TD-OP-S05

GRIDCo

SYSTEM RESTORATION PROCEDURES

GHANA GRID COMPANY LTD

Contents

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

Article 9.60 of the Grid Code requires that the NITS is operated so that it remains in the Normal state at all times. System Disturbances cause the power system to go out of the Normal state of operation.

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

- the system frequency is within the limits of 49.8Hz and 50.2Hz;
- voltages at all NITS buses are within ±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.

Alert State: When any one of the following conditions exist, the Power System shall be considered to be in an Alert State:

- operating reserve is less than the required margin;
- system frequency is outside the limits for the Normal State, but within 49. 0Hz to 51.0Hz;
- voltage at any NITS bus is outside the limits of +5% of the nominal value but within the limits of 10% of the nominal value;

- there is critical loading or imminent overloading of transmission lines of substation equipment;

- a weather disturbance has occurred which may affect operations of the NITS; or

Emergency State: When a multiple contingency system condition has occurred without resulting in a total system collapse, in addition to the existence of any one of the following conditions the Power System shall be considered to be in Emergency State:

- there is a generation deficiency; or

- NITS transmission voltages are outside the limits of +/-10% of the nominal value; or

- the loading level of any transmission circuit or substation equipment is above 110% of its continuous rating.

Restorative State: When generating units, transmission lines, substation equipment and loads are being energized and synchronized to restore the Grid to its Normal State, the Power System shall be considered to be in a Restorative State.

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 generating unit which has the ability to start and synchronise to the NITS without using supply from the power system.

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 coordinate and execute 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-bye' at all times (24/7) to assist whenever there are system emergencies. Where necessary, off-duty personnel on 'stand-bye' shall be called–in to come and assist with system restoration.

5.0. Sectionalization

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 synchro-checks exist. Appendix 1 shows the list of synchronization points where synchro-checks are installed on the Ghana power system.

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	1,020	Hydro	161
Kpong GS	Akuse	160	Hydro	161
Bui GS	Bui	404	Hydro	161
Karpowership	Sekondi	470	Natural Gas	330
TT2PP (Siemens)	Tema	80	Natural Gas	161
Ameri	Kumasi	250	Natural Gas	330

The System Operator shall at regular intervals verify the functionality of black start facilities. The black start capability of every generator must be tested whenever a new generator is commissioned on the NITS. A generating facility which is identified as a black start unit must be certified and verified by appropriate tests.

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 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. Providers of reactive power support and voltage control services shall be directed to take any action necessary to maintain stable voltage levels in accordance with Prudent Utility Practice. The table showing the limits for the various voltage classes in the Normal and Alert States are shown in Appendix 2.
11. If voltage are outside the acceptable limits and the means of voltage control are exhausted, SCC shall take all other reasonable actions, including directing changes to demand, selective load shedding, bringing in additional generation or reducing transmission line flows to the extent necessary to restore voltages to acceptable limits.
12. 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.
13. Progressively restore all NITS loads and interconnected systems (SONABEL, CEB etc.) as generation facilities are restored until all loads are on supply.

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, isolate the affected equipment from the power system to avoid damage to equipment as well as curb its escalation 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. NOTE: Plant operators should not under any circumstances start and synchronise their units until SCC has issued a Dispatch Instruction for them to do so.
        - Plant operators shall comply with dispatch instructions from the system control center to take any actions necessary to maintain stable voltage levels in accordance with relevant provisions of connection agreements within the technical limits of the power plants.
    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 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.

References

- ✓ NYISO Restoration manual
- ✓ Siemens PTI- An Overview of restoration issues and black start analysis

Appendix 1: Normal and Alert State Limits for the various voltage classes chart

Voltage	90% (Low)	95%	100% (Nominal)	105%	110% (High)
6.6kV	5.9	6.3	6.6	6.9	7.3
11kV	9.9	10.5	11.0	11.6	12.1
34.5kV	31.1	32.8	34.5	36.2	38.0
69kV	62.1	65.6	69.0	72.5	75.9
161kV	144.9	153.0	161.0	169.1	177.1
225kV	202.5	213.8	225.0	236.3	247.5
330kV	297.0	313.5	330.0	346.5	363.0