.
8. Loading of generator supplying the start-up power should not exceed 80% of its capacity. Efforts should be made to keep the generator operating on lagging side and if it is not possible then it should operate at least near to unity power factor.
9. All communication channels required for restoration process shall be used for operational communication only, till grid normalcy is restored.

CHAPTER 5: GUIDELINES FOR BLACK START AND RESTORATION ACTIVITIES

5.1 Guidelines during black start

For performing black start and restoration activities, various guidelines are required to carry out activities to ensure smooth coordination. The following list of detailed guidelines are required to be prepared in coordination with User, NLDC, RLDCs and SLDCs for smooth coordination of restoration activities post blackout. Further, these guidelines would also help in preparation for such exigencies through coordinated mock drills.

5.2 Guidelines during Extending Black start Support for Generators requiring Auxiliary Power

The order of re-energizing power plants affects how much and how soon load and other generators can be restored. Larger capacity power plants, once restarted, can provide more power to restore other generators and loads; but they usually require more station power (either drawing more power from the recovering grid or requiring more black start resources on-site) than smaller generators.

There is a trade-off regarding larger power plants: their advantage is that, once restarted, they can expedite restoration of other plants; their disadvantage is that they require more grid power (or black start capability) to be restarted.

In the early period of grid recovery, as operating generators are brought online and operate to match load (either reconnected loads or station power for offline generators), the system frequency will not be as stable as during normal operation it can oscillate much higher or lower than the standard operating limits for normal 50Hz frequency.

Prioritizing the generators to be restarted next (or deciding which ones should be provided with black start capability) is based on

1) The amount of generation and load (and their balance) on the electrical island
2) The amount of station power or black start resources required to restart a plant.
3) The plant's maximum capacity.
4) The plant's available transmission connections to other plants (including connections that are out of service and could be energized by the target plant and connections that are in service and capable of supplying station service to restart the target plant or its non–black start generators)
5) The plant's minimum operating load level and its ramp rate for changing output level.
6) The plant's ability to operate (without tripping) during frequency excursions.

Auxiliary power

Start-up power required for a thermal unit is around 5-8% of the unit capacity. This is because major auxiliaries like Boiler Feed Pump (BFP), Induced Draft (ID) Fan, FD (Forced Draft) Fan, Cooling Water (CW) Pumps etc., are of bigger size and their starting torque is considerably high.

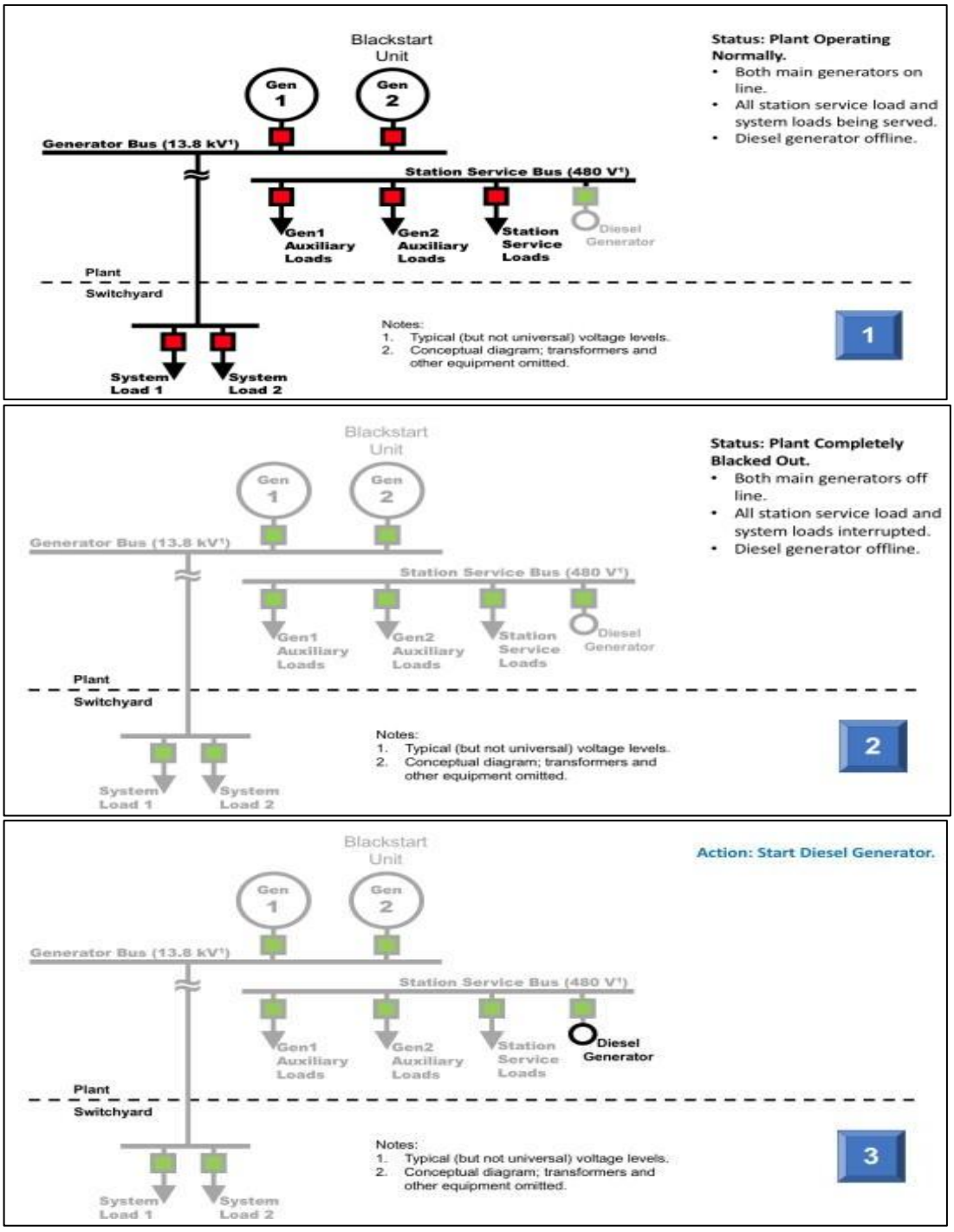
For hydro units, the start-up power is not significant since there are very few auxiliaries.

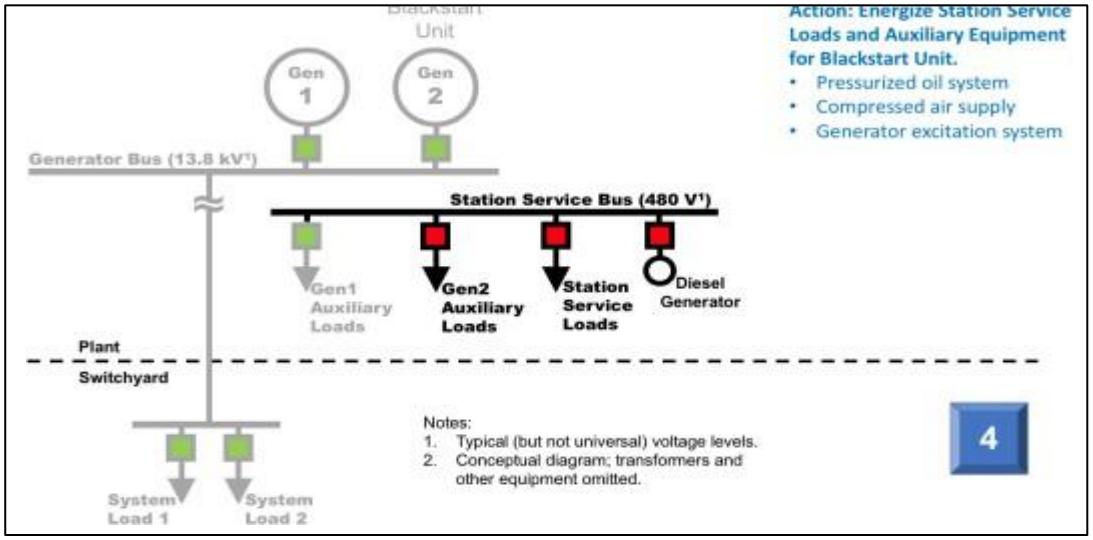
Before asking power station to draw start-up power, the capacity of island to sustain the starting current of biggest Induction Motor (generally BFP) should be checked.

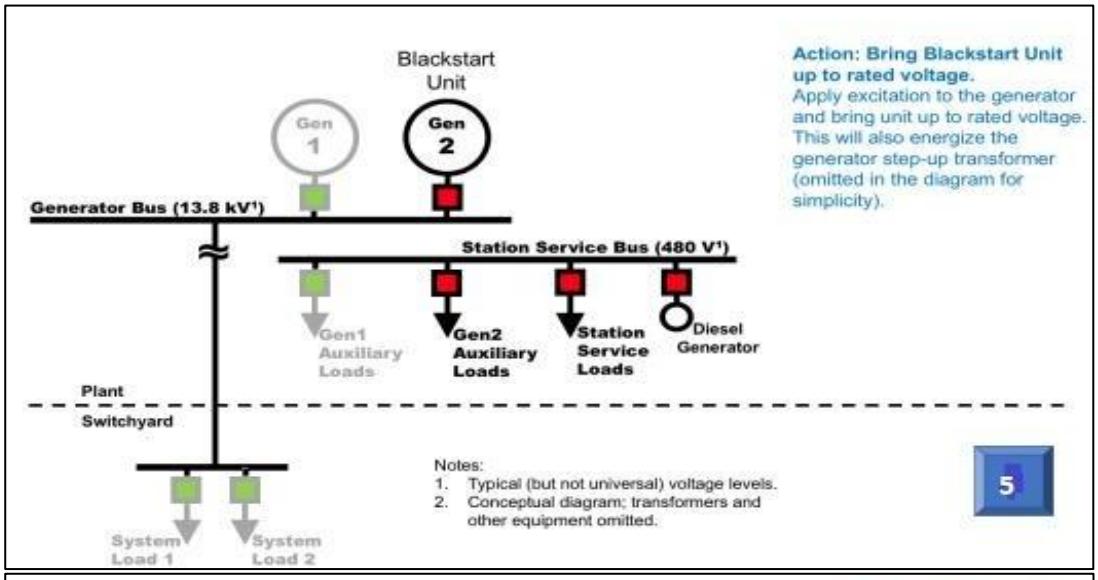
Start-up of large motors (auxiliaries) of thermal plants from black started units. Normally when thermal power stations' auxiliaries are energized from black started units, minimum auxiliaries essential for start-up have to be energized.

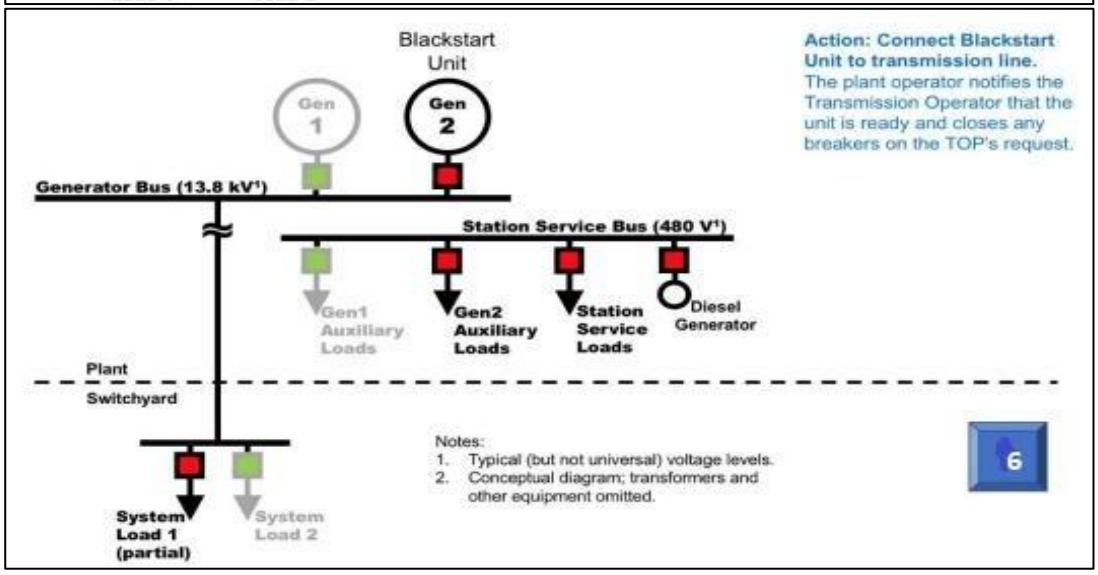
Out of the various auxiliaries as far as possible and based on the start-up sequence the largest motor has to be started first. The other motors are started thereafter one by one in a sequential manner. (With larger ones preceding the smaller ones).

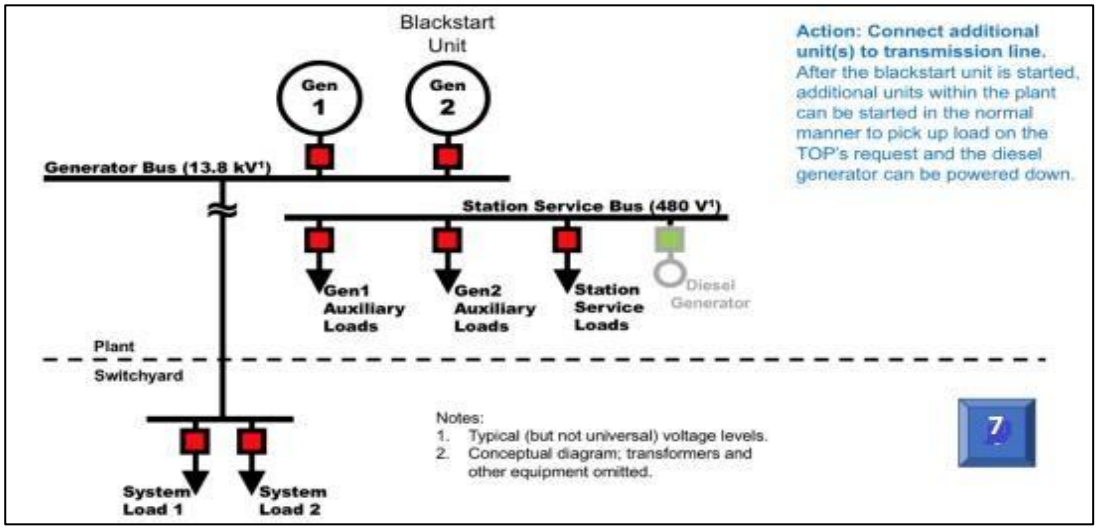
Sequence of Black start may be seen as mentioned below,




Blackstart Unit
Gen 1
Gen 2
Generator Bus (13.8 kV¹)
Station Service Bus (480 V¹)
Gen1 Auxiliary Loads
Gen2 Auxiliary Loads
Station Service Loads
Diesel Generator
Plant Switchyard
System Load 1
System Load 2
Action: Energize Station Service Loads and Auxiliary Equipment for Blackstart Unit.
• Pressurized oil system
• Compressed air supply
• Generator excitation system
Notes:
1. Typical (but not universal) voltage levels.
2. Conceptual diagram; transformers and other equipment omitted.
4


Blackstart Unit
Gen 1
Gen 2
Generator Bus (13.8 kV¹)
Station Service Bus (480 V¹)
Gen1 Auxiliary Loads
Gen2 Auxiliary Loads
Station Service Loads
Diesel Generator
Plant Switchyard
System Load 1
System Load 2
Action: Bring Blackstart Unit up to rated voltage.
Apply excitation to the generator and bring unit up to rated voltage. This will also energize the generator step-up transformer (omitted in the diagram for simplicity).
Notes:
1. Typical (but not universal) voltage levels.
2. Conceptual diagram; transformers and other equipment omitted.
5


Blackstart Unit
Gen 1
Gen 2
Generator Bus (13.8 kV¹)
Station Service Bus (480 V¹)
Gen1 Auxiliary Loads
Gen2 Auxiliary Loads
Station Service Loads
Diesel Generator
Plant Switchyard
System Load 1 (partial)
System Load 2
Action: Connect Blackstart Unit to transmission line.
The plant operator notifies the Transmission Operator that the unit is ready and closes any breakers on the TOP's request.
Notes:
1. Typical (but not universal) voltage levels.
2. Conceptual diagram; transformers and other equipment omitted.
6



Survival power means the power needed for avoiding the damage to the equipment in case of supply failure. This power may be required by thermal power stations for:

1. Turbine emergency oil pump
2. Jacking oil pumps
3. Barring gear of the turbine
4. Lubricating oil pumps
5. Compressors for ABCB operation
6. Emergency lighting
7. Battery chargers of Units, Stations, Communication & Telemetry system.

5.3 GUIDELINES FOR CHARGING OF TRANSMISSION LINES

1. All the CBs of all the lines, ICTs, reactors, and other equipment must be opened first before starting any action.
2. Ensure that line to be charged is free from fault. i.e., faulty line shall not be charged.
3. Before charging, it is to be ensured that proper communication is available between both ends and all protections are in service and desired settings are in place.
4. During restoration, lines of lower voltage levels and shorter length should be given priority.
5. The line should be charged from the end with higher fault level so that the voltage rise at charging end as well as at the open end is limited. It is to be considered that the new fault level of the station during disturbed condition may be very low compared to that of the healthy system because of tripping/isolation of generators and lines.

$$\Delta V/V = \Delta Q(MVAR) / FAULT\ LEVEL\ OF\ BUS(MVA)$$

ΔV: change in voltage (kV) at the respective bus

V: Voltage level of the bus

ΔQ(MVAR): Change in reactive power at the bus

FAULT LEVEL: fault level at bus during disturbed condition

6. If two buses have almost same fault level (3-phase) and neither is a generating station, then the line should be charged from the bus with lower voltage as the rise in voltage would be lower as per the relation in Figure 1. At the charging end, necessary measures should be taken to control high voltage:
    i. Bus reactors may be taken into service.
    ii. Suitable measures may be taken to avoid large frequency variations.
    iii. Loads may be taken into service in small steps.

7. In case one bus is completely dead, all breakers should be opened at the dead bus end and the line should be charged from the other end and then the breaker is closed at the dead bus end. However, the bus/line reactors may be kept in service (as per requirement) with breaker/isolator in closed position before charging the dead bus.

8. At the synchronizing end, control of standing phase angle (SPA) to less than or equal to 20° helps in minimizing jerk or sudden rush of power. For reduction of SPA, the following measures need to be taken up:
    i. Reduce generation at those generators that are sensitive to the SPA.
    ii. Shed loads at selected buses.
    iii. Simultaneous backing down of generation and shedding of load.
    iv. Increase of generation at the sensitive buses.
    v. The recommended practice for synchronizing lines is always through check synchronization relay that normally is set for 35° (above which breaker closing is not permitted). For most of the lines, SPA < 35° would suffice. However, in case of lines inter-connecting two major generating stations, it is prudent to limit the SPA to around 20°.
9. Open-end voltage should not exceed the voltage level at which over-voltage protection operates (generally 110% of nominal voltage). Reducing the voltage at the charging end could control the open- end voltage. The end with lower voltage would be ideal for charging as this minimizes the rise of voltage at the open end as per the relation in Eq- 1.
10. If the open-end voltage is too high leading to high line charging VARs, it may be difficult for the charging end to sustain the voltage increase. Therefore, adequate voltage control measures at the charging end to contain high open-end voltage must be ensured. The charging end voltage should be kept as low as possible. If required transformers at the charging end may be used as bus reactors by keeping it energized while line charging.

11. While back charging long 400kV lines, the problem of ferro-resonance may occur. Hence, adequate measures such as taking bus/tertiary reactors into service and most importantly some load on the transformer shall be taken.

Line charging with one end as generating station end:

1. While charging a line from generating stations during restoration, care should be taken to ensure that sufficient generation is available and/or connections with other stations at the charging end

to absorb the (leading VARs) reactive power without difficulty. Before charging, ensure by addition of load preferably or through excitation control, that these generators are operating in such a manner that sufficient margin is available for absorbing line charging MVAR. Also ensure that the generator EHV bus voltages are kept low around 0.9 per unit or even less by excitation control to ensure less open-end voltage rise.

2. While charging two islands, it is preferable to charge and synchronise at the generating stations ends. At least, synchronising end must be a generating station. In addition, frequency difference should also be checked (0.2 Hz-0.5 Hz.). This would avoid sudden jerk. Further it is advisable to charge at the end with maximum generation level.

Line charging with one end as reactor end:

1. In case, line reactor is available at only one end, it is preferable to charge the line from the end without reactor and synchronize at the end with reactor.
2. If the line is to be opened, open from the end where line reactor is available. Thumb rule is to synchronize or open from the end where line reactor is available.
3. Transmission corridors being used for startup power should be isolated from any damaged/faulty equipment and should be of minimum length and minimum voltage level to avoid excess line charging VAR and consequent voltage rise.
4. The transformer taps should be checked for desired settings to minimize voltage difference between the two ends. Initially, it is advisable to be kept at the nominal setting i.e., at tap position 9 for a transformer with typical 17 tap provision.
5. Energizing long high voltage lines and cables should be avoided until adequate generating capacity is available on bar.

5.4 GUIDELINES FOR DEGRADED SYSTEM OPERATION DURING RESTORATION

As per clause 7 of IEGC 2023 regulation 34, during the restoration process following a blackout, SLDC, RLDC and NLDC are authorized to operate with reduced security standards for voltage and frequency and may direct the implementation of such operational measures, namely, suspension of secondary or tertiary frequency control, power market activities, defence schemes, reduced governor droop setting as necessary, in order to achieve the fastest possible recovery of the grid.

General guidelines regarding grid operation with reduced security standards during system restoration are as follows:

1. Control actions shall be taken to reconnect the system elements and restore system load. The power system transits from a restorative state to either an alert state or a normal state, depending on the system conditions.
2. Grid operation with broad range of voltage and frequency may be done if seems necessary during restoration. Pick up and time delay settings of over voltage/under voltage and over frequency / under frequency protections can be increased but they shouldn't be disabled during restoration phase.
3. System operations on low transmission security standards i.e., N-1/N-2/N-1-1 non-compliance may be allowed, if aids in fast restoration.

4. Secondary and tertiary frequency control system may be suspended if require during restoration phase.
5. Necessary changes in AVR settings shall be done to smoothly vary the excitation of the black-start unit over the entire range of the generator capability curve so that bus voltage can be smoothly varied.
6. Necessary changes in settings of the low forward power relay/reverse power relay installed on the generating units and manufacturer's recommendations for this relay settings, if any, during black-start process shall be done.
7. Defence protection system i.e., SPS, UFR & df/dt may be kept off in feeders during restoration phase.
8. Droop setting of governor of generating stations may be reduced for fast response during restoration to maintain the stable frequency.

Power market activities shall also be relaxed and suspended: scheduled generation of all the ISGS and scheduled drawal of all the beneficiaries shall be deemed to have been revised to be equal to their actual generation/drawal for all the time blocks affected by the grid disturbance and further restoration.

5.5 GUIDELINES DURING BLACK START FOR FREQUENCY CONTROL

5.5.1 Generating Resources for Frequency Control

i. The Black-Start Resources Generators frequency settings to be kept up to its emergency operational limits i.e. 47.5 Hz (-5%) to 51.5 (+3%).

ii. During system restoration, governors must not be blocked and generators must operate in a mode which allows the governors to respond to frequency deviations.

iii. During Black-start restoration all the generators to operate with their Governor in Free Governing Mode of Operation

iv. The Black-Start Resource Must Operate with Isochronous governor mode i.e. a mode in which the governor maintains the same speed regardless of the load in service.

v. When not operating in isochronous mode the Black Start resource facility must be capable of switching/operating in droop governor control mode with governor response enabled, at a minimum response value of 3% droop(thermal) and 0% droop for Hydro

vi. During black-start restoration small Islands needs to be built up using the generator's in Isochronous Mode, sufficient care needs to be care for only One Generator needs to be operated on Isochronous Governor Control per Island.

vii. Generators Despatch to be in such a way that doesn't limit the full governor response if a frequency decay/rise occurs. That is Generator's Despatched at either Pmax or Pmin.

viii. During black-start Governors must be in service at all times to respond to large frequency deviation ix.Plant operators must take action on their own to control frequency outside the range of 49.5 Hz –50.05 Hz

5.5.2 Load Actions for Frequency Control

i) During early stages of building an island, the load response against frequency will be very small and may be ignored.

ii) Hence, during the black-start restoration, the load must be added gradually in steps and within the generator's capability, which allows the Isochronous Governor controller to maintain the frequency to the Target Frequency (50 Hz)

iii) Adequate load management need to be done to keep the frequency above 49.50

iv) Increase frequency to 50.00 - 50.50 prior to restoring a block of load

v) Restore load in small increments to minimize impact on frequency

vi) Restoration of loads in blocks to be lesser than 5% of the total synchronized generating capability

vii) As a guide, shed approximately 6-10% of the load to restore the frequency 1 Hz

viii) Restore large blocks of load only if the system frequency can be maintained at 49.90 or higher

ix) Estimation of New Frequency following load addition

Frequency change = (Load Change/Connected capacity) * Governor Droop (In percent, not decimal)

New Frequency = Frequency Prior – Frequency Change

Smaller systems have larger frequency fluctuations when restoring

5.5.3 Synchronization of Island

i) Build multiple Islands which are operating stably with sufficient reserve margin in generators (i.e. both Up & Down Margin)

ii) During system restoration, the frequency of each island that is created need to be monitored to ensure the balance of generation and load

iii) Before synchronization of two Islands, the Isochronous Generator in the smaller Island needs to be operated in Droop Mode.

iv) At Synchronization point, observe island voltages and match appropriately.

v) Observe Synchroscope and adjust generation in smaller island and close the breaker at the proper phase alignment (As minimum as possible)

Maintaining the frequency is critical when it is time to interconnect these islands, to prevent damage to equipment or the failure of the built island(s). Hence, Generation or load may be adjusted in the islands in order to match the frequencies.

5.6 GUIDELINES DURING BLACK START FOR VOLTAGE CONTROL

During power system restoration, significant voltage deviation and fluctuation will be observed due to low system strength. Even small changes in loads have a significant impact on voltage and frequency in islanded system. During initial stages of restoration, due to lack of reactive support and lightly loaded transmission lines, major challenge observed is high voltage. While when restoration is being built up and load is being taken then issue of low voltage is being faced. Thus, it is a recommended procedure to maintain voltage within safe limits to prevent any sort of equipment damage. Therefore, a clearly defined strategy is required for voltage control during restoration sequence activity. It is required that during restoration activity voltage at any point should not be exceeding maximum/minimum rating for that voltage level as provided in CEA grid Standard 2010.

Nominal Voltage (KV – rms)	Maximum Voltage (KV- rms)	Minimum Voltage (KV – rms)
765	800	728
400	420	380
230	245	207
220	245	198
132	145	122
110	121	99
66	72	60
33	36	30

Table: Minimum and maximum voltage level as per CEA grid Standard 2010

Based on cumulative experience, a set of guidelines have been provided below for voltage control during initial stages of restoration activity.

1. For black start unit, its AVR initially should be kept in manual mode for charging of line. In case it is expected that voltage at remote end would be high then AVR set point should be kept low so that voltage at remote end is within limits. Hence, Black-start Unit may be started at the field flashing limit and then the terminal voltage may be increased gradually by keeping AVR in manual mode after dead bus and consequently deadline charging by maintain end voltage within acceptable limits.
2. Considering the equipment voltage limitations and any untoward event during restoration, it is recommended that 132 kV and above transmission line shall be energized in a way that the voltage at the remote end of line would be less than 1.1 p.u. In case it is expected that voltage would be higher then appropriate measure should be in place like bus reactor, load addition in tune of 5% of black start unit capacity.
3. It is recommended to energize lower voltage lines first (as consume less reactive power for charging) and such numbers of lines should be kept at minimum and only to complete restoration path.
4. Post black start and remote substation charging, small steps of load quantum (Less than 5 % of Unit MVA) should be taken in steps to avoid large voltage and frequency fluctuations.
5. It is recommended to connecting reactive loads (lagging power factors) to the underlying system including shunt reactors to maintain voltage level below 1.1 pu. It is advised that

large induction motor- based loads may not be connected initially as it will result in large voltage dip due to large initial requirement of reactive current.

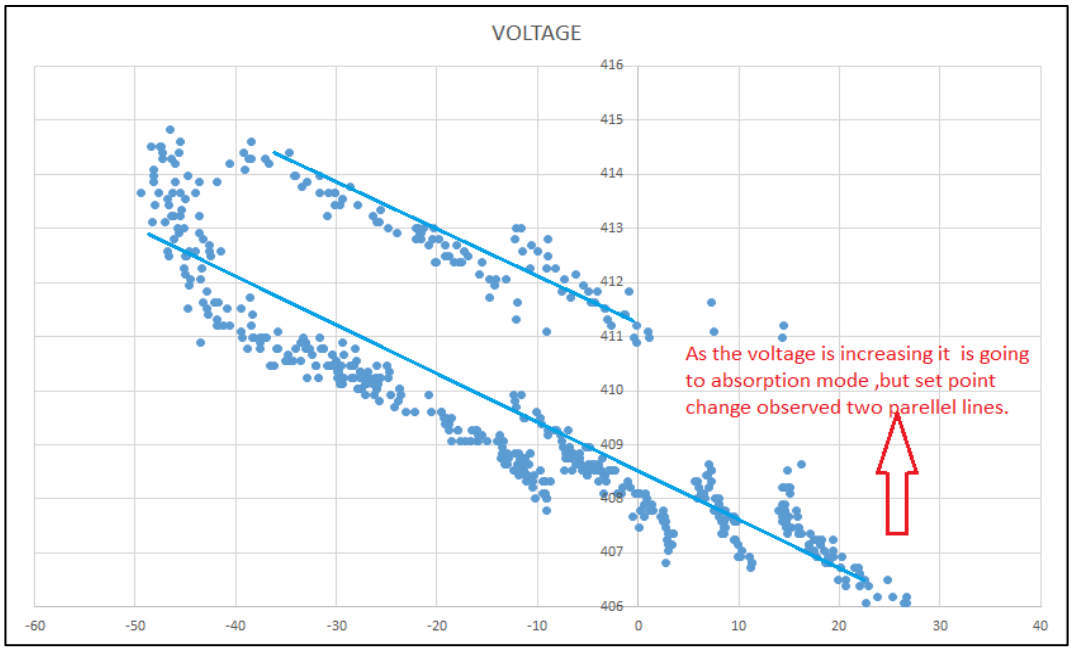
6. It is recommended that removing all sources of reactive power and switching off shunt capacitors to maintain voltage level within safe limits during restoration in restoration path.
7. Taps of transformers to be changed before charging for feasibility of cranking path and managing load end point voltages.
8. After significant load is restored (25-30 % of Black start unit MVA), Black start unit AVR can be put in automatic mode for better voltage control.

Guidelines for voltage control post black start island formation and restoration of large conventional units in the island

1. Generator AVR setpoint to be started from reduced setpoint to avoid transient as well as steady state overvoltage's during line charging.
2. Post significant load is restored with conventional generation in service in the island, Operating conventional generators at minimum voltage levels (at lagging pf). The extent of the voltage reduction is usually constrained by under excitation of generators by a few limiting factors, including generator terminal low voltage limit (as limited by power plant auxiliary equipment), reactive ampere limit relay, minimum excitation limit relay, and rotor core and heating limit (as per respective capability curve). So, proper checks should be ensured by plants for operation at minimum voltage levels for units.
3. Generators should ensure having sufficient under excitation capability as per their capability curves.
4. Energizing only those transmission lines which carry significant load and avoiding the energization of extra lines which will generate unwanted reactive power.
5. Charging of lines with series capacitors is to be avoided at all cost.
6. Filter-banks at HVDC stations, STATCOMs, Inverters of RE generating stations may be used for voltage control.
7. If the steady state voltages are less than 1.1 per unit of their nominal values, the switching transients can be managed by typical arrestors.
8. It is recommended that whenever charging a long line in the weakly connected system, a delay of 100 msec shall be introduced (only during charging) in the overvoltage stage-II (at 150% over-voltage) protection which is otherwise instantaneous.
9. Transmission transformer units with on load tap changing capability can be set to tap positions that will allow power system operators to help control voltage in the cranking path.

Guidelines for Generating Unit AVR setpoint change and optimization:

1. Generator excitation loop responds as per the setpoint of AVR so setpoints may be tuned accordingly to enhance or maximize the dynamic reserve of reactive powers for voltage control.
2. As shown below in QV plot of machine, it can be observed that with different set points machine reactive power injection and absorption are changing and at lower voltage set points more capability is being observed.



Maximizing Dynamic reactive reserve of Units by Switching On/OFF Static devices (Reactor)

1. Wherever required specially for low fault level nodes or weak nodes where voltage sensitivity is high, and contingencies may hamper transient voltage stability. Switching of static devices such as Bus reactor /L/R may be done to increase the dynamic margin of units which will provide an automatic voltage control action by absorbing/injecting reactive power automatically.
2. For example: It is also possible that voltages are within limit that is due to control action of AVR by Generator and Generator has exhausted its capability. As the generators voltage control action via AVR is dynamic as per the system requirement so that margin may be always kept as a reserve to take care of any further requirements of voltage control during Contingency events.
3. To achieve/create this dynamic reactive margin at unit level, reactor switching decisions can be taken with proper study.

Guidelines for Tap Optimization

Tap positions that are appropriate for normal conditions, generally having significant current flows, may result in high system voltages under the lightly loaded black start condition.

1. Since most taps on generator step-up transformers and station auxiliary transformers cannot be changed under load, the selection of transformer taps must be a balance between the needs of the black -start period and normal operation when the power system is supplying a significant amount of load.
2. UAT Tap optimization in co-ordination with GT Tap: GT Tap optimization in co-ordination with UAT (Unit auxiliary transformer) is necessary for Power plants, as many a times auxiliaries experience low/High voltages due to improper UAT tap so wherever required to maximize the absorption/generation of reactive power by units, co-ordinated Tap optimization of GT along with UAT to be done.

5.7 GUIDELINES FOR PROTECTION SYSTEM DURING RESTORATION

5.7.1 Line Protection:

i. Transmission lines are protected either by impedance-based distance protection schemes or current based protection schemes. Redundant protection systems generally installed on transmission lines at higher voltages, may have a combination of these two types of schemes.

ii. In current based schemes, the fault currents available with new system configuration should be above the minimum settings for the relay operation.

iii. Not enough short circuit current available for relay operation and electromechanical relays failing to detect broken conductors.

iv. Remote phase and ground overcurrent operation in a nonselective manner may even render the restoration process very difficult and in some instances impossible.

v. Restoring the healthy lines on the network may be difficult because of heavy loads.

vi. In most of the distance-based protection scheme designs, trip outputs are supervised by overcurrent fault detectors to prevent undesired tripping due to loss of potential input to the relay. This practice will limit the sensitivity of the protection during system restoration. The sensitivity of the distance protection fault detectors under the very weak source conditions of system restoration will be important.

vii. Unbalanced voltages during system restoration should be determined prior to energization and verified that the relays are not blocked due to sensitive voltage settings in the loss of potential logic.

viii. It may be desirable to change these settings to make the element immune to unbalance voltages resulting during system restoration.

ix. In schemes using sequence quantities for directional determination, it is important to verify that the threshold levels for operation is met to clear faults with new system configuration.

x. Distance relays with Mho characteristics and with large impedance settings may operate during restoration due to heavy loads and below nominal operating voltages. Settings of these overreaching zone elements should be verified when picking up load during restoration. Load encroachment blinder should be enabled and set appropriately when available.

xi. Impedance relays without out-of-step blocking may trip lines due to transient power swings during restoration.

xii. During system restoration, consideration may be given to blocking some automatic reclosing functions. This will ensure that reclosing does not happen during the presence of faults and put the recovering system at risk of collapse.

5.7.2 Negative/Zero sequence protection Operation due to Unbalance:

i. During restoration voltages of the phases may be unbalanced due to line configuration and unbalanced loading this imbalance can cause some relay problems. Any voltage relay that responds to negative and zero sequence voltage may be affected.

ii. Unequal phase coupling may cause unbalance current flow into the reactor, which is sometimes sufficient to cause the relay to operate. After raising the pickup setting of

the negative sequence function, Mock Blackstart/Restoration may be completed as planned.

iii. The cranking of motors protected by phase unbalance or negative sequence current may be affected too. The settings of these devices should be evaluated and readjusted. For example, during a black start test, a phase unbalance relay (46) may trip due to unbalanced starting current for a cranking motor. The pickup of the relay was changed in order to have the black start test to proceed. If necessary, the relays can temporarily be disabled as a part of the switching process. Desensitizing the relay to override the temporary conditions is the recommended practice. Here the benefits of multiple setting groups available on digital protection systems become apparent.

5.7.3 Transformer Protection

i. Nowadays, all numerical Transformer/Feeder protection relays are equipped with the feature of inrush restraint / inrush blocking / harmonic restraint, which is to be activated/enable in relay. To prevent any mal-operation of relay during transformers energizing, it is advisable to enable the inrush restraint/harmonic restraint feature and set inrush 2nd harmonic ratio at 15% 20%. These feature in relays blocks operation of the protection, if the harmonic(s) exceed a given percentage of the fundamental component for few cycles.

ii. Severe magnetizing currents due to transformer core saturation can result in inrush lasting several seconds and can cause severe temporary overvoltage on an islanded network. Surge arrestors and overvoltage relays can cause undesired line openings during system restoration.

iii. It has been observed that during black start while charging any transformer for load pickup in downstream, large switching inrush current has caused tripping of Black starting Unit due to operation of Rotor overvoltage protection. Hence it is better to identify the sequence and preclose the breakers of transformers to avoid such tripping of Black starting units and then load may be slowly increased as instructed.

5.7.4 Overvoltage Co-ordination:

i. For stage-1 Overvoltage settings should also be reviewed and kept to the maximum extent possible without damaging any end equipment's this will reduce chances of tripping on account of steady voltage rise along the path.

ii. Studies should be done in Consultation with O/V setting of the lines as some of the hydro plants are also having cable portions.

iii. During energisation of long lines while restoration, stage 2 over voltage relay operation has also caused tripping and therefore minor delay of few milliseconds could be introduced rather than instantaneous setting for stage2 over voltage relay also.

iv. Third harmonic neutral undervoltage protection may be bypassed in some hydro units, if present. The protection settings may be normalized after completion of the black start exercise.

v. Bus reactors at remote ends prior to charging long lines should remain pre-closed during initial phases.

5.7.5 Generator over- and under-excitation limiters and volts/Hz

i. The modelling of equipment that does not generally operate under normal conditions such as over- and under-excitation limiters and volts/Hz protection can also be important. Reactive power from the long line energization could exceed the black start generators reactive power absorption capability. It can hit generator under excitation limiter. Generator must operate between minimum and minimum active power operation limits. Generator reactive power must be maintained within its reactive power capability.

ii. Switching events should not trigger the operation of generator limiters and protection Generator must maintain voltage in the system Generator must stay stable and be able to maintain stability of the system.

iii. Similarly for Over fluxing of Generator Transformer and Power transformers it should be co- ordinated as per IDMT characteristic instead of any definite stage setting or instantaneous setting as during restoration, extreme voltages and frequency variations may lead to high over fluxing.

5.8 GUIDELINES FOR DEFENCE MECHANISM DURING RESTORATION

i. Ensuring adequate relief by defence mechanism such as UFLS, df/dt is necessary to prevent,total or partial collapse. hence total load connected under these feeders also needs to be reviewed periodically as the load feeder distribution changes with time and if any additional requirement is there that also needs to be ensured on a periodic manner.

ii. There Should be uniform policy of UFR that there should not be any intentional delay. The settable measurement delays should be as minimum as possible and should be less than 4-5 Cycles.

iii. Healthiness and testing of all UFR relays need to be ensured and Electromechanical relays may be replaced with Numerical to avoid delayed operation as Faster UFR operation may further avoid next stage of operation

iv. Once the partial or Total blackout has occurred during initial island build-up for restoration it is better to keep UFLS & df/dt relay disabled as during initial phase of island build-up inertia will be too low for system which may result into operation of these relays, and uncontrolled frequency excursion event will happen. Once an island has been built up with moderate inertia these may be enabled.

v. Df/dt relays should be implemented in different rate shedding so that not all loads should trip at a place with frequency excursion events and may cause overloading of lines within small islands.

vi. These defence mechanisms setting if kept enabled during island build-up then settings may be selected based on studies as the behaviour of island will be very different from a normal grid connected system such as high rate of change of frequency, high change in voltages due to low fault level and grid strength.

vii. Similarly, for any UVLS setting (Under voltage shedding schemes) also IDMT type characteristic with suitable delay to be enabled to prevent any voltage collapse.

viii. HP/LP bypass facilities would match the turbine load with boiler output and then can be actuated based on frequency and rate of change of frequency.

ix. During islanding house load operation of generators would enable a faster restoration as generators can go to house load operation and survive supplying their own auxiliaries.

x. Controlled islanding schemes may be planned so that whenever after operation of every defence mechanism if system frequency still falls then these islands will be able to extend supply for early restoration.

5.9 GUIDELINES DURING BLACK START AND BLACK START MOCK DRILL FOR SYNCHRONIZATION

For power system synchronization four parameters are important to be monitored across the circuit breaker through which the two islands are being connected. These parameters are voltage magnitude difference, voltage angle difference, frequency difference and voltage phase sequence. Although during system designing voltage phase sequences are matched so this in general not required for monitoring during island synchronization in overall restoration process sequence. However, the other three quantities are quite vital for monitoring. Tool and equipment through which substation operator where the synchronization would be performed are:

i. Synchronizing trolley (For manual synchronization at conventional substation)

ii. Synchroscope Display with Synchrocheck Relay (For manual synchronization in SAS substation)

iii. Auto-synchronization relay with Synchrocheck relay (For automatic synchronization in SAS substation)

Thus, for quicker restoration, synchronizing trolley or synchroscope or auto-synchronization relay needs to be provided at all substations in the identified restoration path to facilitate synchronization with other islands. These will ensure quick and smooth integration of two islanded systems with each other when connected through AC transmission lines. However, it is important to decide on settings of these parameters for smooth synchronization at various voltage levels depending on size and strength of islands. In addition, there should be facility and engineering judgment when devising these settings and real-time coordination for changing these settings based on system assessment. All these tools and equipment check these conditions and ensure that they are within the permissible limit so that smooth synchronization can be done.

Thus, setting of these synchronization parameters in the synchroscope or auto synchronization relay is very important and may be finalized and revised based on prior experience and studies for smooth and successful synchronization. During restoration and black start conditions it will be different than that of normal conditions. As per IEEE Standards C50.12 and C50.13, the recommended synchronization parameters are:

Generators shall be designed to be fit for service without inspection or repair after synchronizing that is within the limits listed below.

- Phase Angle Difference: ±10°
- Voltage difference: 0% to 5%
- Frequency difference: ± 0.067 Hz

5.9.1 Guidelines for Synchronising parameters setting for smooth synchronization.

Apart from synchroscope setting, there is a requirement that these synchronizing parameters may be ensured as mentioned below across the synchronizing line or synchronizing breaker:

a. Voltage magnitude difference: Difference in voltage between open end line voltage and grid voltage should be less than a preset value such as 20 KV so that sudden flow of reactive power can be minimized, and the black starting unit should be capable of absorbing the voltage difference without hitting any under or over excitation limiter in a stable manner.

b. Voltage phase angle difference: Angular difference between Islanded system and Grid system (Or another island) should be kept as minimum as possible to avoid sudden inrush of active power.

c. Frequency difference: Frequency difference between the two systems should be kept as minimum as possible prior to synchronization. In addition, for black starting of unit or where only one generator is there in the island in that case island frequency should always be kept little higher than the grid side so that flow of power should be from black start unit to Grid side during initial swing until it stabilizes else units may trip on Reverse power flow protections.

During synchronizing two islands, for matching the frequency, it is preferable that smaller island has a higher frequency than the bigger island as frequency change in smaller island is easier and immediately after synchronization, power flow direction would be from smaller island to bigger island. This would avoid likely network issues within the smaller island.

To quickly strengthen the interconnection between islands, apart from single synchronizing path, other parallel links shall also be kept ready and be connected quickly after first synchronization. If such additional interconnections are not possible, the exchange of power between newly synchronized areas to be kept minimum through load generation balance in both the areas.

d. Phase Sequence: Phase sequence should be always same for an interconnected system so this is always true for an interconnected system but whenever a system is being restored for the first time after any calamity i.e., damaged towers, restringing, new tower erection etc., ensuring same phase sequence is must and should be checked.

5.9.2 Guidelines for Synchro check Trolley availability at conventional substation

i. All conventional substations of 132 kV and above which are in synchronization path in the prepared restoration path sequence should have Synchrocheck trolley provision in respective control room.
ii. Presently with SAS upgradation and BCU based system where auto-synchronization facility and synchroscope display with Synchrocheck relays are available, Synchrocheck trolley would be required in conventional substation.
iii. Substation with Synchrocheck trolley should keep these healthy and should test this trolley during normal synchronization.

5.9.3 Guidelines for providing auto synchronisation facility in BCU

In SAS based substation, Synchrocheck relay is provided for each transmission line and bus coupler breakers to ensure line are closed at specified angular separation, voltage magnitude difference to reduce stress across breaker. During island synchronization, Substation Operator checks output of

Synchro check relay (25) in substation automation system (SAS) display for synchronization. When Synchro Check relay provides "All Parameter Ok" condition then substation operator enable auto-synchronization function for the breaker. Now when the closing pulse is generated it will be held by Synchrocheck relay again to ensure that after auto synchronization is enabled, parameters are still meeting the set condition. If the synchro check relay again gives go through signal (All parameters Ok), then immediately closing command should go to circuit breaker for closing without any delay.

Thus, it avoids any manual intervention in actual breaker closing and making it a fast and accurate process.

In view of this following is required in the Indian power system:

i. Auto-Synchronization facility should be made available and enabled in all transmission lines and bus couplers.
ii. A standard guideline for the setting on frequency, voltage and phase angle difference for these auto-synchronization facility can be discussed at RPC level.
iii. Auto-Synchronization parameters for restoration will be provided by RLDC in discussion with power plant and these may be changed in real time during actual restoration. Adequate trained personnel should be available to change these parameters either locally or remotely.

5.9.4 Guidelines for Synchronizing breaker closing through auto-synchronisation facility or Synchro check relay in SAS based substation

- Any closing command to synchronizing breaker should always go through Auto synchronisation relay. There should not be any delay when command has been checked by the auto synchronization relay to synchronizing breaker.
- Even if the manual closing command is being issued after checking in synchronizing device, it should go through the Synchrocheck relay which will ensure the parameters are within permissible limit before breaker closing. It is due to the fact that during restoration if manual command is being issues ensuring all parameters within prescribed limit still due to human delay, synchronizing parameters such as angular difference may vary quickly if frequency difference is varying and may close out of phase or at large angular difference resulting into generator tripping and island collapse.

5.9.5 Guidelines for provision of Digital Synchroscope in HMI at SAS based substation

i. Generating plant have digital synchroscope in their system for respective units as all synchronization of units that is being performed is through digital synchroscope and auto synchronizer. Digital synchroscopes help plants in achieving desired parameters level to ensure and better coordination with respective control room and load dispatch centre. During manual synchronization, such scope helps in ensuring proper synchronization.
ii. At major transmission substations having SAS, digital synchroscope display should be available for the operator to perform manual synchronization when required. Further, it will also help operators in enabling auto-synchronization after system course correction has been taken to bring parameters within limits. In its absence, visibility of local substation operator is limited in providing desired details.

iii. For Conventional substation should have synchronization trolley with check sync relay for each transmission line and bus coupler bay directly provides such information for performing synchronization

Scenario when neither auto-synchronization facility is enabled, nor digital synchroscope is available at transmission system level in restoration path or mock drill path at SAS based substation.

i. If already there is one island formed and that has to be synched with black start unit at other substation, then unit can be black started and synchronization to be done at its own generating substation through auto- synchronization during restoration/mock drill to avoid any wrong synchronization.
ii. If black start unit is the only source for building the island, then in that case if auto synch facility and digital synchroscope both are not present at transmission substation in restoration path where it is going to be synchronized then in that case:
    a. For manual synchronization using HMI, breaker closing command should be through synchro check relay (25) only to ensure wrong synchronization command due to delay in command execution through HMI is not processed.
    b. For this, local setting should be ensured by the substation operator

5.10 Guidelines for Priority Load restoration

Loads connected with power systems during restoration activities are required to be classified under Critical and priority load. Their details are provided below:

Critical loads are loads essential to performing the restoration and sustaining the operation of the bulk power system. Examples of critical loads include following.

i. Auxiliary power for safe shutdown/stabilizing island of nuclear power plants
ii. Station service at transmission-level power control centres
iii. Startup power for generating stations and Transmission substations in cranking path
iv. Gas pipeline compression stations
v. Power system communication facilities
vi. Protective relays and schemes used to ensure public and personnel safety and to maintain the integrity of the electric grid
vii. Power transmission monitoring and control systems

Priority loads are important consumer loads that need to be restored promptly to mitigate the impact on public health and safety, the environment, or the economy. These include (in no order),

i. Key military facilities
ii. Mines
iii. Hospitals
iv. Water and wastewater treatment plants
v. Telecommunication centres
vi. Oil refineries
vii. Major financial centres

viii. Traction supply

Priorities of load which is to be connected in steps should be documented and while releasing loads for example Traction loads, underground coalmines/deep gassy mines/AIR/TV/Telephone exchange, hospital, pumping station etc. should be given priority depending on available generation.

5.10.1 Guidelines for Priority load restoration

The main priorities after power supply are available for system restoration (from black start generators or from neighbouring areas/region) are as follows:

i. Extending start-up / Auxiliary power to thermal power plants.
ii. Extending start-up power to hydro and Gas based power plants which are capable of rapid restart.
iii. Extending power for restoration of traction power supply.
iv. Extending power for Building up subsystem and synchronizing with each other.
v. Restoration of supply to other essential loads such as hospitals, collieries (coal mines), telecommunication, Airports, defence establishment, district head quarter etc.
vi. Restoration of supply to all other customers.
vii. Power stations receiving start-up power may extend supply to other nearby power stations for start-up without waiting for code from SLDC
viii. Code may be taken from SLDC for synchronization if start up power supply is available from two different sources.
ix. Due priority shall also be given to restore power supply to communication system nodes and repeater stations.

5.11 GUIDELINES FOR TRACTION LOAD RESTORATION

Constituent-wise priorities of load which are to be connected in steps should be well documented and while restoring loads, essential loads such as railway traction loads, underground coal mines/deep gassy mines, Airport, TV station, Telephone exchange, hospital, pumping stations etc., should be given priority depending on available generation on bar.

Guidelines for traction load restoration:

i. During the time of System Restoration (Black Start) due importance is required to be given to the traction load and the supply to the grid points feeding the Railway Traction Station is to be extended on priority.
ii. Prior coordination with Railways is to be done to co-ordinate shifting of loads between two Railway feeding points.
iii. While extending power supply to the traction network during the system restoration process, phase balancing should be kept in mind. Also, the quantum of actual load released from the sub- station should be known before the process of restoration.
iv. Railways should ensure that power supply should be used for only mobilizing the rakes held up in between stations.
v. Negative phase sequence currents, unbalanced voltages should be monitored to avoid untoward incidents.

vi. While releasing supply to traction some urban/city loads (inductive) should also be simultaneously released to check the high voltages, jerks, and unbalancing.

5.12 GUIDELINES FOR STARTUP SUPPORT FROM SURVIVING DESIGNED ISLANDS

i. In the event of a blackout scenario, the priority is to ensure the survival and stability of the surviving island until synchronization is achieved with the stabilized grid or another designed island.
ii. Major cities in India have an islanding scheme in place or is in process of getting one. The idea behind such islanding schemes are that in the event of a grid disturbance, critical loads in the city (railways, hospitals, airport, metro rail, etc.) continue to get supply from the identified generating stations in the separated island.
iii. The startup power from the surviving island shall be extendeded to the nearby generators with careful consideration of the sensitivity of loads within the surviving island. This extension should only be carried out once the surviving island has reached a sufficient level of stability. Furthermore, conditions for extending startup power, the designated startup supply path, and loads to be brought into service along the way must be clearly defined in the restoration procedure. Expected voltage rise along the startup supply path shall be known beforehand to anticipate the rise in voltage at the surviving island bus and the generator (to which supply is being extended) bus in order to avoid line tripping on overvoltage in the surviving island. Startup supply path shall preferably avoid the cables. Stepwise load to be taken after synchronization of the generator shall be available with the operator.
iv. For example, in the Mumbai restoration system, it is stated that following separation, the Mumbai sub-system should continue to operate independently, relying on its own generation and serving critical loads such as railways, hospitals, and the airport. Therefore, the extension of startup power to the MSETCL system from the Mumbai Island shall be avoided.
v. If the island is a part of multi-level islanding scheme, then startup power shall be extendeded to generators in other islands within this islanding scheme, but only after the stabilization of the initial island. This extension shall be carried out in strict accordance with predefined restoration protocols. For example, in the Mumbai system restoration plan, it is specified that if the Tata (TPC) island has survived or the system is reactivated through the blackstart of TPC hydro units, then the startup power supply to Adani Dahanu (AEML island) shall be extendeded only after the stabilization of the Tata Power (TPC) sub-system.

5.13 Guidelines for support from Neighbouring System

A Top-Down approach involving the assistance of neighbouring system must be adopted as a restoration strategy. During this approach NLDC will take restoration activities in consultation with RLDCs.

i. Conduct an initial assessment to determine system conditions and identify the shortest interconnected transmission line from the neighbouring healthy system.
ii. Synchronization facilities must be available and in healthy condition in the interconnection points.

iii. Energize the shortest interconnection line to facilitate system restoration and extend start up power to generators.
iv. Care must be taken to control voltages at various intermediate nodes by providing loads, and adjusting the taps of the transformers at the intermediary stations while extending start up power to generators via shortest link.
v. Energize fewer high voltage line in the path of providing start up power to the generators. Bus reactor to be taken into service to control voltages at intermediate points.
vi. Restore only critical load in small increments during early stage to avoid overloading of interconnected transmission line.
vii. Synchronize with other remaining neighboring system to make the grid stronger.

5.14 Guidelines for RE generation interconnection during restoration

5.14.1 Guidelines for Line Charging during Restoration in RE complex:

1. Immediate charging of tripped lines should be avoided. Ensure vide written communication from the concerned ISTS pooling station and concerned RE plant(s) (in case the dedicated line(s) connecting the plant(s) to the pooling station has tripped) that the line to be charged is free from fault as failed attempts have the potential to trigger cascade tripping of other elements.

2. In case a line is tripped on fault, the restoration may be avoided during solar hours unless it is critical for reliable evacuation of existing generation.

    i. For a single line to ground fault with fault current less than 4 kA, if the line owner confirms that the fault was transient in nature and the line is now in healthy condition, then only charging of the line may be considered.
    ii. For Line-to-Line and 3-phase faults, charging of the line should be attempted only if the line owner confirms healthiness of line following a thorough patrolling. The information from site should be supported by relevant photographs taken before and after rectifying the fault.

3. Before charging, ensure that voice and protection communication (if any) between both ends are healthy and protections are in service and that no protection is by-passed.

4. If continuous oscillations of voltage and/or power are observed in the RE evacuation system, then the same should first be addressed by backing down generation or other appropriate measures at appropriate RE plants, before attempting charging.

5. Fresh calculation of modified fault MVA at the charging end in depleted system is necessary before taking charging attempt. The line should be charged from the end with higher fault level in order to limit the voltage rise both at charging and remote (open) ends.

    i. If two buses have almost same short circuit level (3-ph), charge the line from the bus with lower voltage.
    ii. In case line reactor is available at only one end, it is preferable to charge the line from the end without line reactor and synchronize at the end with line reactor.

6. At the charging end, all measures should be taken to control the pre-charging voltage as much as possible to the nominal level like taking into service local Bus reactors and Line Reactors as well as those in nearby stations, if necessary.

   i. In solar pocket, during charging a line, high voltage may occur at a nearby station where charging is not being done. So, it is preferable to reduce voltage at all nearby stations by taking reactors in service.

   ii. Before charging the dedicated evacuating line of RE plant(s), mode of operation (V-control, Fixed-Q or Fixed-PF) of RE plant(s) must be ensured, it is preferable to keep the plant in V- control mode such that any voltage rise/voltage drop can be addressed by reactive power (MVAr) response of the plant(s) or any other suitable mode of operation (V-control, Fixed-Q or Fixed- PF) of RE plant(s) may be kept based on real-time grid condition as per RLDCs/NLDC instruction.

   iii. To control the voltage of RE pooling stations, operator can give directions to RE plant(s) to operate in suitable mode of operation (V-control, Fixed-Q or Fixed-PF) based on real-time grid condition to either absorb/inject fixed reactive power (MVAr) or to support in voltage control mode.

5.14.2 Guidelines for Dead Bus Charging during Restoration in RE complex:

1. Charge the line from the nearest substation, which is live and pre-close the line circuit breaker (CB) at the dead bus end. Before closing the CB at the charging end, it is to be ensured that all other breakers at the dead bus are open.

   i. Before closing the CB at charging end, it is to be ensured that all other CBs at the dead bus end are open.

   ii. However, to minimise the rise of post-charging voltage, the bus reactor of the bus that would be charged and/or line reactor at the remote end of the line being charged may be kept in service (as per requirement) with its CB and isolator in closed position before charging the dead bus.

2. If a 765/400 kV station is to be energised from grid side, it is preferable to extend supply at 400 kV level. This would ensure keeping the voltages low while charging. Generation may be revived based on evacuation limits of 400 kV network.

3. Charge both the buses of a dead station and couple them by closing the bus coupler or tie CB before energising lower voltage buses. That is, if extending supply from 765 kV side, charge both 765 kV buses before extending to 400 kV buses.

4. If extending supply from 765 kV side, energise 400 kV Bus along with bus reactor before charging other lines. Usually, station supply at RE pooling stations is being fed by tertiary of 765/400 kV ICT.

5. No interlocking bypass to be done while initiating the charging attempt. Angle difference between both ends of lines to be taken care.

6. Energize initially only one of the circuits for each double circuit line followed by charging of their respective other circuits.

i. This ensures strong network connectivity as well as N-1 safety. This will also ensure that each station is connected to its immediately neighbouring stations by at least two lines.

ii. For radially connected generation pooling stations, if two 400kV circuits are there then 2nd circuit should be taken into service after generation pooled at pooling stations reaches around 100 MW, for reliable evacuation.

7. Once the minimum required evacuation path from a pooling station is established, RLDC and NLDC to instruct each pooling station to allow connection and injection of the underlying generators in a gradual manner, preferably in the steps of 50 MW. All the plants connecting to a pooling station should ensure that they operate in voltage control mode so that steady voltage is ensured even under the depleted network condition.

5.14.3 Guidelines for Switching Coordination and Operation Code Exchanges:

1. Contact Details of all RE plants i.e. phone nos. and Email IDs along with their respective Nodal persons' Name and Mobile nos. are to be essentially maintained and updated regularly at SLDC & related Control rooms.

2. RLDC and SLDC control rooms should discuss and mutually agree upon a common step-wise restoration plan in real time to avoid any confusion regarding actions to be taken and attain clarity before exchanging operation code(s).

3. RE plants should ensure execution of issued operation code within a reasonable time of fifteen (15) minutes, failing which the reason must be promptly communicated to SLDC for revision in operation code, if any required.

   Those RE plant(s) having inherent black start capability (having energy storage system (ESS)) can support the grid during restoration if required based on SLDC instruction.

5.15 Guidelines for Backup Control Centre

During any blackout, there is a possibility that there can be a loss of supply situation at Control Centres of NLDC/RLDC/SLDC. Under such conditions it is important to first ensure adequate backup power supply and readiness of backup control centres. In addition, during COVID19 pandemic, it has emerged to also establish local control centre to ensure shift manpower handling control room activities are kept isolated. The associated guidelines for disaster recovery of main control centre, backup control centre and local control centre is provided below.

Failure of Main supply

The Load Despatch Centre shall have redundant sources of auxiliary supply. In case of failure of AC mains (From Local DISCOM) the essential load shall automatically switch over to the UPS supply. There shall be a provision for auto start of Diesel generators to support the battery and meet the other power requirements (Space cooling, lighting etc).

In line with IEGC the local DG set shall be tested weekly and appropriate record shall be maintained. The failure over test of UPS shall be periodically conducted.

Remote Backup control Centre

The load dispatch centre is equipped with Supervisory Acquired systems, Energy Management Systems and Wide Area Monitoring System for situational awareness and decision making in real time. In line with CERC (Communication System for inter-State transmission of electricity) Regulations, 2017, there shall be adequate redundancy in communication network to ensure availability of these systems round the clock.

Further there shall be a provision of well-equipped backup control centre. Operation from the backup control centre shall be tested at least once in a year. Detailed procedure shall be tested and maintained by concerned department.

Local Backup Control Room

In order to handle situations like pandemic and city floods, there shall be a provision to create local backup control room within the office premises. Technologies that support work from home (distributed control) shall be deployed with to enable control centre operation even in case of curfews, local travel constraints etc.

Disaster Recovery System (For STOA, Scheduling, Fees and Charges, Metering, FTC etc.)

All the IT applications of a LDC generally reside on servers located within the LDC. These applications along with their databases are periodically backed up in separate physical storages (SAN, NAS. HDD etc.) within the LDC.

In the event of contingency when a LDC becomes non-operational due to factors such as pandemic, flood, earthquake, terrorist attack etc. requirement of Disaster Recovery (DR) becomes necessary for the Business Continuity.

Periodicity of Disaster recovery

In case of system failure, the DR of LDC should be made operational within shortest possible time. The entire DR failover and failback operation should be tested at least every 6 months. During this operation for some time DC should be shut down and all operations should happen from DR. A detailed procedure shall be available with concerned department head.

CHAPTER 6: COMMUNICATION AND INFORMATION EXCHANGE

6.1 RESPONSIBILITY

1. SLDC shall be responsible for reporting Grid Incidents/Grid Disturbance to NERLDC / NERPC Secretariat as the case may be.
2. All Users, STU, DISCOM shall be responsible for collection and reporting of all necessary data to SLDC for reporting Grid Incidents/Grid Disturbance analysis as the case may be.

6.2 PROCEDURE TO BE FOLLOWED DURING AN EVENT

1. In the case of an event on the intra-State transmission system that may significantly impact the inter-State transmission system, SLDC shall immediately inform the RLDC
2. Immediately following an event on the regional grid, the RLDC shall inform the concerned users and the concerned SLDC of the necessary action to be taken.
3. Any warning in respect of system security issued by NLDC or RLDC or SLDC shall be taken note of immediately by the concerned users who shall take the necessary action to withstand the said event or to minimize its effect.

6.3 REPORTING OF GRID DISTURBANCE:

1. Immediately following an event (grid disturbance or grid incidence as defined in the CEA Grid Standards Regulation and amendments thereof) in the system, the concerned User or SLDC shall inform NERLDC through voice message.
2. Written flash report shall be submitted to SLDC by the concerned User within the time line specified in Table below.

Sr. No.	**Grid Event^ (Classification)**	**Flash report submission deadline (Users/ SLDC)**	**Disturbance record and station event log submission deadline (Users/ SLDC)**	**Detailed report and data submission deadline (Users/ SLDC)**	**Draft report submission deadline (RLDC/ NLDC)**	**Discussion in protection committee meeting and final report submission deadline (RPC)**
1	GI-1/GI-2	8 hours	24 hours	+7 days	+7 days	+60 days
2	Near miss event	8 hours	24 hours	+7 days	+7 days	+60 days
3	GD-1	8 hours	24 hours	+7 days	+7 days	+60 days
4	GD-2/GD- 3	8 hours	24 hours	+7 days	+21 days	+60 days
5	GD-4/GD- 5	8 hours	24 hours	+7 days	+30 days	+60 days

3. Disturbance Recorder (DR), station Event Logger (EL) and Data Acquisition System (DAS) shall be submitted within the time line specified In the table above.

4. SLDC shall report the event (grid disturbance or grid incidence) to CEA, NERPC and all regional entities within twenty-four (24) hours of receipt of the flash report.
5. After a complete analysis of the event, the User shall submit a detailed report in the case of grid disturbance or grid incidence within one (1) week of the occurrence of event to SLDC.
6. SLDC shall prepare a draft report of each grid disturbance or grid incidence including simulation results and analysis, which shall be discussed and finalised at the SPCC and the Protection sub-committee of NERPC, wherever applicable, as per the timeline specified in Table below.
7. The implementation of the recommendations of the final report shall be monitored by the Protection sub-committee of the NERPC. NLDC shall disseminate the lessons learnt from each event to all the RPCs for necessary action in the respective regions.
8. Any additional data such as single line diagram (SLD) of the station, protection relay settings, HVDC transient fault record, switchyard equipment and any other relevant station data required for carrying out analysis of an event by RPC, NLDC, RLDC and SLDC, shall be furnished by the Users including RLDC and SLDC, as the case may be, within forty- eight (48) hours of the request. All Users shall also furnish high-resolution analog data from various instruments including power electronic devices like HVDC, FACTS, renewable generation (inverter level or WTG level) on the request of RPC, NLDC, RLDC and SLDC.
9. Triggering of STATCOM, TCSC, HVDC run-back, HVDC power oscillation damping, generating station power system stabilizer and any other controller system during any event in the grid shall be reported to SLDC, if connected to an intra-State system. The transient fault records and event logger data shall be submitted to the SLDC within twenty-four (24) hours of the occurrence of the incident. Generating stations shall submit one (1) second resolution active power and reactive power data recorded during oscillations to SLDC within twenty-four (24) hours of the occurrence of the oscillations.
10. A monthly report on events of unintended operation or non-operation of the protection system shall be prepared and submitted by each User to SLDC within the first week of the subsequent month.

6.4 FORM OF WRITTEN REPORTS:

A written report shall be sent SLDC with the following details of the event.

1. Time and Date of Grid Incident/Grid Disturbance
2. Location
3. Plant and/or Equipment directly involved.
4. Description and cause of incident/disturbance
5. Antecedent conditions of Load and Generation, including Frequency, Voltage and the Flows in the affected area at the time of tripping including Weather Condition prior to the Grid Incident/Grid Disturbance
6. Duration of interruption and Demand and/or Generation (in MW and MWh) interrupted
7. All Relevant system data including copies of records of all recording instruments including Disturbance Recorder, Event Logger, DAS etc
8. All operational data, including Disturbance Recorder and Event Logger Reports, for analyzing the Grid Incidents and Grid Disturbance and any other data which in its view can be of help for analyzing Grid Incident or Grid Disturbance shall be furnished by all the Entities within twenty-four hours to NERLDC and NERPC. No Entity shall block any data/information

required by NERLDC and NERRPC for maintaining reliability and security of the Grid and for analysis of an event

9. Details of Relay Flags
10. Remedial measures

CHAPTER 7: RESTORATION PROCEDURE

SYSTEM 1: RESTORATION OF CAPITAL AND SAMAGURI SECTION BY BLACK START OF KOPILI / KHANGDONG (NEEPCO)

To revive Capital and Samaguri section of Assam, power shall have to be first extended to 220kV Samaguri GSS from the following Substations:

A. **Shankardevnagar GSS (AEGCL):** Black start Source – Lower Kopili HEP (APGCL).
After black start, power from LKHEP (APGCL) shall be extended to Shankardevnagar GSS and then to Samaguri GSS via 220kV D/C lines.

OR

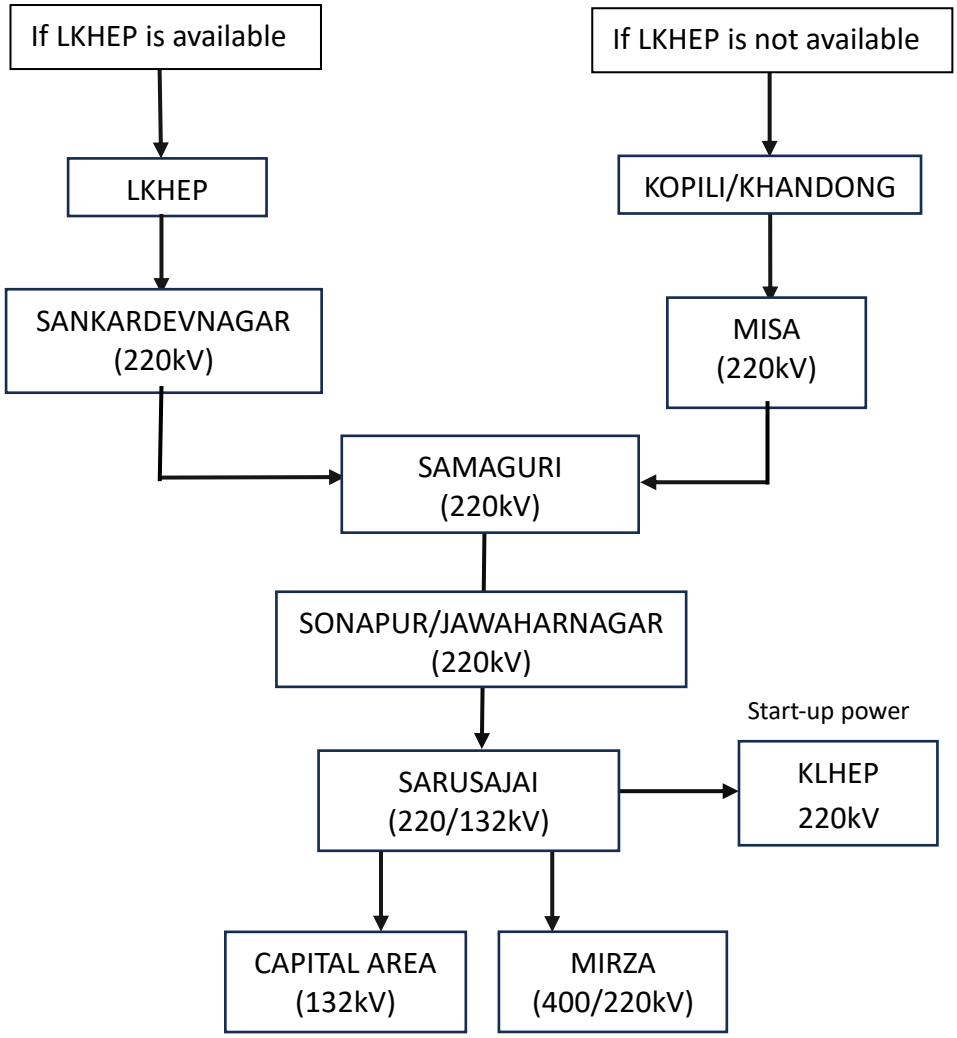
B. **Misa GSS (PGCIL):** Black Start Source - Kopili (NEEPCO)/Khangdong (NEEPCO).
After black Black start, power from Kopili (NEEPCO)/Khangdong (NEEPCO) shall be extended to MISA GSS via Kopili-Misa (PG) or Khangdong-Kopili-Misa (PG) Lines.

Method of Restoration:

1. Power shall be extended to Capital area via
   i. 220kV Samaguri- Sonapur- Sarusajai and
   ii. 220kV Samaguri- Jawaharnagar- Sarusajai.
2. Loads at Jawaharnagar and Samaguri shall be connected in steps to contain overvoltage.
3. Start-up power to Karbi Langpi HEP shall be extended via 220kV Sarusajai-KLHEP D/C Line. Subsequently, KLHEP shall be synchronised. Connect loads at Sarusajai .
4. 220kV Sarusajai- MIRZA D/C shall be charged in the next step.
5. Charge 220/132kV ICT's and bus at Sonapur.
6. Charge 132kV Sonapur-Narengi. Load at Narengi to be connected.
7. Charge 132kV Sarusajai- Kamakhya.
8. Charge 132kV Narengi- Kahilipara.
9. Charge 132kV Sonapur - Chandrapur (CTPS), 132KV CTPS-Dispur and 132kV Dispur-Kahilipara sequentially.

All other transmission lines can be charged sequentially and load to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained and frequency/voltage shall be continuously monitored.

Flow Chart depicting the restoration paths for Capital & Samaguri sections:



Alternate source for restoration

Black start power source: **Bongaigaon Thermal Power Project BGTPP (NTPC)**. In the event of failure of Kopili/Khandong plants and LKHEP units to black start, power may be extended to Capital region by availing power from BGTPP plant via the following routes:

1. **Charging through 400kV network**: 400kV Mirza GSS will be charged through 400kV Mirza-Bongaigaon line.

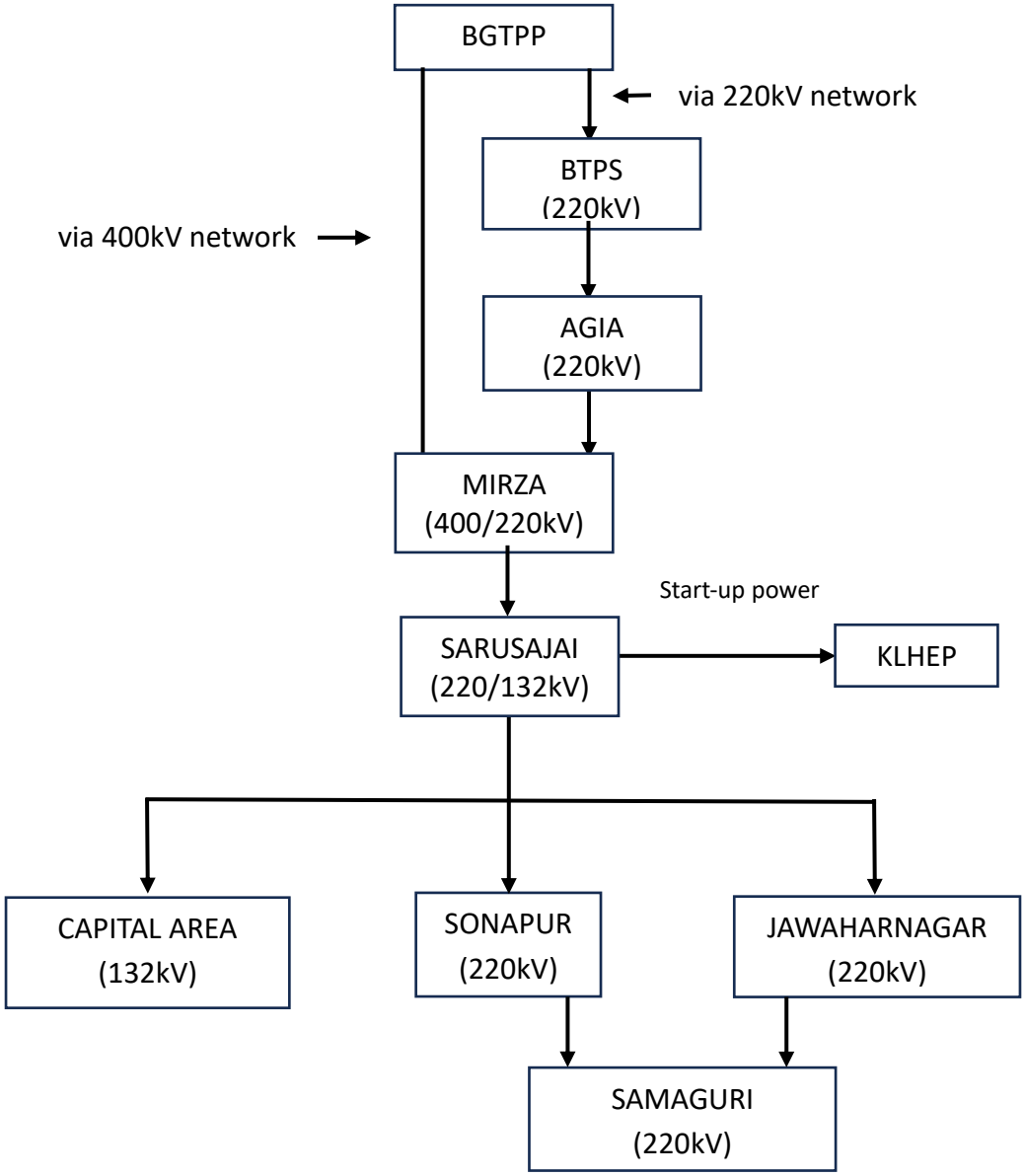
2. **Charging through 220kV network**: 220kV BTPS-NTPC D/C will be charged first. After that power will be extended to 220kV Agia GSS via 220kV Agia-BTPS D/C lines. Then 220kV Agia-Chaygaon-Boko-Mirza link will be charged.

Method of Restoration:

1. After 400kV Mirza GSS is charged, power shall be extended to 220kV Sarusajai GSS.
2. Once Sarusajai GSS is charged, power shall be extended to KLHEP for Black Starting their units. Subsequently, KLHEP shall be synchronised.
3. Power shall be extended to Samaguri section by 220kV Sarusajai-Jawaharnagar-Samaguri & 220kV Sarusajai-Sonapur-Samaguri Lines.

4. Power shall be extended to rest of the Capital region by charging 132kV Kahilipara, Dispur, Narangi, Kamakhya, GMC, Paltanbazar, Amingaon GSSs.
5. Power can also be extended to LKHEP via 220kV LKHEP-Sankardevnagar D/C lines after charging 132kV Samaguri-Shankardevnagar D/C lines.

Flow Chart depicting the Alternate restoration path for Capital & Samaguri section



SYSTEM 2: RESTORATION OF NORTH BANK OF ASSAM BY BLACK START OF PARE / PANYOR (NEEPCO)

To revive the North Bank section of Assam Grid, power shall have to be first extended to either 132kV Pavoi GSS or 132kV Nalkata GSS from the following Black Start power source available.

A. **Pare Hydro Electric Project (NEEPCO)** shall black start machines and shall synchronize with the Assam Grid at Nalkata GSS.

B. **Panyor Lower Hydro Power Station (NEEPCO)** shall also black start machines and shall synchronize with the Assam Grid at Pavoi GSS via Pavoi - Biswanath Chariali (BNC) (PG) D/C lines.

In case one of the source fails, other can provide support to this region.

Method of Restoration:

1. Upon receipt of power at Nalkata GSS from Pare, power can be extended via the following route.
   a) Nalkata - Dhemaji- Silapathar S/C Lines
   b) Nalkata- Majuli

2. Upon receipt of power at BNC (PG) GSS from PANYOR, power can be extended to the state grid by the following paths
   a) BNC (PG) - Pavoi D/C LINES
   b) Pavoi - Gohpur D/C LINES

All other transmission lines can be charged sequentially and load to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained and frequency/voltage shall be continuously monitored.

Alternate path for restoration:

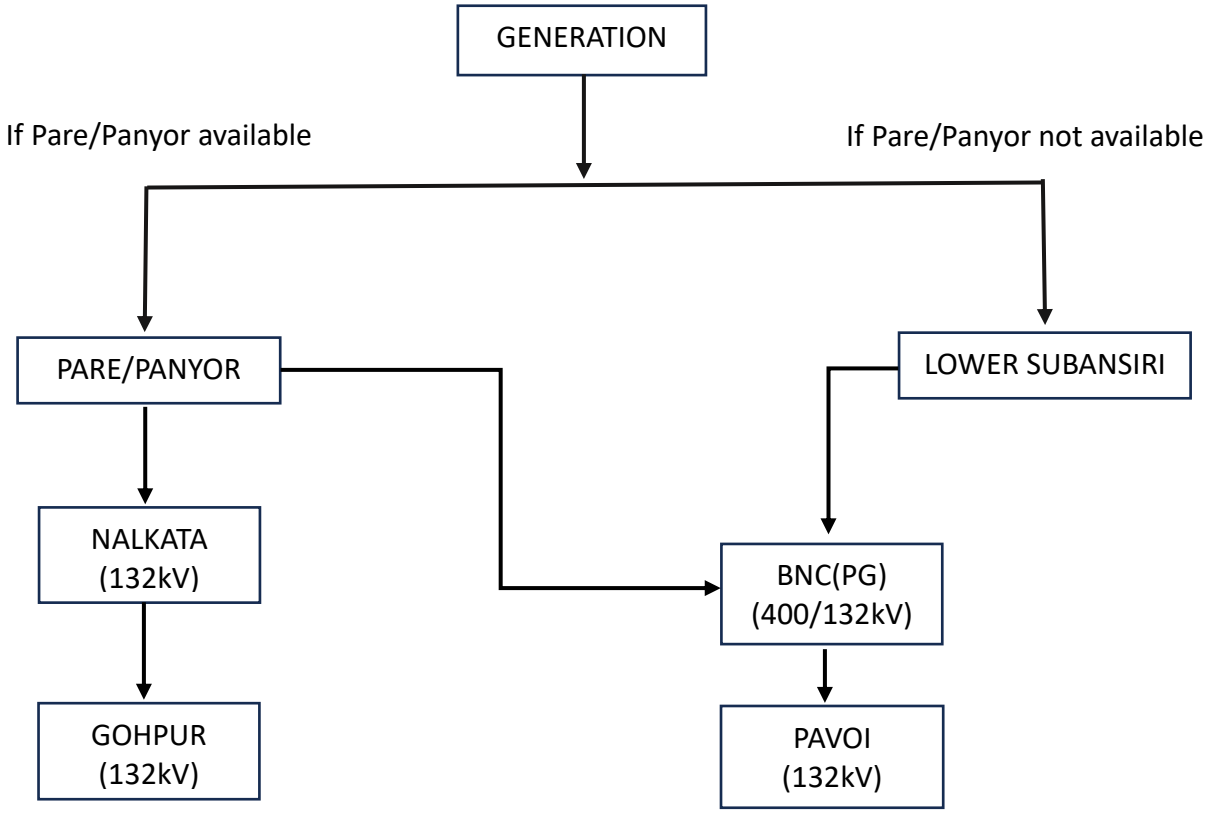
In the event of unavailability of Pare & Panyor machines, Lower Subansiri can black start and extend power to BNC (PG) GSS.

Upon receipt of power at BNC (PG) GSS from Lower Subansiri, power can be extended to the state grid through the following paths

a) BNC (PG)- Pavoi D/C LINES
b) Pavoi - Gohpur D/C LINES

Power can then be extended to Nalkata section via 132kV Nalkata-Gohpur D/C lines and then to Dhemaji and Silapathar Lines. Load and generation balance to be maintained.

Flow Chart depicting the restoration path for North Bank region



SYSTEM 3: RESTORATION OF SONABIL SECTION OF ASSAM BY BLACK START OF KAMENG/PANYOR (NEEPCO) OR LOWER SUBANSIRI (NHPC)

To revive the Sonabil section of Assam Grid, power shall have to be first extended to 220kV Sonabil GSS from 220kV Balipara (PG) GSS. The Black Start sources available for energisation of Balipara (PG) GSS are as follows:

A. **Kameng Hydro Power Station (NEEPCO).** Power can be extended via 400kV Kameng - Balipara D/C lines.

B. **Panyor Lower Hydro Power Station (NEEPCO)**. Power can be extended via 400kV Panyor-BNC- Balipara (PG) lines.

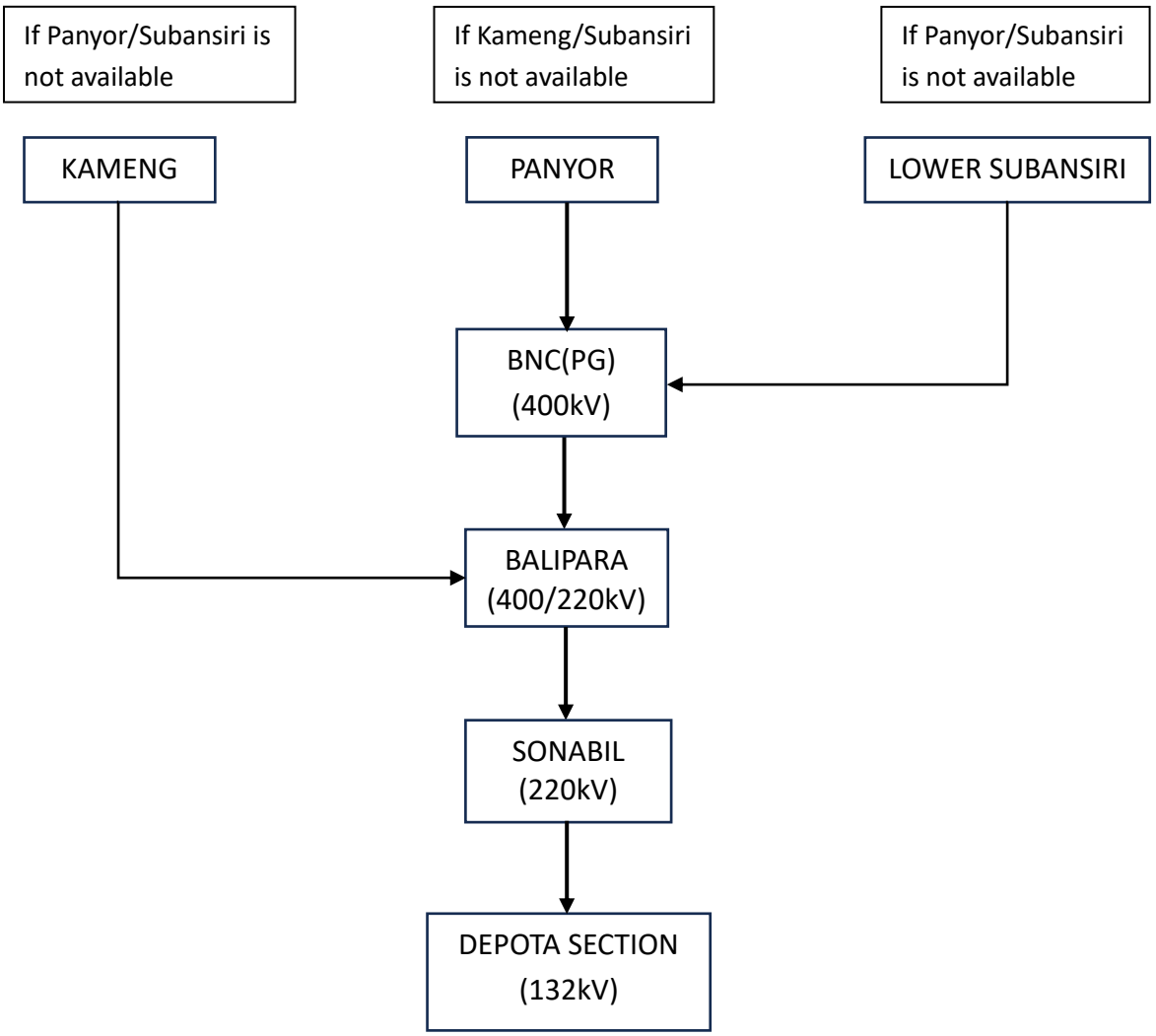
C. **Lower Subansiri Hydro Electric Project (NHPC).** Power can be extended to Biswanath Chariali (BNC) (PG) substation & subsequently to Balipara substation via 400kV Lines.

Method of Restoration:

1. Upon receipt of power at Balipara (PG), power can be extended to 220kV Sonabil GSS via 220kV Balipara- Sonabil D/C lines.
2. Charge 132kV Sonabil- Depota, 132kV Sonabil- Ghoramari and 132kv Ghoramari Depota lines in succession.
3. Charge 132kV Sonabil- Tezpur D/C lines.
4. Charge 132kV Depota- Rowta, 132kv Depota- Dhekiajulee & 132kV Rowta- Dhekiajulee lines one after another.
5. Supply power to Sipajhar and Tangla from Depota side if not already charged from Rangia end.

Loads are to be connected in line with generation available. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. In case load is not sufficient to balance the generation then 220kV Samaguri - Sonabil is to be connected and load is to be supplied to Sonabil section.

Flow Chart depicting the restoration path for Sonabil Section



SYSTEM 4: RESTORATION OF LOWER ASSAM

To revive Lower Assam power shall have to be extended from 400/220kV Bongaigaon (PG) GSS. Black start power up to Bongaigaon (PG) can be extended from the following sources:

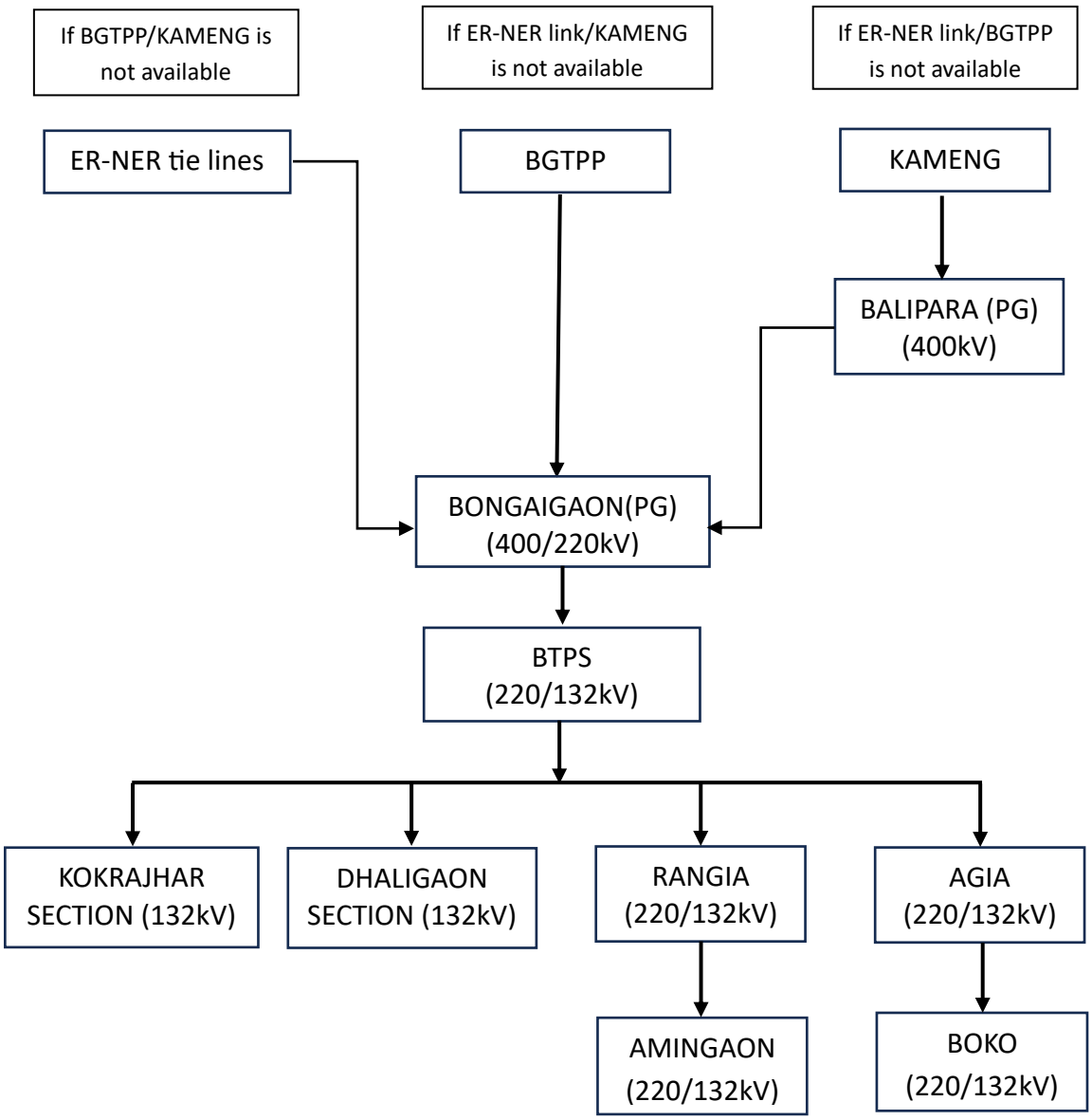
A. **Eastern Region-North East Region tie lines.**
B. **Bongaigaon Thermal Power Project (NTPC),** via the 220kV BGTPP- Bongaigaon (PG).
C. **Kameng (NEEPCO),** 400kV Kameng- Balipara- Bongaigaon (PG) shall be charged.

Method of Restoration:

1) After Bongaigaon (PG) is energised, it shall extend power to 220kV BTPS GSS.
2) Charge 132kV BTPS- Dhaligaon D/C lines.
3) Charge 132kV BTPS- Kokrajhar D/C lines.
4) Power to be extended to Bilasipara & Gauripur via 132kV Kokrajhar- Bilasipara-Gauripur link.
5) Charge 132kV Dhaligaon- APM, Dhaligaon-Barpeta & Dhaligaon- Barnagar sequentially.
6) Charge 220kV BTPS- Rangia D/C LINES.
7) After power is available at Rangia GSS, charge 132KV Rangia-Tangla, 132kV Rangia-Sipajhar, 132kV Rangia-Nalbari, 132kV Rangia- Nathkuchi, 132kV Rangia- Kamalpur D/C lines.
8) Charge 220kV Rangia – Amingaon D/C lines.
9) Charge 220kV BTPS- AGIA D/C lines and restore power to Agia.
10) 220kV AGIA-BOKO- MIRZA to be charged.

All other transmission lines can be charged sequentially and load to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained and frequency/voltage shall be continuously monitored.

Flow Chart depicting the restoration path for Lower Assam region



SYSTEM 5: RESTORATION OF GSS OF UPPER ASSAM BY BLACK START OF KATHALGURI (NEEPCO)

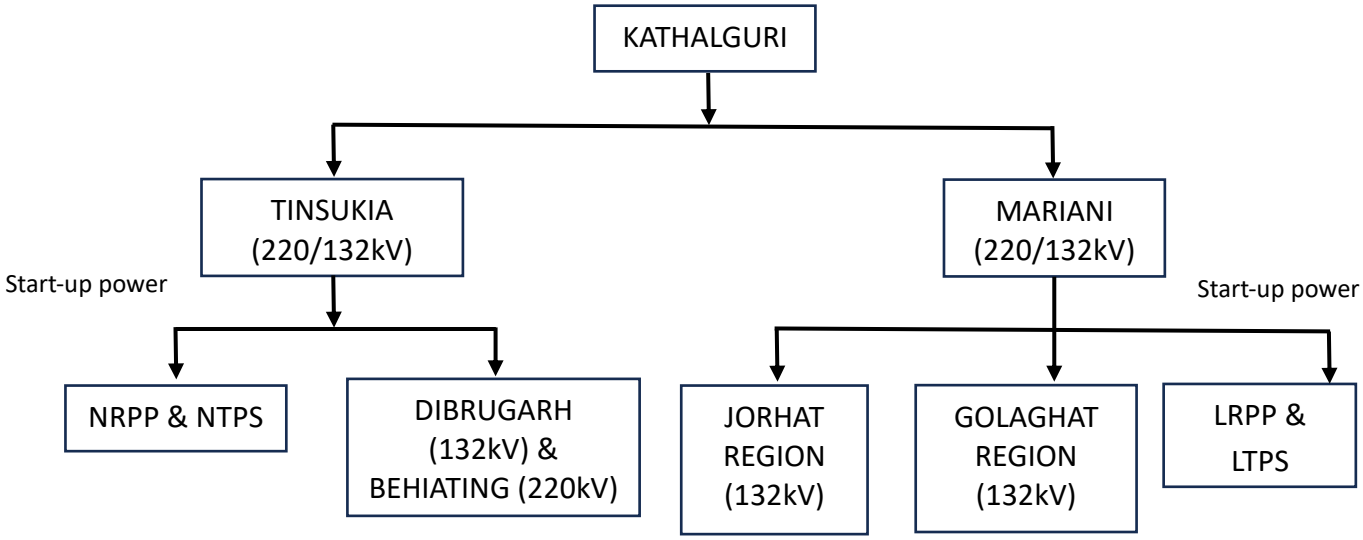
To revive Upper Assam region, power shall have to be extended to 220kV Tinsukia or Mariani (PG) GSS from **Assam Gas Based Power Plant, Kathalguri (NEEPCO)** via 220kV Kathalguri-Tinsukia D/C lines.

Method of Restoration:

1. Upon receipt of power at Tinsukia GSS power, around 20 MW load can be connected to stablilize the generation.
2. 132kV Tinsukia-Dibrugarh to be charged. Load of around 10MW to be connected at Dibrugarh.
3. 220kV Mariani-Kathalguri to be charged. 10 MW load to be connected at Mariani.
4. 132kV Mariani-LTPS to be charged and start up power to LRPP machine shall be provided.
5. LTPS & LRPP machines to start generating after receiving start up power.
6. 132kV Jorhat- Mariani D/C to be charged, 132kV Jorhat-Teok, 132kV Teok-Nazira, 132kV LTPS- Nazira to be charged sequentially.
7. 220kV Tinsukia- Behiating D/C lines to be charged, 132kV Dibrugarh-Behiating, 132kV Behiating- Moran, 132kV LTPS- Moran to be charged sequentially.
8. 220kV Mariani-Amguri-NTPS to be charged. 220kV NTPS-NRPP & 132kV TSK-NRPP to be charged sequentially.
9. Start Up power to NRPP & NTPS shall be provided.
10. 132kV Bokajan-Dimapur, 220kV Mariani-New Mariani, 220kV Samaguri-Mariani shall be charged thereafter.

All other transmission lines can be charged sequentially and load to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained and frequency/voltage shall be continuously monitored.

Flow Chart depicting the restoration path for Upper Assam region



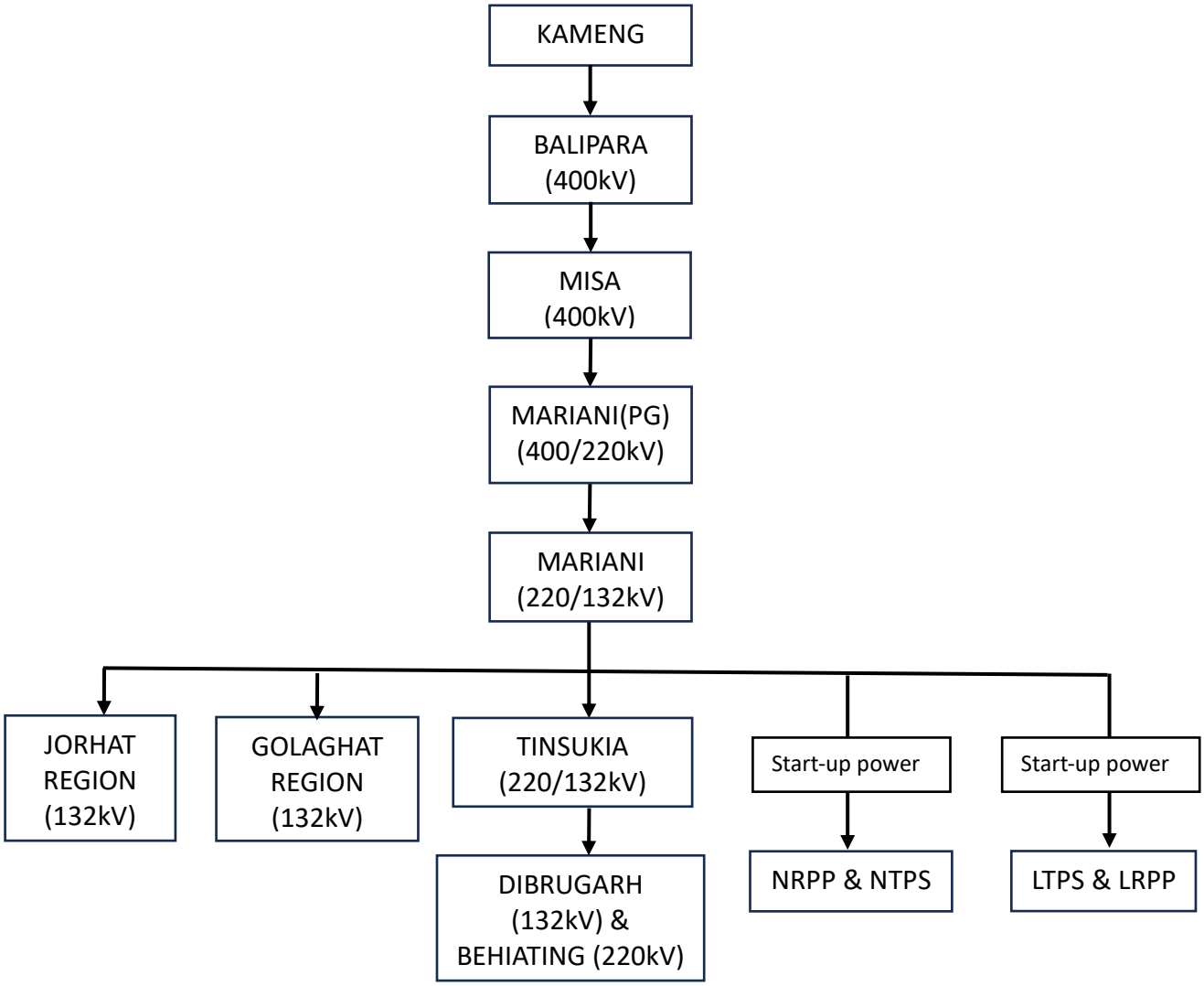
Alternate path for restoration:

In case AGBPP (Kathalguri) fails to synchronise, power can be restored to Upper Assam section by:

1. Charging 400kV Mariani (PG)-Misa line. Misa (PG) will receive power from Balipara lines (generation from Kameng).
2. Charging 220kV Mariani (PG)-Mariani line.
3. 132kV Mariani-LTPS to be charged and start up power to LRPP machine shall be provided.
4. LTPS & LRPP machines to start generating after receiving start up power.
5. 220kV Mariani-Amguri-NTPS to be charged. 220kV NTPS-NRPP & 132kV TSK-NRPP to be charged sequentially.
6. Start-up power to NRPP & NTPS shall be provided and the units will be brought to service.
7. 220kV Tinsukia- Behiating D/C lines to be charged, 132kV Dibrugarh-Behiating, 132kV Behiating- Moran, 132kV LTPS- Moran to be charged sequentially.
8. 132kV Bokajan-Dimapur, 220kV Mariani-New Mariani, 220kV Samaguri-Mariani shall be charged then after.
9. 132kV Jorhat- Mariani D/C to be charged, 132kV Jorhat-Teok, 132kV Teok-Nazira, 132kV LTPS- Nazira to be charged sequentially.
10. 220kV Tinsukia-Kathalguri D/C lines to be charged and start up power will be provided to AGBPP to start its generation.

Loads are to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained.

Flow Chart depicting the Alternate restoration path for Upper Assam region



SYSTEM 6: RESTORATION OF SOUTH ASSAM BY BLACK START OF TURIAL (MIZORAM)

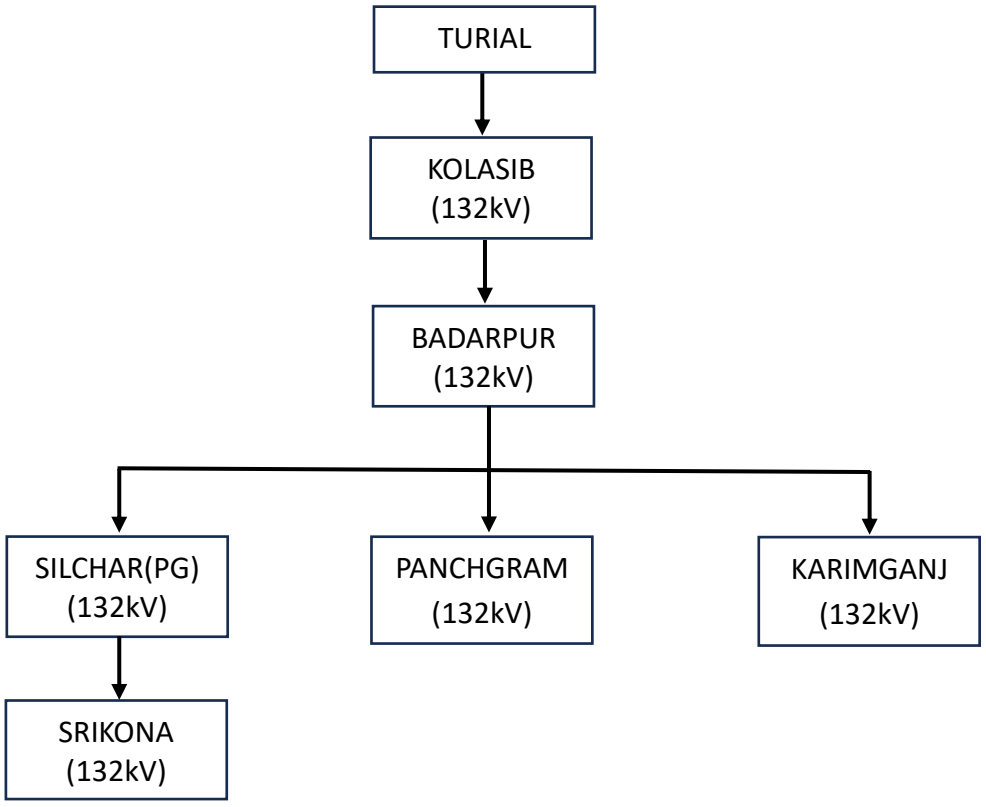
To revive South Assam region, power shall have to be extended to Badarpur (PG) GSS from the **Tuirial (Mizoram) Hydro Power Station** after black start of the machines via the 132kV Turial- Kolasib- Badarpur Transmission Lines.

Method of Restoration:

1. 132kV Badarpur (PG) - Silchar (PG) D/C LINES to be charged.
2. 132kV Silchar - Hailakandi line can be charged. 132kV Hailakandi-Dullavcherra can be charged next.
3. Charge 132kV Silchar- Srikona line.
4. Charge 132kV Hailakandi- Panchgram line.
5. 132kV Badarpur- Karimganj can be charged next
6. Charge 132kV Srikona-Pailapool line.

Loads are to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained.

Flow Chart depicting the restoration path for South Assam region



Alternate path for restoration:

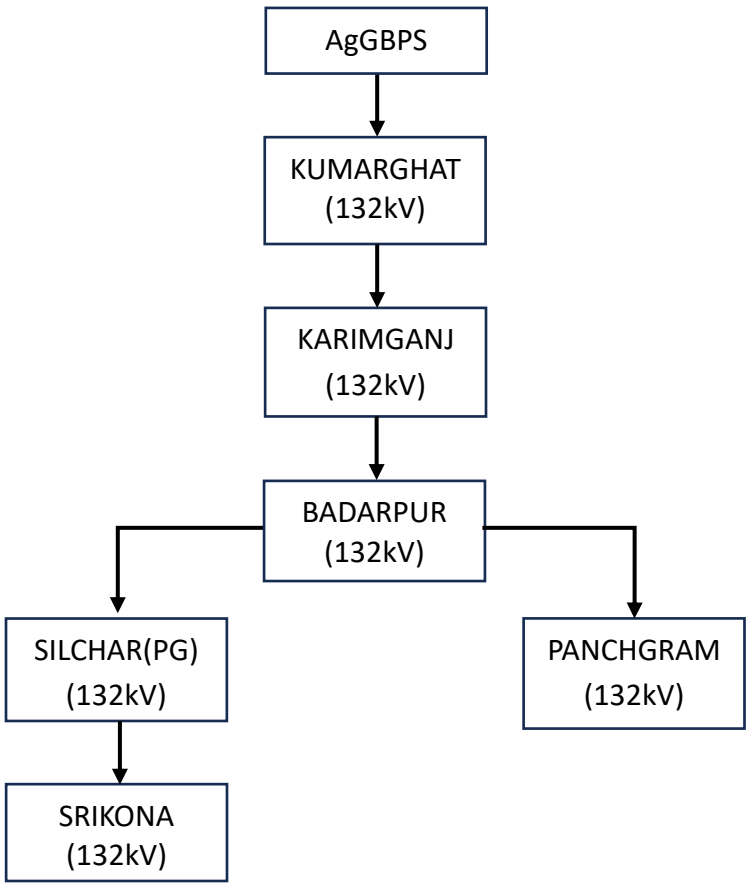
In case of Tuirial generation is not available, power can be provided to southern Assam region by initiating black start at **Agartala Gas Based Power Station (AgGBPS) NEEPCO**. Power can then be extended by the following process:

1. Charge 132kV Badarpur (PG) through 132kV AgGBPS-Kumarghat-Karimganj-Badarpur link.
2. 132kV Badarpur (PG)-Silchar (PG) D/C lines to be charged.
3. Charge 132kV Silchar- Srikona D/C lines.
4. 132kV Silchar- Hailakandi can be charged. 132kV Hailakandi-Dullavcherra can be charged next.
5. Charge 132kV Hailakandi- Panchgram lines.
6. Charge 132kV Srikona-Pailapool.

After restoration of power to all the GSSs, rest of the interconnecting lines can then be charged sequentially.

Loads are to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation. Load and generation balance to be maintained.

Flow Chart depicting Alternate restoration path for South Assam region



SYSTEM 7: RESTORATION OF HAFLONG & UMRANGSHU BY BLACK START OF KHANGDONG (NEEPCO)

To revive the Haflong GSS & Umrangshu GSS, power shall have to be extended from **Khangdong Hydro Electric Project (NEEPCO)** via the 132kV Khandong – Umrangshu Line.

Method of Restoration:

Upon receipt of power at Umrangshu GSS, AEGCL power can be extended using the following paths:

1. Charge 132kV Umrangshu- Haflong (PG) line.
2. Charge 132kV Haflong (PG)- Haflong line.

Alternate sources for restoration

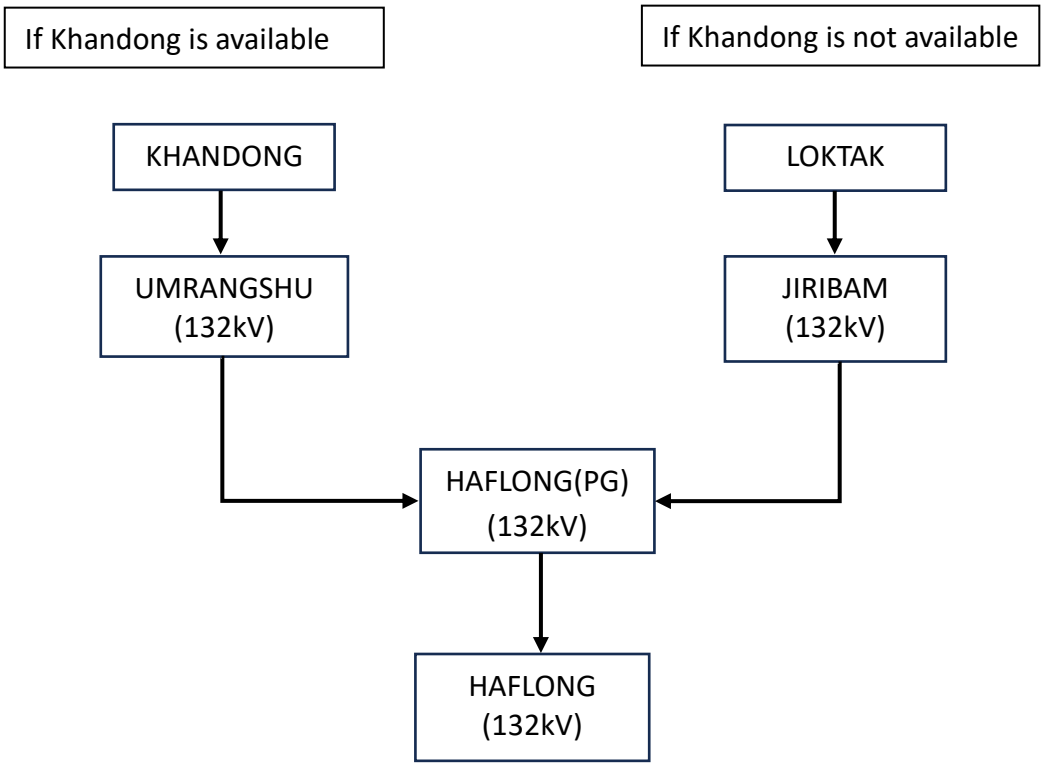
Power can be extended to Haflong & Umrangshu GSS after black start of **Loktak Power Station (NTPC)** via the following lines:

a. Charge 132kV Jiribam GSS via 132kV Lokatak-Jiribam line.
b. Charge 132kV Haflong(PG)-Jiribam line.
c. Charge 132kV Haflong(PG)-Haflong.
d. Charge 132kV Umrangshu- Haflong (PG).

Loads are to be connected in staggered manner. While connecting the load, the generation of the supporting generator shall be taken into account. Load connected should be around 20-25% of the current generation.

Load and generation balance to be maintained.

Flow Chart depicting Alternate restoration path for Haflong & Umrangshu region



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