

SYSTEM RESTORATION PROCEDURES

1.0. Purpose

This procedure outlines the principles and processes to be followed to restore the power system to normal state of operation following a system disturbance or a system collapse. It also outlines the roles to be played by each stakeholder towards an effective coordination of restoration efforts across the power supply value chain.

2.0. Introduction

System disturbances in power systems are often triggered by an initial fault. This initial fault then escalates due to cascaded tripping of other power system equipment which then spreads across the system through the combined effect of inadequate generation/load balance, instability, equipment malfunction, improper operation, human error, etc.

Following a system disturbance, all efforts must be geared towards quickly assessing the situation and systematically returning the system into its normal state of operation.

3.0. Definitions

Normal State: The Power System is considered to be operating in the Normal State when the following conditions are satisfied:

- the system frequency is within the limits of 49.8Hz and 50.2Hz;
- voltages at all NITS buses are within $\pm 5\%$ of their nominal values;
- all transmission circuits and substation equipment are loaded below 85% of their continuous ratings;
- all interconnection tie-lines are operated within their ratings; and
- the NITS is configured such that it can remain secure in the event of any potential N-1 contingency event.

System Disturbance: Refers to an incident which causes the power system to go out of its normal state of operation.

Partial System Collapse: Refers to a system disturbance which causes several power system equipment and installations to trip such that a section of the power system experiences blackout.

Total System Collapse: Refers to a severe system disturbance which causes all equipment and installations on the power system to trip leading to a total blackout.

Black start Unit: A black start unit is one that when shutdown, can be started without assistance from the NITS. A black start unit is required to produce power to first energise the NITS in order to begin power system restoration in the event of a major system collapse or a system-wide blackout.

4.0. General Principles

- i. After a system disturbance, several consumers, power system equipment and installations go off supply. The effort should be to restore supply as quickly as possible to minimize down time.
- ii. Following a system disturbance, dispatchers and operating personnel should conduct a thorough assessment of the state of their network before going ahead to commence restoration.
- iii. During restoration, priority shall be given to restoring the connectivity of the NITS.
- iv. The System Control Centre (SCC) shall lead to execute and coordinate all switching activities in connection with power system restoration. In that regard, operators at remote stations, generating stations as well as load entity operators shall not operate, switch in/out any equipment until they have received dispatch instructions from SCC to do so, except during emergencies.
- v. Teams of Maintenance/Operating personnel shall always be kept on 'Stand-by' at all times (24/7) to assist whenever there are system emergencies. Where necessary, off-duty personnel on 'stand-by' shall be called to come and assist with system restoration.

5.0. Sectionalisation

Following a disturbance, the power system is typically not very stable. In such situations transient oscillations associated with equipment switching operations could quickly get amplified leading to cascading trips and possible system collapse.

Therefore, it is expedient that prior to the commencement of restoration, the power system is segmented into smaller 'Sections'. Upon commencement of restoration, these 'Sections' shall be progressively restored using an agreed energization path to ensure a gradual and controlled progression with system restoration.

The action of segmenting the power system into smaller sections is termed "sectionalisation". Dispatchers at SCC shall determine the extent of sectionalisation required for each restoration event.

Where available, sectionalisation must be carried out at nodes where synchronization points/synchro-checks exist. **Appendix xx** shows the list of synchronization points/synchro-checks on the Ghana power system and where they are installed.

6.0. Restoration

i. Black Start

The following power plants have capability of providing black start on the Ghana power system in the event of a system collapse.

These are tabulated below:

Plant	Location	Capacity	Fuel	Voltage (kV)
Akosombo GS	Akosombo		Hydro	161
Kpong GS	Akuse		Hydro	161
Bui GS	Bui		Hydro	161
Karpower Ship	Sekondi		Natural Gas	330

TT2PP (Siemens)	Tema		Natural Gas	161
Ameri	Kumasi		Natural Gas	330

ii. **Actions by SCC**

Following a system disturbance incident, dispatchers at the System Control Centre shall carry out the following actions:

1. Lead and coordinate restoration actions together with all remote station operators, all power plant operators and all load entity operators.
2. Communicate with all remote stations, power plants and load entities informing them about the system disturbance, giving available details.
3. Conduct an assessment of the state of the power system. Inquire from remote station, power plant and load entity operators of the conditions at their stations taking note of possible faulty/damaged equipment, fire outbreaks, etc.
4. Inform the System Control Center Manager and the Manager Dispatch Operations of the system disturbance, giving available details.
5. Lead to carry out 'Sectionalisation' of the parts of the power system which have experienced a black out.
6. [Issue dispatch instructions to start a black start generating unit.](#)
7. When a black start unit has successfully been synchronized, the power system shall be progressively restored to ensure a gradual and controlled progression with system restoration.
8. Critical Loads:
 - a. VALCO is a critical load. The alumina in their pots could cake (solidify) if the plant stays out of supply for more than one (1) hour. Accordingly, efforts in system restoration whenever supply to VALCO has been lost should be to ensure a restoration path that enables restoration of supply to VALCO in less than an hour.
 - b. Some Mining companies operate Underground facilities. The lives of personnel and the safety of the equipment that operate in these underground mines are threatened whenever there is a loss of power supply.

9. The Ghana power system is more stable when as many loops are closed. The effort to restore the transmission network shall be to establish the closing of the loops on the network as quickly as possible.
10. When substantially restored, it is helpful to restore interconnection with the power systems of Cote d'Ivoire as it contributes to make the system even more stable.

iii. Actions by Remote Station Operators

Following a system disturbance incident, operators at remote stations shall carry out the following actions:

Quickly conduct an assessment of the state of operation of their local substations and their associated NITS equipment. Such assessment shall especially identify any:

- ✓ equipment which tripped during the disturbance, noting all associated relay operations
- ✓ equipment malfunction
- ✓ abnormal situation, smoke, or fire (from substation equipment or in the proximity of the substation), etc.

After the assessment, the remote station operator shall promptly inform SCC and the Area Manager of the incident, giving details of findings from the assessment.

In case of equipment malfunction, the remote station operator shall promptly inform the relevant maintenance team supervisor to arrange to troubleshoot and repair the equipment.

In the case of emergency (such as fire, smoke, etc) remote station operator shall promptly apply every necessary interventional action to control the incident and curb its escalation to avoid damage to equipment and interruption of supply to consumers.

iv. Actions by Wholesale Suppliers

Following a system disturbance incident, operators at generating stations shall carry out the following actions:

Check the state of operation of their generating units.

- a. If the generating unit(s) are still in operation, the plant operators shall apply all endeavours within the limits of operation of the units to keep them in service to support system restoration.
- b. If the generating unit(s) tripped in the course of the disturbance, the plant operators shall conduct an assessment of the unit and its associated systems to determine its operability.
 - a. If the generating unit is assessed to be in a state where it could return into operation to support restoration,
 - the plant operators shall go through the procedure to bring the unit to the state of readiness to start and advise SCC of same.
 - When needed in the process of restoration, SCC shall issue Dispatch Instructions to the Plant Operators to start and synchronise the unit. Plant operators should not under any circumstances start and synchronise their units until SCC has issued a Dispatch Instruction for them to do so.
 - b. If the generating unit is assessed to be in a state where it cannot return immediately into operation to support restoration, the plant operators shall advise SCC of same and declare the unit unavailable.

v. *Actions by Load Serving Entities*

Following a system disturbance incident, operators of Load Serving Entities (LSE) shall carry out the following actions:

Check the state of supply to their load.

- a. If the load of an LSE is remains on supply
 - i. and the quality of supply is within the limits of emergency operation, the operators shall apply all endeavours within the limits of operation to keep the load in service to support system restoration.
 - ii. but the quality of supply is outside the limits of emergency operation, the LSE operators shall advise SCC and

- ✓ apply any available corrective methods in an attempt to correct the quality of supply and bring it within the limits of operation.
 - ✓ If this is not successful, operators shall advise SCC and quickly take off the load to avert damage (or malfunction) of load facilities.
- b. If the load of an LSE tripped in the course of the disturbance, the LSE operator shall conduct an inspection of the load and its associated systems to determine its state.
 - i. If the load is assessed to be in a state where it is ready to be restored on supply,
 - ✓ the LSE operators shall advise SCC that its load is in a state of readiness to be restored on supply and wait.
 - ✓ In the course of restoration, SCC shall restore supply to the relevant feeder(s) on which the load of the LSE is supplied.
 - ✓ SCC shall request LSE operators to check for potential on their incomer bus.
 - ✓ If potential is realized, SCC shall coordinate the restoration of the LSE load.
 - ✓ LSE operators should not under any circumstances restore their load until SCC has issued a Dispatch Instruction for them to do so.
 - ii. If the LSE load is assessed to be in a state where it cannot return immediately into operation to support restoration (eg. due to fault, etc.) , the LSE operator shall advise SCC of same.

7.0. Disturbance Reporting

Following an event where this system restoration procedure is invoked, the System Operations Department shall prepare a report on the event, indicating the cause(s) of the disturbance, the restoration process used and making appropriate recommendations where needed.

Key Points to consider for inclusion:

A simple restoration SLD showing the 161 & 330kV networks that needs to be restored first

Identify the synchronization points/synchro checks and where they are installed in the Ghana power system

Identify interconnection points which can assist with power restoration

Define the preferred energization paths

Identify loads, their location and magnitude that are required to control voltages and frequency within acceptable limits

The System Operator shall at regular times determine black start facilities through operational studies and simulations. These studies must be updated whenever a new generator is commissioned on the Ghana NITS. The characteristics of the black start facility should include but not limited to the location , type of unit, MW& MVar limits etc. A generating facility which is identified as a black start unit must be certified verified by appropriate tests

Identify capabilities of generating resources that can control voltages and frequency within limits when the restoration process begins

Bus voltage energization chart

Voltage	90% (Low)	95%	100% (Nominal)	105%	110%(High)
69kV					
161kV					
225kV					
330kV					

References

NYISO Restoration manual

Siemens PTI- An Overview of restoration issues and black start analysis